

The puzzle of the methanol maser rings - physical properties and molecular gas emission tracers

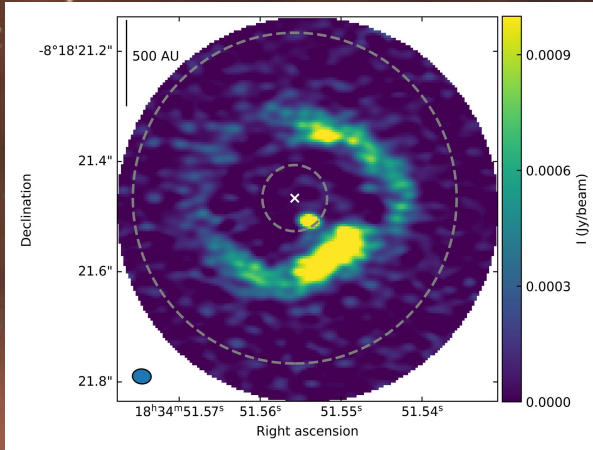
Agnieszka Kobak, co-authors: Katharina Immer, Anna Bartkiewicz



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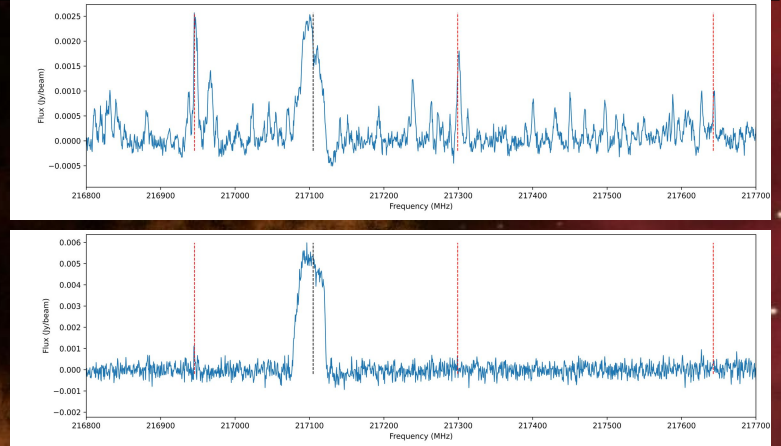
G23.657-0.127 was discovered as a 6.7 GHz methanol maser source in the Toruń survey (Szymczak et al. 2000). Later, interferometric observations with the European VLBI Network (EVN) revealed a nearly circular maser ring with a radius of 405 AU and a width of 95 AU at a distance of 3.19 kpc (Bartkiewicz et al. 2009). The ring morphology suggests a connection with the accretion disk, but the proper motion studies indicate expansion (Bartkiewicz et al. 2020). To resolve the dust and gas at similar spatial scales, we observed this source with the Atacama Large Millimeter/Submillimeter Array (ALMA). The continuum band 6 ALMA observations with a high angular resolution of 25 mas reveal a central continuum source and a ring-like structure (Kobak et al. in prep.). The spectral lines, e.g. CH₃OH, H₂CO, CH₃CN, also show a ring structure coincident with the continuum emission.

Band 6 continuum emission

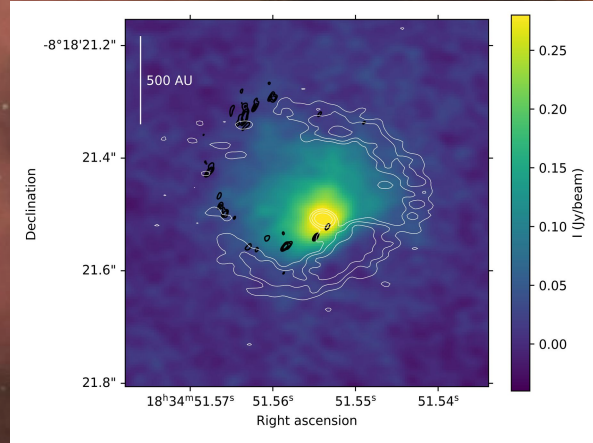


The outer edge of the ring is located at a distance of ~260 mas (830 AU) from the center (marked with a white cross). The ring has a width of 80 mas (255 AU). The point-like continuum source near the center of the ring is unresolved. A gaussian fit to the spatial distribution of the emission yields the size of the beam (19x28 mas, 60x90 AU).

The flux integrated over the circular areas (marked by grey dashed ellipses on the continuum image) covering the whole ring structure with a radius of 300 mas (top), and over the area covering only the point-like continuum source with a radius of 60 mas (bottom). Red lines show the three thermal methanol lines and black lines the SiO line.

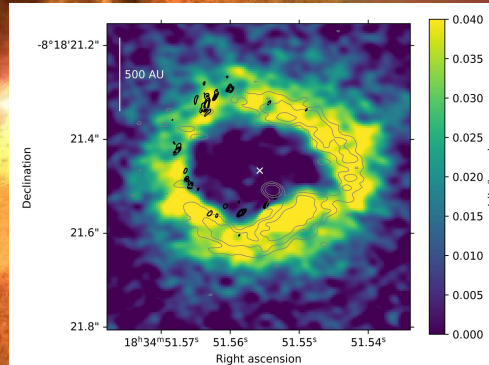
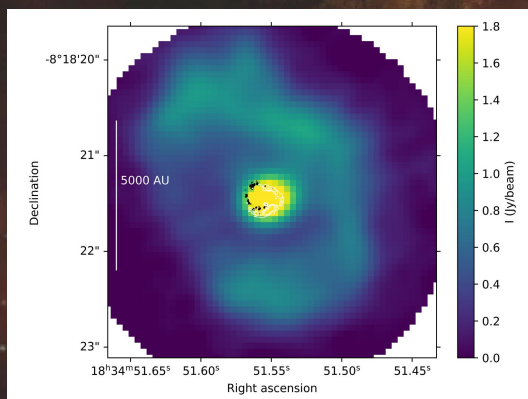


SiO emission - signs of inflow/outflow?



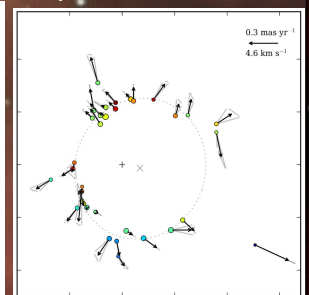
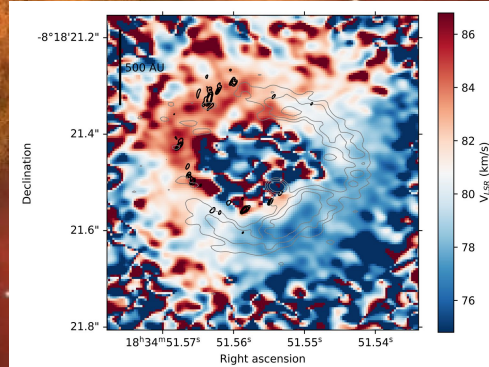
The moment zero map of the SiO line (217.1 GHz), with 6.7 GHz methanol maser emission (black contours), and continuum emission (white contours). The SiO emission coincides with the point-like continuum source.

Large-scale observations from the ALMAGAL survey (2019.1.00195.L) show SiO emission extending beyond the central ring.



Zero (left top) and first (left down) moments maps for thermal methanol emission (216.95 GHz) with emission of methanol maser line (6.7 GHz) overlaid with black contours, and continuum emission overlaid with grey contours.

Bottom: the same 6.7 GHz methanol maser emission marked as spots with proper motions, which suggest the expansion of the methanol maser ring (Bartkiewicz et al. 2020):



Six thermal methanol lines show the ring structure with an inner radius of around 60 mas (190 AU), and an outer radius between 270 mas (860 AU) and 450 mas (1435 AU), depending on the energy level of the line. The rotational temperature diagram shows T_{rot} equal 260 K and N_{tot} equal $1.6 \cdot 10^{26} \text{ cm}^{-2}$.

