Unveiling Hidden Stellar Seeds by Radio Observations

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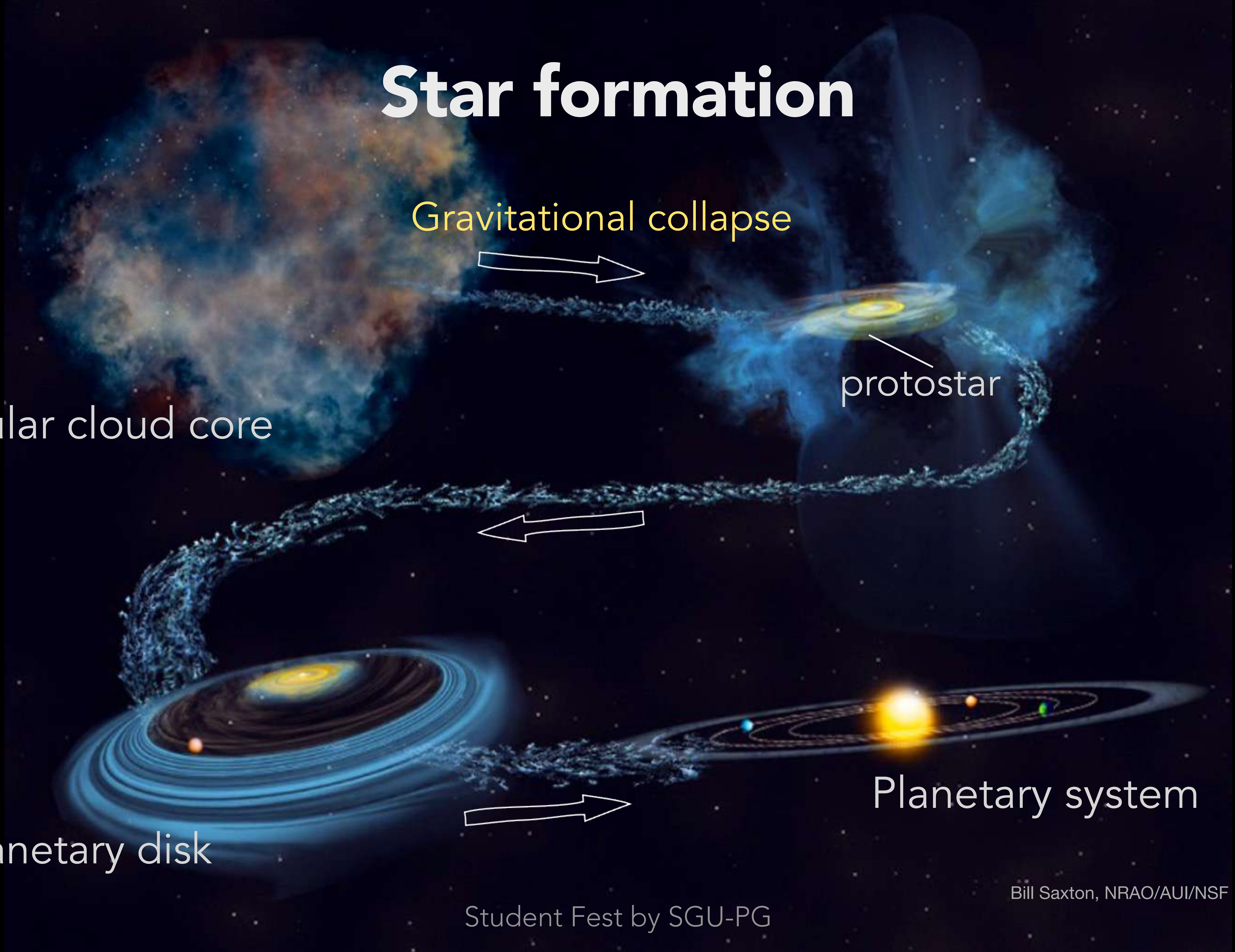
ESO/José Francisco Salgado

How do stars form?

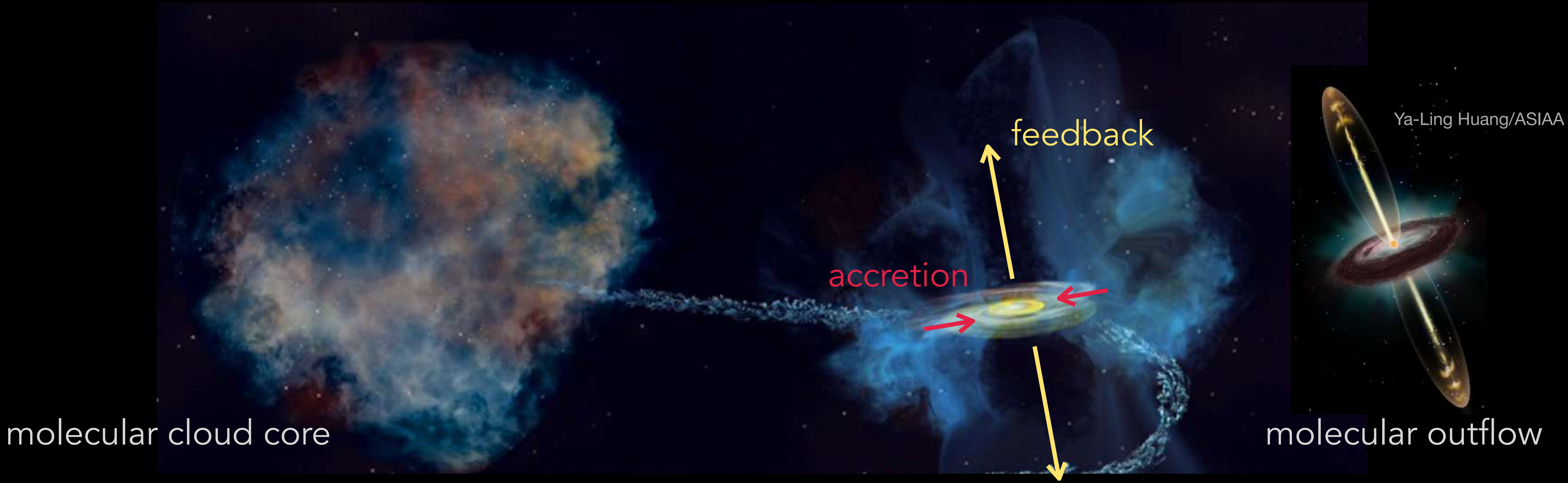
ESO/José Francisco Salgado

Star formation



Bill Saxton, NRAO/AUI/NSF

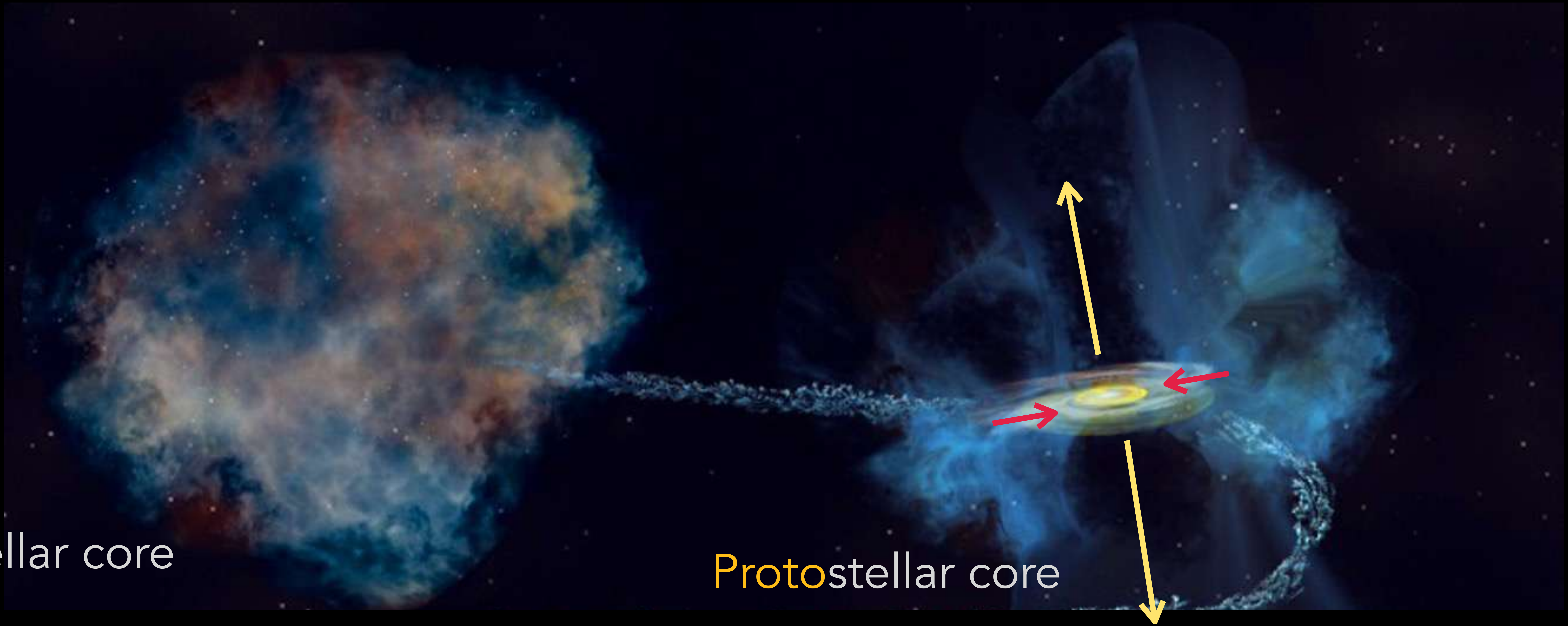
Star formation



Core to star formation efficiency of ~ 30-50%

⇒ Core mass more than $\gtrsim 30\,M_\odot$ and high mass accretion rate ($10^{-3}\,M_\odot\,\mathrm{yr}^{-1}$) are required to form high-mass stars ($> 8\,M_\odot$).

Star formation



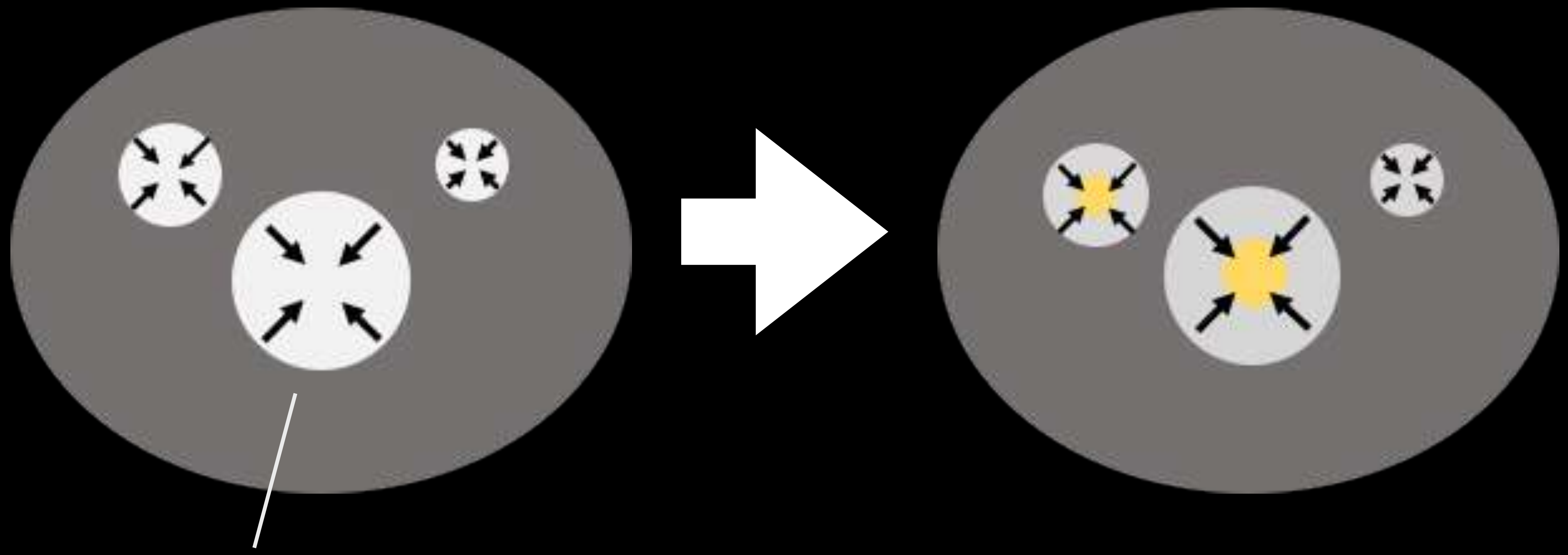
Q: How to form such a high-mass core?

Q: Do high-mass "prestellar" cores exist?

High-mass star formation scenario

Core-fed accretion scenario

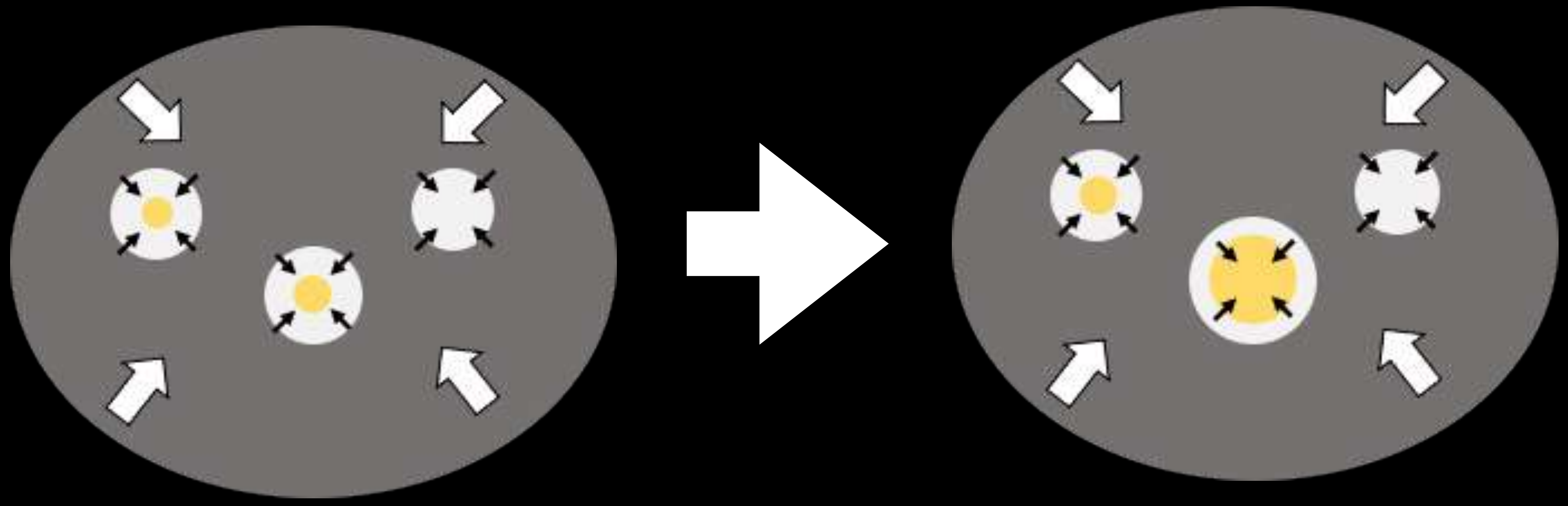
High-mass prestellar core
supported by strong turbulence
or magnetic field



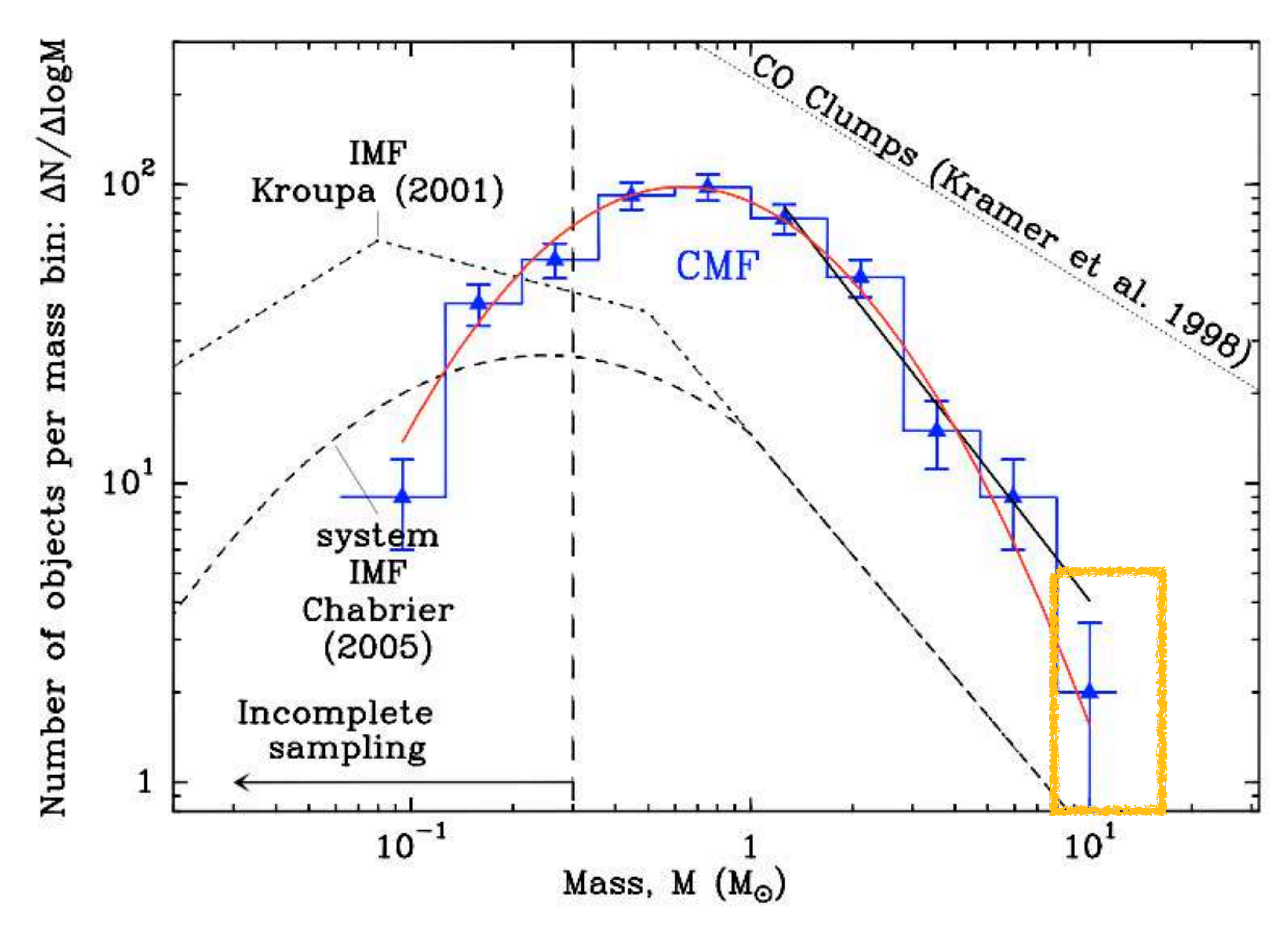
A high-mass prestellar core

Clump-fed accretion scenario

Initially low- to intermediate-mass cores
that grow in mass through gas feeding
to form high-mass protostar



The rarity of high-mass stars



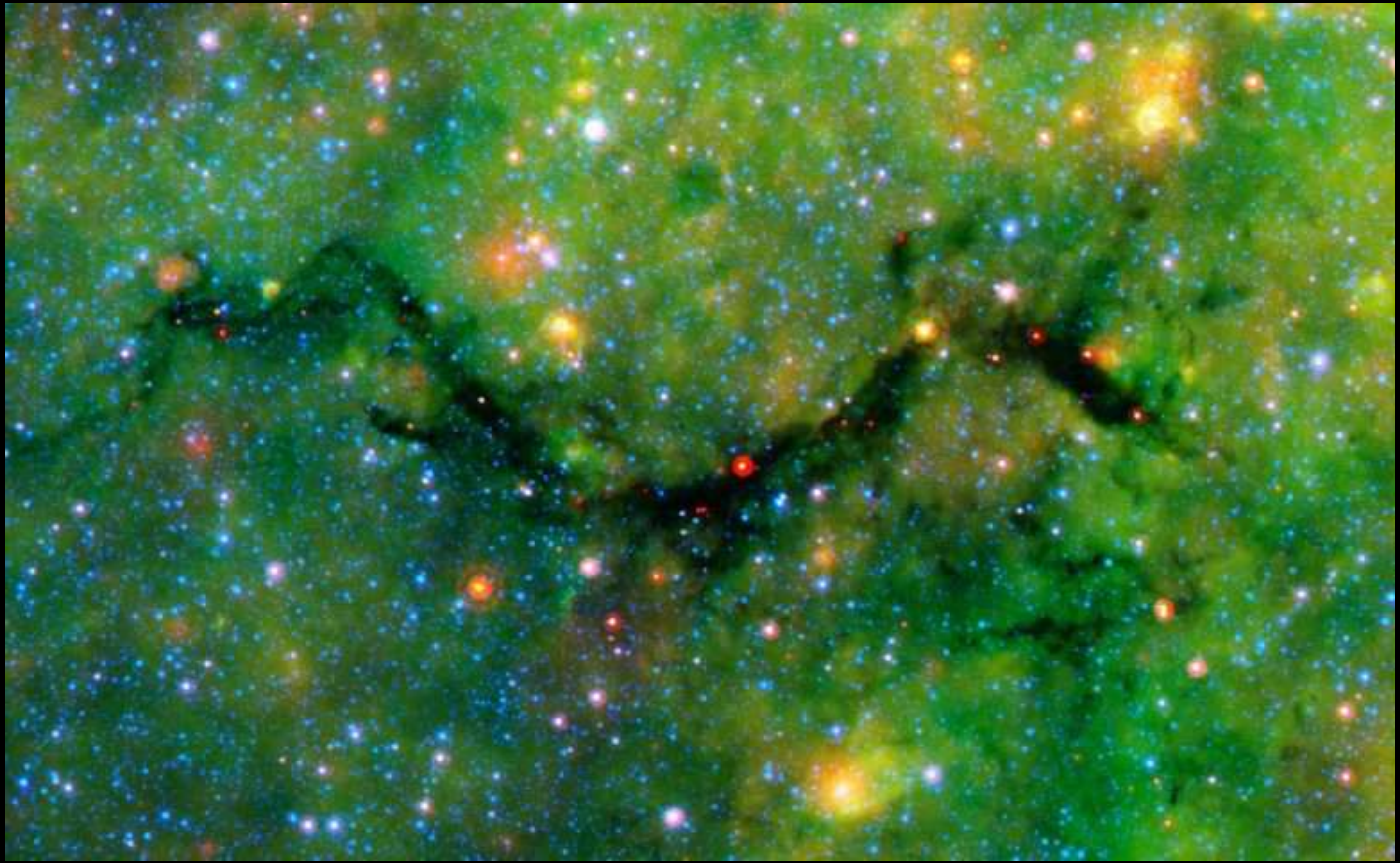
Konyves et al. 2010

Initial mass function (IMF) suggests that the ratio of high-mass stars is ~1%.

They are rare, and locate far from the sun.
⇒ Observations are difficult!

So far, only one or two candidates for high-mass prestellar core are reported (e.g., Nony et al. 2018).

Infrared-dark Cloud (IRDC)



NASA/JPL-Caltech
S. Carey (SSC/Caltech)

Massive (>10^3 Msun),
dense (>0.1 g cm^{-2}),
and cold (T<10 K) region

d > 3 kpc
(~10,000 light year)

Dark at optical and IR wavelength, but bright at radio

Difficulties in observing IRDCs

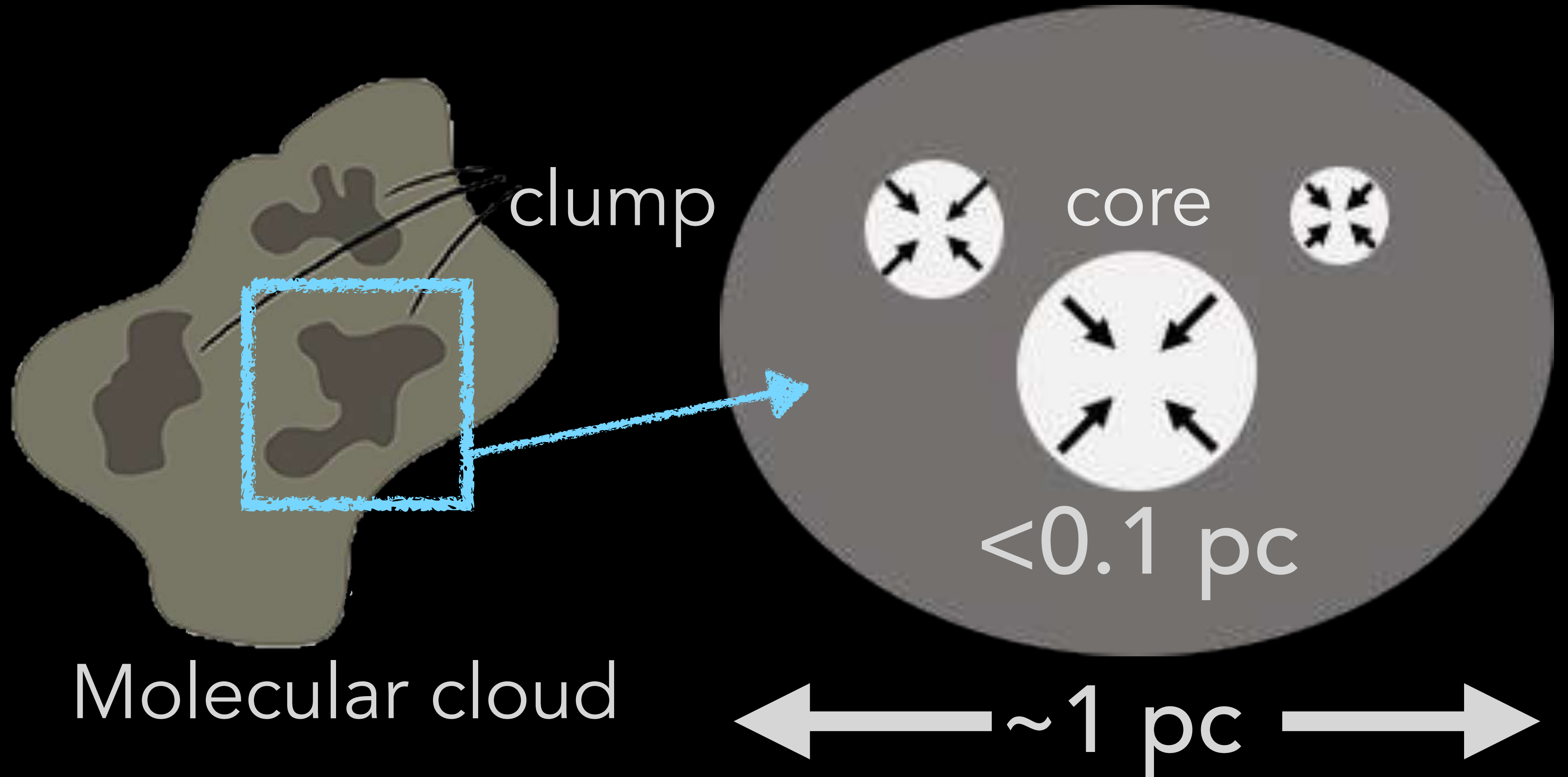
Angular resolution ~ wavelength / diameter

Nobeyama 45 m telescope

Angular resolution: 14.4 arcsec.

⇒ 0.20 pc (at 3 kpc target)

NOT enough to resolve cores

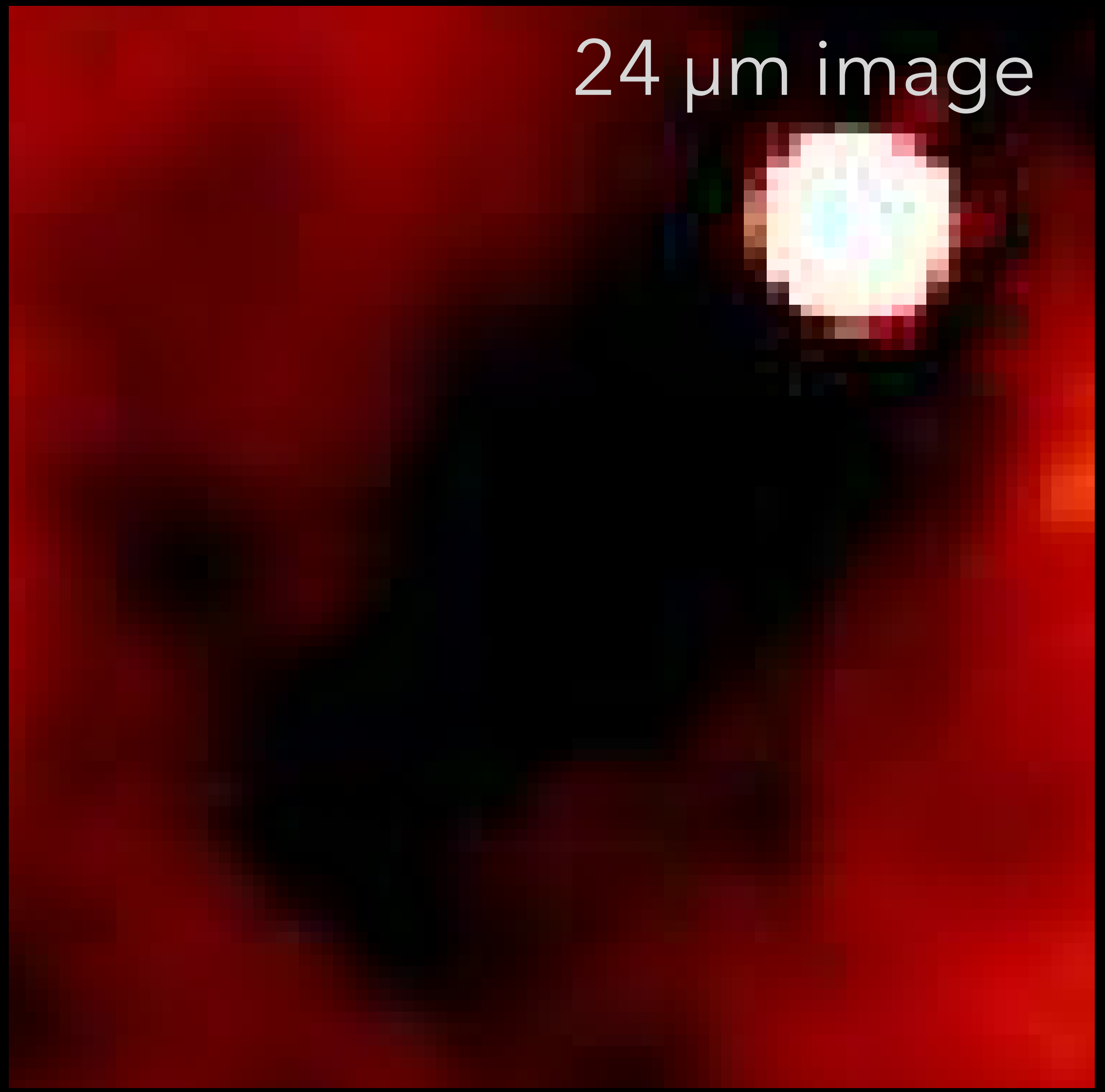


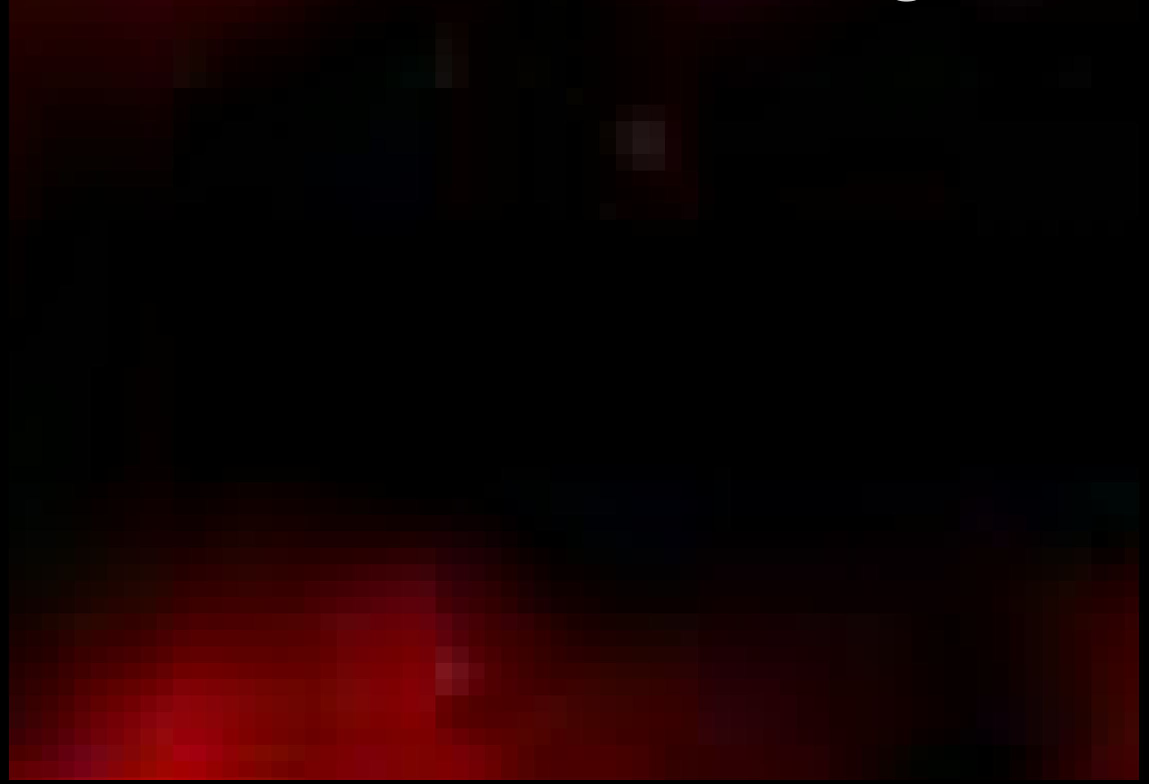
Atacama Large Millimeter/submillimeter Array

Maximum spatial resolution: ~0.04 arcsec. ⇒ 7×10^{-4} pc (at 3 kpc target)

Clem & Adri Bacri-Normier/ESO

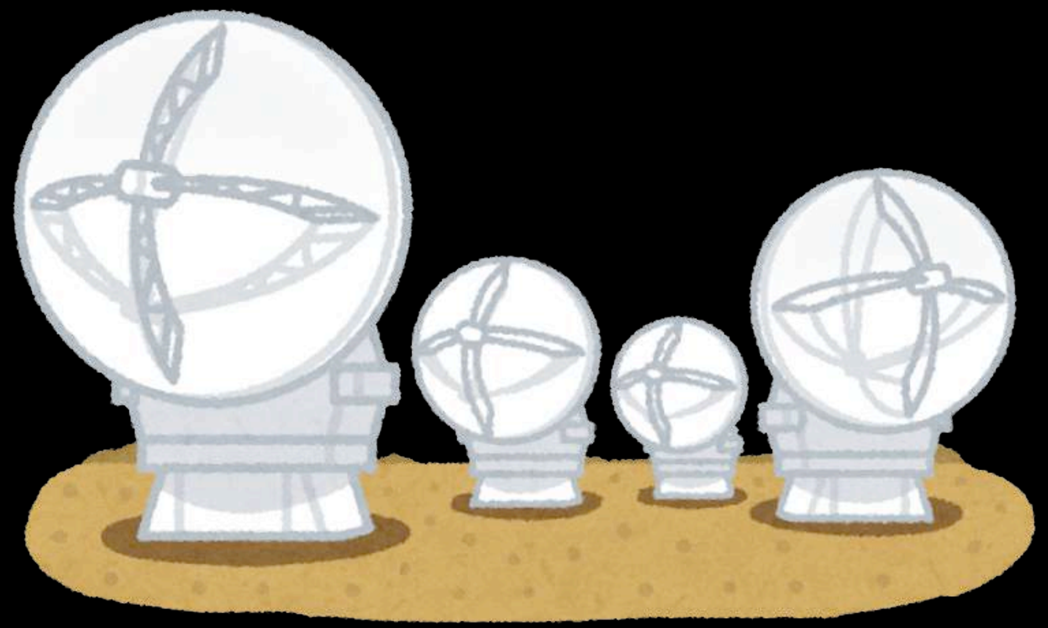
Radio observations reveal cold stellar seeds

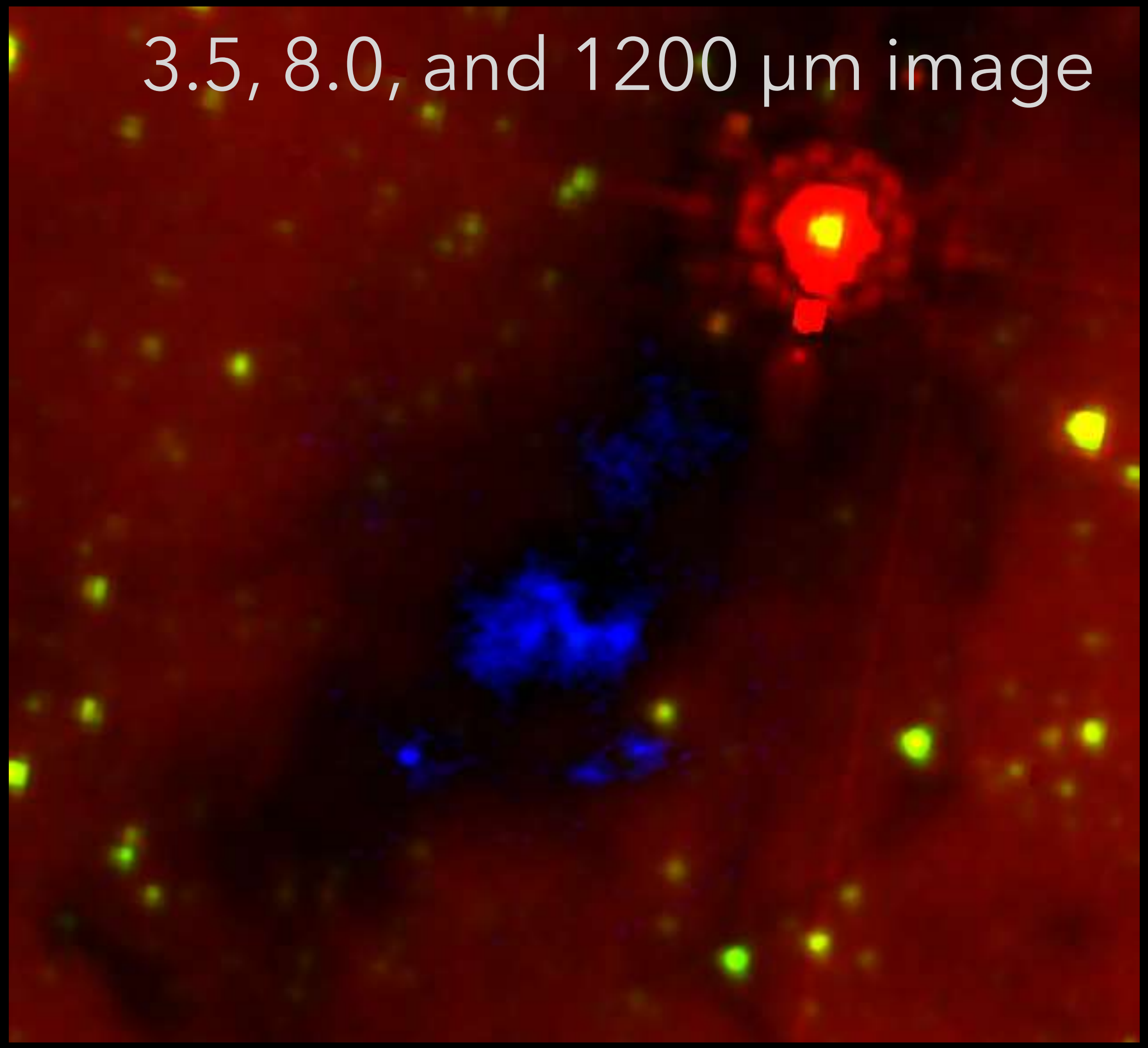




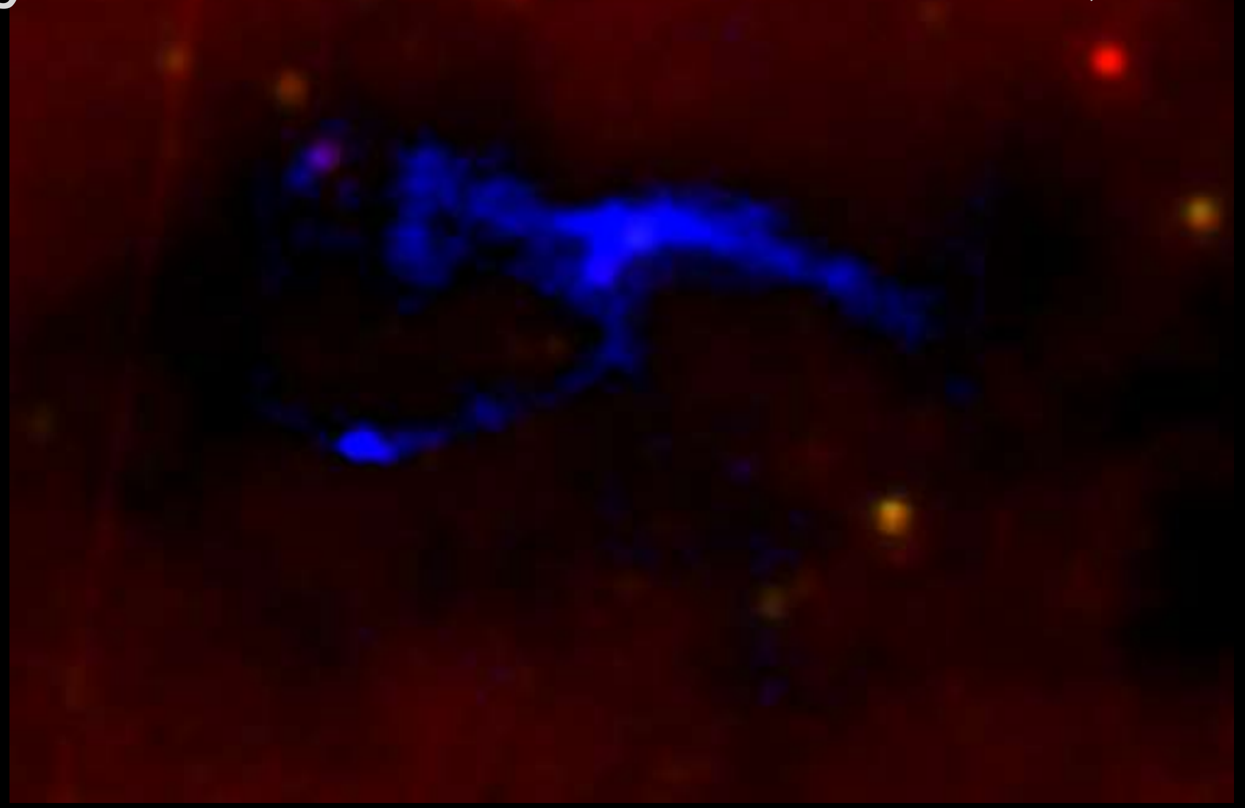
Dark patches are invisible at optical and IR wavelengths

ALMA



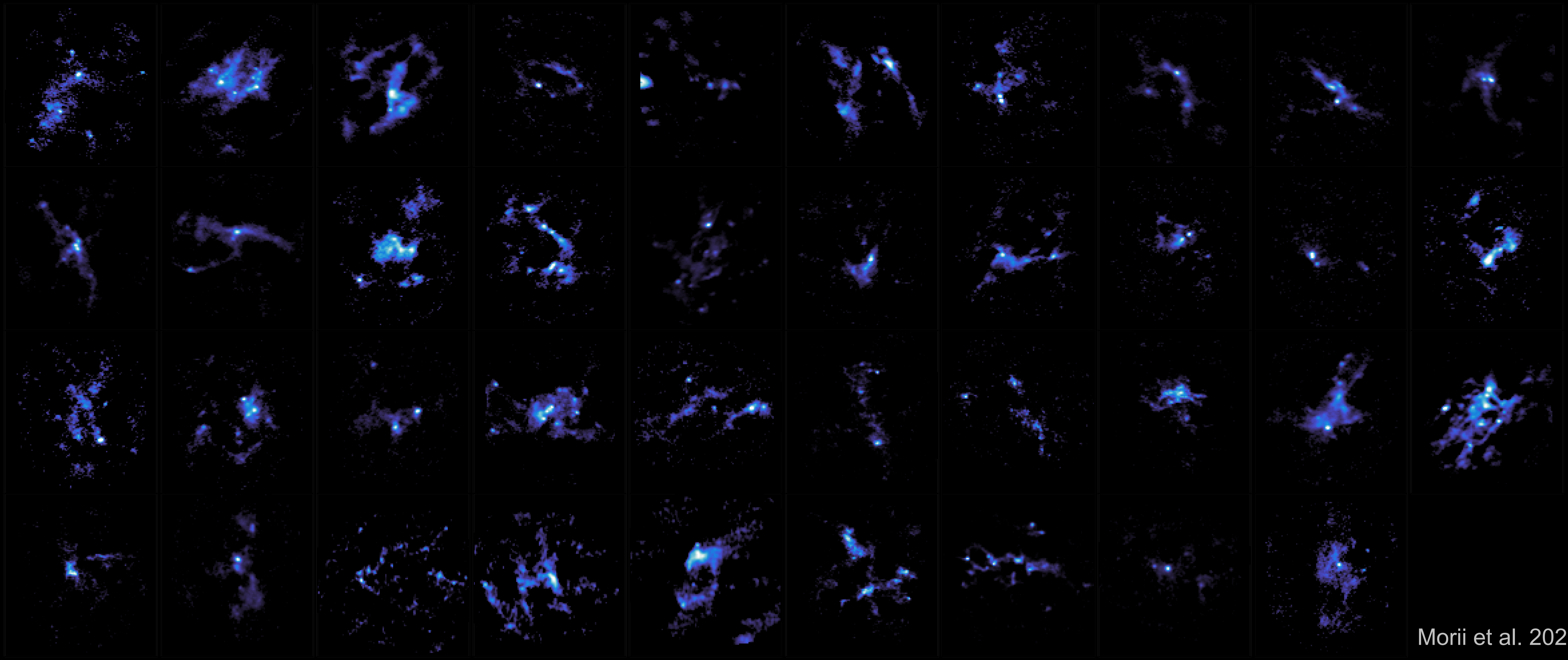


Deeply embedded star formation can only be revealed with ALMA (blue color)



Morii et al. 2023

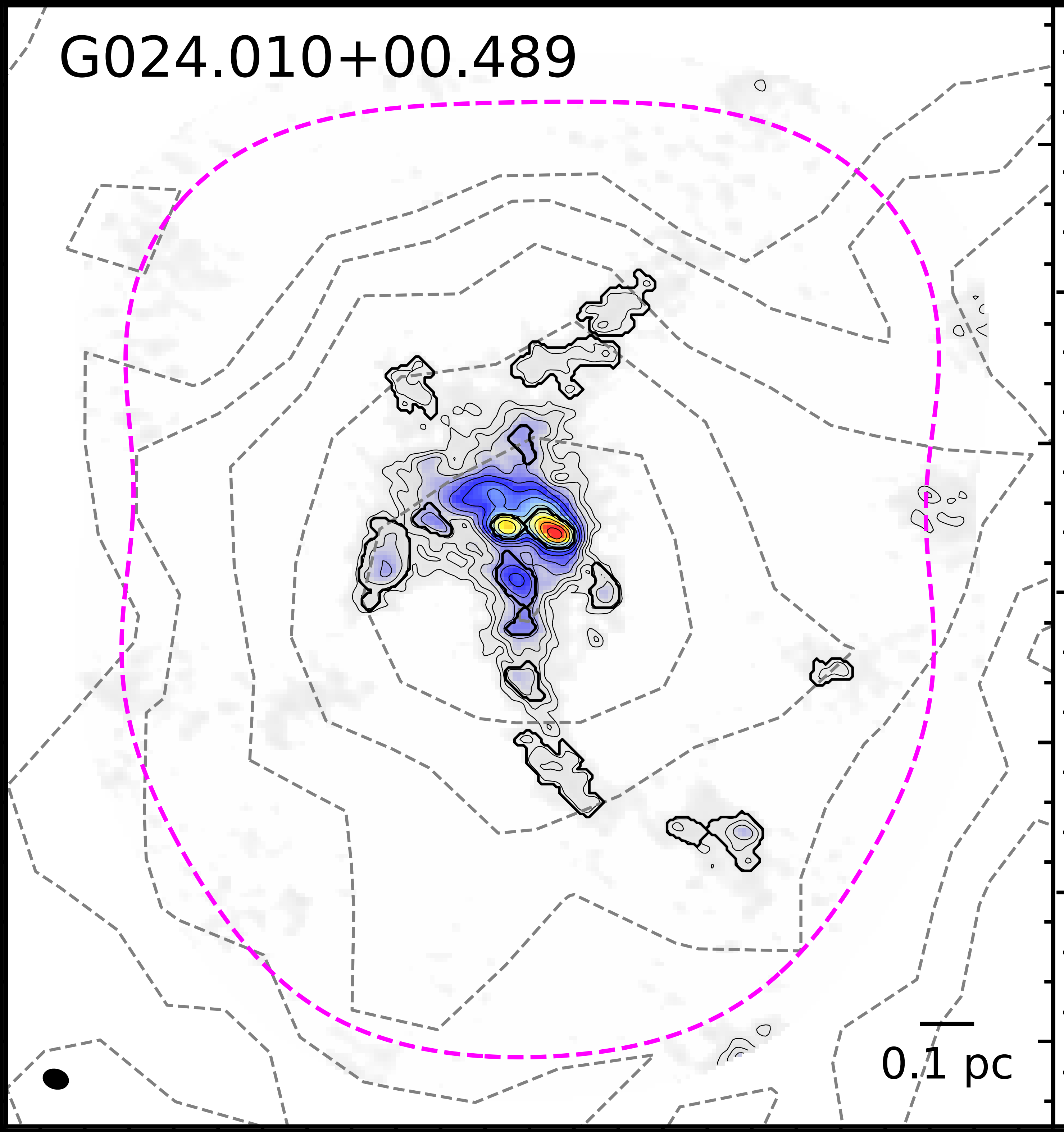
The ALMA Survey of 70 μm dark High-mass clumps in Early Stages (ASHES)



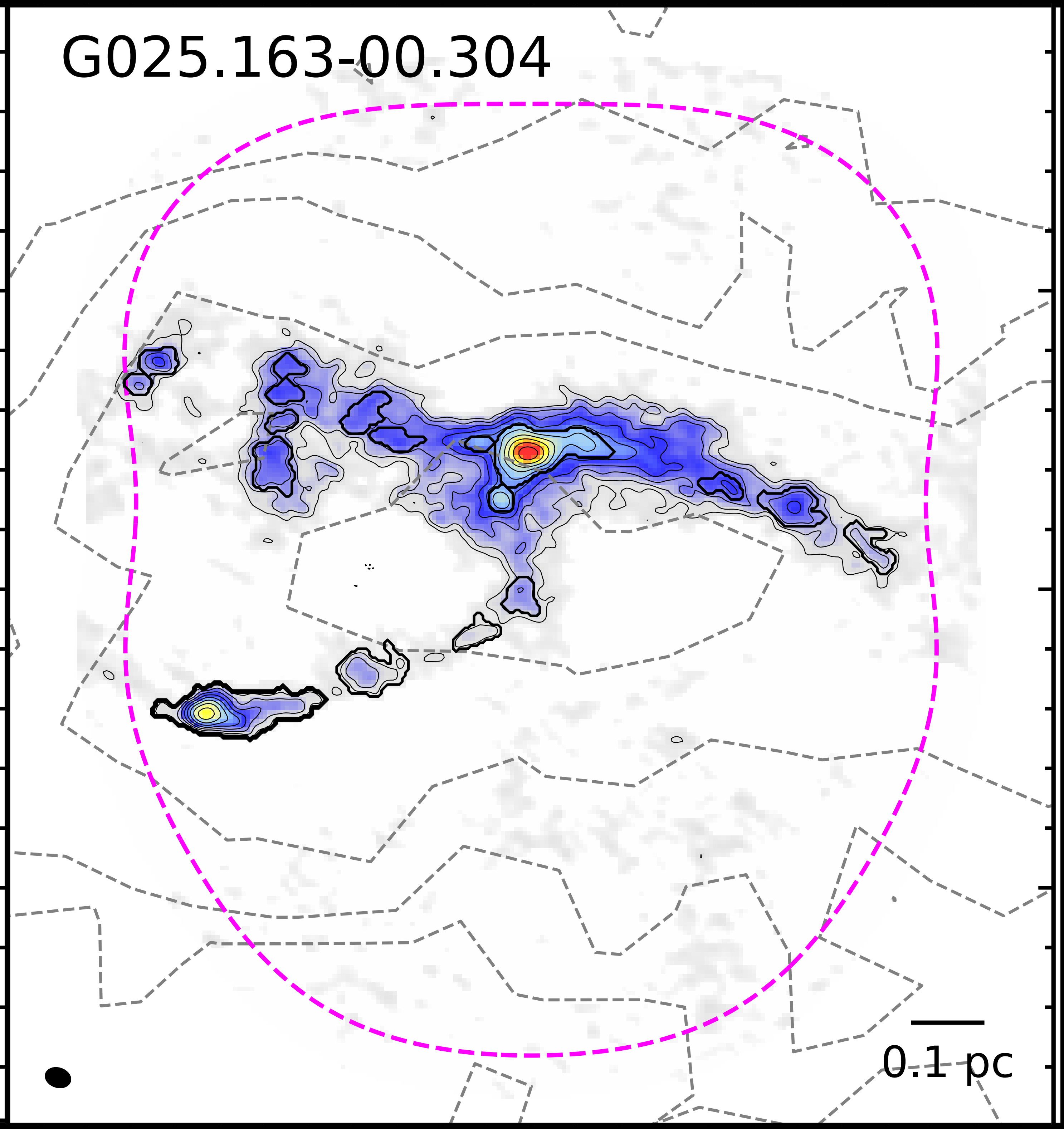
Morii et al. 2023

Internal structure of 70 μm-dark massive clumps

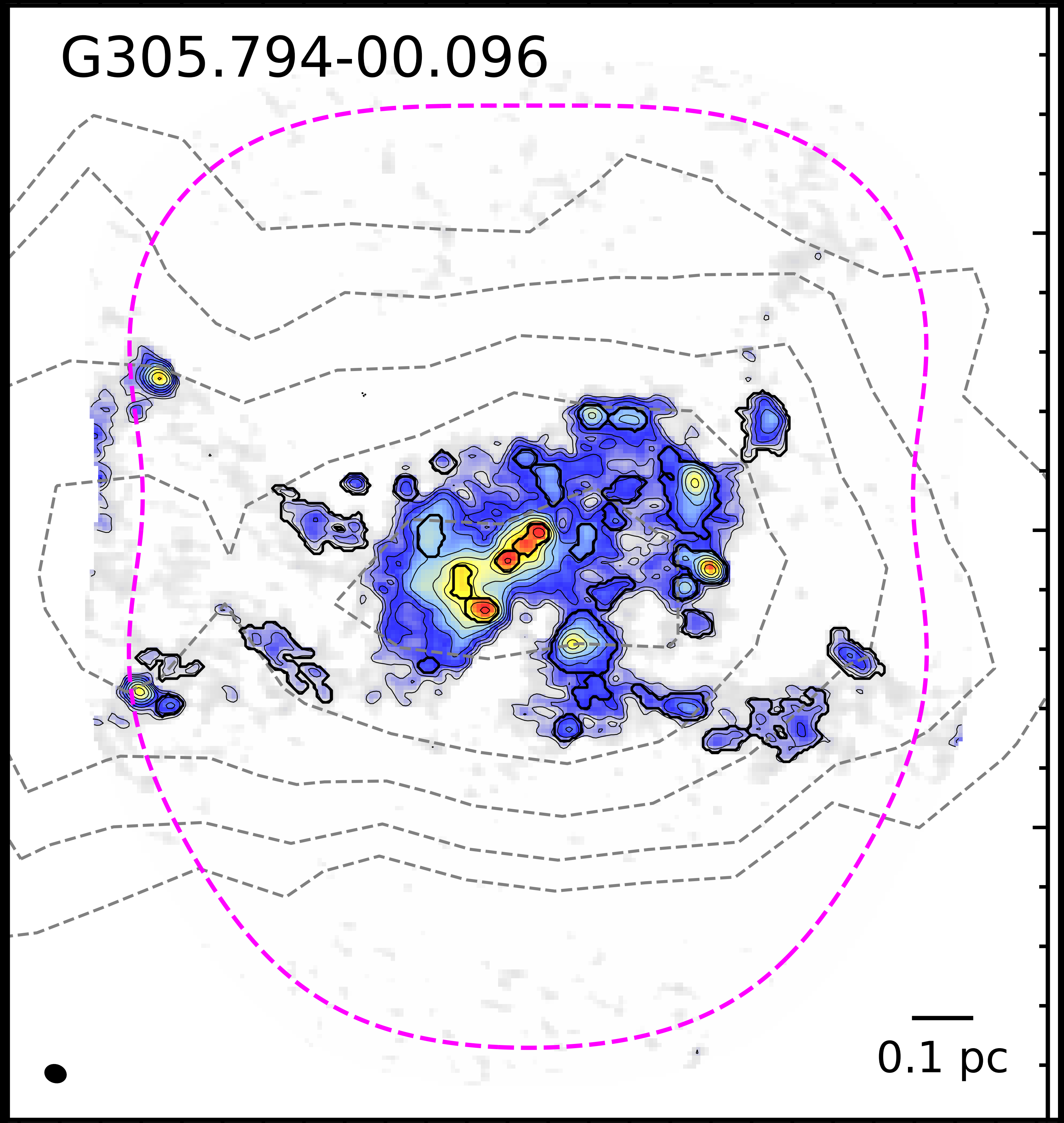
Filamentary structure



Hub-filament system



Clumpy structure



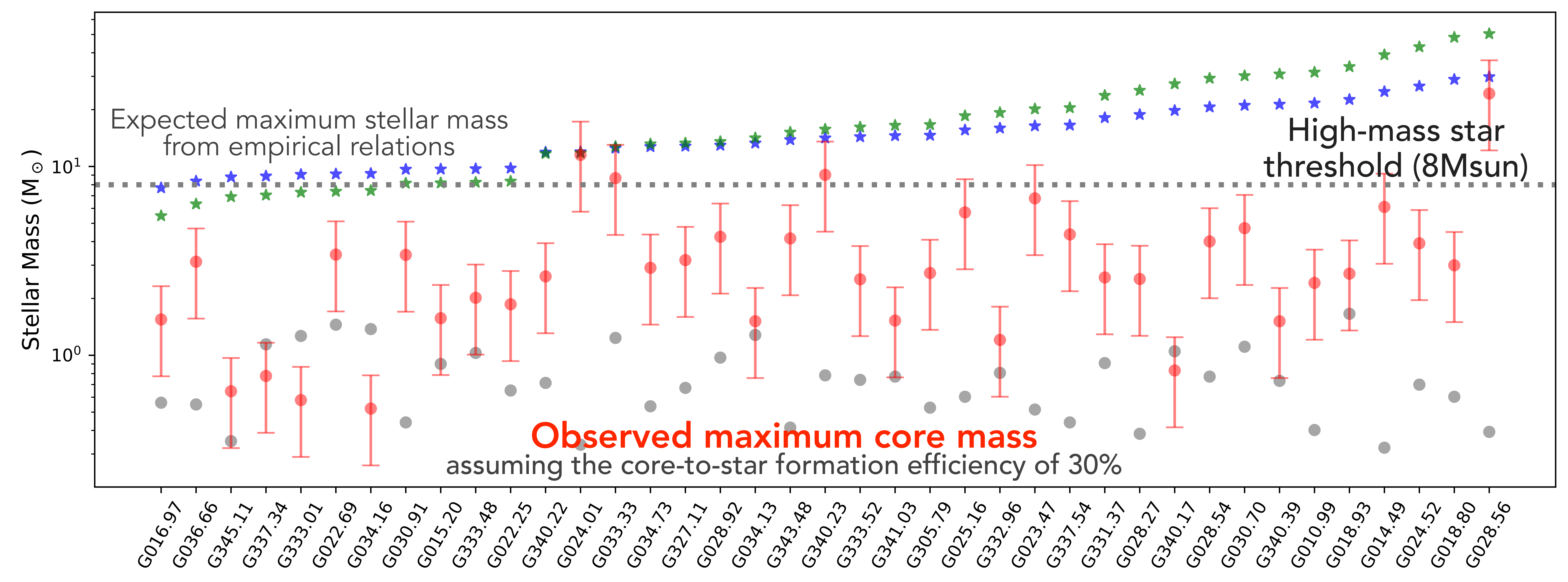
dendrogram algorithm →

839 cores

Morii et al. 2023

Core Mass

$F_{1.3\,\mathrm{mm}} \rightarrow M_{\mathrm{dust}} \rightarrow M_{\mathrm{core}}$



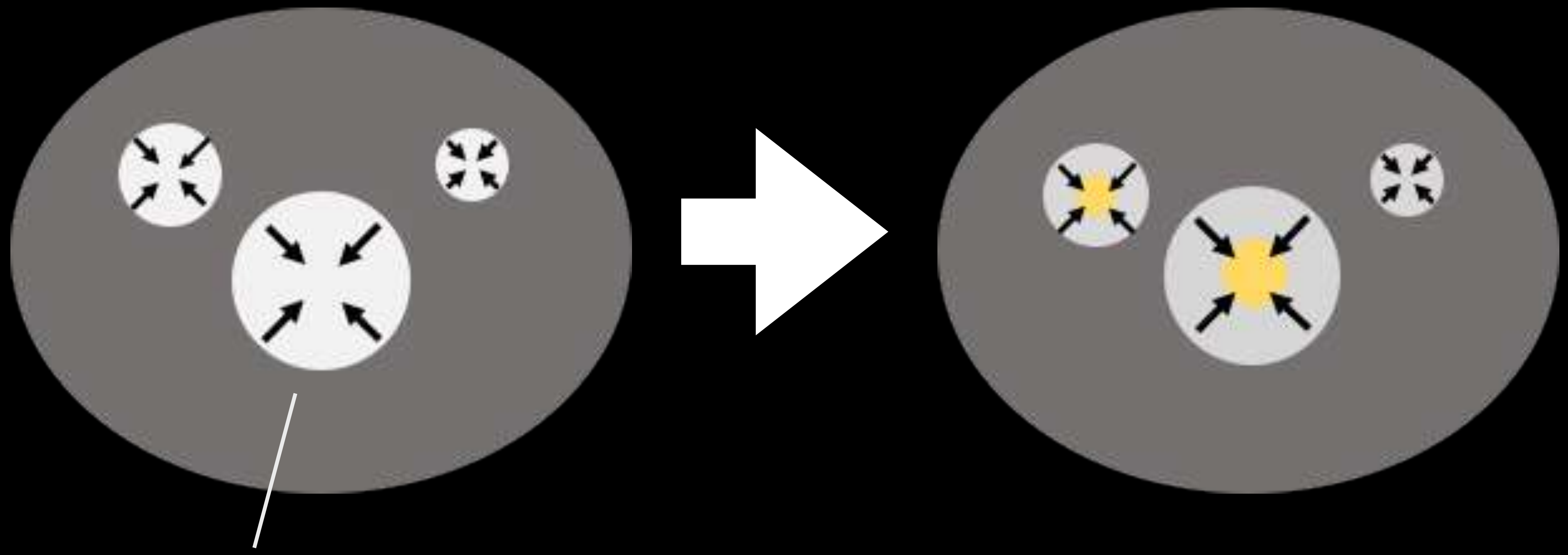
The most massive cores are low- to intermediate-mass cores,
not enough massive to form HM stars.

Morii et al. 2023

High-mass star formation scenario

Core-fed accretion scenario

High-mass prestellar core supported by strong turbulence or magnetic field



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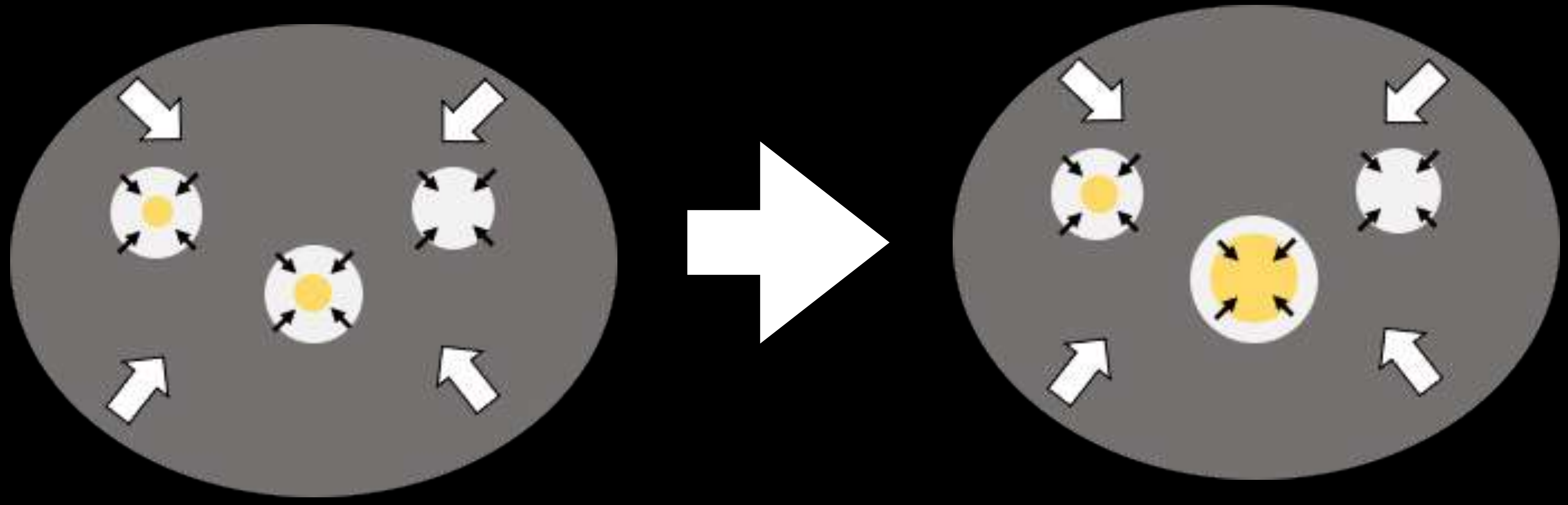
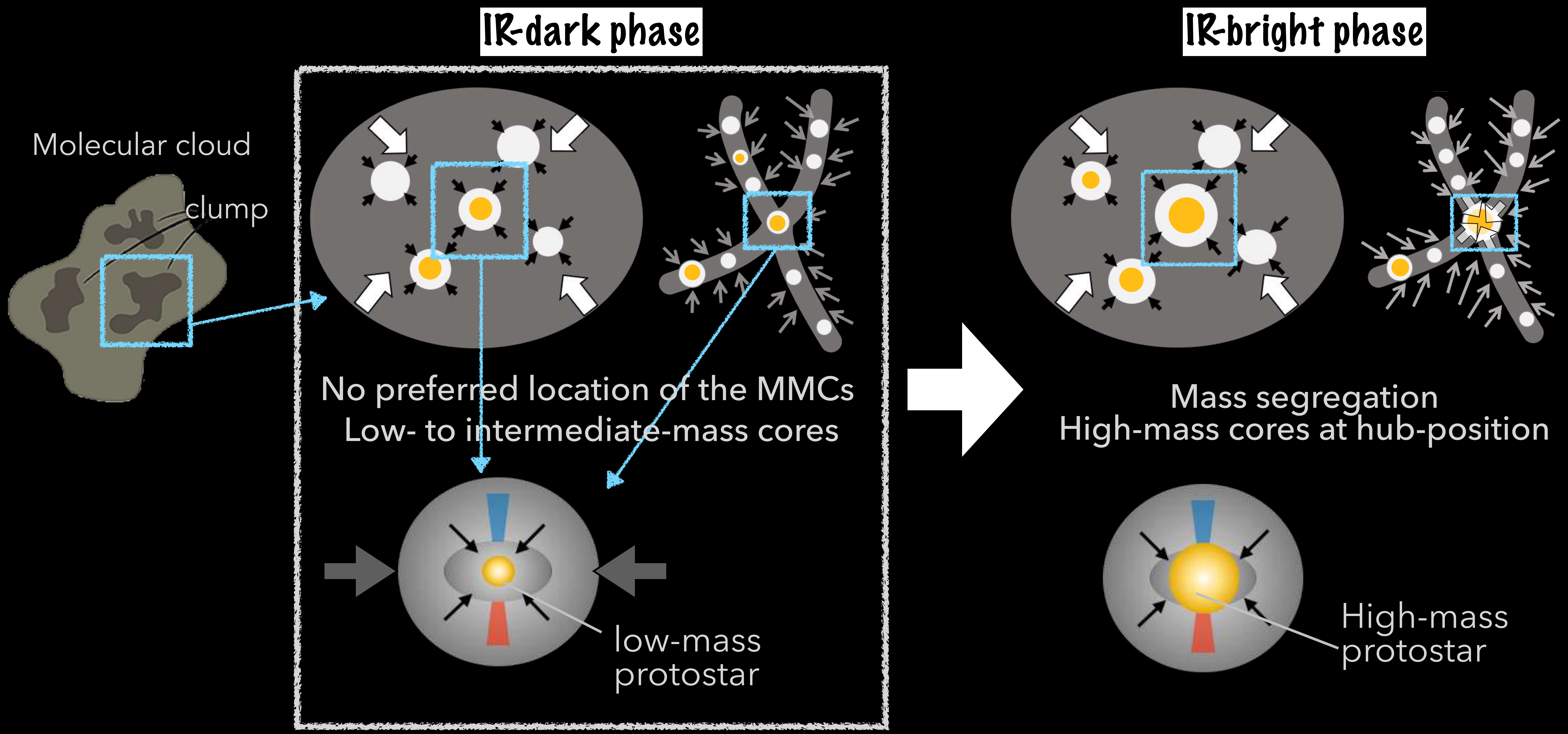


High-mass star formation picture



Radio telescope in France

The Northern Extended Millimetre Array (NOEMA)
consists of 12 individual 15-meter antennas
@Plateau de Bure, Hautes-Alpes

Enjoy your stay in Japan


Noh

Kabuki


Tea ceremony


Visit various part of Japan, and enjoy Japanese food and culture!