RADIO ASTRONOMY

Journal of the Society of Amateur Radio Astronomers

December 2010/January 2011

Journal Contents

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John C. Mannone, Senior Editor
William Seymour and Whitham D. Reeve, Associate Editors

Society of Amateur Radio Astronomers – A membership supported, nonprofit [501 (c) (3)]
Educational Radio Astronomy Organization, founded 1981

Journal Contents

RADIOWAVES SECTION

~ The President's Page ~

The SARA Officers and Board of Directors have been discussing what projects SARA might take on as an organization. We already are very involved in the Stanford SuperSID project, building and shipping units all over the world. We also partner with Radio Jove and the Inspire Project on outreach venues such as the Dayton Hamvention and Orlando Hamcation.

There has also been more of an effort to provide resources for members just getting started in radio astronomy. Take a look at the new Beginner's Brochure written by Jon Wallace. Jon also wrote a series of articles for QEX and these, along with the Beginner's Brochure, can be found at http://www.radio-astronomy.org/node/199.

You will also find on the website a list of Radio Astronomy Abbreviations and Acronyms, thanks to the efforts of Whit Reeve. Please take a look and let Whit know if he missed any :-) http://www.radio-astronomy.org/glossary/

I would like to hear from our members if there are other projects they think SARA should be working on and/or promoting. Tell me why we should do a particular project and what you would expect from SARA, and if you would be able to participate in its development.

We are also building a Facebook page for SARA. It will provide general information about radio astronomy in an effort to attract more young people. If you would like to help keep the page updated, contact me with your ideas and suggestions.

Reminder- SARA will be in booth 223 at the Orlando Hamcation on February 11, 12 and 13. http://www.hamcation.com/ If you want to volunteer and help man the booth, contact Tom Crowley at crowleytj_at_hotmail.com. Tom is not too bad a sort to work for- he will give you time to leave the booth and check out the rest of the vendors:-) If you plan to attend, stop by and say hello to Tom.

Until next time, happy monitoring.

Bill Lord
KJ4SKL

~ From the Editor's Desk ~

❄ We hope that you had a joyous Christmas season
And a delightfully happy beginning to your New Year ❄

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Thank you for your continued support. We accept a wide variety of submissions formatted in Microsoft Word. The editorial staff appreciates your contributions and we encourage you all to keep those articles coming. In particular, we are always looking for basic radio astronomy articles. Please follow the guidelines uploaded to the SARA website as a downloadable PDF file, http://radio-astronomy.org/publicat/authjrnl.pdf. Noncompliance greatly increases the workload of the staff and will cause scheduling and distribution delays. Thank you for understanding. Please send your submissions to our editorial staff: editor@radio-astronomy.org. A tentative publication schedule is included on the next page to assist you in making your contributions. (Though there is usually some flexibility with the submission dates, please try to comply with them.)

Note that there is a printer-friendly version of the table of contents; simply instruct your printer to print from page 2 onward to conserve ink.

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This issue has a wide variety of news and feature articles, especially Jim Sky's learned discussion of amateur radio astronomy software, as well as a candid interview of him. The SID and Supersid has achieved some notable position in the news, so Dave Benham's article on the trials and tribulations of VLF monitoring is apropos. Whit Reeve's basic article on celestial radio sources is informative. We hope you will enjoy this issue.

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Future issues will feature a comprehensive treatment of Maxwell's equations (Bill Seymour), a brief history of the horn antennas (Vicente Rodriguez) and developments on 1420 MHz receiver design.

Tentative SARA Journal Publication Schedule

Release dates are targeted for the last Wednesday of the publication month. Times will vary due to logistics, including holiday and travel schedules. (Officer review copies are targeted a couple days before that.) Papers should be submitted at least 2 weeks (and preferably 4 weeks) before the release date (we are flexible with this). Front-end material to the Journal, like the President's Letter, New Members, etc. should be in the Editors' hands within two days of the review date (we are flexible with this, too). We will try to send out a courtesy reminder a week in advance, but we may not always be able to do this. Please make the submissions to the editorial staff (editors@radio-astronomy.org). Please read additional instructions on *From the Editor's Desk* section of the Journal for additional information. Underlined dates apply to the forthcoming issue around Thanksgiving.

Target Distribution Dates
(Subject to change)
Feb/Mar Wednesday March 30
Apr/May Wednesday May 25
Jun/Jul Wednesday July 27

Review Dates
Authors & Selected Officers:
Feb/Mar Monday March 28
Apr/May Monday May 23
Jun/Jul Monday July 25

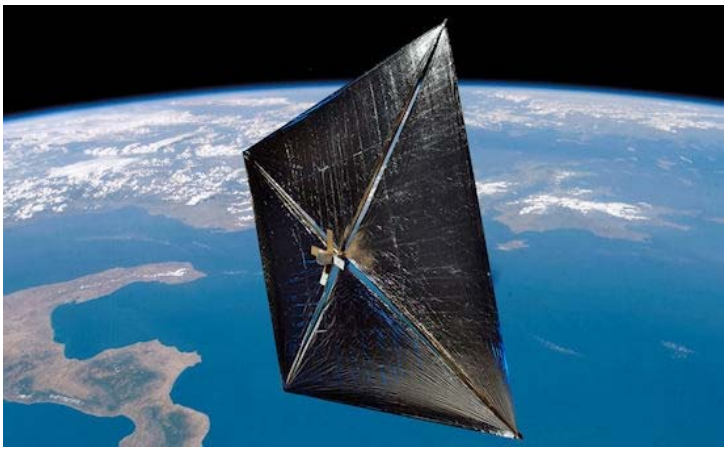
Due Dates
Journal Articles/Columns:
Feb/Mar Monday March 14
Apr/May Monday May 9
Jun/Jul Monday July 11

Due Dates
Radiowaves & Administrative Sections:
Feb/Mar Saturday March 26
Apr/May Saturday May 21
Jun/Jul Saturday July 23

John C. Mannone, Senior Editor
Bill Seymour, Associate Editor
Whitham D. Reeve, Associate Editor

~ NanoSail-D Mission ~

By John C. Mannone



After being stuck for a month and a half inside the mother ship, NASA's NanoSail-D spacecraft spontaneously ejected (January 17, 2011) and subsequently deployed (January 20, 2011) its solar sail in low Earth orbit. The unfurled gleaming sheet of space-age fabric is 650 km above Earth, becoming the first-ever solar sail to circle our planet. It is expected that it will remain in orbit between 70 and 120 days. The mother ship — the Fast, Affordable, Science and Technology SATellite (FASTSAT) — was launched in November 2010. (Picture courtesy NASA, Huntsville, AL)

According to the principal investigator, Dean Alhorn, its mission is to "circle Earth and investigate the possibility of using solar sails as a tool to de-orbit old satellites and space junk." See the mission pages,
http://www.nasa.gov/mission_pages/smallsats/nanosaild.html.

NASA RELEASE: 11-009 (January 19, 2011) states that NASA Seeks Amateur Radio Operators' Aid to Listen for Beacon Signal at 437.270 MHz,
http://www.nasa.gov/centers/marshall/news/news/releases/2011/11-009.html.

NASA RELEASE: 11-027 (January 24, 2011) announces an amateur astronomy image contest,
http://www.nanosail.org

Now let these things be food for thought.

Though we don't yet know when and where reentry will be because of unknown orbital decay parameters. It would have been worthwhile for SARA members to participate in beacon tracking to help NASA with telemetry, but the 437.270 MHz beacon died. Nevertheless, we might join in the photograph contest. I think that if we can complement any photographs that we might be lucky enough to get with some radio science, then I think this will give us even more favorable visibility with NASA. This might involve FM "meteor" scatter from the plasma trail created on reentry and concomitant with that, SID (Sudden Ionospheric Disturbance) monitors might see a sudden enhancement of terrestrially transmitted VLF signals, if they are positioned fortuitously with respect to the reentry trajectory. Additional information is on the dashboard page:
http://nanosaild.engr.scu.edu/dashboard.htm

I encourage a discussion on the SARA listserve and with the SID and SuperSID folks.

~ Select Resources ~

Compiled by Whitham Reeve

Mathematics Support Pack and Reference

SARA members can now download a mathematics support pack from the Publications and Getting Started tabs of the SARA website at: http://radio-astronomy.org/ or go directly to: http://radio-astronomy.org/pdf/math-support-pack.pdf.

The Math-Pack was prepared by University of Central Lancashire in the UK for support of their astronomy courses, and UCLan kindly granted SARA permission to use it. For additional information on UCLan go to: http://www.studyastronomy.com.

The Math Support Pack covers powers of ten, logarithms and trigonometry (among other things) and can be used as a quick reference to help SARA members understand and "appreciate the extreme scales and sizes that we encounter" in our pursuit of radio astronomy.

Glossary of Acronyms and Abbreviations

The SARA website now has a glossary of acronyms and abbreviations, which can be accessed from the Publications and Getting started tabs mentioned above or by going directly to: http://radio-astronomy.org/glossary. There also is a link on the homepage.

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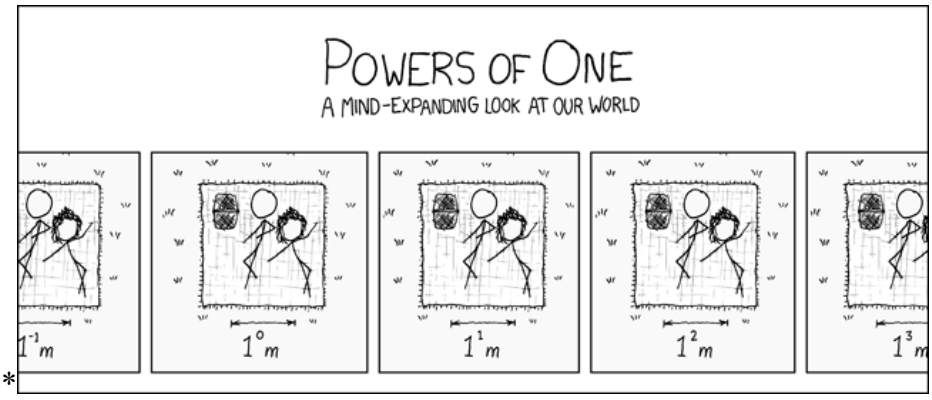

~ NASA Reviews & Recommends SuperSID ~

By Bill Lord

As many SARA members know, Stanford Solar Center and SARA teamed up to produce and distribute the SuperSID (Sudden Ionospheric Disturbance) monitor, which is used to record the effects of solar disturbances on terrestrial radio propagation. The monitor utilizes a simple pre-amp to amplify terrestrial VLF radio signals, which are then fed into a high definition sound card. This design allows the user to monitor and record multiple VLF frequencies simultaneously. The unit uses a compact one-meter loop antenna that can be used indoors or outside. This is an ideal project for the radio astronomer who has limited space.

This past October, Stanford Solar Center and SARA submitted ten complete sets of the SID/SuperSID project to the NASA Education Product Review. As stated on NASA's website (http://science.nasa.gov/educators/), "NASA's Science Education Program creates products using NASA's results in Earth-Sun system science, solar system research, universe exploration, and the development of new technologies to support learning. The program sponsors educational activities at all levels of formal and informal education to provide opportunities for learners to investigate their world and their universe using unique NASA resources."

Our submittal included the instrument, installation instructions, manual, the teacher resource guide (by Ben Burress at Chabot Space & Science Center), the data resource guide, and all other materials. The judges were pleased with the SuperSID resources and recommended them for full distribution without reservation in their statement:

> "These products received great ratings overall and the panel recommended them for distribution. Congratulations on producing excellent products! Products that pass the review will be identified as exemplary products and listed in DLESE and the upcoming NASA science education database (under development)."

One reviewer stated, "This might be the most well put together resource I have ever reviewed."

You can also visit http://nasareviews.strategies.org to see the evaluation forms, guidelines for products developers and other information about the review. Providing teachers and students with high-quality science education learning resources is an essential component in meeting the NASA's mission to inspire the next generation of explorers.

If you are interested in obtaining a SuperSID go to http://www.radio-astronomy.org/node/142. If you know a teacher or student that would like this or another radio astronomy project refer them to SARA grants at http://www.radio-astronomy.org/?q=node/32.

~ Mission *Raise Awareness Space Balloon* ~

By Romeo Durscher, Senior Manager HEPL Solar Physics

Fuzz Aldrin and I are very pleased to announce our BTS-1 mission to the edge of Space in April 2010 out of Texas. This mission is to demonstrate how easy it is to get to the edge of Space and to inspire kids, students and adults to get involved in projects like these. Once the balloon launches it can be tracked online, including various telemetry data.

Our capsule will be equipped with still and video cameras to capture the beauty of our planet's upper atmosphere and the darkness of space. We are also including several alternatives for tracking and recovery operations, including GPS and APRS. We will continue to keep you updated on our progress via social media (blogs, Facebook and Twitter profiles). We will now leave you with an introduction of our mission patch.

The mission patch of the Raise Awareness Space Balloon (RASB) project is based upon the symbols of both Fuzz Aldrin and Camilla SDO's purpose.

In the foreground, a solitary balloon ascends into the dark of Space. Above the balloon is the constellation Ursa Minor (Little Bear) for Fuzz Aldrin. To the left of the balloon is the to-be discovered constellation Pullus (the Latin word for Chicken) symbolizing Camilla Corona SDO.

The blue ring highlights our planet Earth. The words *Scientia quod Pacis* around the edges of Earth represent both Camilla and Fuzz's mission; Science Education and Peace. The color white was chosen for *Scientia quod Pacis* to symbolize that not even the sky is the limit. The red outer ring, the blue inside ring, and the white font represent the colors of the flag of the United States of America and are dedicated to all our U.S. Astronauts, active, retired and the ones who have lost their lives in the name of Space Exploration.

The star on the left is for Fuzz and signifies the night time peace and our children of the future, while the dawning Sun on the right is spreading its light across Earth during day time and represents Camilla and the NASA SDO education and mission.

Similarly to NASA's Space Shuttle mission (STS, which stands for Space Transportation System) the RASB choose the abbreviation BTS for Balloon Transportation System. Since the upcoming launch will be RASB first, BTS-1 has been assigned.

Information about the AstroMascot Crew

Fuzz Aldrin joins Miles the Traveling Bear as a touring ambassador of Bears on Patrol. While Miles is raising awareness on a personal level by meeting people, Fuzz is taking a global approach, joining forces with Camilla Corona SDO to promote science education and peace for our children.

Bears on Patrol seeks to make traumatic situations bearable for children by providing free teddy bears for police officers to give to children they encounter on calls.

For more information:

Fuzz Aldrin
http://www.bearsonpatrol.org/fuzz

Bears on Patrol
http://www.bearsonpatrol.org/

Camilla Corona SDO is the EP/O (Education and Public Outreach) mission mascot for NASA's Solar Dynamics Observatory. Camilla's role is to help with informing students, teachers, parents, and anyone interested about the Sun, Space Weather and its impact on life on Earth (and Space). Camilla's dream is to visit her best friend Little SDO in Space.

Little SDO is NASA's Solar Dynamics Observatory and is designed to help us understand the Sun's influence on Earth and Near-Earth space by studying the solar atmosphere on small scales of space and time and in many wavelengths simultaneously.

For more information:

Camilla Corona SDO
http://solar-center.stanford.edu/camilla/

NASA SDO
http://sdo.gsfc.nasa.gov/

~ SARA Western Regional Conference ~

April 2-3, 2011

Embry-Riddle Aeronautical University

Prescott, Arizona

The SARA Western Regional Conference will be held at Embry-Riddle Aeronautical University in Prescott, Arizona April 2 and 3, 2011. SARA member Ray Fobes is a Staff Radio Astronomer at the university and is coordinating the event. We are looking for members to present papers on radio astronomy hardware, software, education, research strategies, philosophy, observing efforts and methods. Submit your letter of intent with a proposed title and abstract to westernconference@radio-astronomy.org.

Registration is just $60.00,which includes breakfast and lunch on Saturday and Sunday, as well as a print and disk copy of the Western Conference Proceedings. There are a lot of historical attractions, activities and great places to visit in and around Prescott. http://www.radio-astronomy.org/node/192. Make plans now to attend and participate.

Here is a sampling of the papers that will be presented:

21 cm Cosmology
Dr. Judd Bowman, Arizona State University

Abstract: How did the homogeneous and energetic universe that immediately followed the Big Bang evolve into the rich populations of giant clusters, galaxies, stars, and planets that we see today? Connecting these disparate times requires a detailed understanding of the evolution of pervasive hydrogen gas in the early universe. I will focus on use of two strategies to characterize interactions between primordial hydrogen and the very first generations of stars, black holes, and galaxies less than 700 million years after the Big Bang. The Murchison Widefield Array (MWA), under construction in Western Australia, and the Experiment to Detect the Global EoR Signature (EDGES) are two new radio telescopes that aim to exploit different observable properties of the 21 cm hyperfine transition line of neutral hydrogen to probe the cosmological epoch of reionization (EoR). Both instruments have recently passed important milestones and will soon open fundamentally new views of the early universe.

Geomagnetism Tutorial
Whitham D. Reeve, Anchorage, Alaska USA, Member, Society of Amateur Radio Astronomers

Abstract: Geomagnetism is the study of the Earth's magnetic field environment. This paper provides a brief tutorial on magnetic units and the causes and characteristics of the Earth's magnetic field and is an abridged version of a tutorial that may be downloaded from the web. This tutorial accompanies a paper on building and using the Simple Aurora Monitor, SAM-III 3-axis geomagnetometer, in the SARA 2011 Western Conference Proceedings.

Building and Using the SAM-III 3-Axis Geomagnetometer
Whitham D. Reeve, Anchorage, Alaska USA, Member, Society of Amateur Radio Astronomers

Abstract: The original 2-sensor Simple Aurora Monitor (SAM) geomagnetometer kits were retired in July 2010 and replaced with the SAM-III Kit. The SAM-III is a similar design but capable of using three sensors for orientation north-south, east-west and up-down (vertical). This paper describes the construction of the SAM-III and its application at Anchorage, Alaska USA. Also described are several software application programs for viewing and logging SAM-III data and statistical analysis.

Solar Cycle 24 – Will It Be Unusually Quiet?
Rodney Howe (HRHA), SID Analyst, AAVSO Solar Section

Abstract: For the last 40 years or so all the AAVSO (American Association of Variable Star Observers) Very Low Frequency (VLF) Solar Ionospheric Disturbance (SID) data has been sent to NGDC (National Geophysical Data Center). In this paper these data are put into a database and graphed in hopes of understanding these VLF SID submissions. The graphics show the NGDC accumulated Importance Rating, (an index of the duration of solar flares), for all the AAVSO VLF SID submissions over the past 40 years. If we compare these VLF SID data with the last 3 solar cycles of sunspot number counts compiled by the Solen group (Jan Alvestad) it seems that the AAVSO VLF SID submissions to NGDC show our accumulated Importance Rating signals lag by 18 to 24 months after the start of each of the last three solar cycles! That puts our VLF radio's SID IR index measure at a point where it takes at least 100 sunspot counts per month before the VLF SID accumulated IR index even shows a signal through the noise floor of our ionosphere. The VLF observer's Importance Rating index is just monitoring the tip of these solar cycles with our VLF radios when compared to the sunspot number count indices. And if the Solen sunspot predictions are right for Cycle 24, the solar sunspot peak will not even reach the 70 mark for this next cycle. So, our VLF SID IR index signal submissions may not even be detectable in Cycle 24!

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~ SARA Annual Conference ~

June 26-29, 2011

National Radio Astronomy Observatory (NRAO)

Green Bank, West Virginia

The Annual SARA Conference is scheduled for June 26 through June 29, 2011 at the National Radio Astronomy Observatory (NRAO), Green Bank WV. Papers on radio astronomy hardware, software, education, research strategies, and philosophy are welcome. Submit your letter of intent with proposed title and abstract to vicepres@radio-astronomy.org by March 1, 2011. Once again, we will have hands-on radio astronomy projects set up on Sunday and Tuesday evening with a swap meet on Monday night.

Conference Registration Fees:
The fee for the 2011 Conference has been set at $165 US for all registered participants. This fee includes conference registration, payment of your 2011 SARA membership dues, one copy of the published Conference Proceedings (to be distributed at the meeting), morning coffee breaks, afternoon snack breaks, evening refreshments, and eight meals as indicated below. Please note that all SARA 2010 memberships expire on June 15, 2011. Since SARA membership dues are now inseparable from conference registration, all registered attendees automatically become SARA Members in *good standing* through June 15, 2011.

SARA Life Members, or those who have already paid their 2011 membership dues prior to registration, may deduct $20 from the above amount. Those registered for the 2011 Conference who subsequently purchased a Life Membership any time during the 2010/2011 membership year, may deduct $20 from the Life Member Fee (currently set at $400 US). And, because SARA offers a special membership rate of $5.00 for students, all fulltime students under the age of 18 may deduct $15.00 from the above conference registration fee.

The attendance fee for an accompanying family member (non-participating spouse, child, or companion of a registered Conference attendee) is $80, which includes morning coffee breaks, afternoon snacks, evening refreshments, and meals. The cited fees are calculated on a *break-even* basis, and apply only to advance registrations received prior to May 31, 2011. *All* registrations received thereafter are subject to an additional late registration fee.

Conference Proceedings:
Once again this year, a formal, printed Proceedings, which includes technical papers and supplemental material, is being professionally published. One copy of the printed Proceedings is included with your paid conference registration. (Proceedings are *not* provided to accompanying family members.) A limited number of additional copies of this year's and previous years' Proceedings will be available at Green Bank for $20 US each. You may reserve and prepay for additional Proceedings copies by including the appropriate amount in your check to the Treasurer.

Advance Registration Deadline:
Because SARA Conferences require quite a bit of advance planning, early registration is encouraged. To register for the 2011 SARA Conference at the rates cited above, you must have your full remittance *delivered* to the Treasurer (not simply *postmarked*) by not later than May 31, 2011. All registrations received after that date, including walk-in registrations, will be assessed an additional 15% late registration fee.

Payment of Conference Fees:
Checks (in US Dollars only, drawn on a US bank) should be sent in advance to:

SARA Treasurer Melinda Lord
2189 Redwood Ave
Washington, IA 52353 USA

Email contact: treasurer@radio-astronomy.org
Phone contact: +1 319-591-1130

NOTE: You may now remit your SARA Conference Registration via www.PayPal.com. It is still necessary to send your name, address, membership status, name(s) of accompanying person(s), and any other pertinent registration information to the Treasurer via post or email.

Included Meal Plan:
Green Bank is a small community with few dining establishments. Thus, SARA has arranged for conference registration to include a meal plan at the NRAO employee's cafeteria, to include:

- Dinner Sunday night
- Breakfast / Lunch / Dinner Monday and Tuesday
- Breakfast on Wednesday

The NRAO Cafeteria is *not* a public dining facility, does *not* sell individual meals to visitors, and is, in fact, doing us a favor in allowing our group to use their cafeteria at all. Thus, the Meal Plan is an integral part of, and inseparable from, the conference registration. Please note that in addition to the above meals, the conference fee (even for accompanying persons) includes refreshments and coffee breaks during the conference presentations, as well as snacks and beverages in the Drake Lounge in the evenings.

Exceptions to the meal plan will be considered on a case-by-case basis, such as for those conference attendees residing on site or others with special dietary needs. Please contact the Treasurer directly with your specific requests. In general, except under unusual circumstances, one should consider the cost of meals to be a part of, and inseparable from, the conference registration fee.

~ New Members ~

Please welcome our new or returning SARA members who have joined since the issuance of last issue. (Please accept our apologies if your name is missing. If it is so, please send an email to the Treasurer (Melinda Lord) and to my Associate Editors (Bill Seymour and Whitham Reeve). We will make sure it appears in the subsequent Journal issue). As of January 10, 2011:

First Name	Last Name	City	State	Country	Ham ID
Dave	Cohen	Gum Spring	VA	U. S. A.	KC4UTI
Allan	Cook	Brunswick	OH	U. S. A.	
John D	Culter	Naples	FL	U. S. A.	KJ4QAY
Hal	Feinstein	Vienna	VA	U. S. A.	WB3KDU
Harold	Hall	Terrell	TX	U. S. A.	
Fernando	Nino	Souix Falls	SD	U. S. A.	
Emil	Pimentelli	Round Rock	TX	U. S. A.	
Jan	Slegr	Litomysl		Czech Republic	
Stephen	Wessling	Fremont	MI	U. S. A.	

~ Membership Dues & Promotions ~

SARA Membership Dues

Membership dues are $20.00 US per year and all dues expire in June. Student memberships are $5.00 US per year. Members joining from June to December of 2010 will renew their membership June 2011. Members joining January to June 2010 will renew June 2011.

Or pay once and never worry about missing your dues again with the SARA Life Membership. Sara Life Memberships are now offered for a one-time payment of twenty times the basic annual membership fee (currently $400 US).

Journal Archives & Other CDs Promotion

The entire set of The Journal of The Society of Amateur Radio Astronomers is available on CD. It goes from the beginning of 1981 to the end of 2010 (over 4000 pages of SARA history!) Or you can choose one of the following CD's or DVD:* (Prices are US dollars and include postage.)

- ☐ SARA Journals from 1981 through 2010
- ☐ SARA Mentor CD, compiled by Jim Brown
- ☐ SARA Navigator (IBT) CD *and* DVD, compiled by Jon Wallace
- ☐ The Quest for Contact narrated by Dr. Jill Tarter (DVD)

Members	Each Disk*		$15
	Disk + One year Membership extension	$30	
Non-Members	Each Disk		$25
	Disk + One year Membership	$30	
Overseas Members	Each Disk		$20 (Airmail)
	Disk + One year membership extension	$35	

*Already a member and want any or all of these CD's or DVD's? Buy any one for $15.00 US *or* get any three for $35.00 US.

SARA Store Now On Line

SARA offers the above CD's, DVD's, printed Proceedings and Proceedings on CD at the SARA Store at http://www.radio-astronomy.org/node/120. Proceeds from sales go to support the student grant program. Members receive an additional 10% discount on orders over $50. Payments can be made by PayPal or mail check or money order to:

SARA
c/o Melinda Lord
P.O. Box 915
Washington, IA 52353

Melinda Lord, Treasurer

~ Radio Astronomy Resources ~

SARA
http://radio-astronomy.org

SETI League
http://www.setileague.org

European Radio Astronomy Club
(Peter Wright)
http://www.eracnet.org/

Pisgah Astronomical Research Institute
(Don Cline)
http://www.pari.edu

Tamke-Allan Observatory
(David Fields)
http://www.roanestate.edu/obs

Deep Space Exploration Society
(Rex Craig/Jamie Riggs)
http://www.dses.org/

Jamesburg Earth Station volunteer group
http://www.jamesburgdish.org
http://www.bambi.net/jamesburg.html

Radio Sky Publishing
(Jim Sky)
http://www.radiosky.com

RF Associates
(Richard Flagg)
1721-I Young Street
Honolulu, HI 96826
(808) 947-2546

National Radio Astronomy Observatory
http://www.nrao.edu

NASA Radio JOVE Project
http://radiojove.gfsc.nasa.gov

The Inspire Project
http://theinspireproject.org

Sanford Solar Center
http://solar-center.sanford.edu/SID/solarsid

Radio Astronomy Supplies
(Jeffrey M. Lichtman)
http://www.radioastronomysupplies.com
Jeff@RadioAstroSupplies.com

RFSPACE, Inc.
(Pieter Ibelings)
Radio Astronomy Receivers)
http://www.rfspace.com
info@rfspace.com

Shirleys Bay Radio Astronomy Consortium
(Marcus D. Leech)
marcus@propulsionpolymers.com

GNU Radio
(Eric Blossom)
http://www.gnu.org/licenses/gpl.html

Simple Aurora Monitor: SAM-International
(Whitham D. Reeve)
http://www.reeve.com/SAMDescription.htm
SAMInfo@reeve.com

Radio Astronomy Links
http://www.cv.nrao.edu/fits/www/yp_radio.html

JOURNAL ARTICLES & COLUMNS SECTION

~ Programming for Amateur Radio Astronomy ~

By Jim Sky, Radio-Sky Publishing

Amateur radio astronomy is one of those avocations where do-it-yourselfers enjoy taking control of all aspects of the hobby. That means that there will always be people who want to write their own software for their projects. This article is a short reflection on my experience with writing amateur radio astronomy software. Perhaps, you might get a tip or two that will be helpful in your own efforts. If you are writing programs for your own use you have the luxury of not having to nit-pick over every detail of the programs presentation and convenience. Programming can be fun, and extremely useful in our little geeky corner of science. If you never intend to program anything then maybe this article will at least give you a glimpse into what others do.

Acronyms used in this article:
CPU: Central Processing Unit
DSP: Digital Signal Processing
FFT: Fast Fourier Transform
FTP: File Transfer Protocol
HTTP: HyperText Transfer Protocol
LAN: Local Area Network
PC: Personal Computer
PHP: Hypertext PreProcessor
ROM: Read-Only Memory
SDR: Software Defined Radio
TCP: Transmission Control Protocol
UDP: User Datagram Protocol
WM API: Windows Multimedia Application Programming Interface

Additional terms in *Italics* are defined at the end of the article

I won't bore you with stories of analog computers and paper tape terminals, though I have some. Home computer programming really started for me when Texas Instruments (TI) dropped the price of their *8-bit* wonder the TI-99A to almost free in the 1980s. The only language available was BASIC and I ended up producing a few educational games for my kids. The real fun began when Timex/Sinclair released their TS-1000 in the US. This tiny computer was different. You had access to its inner workings, a hackers dream. You could circumvent portions of the operating system and write programs in machine *code*. This entailed looking up the hex values of the various Z80 microprocessor commands and calculating addresses by hand. Later I graduated to using an assembler program that removed this tediousness. It was about this time that I became interested in amateur radio astronomy. The uses for a computer in this field were immediately obvious.

Figure 1 – Timex/Sinclair TS-1000 computer

One possibility was to replace the strip chart recorder with a printer. The Timex/Sinclair printer was a small (4 inch?) thermal paper device. Busting into the *ROM code* of the 1000, I was able to decipher the way it worked and found a way to print graphics to it. Analog to digital converters were expensive and hard to come by in those days so I built a voltage to frequency converter and applied the signal to the cassette audio input (remember those?). A bit more *assembly code* and the computer was producing strip charts for my early radio telescopes. My basement became filled with cheap 8 bit computers. An Apple II became my first antenna-moving computer. It worked in elevation only for drift scan work. There are lots of little projects

that I could describe, but I think the importance of any of this is that it provided a good background for the programming that lay ahead.

WHAT LANGUAGE? THE CPU TOWER OF BABEL…

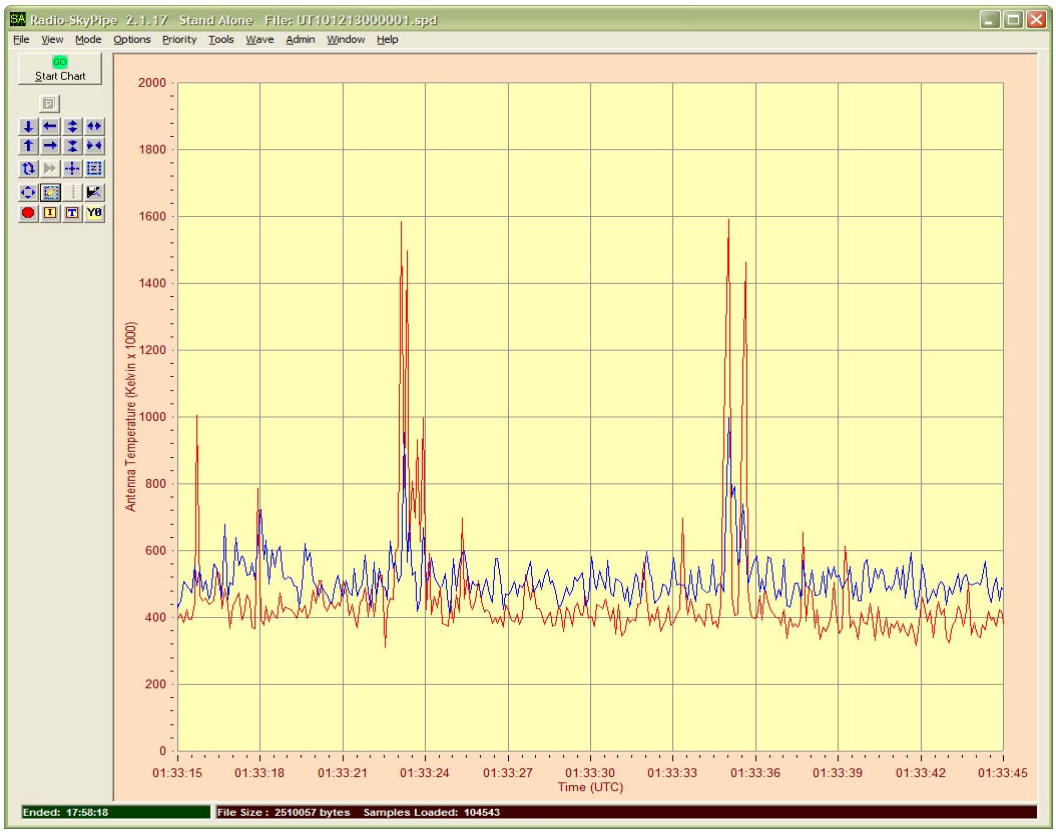


Figure 2 – Radio-SkyPipe screenshot of Io-B emissions at 20 MHz

The idea of producing software that others could use occurred to me when I took over the SARA librarian/education coordinator position in the early 90's. IBM PCs were finally affordable for home use. DOS programs were developed for Jupiter noise storm predictions, data collection, and even observation planning in the form of Radio-Sky Planetarium. QuickBasic was the language of most DOS programs of the time. Windows 3.1 brought with it Visual BASIC 3.0 and the whole new paradigm of event-based programming was opened to me. Along the way I used other languages like Pascal, C, and even some IBM assembly language, but Visual Basic (VB) always seemed to be the fastest and easiest way to get things done so I primarily stuck with it. Today I still use VB6 90% of the time, but that is changing. Microsoft has quit supporting VB6 and you cannot even load the development environment on the new Windows 7 platform (though the programs produced by VB6 will still run on Win7). I think this is Microsoft's way of killing the powerful workhorse and forcing us to move on to VB.NET which is the replacement. Unfortunately, the transition is terribly painful. So much changed in going from VB6 to VB.NET that large programs are almost impossible to simply *port* over and must be re-written from the ground up. This is a huge burden for a one-man shop like Radio-Sky Publishing. Radio-SkyPipe

has over 30,000 lines of *code* in it! Re-writing it for VB.NET would take me a solid year. So the lesson for the new guy or gal in this field is to start out writing in the latest available language so that your gargantuan *code* project can live a long life. In other words, even though VB6 is easy and powerful, don't be tempted to start new large projects in it. However, for small projects VB6 will get done quickly and with minimal effort, (provided you have an old XP computer to develop on).

Microsoft is doing one thing right. It is giving away "Express Editions" of its newest programming languages. You can go to their website and download these very heavily featured versions of BASIC, C# (C-Sharp), C++, and the Visual Studio work environment. I think Apple would be today's Microsoft in terms of PC market share, had they made the smart move of producing easy to use programming languages and environments for the public. Instead, they pretty much did nothing in that realm and writing programs for Apple computers after the old Apple II was not promoted. Few developers meant fewer applications and less utility for the computer itself. That's too bad. I think that would have been fun.

On the down side, Microsoft has made programming more difficult in some ways. The .NET (pronounced "dot net") languages are full-on object-oriented implementations. That is just fine for some things but for others it's a pain in the bum. Writing in these languages produces extremely wordy *code* with deep layers of abstraction that can be confusing. The learning curve is much steeper in my opinion than that for VB6 and this might be discouraging to the new programmer. My advice is to just stick with it a little at a time. Start out writing something very simple, like a dipole calculation program and gradually add new features to it one at a time until you master such things as graphics. If you begin by trying something too complicated, you just might get discouraged with all of the compile errors and quit before you get that little adrenaline boost that comes from having your program actually work.

CHALLENGES RELATED TO RADIO ASTRONOMY

For the most part, I am still writing programs that fulfill the needs addressed by those early DOS programs; data collection and observation planning. The internet has added new dimensions to these areas and greatly increased the amount of collaboration that is possible. There are no doubt scads of uses for computers in radio astronomy that I have not thought of but for the most part it seems to that the main challenges are interfacing to the real world, simulating the real world, and in processing data.

Real world interfacing for me usually means hooking up your PC to some external device to control it and/or receive data from it. On the device end we are usually talking about some sort of microcontroller that can accept commands and translate them into motor control, ADC queries, etc. Interfacing to a personal computer at one time included options such as soldering to the address and data pins on the motherboard! Then we graduated to using the serial and parallel ports. Oops, those are now gone and we are left with USB and sound card inputs. Actually, the serial port is still usable via a serial to USB converter cable and that is probably your most useful option for most custom projects. You don't want to find yourself writing USB driver *code* if you can help it. The high level programming languages still include serial port communications

capabilities, and if your real world device can talk serial, you can control them from VB.NET or C#, or just about any other language. The primary serial port limitation is speed. If you need to transfer large amounts of data quickly you need something else. One possibility is Ethernet using TCP or UDP protocols. From the PC side, this is a very easy task using windows (or Linux) sockets. This seems to be the route that RFSpace has taken with their new lines of software defined radios (*SDR*s). On the real world device end, many microcontrollers are becoming available that use Ethernet interfaces or at least *code* modules that implement a TCP stack interface. Adding networking to a project is no longer a huge task.

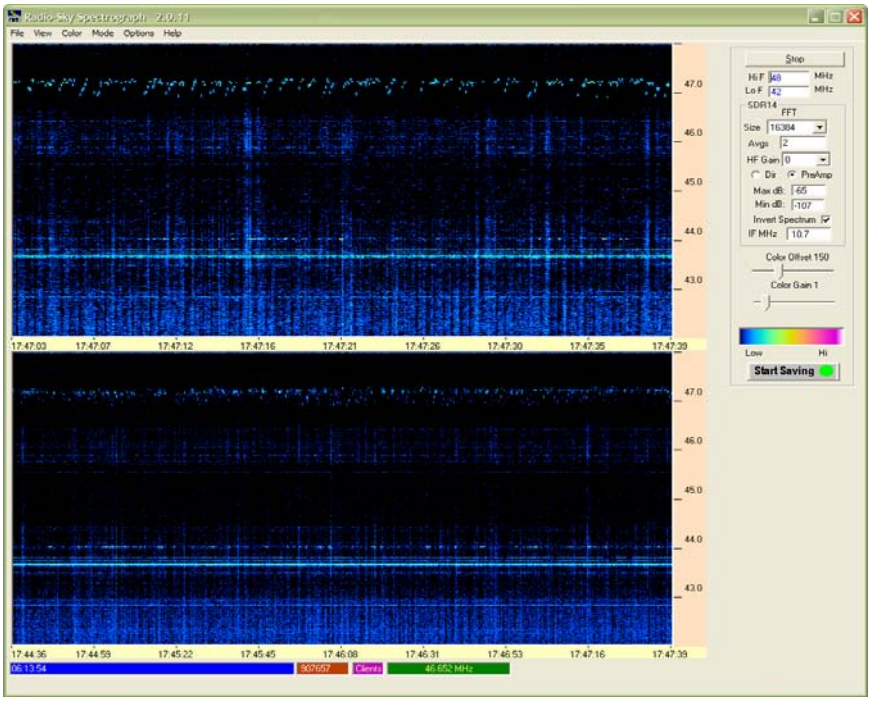


Figure 3 – Spectrograph screenshot of meteor burst communications system in the 42-48 MHz frequency band

You probably have noticed that the world is now permeated with microcontrollers that add functionality and some amount of intelligence to everything from cars to toasters. If you intend to use your computer for device control, get ready to have some fun with microcontrollers. I love them. These devices are similar to the 8 bit microprocessors that were the heart of all those Ataris, Commodores, Apples, and so forth from the 1980s. It was fairly easy for me to catch on to programming these things because of my machine coding from the early days. But take heart, all of these devices have higher language programming tools available for them. Some chips even have built in BASIC compilers (like the PicAxe and BASIC Stamp). Some have gone beyond the 8-bit stage and now run 16 or 32 bits. The amount of peripheral support that you can get on a small board for less than $60 is amazing. You probably won't have to solder a thing to get started using most of the development boards. If you have not yet done so, I suggest you invest the time to familiarize yourself with at least one microcontroller family. The most popular is probably still the PIC family of controllers from the MicroChip Corporation. MicroChip provides a free assembler and C language compiler for this large family of devices. (Remember the Apple computer flub? Microchip is out front because they encourage developers!) There is

more in the way of example *code* for the PIC devices than for other microcontrollers. The internet will supply you more than you can use. Your time and learning investment will reap many rewards if you enjoy developing your own electronic projects. Programmers can be purchased for less than $30. Buy one with a ZIF (zero insertion force) socket. Soon, you will find yourself replacing huge arrays of logic chips with small 8 to 40 pin packages. Your hardware will not only become smarter, it will have an inherent flexibility that allows you to make improvements without redesigning everything. Some microcontrollers have in-circuit programmability and you may not even have to remove the chip from the circuit board to change programs.

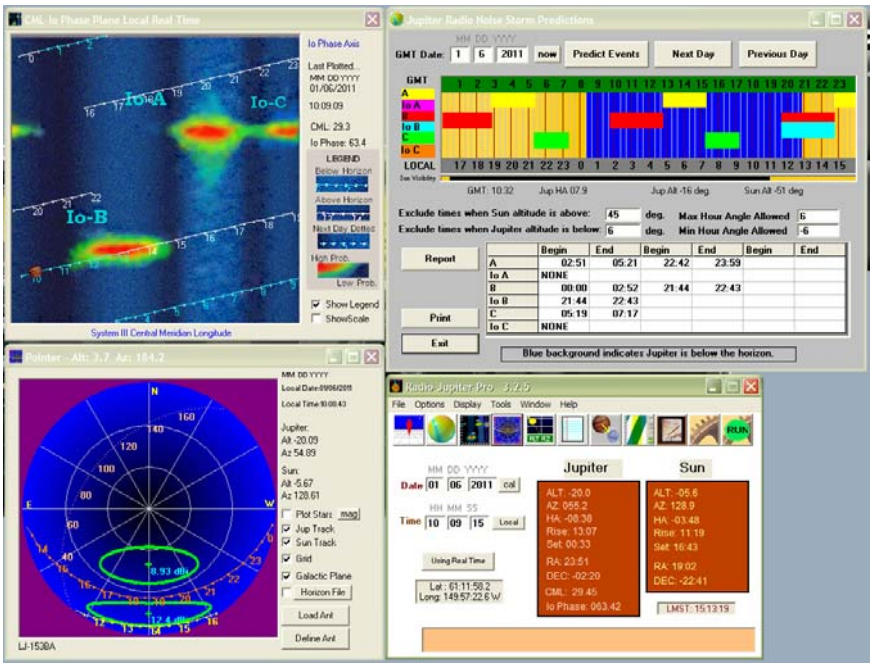


Figure 4 – Radio-Jupiter Pro showing four of almost a dozen windows for predicting Jupiter emissions

The sound card also provides a way to get information into your PC. Most readily of course, you can input the audio output of a receiver into the line-in jack, but it is also possible to monitor slowly changing DC voltages by using a chopper circuit that modulates the DC signal. See my web page about this at:

http://radiosky.com/skypipehelp/V2/using_a_sound_card_to_measure_dc.htm

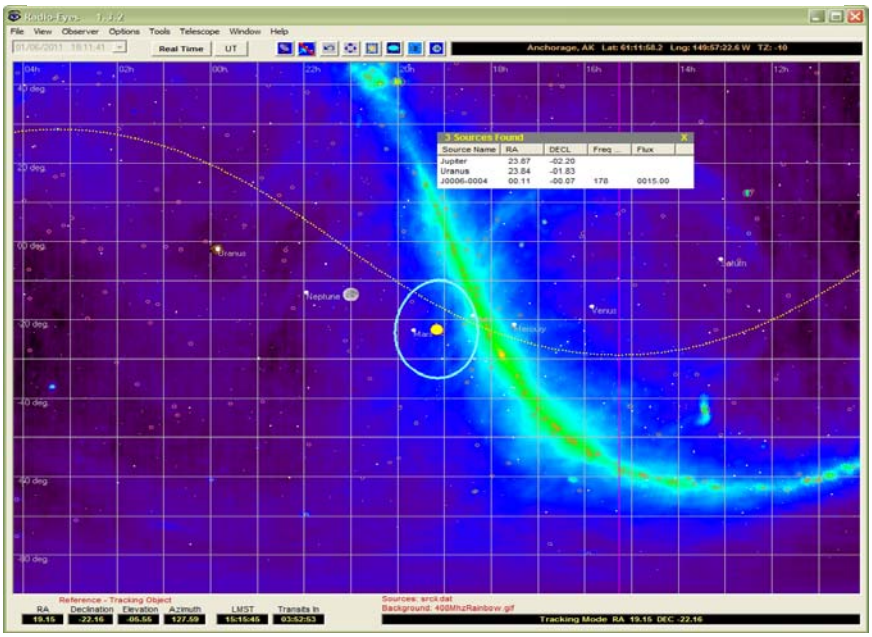
Communicating with the sound card from the PC requires you to use some low level *code*. There are two common Windows approaches to this, using the Windows Media Application Programming Interface (WM API) and using DirectX interfaces. I have been using WM API for many years. Most of the time I have relied on ActiveX controls from the German Swiftsoft.de company. Unfortunately, they have virtually no support available and the controls are not documented except for some example programs. Now I find myself digging into the WM API directly in order to have better control of the sound data and the mixer functions. Linux programmers will find some great example *code* for accessing the sound card data in David Brodrick's fringes.org project.

This leads me to a side topic. One really nice aspect of VB6 and VC++ (as well as Delphi Pascal by Borland) was that they made it possible to achieve big jumps in functionality with very little coding by the use of ActiveX controls. These are little *widgets* that you plug into your program to give it some feature that you really don't want to *code* yourself. ActiveX controls usually cost

you money. The actual strip chart in Radio-SkyPipe is an ActiveX control from iocomp.com. If you want to include it in your own strip chart program you will have to shell out about $800! But other controls are often more reasonable and some are even free. ActiveX is now considered an old technology but it is still possible to use it in the new .NET environment.

There are other ways of cutting back on how much coding you have to do. I suggest you modularize your *code* as much as possible. Sometimes you will have a group of routines that have some common theme; perhaps flux density or FFT related routines. Anything that you might use in more than one program is a good candidate for placing in its own module.

Figure 5 – Radio Eyes screenshot of program in tracking mode



Back from the aside and on to the challenges of simulating the real world. To make visibility predictions, aim a telescope, or other tasks related to observing the sky, we need to have all the right algorithms and put them together in a way that gets us our answers. This sent me to the bookshelf back when I was writing those early DOS programs. Lucky for me, a few others had already been approaching these problems using BASIC and C languages. So for the most part, I cobbled together routines that made the desired predictions based on the work of these early programmers. An excellent aid that came along a little late for my early work is Fundamental Ephemeris Computations by Paul J. Heafner, published by Willmann-Bell in 1999. [*Editor's note: This still is available from Willmann-Bell at www.willbell.com/math/index.htm along with many other books on astronomical computations*] On occasion there was no readily available computer *code* on which to base my routine. In those cases I had to go straight to the formulas and work them into *code*. Many years have elapsed since then and you should be able find most of the astronomical routines you need on the Internet. You might have to translate then from another language but that can be fun and educational (or a pain in the bum). One thing you need to ask yourself is how accurate do my position and time coordinates need to be? It sometimes can be a lot of trouble to get that extra decimal point and if you have an antenna with a wide beamwidth you may just be wasting your time to achieve the unneeded accuracy.

The last area I want to mention is that of data processing, that is, what we do with the data once we collect it. Processing could mean nothing more than storing it away in some optimum format so that it might be used later, or it might be plugging it into a program that pops out an elegant

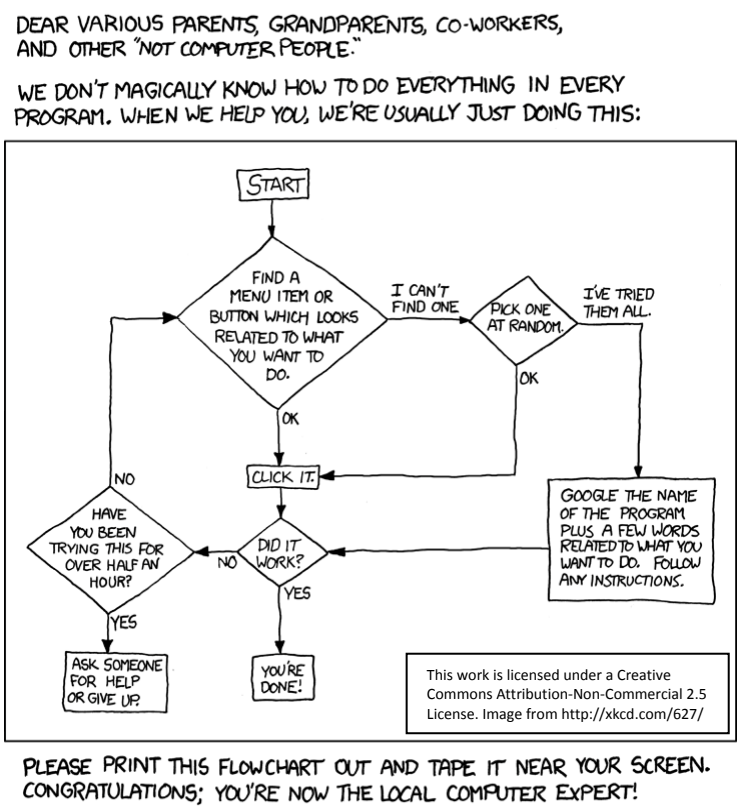
map. Sharing the data on the internet is another interesting possibility. Third party general purpose software like, Excel, MathLab, gnuplot, etc., are great tools for some efforts. The trick is to simply understand the applicable data format and produce a compatible file type to use these. It is probably not worth the effort to develop a plotting presentation from scratch if one of these programs will meet your needs.

Figure 6 – Sidereal Clock screenshot. It displays local mean sidereal time and coordinated universal time

Putting your data where it is available to others probably means working with a web site. Here the options are far beyond what I can keep up with. But I can tell you about what I have been so far doing to this end. For peer-to-peer communications I have been using TCP protocol and an ActiveX called the Socketwrench control by Catalyst software. This has made it much easier to *code* data exchanges than using basic sockets. Peer to peer communications that reaches across the internet (and not just a LAN) is hampered by all of the roadblocks we try to put up against hackers getting into our computers. This makes it more attractive to try and find ways to use web site based data presentations. In Radio-SkyPipe I built in an FTP uploader to send images of charts to a web site. It works after you find out all of the right settings to access your site by FTP, but it feels like a very clumsy approach. More recently I have begun using an HTTP submission approach that uses a small PHP program on the website and the Chilkat HTTP file uploader tool.

If you have a web server on your home PC you have the advantage of not needing to upload anything. Your presentation can be very dynamic because you have the server and the data collection PC in one box. For a very able but small and efficient web server I suggest trying the Abyss free web server from Aprelium.com.

Really, there is much to talk about and this can only be a very incomplete rant about the topic. We really haven't talked about *DSP* or *SDR*, and what about digital correlation? Everyone should learn a little programming, if for no other reason than to give you some empathy for those that do. But be careful, you might spend years doing this stuff!



GLOSSARY

8-Bit: The size of the data bus on early computers. Values greater than 255 took multiple steps to process.

API: Application Programming Interface, a set of routines provided by a large program or operating system that allows programmers to access important functions.

Assembly Code: A very low level language that allows you to program the actual commands acted upon by the microprocessor. While assembler programming is tedious it is very powerful.

Code: What you type in when you are writing a computer program. This is your list of instructions for manipulating data in the computer; a computer program. As a verb it means to write these instructions.

DSP: Digital Signal Processing - acting upon analog signals by digitizing them and applying functions to the resulting arrays of values.

Object Oriented (Programming): The way almost all high level programming is done now. Data and procedures are logically packaged into "objects" and everything that happens in the program relies on the interactions between these. In many ways OO programming is very useful but it can go too far! It can be almost unreadable.

Port: As a verb it means change from one language or platform to another.

ROM code: The permanent instructions held in Read Only Memory that control how the computer works.

SDR - Software Defined Radio - Radio that relies on a computer to handle many of processes (such as filtering, noise removal etc.) that were historically handled by analog circuitry.

Widget: A small program, or piece of computer code, that has specific utility.

~ Interview with Jim Sky ~

Owner of Radio-Sky Publishing Company and Preeminent Creator of Computer Software for Amateur Radio Astronomy

By Bill Seymour, KM4YL

When earlier in your life did you first become interested in astronomy?

I do remember receiving a small hand-held telescope one Christmas when I was about eleven years old. I soon realized that you couldn't hold a steady image of anything astronomical. Another problem was that I lived in the city, and the glare of the lights in our apartment complex overwhelmed me. I took a cardboard box and cut a hole in it and wedged the telescope snugly into it. I would then sit on the ground with my head inside the box and the little scope sticking out pointing at the Moon. I have been annoying neighbors ever since.

Radio astronomy came to me after an interest in UFO's in my teens and twenties. I eventually became convinced that there were no alien visitors but became aware of SETI and found that it fit right in with my love of all things radio. I was a ham operator and had always played with electronics. SETI in turn led me to radio astronomy, which eventually won out completely for my attention. It provided far more positive results.

What was your involvement with the famous radio astronomy program at the University of Florida?

My connection to the UFRO came late. I was writing the early DOS versions of Radio-Jupiter. I somehow found out that there was this fellow named Dick Flagg, and I wrote him (snail mail) asking him if he had any Jupiter recordings. Believe it or not, he sent me back a copy of the audiotape of Jupiter sounds that he narrated from the UFRO. A long friendship began. Eventually, Dick invited me to join this new group of people called the Radio Jove Team. Then I met the rest of the UFRO crew, and life hasn't been the same since. I was soon able to visit the UFRO observatory and see what remains of a long history of Jupiter radio studies. It was better than Disneyland for me!

Could you give some information about your life in terms of education and career prior to the point where you contacted Dick Flagg at UFRO about the Jupiter recordings?

I graduated from the University of Louisville in 1976 with a Bachelor's in Biology. I wanted to be an ichthyologist, but I had a family and couldn't afford more years of grad school. I began working at a bank in the office machines department where my electronics hobby skills seem to be valued. We actually developed some circuitry there, and I learned about digital circuits. Later I got in telecom and IT.

When did you locate to Hawaii? Are you a native?

I quit the bank after 22 years and came to Hawaii to live in 2001. There was no job waiting here. It was just because I had always wanted to live someplace tropical, and I didn't want to die in a cubicle. It has been a wonderful place to live. No, I have no relatives here, but it is wonderful to live in such a diverse community.

How often do you return to the mainland U. S.?

For the past two summers we have returned to be with the Grandkids and family. Last year I was able to attend the Dayton Hamvention and the SARA conference. We plan to continue these trips in the summer. I will suffer the heat like most of you.

Describe the set up of your home observatory including your ham station and radio and optical telescopes and antennas.

Well, it is always changing. Right now my prime instrument is the stick and wire log periodic dipole array for 17 to 30 MHz that I use for Solar and Jupiter work. It feeds a SDR-14 Receiver. In recent use I have had a 50 MHz Moxon that I unsuccessfully used to try and obtain interferometer fringes from the ocean…but I haven't given up! I have two Jove receivers that I am working on to use as an interferometer proof of concept experiment like Dave Brodrick's fringes.org system. However, because I do not have the real estate to widely separate the two 20 MHz antennas, I am building a pair of down-converters from 2 meters. Then I can use a couple of 2m Yagis and fit them on my lot. I programmed a cross-correlation detector into the latest Radio-Skypipe to do the processing, but I will not know if it works until I get the hardware done to test it. Also here is an eCallisto spectrograph fed by a large TV array.

My ham station is a collection of home brew QRP stuff and some old rigs like a TS-520 and even a HW-16! Everything I do is on a budget. Really it is more fun that way. The $10K radios don't really attract me. Doing something with a few resources really excites me. I love cw, but it is harder here to make contacts with simple dipoles. I am always busy with RA stuff. Optically, I have nothing but a pair of binoculars.

Do you have clear skies and high elevation?

The sky at my home at 1900 ft. elevation is often cloudy at night, though just 10 miles away the views are fabulous. This is because the area around a large volcano has cloud forming regions. We live just below a cloudy spot. Doesn't affect radio, though. Most of the time we do not have power line interference, but sometimes we do. However, like the optical, I could always pack up the system and take it to where the viewing is good.

You are a very good writer, based on the logic, flow, and organization of your books, and the article that you submitted to Dec./Jan. RADIO-ASTRONOMY. Does the publisher of your books need to do much further editing? It does not seem there would be much of a need.

Thank you. I am actually my own publisher and the publisher for others (Radio Sky Publishing). Editing is painful, and if you are not careful you will never publish anything because you are endlessly revising. As the years grow fewer, I am less inclined to try and get things perfect. I feel like this about my electronic projects, too. Get it out there when you have confidence it is right but not before you are absolutely sure that it is perfect. A lot of creative people are stifled by their perfectionism. I would hope that potential submitters to the SARA Journal would not fall into that trap. We have a good editor in John M. to help us get things into acceptable shape.

Where do you see the future of computer programming for amateur radio astronomy? For example, those of us who are involved in ham radio are very aware that the Federal Communications Commission considers software defined radio to be experimental and presently restricts the use of spread spectrum operations to amateur frequencies above 222 MHz. But many of us strongly feel that this is the way of the future. What do you think?

I am hopeful that we will see some innovation from young recruits in this hobby. From those young programmers we can only predict that they will think of things we have not. Perhaps there will be some good work in converting many of the professional tools into forms that are easy for the casual amateur to use. There is so much that can be done in digital signal processing, but no one has produced a widely usable tool with the amateur radio astronomer in mind. We can be sure that software that supports collaboration will be important. I can't help but think that if we can somehow link our simple telescopes (not necessarily as an interferometer) and data that we can make a real contribution to astronomy.

I have been expecting for years that spread spectrum would take over. I imagined seeing this only as a slow rise in the background noise at virtually every band below 12 GHz. I pictured the spectrum to look basically flat because every signal would only live for a tiny fraction of a second at any given frequency. I wasn't sure how it would affect radio astronomy. But in any case, it hasn't happened.

Let me relate a fantasy that I had as a much younger amateur scientist. I felt like there was a pretty good chance that ET was talking to us with a booming signal. The catch was that ET was using spread spectrum, and all we had to do was to figure out the frequency-hopping algorithm and the timing. Certainly these would be keyed to some fundamental constants. But then I decided it would be easier to make a drift scan of the Sun.

What is your favorite programming language?

I love VB6. But as I said in my RADIO-ASTRONOMY article, it is no longer supported by Microsoft, so I must move on. I am working in VB.NET now. My aim has never been to be a top-notch programmer, following all of the rules of modern programming dogma. I do not care if someone thought C was better than BASIC or if my use of a GOTO statement was sacrilege. My goal was to produce programs that the public and I would find useful and educational.

What are the various strengths and drawbacks of the programming languages that you work with?

That is a good question. But I think that those experimenters that will do most of their own programming will have their own preferences develop over time. It is kind of fun that sooner or later you meet challenges that your particular language does not solve well. Then you have to branch out. You find yourself writing a PERL program for the Internet, A C DLL because BASIC is too slow, or maybe something in ADL to take advantage of the astronomical computation code available. Most programmers know one or two languages well and dabble in a dozen or more to get special tasks completed.

From the paper you submitted to the Dec./Jan. SARA Journal, you state that you didn't get into DSP, SDR, and digital correlation. Some of the more advanced SARA members might like to hear you provide some further details on these subjects.

These are topics that deserve entire treatments, and I am by no means an expert on any of it. I have read a number of articles on each of these topics, as have many of you. I followed the QEX series that led to the first popular amateur transceiver. I have experimented with the SoftRock simple receivers and was amazed at the performance of such a tiny board plugged into your computer. I have a small pile of un-built SDR's in my shop. I now have a SDR-14 from rfspace but could not have designed it.

DSP is something intimately connected to software-defined radios, but also a whole world unto itself. My DSP efforts have been very elementary. I am a bit put off by how mathematical it can be. I want what many others do—a black box that will take my noise and make sense of it. I challenge the whiz kids out there to come up with a little black DSP box that will solve all of our interference related problems, or even just one of them. It's getting harder to be an amateur radio astronomer these days because we are so heavily clobbered with interference from our wireless world. Anything that helps solve that—goes a long way towards promoting our hobby.

Do you have any new amateur radio astronomy software projects under development?

I am working on some software tools that will help us easily submit Radio Jove observations to a common database. On the server side, I want to develop tools that present this crunched data in useful real time ways. What we want is to produce some collaborative science projects using Radio Jove. The key to that is accumulating high quality data and efficiently processing it. Expect to see some trials soon.

Radio-Jupiter 4 has been under construction for quite a while. New features include a view of the Earth from Jupiter, better integration with Radio-Skypipe and RadioEyes, a new observation reminder system, and more.

I am working a lot with microprocessors. For years I have wanted to make a very good data collection device that is GPS time-stamped, fully buffered, and easy to interface. I have had a couple of stabs at it without good results. So, I hope to get this done this year...and lose 20 lbs.

~ Trials and Tribulations of VLF SID Monitoring ~

By Dave Benham

McMATH-HULBERT SOLAR OBSERVATORY

Our playground, the McMath-Hulbert Solar Observatory (MHO) in Lake Angelus, Michigan, has been in existence for about 80 years. It was originally privately owned, then the University of Michigan owned and operated it until 1979, then it eventually became privately owned again. Over the years a lot of important solar research was done here. The first motion pictures of the surface of the sun in hydrogen alpha were taken here in 1934. Much work was done to classify sunspots and solar emission types. Several renowned astronomers cut their teeth at MHO. Now the observatory is manned with a small but dedicated crew of volunteers who are trying to restore the place as well as do some research and educate kids.

Figure 1: This photo is what the observatory looked like in about 1940

See www.mcmathhulbert.org.
Email: info@mcmathhulbert.org

In reviewing old materials at the observatory, we found that during the International Geophysical Year (IGY, 1957-1958) the scientists at MHO monitored VLF and 18 MHz to record, respectively, atmospheric noise and galactic noise levels.

Being that a couple of our volunteers are ham radio operators, we found this interesting and had always wanted to simulate what had been done 50 years earlier but with more modern equipment. Since we should be approaching another upswing in the solar cycle, we felt it was a good time to get involved with VLF reception, data logging and plotting.

Another reason for us to get into radio astronomy is that visual observing was not going well in Michigan (why would anyone in their right mind build a solar observatory in Michigan? Has the weather changed since 1930? Can you tell the author went to Michigan State University?). Radio astronomy generally works around the clock. So we gave it a try.

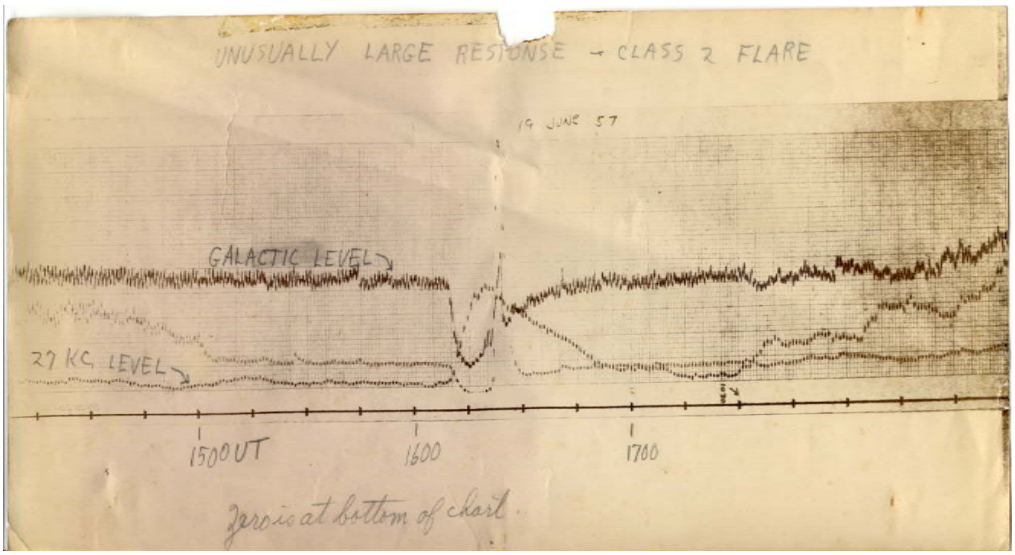


Figure 2: A typical plot of an "unusually large response" to a "Class 2 Flare." June 19, 1957

THE GYRATORS

Our first step was building two simple receivers, the Gyrator II and the Gyrator III, and feeding their output to a Dataq analog to digital converter, and into a computer, recording data with Dataq's "Lite" (free) software. FAR Circuits (www.farcircuits.net) has the printed circuit boards at a very reasonable cost and we rounded up the other necessary parts from ham radio swaps and online ordering houses. The Gyrator II worked quite well from the beginning. The Gyrator III seemed to go into self-oscillation when its gain was increased. A triple check of the wiring/soldering job and critical components showed nothing unusual. We eventually found a decent balance for the internal and external gain controls that prevented the oscillation but still gave us enough gain for decent data. Still, we recommend the Gyrator II.

One problem with the Gyrators is tuning to the frequency of interest and having it stay put. They seem to be rather broad-banded to effectively separate stations like NAA (24 kHz), NLK (24.8 kHz) and NML (25.2 kHz) which are the three strongest stations we receive at MHO.

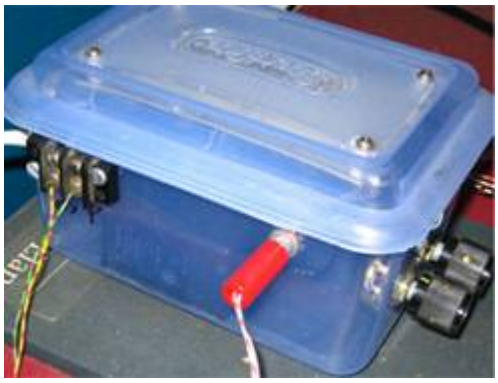


Figure 3: Gyrator II

Figure 4: Gyrator III

THE LOOPS

We built various loops with various degrees of success, usually starting with a known design pulled from the Internet or a radio magazine. Our first antenna was a loop made from 100' of 6-wire telephone cable. The loop was scramble wound to a rough diameter of 15", then the tag ends from each end of the sheathed wires were alternately attached to another wire, effectively increasing the overall length from 100' to 600'. We then switched about six different capacitors in or out of the circuit to tune the loop. We used a Standard 1001A signal generator and an oscilloscope to find the peak tuning ranges of the different capacitors in the antenna, then found the best combination for 24 kHz, NAA.

Figure 5: Our loop: Primary =120 turns of #30 wire. Secondary = 12 turns of #30 wire. Tuned by 500 pF tuning condenser. Frame approximately 19" square

Being ham radio tinkerers, all the loops we built were tuned, either by switching capacitors in and out, or by using a variable capacitor. One larger version (5' diameter) of the telephone wire loop above just did not work. We feel that capacitance between the loop wires was too great and did not allow us to tune it low enough to work at VLF. It sure was pretty though! The most effective loops we have built have used small diameter wire (magnet wire) and have been wound side by side rather than scramble wound. They are tuned by variable capacitors. They have all been used indoors on the first floor of the building.

Figure 6: General Radio Standard 1001A signal generator

TUNING

We used the General Radio Standard 1001A and the scope to tune the radios as well, although in the end we used a different method. One of us had an older Lampkin 107C communication service monitor that went down into the VLF range. The Lampkin had an antenna that could be used to radiate a low power signal a few feet, so we set the Lampkin to the frequency of interest and tuned the Gyrator for maximum output as seen on the computer. This worked well, but we found that periodically NAA would later swamp out the Gyrator that was tuned to NML so that we had

two Gyrators tracking the same frequency.

As an aside, the Standard 1001A is a beautiful piece of equipment. When we first resurrected it to put back in service, we found that the generated frequencies were still dead nuts to a modern calibrated frequency counter. Also, General Radio built beautiful looking equipment – you can feel the quality. You can tell the people who built it cared about the work they did. So, don't be fooled just because something is "old" – just fool the guy you're buying it from.

REAL RADIOS

The next step was to use a couple of Rycom "selective level meters" and feed their output through the Dataq to the computer. The Rycoms have two different selectivity levels from rather wide to extremely narrow (50 Hz in the Rycom 6040). They also have an AFC (automatic frequency control) that can be switched on to lock the frequency. However, we found it difficult to use the AFC with the low levels of signal involved. It was generally not strong enough to lock the AFC. With the AFC unlocked, it tended to drift far enough to degrade the received signal strength. These Rycoms were purchased "used" and may need alignment or parts replacements. I'm sure they have seen better days despite their apparent continuing functionality.

We also tried using an older McKay-Dymek DR-55 both alone (which directly tunes VLF) and with a Palomar VLF converter which converts 0 to 500 kHz into 3.500 to 4.000 MHz. Both these methods worked well, but will be reserved for DXing interests (listening to distant stations) for particular stations. The Heath HD-1420 VLF converter also works well. You simply plug the antenna into the converter and run a coaxial cord with the correct connectors between the converter and the receiver. Tune the receiver to the correct tuning range, and away you go.

Figure 7: Rycom 6040 selective level voltmeter

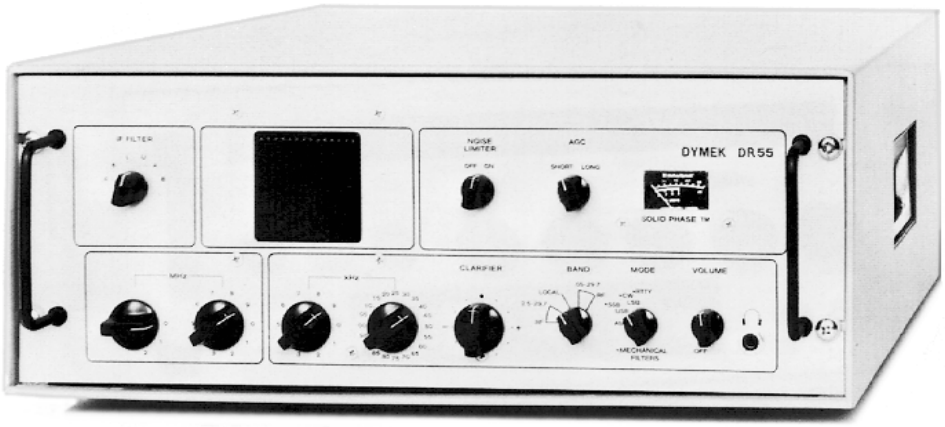


Figure 8: McKay Dymek DR55. Ever see one of these? I doubt it.

Figure 9: Palomar VLF converter

Figure 10: Heath HD-1420 VLF converter

AMBIENT TEMPERATURE

Another factor which may have influenced all the radios tried to this point is the ambient temperature inside the observatory. Although we have the radios set up in our administration building (the three observing towers are not heated – heat distorts the views) where heat is available, in order to conserve energy, we turn the heat down very low when we are not there. During the winter, the temperature may vary over 30 degrees F as we come and go. This is bound to degrade the needed rock solid frequency control. A more consistent ambient temperature may have prevented these problems, or the degree that we experienced.

ENTER THE SUPERSID

About 9 months ago, while scouring the web for new information regarding our VLF interests, we discovered the SuperSID program coordinated by SARA and Stanford University. We applied for admission to the project, were accepted and soon had our SuperSID, software and antenna materials. The beauty of the SuperSID is that one little pre-amplifier the size of a tin of snuff can receive anything from 0 to 48 kHz and record data for practically as many stations as you like. Its output merely feeds a 96 kHz computer sound card.

Figure 11: SuperSID hardware

SUPERSID LOOP

We built a loop about 5' square from PVC pipe. The plans we had seen on the SARA site called for 1 ½" diameter pipe but we could not find the cross piece for the center in that size at any local building store (most plumbing projects call for several trips to several stores). We did find it in ¾", so we used ¾" PVC for the project. It's a little flimsy but the wire wrapped around it helps to make it more rigid. The wire was about 400' long as provided by SARA in the kit. We wound all of it, about 27 turns total, and fed it with the coax provided by SARA.

Figure 12: SuperSID loop similar to ours. Photo taken at Green Bank 2010

We tried this loop outdoors and found little difference from its performance indoors, so we left it inside. We have not tested the natural resonance of this loop but have found that the fact that it is not tunable (unlike our other loops that are tunable) seems to increase noise and decrease signal-to-noise ratio. It is much more broad-banded than our tuned loops, which is to be expected. At this point, we favor our approximately 19" tunable square loop wound with magnet wire. We peak that loop for 24 kHz with the tuning capacitor which seems to provide a good compromise across our frequencies of interest (20 – 40.75 kHz).

One modification we did later was to cut the horizontal support legs off and insert threaded PVC adapters so we could transport the loop easier. Anyone who saw Michael Rudolph driving off into the sunset from Green Bank last summer with the VLF loop awkwardly strapped to the trailer hitch can appreciate this feature.

NOISE ISSUES

Noise was mentioned above. The SuperSID receives more noise than the true radio receivers we used prior. We suspect some of the noise is coming from the computer and some from the power lines throughout the building. Some of it seems to abruptly switch on and off, often with the furnace blower (induction motor). We used Spectrum Lab's software (see below) and found it was very useful in tracking down the noise. It provides a waterfall view that is real time, so when we tried various tricks to eliminate noise, we could see its effect immediately across the entire spectrum of the soundcard.

The first noise source we isolated was a CFL light bulb right over our heads. It created a very wide "hump" from about 25 to 35 kHz with tails that reached into our frequency range of interest. We replaced that bulb with an incandescent. We discovered later that this instance was probably caused by one "bad" CFL. Other CFL's of the same brand and wattage are quiet. As an aside, there was a terrific noise at home that eventually was found to be coming from a burned

out CFL located in the garage. Even though it was no longer putting out light, it was putting out plenty of noise (which to my knowledge started after the CFL died).

Next we roamed the building with a transistor radio tuned to 150 kHz (the lowest frequency covered) using the internal ferrite loop antenna to pinpoint other sources of noise. About all we found was a microwave on the second floor that was noisy with the portable radio within a foot of it, so we unplugged it. Surprisingly, the furnace yielded nothing (later, we suspected the correlation between the furnace turning on and the noise in the SuperSID have been be static from the blower belts). We also found a very strong square wave coming from the electrical wires in the wall very near where the SuperSID is set up. This may be due to the computer, but we're not sure at this point. A couple other things we noticed in our noise investigation: when we bunched up the cable coming from the SuperSID's 9VDC wall wart and grabbed it with our hands, the noise essentially disappeared. When we released our hand grip on the wire, the noise returned, like a switch was flipped. Grab the wire again, and the noise disappeared. And so on. The ultimate solution would not be to stay there and grab the wires for 24 hours a day. Since this method seemed to be introducing capacitance, we tried putting a small .001 uF capacitor inside the SuperSID, across the lines to the computer. This degrades the signal 5-7 dB but reduces the noise by about 20 dB, so S/N ratio is improved (sometimes more power a la "Home Improvement's" Tim Allen is not the goal). We plan to try other values of capacitors in order to optimize the S/N ratio.

SPECTRUM LAB SOFTWARE

Spectrum Lab software was mentioned above. This can be downloaded for free from http://www.qsl.net/dl4yhf/ and is great software for VLF listening, visually tuning radios or antennas while in operation, tracking noise, etc. It is very complex software and unfortunately it does not seem to have an independent user's manual. There is a user group on the web and a web site where substantial help is available. This software allows you to see signals that are otherwise indistinguishably buried in the mud. We have seen France, Iceland, England, Italy, Australia on the waterfall despite not hearing them at all and often not seeing them on SuperSID. Of course the output from Spectrum Lab is not suitable for data submission to Stanford, but it is still very useful (and fun!). It has been particularly useful in tracking down noise sources.

SUPERSID CONFIG FILE TRICKS

We found a trick to use with the SuperSID config file. The default six stations can be changed, and additional stations can be added. Also, we added off-station frequencies to plot noise levels throughout the day. Follow the exact same format as is used for the original stations and enter it below the existing entries – don't forget to change the total number of stations being monitored which is shown above these entries in the config file. For example, we named ours "QRN20" (for monitoring noise on 20 kHz) and "QRN35" (for monitoring noise on 35 kHz). The only thing we have not figured out is the code used for the color of the plot lines. Since we do this analysis using Excel, it doesn't matter to us (plus, the author is colorblind!) – just use a letter that has not been used for the other stations. Tracking this way should help us identify patterns in the noise to help identify its source. Most of the noise we have is quite broad in nature, but we have seen at least 3 different spikes in Spectrum Lab which look identical to the weaker signals in

SuperSID's software but are not on a frequency that is associated with any VLF station. With Spectrum Lab one can listen to a particular frequency with a narrow filter. When listening to these "signals", it sounds "buzzy" like noise, not at all like the US Navy stations which send 50 baud encrypted radioteletype or RTTY (keep in mind that we have been ham radio operators for many years and have pretty good ears for this – the "buzzy" noise might sound the same as a true signal to the uninitiated). We have set the config file to monitor them to see what their pattern may be. An important caveat when tinkering with the config file, is to always save the original file under another name so you can go back to it if necessary.

One potential issue with doing the above, if you are adding frequencies for tracking noise or other things of local interest, and you also send your files to Stanford automatically, *all* files go to Stanford. There is no way to send only the ones in which Stanford would have interest (we don't suppose Stanford wants their database cluttered with personal problems!). This is not a concern to us because we manually submit our data via ftp and can pick and choose which files to send.

RESULTS, FINALLY

So we are finally doing effective recording of VLF stations, submitting data to Stanford and continuing to monitor the noise situation. We hams just want to tinker and solder and turn knobs and work DX and solder some more. The real goal of SID tracking is to be able to have a nice clean plot that is able to show a SID when one occurs. That can be done on NAA alone from most parts of the USA, or the strongest "local" station wherever in the world you may be. The rest of it is gravy (and fun!).

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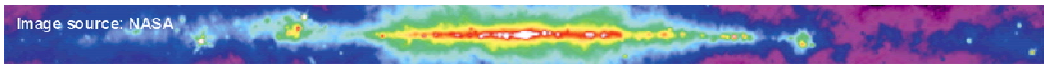
Dave Benham, McMath-Hulbert Solar Observatory

Dave is retired from Chrysler Corporation having worked there in Supplier Quality, Supplier Development and Program Management. He is an ASQ Certified Quality Engineer and Certified Reliability Engineer, a member of the American Society for Quality and the Society of Automotive Engineers. He was graduated from Michigan State University with a B.S. in Psychology and an M.A. in Education. Dave has been an amateur radio operator, licensed as K8TRF for over 50 years. He is treasurer of the McMath-Hulbert Astronomical Society and volunteers at the McMath-Hulbert Solar Observatory in Lake Angelus, Michigan, where they also run Radio Jove and natural radio projects. Dave and SARA member, Tom Hagen, NE9Y, also operate K8MHO from the observatory.

~ Radio Astronomy Quick Tutorial No. 6 ~
Celestial Radio Sources

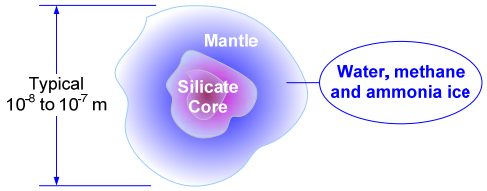
By Whitham D. Reeve



A. Introduction: Our solar system lies in a very large conglomeration of stars and other matter that we call the Milky Way galaxy. Stars in the galaxy are separated by distances on the order of light-years and extend tens of thousands of light-years from the galaxy's central region. The interstellar medium includes individual atoms and molecules, mostly hydrogen and helium but other chemicals and dust grains as well. As we move away from the galaxy's central region, the stars thin out toward the edge. Farther out there are huge areas of what we think of as empty space but some of it consists of interstellar matter in clumps and clouds, called nebulae, with dimensions of thousands of light years.

At distances of millions of light-years from the Milky Way there are other galaxies and in between there is interstellar matter including gas. It is estimated that an even distribution of all the interstellar gas throughout the universe would result in a density of about 105 atoms per cubic meter. To put this in perspective, the air at normal sea level pressure on Earth contains about 1024 atoms per cubic meter. The density of dust grains in outer space is far less than the gas. A cubic volume of space, one kilometer on a side, contains perhaps a few hundred or few thousand dust grains, each smaller than about 0.0001 mm (Fig. 1).

Figure 1: Interstellar dust grains are thought to consist of a rocky core of silicate or graphite surrounded by a mantle of ices



Every object and all matter – stars, planets, atoms, molecules, and dust grains – in the universe emit radiation in one form or another. All emit more strongly at some frequencies than others. Although we are mainly concerned with radio sources detectable by amateur radio astronomers, we will provide a more general overview of the many types of radio sources in the universe. Emissions from celestial radio sources can be broadly categorized as thermal and non-thermal.

B. Thermal radiation: All matter with a temperature above absolute zero (0 K or –273 °C) emits *thermal radiation*. If you put a large rock in a campfire, let it heat up and then pull it out, the rock will radiate the energy it absorbed from the burning wood, and you can feel the heat. This thermal radiation is called *blackbody* radiation (also called cavity radiation). The rock absorbs all the energy that reaches it and then re-emits that energy at *all frequencies* at the same rate it absorbs the energy. The characteristics of thermal radiation depend only on the material's temperature and not on the shape or material itself. Other familiar examples of thermal radiation are the heat from sunlight and the heat from an overhead heater in a bus stop shelter.

Although a blackbody radiates at all frequencies, it does not radiate equally at all frequencies. If we raise the temperature of a blackbody to some temperature and measure the intensity of the radiated energy at a number of different frequencies and plot our measurements, we will obtain a blackbody radiation curve (Fig. 2).

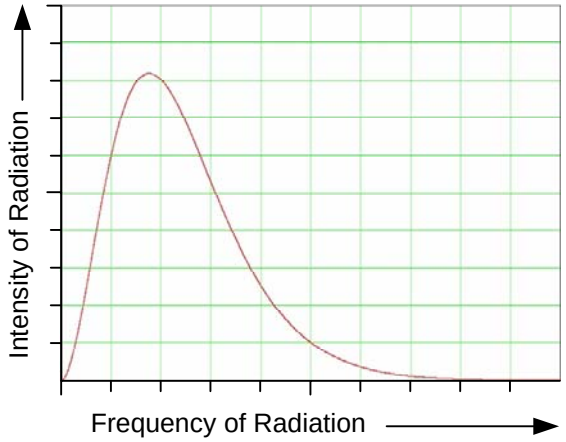


Figure 2: Blackbody radiation curve. As the frequency increases from a low value, the electromagnetic radiation rises to a peak and then falls off, following a smooth curve. The peak depends only on the temperature of the blackbody and not on the type of material. The curve for blackbodies of all kinds will have the same general shape.

When a blackbody, say a cube of steel, is at room temperature it emits mostly infrared frequencies and only a very small amount at radio frequencies. If the temperature is increased the radiation will become stronger at visible light frequencies (shorter wavelengths). With increasing temperature it will appear red, orange, yellow, white, and blue, the colors of the visible spectrum. By the time it is white hot, it will be radiating at ultraviolet frequencies. If the blackbody temperature is decreased below room temperature, it will radiate at progressively lower frequencies from infrared to radio frequencies (longer wavelengths). These emissions will be very weak because the thermal energy is very low at low temperatures.

If we lower the temperature to about 3 K (–270°C), we will notice the radiation peaks at about 160 GHz (1.9 mm wavelength). This temperature is close to the temperature of the *cosmic microwave background* radiation (abbreviated CMB, also called *cosmic background radiation*, CBR, and *microwave background radiation*, MBR), a relic of what is thought to be the Big Bang – the beginning of the universe.

If we analyze the radio frequency radiation from a blackbody, we find that it is indistinguishable from the noise voltage produced across a hot resistor or at the junction in a semiconductor diode or transistor (Fig. 3). We also find that the noise power at radio frequencies is proportional to the blackbody temperature; that is, the power in the thermal radiation at radio frequencies increases linearly as the temperature increases. We can use the correspondence between noise power and noise temperature as the basis for measurement of celestial radio sources, which are noise sources themselves.

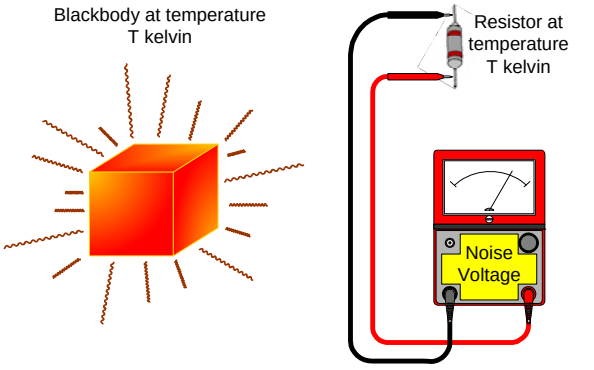


Figure 3: The radiation from a blackbody at some temperature, T, is indistinguishable from the noise voltage across a resistor at the same temperature.

Many celestial objects radiate like blackbodies, and we would expect to receive light waves as well as radio waves from them. However, depending on the characteristics of the source, its radiation at radio frequencies may be much weaker than at light wave frequencies. If the measured radiation from a celestial body departs from the smooth blackbody radiation curve shown above, it indicates there are other (non-thermal) emission mechanisms at work. These non-thermal emissions always are worth investigating and are of great interest to both amateur and professional radio astronomers.

C. Non-thermal radiation: Non-thermal radiation from celestial sources is produced by natural processes, most commonly cyclotron and synchrotron radiation. Both are caused by a similar mechanism (Fig. 4). An electron is constantly accelerated as it circles or spirals along a magnetic field line, and it radiates electromagnetic waves – a process called *cyclotron radiation*. If the electron has an initial energy in the relativistic range, where its speed is a significant fraction of the speed of light and its apparent mass has noticeably increased as a result, it will radiate not only at its fundamental (gyro) frequency but also at a number of harmonics. The more nearly an electron approaches the speed of light, the more numerous and prominent the harmonics become. Eventually the fundamental frequency disappears and all radiation is concentrated in a very large number of closely spaced harmonics that merge to form a broad continuum. This type of radiation is called *synchrotron radiation*. When large numbers of electrons are radiating in this manner, the intensity of the emissions can be quite strong.

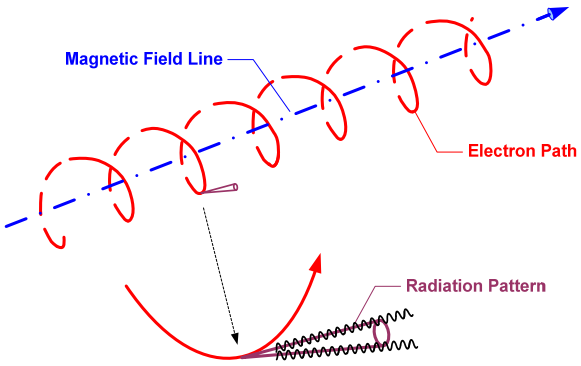


Figure 4: Cyclotron and synchrotron radiation. When the spiraling electron's velocity around a magnetic field line is low, the radiation pattern is very broad and the spectrum very narrow. When the electron's velocity is a significant fraction of the speed of light, the radiation pattern becomes narrower and the spectrum wider.

Another type of non-thermal emission that is received by radio telescopes is *stimulated emission*. Stimulated emission is a process by which an electron is disturbed by a radio wave with a certain amount of energy. This results in the emission of another radio wave identical to the incident wave. One name for this type of emission is *maser* (microwave amplification by stimulated emission of radiation), analogous to laser except at microwave frequencies. Space masers can occur naturally in molecular clouds in the interstellar medium and in the envelopes of old stars. However, these emissions are very weak when received on Earth.

D. Radio wave units of intensity: The strength of celestial radio emissions as received on Earth is an important topic and can be described in a number of ways. First, a radio wave's strength can be measured in terms of the voltage produced in space by the electric field. This is called the *field strength* and it is measured in units of volts/meter (V/m). The field strength is the same voltage that the magnetic field of the wave induces in a conductor 1 meter long when the wave sweeps past it. Thus, the strength of the radio wave not only represents the voltage due to

the electric field but also the voltage induced in a conductor by the magnetic field. They are not separate phenomena, and it does not matter which one is considered to cause the condition.

Of particular interest in radio astronomy are power density and flux density. *Power density* is the energy flow through an area during a given time period, say of a radio wave through one square meter of space in one second. The ordinary unit for power density is joules per second per square meter or its equivalent watts per square meter (W/m^2). The energy flow may be spread out over a wide bandwidth – usually much wider than the bandwidth of our radio telescope receivers – so we break it down into increments of 1 Hz to enable comparison of different sources. We call this the *flux density*, and its unit is watts per square meter per hertz bandwidth (W/m^2 Hz).

The energy flow may be radio waves from a celestial object. If we assume the energy flow from this object is the same in all directions (we say the source is *isotropic*), we can see how the total area the radiation flows through as it travels away from the source is the surface area of an ever-larger imaginary sphere (Fig. 5). By the time it reaches our radio telescope on Earth, the radius of this sphere could be millions of kilometers or millions of light-years.

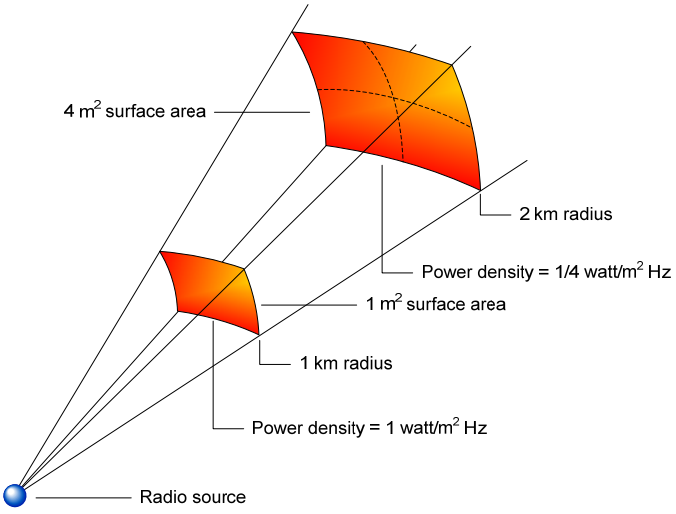


Figure 5: Small portions of an imaginary sphere that surrounds the source in the lower-left. The surface area of the sphere gets larger as the distance from the radio source increases. In the example shown, the distance doubles from 1 km to 2 km and the area quadruples from 1 m^2 to 4 m^2. The power per unit bandwidth in radio waves traveling away from the source is spread out over the ever-increasing area. We see this as a reduction in flux density from 1 W/m^2 Hz to 1/4 W/m^2 Hz. By the time we receive the radio waves on Earth, the surface area of the sphere is very large, giving a very small flux density at our radio telescope location.

If we take the original energy leaving a typical celestial object in one second and divide it by the surface area of this very large imaginary sphere, we get a very small number for the flux density at our radio telescope location, on the order of, say, 10^{-26} W/m^2 Hz. A more convenient unit for purposes of radio astronomy is the *jansky* (abbreviated *Jy*), where 1 Jy = 10^{-26} W/m^2 Hz (for a review of power of ten notation, see QT No. 2, Units of Measurement). Flux density in W/m^2 Hz can be easily converted to Jy by multiplying it by 10^{26}. The jansky was named after Karl G. Jansky, who first identified celestial emissions in 1932.

As an example, consider the Crab Nebula at 1,420 MHz. Measurements show the flux density to be about 8.75 x 10^{-24} W/m^2 Hz. We multiply this value by 10^{26} to convert it to Jy, giving 8.75 x 10^2 Jy or 875 Jy – a number that is the same magnitude but much easier to work with. The Crab Nebula is a powerful source, and the flux densities we receive from many other celestial radio sources are much smaller.

The flux density unit is useful when we are working with emissions from a point source – that is, a source whose angular size is much smaller than the beamwidth of our radio telescope antenna. This usually is the case for amateur radio telescopes. Professional observatories use very large antennas and interferometers that have very small beamwidths and very high resolutions.

When we use very small antenna beamwidths to observe celestial radio sources that are larger than the beamwidth, the measurements include only that portion of the source within the antenna beam. In this case, it is more useful to measure the source's *radio brightness*. Radio brightness is the flux density per unit solid angle of the source. Its units are watts per square meter per hertz per steradian, or W/m^2 Hz sr. The steradian (abbreviated sr and sometimes sterad) is a dimensionless unit that describes an angular area (Fig. 6). The brightness of a celestial radio source is intrinsic to the source and does not change with distance (in other words, the brightness is the same whether measured at the source or the detector), whereas flux density decreases with distance from the source as previously explained. A simple analogy is to consider that the source is, say, a 100 W transmitter connected to an isotropic antenna. An isotropic antenna radiates equally in all directions. The 100 W rating is analogous to the source brightness. Our receiver does not receive the full 100 W (the full brightness) but only a small fraction depending on its distance away.

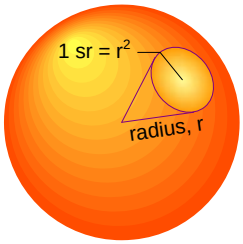


Figure 6: The dimensionless unit steradian is related to the surface area of a sphere in the same way a radian is related to the circumference of a circle. 1 radian is that portion of a circle's circumference with length equal to the circle radius, and there are 2π radians in a full circle. 1 steradian is that portion of a sphere's surface with area equal to the radius squared, and there are 4π steradians in a full sphere.

Another unit of power measurement is noise temperature in kelvin (K). In our discussion about thermal radiation we learned that noise power at radio frequencies is proportional to noise temperature. Because of this correspondence we can say that the noise power in celestial emissions is equivalent to the power radiated by a blackbody at an equivalent noise temperature. For example, say our calibrated radio telescope measured a solar burst at radio frequencies and found it peaked at 1,000,000 K. This does not mean the temperature of the burst reached 1,000,000 K (although it was undoubtedly very hot). It means that the burst had the power equivalent to a blackbody at a temperature of 1,000,000 K.

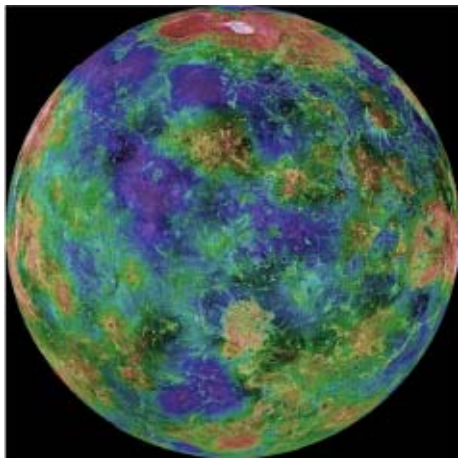


Figure 7: An enhanced radar image of Venus. Image source NRAO

E. Our solar system: All planets and their moons receive light and heat from the Sun, and all emit thermal radiation. The Moon is our nearest celestial neighbor, located about 384,000 km from Earth. The Moon's emissions have been extensively studied over a wide range of frequencies. These emissions are due to heating of the Moon's surface and subsurface layers by the Sun and the subsequent thermal radiation. The radio emissions are very weak and have been found to be dependent on the

Moon's phase (its appearance to us as it orbits the Earth). Radar also has been used to study the Moon and maps of its surface have been produced from these studies.

Our two orbital neighbors, Venus and Mars, are very weak emitters of thermal radiation at radio frequencies. Mars has been studied by professional observatories at around 9.5 GHz by large (15 m) parabolic dish antennas and special receivers. Venus, with its continuous cloudy cloak, has been studied more extensively with radar (Fig. 7) and at frequencies of 7.5 to 75 GHz and in the infrared band. Mercury is very difficult to observe because of its close proximity to the Sun (the Sun's emissions overwhelm Mercury's comparatively meager thermal emissions).

Much of what we receive from the planets is thermal radiation at visible frequencies and closely follows the blackbody curve but some, for instance Venus and Jupiter, emit non-thermal radiation at radio frequencies. This means the planets have a non-thermal source of radiation not directly related to the energy it receives from the Sun.

Of great interest to amateur radio astronomers is Jupiter, the largest planet in the solar system and also a powerful radio source. Jupiter's emissions were received in 1950 but it was not identified as the source until 1955. Investigators believe its emissions are cyclotron radiation enabled by the planet's huge magnetic field and enhanced by charged particles associated with volcanoes on Io, one of Jupiter's innermost moons. The emissions have been found to be continuous in a cone-shaped pattern (Fig. 8), but we receive them most often when Jupiter, its moon Io and the Earth are lined up in certain ways. We can predict when the emissions are likely to occur but our reception is intermittent and challenging.

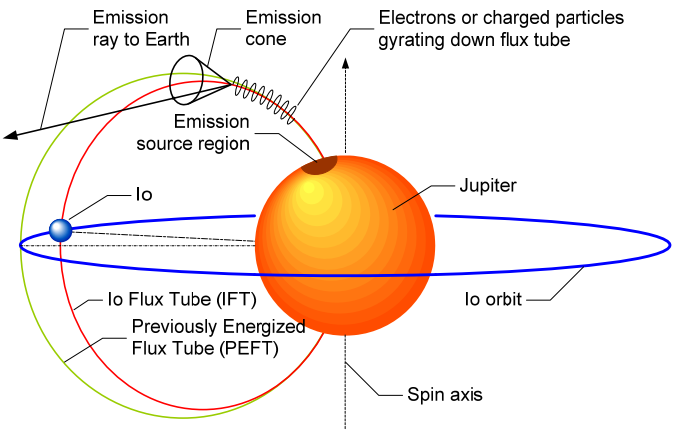


Figure 8: Radio waves from Jupiter are produced by a complex process involving the planet's very large magnetic field and charged particles in its ionosphere

Jupiter emits over a wide radio frequency range, around 50 kHz to as high as 40 MHz (wavelengths of 6,000 m down to 7.5 m), but frequencies below around 15 MHz (20 m and longer wavelength) are blocked by the Earth's ionosphere. The lower limit received on Earth is determined by the amount of sunspot activity and its effects on Earth's ionosphere. Emissions above 23 or 24 MHz are progressively weaker. The best frequency for observing Jupiter has been found to be near 20 MHz (15 m wavelength).

Saturn is a very large planet with a magnetic field that enables the production of radio waves much like Jupiter. However, Saturn's emissions are at lower frequencies than Jupiter's and we cannot receive them on Earth because of the blocking effect of the Earth's ionosphere. Thermal emissions at radio frequencies from the remaining planets in our solar system, Uranus and Neptune, are too weak for us to receive. These planets are not sources of non-thermal emissions.

The strongest celestial emissions we receive on the Earth are from the Sun (Fig. 9). The Sun is only about 150 million km away from us on average. The nuclear fusion of hydrogen in the Sun's core along with the different layers of hot ionized gases in the Sun's atmosphere in conjunction with a very large magnetic field produce huge amounts of radiation over a very wide frequency range. From our perspective on Earth, the Sun has two basic radio conditions called the *quiet* (or *undisturbed*) *Sun* and *active* (or *disturbed*) *Sun*. Emissions from the quiet Sun include a background component that is constant for months or years and a slowly varying component that changes from day to day and has a period equal to the Sun's rotation period of 27 days.

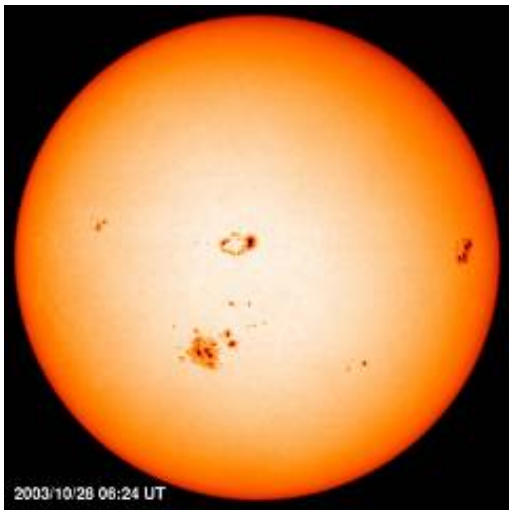


Figure 9: Sun as seen from a 400 MHz radio telescope. Intensity is indicated by gradient colors – darker is lower noise temperature. Image source: NASA

On top of the emissions from the quiet Sun are periods of disturbances from transient phenomena in the Sun's atmosphere. Flares and similar solar bursts are the most familiar. These disturbances follow the approximate 11-year sunspot cycle, increasing toward the solar maximum and decreasing toward the solar minimum. Years of study have revealed that when the Sun is active, its emissions fall into five categories determined by their time and frequency characteristics. The same equipment setup that we use for receiving Jupiter's emissions also can be used for the Sun's emissions. However, because of the wide frequency range, we have opportunities to study the Sun through the full range of the "radio window" and are not limited to narrowband studies.

In addition to Sun, planets and moons, the solar system contains objects that appear transient to observers on Earth, in particular *comets*, *meteoroids* and *asteroids*. A comet is a clump of ices, gases and solid particles and rocks with a large hydrogen halo. Comets orbit the Sun in highly elliptical or parabolic orbits with distances from the Sun ranging from 1 to 10,000 AU. The average lifetime of a comet is 100 passages around the Sun. Periodic comets comprise about 4% of all known comets. Attempts have been made to detect radio emissions from comets but with no success.

Many *meteoroids* are dust grains, rocks and metallic objects ejected by comets. When the Earth passes through or near a comet's path, the meteoroids enter the Earth's atmosphere and burn up. *Meteors*, or "shooting stars" or "falling stars", are the visible and ionized trails that meteoroids make when burning up. The ionized trails left by meteors reflect terrestrial radio waves and frequently are detected by amateur radio astronomers. Asteroids are similar to meteoroids but larger and thought to be remnants of planet formations and collisions. No radio wave emissions have been detected from them.

F. Continuum emissions: The Cosmic microwave background radiation, previously described, is a continuum emission. It originally was noticed by investigators in 1964 as an increase in the output of their 4 GHz receiver that could not be explained as coming from any known source. A continuum emissions source has a constant power density over a wide observation bandwidth, say, several tens of megahertz or more. Many celestial radio sources are physically very large even though their angular size is very small as viewed from Earth. The radio waves from these sources are emitted by a very large number of very small, statistically independent sources such as atoms, molecules and electrons. The resulting emissions are noise-like, and they cannot be distinguished from ordinary noise generated within the receiver itself. We observe continuum sources by the increase in radio telescope output when the source is in view of our antenna. Continuum emissions are thermal in nature.

G. Nova: A *nova* is a star that suddenly experiences runaway nuclear fusion of hydrogen on its surface, causing its luminosity to surge over a timeframe of a day or two by a factor of 10^4 or more. The surge is visible at light and radio frequencies and gradually declines over months or years. Novae are categorized as *eruptive variables*. Unlike a supernova (described below), a nova retains its stellar form and most of its substance after the outburst. A star may experience numerous nova episodes throughout its life. Observations of the Andromeda Galaxy indicate 25-30 nova explosions per year.

H. Galactic radio nebulae: There are many types of radio sources beyond our solar system. We would expect all stars to radiate in a manner similar to our Sun. However, because of the distances, the emissions are considerably weakened and altered during their journey toward Earth and we are unable to receive them. There are some important exceptions.

Particularly interesting are celestial sources that were once called *radio stars*, although none of them are simple stars and most are not even stars at all. One of the brightest radio sources is the Crab Nebula in the Taurus constellation (Fig. 10). This nebula is the remains of a stellar explosion, which was observed on Earth almost 1,000 years ago. The explosion was so bright it could be seen during the daytime. It blew out a huge shell of hot gas, and it is this gas shell that emits radio waves. The shell also emits light, so it can be observed by both optical and radio astronomers.

Figure 10: Crab Nebula in Taurus (the "Bull")
Image source: NASA

An exploding star of this type is called a *supernova* with a categorization of a *cataclysmic variable*. Radio waves from supernovae are believed to be caused by high-speed electrons in the gas shell moving in an area with a huge magnetic field leading to synchrotron radiation. Many of the brightest objects observable from Earth are supernova remnants (abbreviated SNR).

Many of the stars we see in the night sky are part of the Milky Way galaxy (Fig. 11). Some of the gases in the Milky Way can be seen in optical telescopes as large bright, glowing patches

caused by the light and other energy transferred to the gas by nearby hot stars. There are billions of galaxies in the universe, both larger and smaller than ours.

I. Interstellar gases and matter: The clouds of hydrogen gas and other matter dispersed about space generally have very low temperature, on the order of 50 K. The low temperature relates directly to low energy at radio frequencies and, thus, the radio emissions are very weak. Where the matter has been excited by stellar explosions, its temperature can exceed 10,000 K.

Figure 11: Artist's conception of the Milky Way as it is thought to look from above. Image source: NASA

Most of the interstellar gas is hydrogen. Much of it is very cold and gives off no light at all. However, it does emit radiation at a frequency close to 1,420 MHz (21.1 cm wavelength). This is called hydrogen-line radiation, a type of *spectral line emission*. Spectral line emissions are caused when electrons transition between discrete energy levels in atoms and molecules in the inter-stellar medium giving rise to an increase or decrease in electromagnetic radiation (emission or absorption, respectively) at certain frequencies. Thus, we may find that some spectral line emissions are absent while others are stronger. Widths of the associated spectral lines range from 1 kHz to several hundred kHz. However, when we observe the spectral lines we find they often cover a much wider frequency range, up to 10 or 20 MHz, because of Doppler shift of the radio waves. Doppler shift is the change in frequency of radio waves as they move toward or away from our radio telescope.

Optical telescopes cannot observe toward the middle of the Milky Way – toward Sagittarius (the "Archer") – because of interstellar dust. The scattering of electromagnetic waves by particles is related to the size of the particles compared to the wavelengths of the radiation. In this case, the light waves are scattered by the small dust particles. Fortunately, the 1,420 MHz radio waves are not scattered by the dust. As a result, radio astronomers have been able to build up a more complete idea of what the whole galaxy is like and to confirm its shape as thought to exist through optical astronomy. Although the hydrogen emissions are weak, their reception is within the capabilities of amateur radio telescopes.

The nearest large galaxy to the Milky Way is the spiral galaxy in the constellation Andromeda, about 2.5 million light-years away (Fig. 12). This galaxy appears flattened when observed through an optical telescope. However, radio telescopes have detected radio waves from the area all around it and it is clear that the radio emitting gas spreads out much farther than can be seen at visible light frequencies.

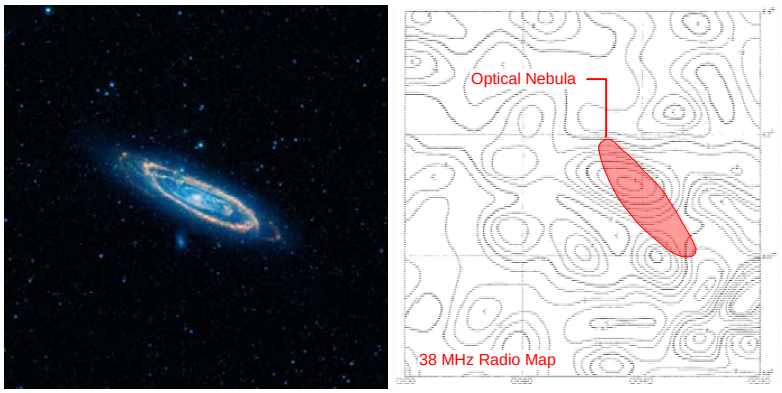


Figure 12: A spiral galaxy in Andromeda as seen through an optical telescope (left) and radio telescope at 38 MHz (right). The image on the right is a radio map with the visible nebula indicated by the shaded area; contour lines indicate a constant intensity of the emissions. Image source: NASA (left) and [Kenderdine] (right)

J. Flare star: Some types of young dwarf stars show a sudden, intense outburst of energy, or flares, at light frequencies and, often, simultaneously at radio frequencies (Fig. 13). Flares may erupt singly or in succession with intervals of hours to days. The flares are thought to be related to magnetic activity and similar to flares we see on the Sun. Flare stars are very faint and difficult to detect with radio telescopes but, nevertheless, were the first stars to be detected as radio sources.

Figure 13: Artist's conception of a flare star in action. Image source: NASA/Goddard Space Flight Center

K. Radio galaxies: A galaxy is a large, gravitationally bound group of stars and interstellar matter. The total mass of galaxies ranges from around 100 million to 100 billion (10^8 to 10^{13}) times the mass of the Sun. The Milky Way is one of what is estimated to be hundreds of billions of galaxies in the universe. Of particular interest are *radio galaxies*. Radio astronomers detected radio waves from the space beyond the Milky Way in parts of the sky where there seemed to be no visible objects. This means that some celestial objects are strong radiators at radio frequencies but are not visible or are very faint at light frequencies. Investigations of these regions by space telescopes, which are unimpaired by the Earth's atmosphere and ionosphere, have revealed visible objects. One of these is the most powerful radio source known – Cygnus A in the Cygnus constellation (Fig. 14). Observations seem to indicate that it is two colliding galaxies.

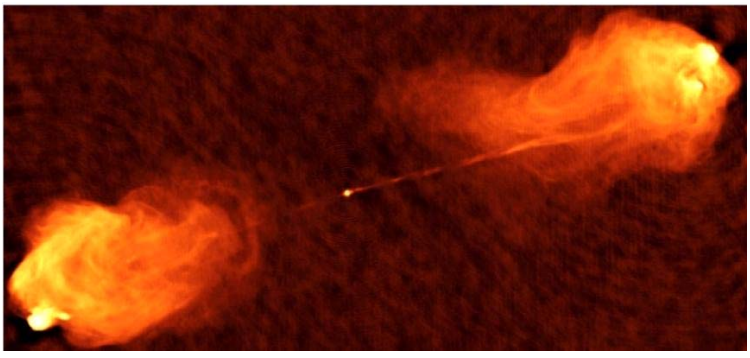


Figure 14: False color radio image of Cygnus A in the Cygnus constellation (the "Swan") from the Very Large Array radio telescope near Socorro, New Mexico USA. A super-massive black hole is thought to be located at image center. Image source: NRAO

L. Neutron star: A neutron star is a very small and very dense star remnant, on the order of 10 km diameter and 10^{17} kg/m^3 density, primarily made from neutrons (for comparison, the density of steel is on the order of 10^4 kg/m^3). At this density, the neutrons align themselves and the spinning star produces a very large magnetic field. Charged particles that interact with this field produce synchrotron radiation. Neutron stars are frequently found in supernova remnants and are the basis for pulsars.

M. Pulsars: *Pulsars* are a special type of neutron star or two stars orbiting each other (binary star) that emit very powerful radio waves over a wide range of frequencies. The emissions axis of the rotating star is not aligned with its spin axis so we receive the emissions (a pulse) only when it is pointed at the Earth – like a rotating searchlight (Fig. 15). Pulsars were first discovered in 1967, and the emissions mechanism is thought to be synchrotron radiation. Pulsar emissions occur at precise intervals on the order of 1 s with a pulse width that is typically 5% of the pulse period, but there are pulsars with much shorter (millisecond pulsars) and much longer periods. Pulsar emissions received on Earth are dispersed in time – lower frequencies that make up the pulse arrive slightly later than higher frequencies. Pulsars are examples of radio sources that emit polarized radio waves.

A special type of pulsar is called a *magnetar*, the name indicating the relatively large magnetic field associated with it. Magnetars have a much slower rotation rate than pulsars, on the order of 8-9 s, possibly indicating they are pulsars that have spun down (pulsars are thought to lose energy through their emissions, causing their rotation rate to slowly decrease over time). A magnetar's field, around 10^{14} gauss (G), is on the order of 20 – 1,000 times larger than "ordinary" pulsars. For comparison, the Earth's magnetic field is around 0.5 G (the magnetic induction magnitudes in more customary units are 10^{10} tesla (T) for magnetars and 0.5 x 10^{-5} T for Earth). Even though emissions from pulsars and magnetars are very powerful at their origin, they are very weak by the time they reach Earth and are difficult to detect with amateur radio telescopes. Nevertheless, their precise periodic nature can be used as a signal processing advantage.

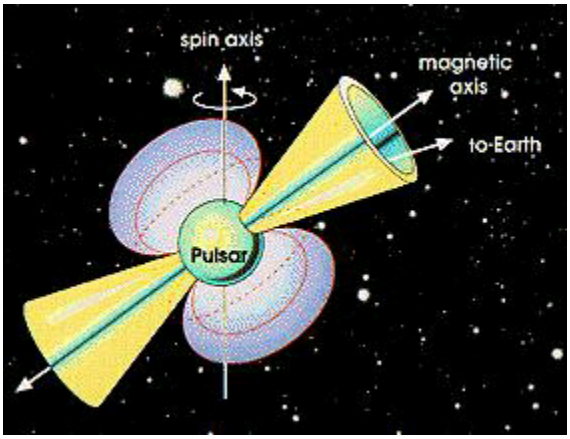


Figure 15: The magnetic axis of a pulsar is not lined up with its spin axis. Emissions are produced by charged particles spiraling in the strong magnetic field. The radio waves are emitted with a cone pattern centered on the magnetic axis. When the cone edges are pointed at the Earth, we detect pulses at regular intervals. Image source: NASA

N. Quasars: *Quasar* is short for quasi-stellar radio source (or, colloquially, just quasi-star). A quasar is a very distant galaxy that is also very luminous; in fact, quasars are the most luminous objects that radio astronomers observe. Quasars were first identified by the unusual characteristics and variations of their radio waves and visible light emissions. They appear to be point sources like stars, rather than spread out like galaxies, but their emissions are very powerful like radio galaxies. Quasars appear to be very old – their emissions are thought to have traveled for 10 – 11 billion years to reach Earth.

O. Important radio sources: A list of the ten most powerful celestial radio sources is provided, including their flux density and associated measurement frequency (Table 1 and Fig. 16).

P. Conclusions: There are many celestial radio sources that may be received by the amateur radio astronomer, but many sources are very weak and very challenging to receive. In particular, pulsars and hydrogen line emissions present technical challenges that may be overcome by improved methods and equipment. On the other hand, two strong sources in our own solar system, the Sun and Jupiter, are comparatively easy to receive with a modest radio telescope.

Table 1: Radio sources important to the amateur radio astronomer. The flux density shown for the Sun is for quiet periods during the low part of the sunspot cycle. During active periods, the flux density of the Sun's emissions, caused by bursts, can increase by a factor of 10^7. The flux density shown for Jupiter emissions is a "back-of-the-envelope" calculation from [Flagg]. Data on sources outside the solar system from NRAO and provided by Tom Crowley

Object Name	Common name or nickname	Constellation	Flux density (Jy)	Frequency
Sun	Sol	N/A	~ 30,000 (quiet)	100 MHz
Jupiter	Jove	N/A	~ 4,500,000	20 MHz
3C 461	Cassiopeia A – SNR	Cassiopeia	2,477	1420 MHz
CTA 59	Centauri A (NGC5128)	Centaurus	2,010	960 MHz
CTB 42	Sagittarius A (galactic nucleus)	Sagittarius	1,800	960 MHz
3C 405	Cygnus A (D galaxy)	Cygnus	1,495	1420 MHz
3C 144	Crab Nebula – SNR	Taurus	875	1420 MHz
3C 400	(None)	Cygnus	576	1420 MHz
3C 145	Orion A – Emission Nebula	Orion	520	1420 MHz
3C 274	M87 – Elliptical galaxy	Virgo	198	1420 MHz

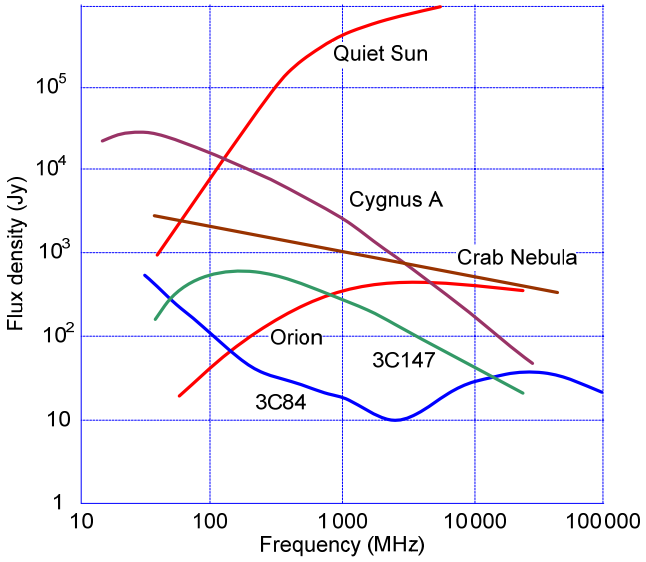


Figure 16: Flux density of some important celestial radio sources with respect to frequency. Data source: [Christiansen]

Q. References and further reading:

- Burke, B. and Graham-Smith, F., An Introduction to Radio Astronomy, 3rd Ed., Cambridge University Press, 2010
- Christiansen, W. and Hogbom, J., Radio Telescopes, 2nd Ed., Cambridge University Press, 1987
- Cohen, J., Spoelstra, T., Ambrosini, R., and van Driel, W., Editors, Committee on Radio Astronomy Frequencies (CRAF) Handbook for Radio Astronomy, 3rd Ed., European Space Foundation, 2005
- Flagg, R., Listening to Jupiter – A Guide for the Amateur Radio Astronomer, Radio-Sky Publishing, 2000
- Karttunen, H., Kröger, P., Oja, H., Poutanen, M., Donner, K., editors, Fundamental Astronomy, 5th Ed., Springer, 2007
- Kenderdine, S. and Baldwin, F., The Radio Spectrum of the Andromeda Nebula, The Observatory, NASA Astrophysics Data System, Feb. 1965
- Kundu, M.R., Solar Radio Astronomy, Interscience Publishers, John Wiley, 1965
- Kraus, J., Radio Astronomy, Cygnus-Quasar Books, 2nd Ed. 2004
- National Radio Astronomy Observatory: http://www.nrao.edu/
- Palagi, F. and Patriarchi, P., Two Dimensional Map of the Sun at 408 MHz, Astronomy & Astrophysics Supplement Series, Vol. 41, pg 129-141, 1980
- Parks, G., Physics of Space Plasmas – An Introduction, Addison-Wesley Publishing Company, 1991
- Pawsey, J. and Bracewell, R., Radio Astronomy, Oxford University Press, 1955
- Rohlfs, K. and Wilson, T., Tools of Radio Astronomy, 2nd Ed., 1996
- Smith, A. and Carr, T., Radio Exploration of the Planetary System, Van Nostrand Momentum Book #2, Commission on College Physics, 1964
- Smith, A., Radio Exploration of the Sun, Van Nostrand Momentum Book #15, Commission on College Physics, 1967
- Stetson, H., Earth, Radio and the Stars. Whittlesey House, McGraw-Hill Book Co., 1934
- Zheleznyakov, V., Radio Emission of the Sun and Planets, Pergamon Press, 1970

~ Three Book Reviews ~

By Whitham D. Reeve

Title: ***Astronomy – A Self-Teaching Guide, 7th Edition***
Author: Dinah L. Moché
Publisher: John Wiley & Sons
Date published: 2009
Status: In print
Availability: New paperback available from booksellers for US$19.95 and from Amazon.com for $13.57. Also available on the used book market (for example, www.abebooks.com) for as low as US$1

Title: ***A Question and Answer Guide to Astronomy***
Authors: Pierre-Yves Bely, Carol Christian, and Jean-René Roy
Publisher: Cambridge University Press
Date published: 2010
Status: In print
Availability: New paperback available from publisher for US$29 and from new and used booksellers and Amazon.com for US$15 to US$20.

Title: ***Starlight – An Introduction to Stellar Physics for Amateurs***
Other: Patrick Moore's Practical Astronomy Series
Author: Keith Robinson
Publisher: Springer
Date published: 2009
Status: In print
Availability: New paperback available from new and used booksellers and Amazon.com for US$20.

The interest of serious amateur radio astronomers goes far beyond electronics. Most also are interested in how stars and other celestial objects form and evolve, the makeup of the solar system and how it works, transient objects such as meteors and comets, and the possibilities of life elsewhere, among many other things.

The following are reviews of three books that cover these topics in a non-technical way. They all emphasize optical astronomy but many topics also apply to radio astronomy. While each book is distinct there is some inevitable overlap. I found all three very useful in my amateur radio astronomy activities. They provided a good refresher of my limited previous knowledge, filled

many gaps, and brought me up to date. I am mainly interested in radio astronomy and not optical, but I feel I gained a much broader knowledge of the universe by reading them.

The authors of these books all are astrophysicists. Moché is an accomplished author of "astronomy books and programs for all ages" and who runs a website called Spacelady.com. Bely, Christian and Roy are heavily involved in the design and use of optical telescopes, and Roy "owns two of the biggest telescopes in the world." Robinson is a full-time writer and educator. While it obviously is very important that authors know their subject, what is written is far more important than who it was written by.

The first two books do not need to be read cover-to-cover but may be used as handy references. The Internet has become a great resource for answering quick astronomy questions but it seems like many queries yield thousands of responses. Most do not provide a useful answer and some are flat wrong. Why not just grab one of these books off the shelf and look it up?

The first book, ***Astronomy – A Self-Teaching Guide***, has a conventional layout but with some added features that make it useful for self-study and learning. For one, icons are printed next to topics to remind the reader of additional learning resources and information in the book:

- Star and moon maps in the back of the book with a star or moon icons placed in chapter text for referral to them
- An icon indicating simple activities that the reader can do to demonstrate a basic idea (for example, in the section on magnetism, the text describes putting a magnet under a piece of paper and sprinkling iron filings on it – an experiment we all performed in school but still fun to do).
- An icon indicating an internet link to images and updated reports

For another, this book provides short quiz questions interspersed throughout the text and a 2-page self-test at the end of each of the 12 chapters. For example, one quiz question in Chapter 8 is: "*How far would a planet be from the Sun if its orbital period were observed to be 8 years?*" The answer is found by applying Kepler's 3rd law of planetary motion, where the square of the planet's orbital period in years equals the cube of its distance from the Sun in astronomical units. (The answer is 4 astronomical units).

The reader is not left wondering about right or wrong answers to quizzes and tests – the author has provided the correct answers on following pages. Space is provided for writing in the answers so, if you buy a used copy of this book, it already may have answers or other marks. Each chapter begins with a list of learning objectives, making it easy to find topics of interest or to skip others while flipping through the pages. For example, one objective stated at the beginning of chapter 8, Exploring the Solar System, is: "*Explain the apparent motions of the planets, including retrograde motion.*" The text explains that retrograde motion is the apparent reversal of a planet's motion as observed on Earth before it resumes direct forward motion. This phenomenon is easily observed with Mars. Although not listed in the book, an animation can be viewed at: http://www.lasalle.edu/~smithsc/Astronomy/retrograd.html

This book will be attractive to readers who fear math – the author says in a message *To The Reader* in the front papers: "*Mathematics is not required.*" Actually, if you are going to apply Kepler's 3rd law in the above quiz question, you will do some pretty basic number manipulation, preferably with a calculator. Approximately five pages of the book's 365 total pages are dedicated to useful resources and websites for periodicals, databases, career information, almanacs, observing guides and star atlases. Another five pages have six appendices including a list of constellations, physical and astronomical constants, measurements and symbols, periodic table of elements, the nearest stars and Messier objects. The reader will refer to these appendices while working on the tests. The index is a little more than 10 pages and **bold** entries indicate the page where the term is defined, making it easy to find. There is a lot of useful information in this book, and the author has made it is easy to learn.

Astronomy – A Self-Teaching Guide starts out with a brief introduction of the *Cosmic View* – the solar system and where it fits in the Milky Way galaxy and where the Milky Way fits in the universe. Chapter 1, *Understanding the Starry Sky*, covers the preliminary details such as locating sky objects by their right ascension and declination, definition of a sidereal day and solar day and why they are different and why we care about the difference, star brightness, apparent daily and annual motion of stars and Sun, and many other basic astronomical topics. Each topic has about one-third to one-half page of explanatory text, usually an accompanying illustration or table, and a quiz question. I found the discussions very easy to read and follow.

Chapter 2, *Light and Telescopes*, has something for both optical and radio astronomers. After a review of wavelength, frequency and the electromagnetic spectrum, the author provides a short discussion of blackbody radiation. There are particularly good discussions and illustrations of the differences between refracting and reflecting telescopes and useful discussions of magnification and resolving power. Unfortunately, the *something* for radio astronomers in this chapter is pretty sparse, amounting to slightly over two pages that are too basic to be very useful.

Chapters 3 – 7 cover in order The Stars, The Sun, Stellar Evolution, Galaxies and The Universe. Many astronomy books start out in the solar system with a discussion of the Earth, the Moon, the planets and the Sun, and then move toward outer space from there. In ***Astronomy – A Self-Teaching Guide***, the solar system is covered in 28 pages in chapter 8, Exploring the Solar System, after we learn about the very big picture of the universe. This book makes good use of illustrations, and the captions are appropriate (right, figure 3.13). In chapter 9, Planets, the objectives include comparing and contrasting the terrestrial planets and the gaseous planets. This is a fairly standard way of learning about the planets, but I think this book takes an additional step by breaking them down by the way we look at them; for example, sections for Mars are Mars: Observing, Mars: The Surface, Mars: The Planet, and Moons of Mars. The descriptions of each

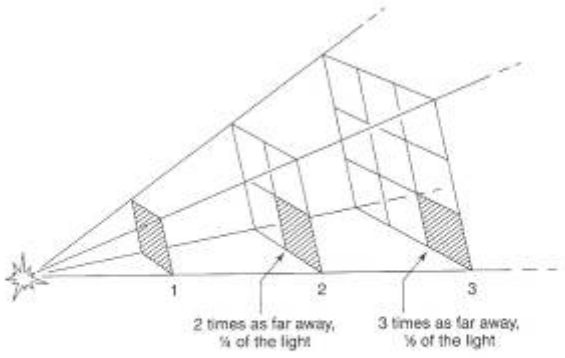
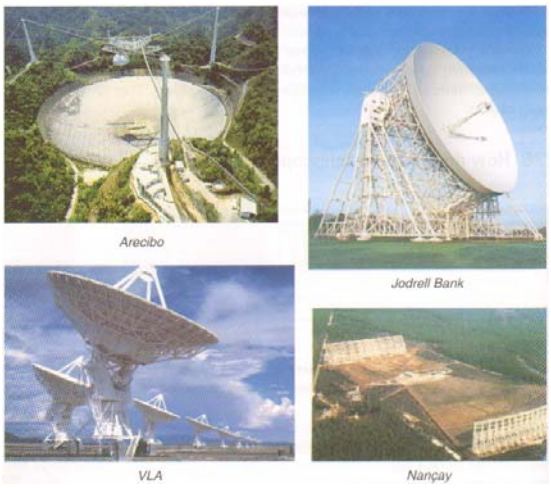


Figure 3.13. Inverse square law. The same amount of starlight that shines on a square at 1 spreads out to illuminate four equal squares at 2 and nine equal squares at 3. Thus, if two stars have exactly the same luminosity but one is twice as far away from you as the other, the distant one will look only ½² = ¼ as bright as the closer one, because you get one fourth the light in your eyes.

planet are concise, and the important facts are well explained.

Comets always have been interesting to people – maybe because of their fleeting nature and mysterious appearance with tails and a nucleus and their recurrence – as short as three years and as long as a million years. And what about that Oort cloud, the spherical shell of icy objects about a light-year from the Sun, which apparently supplies the comets we see? The Oort cloud is discussed in chapter 11, Comets, Meteors and Meteorites, and was named after Dutch astronomer Jan Oort, who first modeled it in the 1950s. You will not find *Nibiru* or *Planet X* in this book.

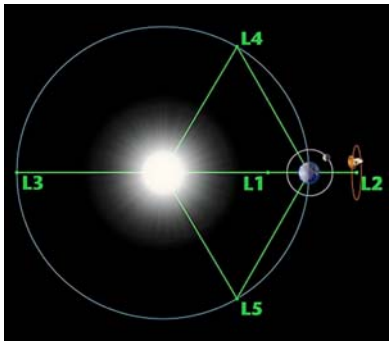
Chapter 12, Life on Other Worlds, is necessarily philosophical and speculative. There is the usual attempt to estimate the odds of other-world life. The answer to a quiz question about estimating the probability of other-world life – "*Why do you think the average lifetime of an intelligent civilization is the most uncertain number of all?*" is a question itself: "*Will* (a civilization) *last long enough for a conversation, or will it self-destruct with nuclear weapons, pollution or overpopulation?*" Ouch! That reminds me of why no intelligent civilization has ever contacted us: They observed Earth and found no intelligent life to contact (they apparently received our television transmissions).



My next book selection is ***A Question and Answer Guide to Astronomy***. As the title says, this book is a series of questions and answers. These have been organized in topical chapters, such as Stars, The Solar System, Earth, Moon, and The Universe. There are chapters on the History of Astronomy, Telescopes and Amateur Astronomy, among others. The authors devote a couple pages, out of 280 total pages, to radio astronomy in the Telescopes chapter. Here they spend one page describing large dish antennas (left, from page 242) but do not mention the other important components such as the receiver and signal processing (Question 228). They do mention some interferometers (Very Long Baseline Array, VLBA, and European Very Long Baseline Interferometer Network, EVN), which are used to improve the resolution of observations. In the question following those discussions (Q229), the authors say "*Observations at radio wavelengths are highly informative . . . .*" but they do not say why they are informative and they say nothing of how an aspiring amateur radio astronomer can get involved in those 'highly informative' observations. However, in the chapter Amateur Astronomy, Grote Reber's important contributions to radio astronomy are acknowledged. The fact that he built his radio telescope in his back yard with his own money and studied radio astronomy on his own time rightly made him an amateur but for almost a decade he was the only radio astronomer on the whole planet. Karl Jansky, the first-ever radio astronomer and the person who inspired Reber, is mentioned in one sentence.

All in all, this book asks and answers 250 good questions, from Why do stars shine? (Q1) to How can you find an amateur astronomy club? (Q250). In between, we have What are

Lagrangian points? (Q63), What causes the Earth's magnetic field? (Q89), What explains the dim light suffusing the dark portion of a crescent Moon (Q113), Why do stars twinkle (Q125), Does the Universe have a center? (Q132), What is Life? (Q169), Can we learn anything from the astronomical phenomena reported in the Bible? (Q190) and Which orbits are used for space telescopes? (Q224).



Q63 is interesting because we have had spacecraft orbiting at some Lagrangian points (right, from NASA). We are told there are five points (L1 to L5) in the Earth's orbit around the Sun where a body with low mass (spacecraft or asteroid) would move in a circular orbit around a large mass (Sun) synchronized with a body of intermediate mass (Earth) because, there, the combined gravitational attraction of the two large bodies is exactly balanced by centrifugal force. The SOHO (Solar and Heliospheric Observatory) spacecraft is located at L1 and WMAP (Wilkinson Microwave Anisotropy Probe) spacecraft is at L2. L3 is behind the Sun and it would be difficult to communicate with a spacecraft there (besides, that is where *Planet-X* is located). I could not find anything on NASA's website that indicated spacecraft at L4 and L5, which are about 93 million miles ahead of and behind Earth.

My final book selection is ***Starlight – An Introduction to Stellar Physics for Amateurs***. Unlike the previous two books, this one is focused on stars. This book does not use the usual language of physics – mathematics – to describe the very complex life of stars. Instead, it uses a little algebra and trigonometry at a level readers learned in high school. The author says at the beginning "*There will surely also be many who would say that for the work they do, they simply have no need for . . . theoretical background – but wouldn't it be nice to have it anyway, especially if it could be made more accessible and didn't require a higher education level background in physics and mathematics? This book is written for those amateur astronomers who would be inclined to answer 'yes' to this question and who do not have said background in math and physics.*"

The coverage of this book is the basic operation of "typical" stars and how we measure them in the visible spectrum; there is little discussion of more complicated stellar implementations such as quasars, pulsars and magnetars. Perhaps it is this limitation in scope that would make this a good beginner's book. It is easy to read and understand, but it does have some annoying traits and distractions.

The length of this book is 277 pages, including a functional 4-1/2-page index and three short appendices (Greek Alphabet, Astronomical and Physical Units and Constants and The Doppler Effect). Each chapter is about 15-25 pages long, but they are not numbered:

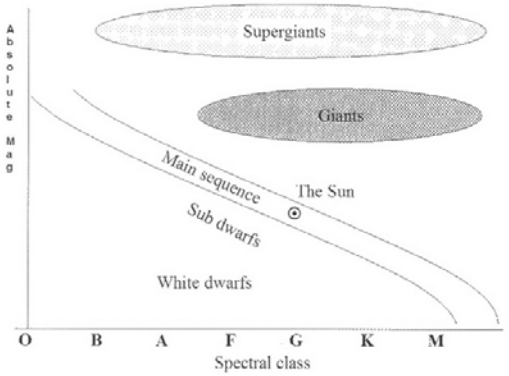
- A River of Starlight
- Starlight by the Numbers
- From Light to Starlight
- Space – The Great Radiation Field
- A Multitude of Magnitudes for the Colors of Starlight

- The Photons Must Get Through – Radiative Transfer
- First Look Inside a Star – The Atmosphere
- Deep Inside a Star
- In the Space Between Stars
- A Star Story – 10 Billion Years in the Making

Each chapter is broken into unnumbered sections of a few pages. Because the chapters and sections are not numbered, there is no easy way to reference the material for discussion, future use or organization. On the other hand, the short sections make them easy to go through without getting bogged down in long and drawn-out discussions where you lose track of what is going on. The author provides a marginally useful one-page list of "Key Points" at the end of each chapter.

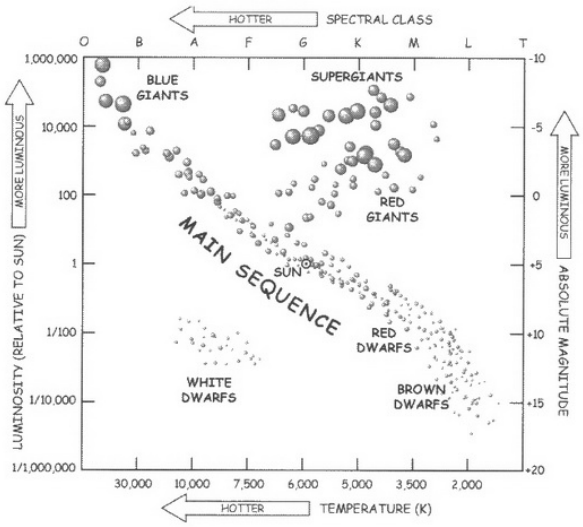
There are only a few tables in this book. It has simple black-and-white and gray-scale illustrations. I felt there could have been more tables and illustrations and the illustrations could have been better quality. It appears that some illustrations were originally made in color and then printed in gray-scale. As a result they are dark with little contrast and detail is hard to see. Readers will not find heavily processed and enhanced images of stars in this book (which makes this book quite different from many books about stars). The question I had to ask was "Does the layout and format of this book inhibit its usefulness?" I believe that, from the viewpoint of reading through the book once, no, but as a future reference, yes.

The author says "*Stellar physics is basically all about learning to interpret and understand the information that is contained in starlight.*" If the author means visible light, then he missed the point by a light-year because stellar physics involves much more than just visible light. If he takes the word "light" to mean electromagnetic radiation in general, then, indeed, studying electromagnetic radiation is the only way we will ever be able to understand stars. However, even though he does discuss the general scope of electromagnetic radiation in the first chapter, nowhere does he acknowledge that our understanding of stars is far from complete if we only study their visible light.



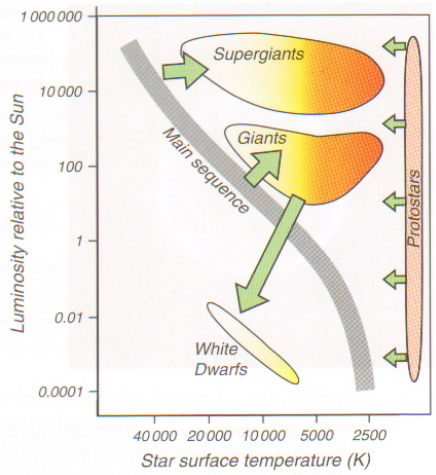
About one-third of the way through there is discussion and some brief applications of the Hertzsprung-Russell (H-R) diagram used to classify stars (right, figure 5 from the chapter A Multitude of Magnitudes for the Colors of Starlight). The H-R diagram plots each star on a scatter graph according to its absolute magnitude or brightness and its temperature and color from the hottest to coolest. It turns out that around 90% of the stars we can see fall on a lazy S-shaped line called the Main Sequence. Stars are assigned a spectral class based on their temperature, where the classes are O, B, A, F, G, K, and M. The letters do not stand for anything in particular; they simply are a sequence of letters that are left over from early work on star classification. Like the star magnitude scale, first-time users will be left scratching their heads as to why something so important has to be illustrated in such a hard way (answer: tradition). Because of the problem remembering the letter

sequence, readers are told that astronomers instead remember the phrase – Oh, Be A Fine Girl (Guy), Kiss Me.



The H-R diagram has many forms, and the author describes some of them. However, we are left with this confusing "Key Point" at the end of the chapter: "*A plot of luminosity or absolute magnitude against stellar spectral class results in the famous Hertzsprung-Russell diagram, which itself showed that stars also need to be classified according to their luminosity*". Add this to the author's annoying use of 'further' in place of 'farther' throughout the book and readers will find themselves wishing there had been a better proof-reader.

It is interesting to compare the H-R diagrams from each of the three books being reviewed here. I think ***Astronomy – A Self-Teaching Guide*** has the best and easiest to understand – it dispenses with the confusing letter classifications and shows temperature on the horizontal scale rather than an unintuitive series of letters (above-left, figure 3.16). The H-R diagram in ***A Question and Answer Guide to Astronomy*** is similar and even simpler (right, from page 17).



In conclusion, I have reviewed three useful introductory books. Readers of this review may ask, "Well, which one is the best?" I liked the first two equally but if I had to choose only one I would take ***Astronomy – A Self-Teaching Guide***. I think readers wanting to focus only on stars will find the last one the most useful, but I cannot help but feel there are better books about stars than this one. One advantage to all three books is their cost will not break the bank if it does not meet your needs.

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Whitham Reeve was born in Anchorage, Alaska and has lived there his entire life. He became interested in electronics in 1958 and worked in the airline industry in the 1960s and 1970s as an avionics technician, engineer and manager responsible for the design, installation and maintenance of electronic equipment and systems in large airplanes. For the next 38 years he worked as an engineer in the telecommunications and electric utility industries with the last 33 years as owner and operator of Reeve Engineers, an Anchorage-based consulting engineering firm. Mr. Reeve is a registered professional electrical engineer with BSEE and MEE degrees. He has written a number of books for practicing engineers and enjoys writing about technical subjects. Since 2008 he has been building a radio science observatory for studying electromagnetic phenomena associated with the Sun, Earth and other planets.

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