# Radio Astronomy

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*This article reports on the activities of the Deep Space Network in support of Radio and Radar Astronomy Operations during September through December 1980. The article concentrates on a report of an experiment selected for use of the DSN by the Radio Astronomy Experiment Selection Panel: that of VLBI observations of the energetic galactic object SS-433.*

## I. Introduction

Deep Space Network (DSN) 26-, 34- and 64-meter-antenna stations are utilized in support of experiments in three categories: NASA Office of Space Science (OSS), Radio Astronomy Experiment Selection (RAES), and Host Country.

## II. Radio Astronomy Operations

### A. NASA OSS Category

During this period, support of Planetary Radio Astronomy (OSS196-41-73) and Pulsar Rotation Constancy (OSS188-41-55-09) observations continued at their previous levels. In addition, the Southern Hemisphere Interferometer (OSS188-41-55-16) made considerable use of DSS 42/43.

### B. RAES Panel Category

**1. RA 175 (SS-433).** This activity continues to be supported at intervals of approximately 40 days, and was recently extended by the RAES panel for another year. The following is a brief summary of the history of the study of SS-433, including a report of the progress made in the VLBI observations of it.

SS-433 is not a newly discovered object. It can be historically traced as an optical variable from plates dating back to 1929. But the SS-433 name was not bestowed until much later. Observed as a red, 14th-magnitude star, its distinguishing bright hydrogen emission spectrum caught the attention of Stephenson and Sanduleak, of Case Western Reserve University, who were compiling a catalog of stars with this particular characteristic. It is the 433rd object in that catalog.

Since the mid-1970's a series of coincidental observations focused new attention on SS-433. Several satellites identified X-ray sources in about the same location. An unresolved variable radio source was also noted in this region. Still another discovery in this approximate location was that of a supernova remnant (SNR) identified as W50. Bruce Margon of

UCLA and his associates closed the historical loop of observation by doing modern optical photometry and spectroscopy of SS-433 as part of a program of observing visible counterparts of galactic radio sources.

Margon's data showed an incredible tripling of emission lines, which shifted rapidly and drastically. Identification of the lines revealed the tripling effect: a zero-velocity emission accompanied by both large red- and blue-shifted variable components. Analysis of this phenomenon, based on the doppler effect, implied velocity maxima of 50,000 km $s^{-1}$ redshift and $-35{,}000$ km $s^{-1}$ blueshift, changing at a rate of 30,000 km $s^{-1}$ in 40 days, which confirms the earliest lightcurve period as $164 \pm 3$ days. When radial velocity (measured as $Z = \Delta\lambda/\lambda$) is plotted against time, a very striking and obvious condition is noticed: a smooth sinusoid about a $Z$ of +0.04. This effect could most simply be explained by a binary star system having an orbital period of 164 days. However, such a system would need to have a total mass equal to about one percent of the entire galaxy in order to exhibit the orbital velocities implied by the red- and blue-shifted spectra. Another possible explanation might be that some of the observed SS-433 characteristics are similar to those of a quasar. This explanation requires that SS-433 be a very remote object, which is not backed up by other observational evidence. Another model was needed.

As more news of SS-433 was disseminated, more and more models proliferated. However, one model seems to best explain the observed phenomena: the so-called kinematic model proposed by B. Margon and his associates at UCLA. This model postulates an object, as yet unidentified, which is ejecting jets of matter in opposite directions along an axis which is itself inclined to an axis of precession. The central object and twin beams account for the doppler shifts and triple emission lines, while the precession of the ejection axis gives a 164-day period. Since the geometry of this scheme is quite specific, forecasts of observations could be made with regard to discrete events such as convergence and crossing of the spectral emission lines. This very event was observed as predicted by Margon in 1979, lending further credence to this model.

Radio observations have determined variations in 2.7 GHz flux densities from 0.5 Jy to 1.6 Jy within a 15-day interval as well as variations in flux density of 140 mJy at 8.1 GHz over four days. An angular diameter of 0.1 arcsec at 8.1 GHz has also been measured.

Yet to be addressed is the relationship between SS-433 and its surrounding neighborhood, the SNR W50. Recent multi-station VLBI experiments undertaken as RA-175 have uncovered some startling results. The position angles of the elongated radio source, greater than 0.1 arcsec, were within 10 degrees of the position angle of W50's apparent bulges. This implies a physical connection between SS-433 and W50.

The features observed in SS-433 – a small active radio core connected by relativistic jets to extended radio lobes – lend support to the suggestion that we are observing the same phenomenon that powers quasars and radio galaxies but on a scale that is a billion times smaller.

Radio results thus far are not discordant with the kinematic optical model. Observations of variations in the separation angle have revealed a separation rate between the radio elongations comparable to that of the optical jets. Measurement of the change in structure shows that radio emission propagates outward from SS-433 in radio "blobs." Assuming these "blobs" travel at the speed of the optical jets, 0.26c, the distance derived is 5 kpc (15,000 ly), which is about one and a half times further than previous estimates to W50. In this, the Goldstone/OVRO baseline is in an orientation peculiarly well-suited for observing the east-west SS-433 jet. Furthermore, the sensitivity of DSN stations for detecting the flux density as well as the unique baselines available to optimize the precision of position angle measurements for variations serves to ensure that the DSN will retain an important position as a major resource for this project.

## C. Host Country Operations

Host country operations were limited to support of pulsar observations in Australia.