Origins: From the Protosun to the First Steps of Life
Proceedings IAU Symposium No. 345, 2018
B. G. Elmegreen, L. Viktor Tóth & M. Güdel, eds.

doi:10.1017/S1743921319001613

Envelope-to-disk mass transport in the FUor-type young eruptive star V346 Normae

Á. Kóspál[1,2], P. Ábrahám[1], O. Fehér[1], F. Cruz-Sáenz de Miera[1] and M. Takami[3]

[1]Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Konkoly-Thege Miklós út 15-17, H-1121, Budapest, Hungary
email: kospal@konkoly.hu

[2]Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany

[3]Institute of Astronomy and Astrophysics, Academia Sinica, PO Box 23-141, 106, Taipei, Taiwan

Abstract. Having disk-to-star accretion rates on the order of $10^{-4}\,M_{\odot}$/yr, FU Orionis-type stars (FUors) are thought to be the visible examples for episodic accretion. FUors are often surrounded by massive envelopes, which replenish the disk material and enable the disk to produce accretion outbursts. We observed the FUor-type star V346 Nor with ALMA at 1.3 mm continuum and in different CO rotational lines. We mapped the density and velocity structure of its envelope and analyzed the results using channel maps, position-velocity diagrams, and spectro-astrometric methods. We discovered a pseudo-disk and a Keplerian disk around a $0.1\,M_{\odot}$ central star. We determined an infall rate from the envelope onto the disk of $6{\times}10^{-6}\,M_{\odot}$/yr, a factor of few higher than the quiescent accretion rate from the disk onto the star. This hints for a mismatch between the infall and accretion rates as the cause of the eruption.

Keywords. stars: pre–main-sequence, accretion disks, circumstellar matter

---

A long-standing open issue of the paradigm of low-mass star formation is that most protostars are less luminous than theoretically predicted. One possible solution is that the accretion process is episodic. The young outbursting FU Ori-type stars (FUors) are thought to be the visible examples for objects in the high accretion state. Mass infall from FUor envelopes may play a fundamental role in refilling the disk, and triggering instabilities causing accretion outbursts. However, our knowledge on the envelope dynamics and on the envelope-to-disk mass transfer is still very limited.

V346 Nor is an embedded FUor in the Sandqvist 187 dark cloud, at a distance of 700 pc. It erupted between 1976 and 1980, stayed in the bright state until 2008, rapidly faded in 2010, and is now showing a partial re-brightening. We modeled the multi-epoch optical-infrared spectral energy distributions and found a peak accretion rate of $10^{-4}\,M_{\odot}$/yr in 1992, and a drop of accretion by at least a factor of 100 in 2010, suggesting that the quiescent accretion rate is less than about $10^{-7} - 10^{-6}\,M_{\odot}$/yr (Kóspál *et al.* 2017a).

We observed V346 Nor with ALMA in the J = 2–1 line of ^{12}CO, ^{13}CO, C^{18}O, and 1.32 mm continuum in one single setting in Band 6. We used a combination of 12 m array configurations, as well as data from the 7 m array and Total Power antennas. We had two runs: in 2014–15 the beam size was 1.″0 with a continuum sensitivity of 70 μJy/beam, while in 2017–18 the beam size was 0.″1 with a continuum sensitivity of 35 μJy/beam.

We detected a fairly compact continuum source coinciding with the near-infrared stellar location (Fig. 1). The source is marginally resolved, with a deconvolved FWHM of 0.″21×0.″15. We interpret this as an inclined disk-like object, with a radius of 50 au. The position angle is NW-SE, same as the CO rotating disk. The central source is surrounded

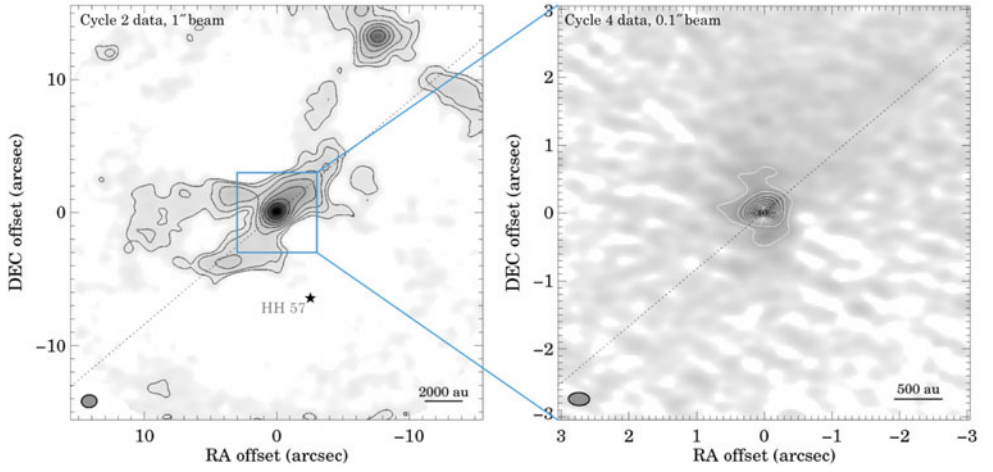

Figure 1. ALMA 1.32 mm continuum map of V346 Nor (left panel from Kóspál *et al.* 2017b).

by more extended, fainter emission out to 6300 au. The dust mass in the compact source within 50 au is $3\times10^{-4}\,M_{\odot}$.

Results from our spectro-astrometric analysis of the $C^{18}O$ data cube indicates that from 350 to 700 au, the radial velocity profile is consistent with a pseudo-disk (infalling-rotating motion with angular momentum conservation). The inner 350 au resembles a Keplerian disk around a $0.1\,M_{\odot}$ central star. The total gas mass within 350/700 au is $0.01/0.03\,M_{\odot}$.

Both the ^{12}CO and ^{13}CO profiles exhibit high-velocity line wings. The redshifted emission shows a parabola opening towards the northeast with a relatively wide opening angle of about 80°. The blueshifted emission forms a narrower ellipse extending towards the southwest with an opening angle of about 40°. The geometry is reminiscent of an outflow cavity, where emission is coming from the swept-up material in the cavity walls. The Herbig-Haro object HH 57 is situated along the axis of the southwestern CO-emitting ellipse, close to its farther edge.

We calculated the infall rate using an analytic formula from Momose *et al.* (1998). The resulting infall rate from the envelope onto the disk is $6\times10^{-6}\,M_{\odot}$/yr, which is a factor of few higher than the quiescent accretion rate from the disk onto the star. It is a hint for a mismatch between the infall and accretion rates. This is the first observational support for such mismatch in a FUor, previously invoked to explain FUor outbursts.

Acknowledgements

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme under grant agreement No 716155 (SACCRED, PI: Á. Kóspál). This paper makes use of the following ALMA data: ADS/JAO.ALMA#2013.1.00870.S, ADS/JAO.ALMA#2016.1.00209.S. ALMA is a partnership of ESO (representing its member states), NSF (USA) and NINS (Japan), together with NRC (Canada) and NSC and ASIAA (Taiwan) and KASI (Republic of Korea), in cooperation with the Republic of Chile. The Joint ALMA Observatory is operated by ESO, AUI/NRAO and NAOJ.

References

Momose, M., Nagayoshi, O., Ryohei, K., *et al.* 1998, *ApJ*, 504, 314
Kóspál, Á., Ábrahám, P., Westhues, Ch. & Haas, M. 2017a, *A&A*, 597, L10
Kóspál, Á., Ábrahám, P., Csengeri, T. *et al.* 2017b, *ApJ*, 843, 45

https://doi.org/10.1017/S1743921319001613 Published online by Cambridge University Press