Five Projects for the Astronomical League's Radio Astronomy Observation Program

Submitted by

Dr. Alex Vrenios

KX9I@arrl.net

Abstract

The Astronomical League recently introduced a Radio Astronomy Observing Program, requiring its members to complete four of its five observing projects: detecting solar radiation, sudden ionospheric disturbances (SIDs), Jupiter's radio storms, meteor scatter and galactic hydrogen radiation. This paper describes my experience with each of these projects, and the development of a modest but working radio telescope along the way.

Introduction

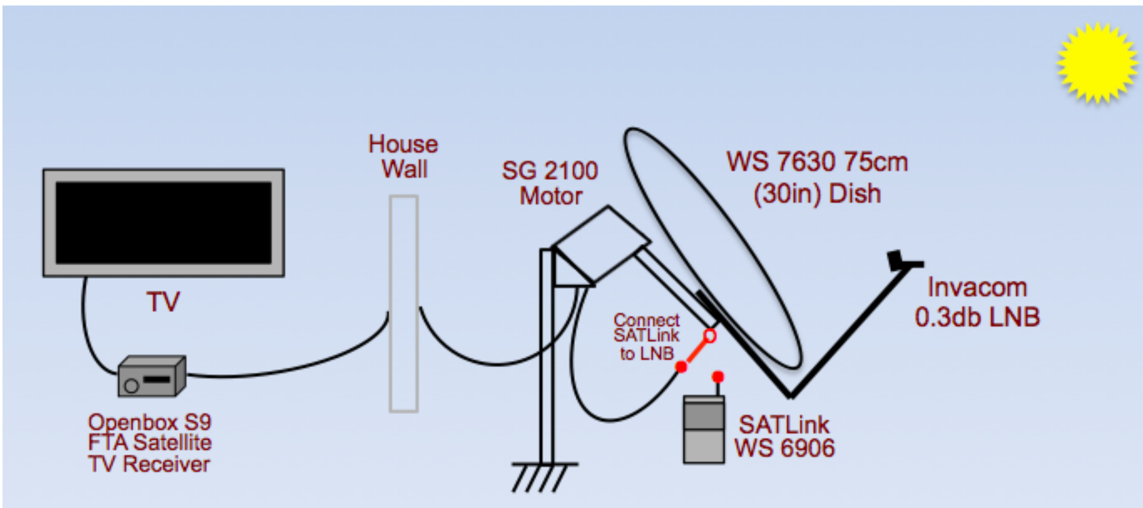
Radio astronomy is probably the most technically complex hobby I've ever explored. I am a long-time amateur radio operator, photographer and visual astronomer. Over the years I've been sporadically interested in radio astronomy, but I never really knew how or where to start. The literature suggests that a 3-meter dish antenna is entry-level, if you wanted to do "serious" work. When I imagined my neighbors' reaction to such an addition to my back yard, my interest quickly faded.

The Astronomical League (AL) recently introduced a Radio Astronomy Observing Program (RAOP). The requirements and the kinds of equipment they recommended seemed within my reach, so I decided to give it a try.

The AL describes five "projects" one can do: solar radiation detection, radio meteor scatter, sudden ionospheric disturbances (SIDs), Jupiter's radio storms and galactic hydrogen radiation detection. One need only complete four of the five, but galactic hydrogen radiation detection must be one of them. Send in the results for one project and get a Bronze level certificate. Do a second project and advance to Silver. Finally, complete two more projects to achieve Gold level. As a bonus, beautifully styled silver and gold pins accompany the silver and gold level certificates, respectively.

Some of the projects were easier than others because I could build the antennas from materials that I already had. I found the galactic hydrogen detection project to be the hardest, requiring me to do online searches and ultimately asking for advice. This paper describes my experience with each of these projects, one at a time.

1. Solar Radiation Detection

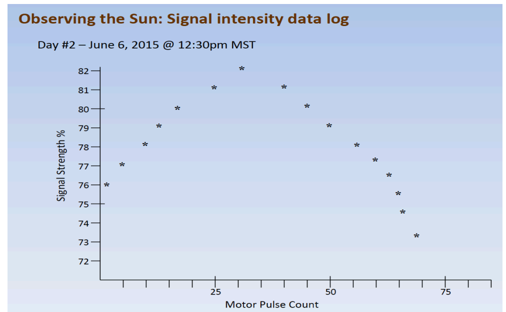


The Sun is a very powerful thermal energy source. Had Karl Jansky's research into interference from thunderstorms not been done during the bottom of a solar cycle, energy from the Sun may have overwhelmed what he labeled a *faint but steady hiss of unknown origin*. He may never have detected it, let alone concluded that it was coming from the center of the galaxy. Grote Reber might never have built that dish antenna, and H. C. van de Hulst may never have discovered the anomaly in a hydrogen atom that causes it to generate a radio frequency pulse at 1420 MHz. Detecting the Sun's energy is an interesting and historically significant place to start.

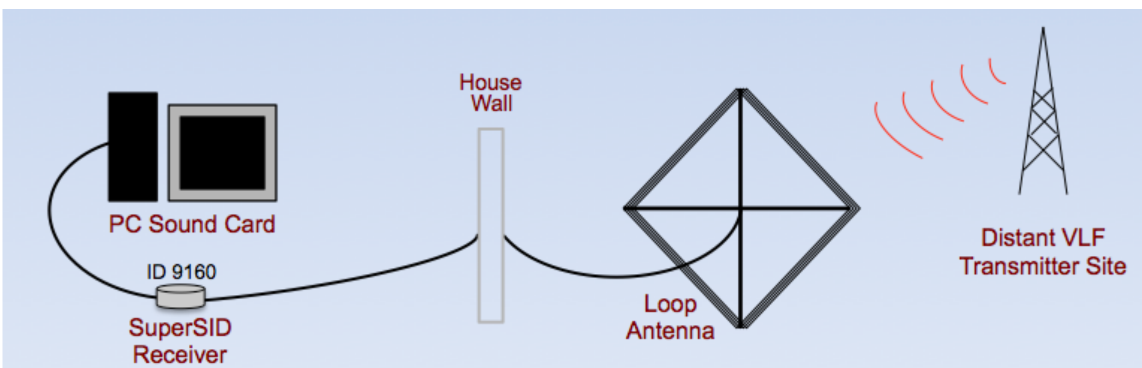
The Astronomical League's web page suggests looking into purchasing the "Itty Bitty Telescope" starter instrument, sponsored by the NRAO, but I had a dish antenna that was ready to be repurposed anyway.

I built a free-to-air satellite TV receiver a few years ago. Most of the programming content was foreign language, and most of the English language programs were of no interest to me. There were a few programs that I enjoyed watching, but over the years almost all of them moved to cable. My unused dish antenna, and a way to measure its received signal strength, seemed like a good way to detect solar energy.

I hooked a signal strength meter up to the dish (Figure 1), pointed it just east of the Sun, and pulsed the motor to make the dish scan incrementally to the west, across the face of the Sun. The signal strength gradually rose and then dropped off again (Figure 2). I recorded the signal strength by hand as it gradually rose and then dropped off again. I made three sets of energy level readings on three separate days and sent in my results. My Bronze level certificate arrived soon afterward.



2. Sudden Ionospheric Disturbances



An x-ray storm, for example, improves the reception of very low frequency (VLF) signals during the daytime by briefly ionizing the Earth's upper atmosphere. A typical uneventful plot over time will show high VLF signal strengths during the evening hours and a low, nearly flat response during the day. When a SID occurs during the daytime, the plot will show a spike in the received signal strength. A plot with such a spike is the goal of this project: evidence of SID detection.

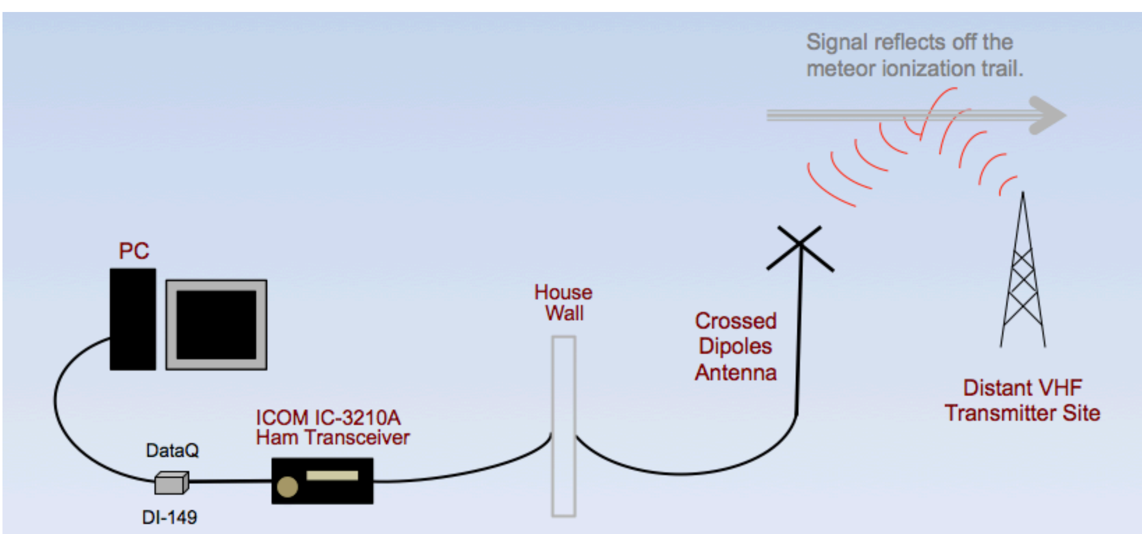
Once you've built a large loop antenna and hooked it up to a VLF receiver, you must slowly rotate it until you find a strong VLF signal reference, and leave it there. VLF radio stations are used by militaries around the world to communicate with their submarines because these signals can be received under water. These communications are encrypted, so you may never extract any intelligence from them, but all we are really interested in here is the relative signal strength.

I first tried detecting SIDs when the project was hosted by the AAVSO (American Association of Variable Star Observers). I was required to buy and populate a circuit board and build a big loop antenna to receive the low frequency signals. I did all that but I could never get a signal, not from any direction. Being not very confident of my construction skills, I always suspected the receiver as the weak link.

This time SARA offered a "SIDs kit" that included a newly designed receiver that was pre-built and tested. I built yet another big loop antenna and, again, there were no VLF signals to be heard. The new receiver was, I'm sure, working just fine. What I never did understand was why the signals were so averse to coming into my backyard! I abandoned the SIDs detection project a second time. I will not be detecting any more SIDs.

I've read the online posts and I understand there are plenty of SIDs monitoring stations out there that seem to be blessed with either a strong VLF signal presence, a lack of interference or both.

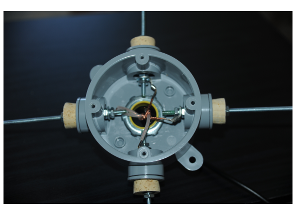
3. Radio Meteor Scatter



I got involved with this activity several years ago so I understood the principles. First, I needed to find an FM radio station as a source. It had to be just far enough away from my home that I couldn't receive it directly, yet close enough that when a meteor streaked through the atmosphere, its signal would bounce off that meteor's ionization trail, and onto my receive antenna. I knew that the National Weather Service had continuous weather forecasting FM radio stations located in major cities across the US, making them a good candidate for my source. But I could never have anticipated the delightful coincidence that I discovered.

I was looking at a list of cities from which the weather forecasts are broadcast and I happened to notice that both Tucson and Flagstaff, Arizona, used the exact same frequency! I'm in Phoenix, which is just far enough away from both of them so as not to be able to receive either of them directly, yet close enough that a meteor's ionization trail would reflect that signal down to my location. This doubled my chances of success in hearing such an event. Now, how do I record the detection?

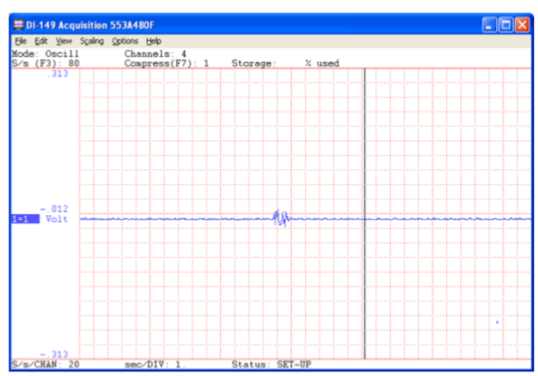
A quick online search revealed the *cross dipole* antenna to be best suited to meteor



scatter reception. I even found a design for one that used a non-metallic electrical box. I ordered one of these and added some cork fittings,

a short length of coax and cut four metal rods to size, for the antenna's elements.

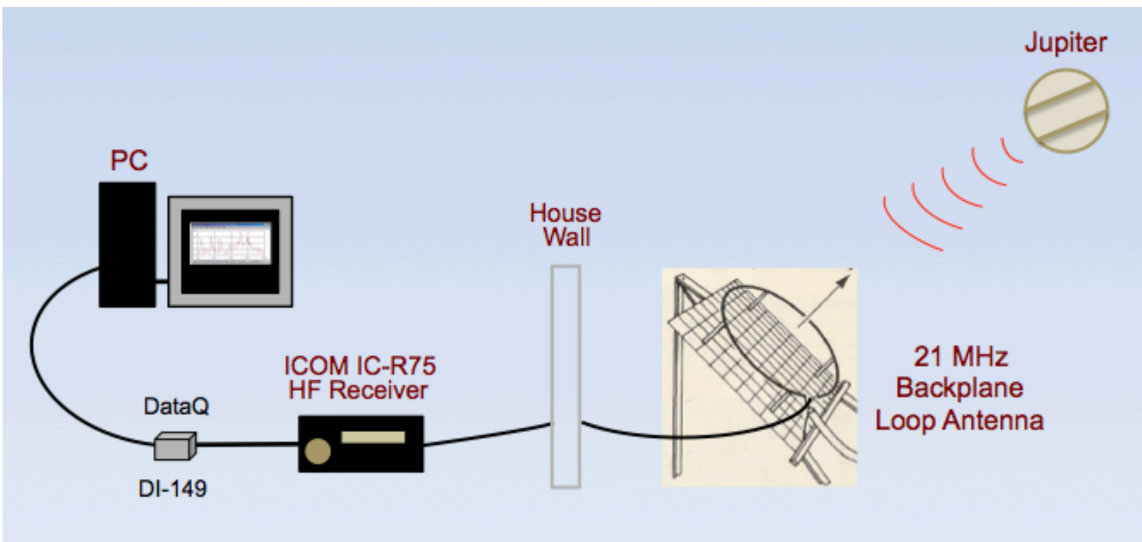
The radio frequency signals directly off a receive antenna are weak and difficult to



detect. At this point in my adventure I'm starting to realize that the radio receivers are in every one of these detection systems because they are very good at detecting the weak RF signals, and at producing a correspondingly loud audio output. (The audio may only be a hiss, but its amplitude is proportional to the strength of the incoming RF signal.) This audio signal can be fed into a home computer's sound card. "Strip chart" or "oscilloscope" software can plot a graph of the signal strength on the screen.

I watched the real-time plot on my computer and waited for a brief beep, a reflected signal from one of the weather broadcast stations. It wasn't too long before I actually heard a short burst, a few syllables from the familiar mechanical voice that the weather services uses to produce its weather forecasting broadcasts. I took a screen shot of the plot and sent it in with the description of how my receiving station worked. The Silver level certificate arrived, along with a silver pin depicting the original antenna that Jansky used to explore the nature of static caused by near and distant thunderstorms.

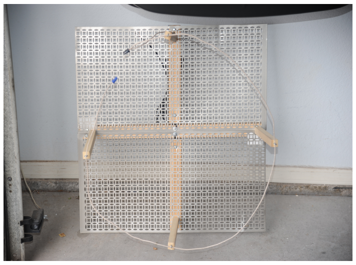
4. Jupiter's Radio Storms



When I read this project description I seemed to recall reading that Jupiter gave off strong radio frequency signals under certain circumstances, and that these radio storm signals could be heard on the high end of the HF (high frequency) band. I'm a ham, and one can hardly find a commercially made HF ham-bands radio these days that doesn't include a full coverage receiver. Unfortunately, being a long-time ham, my aging Kenwood TS-130 doesn't include such a convenience. But I've had my eye on an ICOM full coverage HF receiver for some time now and, as the *Car Talk* guys used to say, "Every new project justifies a new tool!"

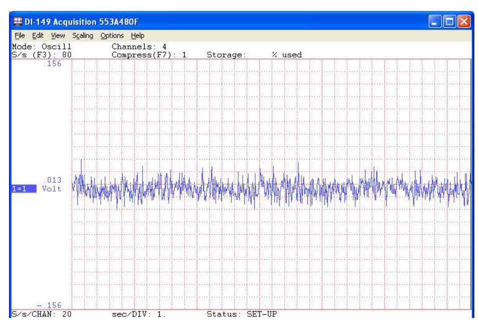
Both the AL web page and the online sources suggest a simple dipole cut for the 15-meter band (about 20 MHz). Even better, a dual or directional dipole cut to that frequency would improve reception. But I found an even more intriguing design.

I save magazine articles that are of interest to me. I happened to be looking through them for a totally different reason when I happened upon an article that was on the back of one I had saved. It showed a 25 year-old SARA design for a Jupiter radio storm receive antenna, employing a 21MHz single loop and a backplane. (*Sky & Telescope*, Dec. 1989, p628.) I built it and connected it to my new HF receiver.



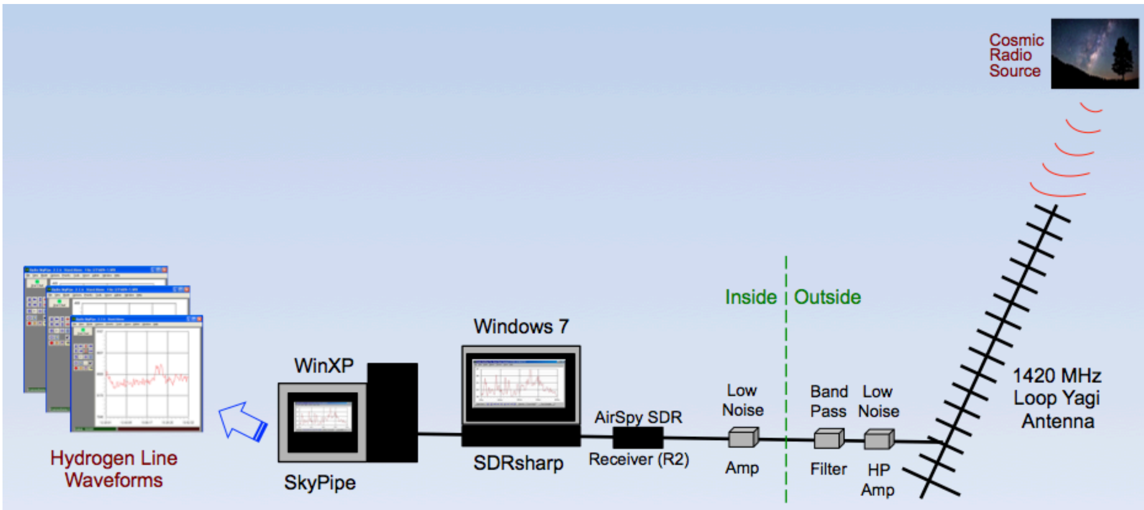
Jupiter storms are a lot more complex than they first appear to be. According to Jupiter Pro, a Radio-Sky software product, there are *sectors* on Jupiter's surface labeled A, B and C. When one of these sectors is facing Earth, one may receive the storm's signals with high, medium and low probabilities (A, B and C, respectively). And, if Jupiter's moon Io happens to be in transit from Earths perspective, the probability of reception is even greater. Jupiter Pro is a computer simulation software product. You configure your location, in longitude and latitude, and it tells you when there is a high probability of receiving a signal from a Jovian radio storm.

Finally, there are two kinds of Jovian radio storm signals: L-Burst (long burst) and S-Burst (short burst). Long burst storm signals sound like "waves crashing upon the shore." Short burst signals sound like either a random ticking noise or a plastic shopping bag flapping in the wind. I definitely heard a random ticking or pecking noise.



I put my Jupiter storm reception documentation on hold until I finished the galactic hydrogen detection project. Advancing to Gold level requires two more completed projects, so I have to send them both in together. I had no idea at the time just how long this hydrogen line detection project would take me. Receiving the extremely weak radio signals at the extremely high 1.4 GHz frequency had its challenges. I met them, but I had to learn a lot before I was able to do so.

5. Galactic Hydrogen Radiation Detection



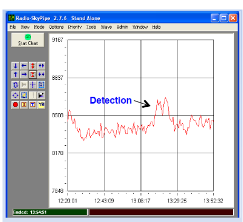
The AL website has several references for novice radio astronomers like myself. There are online papers and websites that describe antennas for atomic hydrogen line (H-Line) reception, including a few professional (large) antennas operated by the NARO and others. I looked into the professionals first, but they cater to groups, like scouts, science classes or astronomy clubs. I spent a lot of time reading the websites and the papers by individuals who built modest H-Line antennas and had some success. There were a few horn antennas, a lot of reworked dish antennas and a few 21 dBi Yagi antenna setups, which especially caught my interest. Finally, there was one paper in particular that got my attention, “Hydrogen-Line Radio-Astronomy as an Elementary-School Science Project,” by Shanni Prutchi. (Proc. 25th Ann. Meeting of SARA, NRAO, Green Bank, WVA, 2006, p91.) Prutchi built a dual Yagi antenna system that successfully received H-Line signals from the Milky Way galaxy, which, I’m told, is not as easy to receive as the others on the AL requirements list.

All these papers offered a variety of selections for the four major components

required for an H-Line detection system: the antenna, amplifiers and filters, the receiver, and the logger. Prutchi’s antennas are available from directivesystems.com and could be employed immediately, without modification. I bought just one, for now. I chose a couple of low noise amplifiers (LNAs) from downeastmicrowave.com, and a band pass filter from radioastronomysupplies.com. One of the dish antenna systems used a software defined radio (SDR) to receive the 1.4 GHz H-Line signal, a USB dongle controlled from SDR# software, which is a free download from AirSpy.com. For logging and plotting I chose anther Radio-Sky Publishing product, their Radio Sky Pipe, from radiosky.com.

I put everything together, pointed the antenna at a bright radio source (Sag A), and got – nothing. After a brief brooding period I signed onto the SARA list and posted of my woes. One person responded by saying that, while my USB dongle was a terrific SDR, it didn't have enough bandwidth to be effective for radio astronomy at 1.4 GHz. He recommended instead, the larger SDR from AirSpy.com, the R2. Cringing at the thought of good money after bad, I put the R2 on order. I was pretty much vested by then anyway.

I hooked up the R2, pointed the antenna at the Sun at local Noon, and got a very clearly defined hump! Even better, my single antenna showed a beam width of twice that of Prutchi's dual antenna setup, as I expected. Not all the several required galactic detections went smoothly, but I eventually got them, sent them in with my Jupiter logs, and finally got the long awaited Gold level certificate and pin.



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Retrospective

What benefits have we gained from these kinds of inquiries? Is there some knowledge to be gained from understanding all bodies give off energy? That Jupiter has radio storms? Let's have a look at each project in turn.

Solar Thermal Energy: One of the points made by the people who talk up the Itty Bitty Telescope is that the human body and almost everything else gives off thermal energy. Being a cost-conscious homeowner, I am concerned about how much of the heat I produce to keep me warm in winter is actually leaking out through the door and window frames (and who knows where else!), to the point where I am considering buying a thermal camera attachment for my iPhone, just to see for myself. I recognize a benefit from what might be considered a curiosity by some.

Radio Meteor Scatter: Back in the 1980s it was fun to hear a beep from an FM radio beacon at the local airport, and know that you heard it from electronics you built and that it happened because of a meteor you could not even see. Ham operators picked up on this and created a completely new mode of communication. Commercial package delivery companies took it to the next level by using burst mode packet communication profitable in Alaska, where line-of-sight was a precious commodity. Benefits from “pure” research? I think so.

Detecting Sudden Ionospheric Disturbances (SIDs): This offers a clear benefit. When solar storms or other activity on the Sun cause an x-ray storm, we can lose valuable communication links. If I understand all this correctly, we have satellites that detect such events, but they do not make decisions. Rather, they download the raw data, which are interpreted by humans – humans who can make mistakes. There are many Earth-based SIDs monitoring stations, most of which are voluntary. When they detect a SID event they upload their data to an international organization, where these events are correlated to those gleaned from the raw satellite data. There are discrepancies, false positives and false negatives. Fixing these discrepancies “cleans” the data. Researchers examine these data in hopes of creating a more accurate prediction algorithm that will minimize the damage that an x-ray storm might cause. I believe this process has an unquestionably clear benefit.

Jupiter’s Radio Storms: Benefits? Not so much. Maybe I’ve just not seen the benefit myself, but this field seems to be still in the exploratory stages.

Galactic Hydrogen Detection: It’s tempting to dismiss this as an ongoing “pure” science effort, but radio astronomy has so increased our understanding of the universe that I have to label the effort beneficial. Such a new field with such a monumental contribution to science must be recognized as worthy of one’s time, effort and even our financial support.

Conclusions

I have a corkboard on my wall with all the pins I've earned from the Astronomical League, and notebooks full of project logs and certificates. With this project, beyond all that, I've got a somewhat modest, but effective 1.4 GHz radio astronomy antenna system.

What's next? I plan to add a second Yagi for a dual antenna system, and maybe even an elevation rotator, following Prutchi's design.

When I first became a ham I built a Heathkit HW-8 low power CW transceiver and fed it into an inverted-V antenna. When a prominent member of the QRP community gave a talk at our local club, we all brought in our low power gear and logs. I got a compliment for the numerous 459 signal reports from several local and a few foreign stations. It was a matter of pride for me to make a lot of contacts (and a few new friends!) from that experience. In that same mindset, I want to see what I can do with that caliber of equipment in my newfound field.