The Astronomical Potential of the RAEGE-Az Radio Telescope:
Probing AGN nature from variability studies

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The RAEGE Network Radio Telescopes

The RAEGE Network (Rede Antlântica de Estações Geodinâmicas e Espaciais), is a joint Spanish-Portuguese infrastructure of geodetic stations. The main goal of the project is the establishment of four stations (two in Spain and two in Azores, Portugal) with VGOS (VLBI Global Observing System) radio telescopes operating in tandem [1].

Currently, two of these telescopes are already operational: one at the RAEGE-Az station of Santa Maria, Azores (SMA), and another at the Yebes Observatory, in Yebes, Spain. The telescopes were designed for the VGOS requirements, and are optimised for geodetic studies, using VLBI observations of bright Quasars to measure the distance between stations at the mm scale. Because the SMA and Yebes telescopes are located at different tectonic plates (African and Eurasian, respectively), this also allows the monitoring of the plates' movements.

The Santa Maria Telescope possesses a diameter of 13.2 metres, a ring-focus optics design and a high-speed data acquisition system. It has a low-noise, ultra-wideband cryogenic receiver from 2 to 14 GHz with ~40 K of system noise temperature at the zenith. Three local oscillators separate the broadband into six 2 GHz sub-bands, and a fast Fourier transform spectrometer (FFTS) can be used as a backend to perform spectroscopic observations.

Figure 1: The Santa Maria Radio Telescope "Colombo"

Figure 2: The RAEGE-Az Station, in Santa Maria, Azores

Potential for Radio Astronomy

The RAEGE radio telescopes were optimised for geodetic studies using VLBI. Since their means of operation consist of astronomical observations, the telescopes are also capable of high-quality research in radio astronomy. As such, the RAEGE-Az station stands out as a facility within national territory with significant potential for research and education in radio astronomy.

Over the past 3 years, under a collaborative agreement between the Institute of Astrophysics and Space Sciences and RAEGE-Az, the use of the telescope for astronomy has been initiated, with initial test observations performed in 2021.

In particular, for the past year, a project has been initiated aiming at the implementation of a monitoring program of Active Galactic Nuclei (AGN). Here, we report the results obtained concerning the tests to the capabilities of the Santa Maria telescope for radio astronomy.

Observations and Preliminary Results

Regular observations of both Galactic and extragalactic sources have been conducted, in order to ascertain the full capabilities of the SMA radio telescope. Spectroscopic observations were performed on an extensive sample of Galactic methanol Masers, at the 6.7 GHz and 12 GHz emission lines. Concurrently, continuum on-the-fly observations were performed on a sample of 11 bright (> 1 Jy) AGN, with redshifts spanning from 0.2 to 2.4. The scans were taken with throws of 1–2 degrees, at a central frequency of 8750 MHz (bandwidth of 1500 MHz). Moreover, sources from both samples were selected for continuum mapping, a procedure that hadn't been fully tested yet with this telescope.

As the results gradually came, the stability of the telescope was evaluated by comparing the data from multiple observations. The conditions at the time of observation were monitored and recorded in order to identify possible patterns (weather, system temperature (Tsys) calibration, RFI). It is important to note that the stability of the internal system itself is remarkable, and that the goal of these tests is to identify possible external sources of instability.

Methanol Masers

The telescope as proved to be able to detect line emission towards several sources in our sample, down to peak flux densities of 6 Jy, within an integration time of 1-2 h.

AGN

We detected continuum emission towards nearly all the sources, with the faintest showing peak flux density of 2.4 Jy at a central frequency of 8750 MHz. We were also able to detect the farthest source in our sample, QSO B0552+398, with a redshift of 2.4 and flux density of 3–4 Jy.

Stability Tests

We find that weather is a significant source of instability during observations. This is particularly important, as weather conditions in Santa Maria can vary significantly and rapidly. Strategies to efficiently plan observations around weather conditions are being developed and implemented.

In order to identify possible sources of RFI, we performed spectral scans of our AGN sample (Fig. 5). Although significant RFI is present, it is well localised (in frequency) and can thus be removed from the spectra during data reduction. Precisely due to the narrow RFI present, and our capability and need to excise it, we find that spectroscopic observations should be used even when identifying the continuum flux of a source – instead of the more traditional "continuum mode" observations.

Mapping

Continuum mapping is performed by taking multiple on-the-fly scans over a region of the sky. We performed several of these mappings on bright sources from our sample, such as Cassiopeia A (Fig. 6). Because the sources are unresolved, the structure present in the map is effectively a 2-D profile of the main beam. We can conclude that the telescope is capable of performing continuum mapping. This could be especially relevant in the mapping of large-scale structures, at a minimum resolution of about 5.7 arcmin (main beam at 14GHz).

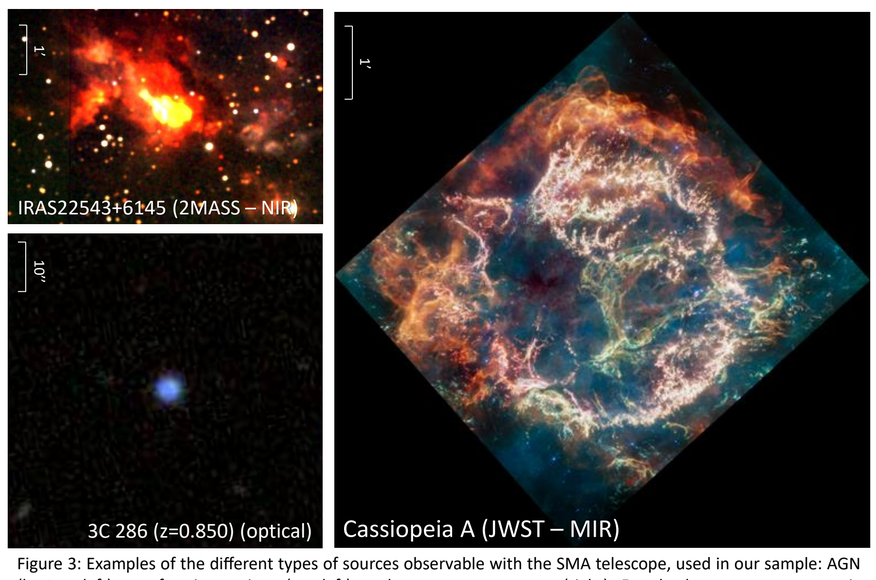

Figure 3: Examples of the different types of sources observable with the SMA telescope, used in our sample: AGN (bottom-left), star-forming regions (top-left), and supernova remnants (right). For the last two, spectroscopic observations are possible for rotational line emission from methanol masers.

Conclusions and Future Work

Over the past year, we have conducted observations of a variety of Galactic and extragalactic sources, employing different methods, in an attempt to ascertain the potential of the SMA Radio Telescope for astronomy.

From these observations, we can conclude that the telescope is capable of observing these objects, both in spectroscopy and continuum, as well as performing continuum mapping. Some instability was detected from RFI and weather conditions, but these can be accounted for with data reduction and appropriate scheduling of observations, respectively.

The results from stability tests provide information relevant to establishing a more efficient observation strategy with the telescope, as well as helping with the implementation of an AGN monitoring campaign.

These results, though preliminary, serve to confirm the SMA telescope's capability to perform radio astronomy, on top of its use in geodetic studies. This opens the door for the RAEGE-Az station to be used as a national facility with potential for research and education in radio astronomy, with particular relevance to advancing Portugal's capabilities towards the upcoming Square Kilometre Array era.

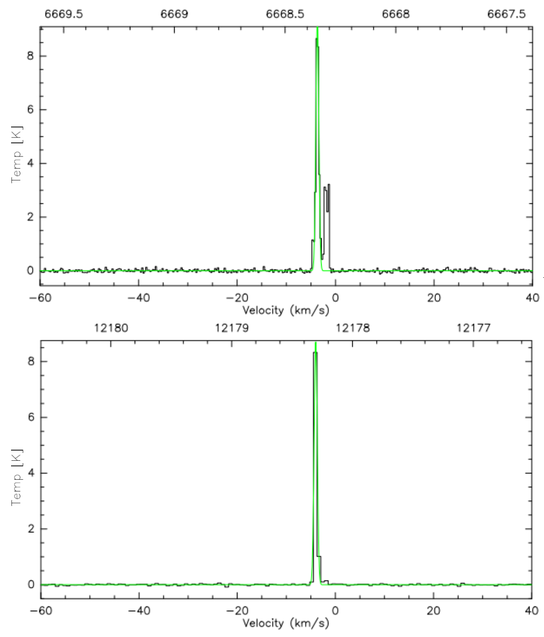

Figure 4: Spectra obtained from observations of a methanol maser in the star-forming region IRAS 22543+6145, from the 6 GHz (top) and 12 GH (bottom) rotational emission lines. In green are the Gaussian fits to the emission lines.

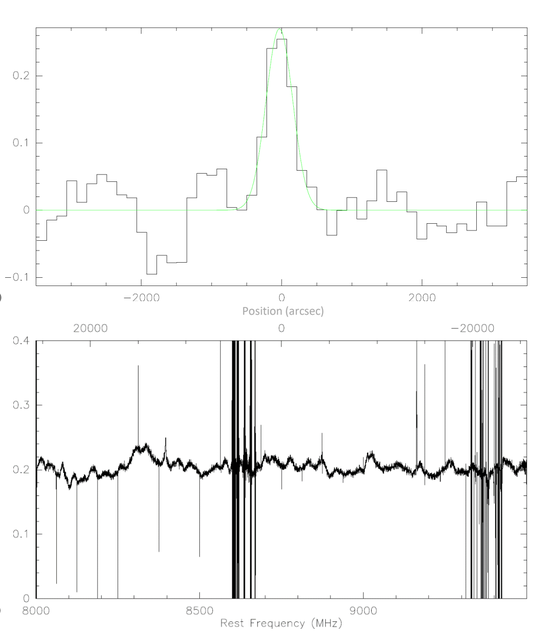

Figure 5: Continuum on-the-fly (top) and spectroscopic (bottom) observations of the AGN 3C286. In green is the Gaussian fit to the main beam. The continuum scan was taken with a throw of 2 degrees, at a central frequency of 8750 GHz. Under optimal observational conditions, the level of the baseline in the spectrum should coincide with the peak temperature of the main beam in the scan. In the spectrum, the two regions with instability correspond to RFI that occur at specific frequencies, and can thus be easily removed.

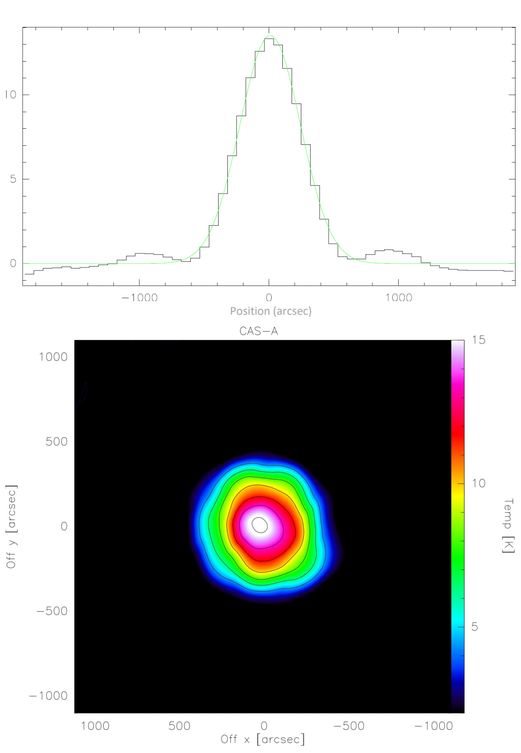

Figure 6: Continuum on-the-fly observation (top) and mapping (bottom) of the supernova remnant Cassiopeia A. The scans were taken with a throw of 1 degree, at a frequency of 8750 GHz. Because the object in question is a point source, the map shows the 2-D profile of the telescope beam.

References

[1] Moreira, M. et al. (2022) "RAEGE Project: Status, Analysis Endeavours, and Future Prospects". EGU General Assembly 2022, Vienna, Austria, 23–27 May 2022. EGU22-8593. https://doi.org/10.5194/egusphere-egu22-8593, 2022.

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