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

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The M2O collaboration	

East Asian Core Observatories Association

Massive Stars (>8 $M_\odot$)

Influence Galaxies

They explode (SN)

They implode (BH)

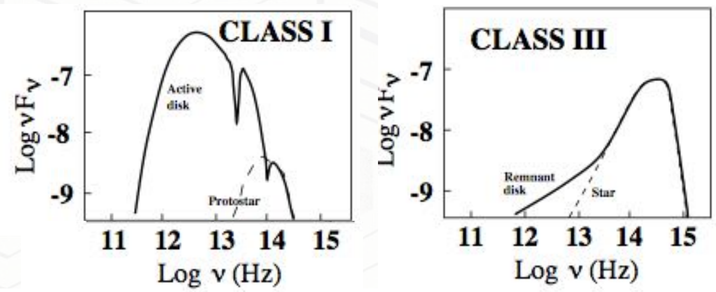
They are mysterious

Produce >Fe elements

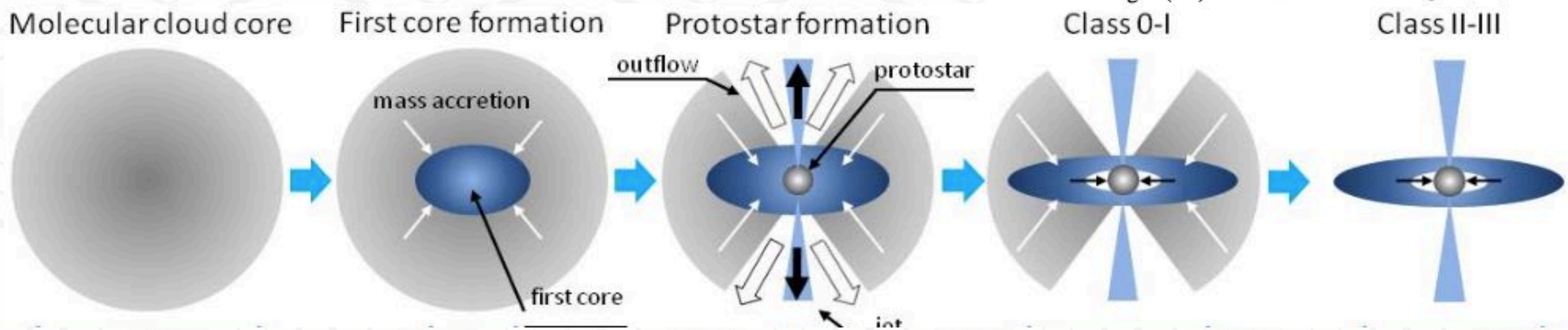
They are our parents

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

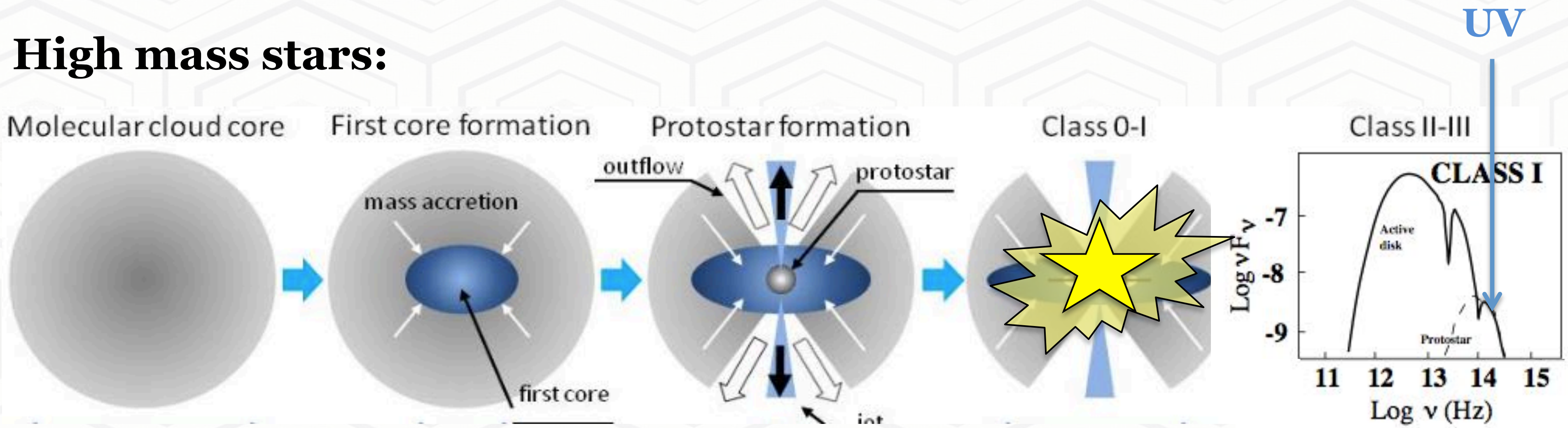
Radiation pressure



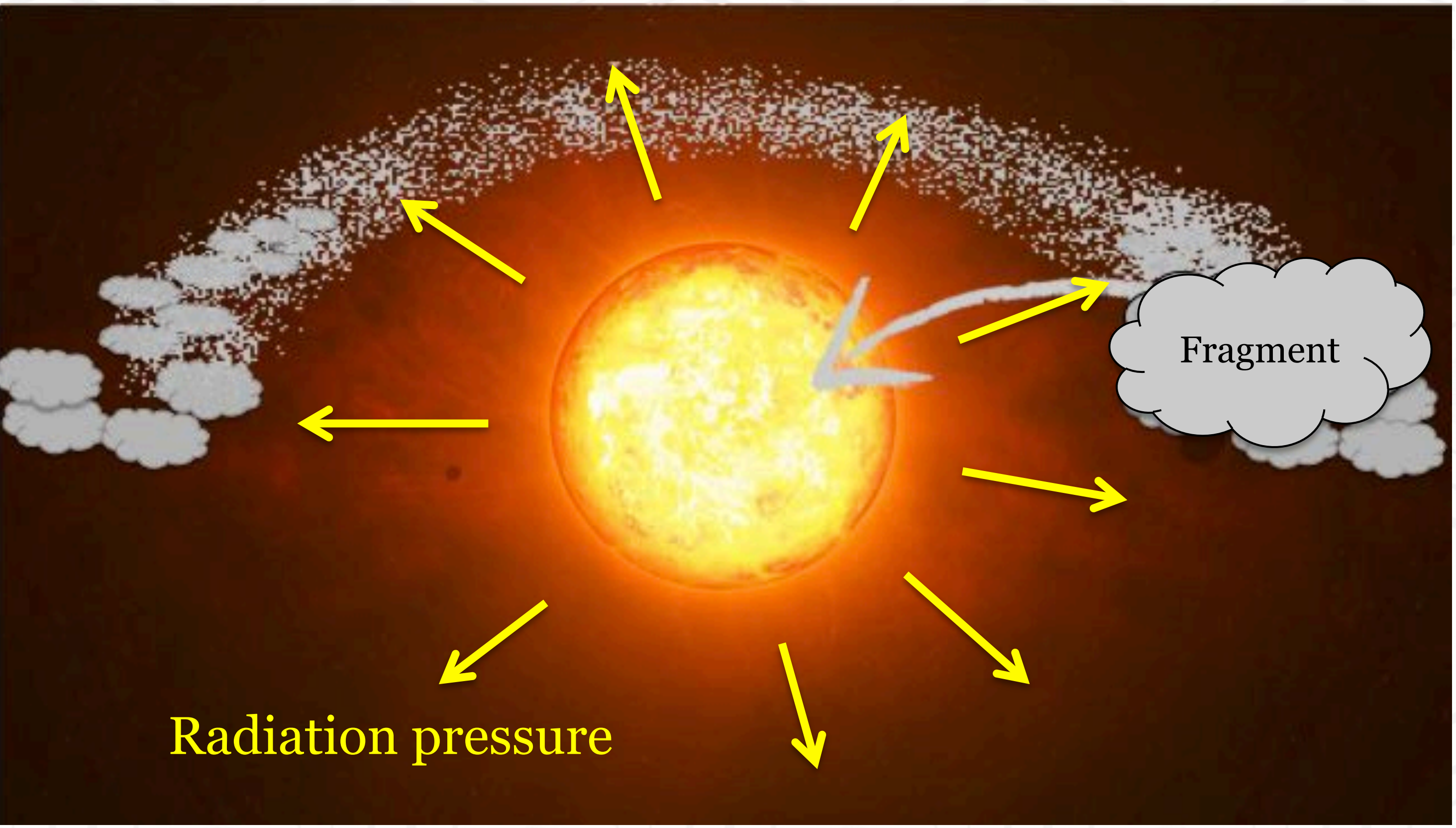
Low mass stars:

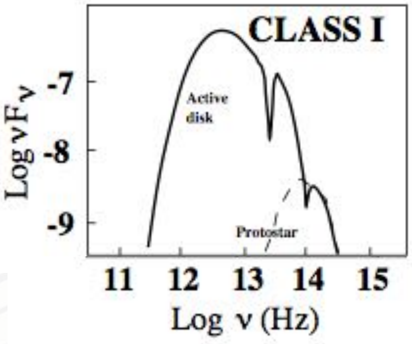


High mass stars:



Problem:
Radiation pressure





Grav. contraction

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

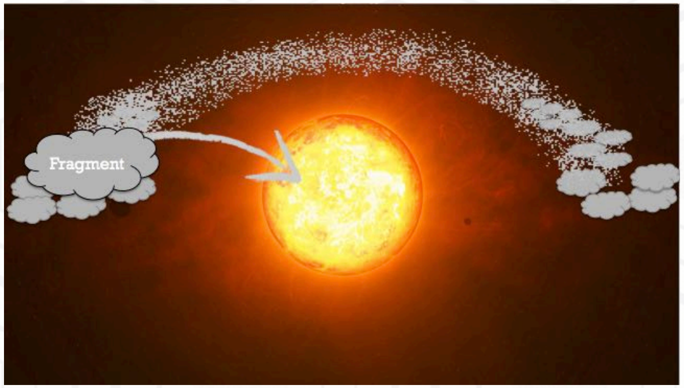
High T -> more UV

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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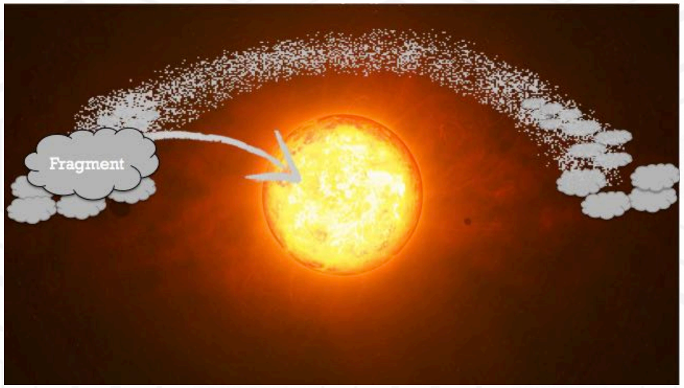
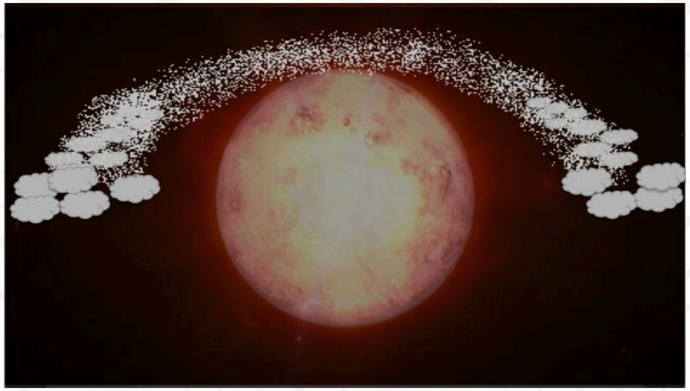


$L = 4 \pi R^2 \sigma T^4$, star will 'bloat'



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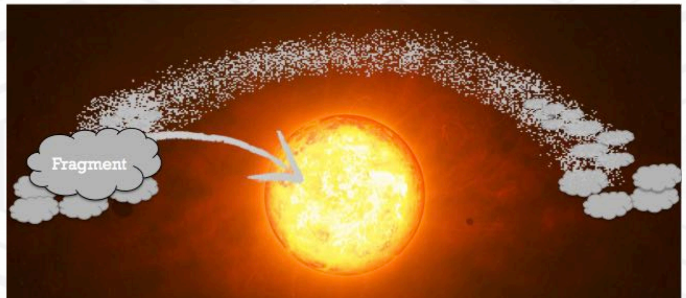
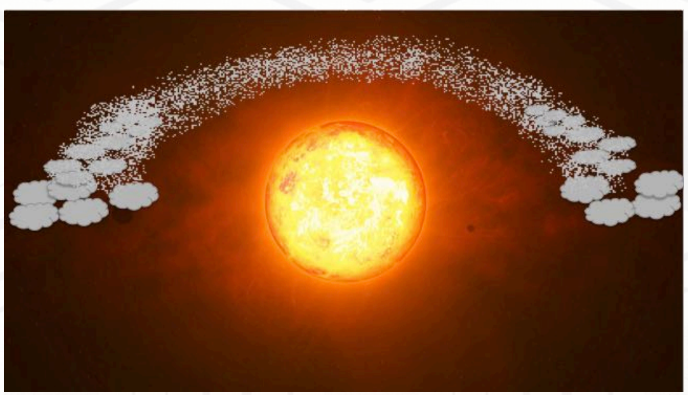


- Beat radiation pressure
- Build very massive stars

Gravitational contraction



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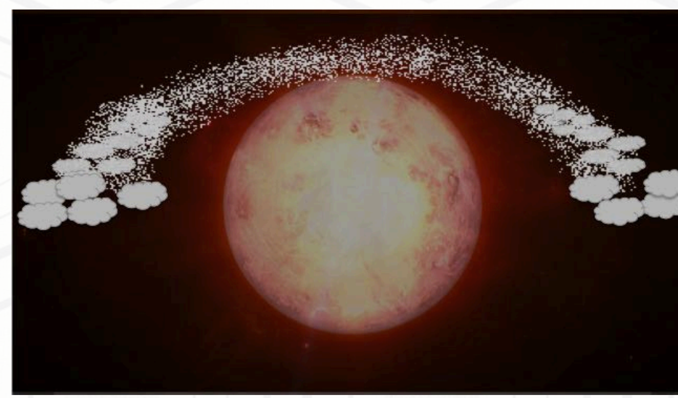
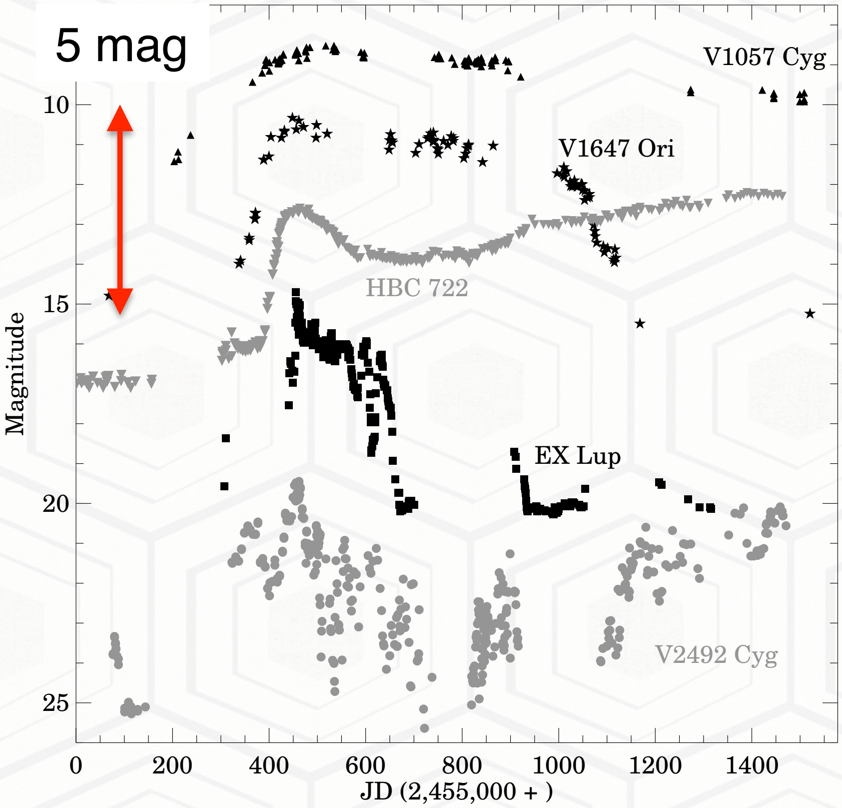


Reference: Hosokawa et al., 2016, ApJ, 824, 119

Episodic accretion:
in low mass star formation

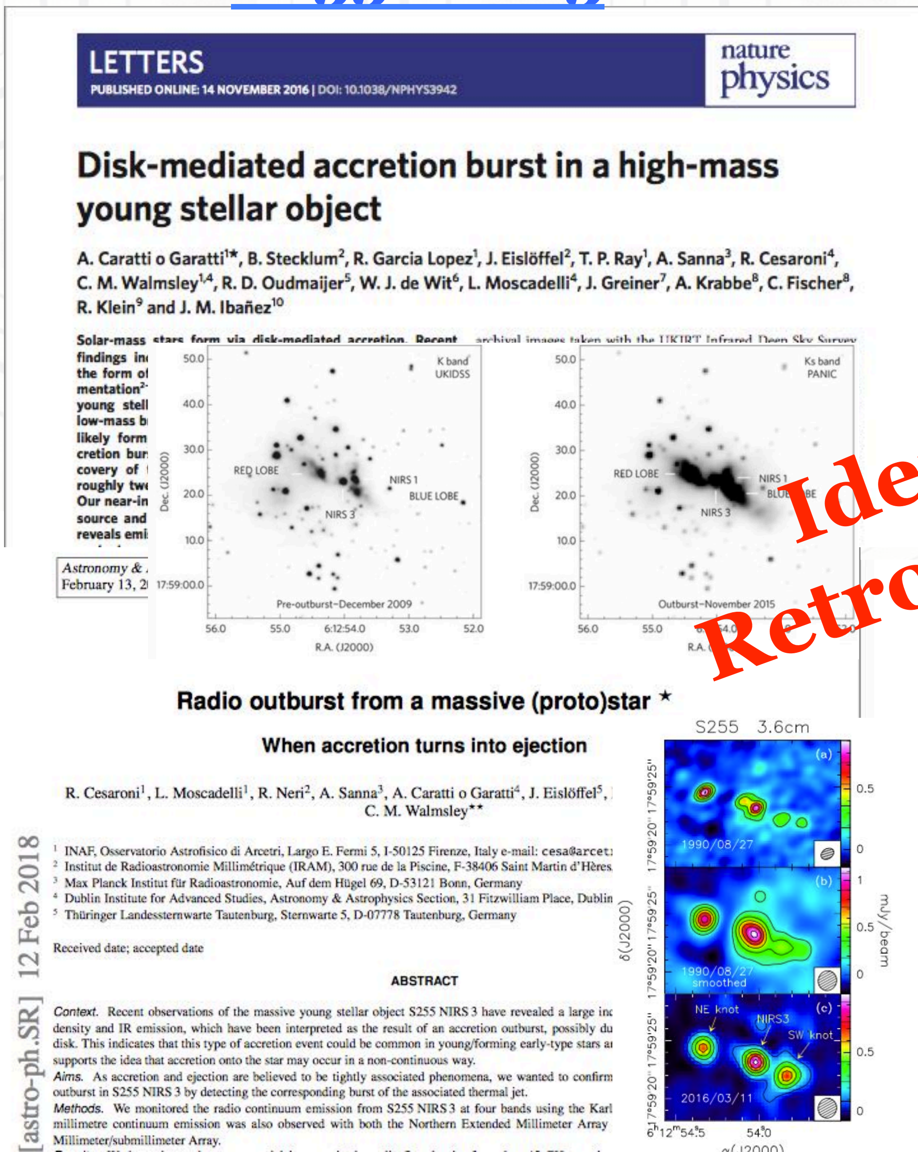
- Discovered in low-mass star-forming regions (e.g., Herbig 66,77)
- Luminosity/Accretion rate increase 1-3 order of mag.!
- Classified into 3 types (see Audard 14; Contreras Pena+ 16)
  - FUors: High amp & Longer > 10 yr
  - EXors: Moderate & Shorter < 1.5 yr
  - MNors: 1.5 yr < & < 10 yr
- Resolve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



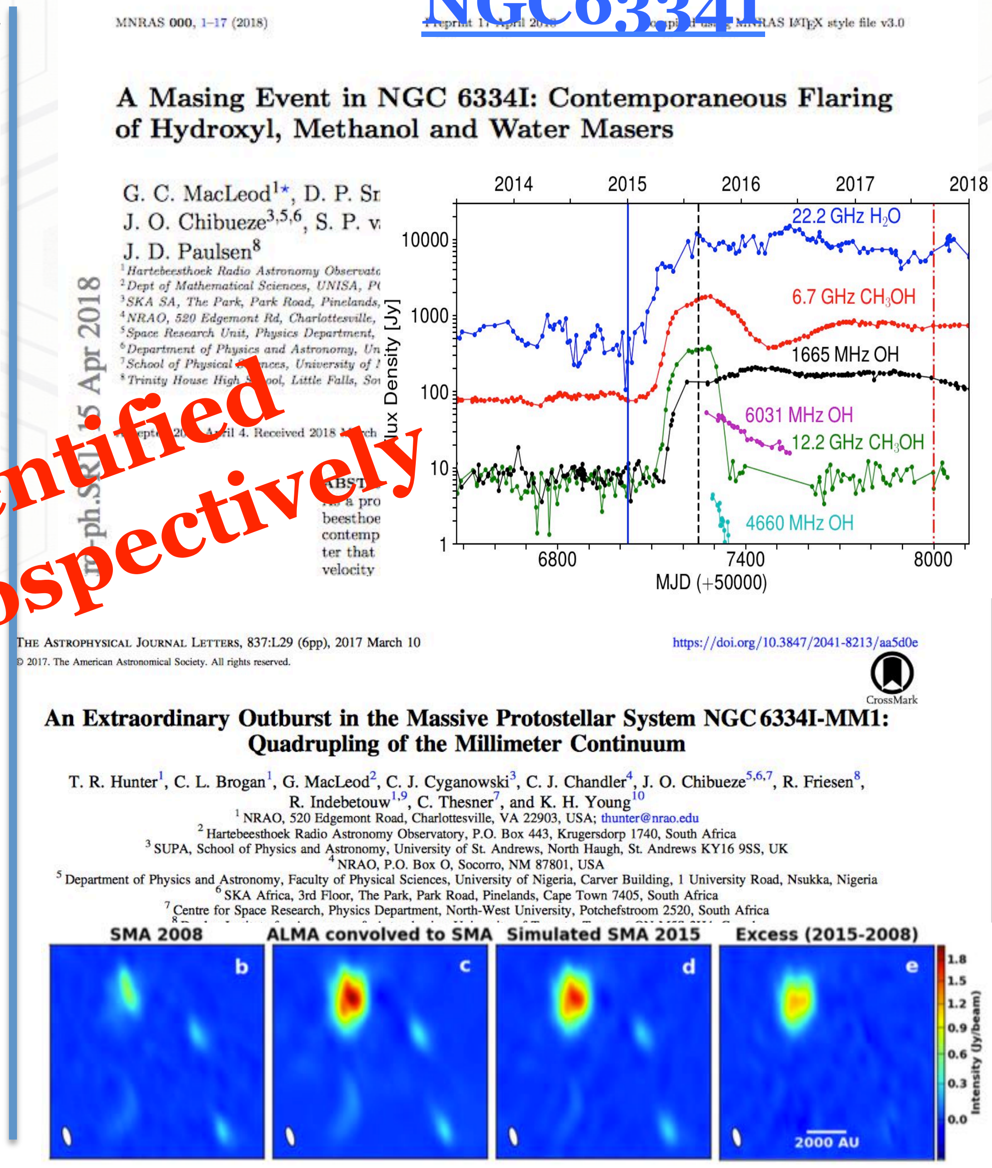
Light curve at Optical-bands
(Kospal+ 2011; Audart+ 2014)

Episodic accretion:
Known accretion bursts

S255NIRS3



NGC6334I

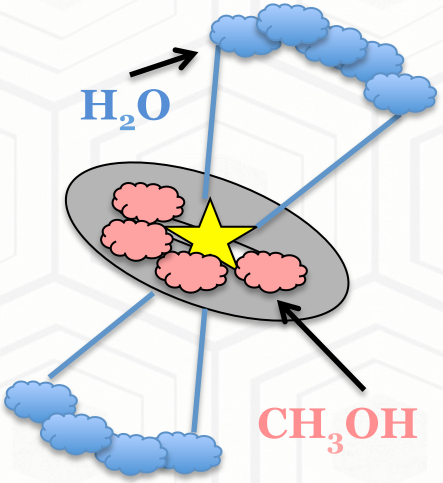


Identified Retrospectively

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


Hitachi 32-m radio telescope (Credit: NAOJ)

【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】

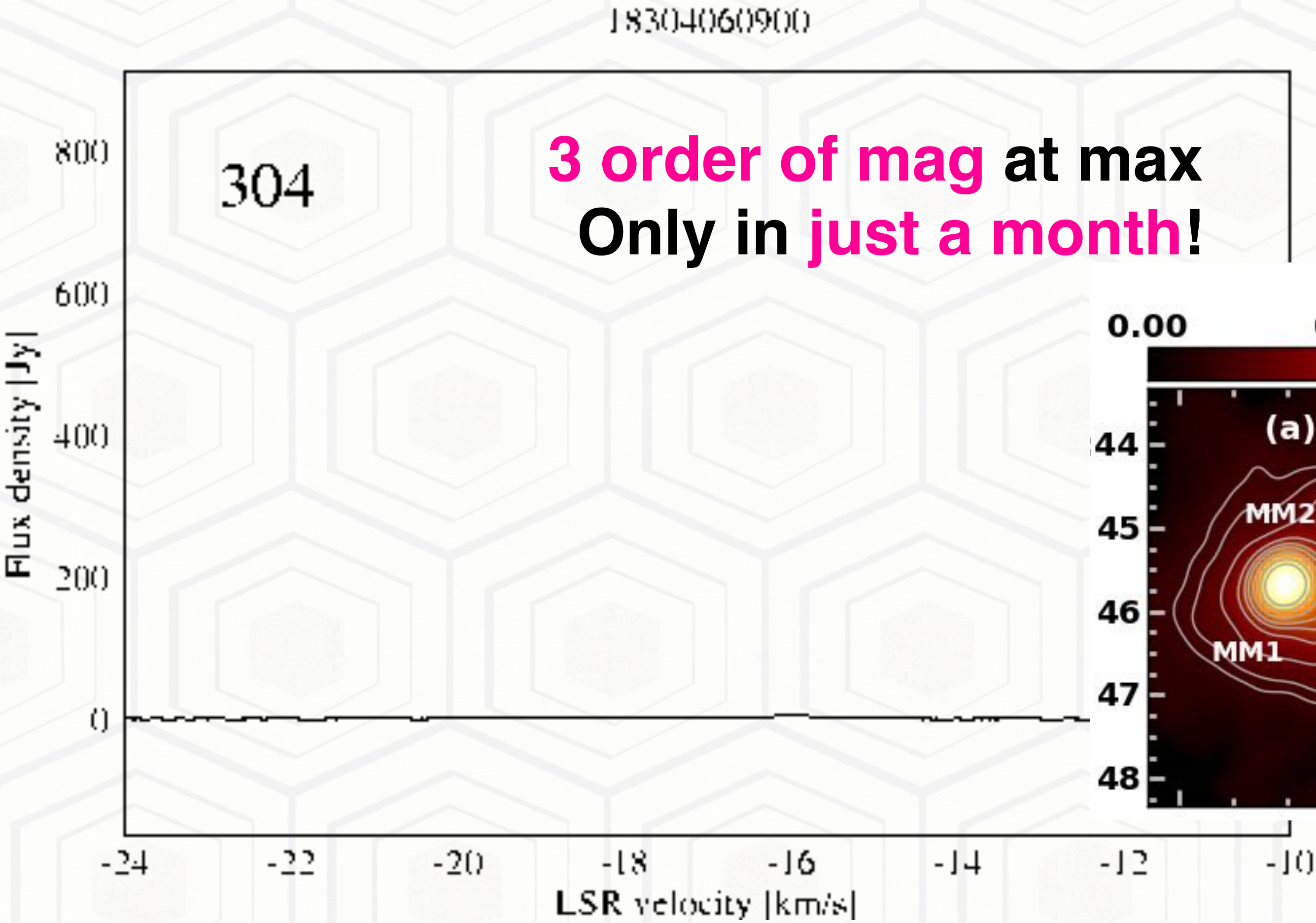
- ~ 2019/01/14 : once / 45-50 d
- 2019/01/16 ~ : 毎日

【G 358.93-00.03】

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

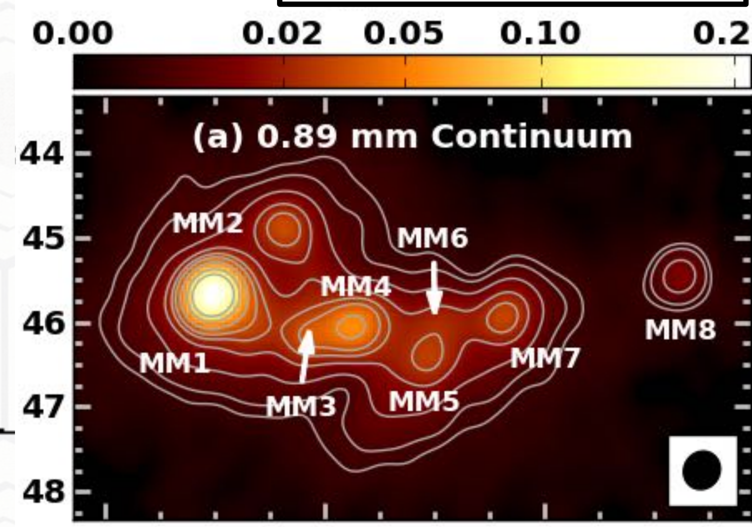
See poster by K. Sugiyama (P21)

High-mass YSO:
G358.93-0.03



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

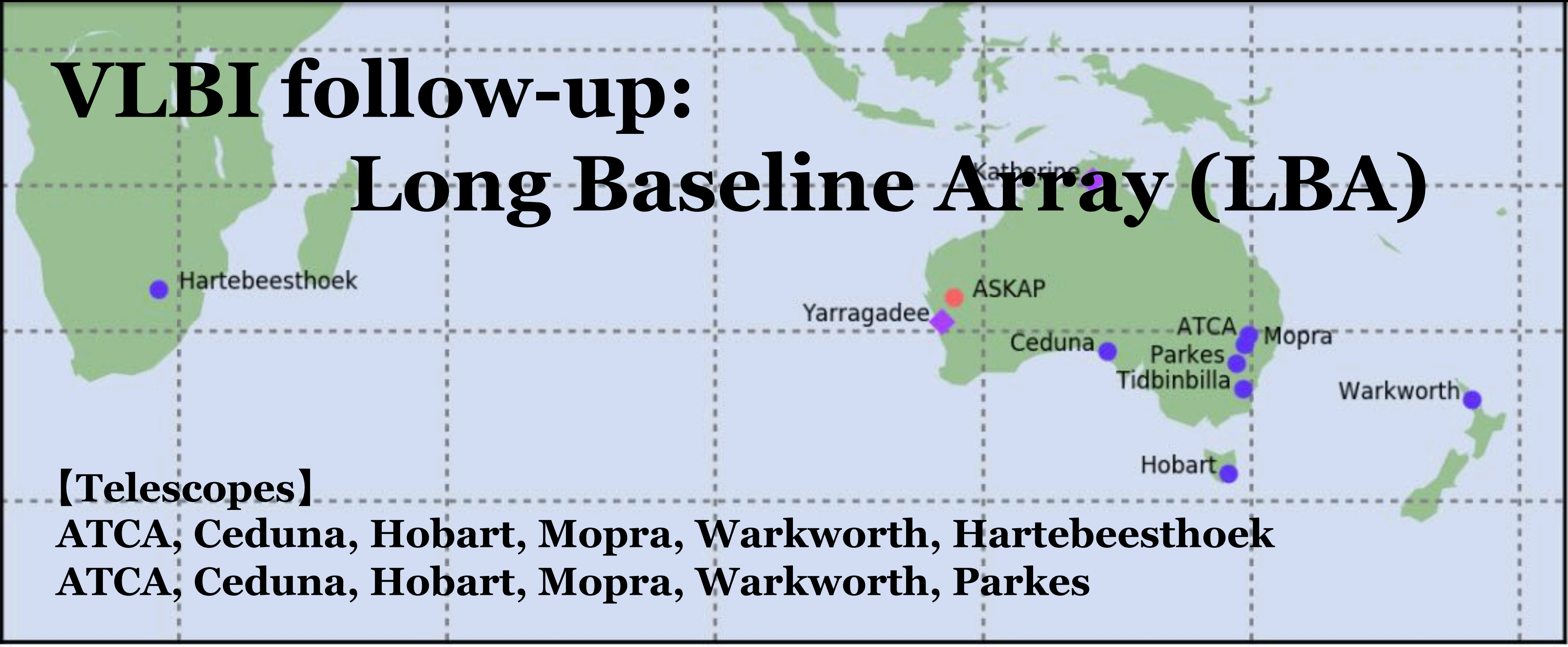
Brogan, Hunter+ (19)



© Ibaraki Univ.
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)



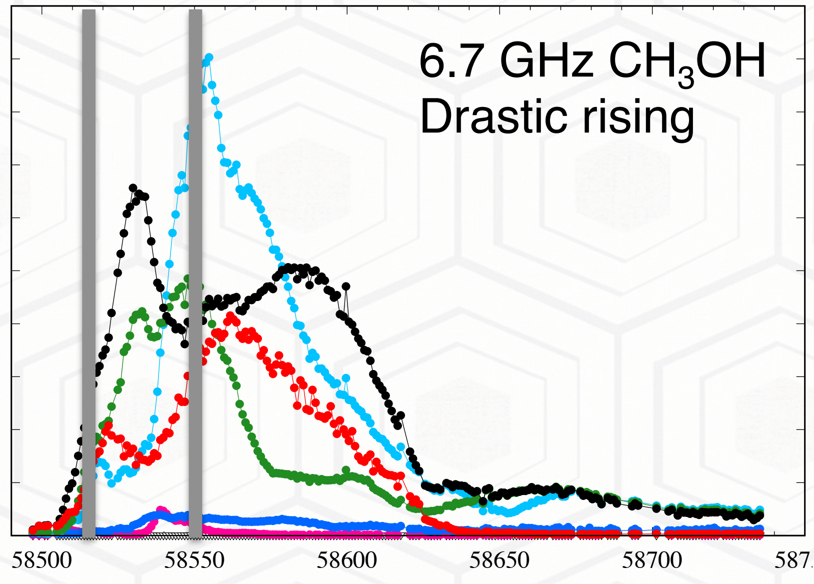
【Telescopes】
ATCA, Ceduna, Hobart, Mopra, Warkworth, Hartebeesthoek
ATCA, Ceduna, Hobart, Mopra, Warkworth, Parkes

【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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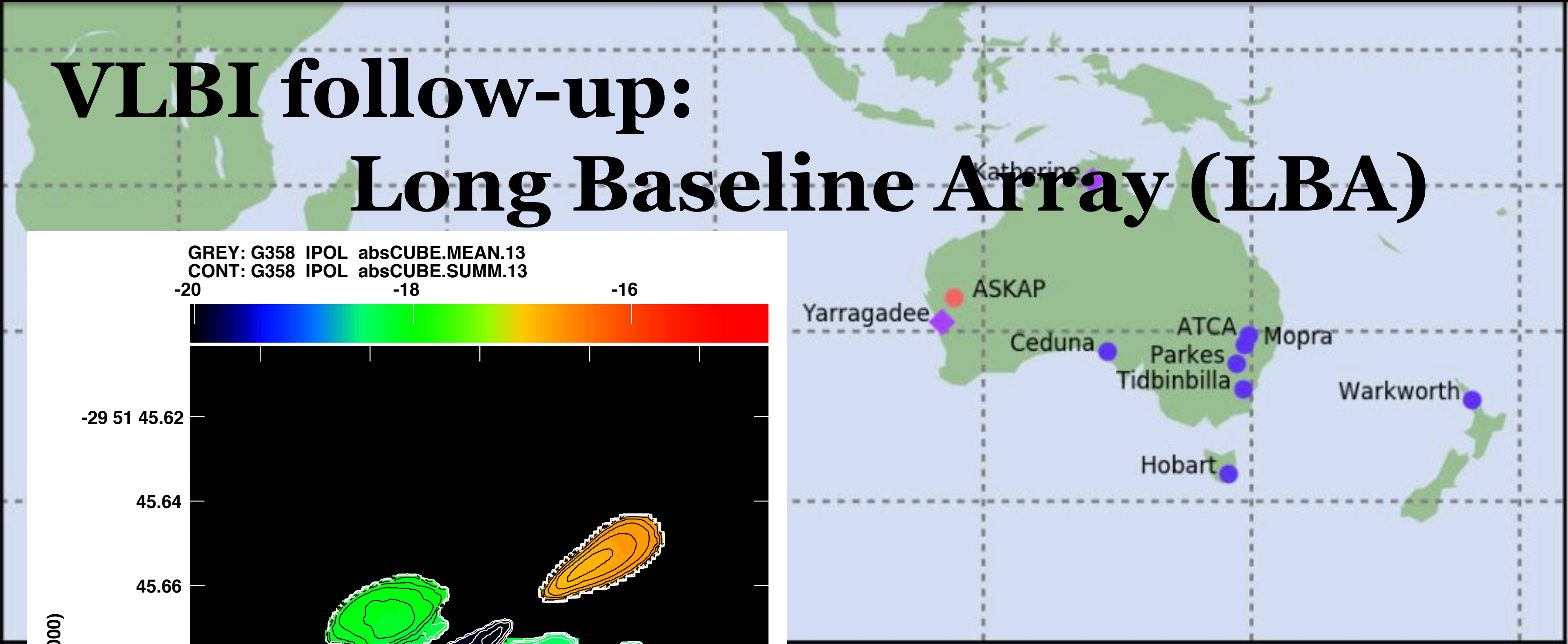
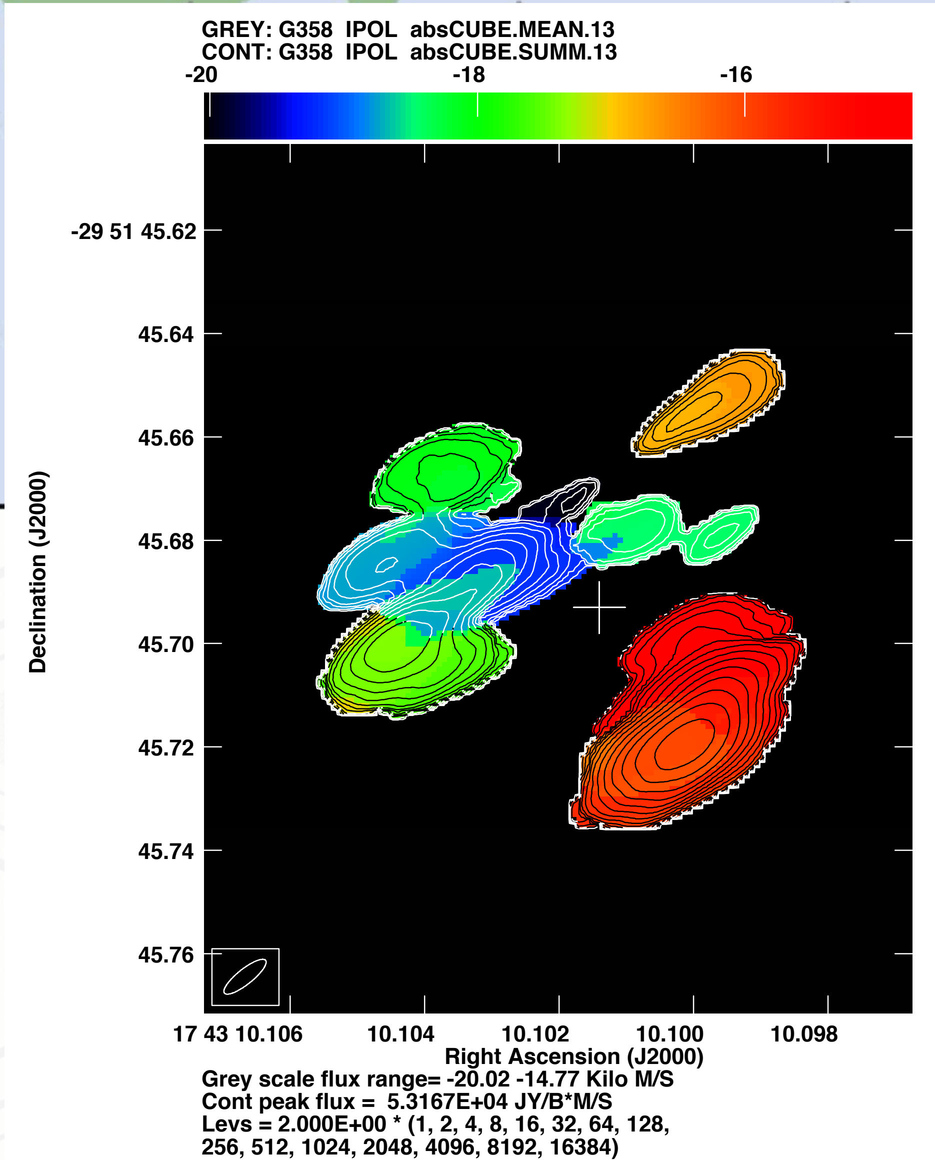
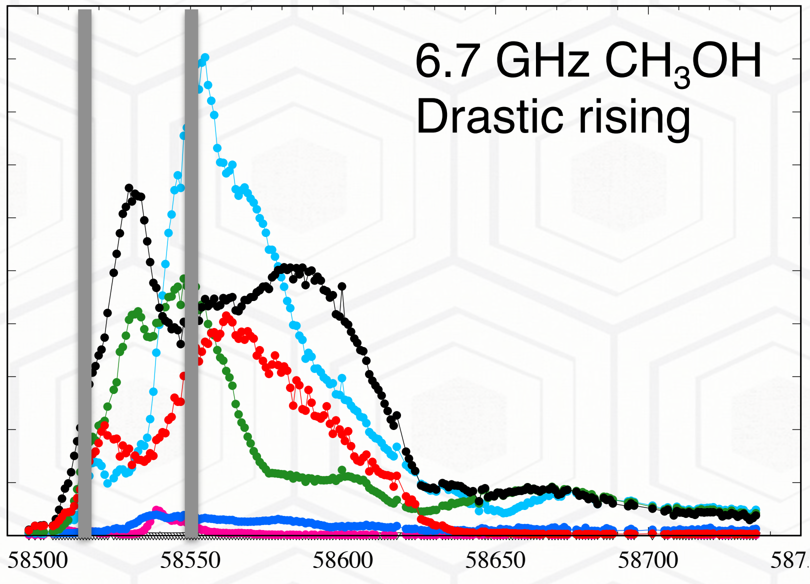
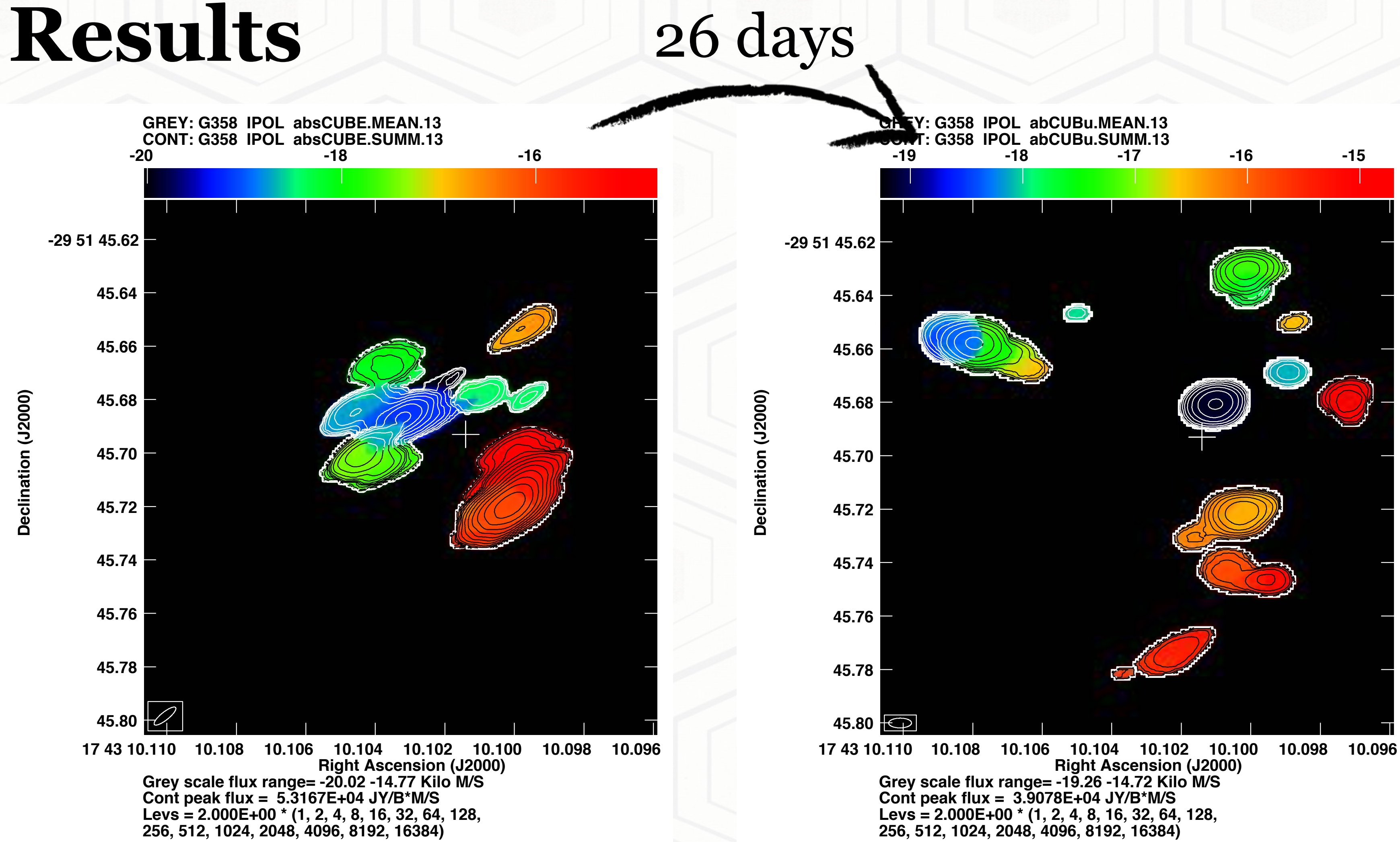






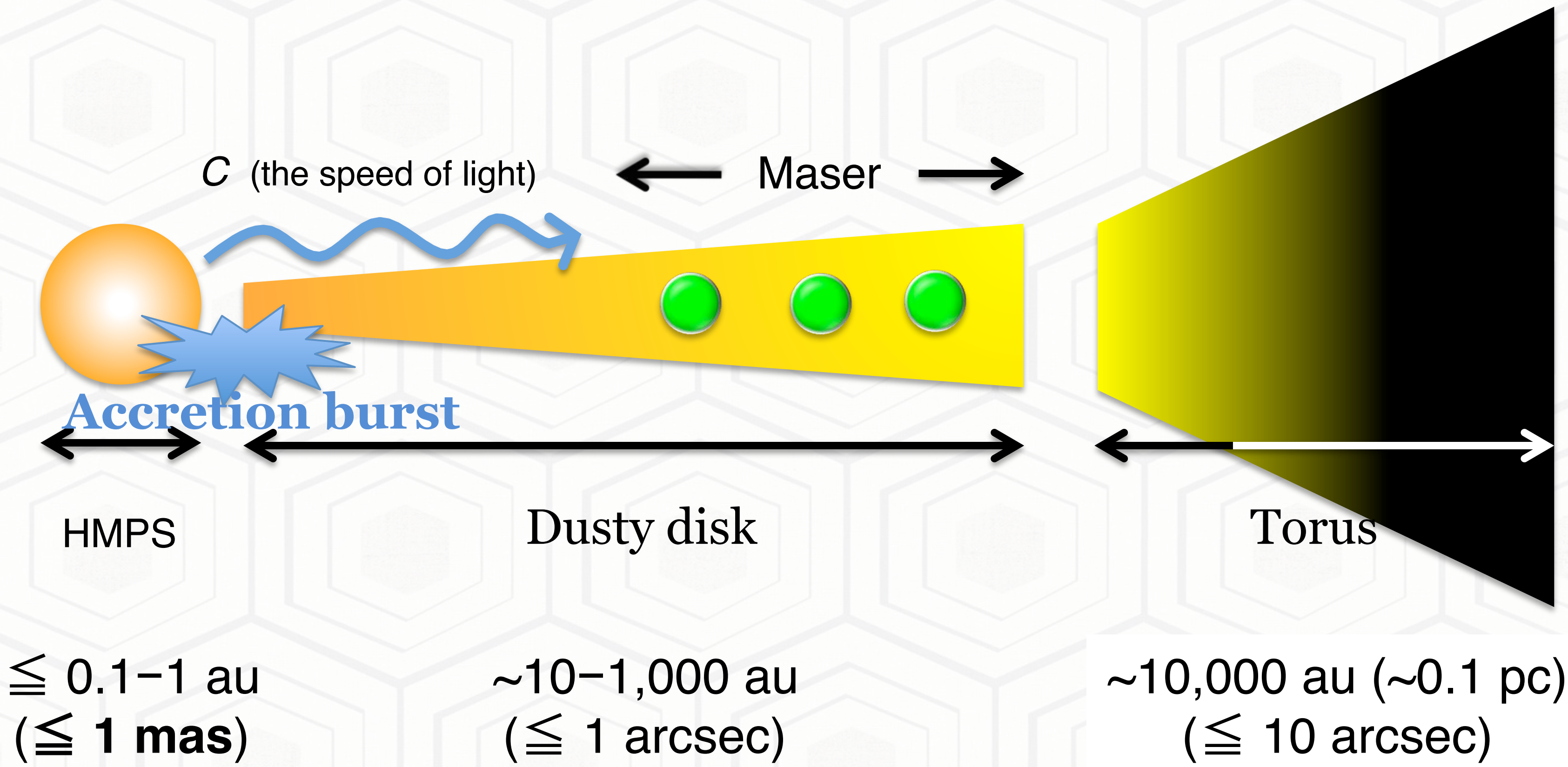
Results



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

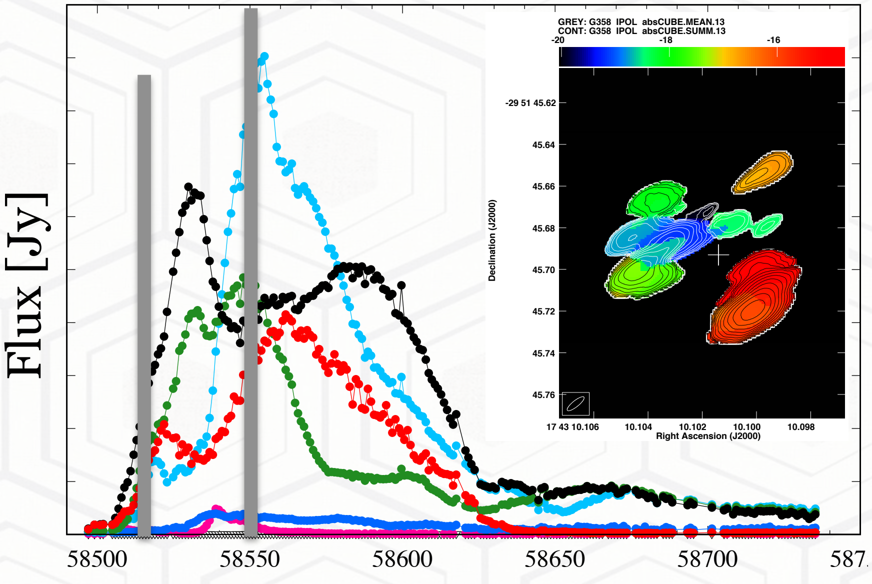


- **Thermal energy from the accretion event propagates outward**
- **Masers are created / destroyed at ever-increasing radii**
- **Strong support for an accretion event**

Concluding viewpoints:

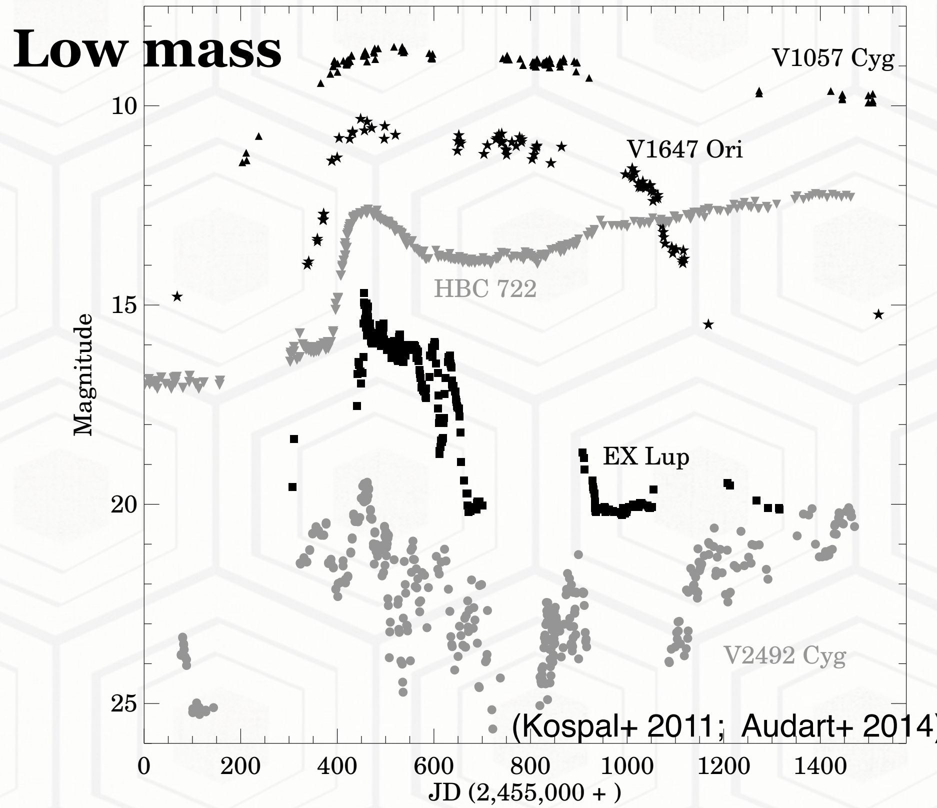
- **The M2O: effective communication and follow-up**
- **Observed a "heat-wave" from the G358 accretion burst**
- **Extreme maser evolution**
- **Fast VLBI responses critical**
- **Dissimilar to S255 / NGC6334**

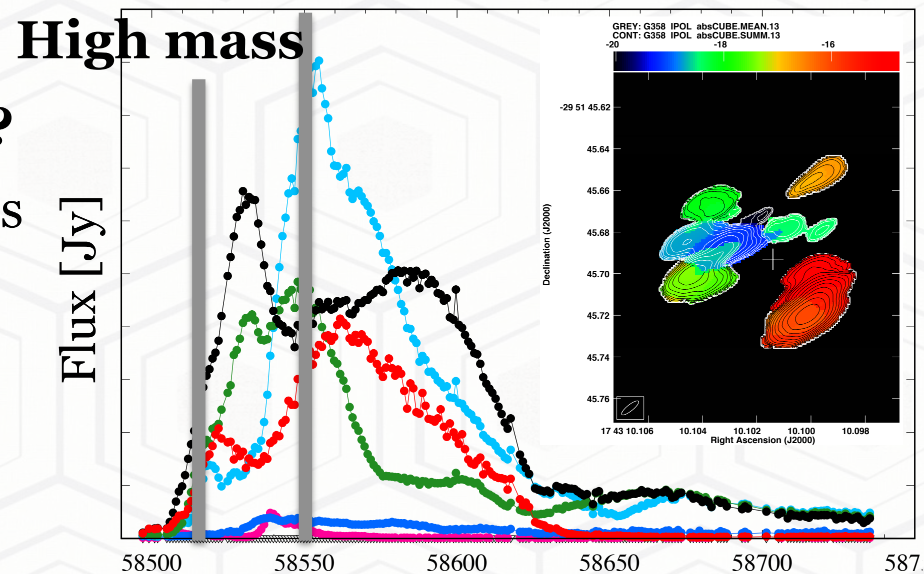
G358 6.7 GHz



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

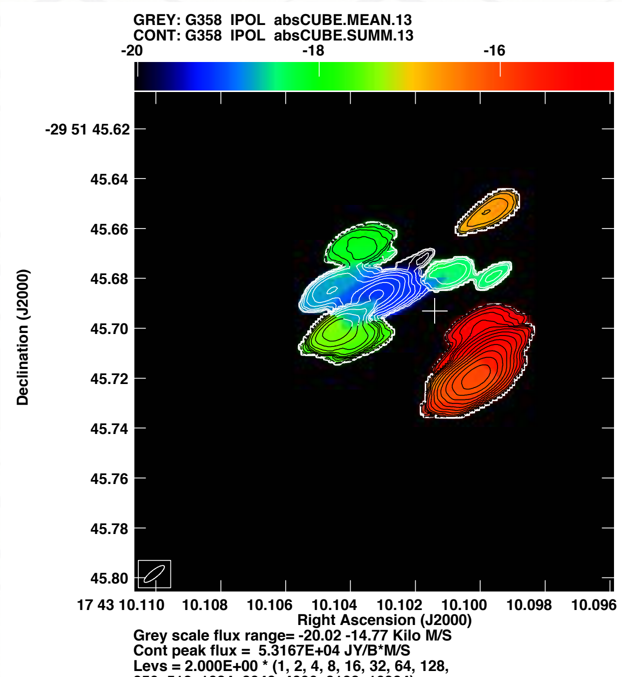


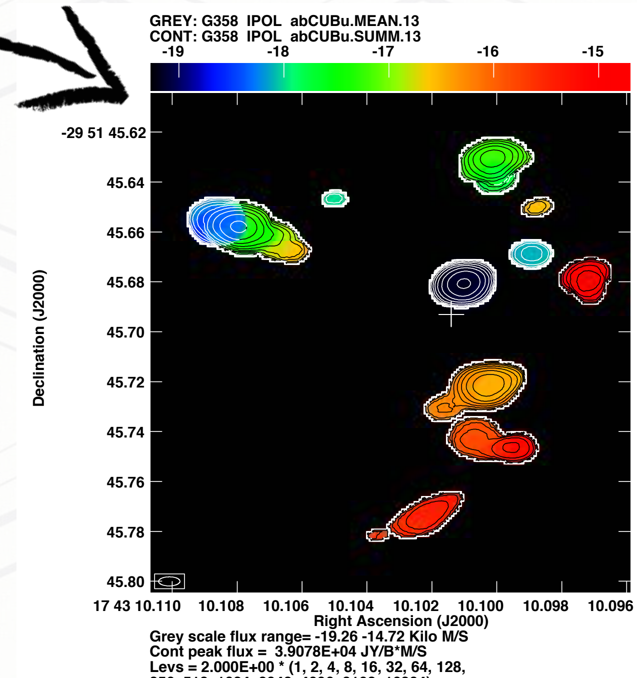


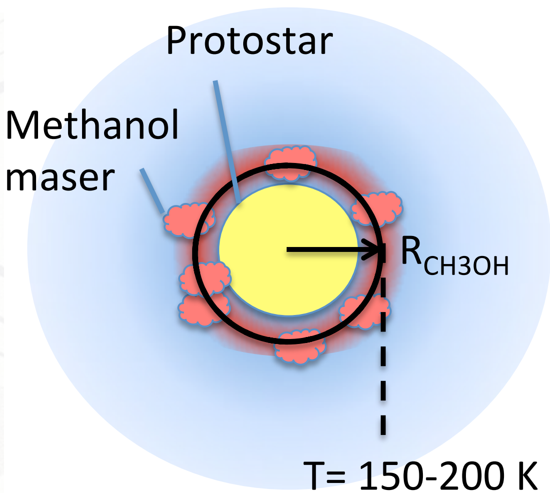
Thank you

Results

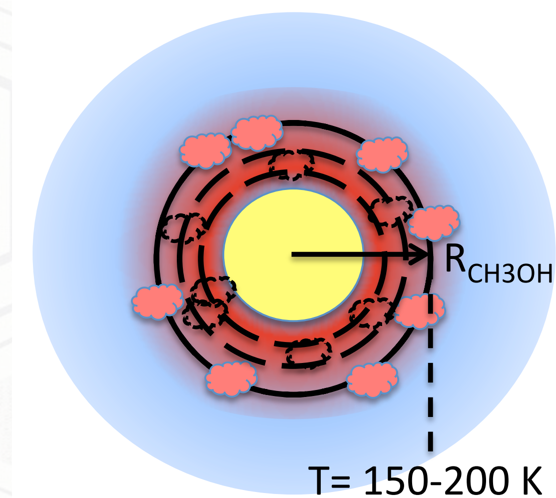
26 days





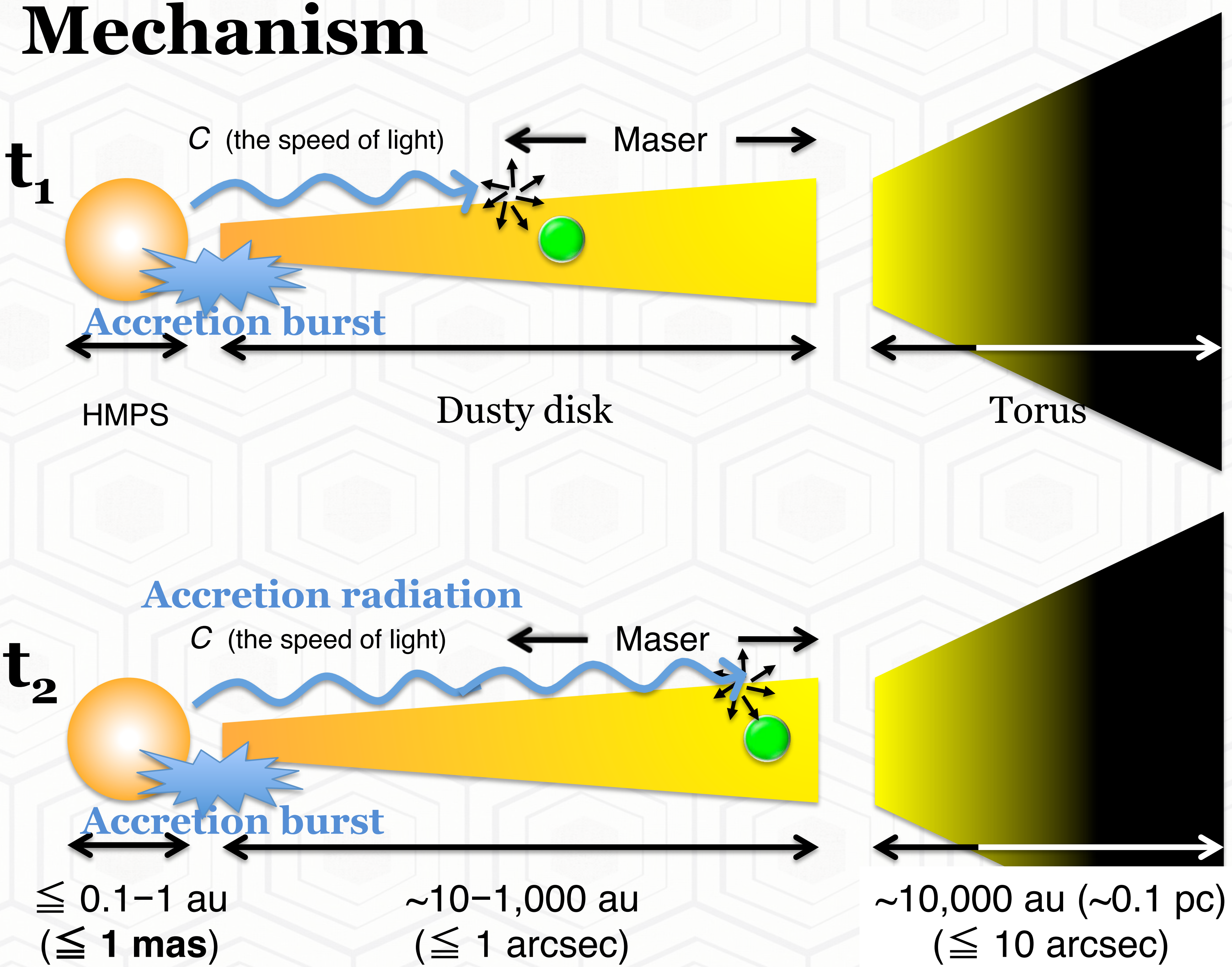


First epoch



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)