

3 Death and Resurrection

Editors' Note: In 1999 the new 100 meter Green Bank Telescope (GBT) was nearing completion. Because the efforts of the Green Bank staff needed to be focused on the new telescope, the 140 Foot was retired.

Bob Rood describes the last astronomical observation done on the 140 foot and expresses what many astronomers felt, that its demise was premature and that the 140 foot was still capable of doing good science.

After a rest of a few years, the 140 Foot was given a new task, starting in 2006, observing radar echos from Earth-orbiting satellites to study the ionosphere.



The subreflector being removed for the last time, August 1999.

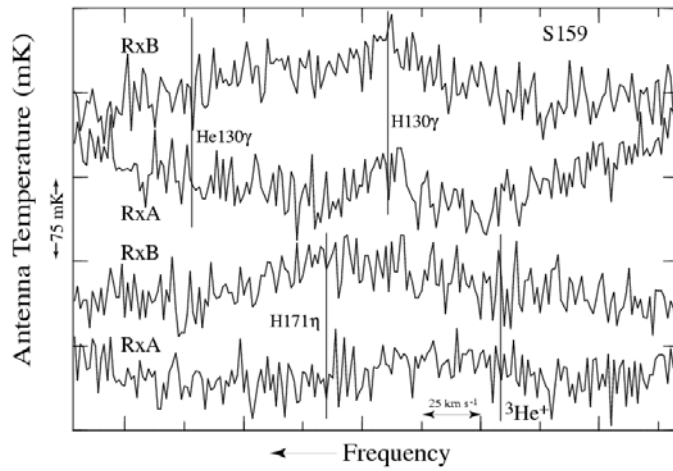


Fig. 1— *The Last Scan at the 140 Foot Radio Telescope: 08:12:20 EDT, 19 July, 1999.*



Fig. 2— *Bob and Red.*

An Old Dog's Last Hunt *

The last Observations of the NRAO Green Bank 140 Foot Radio Telescope

Robert T. Rood (University of Virginia)
 Thomas M. Bania (Boston University)
 Dana S. Balsler (NRAO-Green Bank)

Abstract

At 08:12:20 EDT, 19 July, 1999 the Green Bank 140 Foot Telescope of the National Radio Astronomy Observatory made its last scientific observation, having been given a 12 minute reprieve. That last 12 minute Total Power pair (Figure 1) taken toward the H II region S159 to the untrained eye looks like a noise spectrum, like most of the other roughly 25,000 pairs we have obtained since 1982. However, careful examination revealed a hint of a feature at the frequency of the H130 γ recombination line. Our "target," the much weaker hyperfine line of $^3\text{He}^+$, is readily visible in the 11.8 hours of integration acquired toward S159 over the previous three nights. The fact that we could detect $^3\text{He}^+$ in a mere 11.8 hour integration, or indeed that we would be observing an obscure H II region like S159 reflects both the dramatic improvement in receivers and our change in thinking since 1982. We take this time to reflect on the last days of a noble instrument and its contributions toward our knowledge of an isotope whose cosmic abundance can set important astrophysical constraints for theories of primordial nucleosynthesis and the chemical evolution of the Galaxy.

Prolog

About 10 years after the photograph in Figure 2 was taken, Red was an old rather decrepit dog. An encounter with a milk truck had left his rear legs severely damaged.

Since Red had enjoyed hunting when young, my father and several of his friends decided to take Red on one last hunt. After some time of dragging his rear along Red pointed as if he scented birds. The hunters, thinking him to be a useless old dog, walked ahead ignoring his point. A covey of quail burst noisily into the air. This was repeated several times. Red must have been disgusted: "I may not be able to run, but I can still smell and hunt."

This memory returned during our last observing sessions at the 140 Foot. It was capable of making the best observations of its long and illustrious career. The Autocorrelator and Honeywell 316 were as cranky as ever, but great data spewed

* Adapted from a poster presentation given at the 198th meeting of the American Astronomical Society in Pasadena, CA, June 2001. *Supported by the National Science Foundation (AST 97-31484).*

forth. To kynomorphize*, the telescope must have thought: “I can still smell, why are they turning me off?”

At least Red wasn’t euthanized after his last hunt.

The Final Observation

At the end of our observing session Nathan Sharp, the telescope operator, engaged the 140 Foot executioners in conversation. There was a 12 minute reprieve. Figure 1 shows the spectrum we obtained during that period. We simultaneously observed the $^3\text{He}^+$ hyperfine line and the hydrogen, helium, and carbon recombination lines at two orthogonal polarizations. The typically 1–2 mK $^3\text{He}^+$ line is not visible in such a short integration. However, there is a hint of the H130 γ line in each polarization.

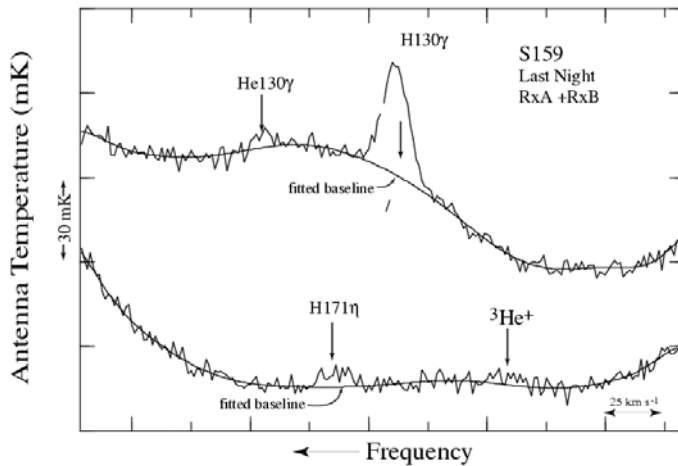


Fig. 3— Average of all data from the night of 19 July.

We were able to observe S159 for 4.2 hrs on the night of 19 July. Averaging all of this data and combining the 2 polarizations (see Figure 3) gives an integration time of 8.4 receiver hours and a noise level 6.5 less than an individual scan.

One obvious feature is that the spectral baselines are not flat. The baseline curvature results from standing waves created by multiple reflections from the telescope superstructure. This baseline structure is real and must be removed. This can be easily done with polynomial fits. The hard part is establishing the reliability of such fits. Over the years we have developed tests which demonstrate that our techniques are robust. Note that the fitted baselines in Figure 3 are plausible.

* From Greek *κυνειος*, “dog-like”; the dog parallel to “anthropomorphize.”

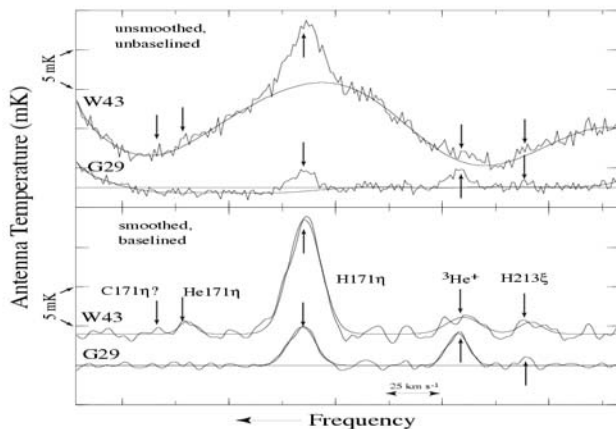


Fig. 4— The importance of H II region density.

Several lines, including a feature at the ${}^3\text{He}^+$ frequency, are visible. From this data alone (and our experience) we would be relatively certain of a detection. However, obtaining a ${}^3\text{He}$ abundance requires good line parameters and considerably more integration time.

Why S159 ?

If one is searching for a weak line in an H II region, wouldn’t the best targets be sources like Orion A or H II regions from the Westerhout catalog? Indeed our first target in this project at 10 AM, 23 February, 1982 was W51; we moved to Orion A when it rose. This is just the first case we encountered where the conventional wisdom was wrong.

Because the strength of the ${}^3\text{He}^+$ hyperfine line varies linearly with density of ionized gas and the radio continuum varies with density squared, the relation between H II region brightness and ${}^3\text{He}^+$ line strength is rather counter-intuitive. Being big (in angular size) and distant, are just as important as being bright. We soon realized this and targeted sources like W43 & S209. However, it turns out that the best targets were not cataloged. So we began to make our own survey of potential targets.

Still we didn’t have the guts to trust the equations showing the best candidates when pushed to their limits. Eventually, for other reasons we tried a few chancy targets and discovered that the plausible target list could extend to the wimpiest of H II regions. Hence, we have been surveying for ${}^3\text{He}^+$ over as much of the Galaxy as possible. We had gotten to S159 when the plug was pulled on the 140 Foot.

The importance of H II region density is illustrated in Figure 4. W43 is probably the best candidate of the classic H II regions. G29 is an anonymous blob in the same complex. Still G29 has a stronger ${}^3\text{He}^+$ line than W43. Perhaps even more important, as seen in the upper panel, is that the baseline structure is considerably less for G29. This is because it has less continuum to bounce around

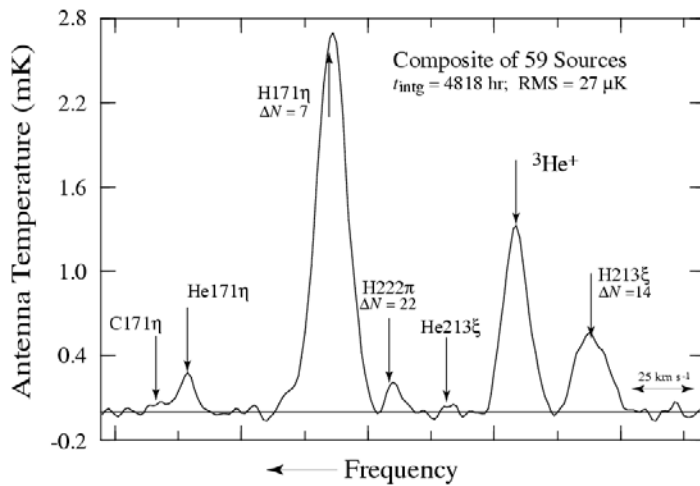


Fig. 5— ^3He at the Green Bank 140 Foot (1982 – 1999).

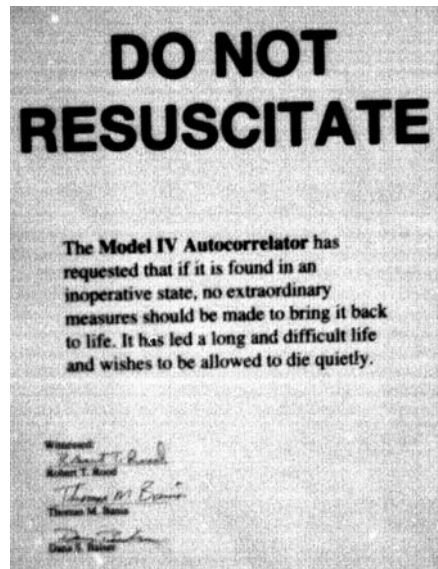
the telescope super-structure. It also turns out that one can model these low density sources more easily and determine better abundances.

In the end we can summarize our 17 years with the 140 Foot with a grand, grand average (Figure 5) of all of our H II region observations.



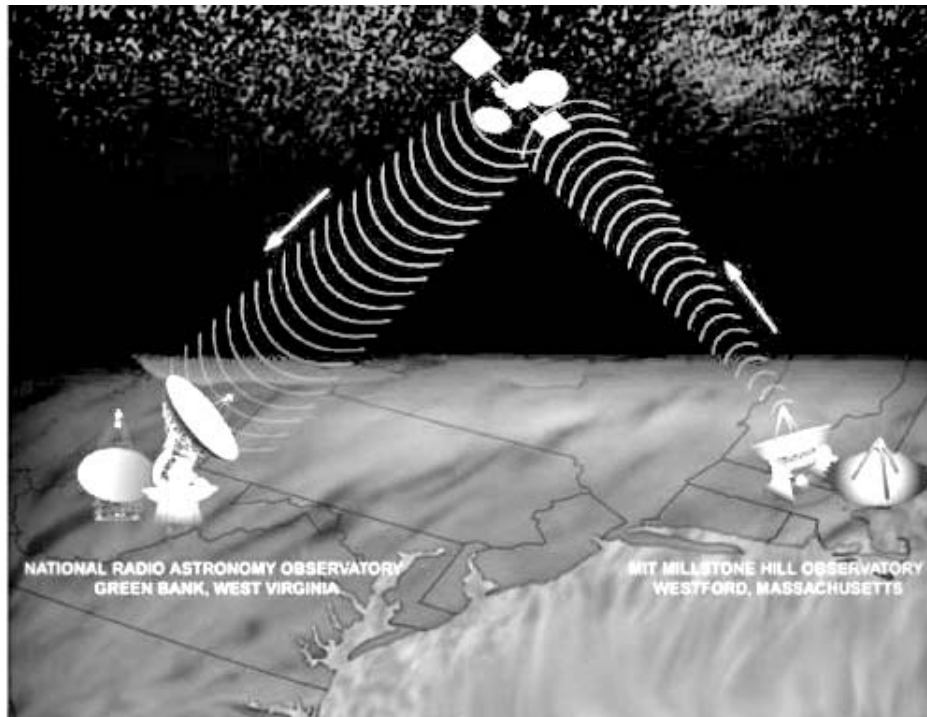
Bob Rood at the 140 Foot celebration, September 1995.

[Photo courtesy R. Maddalena]



Sign placed on the Mark IV Autocorrelator by Bania, Rood, and Balsler during their last observing run, July 1999.

*Resurrection: The 140 Foot is reborn
as the “43 meter”*



Radar signals from the MIT Lincoln Labs are received by the Green Bank 43 Meter Telescope.

**Bi-Static Radar Collaboration to Measure
the Earth's Ionospheric Turbulence**

G. Langston, R. Prestage, P. Jewell (NRAO)
From the NRAO Newsletter No.105, October 2005.

Lincoln Laboratories and the NRAO are collaborating to measure the properties of the Earth's ionosphere using bi-static radar techniques. Lincoln Laboratories is building a special wide-band (150 to 1700 MHz) feed and front end system that will be installed on the NRAO 43m (140ft) telescope. The NRAO is developing an automated system to follow Lincoln Laboratory's spacecraft coordinates. The 43m will track spacecraft beacons and also spacecraft illuminated by the Millstone Radar at Haystack, Massachusetts.

Lincoln Laboratory's engineers will drive a semi-trailer full of high-speed electronics to Green Bank, where it will be installed at the base of the 43m telescope. The trailer is shielded to contain any radio frequency interference the electronics

may generate. The Lincoln Laboratory's electronics will select and sample the RF signals and write the digital data to a disk recording system. The disk packs will be mailed to the Lincoln Laboratories office in Lexington, Massachusetts for further analysis.

The 43m operations was shut down in 1999, and the NRAO feared that it might not be possible to fully restore the 43m to operations. Detailed tests of the hydraulics system were required before the collaboration could begin. The Green Bank staff have worked with dedication to restart the 43m system. The 43m hydraulic systems have now been restored to full operations, and a new control computer system has been installed. We greatly appreciate the hard work of all those who have contributed to this success.

We expect to install the Lincoln Laboratories feed and front end system in September 2005 and make the first test observations in October 2005.

Lincoln Laboratories is operated by the Massachusetts Institute of Technology for the United States Air Force.

Measuring the Earth's Ionospheric Turbulence

G. I. Langston and R. M. Prestage (NRAO)

From the NRAO Newsletter, No.106, January 2006.

Lincoln Laboratories and the NRAO have begun regular observations of the Earth's ionosphere using bi-static radar techniques. . . .

Currently the 43m telescope is tracking spacecraft Tuesday through Friday from 10:00 a.m. to 3:00 p.m. and an operator is present at the telescope to assure proper operations. In early 2006, we will complete an upgrade to the remote monitoring of the 43m hydraulics systems. At that time we will begin un-attended operations 24 hours a day.

Phil Erickson and Frank Lind of MIT have installed a second radar experiment at the 43m as well as an array of 6 "discone" antennas. Their experiment is testing the use of reflected FM radio stations as probes of the ionosphere.