UV irradiated outflows from low-mass protostars in Ophiuchus

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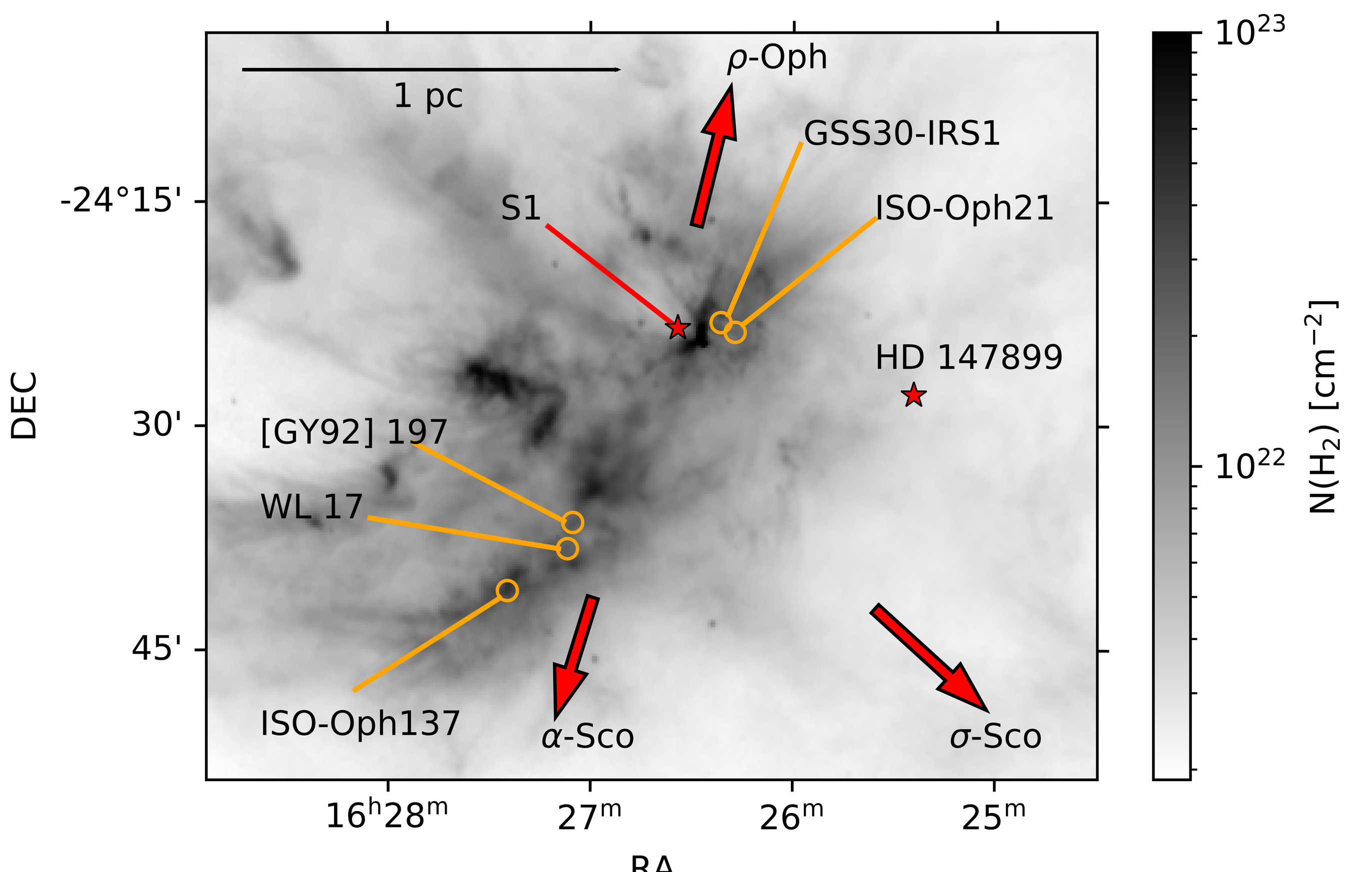
Abstract

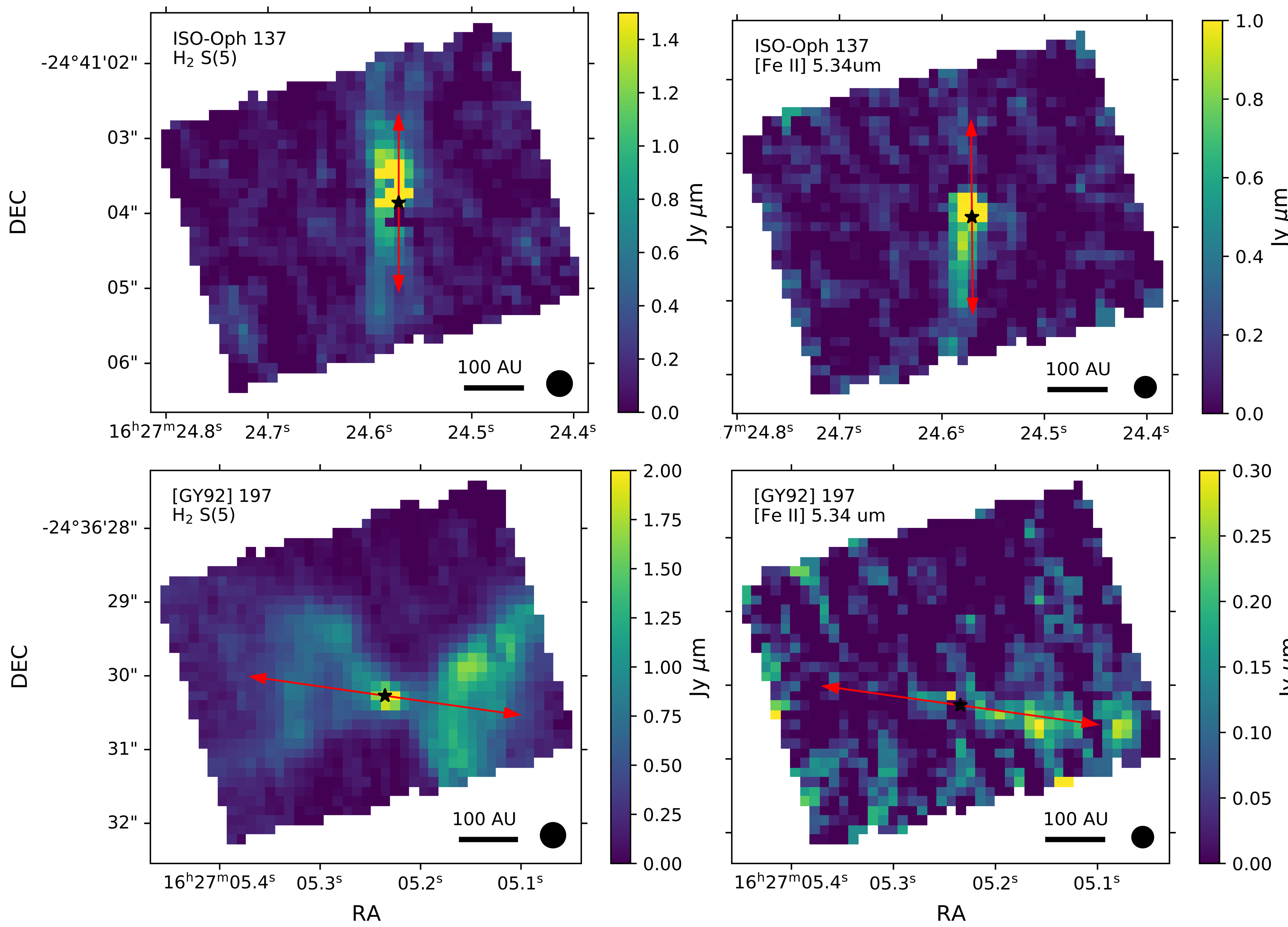
Outflows and jets form a key ingredient of the star formation process. These energetic processes remove excess angular momentum from the system, enabling accretion onto the central protostar. Despite the significance of protostellar outflows, it remains unclear how they are influenced by their environment. In particular, the external UV radiation field may affect the composition and properties of the protostellar jets and outflows therefore directly impacting the accretion process. Here, we present MIRI/MRS observations towards 5 Class I protostars in the Ophiuchus molecular cloud, with varying levels of UV irradiation from nearby stars. Thanks to the high resolution of JWST, we are now able to study the shock-excited molecular H2 component of the protostellar outflows of these sources in unprecedented detail, down to scales of a few hundreds AU. In addition, the multiple H2 transitions available in the MIRI range allow us to constrain the physical conditions and the shock properties of the outflow gas.



Parf of the Ophiuchus molecular cloud L1688, showcasing the target sources (orange) and the nearby notable high mass sources (red). Greyscale is H2 column density from Ladjelate et al. (2020).

Molecular Outflows

- Bipolar outflows detected in four out of five sources.
- Seen in most of the pure rotational transitions of H2 in the MIRI range (4.9 – 27.9 μm covering the S(1) – S(8) transitions).
- Two distinct morphologies seen:
  - Collimated (GSS30-IRS 1, ISO-Oph 137)
  - "Butterfly"-shaped ([GY92] 197, WL17)



Ionic jets

- Ionic jets detected in three out of five sources.
- Seen mainly in [Fe II] transition at 5.34 μm.
- Unipolar detection in most cases.

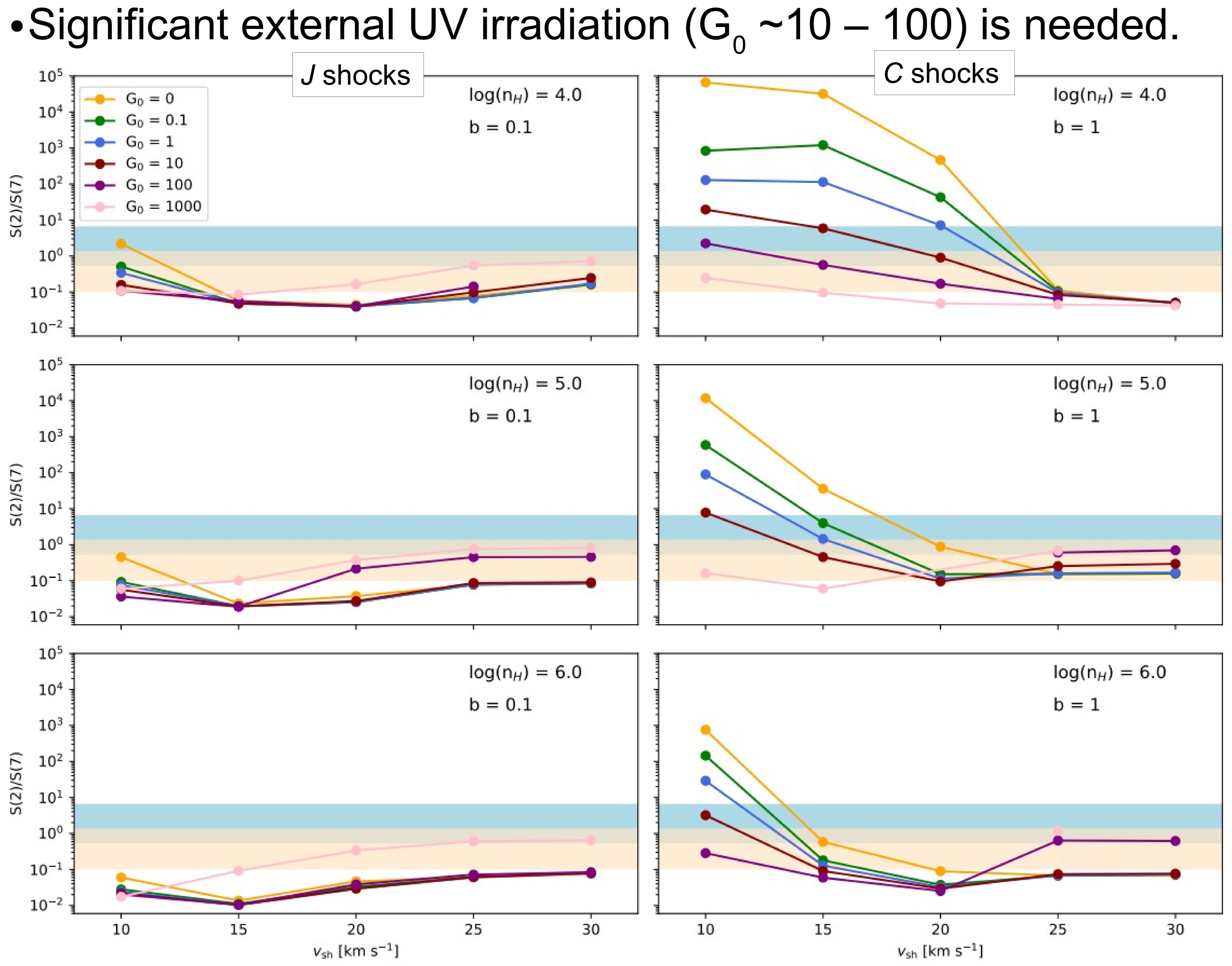
Notable ionic and atomic line detections:

- [Fe II] at 5.34, 17.9, and 25.9 μm
- [Ne II] at 12.8 μm
- [Ar II] at 6.98 μm
- [S I] at 25.2 μm

UV irradiated shock models

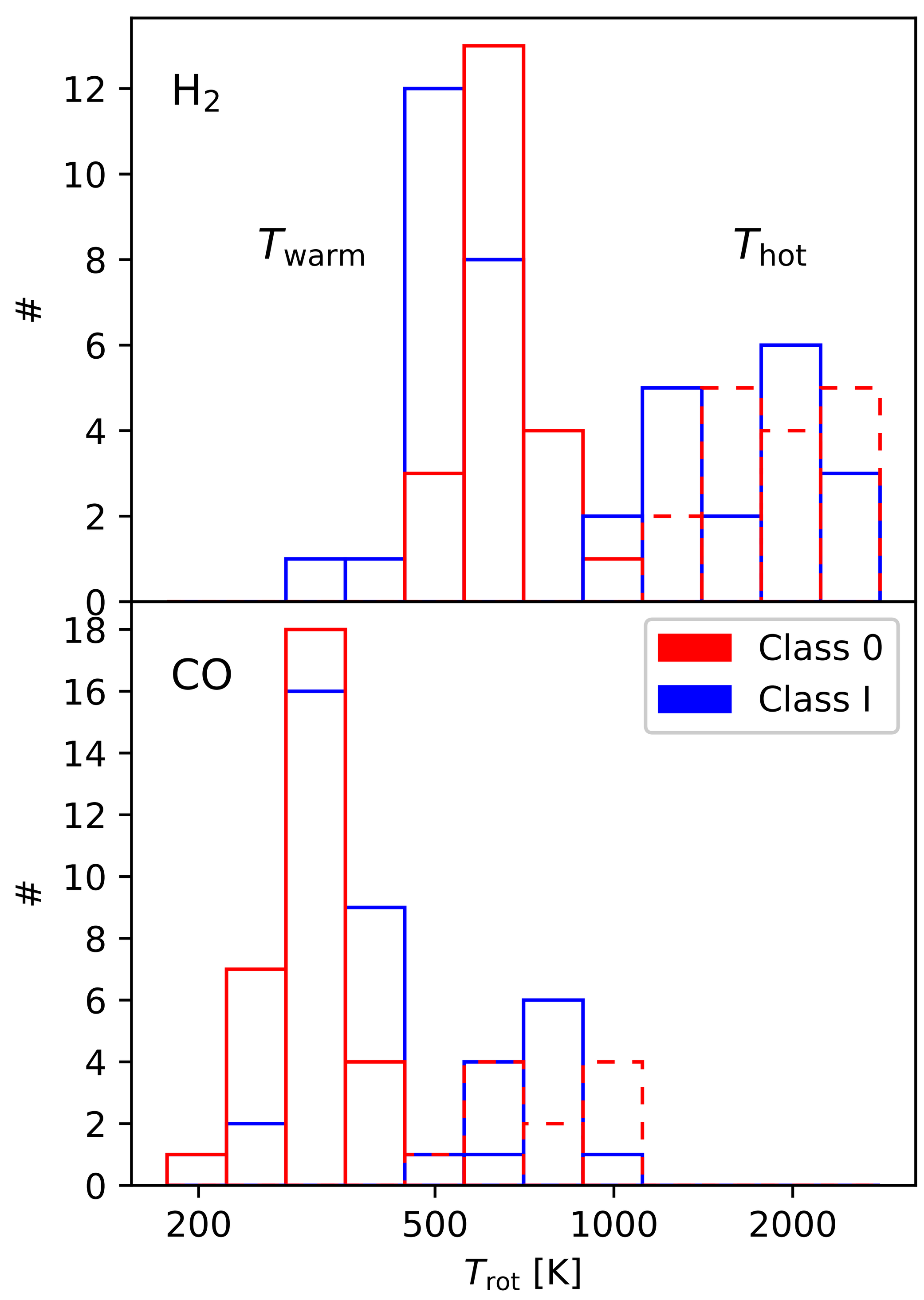
Comparison of the observed H2 S(2)/S(7) line ratio with UV-irradiated shock model predictions from Kristensen et al. (2023) showed that:

- C-type shocks better reproduce the observed line ratios compared to J-type shocks
- Significant external UV irradiation (G_0 ~10 – 100) is needed.



JWST vs Herschel

- Temperatures in outflows of Class I sources follow similar distribution with those of Class 0 sources.
- The hot component temperatures show high spread (1000 – 3000 K) compared to the warm component (500-600 K)
- Temperatures estimated using *Herschel* high-*J* CO observations follow similar trends to those from H_2 but have overall lower temperatures.



High-*J* CO likely traces different outflow component than H_2

References: Skretas et al. Subm., Francis et al. 2025 A&A, Volume 694, id.A174, Tychoniec et al. 2024 A&A, Volume 687, id.A36, Kristensen et al. 2023 A&A, Volume 675, id.A86, Karska et al. 2018 ApJS Volume 235, Issue 2, article id. 30