Probing the complexity of the Interstellar Medium at radio wavelengths

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Wednesday, July 30, 2025, 08:30–10:15

The interstellar medium (ISM) is the galactic reservoir from which stars form, playing a central role in shaping galactic evolution. Star formation, in turn, is regulated by the physical and chemical complexity of the ISM, where the energy balance depends on the interplay of thermal and turbulent pressures, magnetic fields, cosmic rays, gravity, and stellar feedback. These components give rise to distinct ISM phases, which are dynamically linked across a wide range of spatial scales.

Understanding how these forces interact – across physical scales and environments – is a central goal of ISM studies. Yet tracing the ISM as a truly multiscale, multiphase medium remains observationally challenging.

Radio observations, spanning from meter to millimeter wavelengths, offer a unique window into the ISM. They allow us to probe all major gas phases – from ionized to molecular – and to trace fundamental processes such as turbulence, magnetic fields, and stellar feedback.

In this lecture, I will highlight the key contributions of radio astronomy, particularly at centimeter wavelengths and beyond, to our understanding of the ISM. We will focus on selected observational tracers: the 21 cm line of atomic hydrogen, synchrotron and free-free continuum emission, Faraday rotation, and radio recombination lines. I will discuss how these observations constrain ISM physics today and look ahead to the transformative capabilities of next-generation facilities, such as the Square Kilometre Array Observatory (SKAO).

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