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Radio Continuum Spectra of Planetary Nebulae

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1 Extended abstract

Radio continuum observations of planetary nebulae trace thermal emission of ionized gas and provide valuable information about its structure and physical parameters. For a homogeneous shell, the spectral index ≈ -0.1 in an optically thin range and reaches 2 for optically thick emission. A model of an ionized shell containing radial density gradient predicts an intermediate value of spectral index for a limited range of frequencies [1].

Studies comprising observations at more than two frequencies were limited in sample to few objects [2]. Most of previous studies on nebular radio emission based on observed spectral index between two selected frequencies, 1.4 and 5 GHz, in combination with the brightness temperature at 5 GHz, which was measured for a number of planetary nebulae [3, 4]. The observed indices cannot be reconciled with a model of homogeneous shell. Observations indicate that strong radial density gradients are associated with $10-20\%$ of planetary nebulae [3]. An alternative model proposes that a typical nebula consists of two regions having two different values of optical thickness [4].

We analysed radio continuum spectra of planetary nebulae in the range between 150 MHz and 40 GHz collected from various catalogues and instruments to discriminate between the proposed models. Our analysis rules out a homogeneous shell with the observed diameter as a good approximation for majority of planetary nebulae. Their spectra show non negligible optical thickness at low frequencies, even for objects with very low brightness temperatures. This requires non uniform surface brightness distribution with a limited region of the nebula emitting majority of the total radio flux.

At least $\sim$10% of planetary nebulae demonstrate two distinct spectral components. On the other hand, strong density gradients are not as common as previously indicated. Most of the candidates for strong density gradients suggested by [3] show steeper spectra than expected at low frequencies. However, a caveat remains that optically thick region is not well sampled in most of the objects due to limited sensitivity of the surveys. High sensitivty low frequency observations covering optically thick emission are necessary to further constrain the emission of planetary nebulae. They will be provided with the advent of new instruments operating at low frequencies. We will discuss the prospects of application of Low-Frequency Array (LOFAR) for studies on planetary nebulae.

References

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