How fast and how many? A new wide field survey for HH objects in Orion and their proper motions

Thomas Stanke (tstanke049@gmail.com)
Max-Planck Institute for Extraterrestrial Physics, Garching, Germany
Helen Hoefer (TUM/MPE), Filip Milicevic (TUM/MPE), Roland Gredel (MPIA), Jochen Eislöffel (Tautenburg)

Context:

Star formation is accompanied by outflow activity.

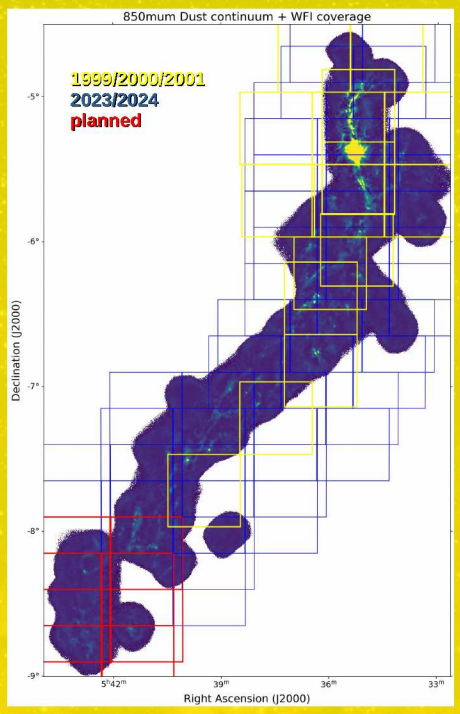
Outflows potentially provide a significant feedback mechanism, providing energy and momentum to the ambient medium to keep turbulence going.

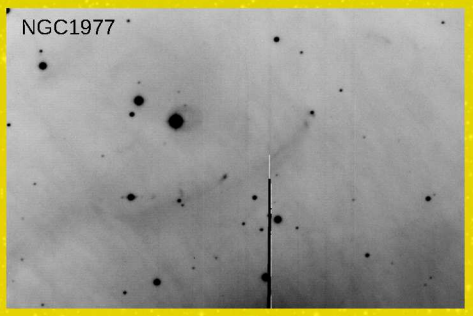
Wide field, unbiased surveys are required to quantify how much energy/momentum a protostar population generates, and how much of it might get lost by outflows leaving the cloud.

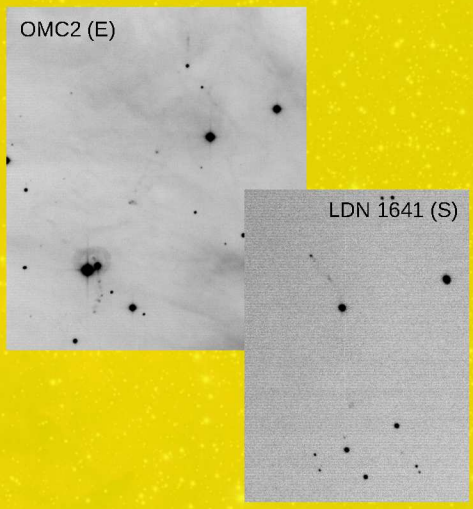
Knots in jets and major shock systems are frequently attributed to accretion variability!

The WFI HH object survey:

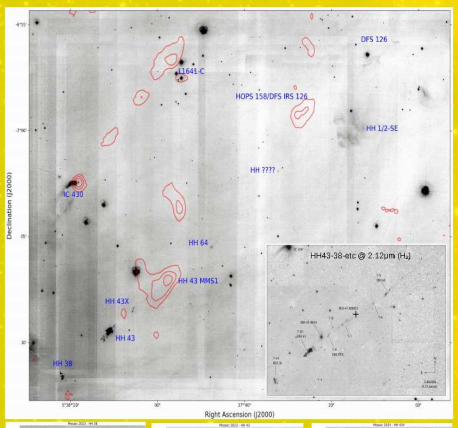
- Telescope/Instrument: (ESO/)MPG 2.2m on La Silla/Wide Field Imager (WFI)
- Hα and [SII] narrow band filters (~45min integration time), Rc broad band (continuum)
- Coverage: ~1.5 square degrees in ~2000, ~6 square degrees in 2023/24
- Goal: complete census of HH objects (shocks in outflows) over full cloud, including its "outskirts"; **proper motions with ~23 years temporal baseline**

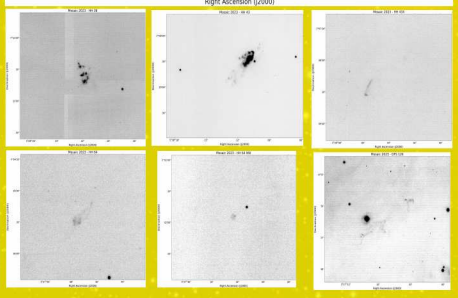






New HH flows (small selection… processing in progress...)



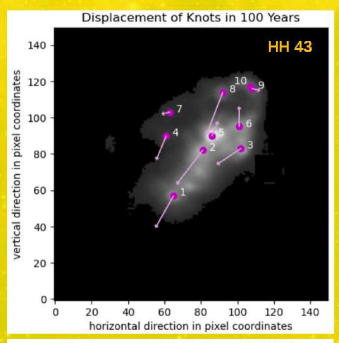


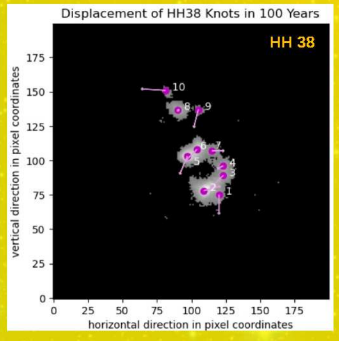
The HH43/38 giant outflow (Stanke et al. 2000, Eislöffel & Mundt 1997), driven by the Class 0 protostar HH43MMS1. The flow from HH38 to HH64 was revealed by NIR H_2 imaging (Stanke et al. 2000, insert). A faint knot NW of HH64 may form another part of the flow. The DFS126 (DFS2009) H_2 shock is found to be more extensive in our data. It may be driven by [DFS] IRS126 or form yet another part of the HH43/38 outflow. HH1/2SE is part of HH1-2 (Ogura 1995).

Conclusion:

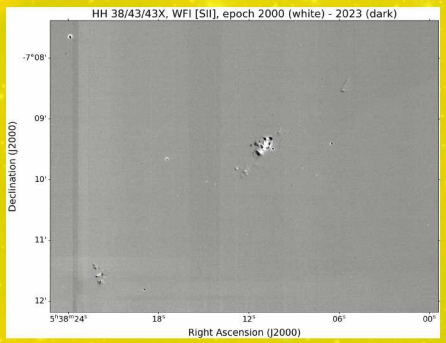
We find new HH objects (processing ongoing…)

We confirm previous findings that HH43 (and possibly HH38) are major shocks created by a flow hitting an obstacle, rather than being internal working surfaces created by major (e.g., FUOri) outburst events. Not all (internal) protostellar outflow shocks may be due to outflow → accretion variability!





Tangential proper motions measured for HH43 (top) and HH38 (bottom). The pixel scale is 0.24"/pixel. Arrows mark the motion extrapolated to 100 years (H. Hoefer, Bsc thesis, 2024).



[SII] difference image between the epoch 2000 and the epoch 2023 images. Displacements between epochs show as pairs of dark/bright features.

Proper motions in HH43/38:

- Epochs: 2000, 2023
- Difference image: systematic motions of HH43/38/43X towards the south-east, away from the driving source HH43MMS1 (Stanke et al. 2000).
- cross correlation technique to determine shifts with sub-pixel accuracy (cf. Davis et al. 2009).
- Proper motions up to 150km/s (HH43) and 80km/s(HH38) towards SE.
- Bimodal behaviour: some knots are consistent with *no motion*. In particular, knots #10/11 (HH43A) and knot #5 (HH43C) seem stationary (also: HH38 #4,7).

Böhm & Solf (1990) conclude, based on spatially resolved IR echelle spectroscopy, that knots HH43A and HH43C mark locations where the outflow is 'stopped' by a dense obstacle (cf. Schwartz et al. 1985).

References:
Böhm, K. H.; Solf, J. 1990, ApJ 348, 297
Davis, C. J., et al. 2009, A&A 496, 153 (**DFS2009**)
Eislöffel, J.; Mundt, R. 1997, AJ 114, 280
Ogura, K. 1995, ApJL 450, L23
Schwartz, R. D., et al. 1985, AJ 90, 1820
Stanke, Th., et al. 2000, A&A 355, 639