ALMA observations of the FU Orionis-type young eruptive star V346 Nor

Á. Kóspál[1,2], P. Ábrahám[1], M. R. Hogerheijde[3], M. M. Dunham[4], E. Vorobyov[5], Th. Henning[2]

[1]Konkoly Observatory, Hungary [2]Max Planck Institute for Astronomy, Germany [3]Leiden Observatory, The Netherlands [4]Harvard-Smithsonian Center for Astrophysics, USA [5]University of Vienna, Austria

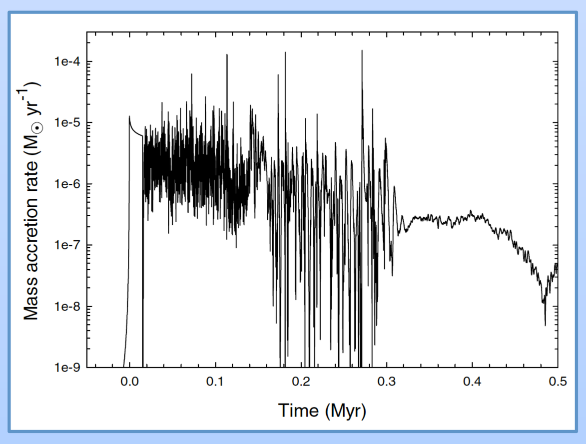
Abstract

A long-standing problem of the general paradigm of low-mass star formation is the "luminosity problem": protostars are less luminous than theoretically predicted. A possible solution is that the accretion process is episodic. FUOri-type stars (FUors) are thought to be the visible examples for objects in the high accretion state. FUors are often surrounded by massive envelopes, enabling the disk to produce accretion outbursts and replenish the disk material. However, we have no information on the envelope dynamics, about where and how mass transfer from the envelope to the disk happens. Here we present new ALMA continuum and CO line observations of the envelope around the FUor-type star V346 Nor. The observations will be analyzed using our modeling environment including a combination of hydrodynamical simulations and radiative transfer, which can model both the infall process and the disk accretion. It will enable us to measure the infall rate in the envelopes and calculate how often the object can produce repetitive outbursts. The results will help us to decide whether FUor-type eruptions can really be the solution to the luminosity problem.

Episodic accretion

- According to the general paradigm, Sun-like stars form when dense cores in the interstellar matter gravitationally collapse. Nascent stars are surrounded by circumstellar disks, from which material is accreted onto the growing star. Initially, the system is embedded in an envelope, the remnant of the initial core, which feeds material to the disk.
- A long-standing problem with this paradigm is the luminosity problem: theoretical models for the collapse of cloud cores predict infall rates on the order of 10^{-6} $M_\odot$/yr, which imply luminosities typically 10 – 100 times higher than what is observed for embedded protostars (e.g. Dunham et al. 2013).
- One way to overcome this conundrum is to assume that the accretion rate is not constant in time, but episodic: the protostar normally accretes at a very low rate, and this quiescent accretion is occasionally interspersed by brief episodes of highly enhanced accretion (Kenyon et al. 1990).

Time evolution of the mass accretion rate onto the star. Example result of our radiative transfer and hydrodynamical simulations that predict short-term variability and episodic bursts (Dunham & Vorobyov 2012).

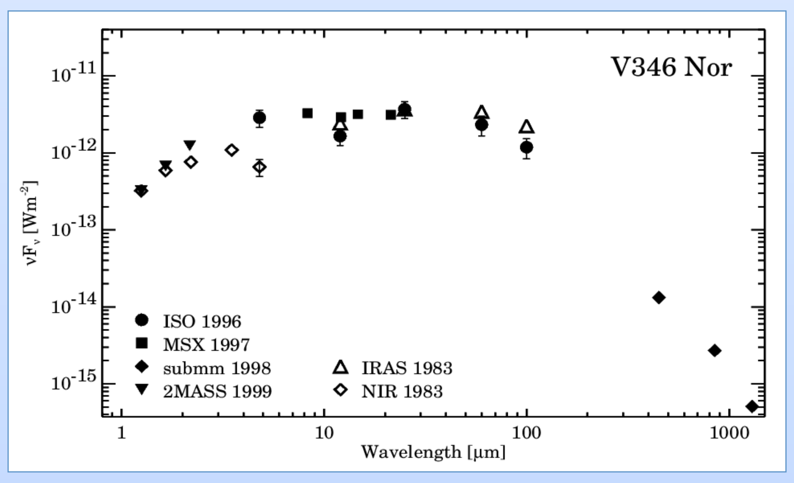


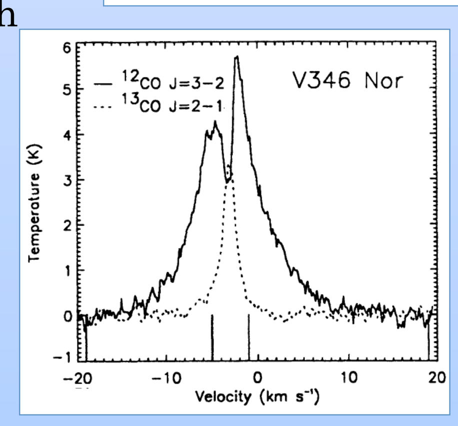
FU Orionis-type stars

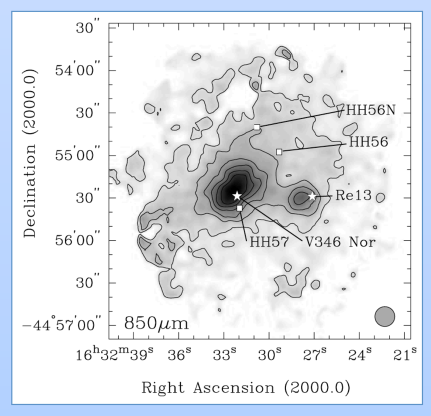
- FU Orionis-type stars (FUors) are the visible examples of episodic accretion.
- They exhibit 5 – 6 mag optical outbursts attributed to enhanced accretion (Hartmann & Kenyon 1996).
- During outburst, the accretion rate from the circumstellar disk onto the star may rise up to 10^{-5} – 10^{-4} $M_\odot$/yr, three orders of magnitude higher than in quiescence.
- Possible physical mechanisms of the outburst:
  - Viscous-thermal instability (Bell & Lin 1994)
  - Gravitational + magneto-rotational instability (Armitage et al. 2001)
  - Perturbation by a close stellar or sub-stellar companion (Lodato & Clarke 2004; Bonnell & Bastien 1992)
  - Accretion of clumps in a gravitationally fragmenting disk (Vorobyov & Basu 2006, 2010)
- Envelopes play a significant role in the outburst of FUors, partly by replenishing the disk material after each outburst and driving the disk to fragment (Vorobyov & Basu 2010), partly by maintaining disk accretion rates that trigger eruptions (Bell & Lin 1994).
- A fundamental parameter is the mass infall rate from the envelope onto the disk, which regulates all these processes and determines the frequency of the bursts (Vorobyov et al. 2013).

Our target: V346 Nor

- The FUor-type star V346 Nor is ideal target to study the envelope
- It is relatively isolated, so we can avoid strong CO emission from the surrounding star forming region
- At d = 700 pc it is not too distant, so we can well resolve the envelope with the 12m ALMA array
- Its SED indicates a massive envelope with 0.5 – 1 $M_\odot$, (Sandell & Weintraub 2001, Ábrahám et al. 2004)
- It is bright in the mm continuum
- CO line emission has already been detected towards this source using single-dish data from CSO (Evans et al. 1994)







ALMA Observations

- J = 2 – 1 line of ^{12}CO, ^{13}CO, and $C^{18}O$, 1.3 mm continuum in one single setting in B6
- Cycle 2
- 12 m array observations – done (2 hours on-source correlation time)
- ACA (Morita array) – done (5 hours on-source correlation time)
- Total Power Antennas – waiting for delivery (13.6 hours on-source correlation time)
- Baselines: 14 – 325 m
- Continuum rms: 0.045 mJy
- Line rms: 8 mJy in 0.04 km/s channels

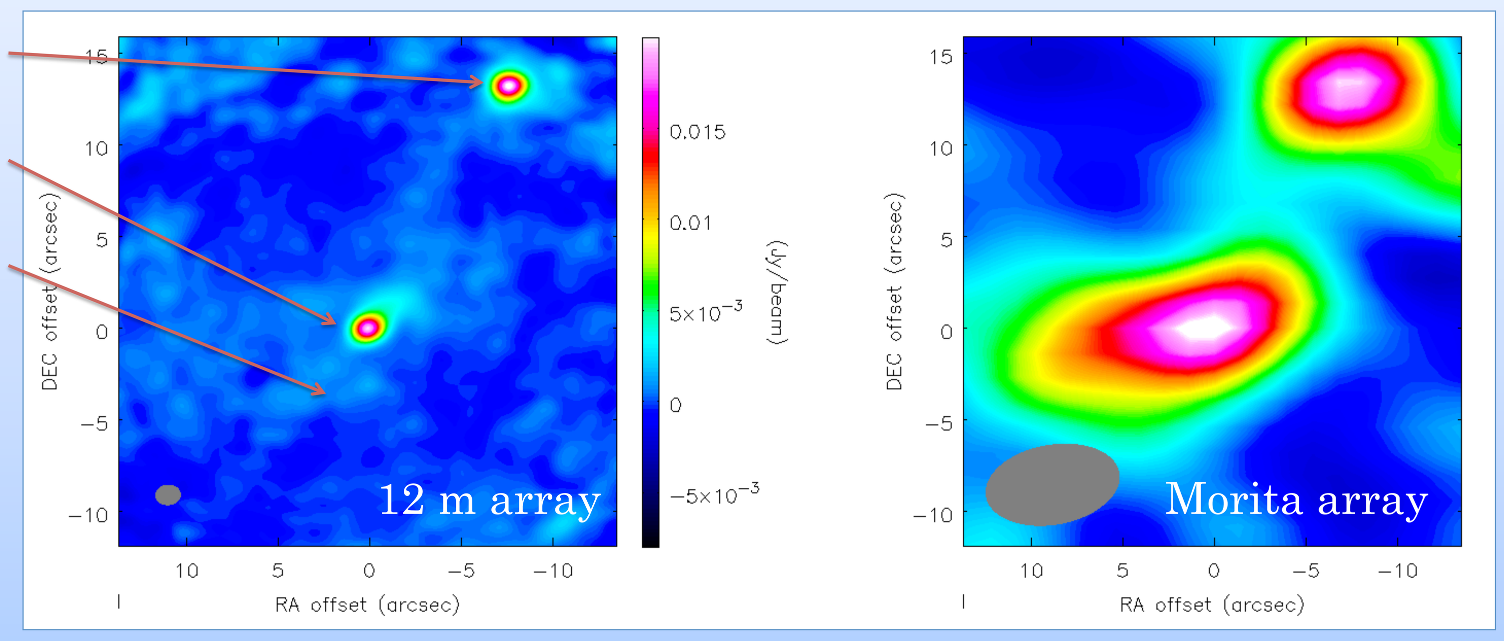
Results: 1.3 mm continuum

Unknown millimeter source

V346 Nor

Faint extended emission

- Total flux in the map: 216 mJy (consistent with earlier data)
- Flux of V346 Nor: 22.8 ± 0.5 mJy

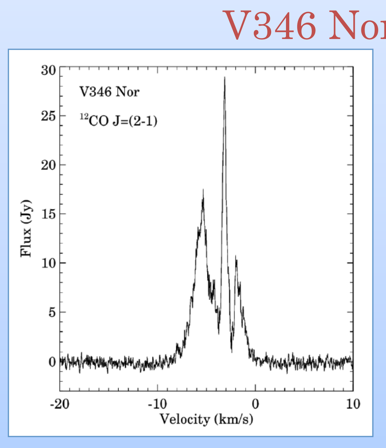


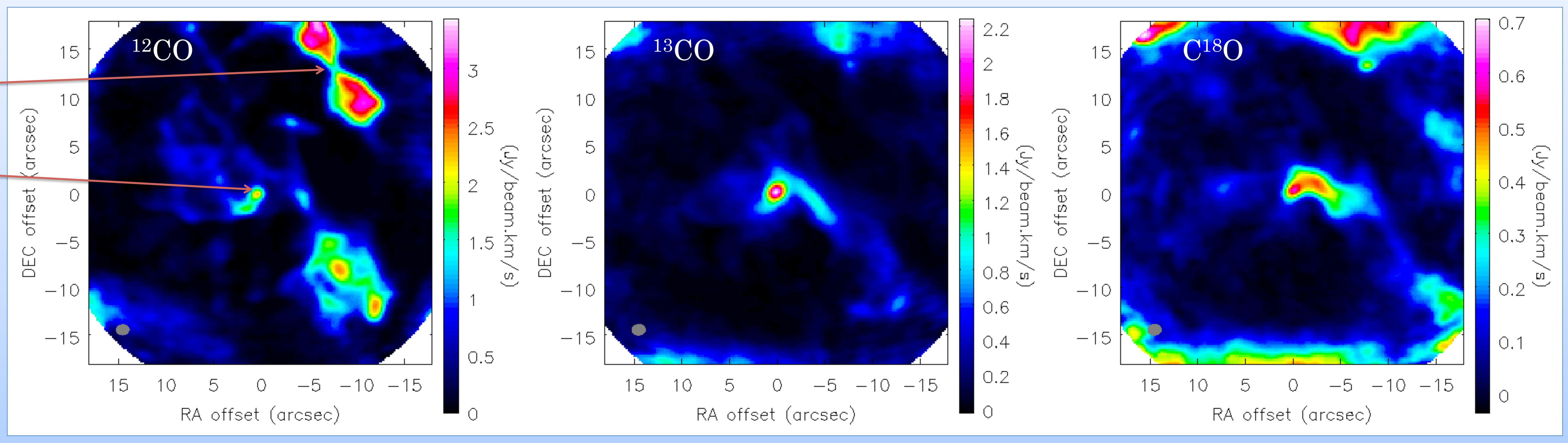
Results: CO lines

- Strong lines
- Complex structure
- Broad lines
- Missing short spacings
- Careful continuum subtraction needed

Bipolar outflow around unknown millimeter source

V346 Nor





References

- Armitage et al. (2001), **MNRAS 324**, 705
- Bell & Lin (1994), **ApJ 427**, 987
- Bonnell & Bastien (1992), **ApJ 401**, 31
- Dunham et al. (2013), **AJ 145**, 94
- Dunham & Vorobyov (2012), **ApJ 747**, 52
- Green et al. (2013), **ApJ 772**, 117
- Hartmann & Kenyon (1996), **ARA&A 34**, 207
- Kenyon et al. (1990), **AJ 99**, 869
- Kolotilov & Kenyon (1997), **IBVS 4494**, 1
- Lodato & Clarke (2004), **MNRAS 353**, 841
- Momose et al. (1998), **ApJ 504**, 314
- Vorobyov et al. (2013), **MNRAS 433**, 3256
- Vorobyov & Basu (2010), **ApJ 719**, 1896
- Vorobyov & Basu (2006), **ApJ 650**, 956
- Zhu et al. (2009), **ApJ 694**, 1045

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Contact: Ágnes Kóspál

Konkoly Observatory
Konkoly Thege Miklós út 15-17
1121 Budapest, Hungary

Phone: +36 1 3919338
E-mail: kospal@konkoly.hu
http://konkoly.hu/staff/kospal