Measurement of Cassiopeia A Scintillation Using a Radio Spectrograph and the JOVE Radio Telescope

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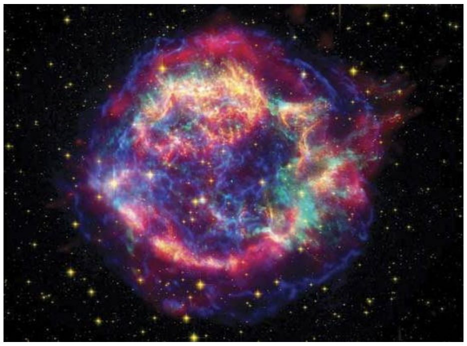

The Jove radio telescope has been used for many years to detect signals from Jupiter, the Sun, and the galactic background. Several Jove team members operate spectrographs in addition to the standard Jove receivers. During nighttime spectrograph observations as far back as 2013 Typinski, Ashcraft, and Greenman observed faint whispy semi-vertical bands of emission on some spectrograph records (2014).[1] Ashcraft suggested that these emissions might be scintillation of Cassiopeia A or Cygnus A, and noted similar scintillation events observed by the KAIRA research instrument in Finland.[2] When Typinski steered his 8-element antenna array toward Cas A the features became much stronger, supporting the belief that the source was indeed Cas A (fig. 1).

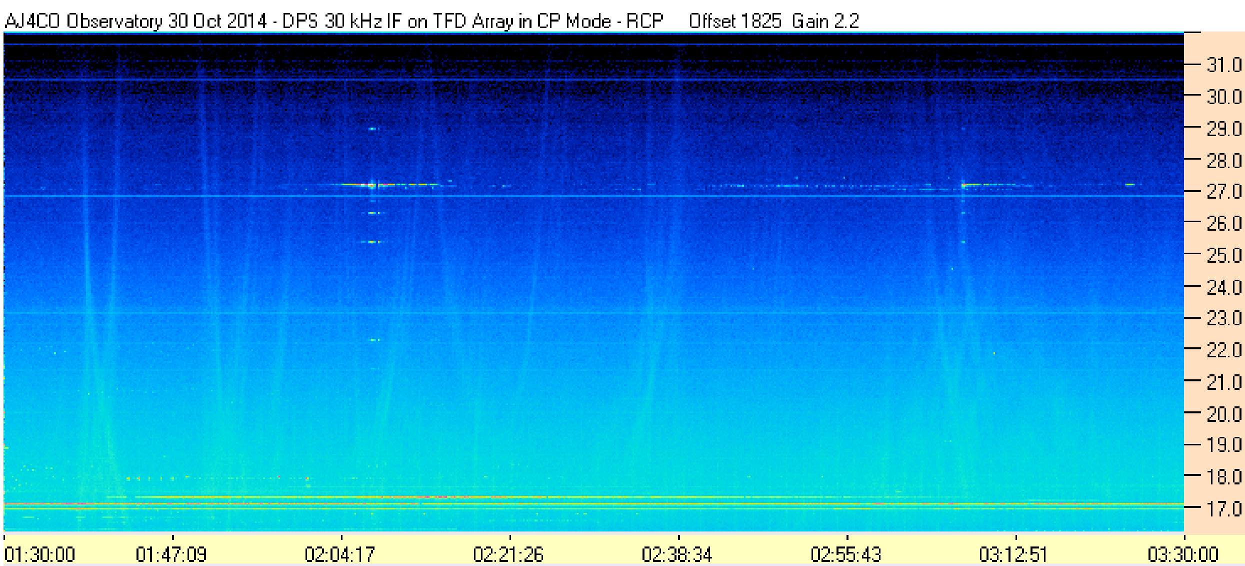

Fig. 1. Cas A scintillation as seen using the 8 element TFD array at AJ4CO.

We have attempted to expand on the work done by Typinski, Ashcraft, and Greenman to show that Cas A scintillation can be observed using a simple Jove dual dipole and a Jove receiver.[3]

Cassiopeia A is the strongest source of radio emission in the sky beyond the solar system. Located in the direction of the constellation Cassiopeia about 11,000 light-years from Earth, Cas A is the remnant of a supernova explosion caused by the collapse of a massive star. High frequency radio waves emanating from Cas A, pass through the Earth's ionosphere where they encounter a non-homogeneous mix of free electrons (fig. 2). Signals are refracted, causing numerous signal paths to converge on the observer's antenna. Phase and amplitude variations of these multipath signals cause scintillation, resulting in either an increase or decrease in signal strength. The result, viewed by a high frequency radio spectrograph using a relatively small antenna is seen as wispy semi-vertical emission bands slightly above the galactic background (GB).

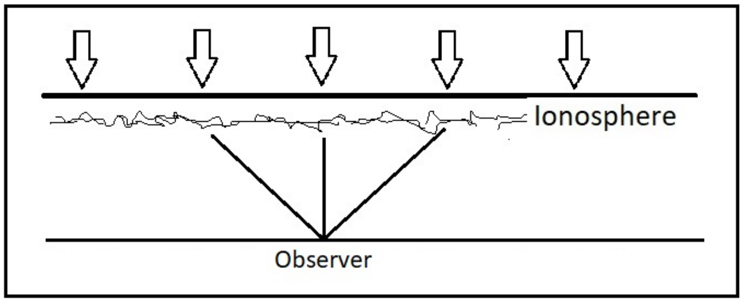

Fig. 2. Scintillation is caused when signals from a point source pass through the ionosphere.

Instruments

Radio spectrograms were captured with a terminated folded dipole (TFD)[4] 4-element array using the SDRPlay RSP2 spectrograph (http://www.sdrplay.com/). Right hand circular (RCP) polarized signals from the array were processed for display using Nathan Towne's SDRPlay2RSS and Radio Sky Spectrograph software[5]. In addition to the spectrograph, a 20.1 MHz Radio JOVE receiver was connected to the TFD antenna. A second Jove receiver was connected to a linearly polarized JOVE dual dipole array. Audio outputs from both Jove receivers were used to produce SkyPipe (strip chart) records. The TFD and Jove antenna beams were aimed north at an elevation of 63 degrees.

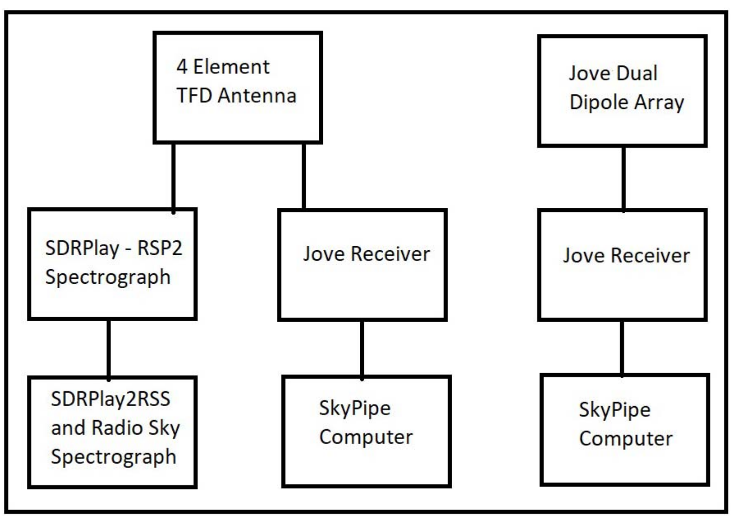

Fig. 3. Equipment used to detect signals from Cas A.

Observations

Observations were made at Hawks Nest Radio Astronomy Observatory (HNRAO) located in Industry, Pennsylvania (40.673N, 80.438W).

Signals were recorded during nighttime observations of Cas A between the 23rd and 25th of October 2017. Three of the most visible scintillation events were selected from the spectrograms. These events were identifiable in both the TFD Array and the JOVE Radio Telescope SkyPipe records.

Prior to the observations, both Jove receiver systems (operating at 20.1 MHz) were calibrated with a common noise source using the Calibration Wizard feature of SkyPipe software. This calibration allows the observer to determine antenna temperature in kilo Kelvin (kK), referenced to the antenna feedpoint. In order to reduce the magnitude of statistical fluctuations in the strip charts, SkyPipe (version 2.7.30)[5] records were post-processed using "Find Lowest Point" with a bin size of 10 and "Smooth by Average" with a bin size of 10.

The antenna temperature (largely due to the galactic background) was measured immediately before and after each scintillation event. These measurements were averaged to estimate the GB temperature at the time of the scintillation event. Then a measurement was made at the peak of the scintillation event. The ratio of the scintillation peak to the average GB was then calculated and expressed in decibels (dB). Data are presented in tabular form (Table 1).

Since Cas A scintillation is caused by the ionosphere, the intensity of scintillations can vary from night to night. Also, the antenna temperature which is predominantly due to the galactic background at a radio quiet site, varies from night to night due to some amount of radio frequency interference (RFI). Analysis of the SkyPipe records indicates that some of the most prominent Cas A scintillation peaks were on the order of ½ dB above the galactic background temperature.

	2017	**TFD**			**Jove Dipoles**		
Event	Date	GB Avg kK	Cas A peak kK	dB rise	GB Avg kK	Cas A peak kK	dB rise
1	10/23	93.0	102.0	**0.40**	91	98	**0.32**
2	10/24	83.0	96	**0.63**	95	112	**0.71**
3	10/25	91	106.0	**0.66**	87	95	**0.38**

Table 1. dB rise = 10LOG (Cas A peak kK / GB average kK)

Data

Data for each of the events listed above are presented below (figs 4, 5, and 6).

Event 1 - 23 October 2017

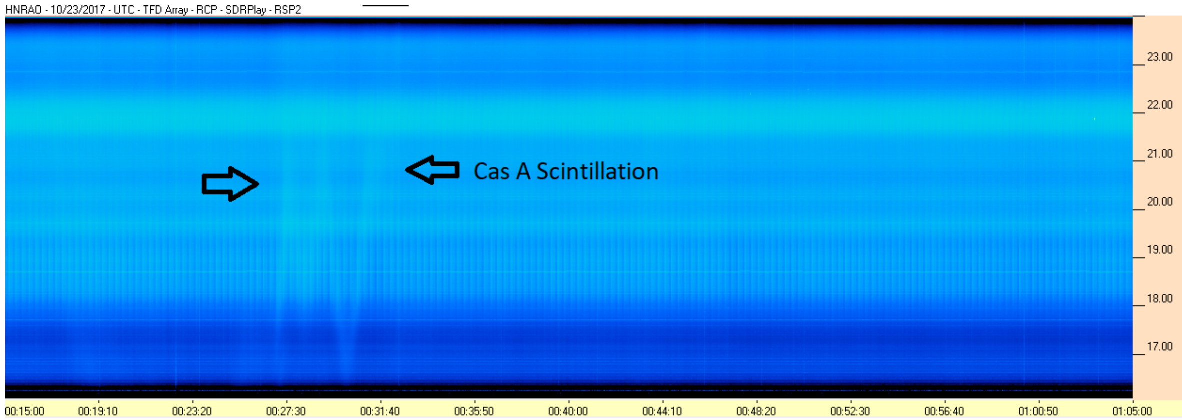

Fig. 4A. TFD array, RCP, SDRPlay RSP2 receiver.

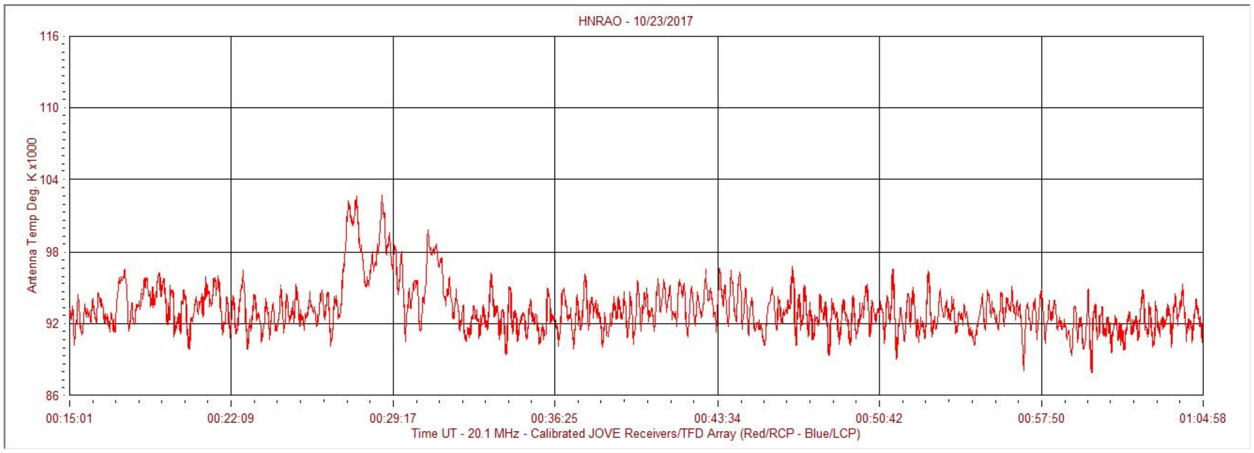

Fig. 4B. TFD array, RCP, JOVE receiver. Avg GB = 93 kK, Peak Cas A = 102 kK, dB rise = 0.40.

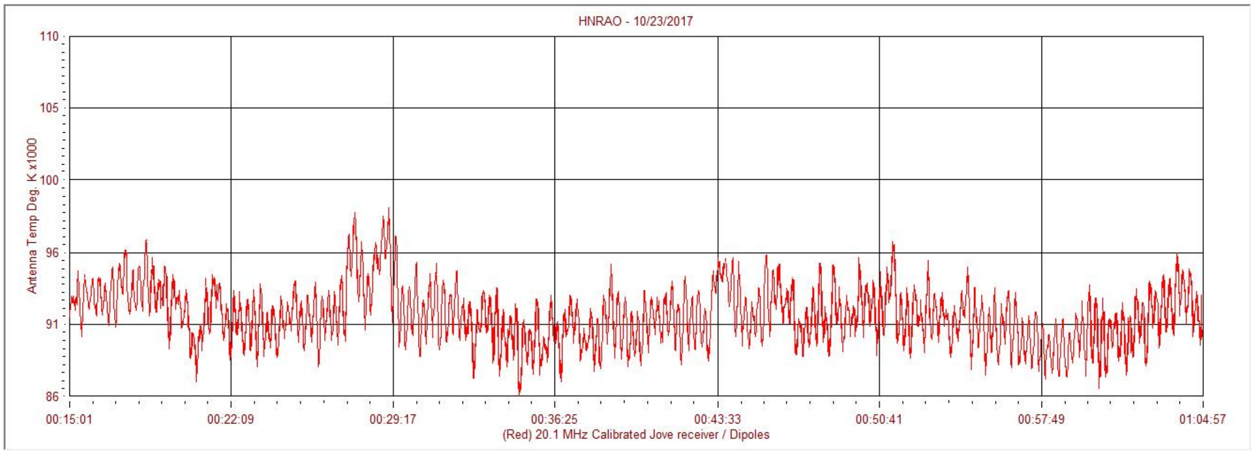

Fig. 4C. JOVE dipoles, JOVE receiver. Avg GB = 91 kK, Peak Cas A = 98 kK, dB rise = 0.32. Some weak RFI is seen as rapid, periodic fluctuations in this SkyPipe record.

Event 2 - 24 October 2017

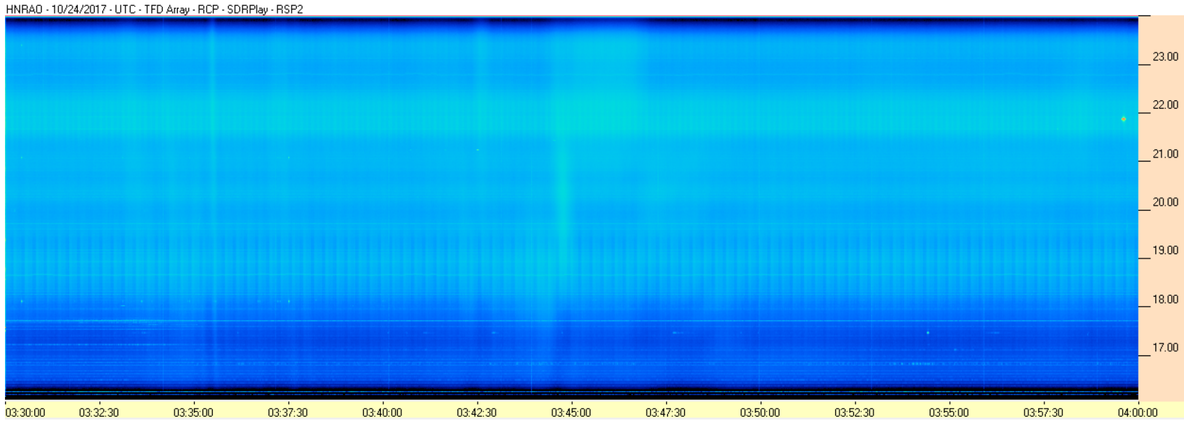

Fig. 5A. TFD array, RCP, SDRPlay RSP2 receiver.

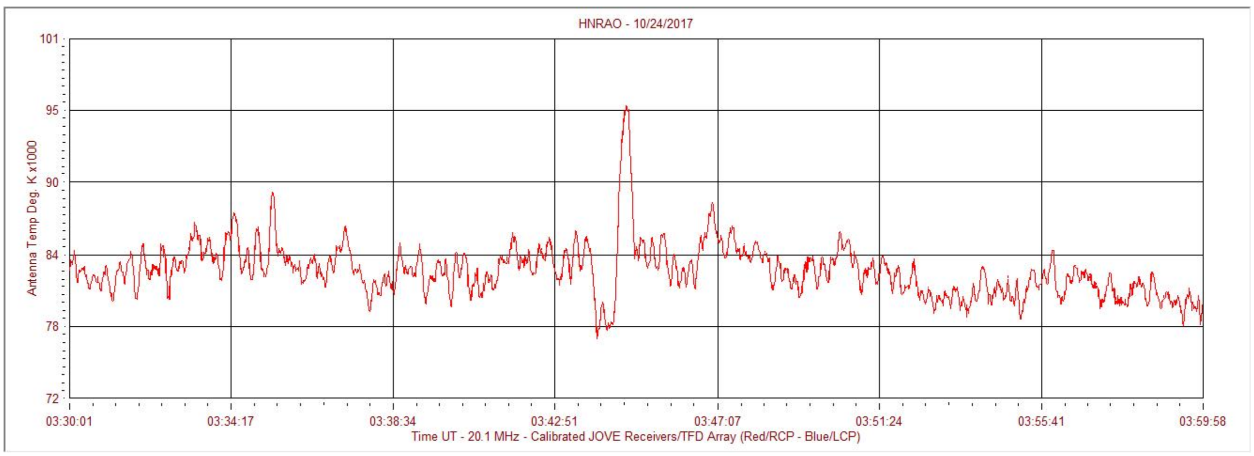

Fig. 5B. TFD array, RCP, JOVE receiver. Avg GB = 83.0 kK, Peak Cas A = 96 kK, dB rise = 0.63 dB.

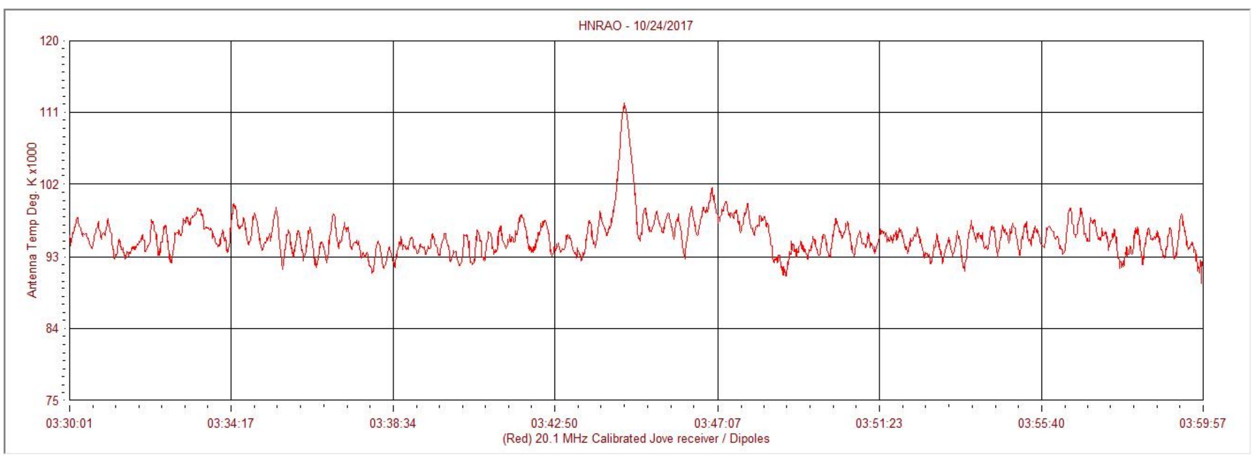

Fig. 5C. JOVE dipoles, JOVE receiver. Avg GB = 95 kK, Peak Cas A = 112 kK, dB rise = 0.71 dB.

Event 3 - 25 October 2017

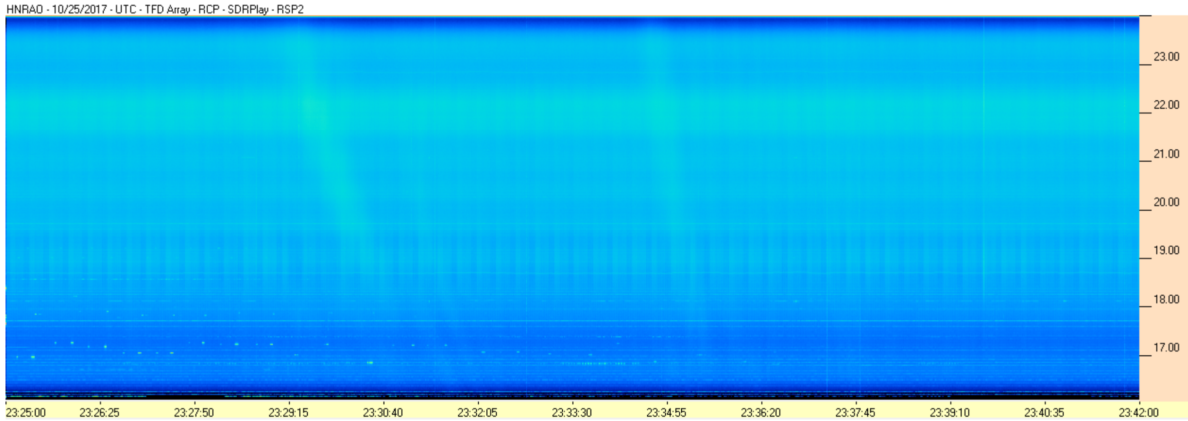

Fig. 6A. TFD array, RCP, SDRPlay - RSP2 receiver.

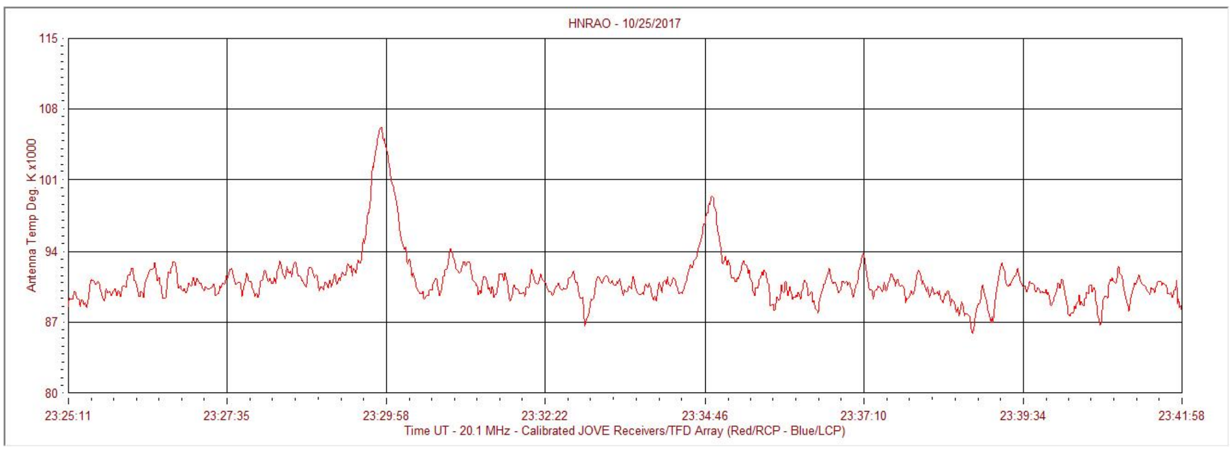

Fig. 6B. TFD array, RCP, JOVE receiver. Avg GB = 91 kK, Peak Cas A = 106 kK, dB rise = 0.66 dB. These measurements are for the larger of the two scintillation maxima, see at 23:29:58.

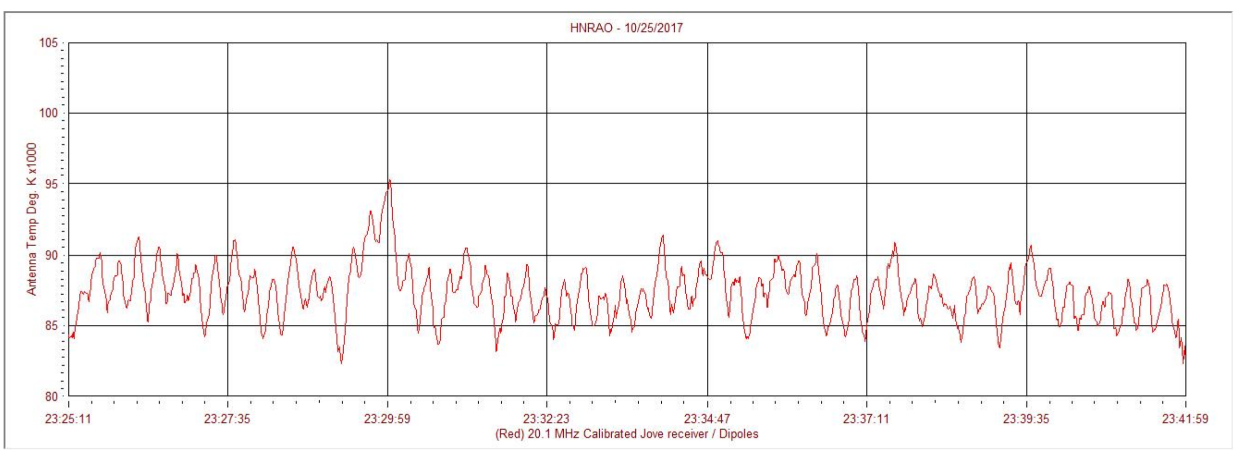

Fig. 6C. JOVE dipoles, JOVE receiver. Avg GB = 87 kK, Peak Cas A = 95 kK, dB rise = 0.38 dB.

Conclusions

It is possible to detect weak emissions from Cas A using a Jove Radio Telescope comprising a Jove receiver, dual dipole antenna and SkyPipe software. Individual scintillation events are weak, sometimes appearing on the order of 0.5dB above the galactic background at a quiet receiving site. Cas A signals are only identifiable using this equipment during periods of signal strength enhancement caused by scintillation. In order to identify the individual scintillation events in a SkyPipe record they should be matched with scintillation features visible in a radio spectrogram.

Cas A (3C461) is located at 23.4h right ascension and a declination of +58.9 deg. Because of the wide antenna beamwidths used in these observations it is possible, but unlikely, that some of the scintillation events observed were from Cygnus A (3C405) which is located at 20h RA and +40.8 deg declination.

Notes

[1] http://www.radiojove.org/SUG/Pubs/ Cassiopeia A Scintillation Observed by Radio Jove Participants, Typinski et al (2014).pdf.

[2] http://kaira.sgo.fi/2012/10/ionospheric-scintillation-with-kaira.html

[3] The standard JOVE antenna is a two element phased dipole array. For these observations the standard Jove array which uses 75 ohm coax cable and a TV power combiner was converted to a system with 50 ohm coax and a 50 ohm commercial power combiner. This modification reduces calibration uncertainty. The Jove receiver is a simple direct conversion receiver for 20.1 MHz https://radiojove.gsfc.nasa.gov/.

[4] TFD Array – terminated folded dipole array comprises a pair of dipoles aligned N/S and a second pair of dipoles aligned E/W in a square configuration fed through a hybrid combiner to produce both right hand and left hand circular polarization.

[5] SkyPipe software: http://www.radiosky.com/

Bio

James Brown, former director of the Planetarium and NASA Educator Resource Center at South Carolina State University in Orangeburg, has been involved with astronomy education for over 25 years. He holds a B.S., M.S.Ed, post graduate work in Communications and an Associate Degree in Electronics Engineering Technology. He has been a member of SARA for over 17 years and has served in several positions on the Board. He has been active in the Radio JOVE program since the late 1990s and currently operates his radio astronomy observatory in Western Pennsylvania, continuing his support of the Radio JOVE program.

Richard Flagg, is a former research associate at the University of Florida where he developed specialized receivers and antennas and studied Jovian S-bursts in high time resolution. He holds a B.S. in Physics and a M.E. in Electrical Engineering. He is a long-time member of SARA and has served on the Board. As a founding member of the Radio Jove program, he designed the Jove receiver and the FSX series of radio spectrographs and is author of *Listening to Jupiter*. In Hawaii he operates the radio observatory at Windward Community College (WCCRO).