An overview about masers in high-mass star-forming regions, a need for high quality counterpart data

Anna Bartkiewicz, Jochen Eislöffel, Bringfried Stecklum, Verena Wolf, Marian Szymczak, Paweł Wolak, Michał Durjasz, Agnieszka Kobak

NICOLAUS COPERNICUS UNIVERSITY IN TORUŃ
Faculty of Physics, Astronomy and Informatics

Email: annan@astro.umk.pl

Masers are amazing!

TLS

Cosmic masers

→ Masers appear naturally in the space.

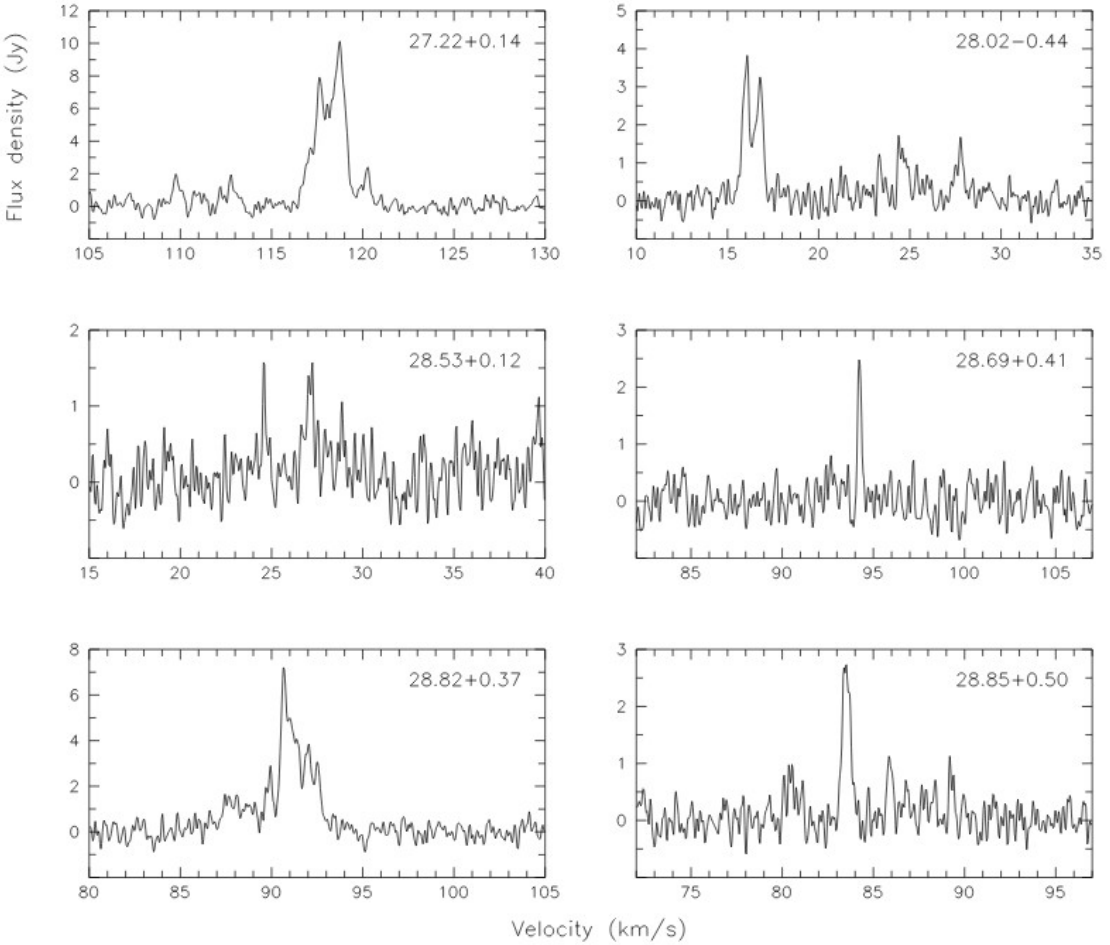
→ Maser emission from OH, H_2O, CH_3OH, SiO appears in regions close to **newly born high-mass** and **low-mass stars,** and **evolved stars**.

→ **The 6.668518 GHz (in short 6.7 GHz or 4.5 cm) methanol maser transition is exclusively related to High-Mass Young Stellar Objects (HMYSOs).**

Toruń spectral line observations

- Since more than 20 years we have been observing HMYSOs at the 6.7 GHz methanol maser transition.

Szymczak et al. (2000,2002,2018) (blind survey of the 6.7 GHz methanol masers line)



JIVE
Joint Institute for VLBI ERIC

EUROPEAN VLBI NETWORK

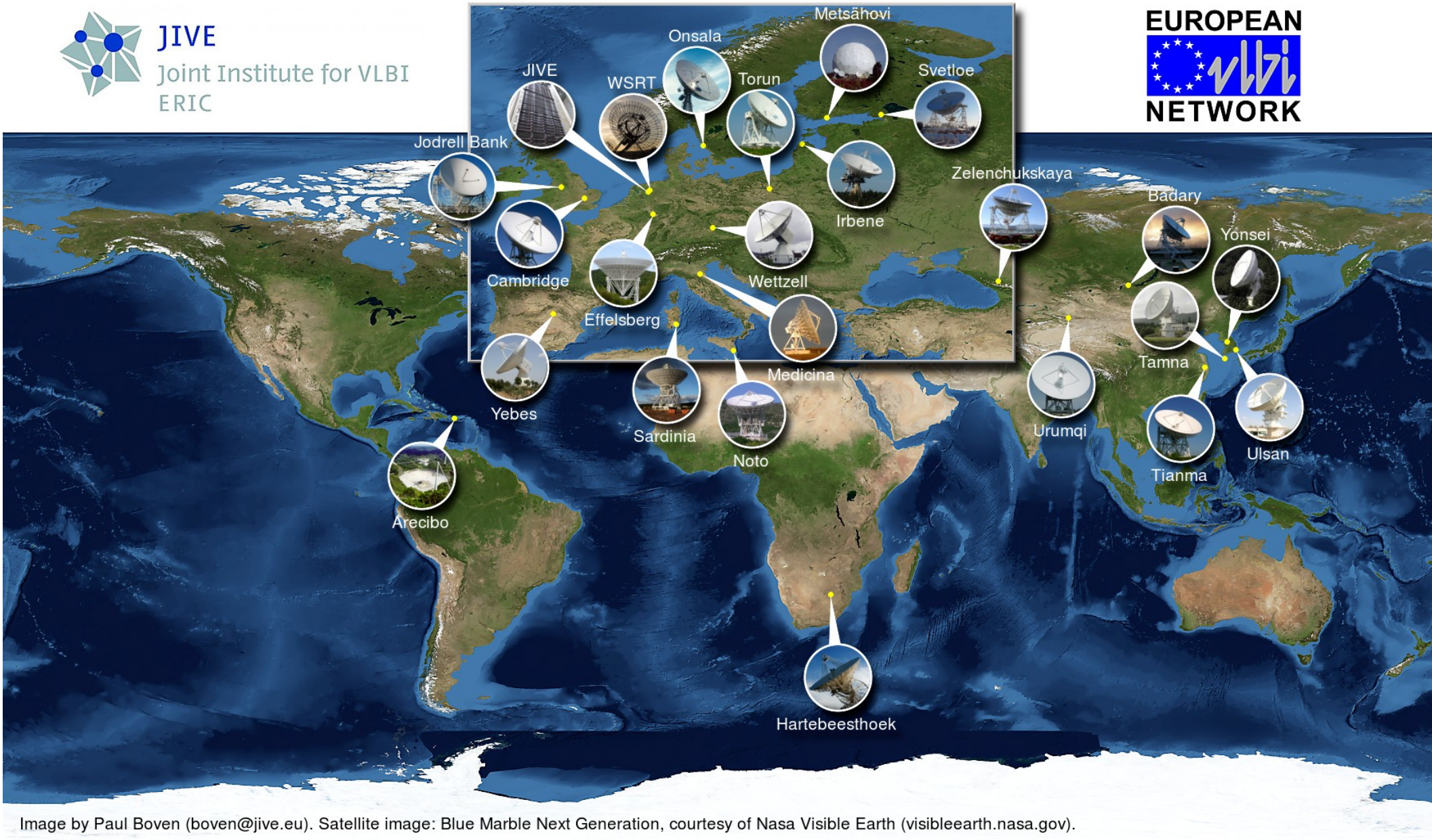
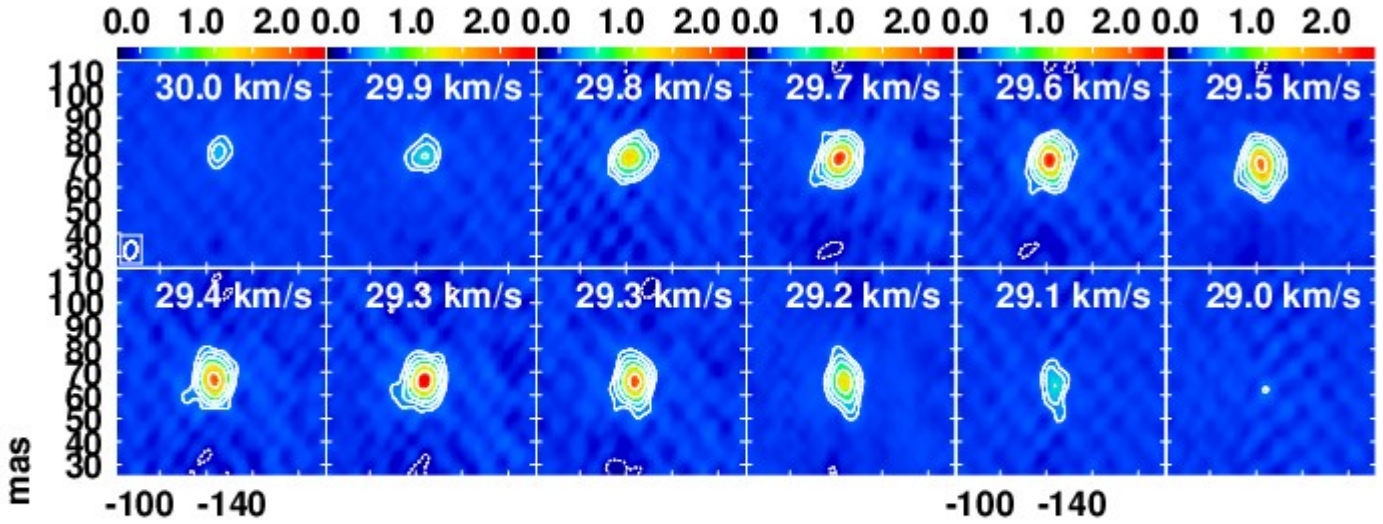


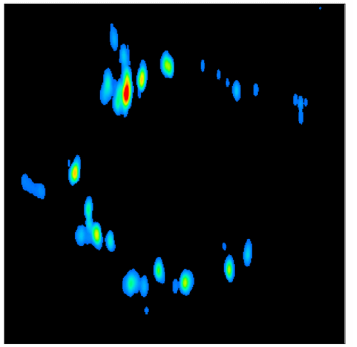
Image by Paul Boven (boven@jive.eu). Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

Using radio interferometers we image the masing clouds

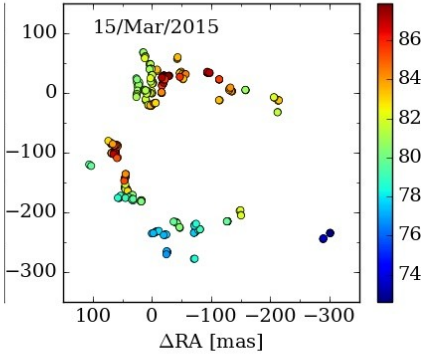
E.g. **6.7 GHz methanol maser** observations:
90 m/s resolution and beamsize ca. 6 mas x 8 mas.

Masers are compact and bright – good tracers of gas kinematics.

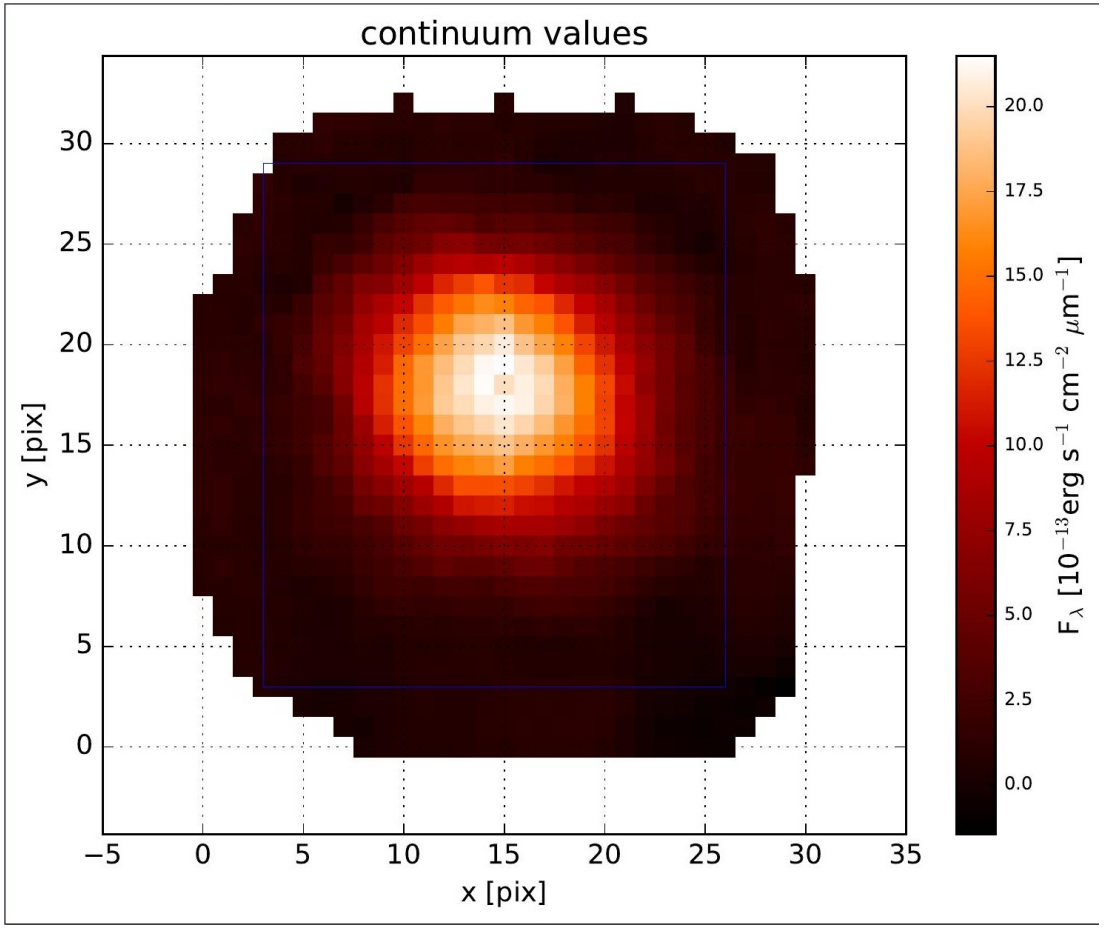




Bartkiewicz et al. 2020



Thüringer Landessternwarte Tautenburg



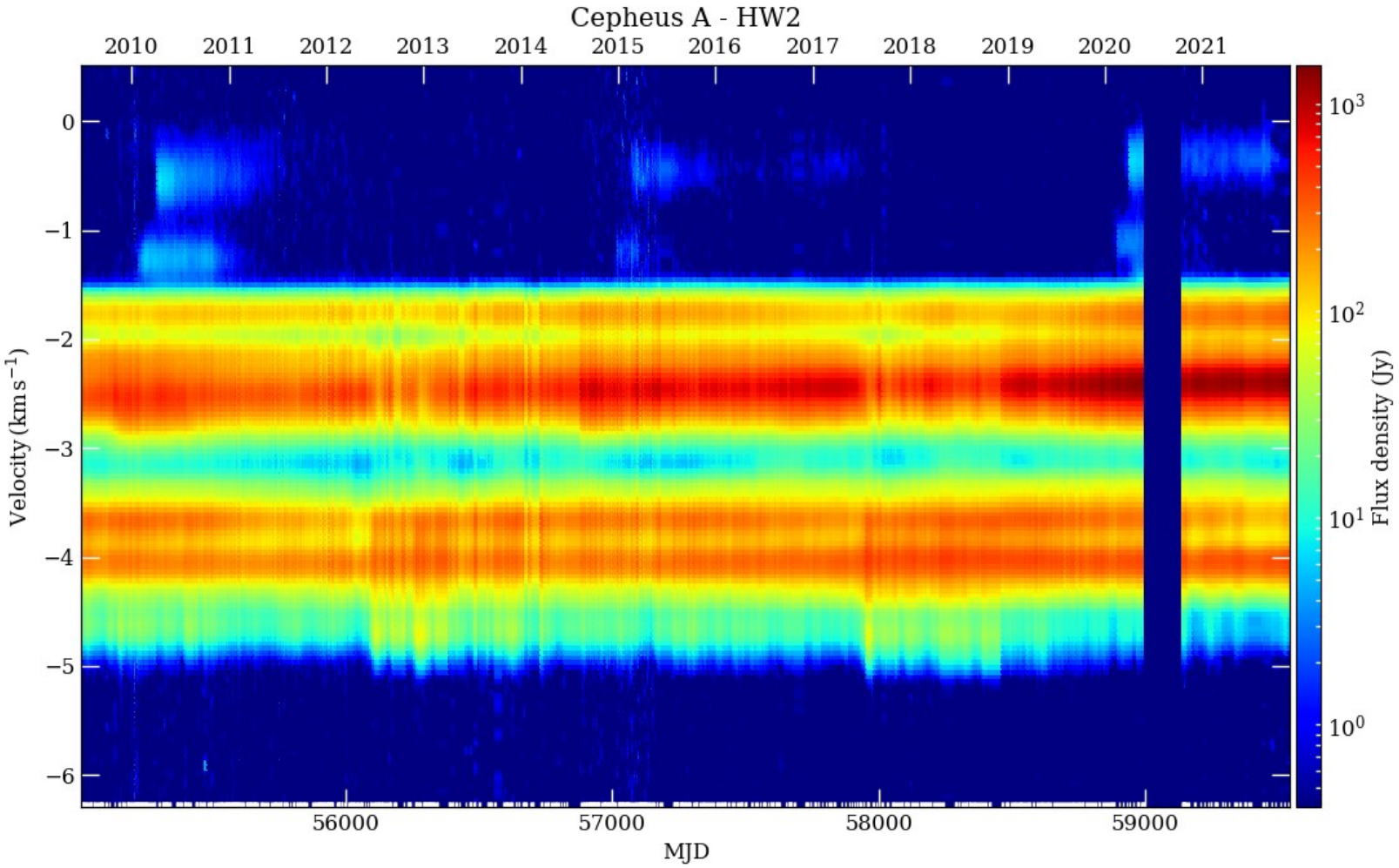
1 px = 1“

Methanol masers at 6.7 GHz are radiatively excited which is the underlying cause for the radio-IR connection.

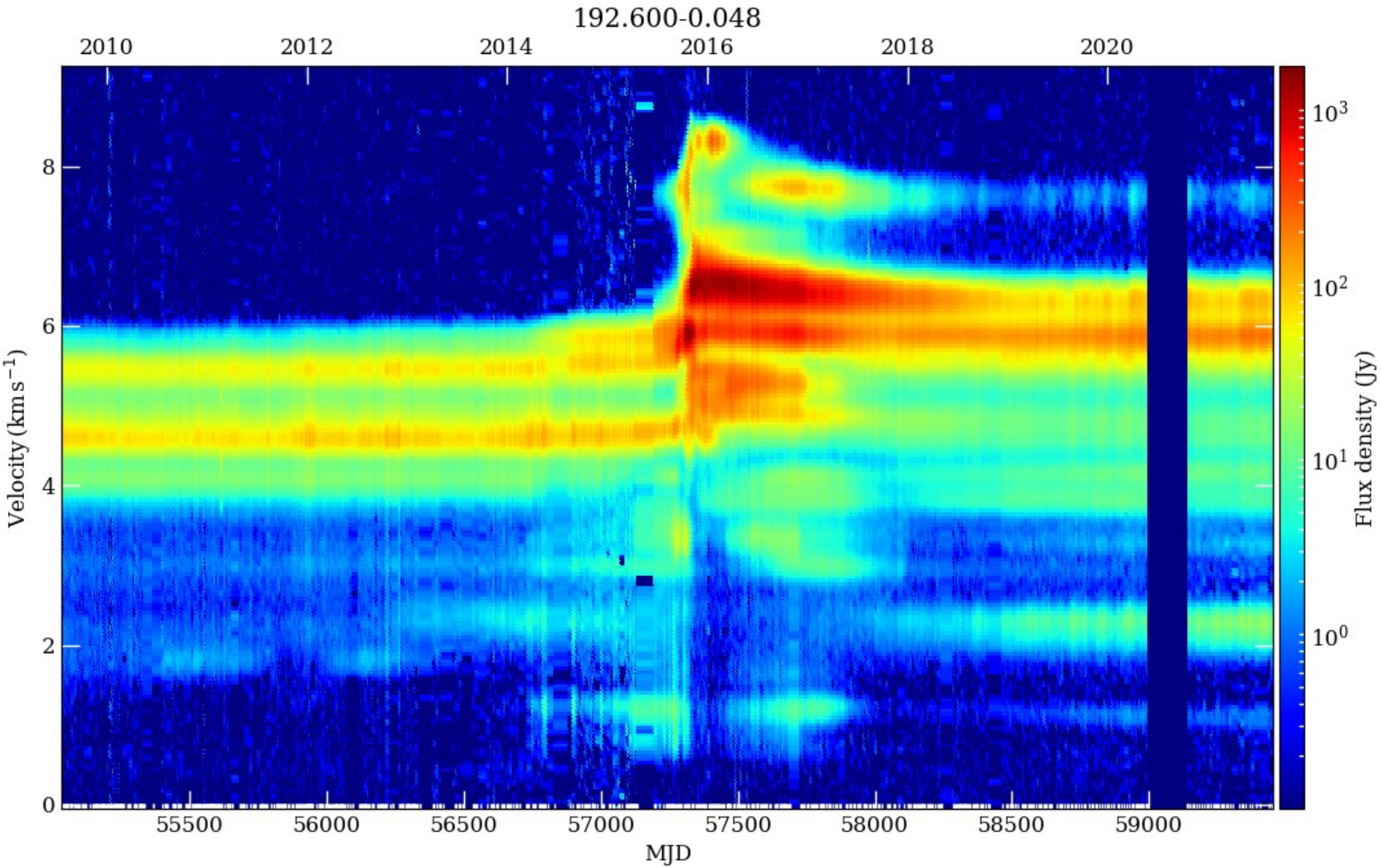
G107.298+5.639 at 63 µm obtained using SOFIA on 2019 (PIs: **Jochen Eislöffel, Bringfried Stecklum**)

Periodic maser sources – PhD starting next year.

Monitoring of maser emission



Monitoring of maser emission



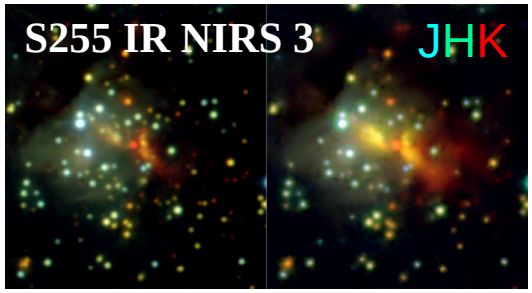
Episodic bursts

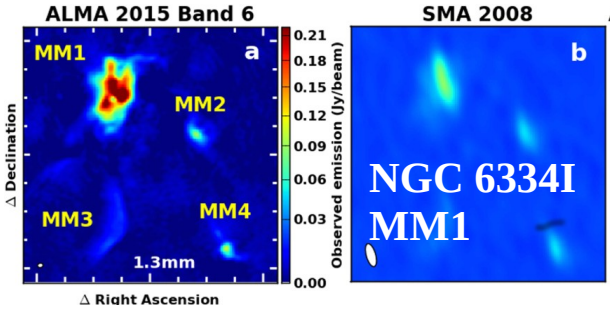
- Recent numerical simulations suggest that all present-day high-mass young stellar objects (HMYSOs) exhibit variable accretion rates and associated episodic bursts (Meyer et al. 2017, 2021).
- They spend up to 2% in the bursting phase, in which they can accrete up to 50% of their final mass (Meyer et al. 2019).
- This process is well related to luminous outbursts...

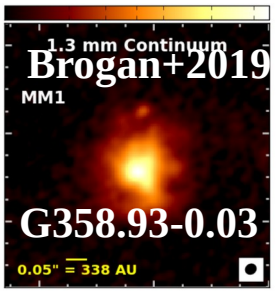
Four accretion bursts detected and studied so far:

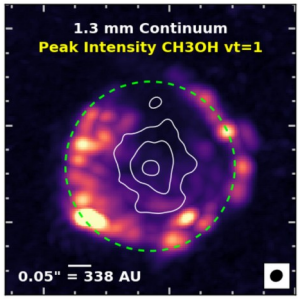
- S255IR NIRS 3: ~20 $M_\odot$ (Caratti o Garatti+2017; Moscadelli +2017; Szymczak+2017; Liu+2018; Cesaroni+2018; Uchiama+2019)
- NGC 6334I MM1: ~20 $M_\odot$ (Hunter+2017,2018; Brogan+2018; McLeod+2018)
- G358.93-0.03 MM1: ~10 $M_\odot$ (Brogan+2019; MacLeod+2019; Breen+2019; Burns+2020; Stecklum+2021)
- G323.46-0.08: ~8 $M_\odot$ (Proven-Adzri+2019; Wolf+ in prep)

The discovery of episodic accretion in HMYSOs has opened a new research field in star formation.





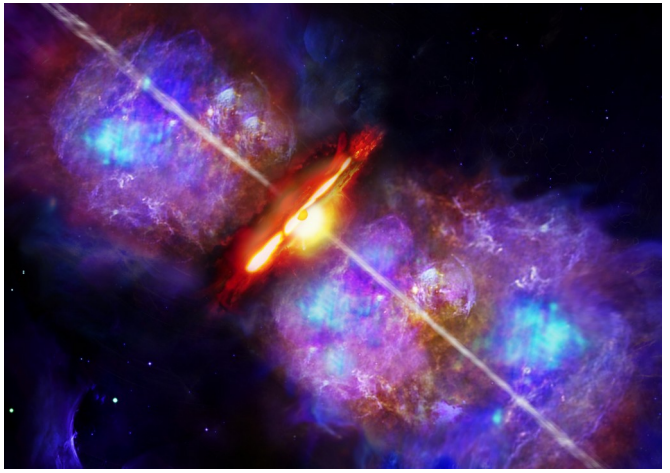




Main characteristics of HMYSO bursts

Despite the small sample we see large variety of physical properties as in low-mass bursts:

- Rising time: from 3 months to 1 year,
- Length: from 7 months to 6 years (1 still active after 6 yrs) ,
- Increase in L_{bol} (ΔL_{acc}): from 6 to 70 times (i.e. from few 10^3 to few 10^5 $L_\odot$)
- Accretion rates in burst: up to several 10^{-3} $M_\odot$/yr,
- Released energy: from few 10^{45} to several 10^{46} erg,
- **All bursts were preceded by methanol maser flares easily detected by single-dishes.**

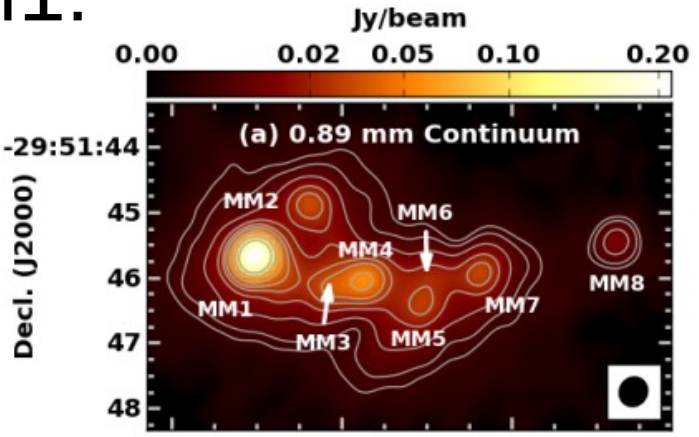


We “just” need to catch the burst

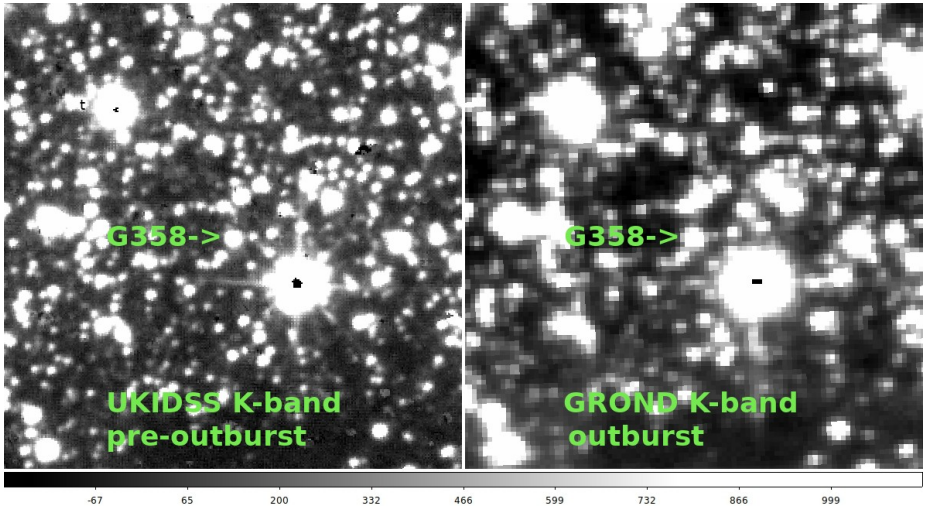
- M2O (A global community for maser-driven astronomy) established in Cagliari, Sardinia during the IAU Maser Symposium: https://www.masermonitoring.com/

Brogan et al. 2019

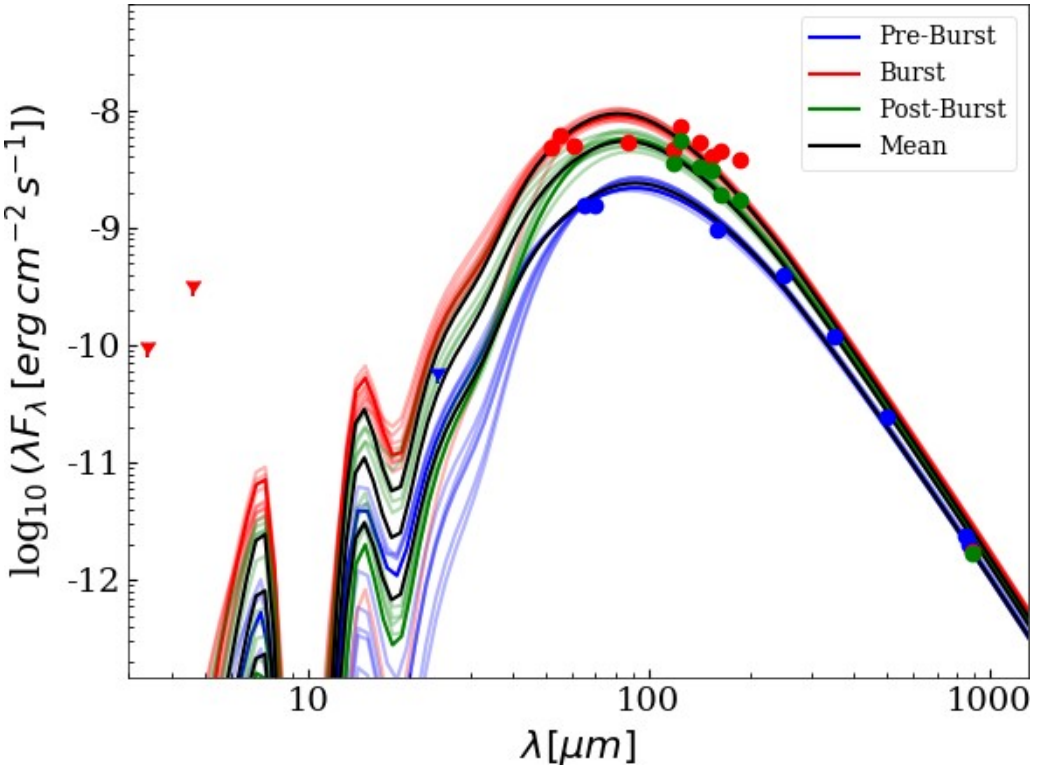
G358.93-0.03-MM1:



- 6.7 GHz CH_3OH burst (ATel)
- HMYSO at d ~ 6.7 kpc, located in a cluster,
- Follow-up by M2O team:
  wealth of masering lines in H_2O, OH, CH_3OH flaring and new maser species HDO, HNCO, $^{13}CH_3OH$ discovered,
- No detection of mm variability,
- No detection in NIR.



Confirmation of the accretion burst by SOFIA



Burst parameters:

ΔL_{acc} = (1.8+/-0.5)x10^5 $L_\odot$

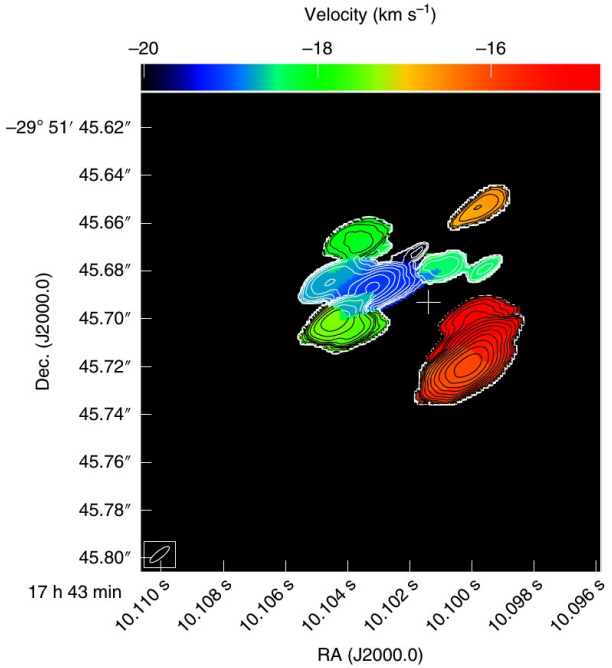
ΔM_{acc}= (5.3+/-11/4)x10^{-4} $M_\odot$/yr

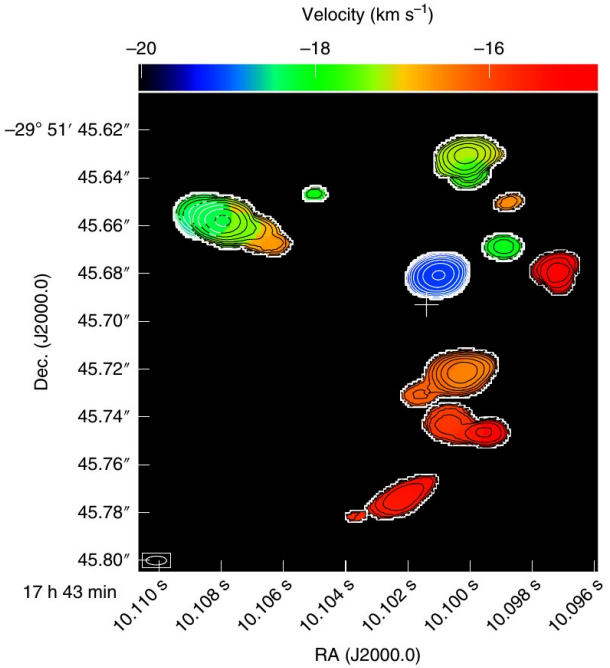
(with M_*=9.7 $M_\odot$ & R_*=3.9 $R_\odot$)

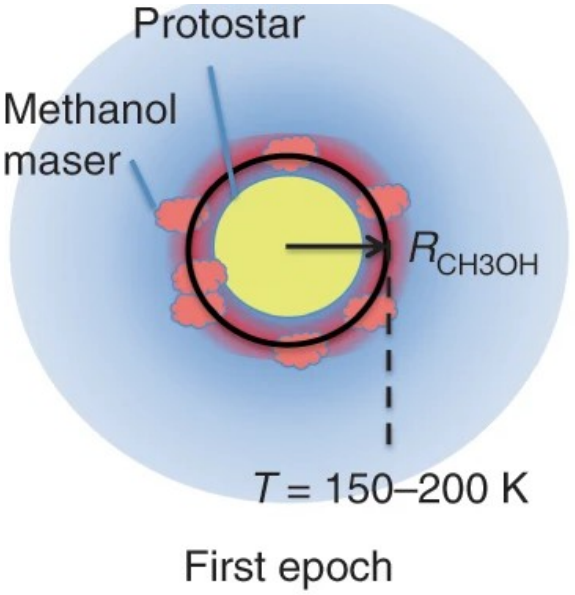
accreted mass ~ 180 M_{Earth}

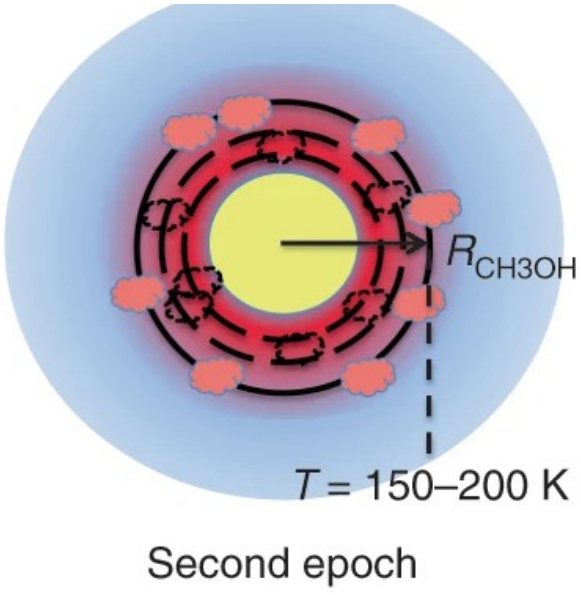
Stecklum et al. (2021)

Evidence for propagation of heat wave induced by the accretion burst as seen using methanol masers.







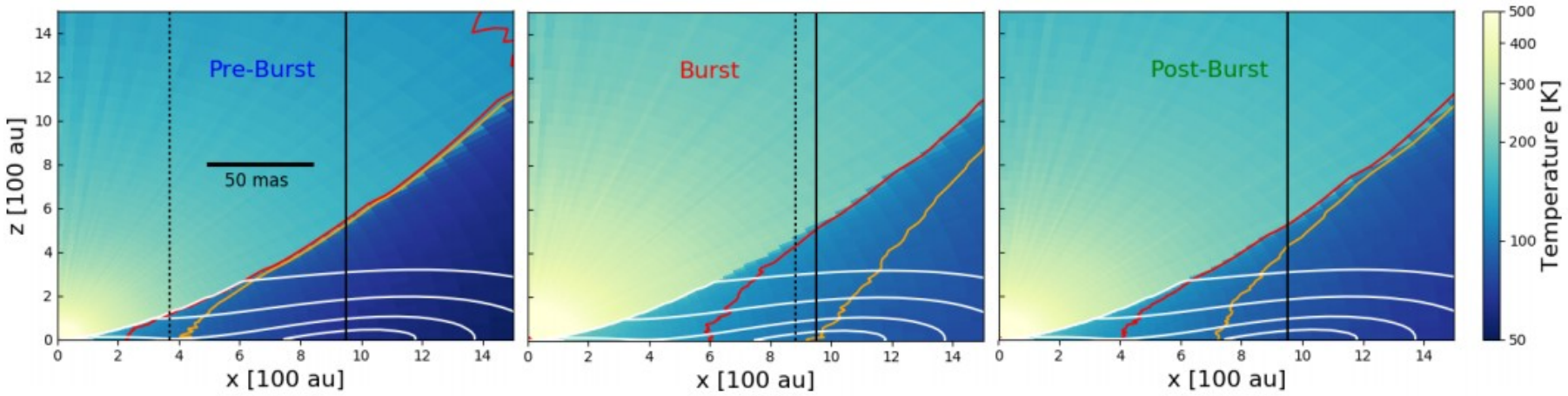


Burns et al. (2020)

Methanol maser relocation (radiative transfer calculations)

Methanol maser ring

disk edge



Methanol desorption **red:** ~ optimum 120-125 K, **yellow:** limit 94 K

Stecklum et al. (2021)

Summary

→ Multifrequency and multi-epoch studies are key to understand high-mass star-formation,

→ CH_3OH maser flares are excellent proxies for accretion variability in HMYSOs,

→ Disk-mediated accretion bursts observed from low- to high-mass YSOs.

Thank you :)