Hot gas feeds spiral arms of the Milky Way

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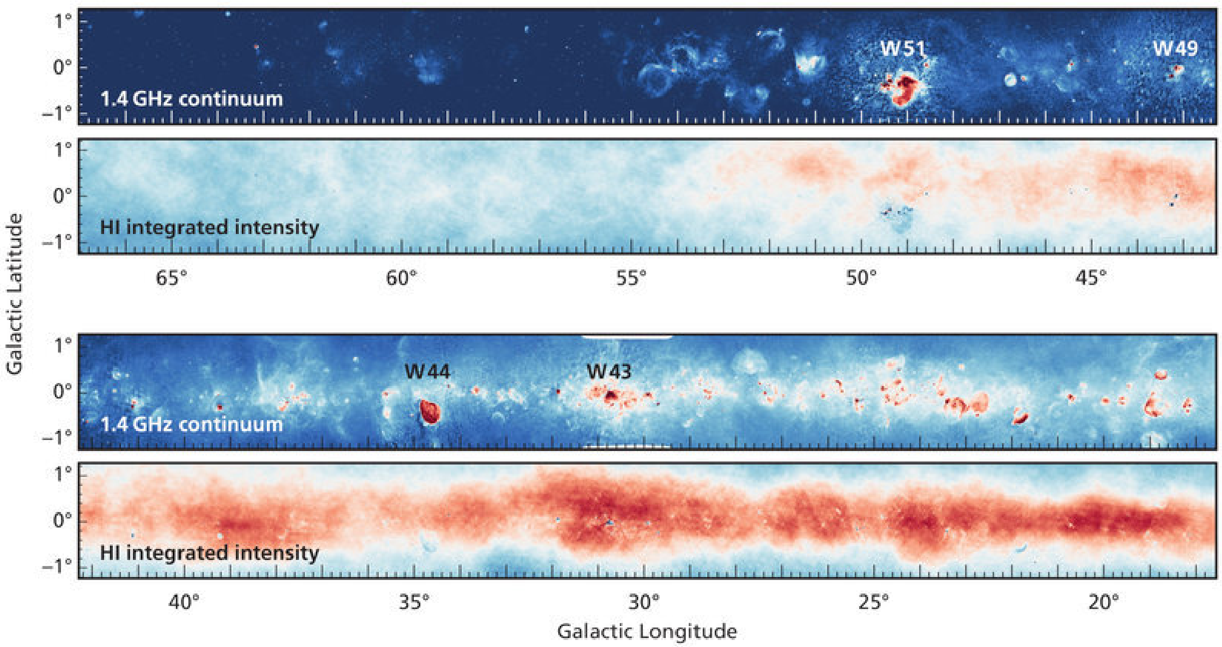
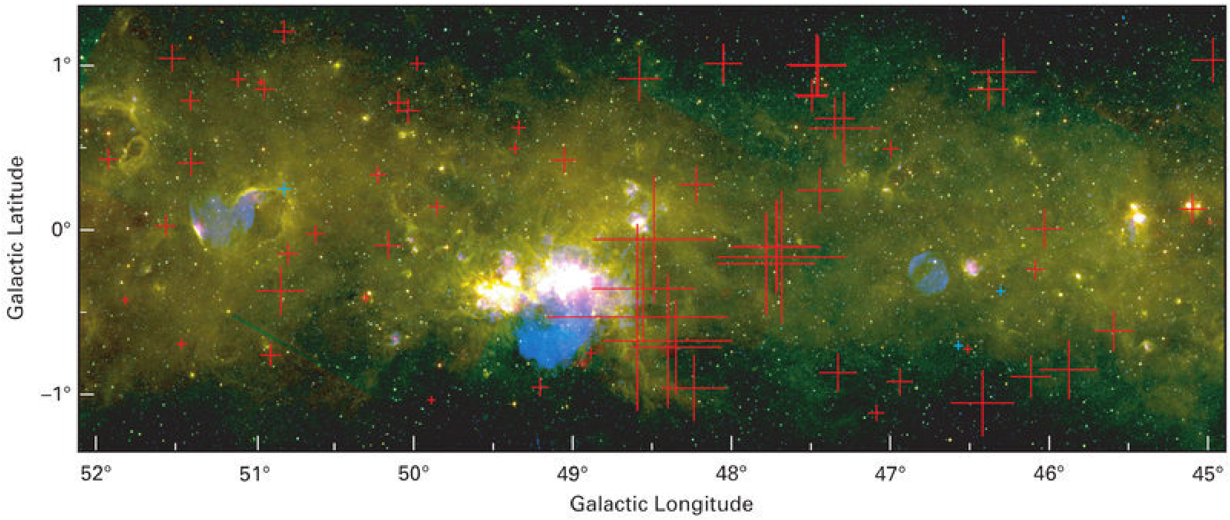


False-colour representation of the radio emission in the Milky Way from the THOR survey at a wavelength of about 21 cm. The upper band (1.4 GHz continuum) shows the emission from different sources, while the lower bands show the distribution of atomic hydrogen. Credit: Y. Wang/MPIA

An international research team, with significant participation of astronomers from the Max Planck Institute for Astronomy (MPIA), has gained important insights into the origin of the material in the spiral arms of the Milky Way, from which new stars are ultimately formed. By analysing properties of the galactic magnetic field, they were able to show that the dilute so-called warm ionized medium (WIM), in which the Milky Way is embedded, condenses near a spiral arm. While gradually cooling, it serves as a supply of the colder material of gas and dust that feeds star formation.

The Milky Way is a spiral galaxy, a disc-shaped island of stars in the cosmos, in which most bright and young stars cluster in spiral arms. There they form from the dense interstellar medium (ISM), which consists of gas (especially hydrogen) and dust (microscopic grains with high abundances of carbon and silicon). In order for new stars to form continuously, material must be constantly flushed into the spiral arms to replenish the supply of gas and dust.

A group of astronomers from the University of Calgary in Canada, the Max Planck Institute for Astronomy (MPIA) in Heidelberg and other research institutions have now been able to show that the supply comes from a much hotter component of the ISM, which usually envelops the entire Milky Way. The WIM has an average temperature of 10,000 degrees. High-energy radiation from hot stars causes the hydrogen gas of the WIM to be largely ionised. The results suggest that the WIM condenses in a narrow area near a spiral arm and gradually flows into it while cooling.



Segment of the THOR survey near the Sagittarius arm of the Milky Way. The crosses indicate the position of sources of polarised radio emission. Their sizes correspond to the magnitude of the Faraday rotation effect. The strongest signals were measured in a rather inconspicuous strip to the right of the bright objects in the middle of the image. The strong radio sources indicate the position of the spiral arm. Credit: J. Stil/University of Calgary/MPIA

The scientists discovered the dense WIM by measuring the so-called Faraday rotation, an effect named after the English physicist Michael Faraday. This involves changing the orientation of linearly polarised radio emissions when they pass through a plasma (ionised gas) traversed by a magnetic field. One speaks of polarised radiation when the electric field oscillates in only one plane. Ordinary light is not polarised. The magnitude of the change in polarisation also depends on the observed wavelength.

In the present study, recently published in *The Astrophysical Journal Letters*, astronomers were able to detect an unusually strong signal in a rather inconspicuous area of the Milky Way, which is located directly on the side of the Sagittarius arm of the Milky Way facing the Galactic

Centre. The spiral arm itself stands out in the imaging data due to strong radio emissions generated by embedded hot stars and supernova remnants. However, the astronomers found the strongest shift in polarisation outside this prominent zone. They conclude from this that the increased Faraday rotation does not originate within this active part of the spiral arm. Instead, it originates from condensed WIM, which, like the magnetic field, belongs to a less obvious component of the spiral arm.

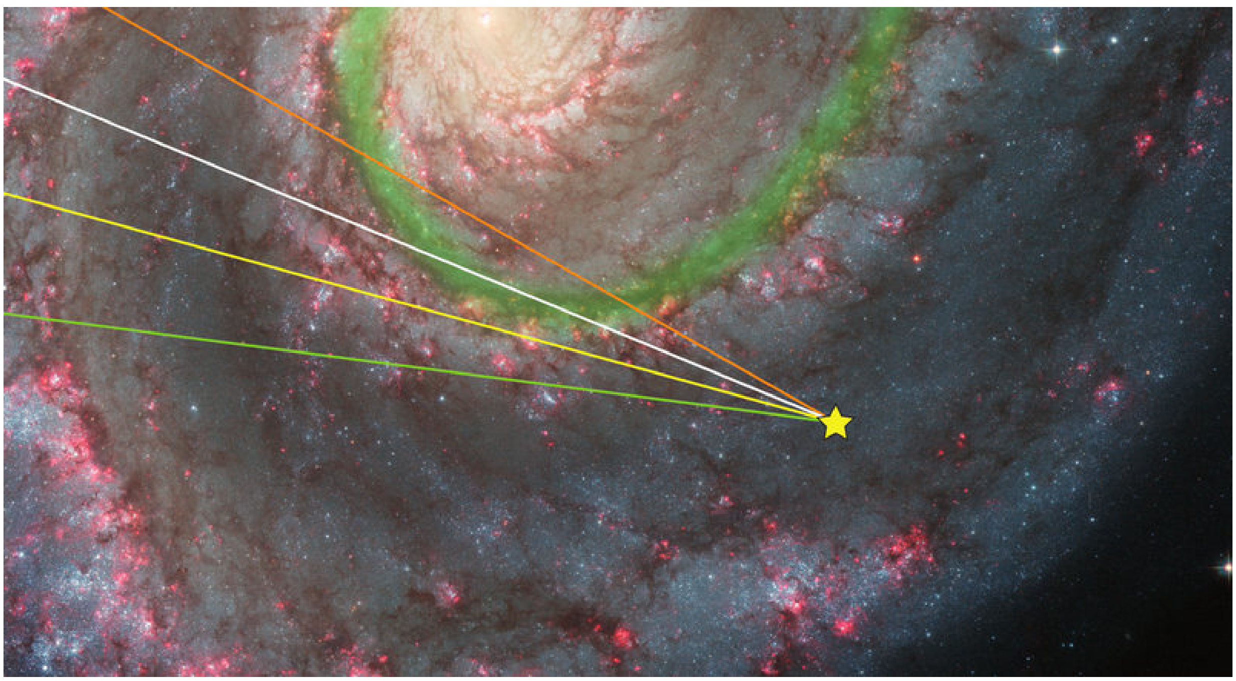


Illustration of selected lines of sight within the Milky Way, which roughly covers the area under investigation. The star indicates the location of the Earth. The green arc indicates the presumed location of the condensed Warm Interstellar Medium (WIM). The white line of sight that runs through this area along the longest distance corresponds to the position with the strongest effect of the Faraday rotation. The orange line of sight passes through the WIM on shorter distances and thus observes a weaker effect. The smallest contributions stem from the lines of sight outside (green) and inside the spiral arm (yellow). Credit: MPIA

The analysis is based on the THOR survey (The HI/OH Recombination Line Survey of the Milky Way), which has been conducted at MPIA for several years now and in which a large area of the Milky Way is observed at several radio wavelengths. Polarised radio sources such as distant quasars or neutron stars serve as "probes" for determining the Faraday rotation. This allows astronomers not only to detect the otherwise difficult to measure magnetic fields in the Milky Way, but also to study the structure and properties of the hot gas. "We were very surprised by the strong signal in a rather quiet area of the Milky Way," says Henrik Beuther from MPIA, who is leading the THOR project. "These results show us that there is still a lot to be discovered in studying the structure and dynamics of the Milky Way."

More information: R. Shanahan et al. Strong Excess Faraday Rotation on the Inside of the Sagittarius Spiral Arm, *The Astrophysical Journal* (2019). DOI: 10.3847/2041-8213/ab58d4

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