# The accretion bursting flare in the high-mass SFR G358.93-00.03 II: VLBI monitoring


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| --- | --- |
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| The M2O collaboration | |


East Asian Core Observatories Association

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国立天文台 NAOJ National Astronomical Observatory of Japan

# Massive Stars (>8 $M_\odot$)

Influence Galaxies

They explode (SN)

They implode (BH)

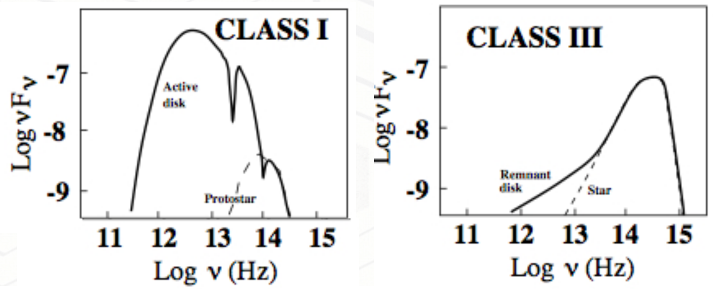
They are mysterious

Produce >Fe elements

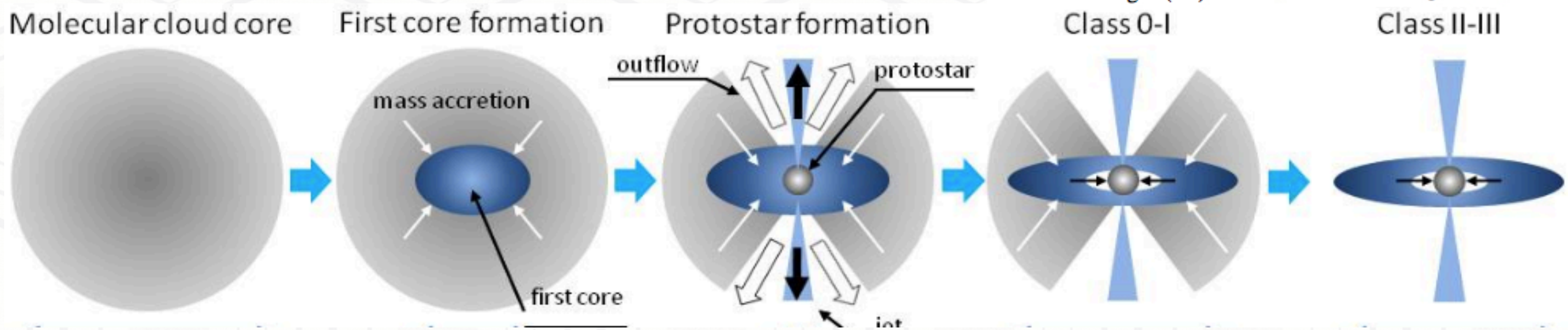
They are our parents

The field has become quite popular recently which helps to get jobs

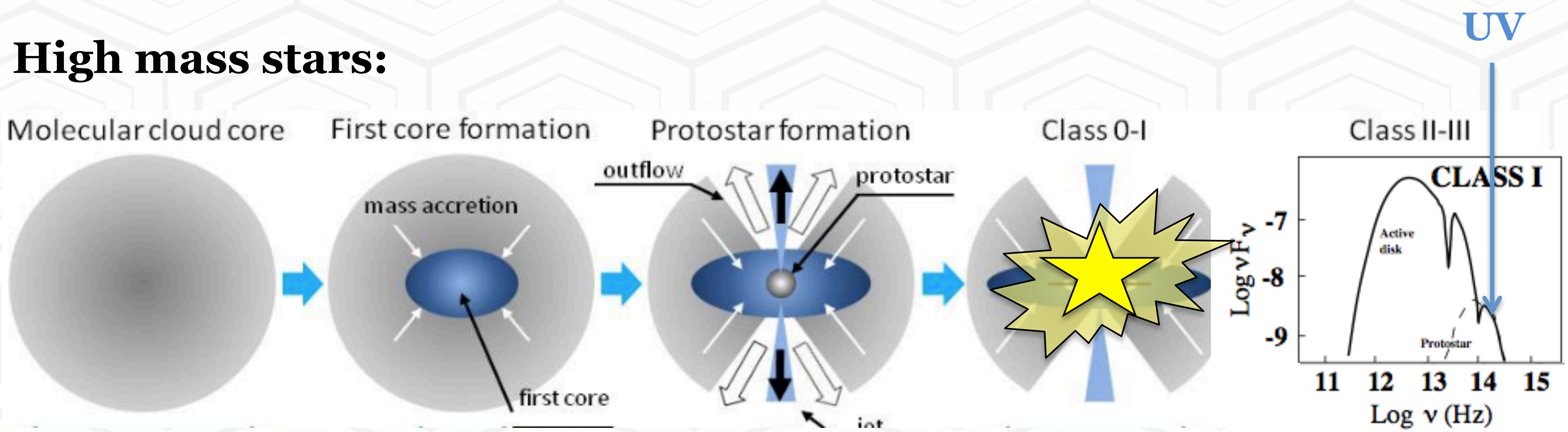
# Radiation pressure



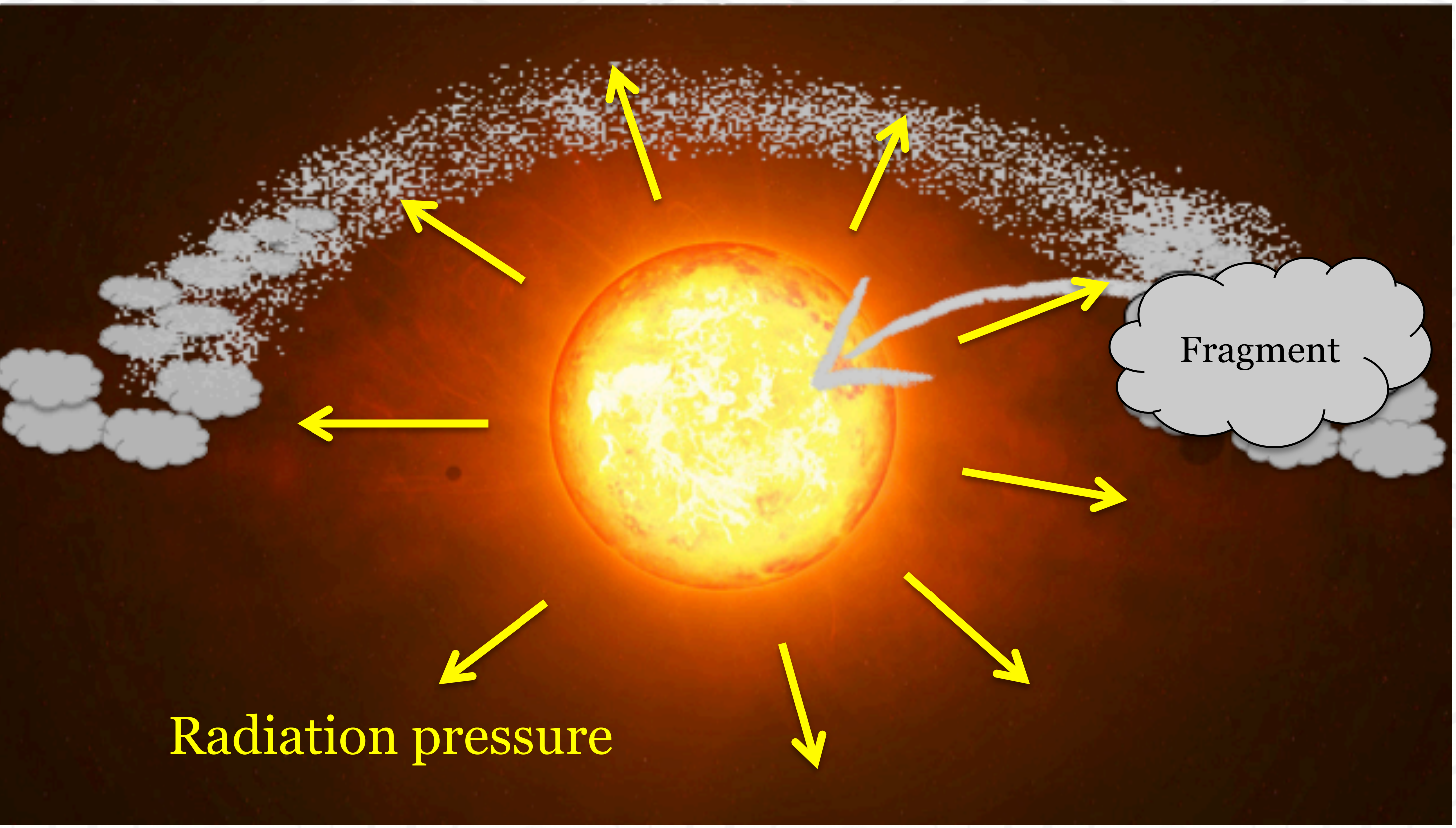

**Low mass stars:**

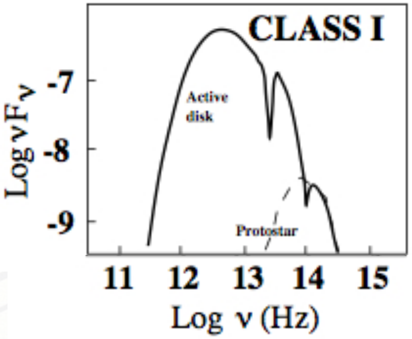



**High mass stars:**



# Problem:
# Radiation pressure




Grav. contraction

$L = 4 \pi R^2 \sigma T^4$

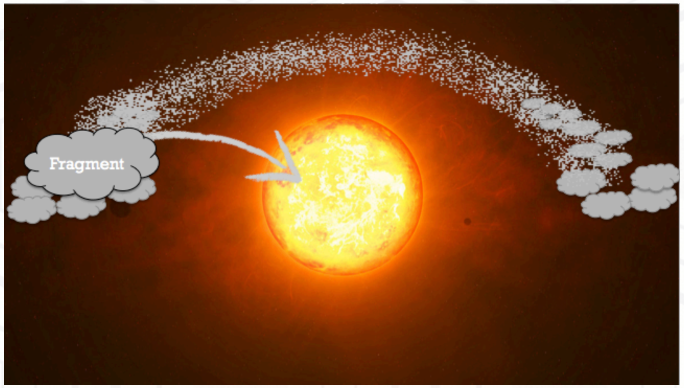
High T -> more UV

Radiation pressure (UV) increases over time until it counteracts further accretion

**This happens at ~ 8 $M_\odot$**

# Theoretical solution: “Episodic accretion”

Accretion from inner disk (via MRI)




Reference: Hosokawa et al., 2016, ApJ, 824, 119

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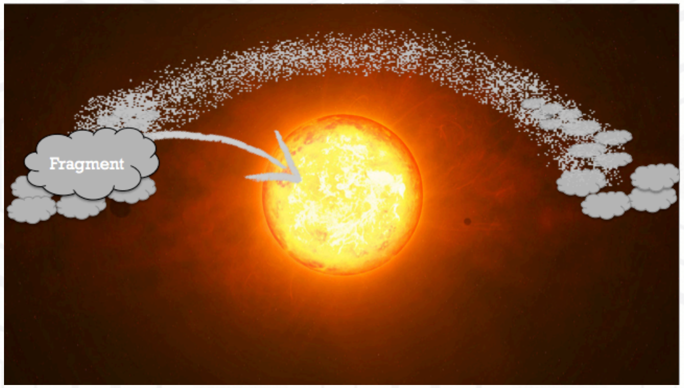
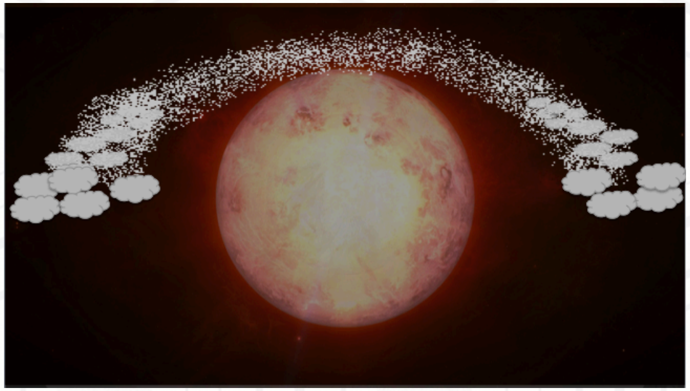



$L = 4 \pi R^2 \sigma T^4$, star will ‘bloat’



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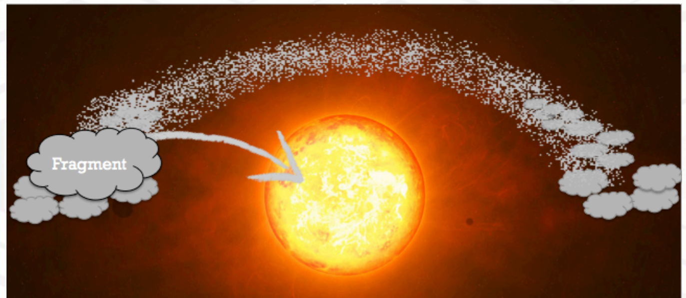
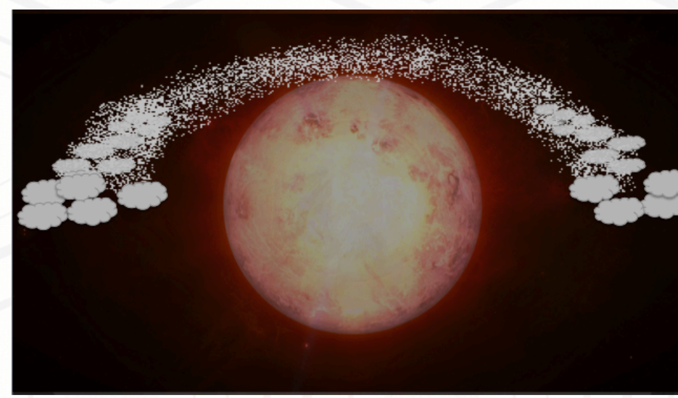
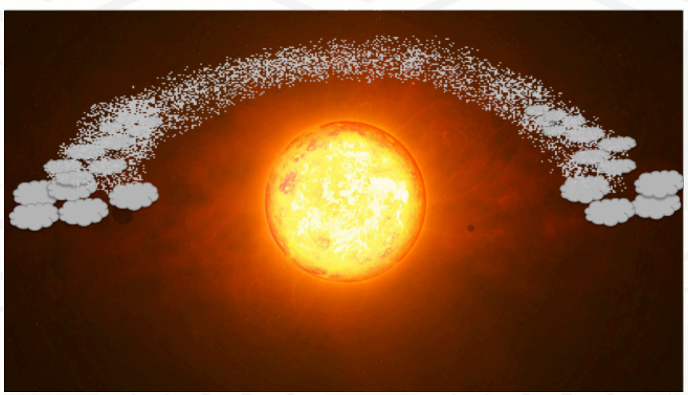



- Beat radiation pressure
- Build very massive stars

$L = 4 \pi R^2 \sigma T^4$, star will 'bloat'



Gravitational contraction



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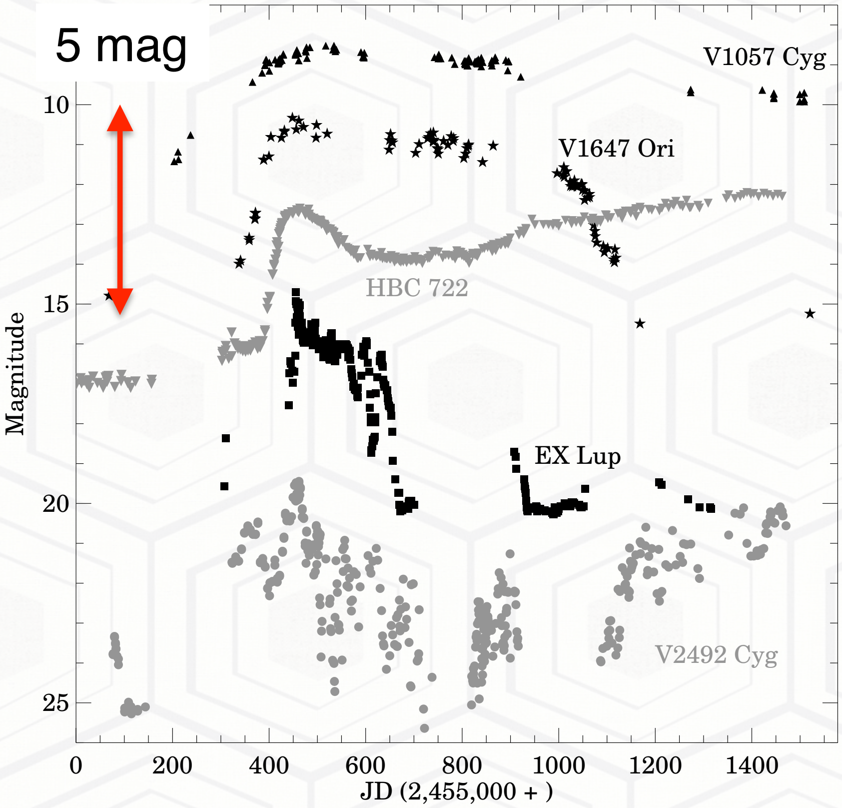
# Episodic accretion: in low mass star formation

- Discovered in low-mass star-forming regions (e.g., Herbig 66,77)
- Luminosity/Accretion rate increase 1-3 order of mag.!
- Classified into 3 types (see Audard 14; Contreras Pena+ 16)
  - FUors: High amp & Longer > 10 yr
  - EXors: Moderate & Shorter < 1.5 yr
  - MNors: 1.5 yr < & < 10 yr
- Resolve *luminosity problem*

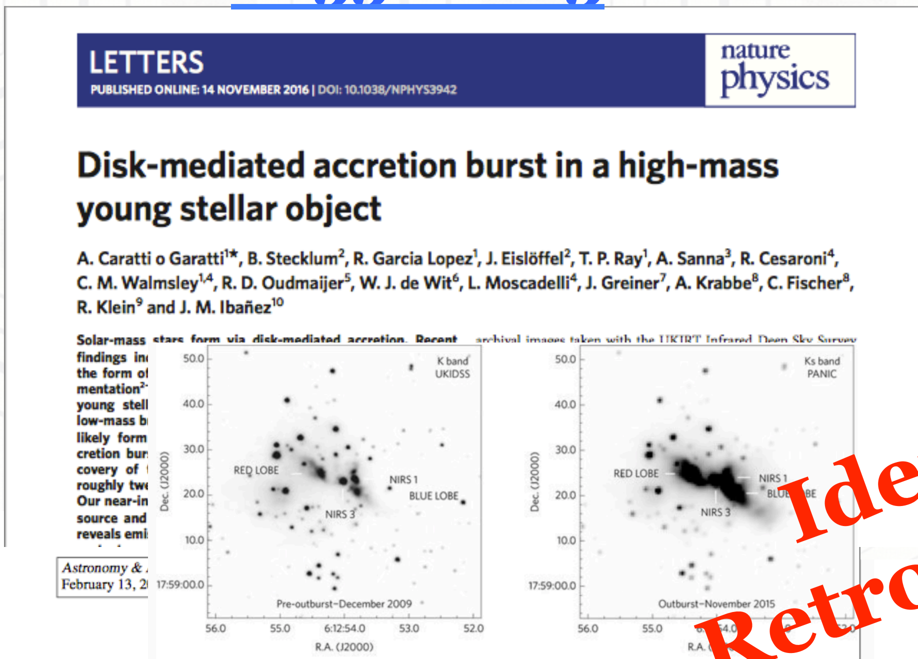


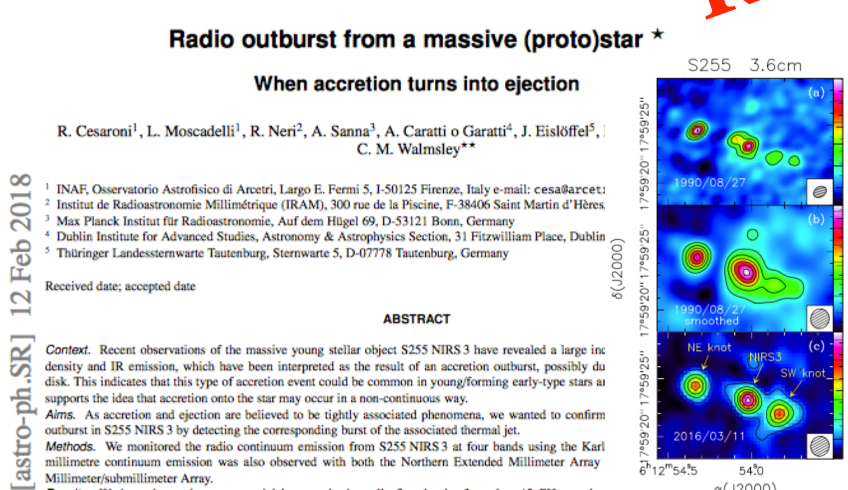

Light curve at Optical-bands (Kospal+ 2011; Audart+ 2014)

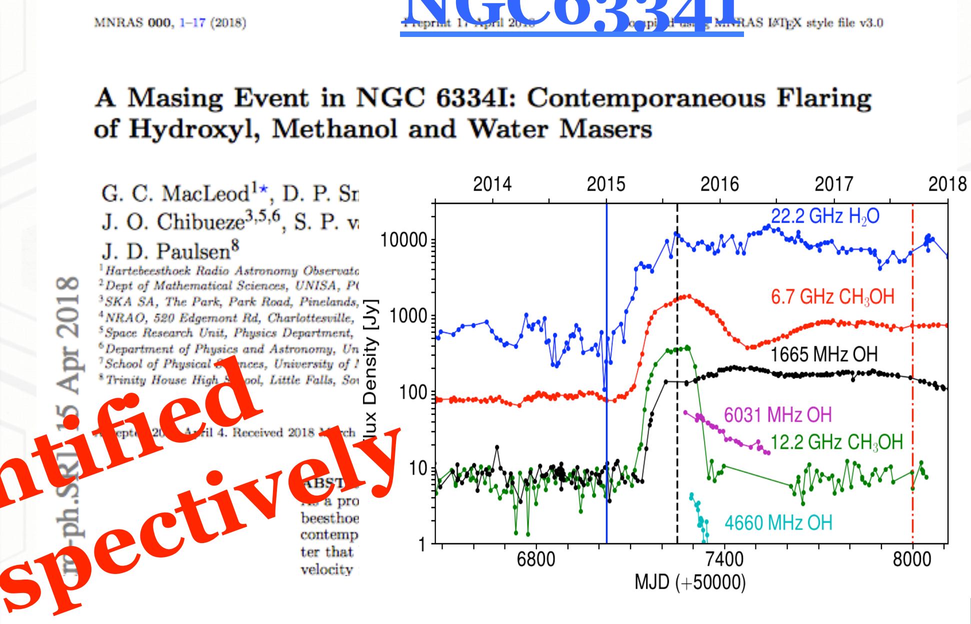
# Episodic accretion:
# Known accretion bursts

**S255NIRS3**

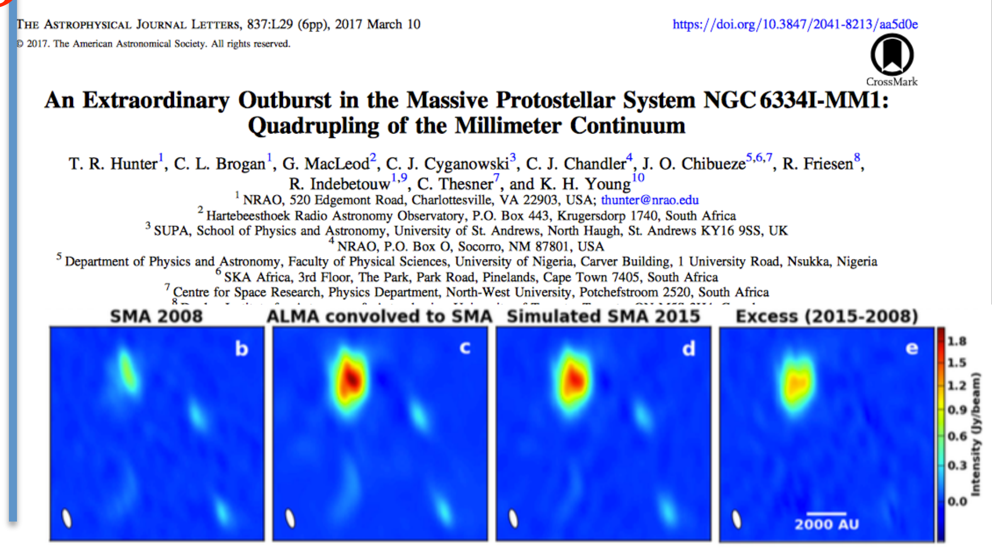
**NGC6334I**



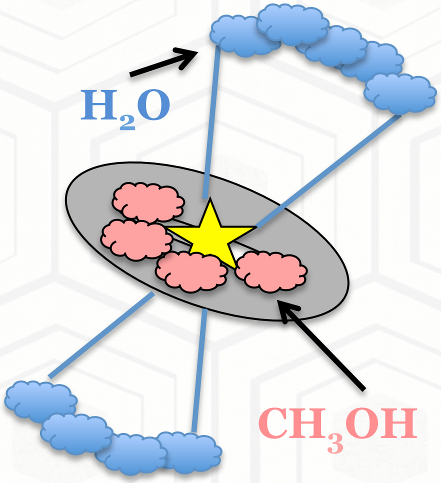

Identified Retrospectively



# Episodic accretion in high-mass stars

Open questions in **episodic** high-mass SF:

- Significant mass accretion?
- Mechanism?
- Timescales?
- Variety? (Exor / MNor / FUor)




**6.7 GHz Methanol masers: observational tool**

# [M2O] Maser Monitoring Organization

(**Led by G. MacLeod & S. Goedhart in South Africa**)

**Launch**: 2017/09/07 @IAU Symp. 336

**Aim**: Unique flux monitor & Follow-up at Radio/NIR

**Participants**: Australia, Canada, China, France, Italy, Japan, Korea, Latvia, Poland, Russia, South Africa, Thailand, Ukraine, USA

# Observations


【**Telescope**】Hitachi 32-m (Yonekura+ 16)
【**Frequency**】6.664-6.672 GHz
【**High-cadence monitor**】On-going from Dec 30, 2019

【**Detection mode of drastic rising-up**】Operators (mainly undergraduate/graduated students) make data reduction via script and check/report to ML in Ibaraki Univ. lab

【**G 358.93-00.03: Interval of monitor obs**】

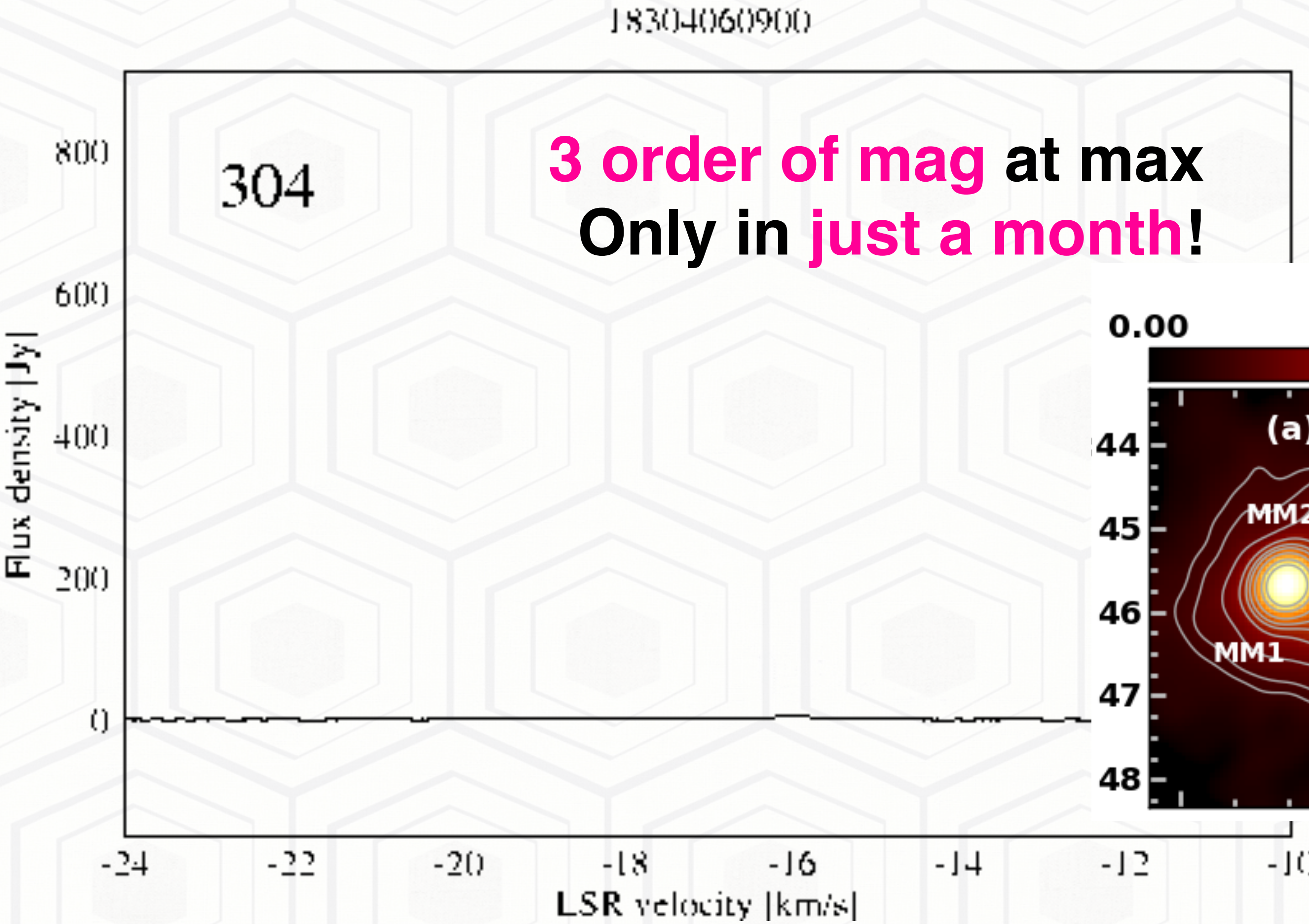
– ~ 2019/01/14 : once / 45-50 d
– 2019/01/16 ~ : 毎日

【G 358.93-00.03】

– Distance : 6.5/10 kpc (kinetic)
– MM1/MM3: Line-rich, Hot core
  - MM1: Possible accretion disk

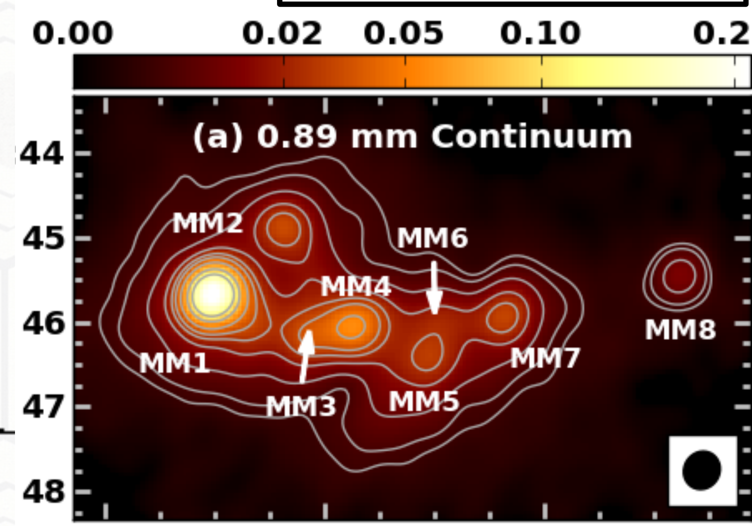
See poster by K. Sugiyama (P0X)

# High-mass YSO:
# G358.93-0.03




**3 order of mag at max**
**Only in just a month!**

Brogan, Hunter+ (19)

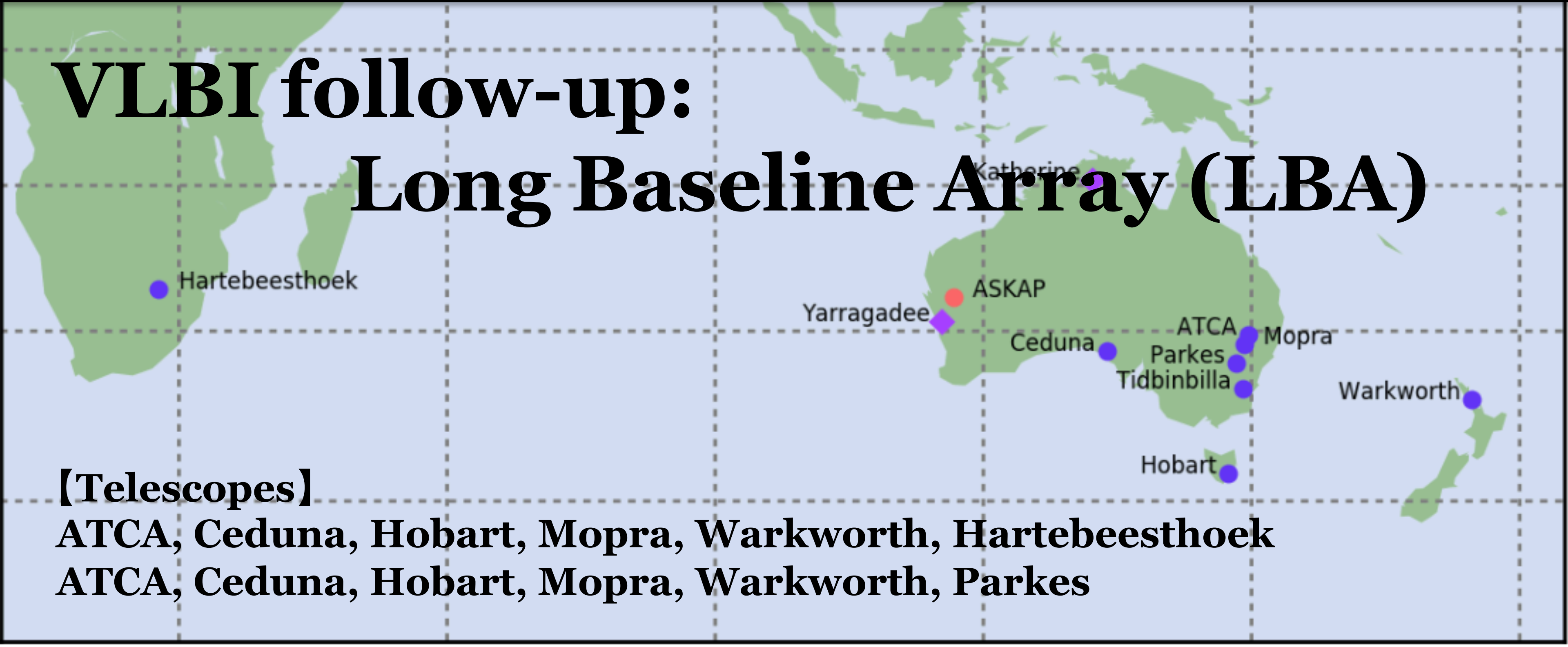





http://vlbi.sci.ibaraki.ac.jp/iMet/G358.9-00-190114/

**KS, Y. Yonekura, et al. (2019), ATel**

# VLBI follow-up:
# Long Baseline Array (LBA)



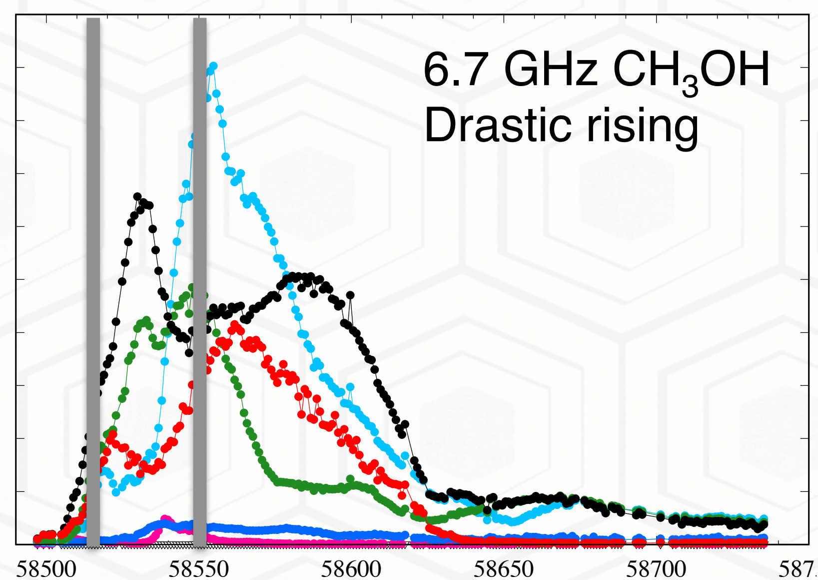

**【Telescopes】**
**ATCA, Ceduna, Hobart, Mopra, Warkworth, Hartebeesthoek**
**ATCA, Ceduna, Hobart, Mopra, Warkworth, Parkes**

**【Obs】**
**2nd Feb 2019 (half month after burst)**
**28th Feb 2019**

**【Freq.】**
**6.668 GHz**

**【Vel. spacing】**
**0.045 km/s**

**【Note】 Phase referencing**



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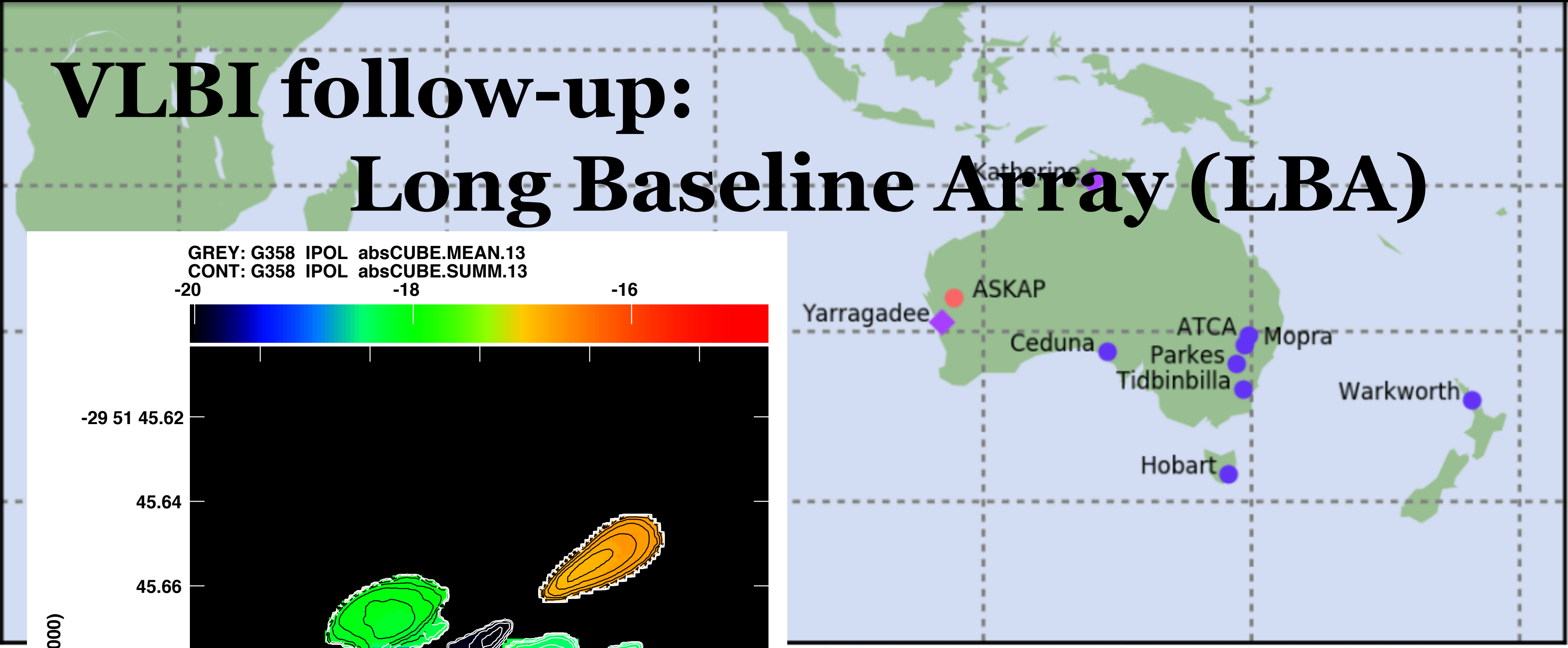
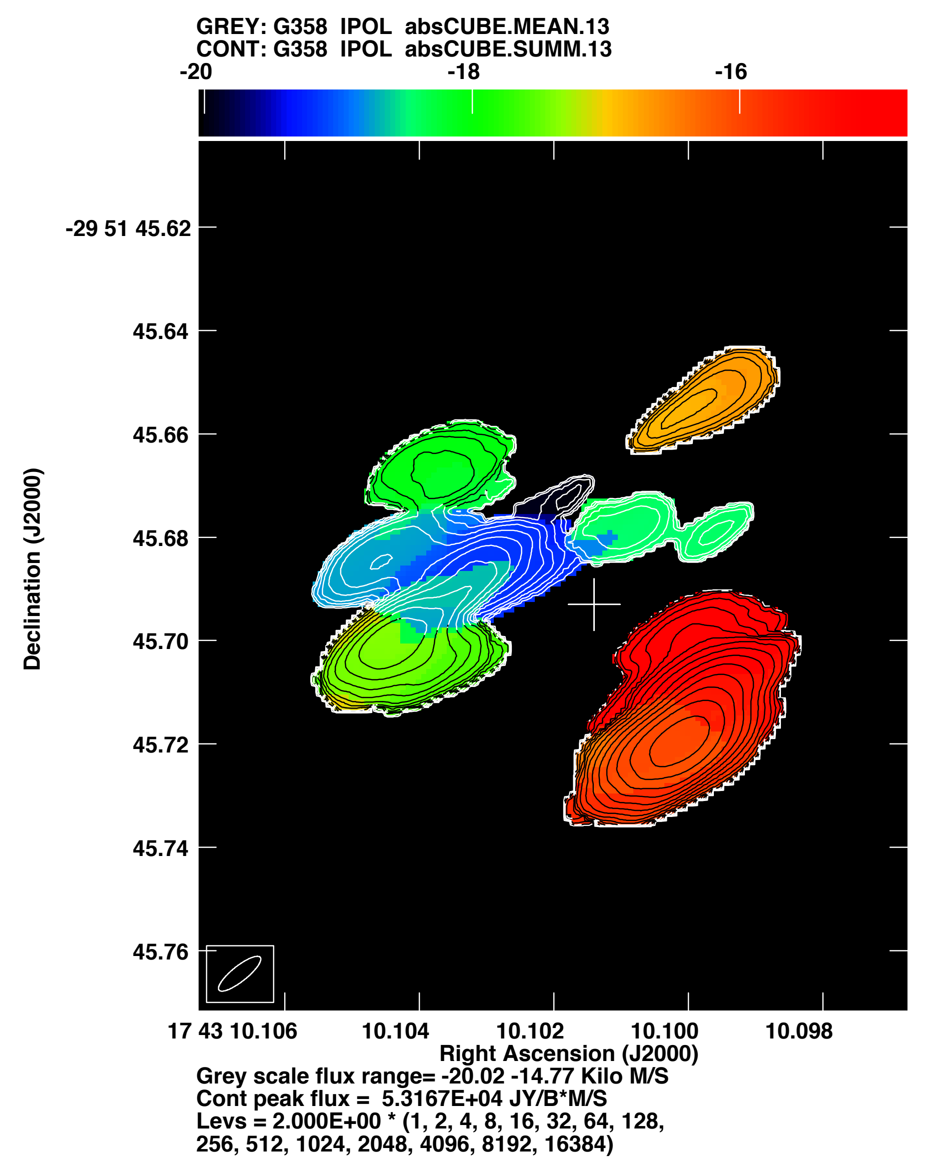
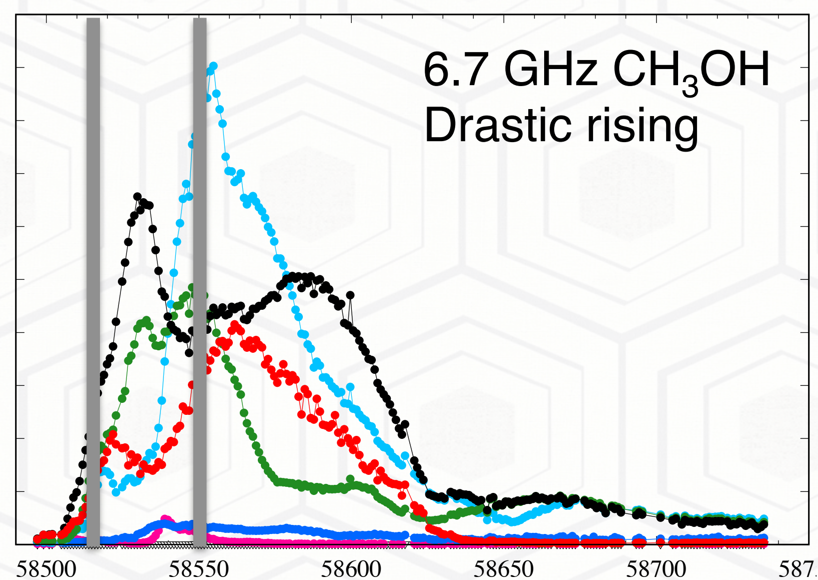
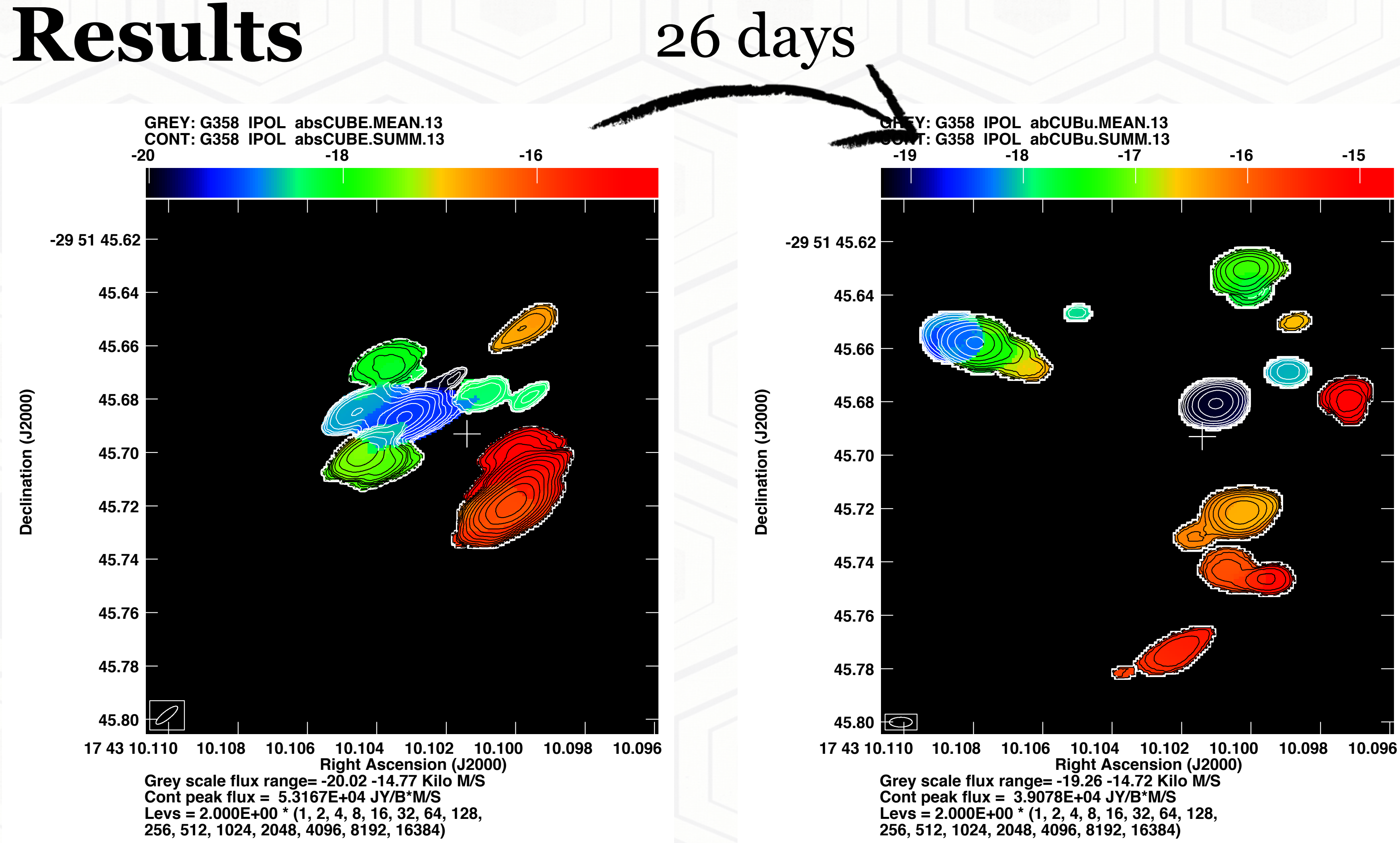


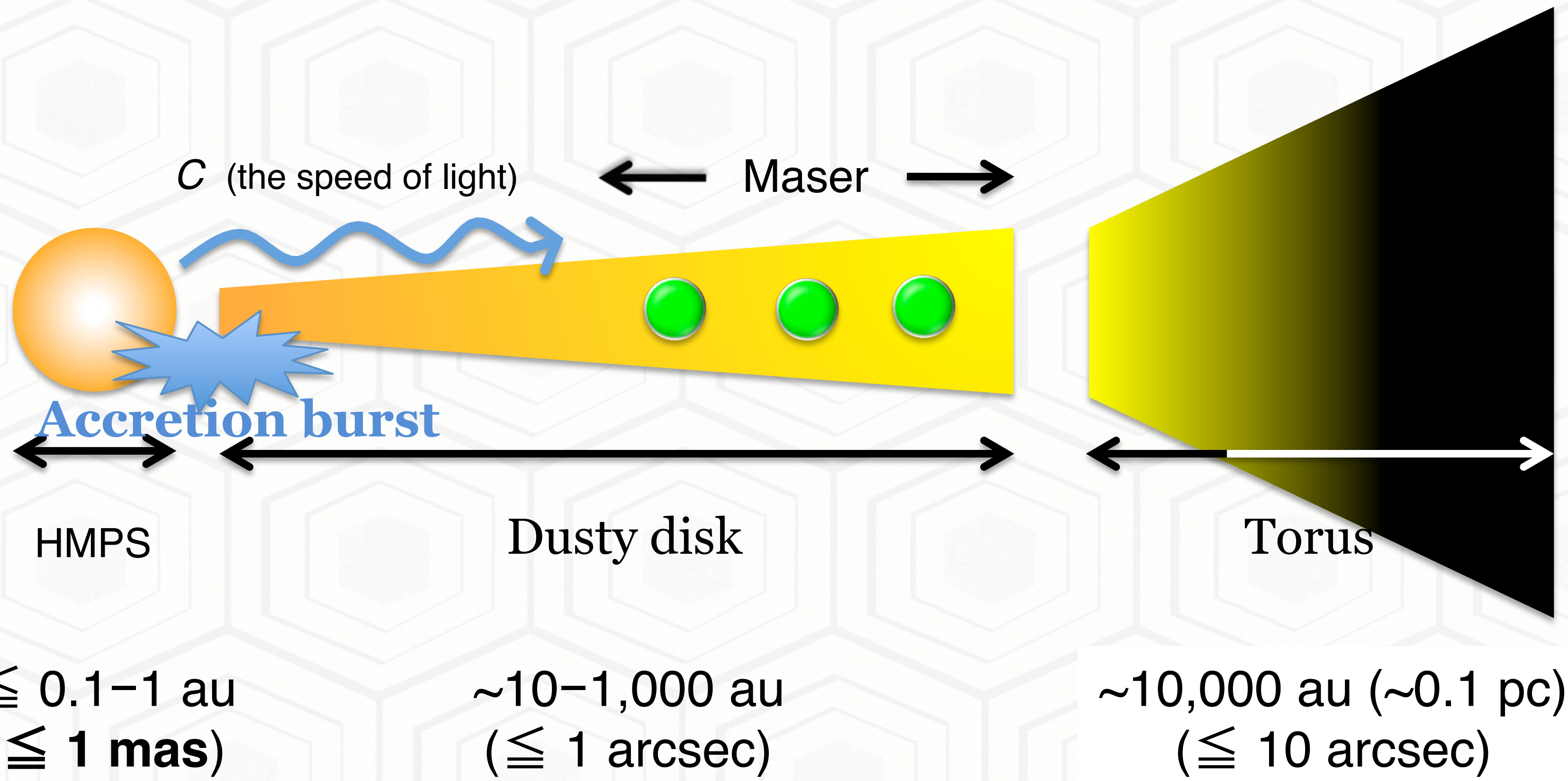
# Results




**Implies a translocation of 1-2 mas/day, which is 11,700 to 23,400 km/s at the source's kinematic distance of 6.75 kpc (equivalent to 0.04 to 0.08c).**

**Methanol masers die at v >10 km/s i.e. Too fast to be proper motion**

# Mechanism

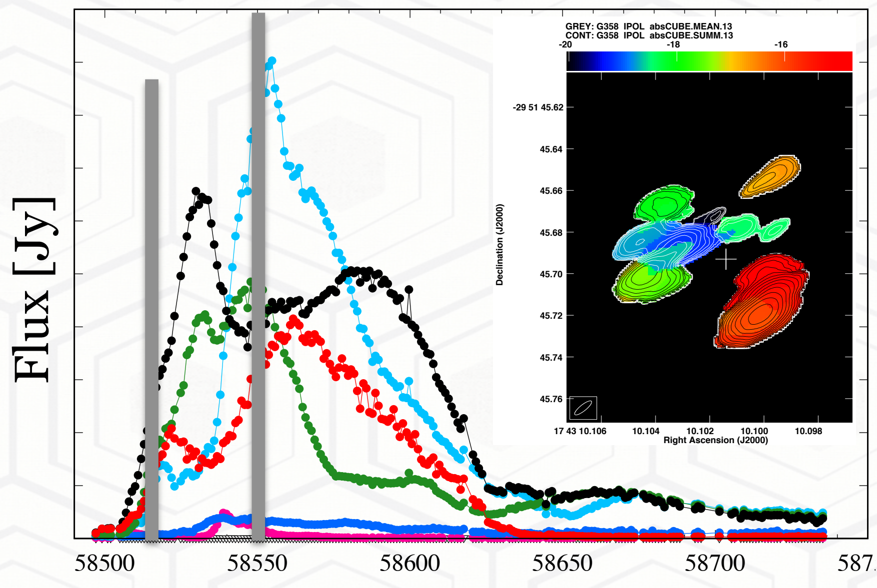



- **Thermal energy from the accretion event propagates outward**
- **Masers are created / destroyed at ever-increasing radii**
- **Strong support for an accretion event**

# Concluding viewpoints:

- The M2O: effective communication and follow-up
- Observed a "heat-wave" from the G358 accretion burst
- Extreme maser evolution
- Fast VLBI responses critical
- Dissimilar to S255 / NGC6334

G358 6.7 GHz



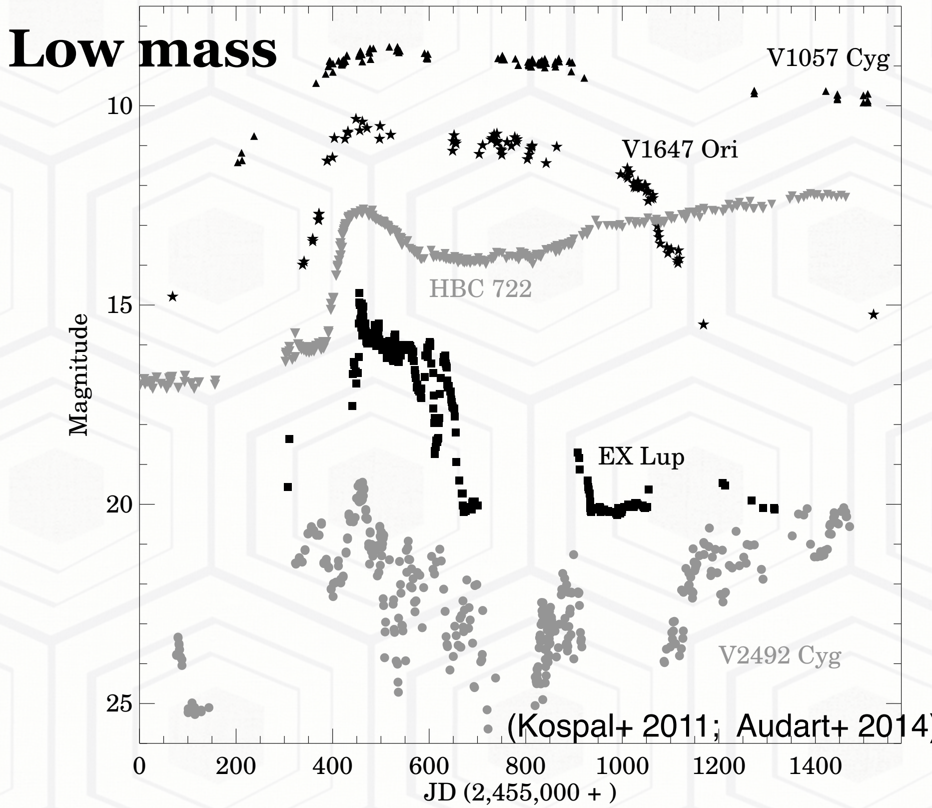
# Future work: Questions:

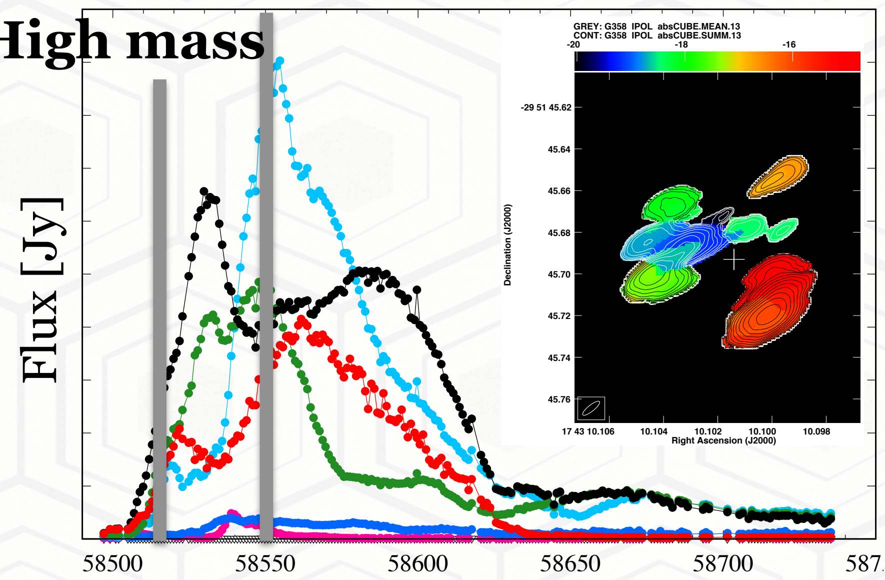
- **Massive EX/MN/FU-Ors?**
  a possible `zoo' of HM bursts?

- **How much mass accreted?**
  how to determine this?

- **What initiates accretion bursts?**
  deeper understanding of mechanisms

- **What else can be learned?**
  refine the investigative process

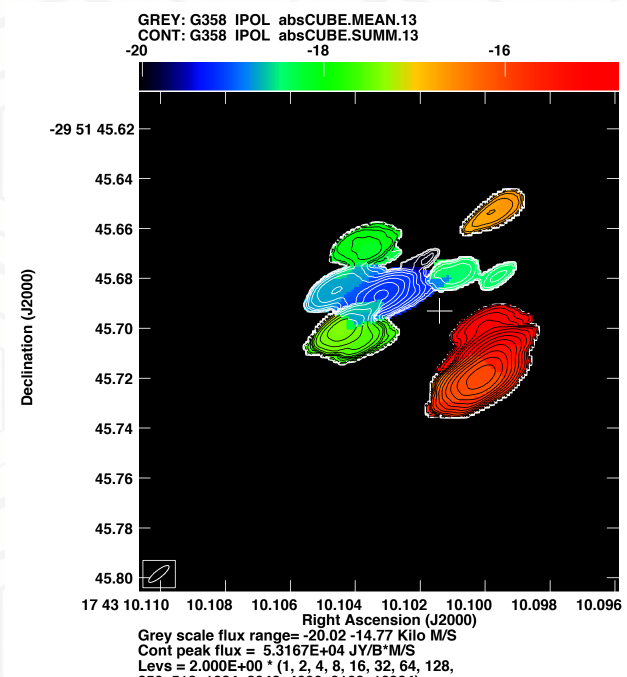


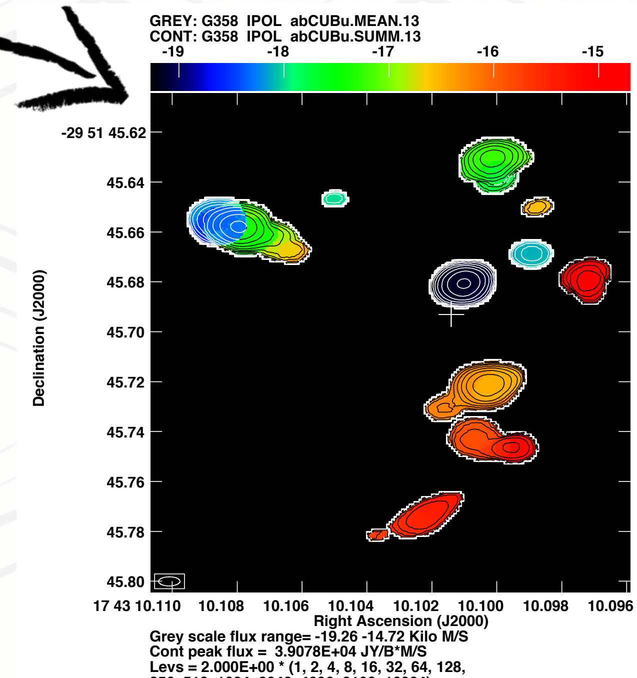



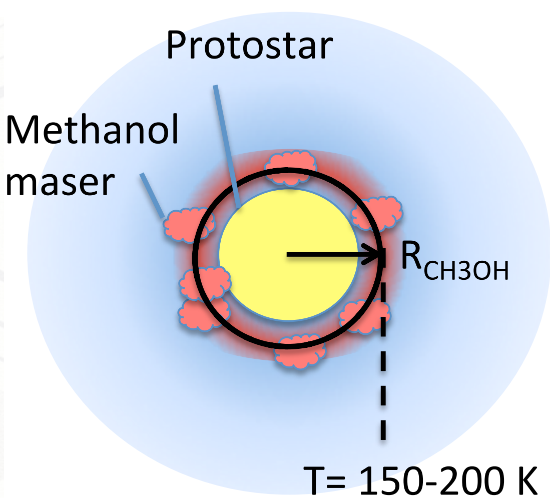
# Thank you

# Results

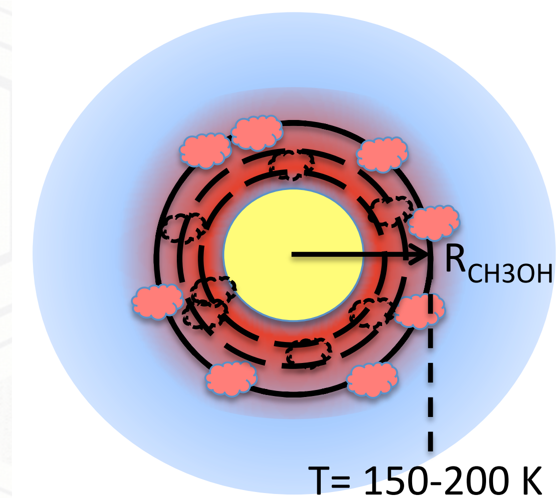
26 days



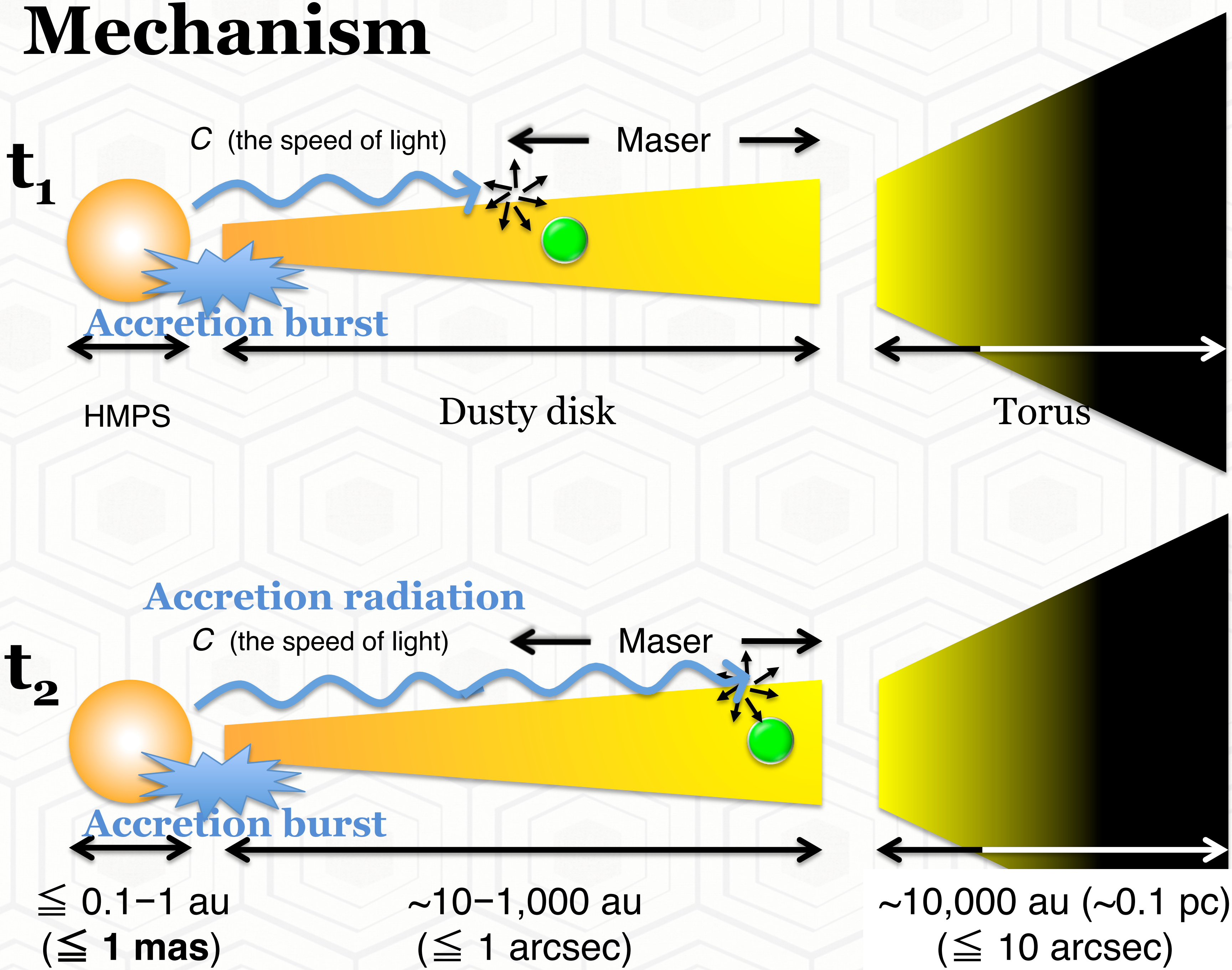




First epoch




Second epoch

# Mechanism



t1
C (the speed of light)
Maser
Accretion burst
HMPS
Dusty disk
Torus
Accretion radiation
t2
C (the speed of light)
Maser
Accretion burst
≦ 0.1−1 au
(≦ 1 mas)
~10−1,000 au
(≦ 1 arcsec)
~10,000 au (~0.1 pc)
(≦ 10 arcsec)