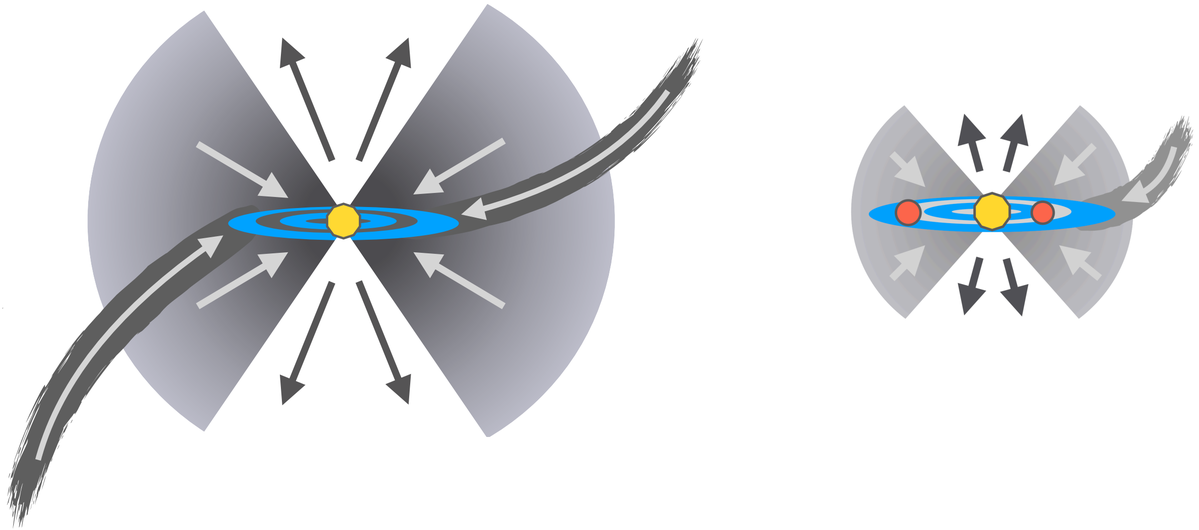
Large scale molecular streamers: A new channel to delivery material to disk scales



Jaime Pineda
Max Planck Institute for Extraterrestrial Physics
Center for Astrochemical Studies (CAS@MPE)


Assume a spherical cow, μ
Fig 1: μ

Prestellar core

t = 0 yrs
~10,000 au

Class 0/I protostar

t < 10^6 yrs
~1,000 au

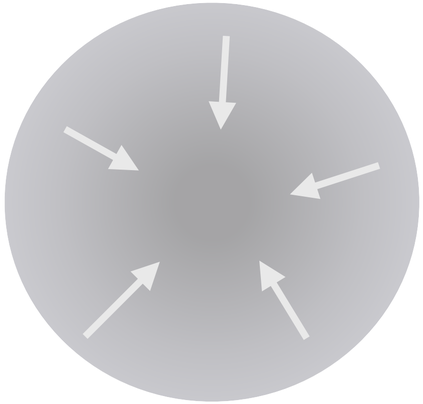
Class II/III pre-main sequence star

t ~ 10^6 yrs
~100 au

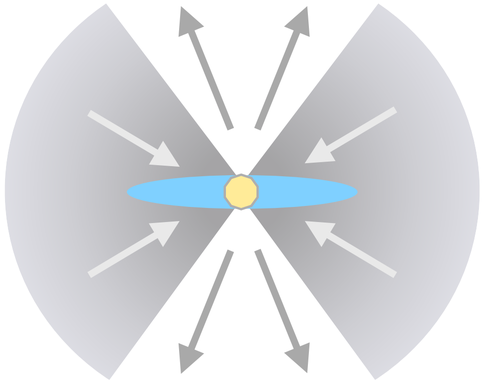
Star and planet system

t > 10^7 yrs
~100 au

What we thought

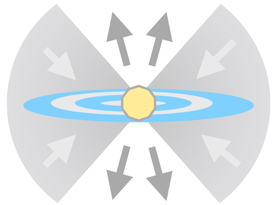


spherical infalling core



infalling envelope

smooth disk

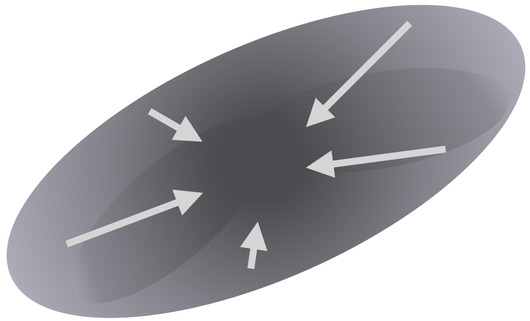


envelope remnants

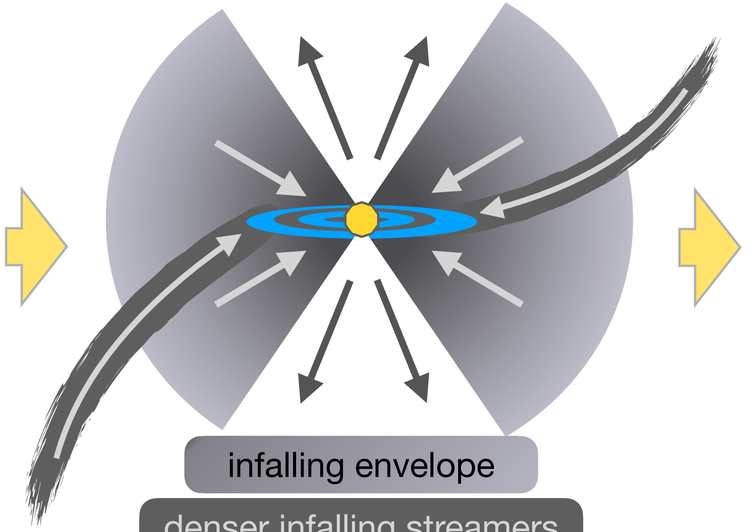
ringed disk

planets

Where we are headed



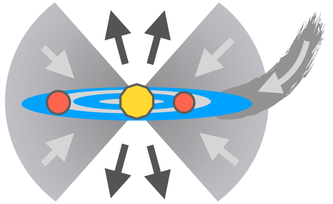
asymmetric infalling core



infalling envelope

denser infalling streamers

ringed disk



envelope remnants

streamer remnants

ringed disk

planets

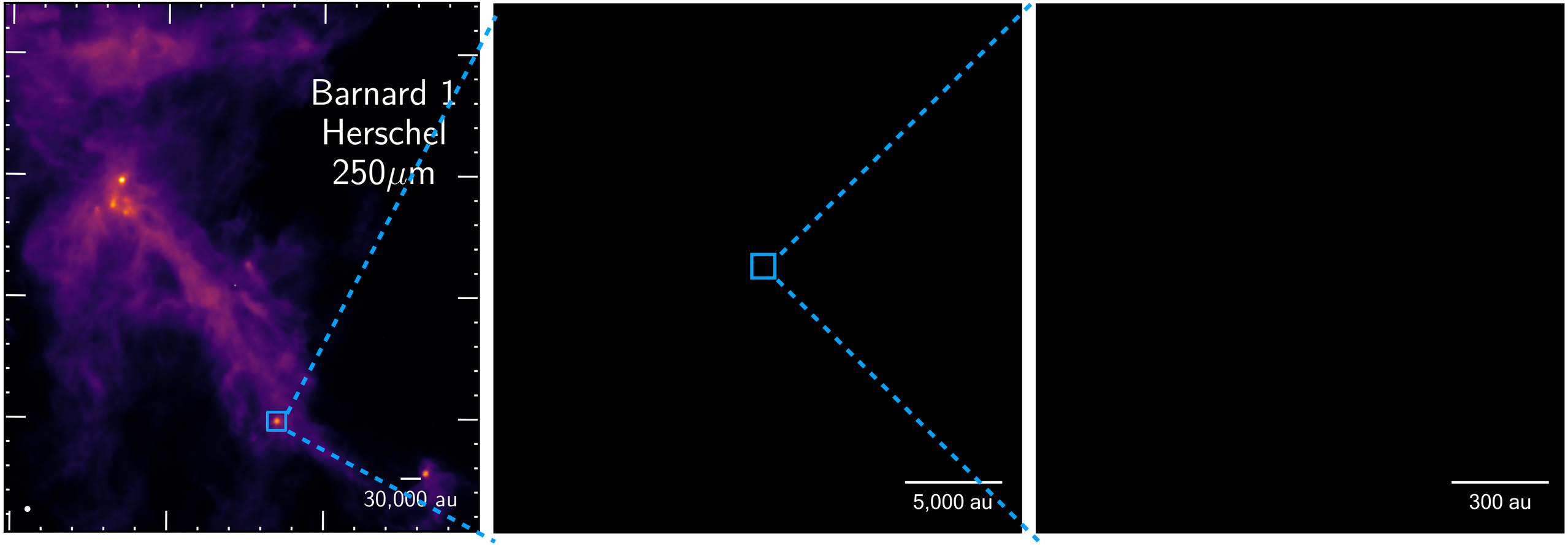
planets

Pineda+ PP7
Segura-Cox et al. in prep

The Need to Connect Scales

Per-emb-2 (Class 0)

Filament Scale | Core/Envelope Scale | Disk Scale

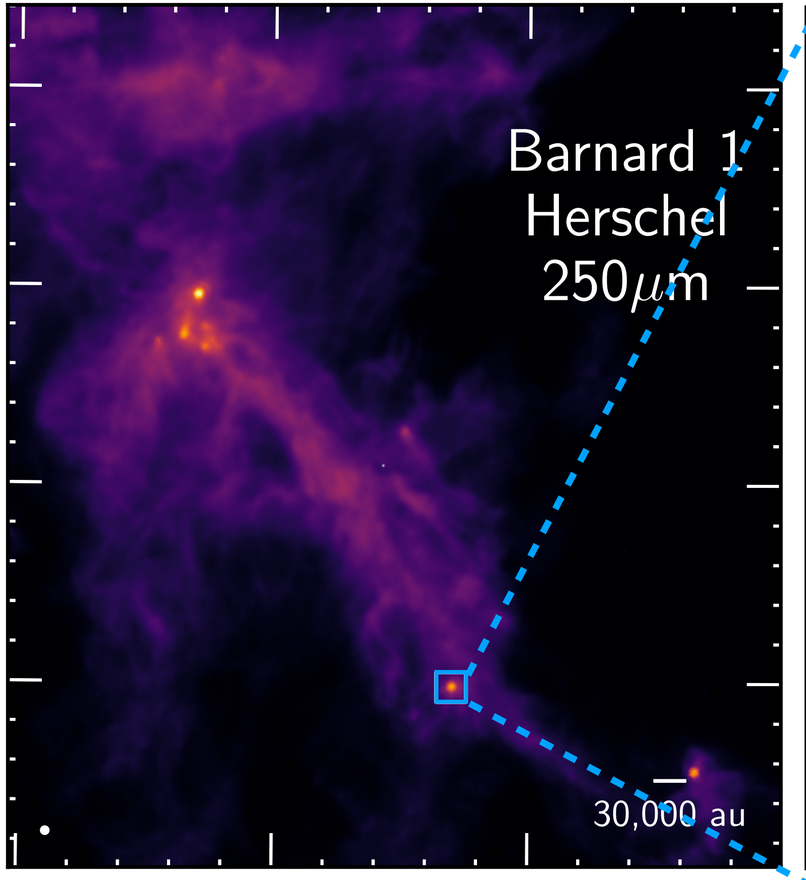


Sadavoy et al. (2012, 2014)

The Need to Connect Scales

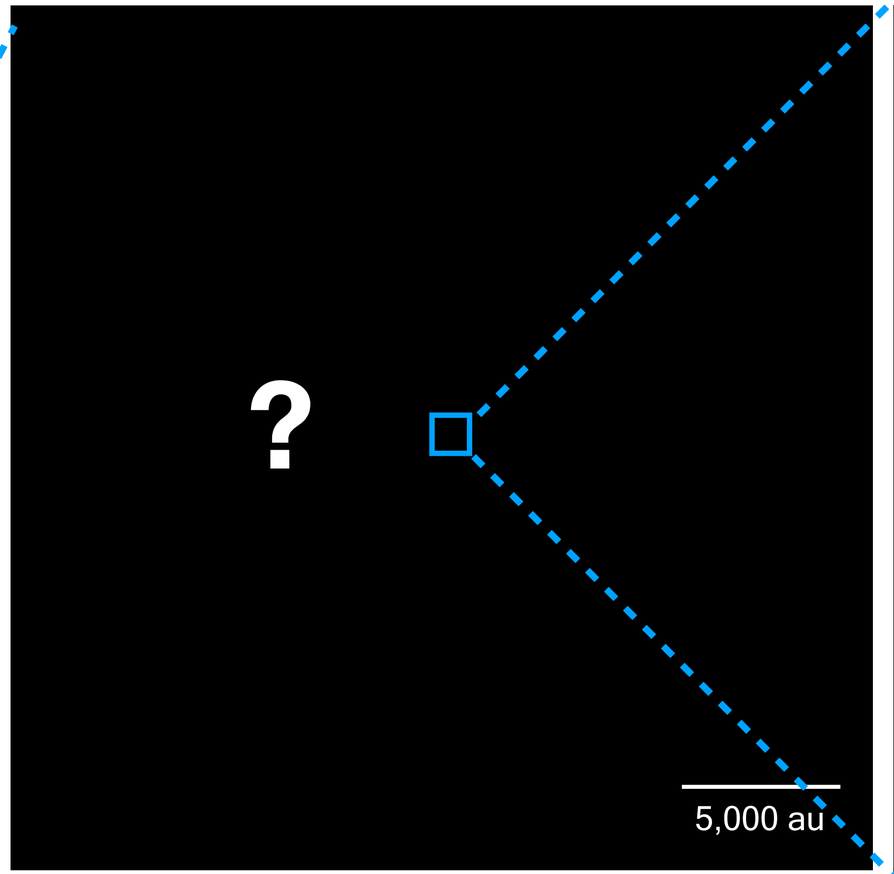
Per-emb-2 (Class 0)

Filament Scale

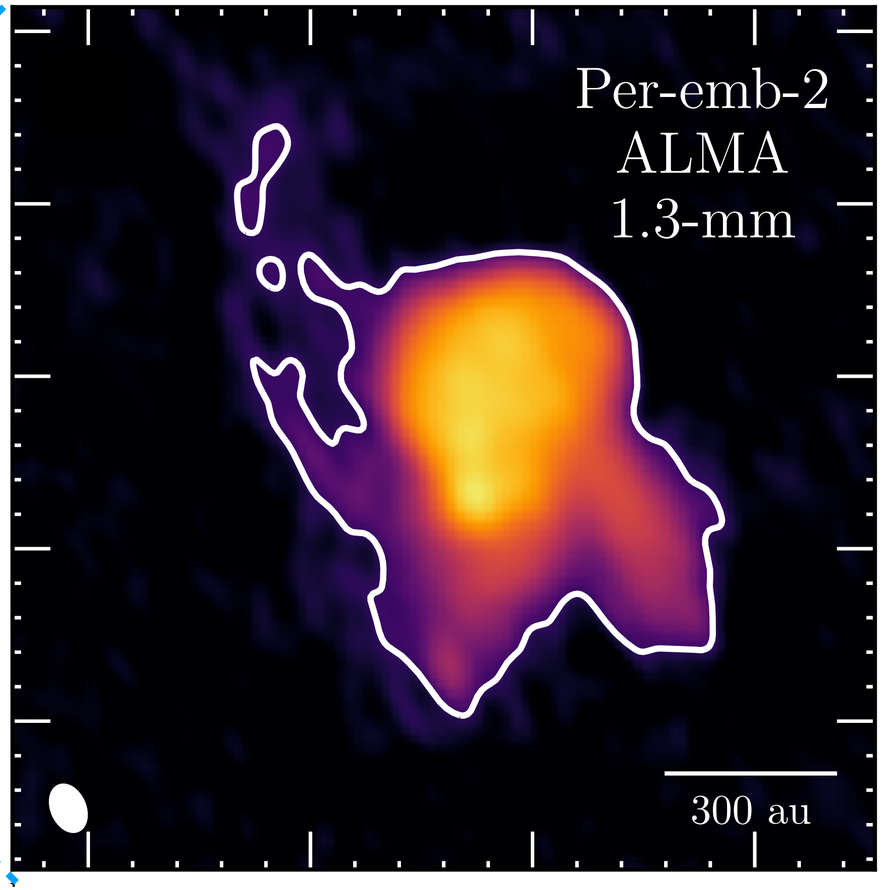


Sadavoy et al. (2012, 2014)

Core/Envelope Scale



Disk Scale

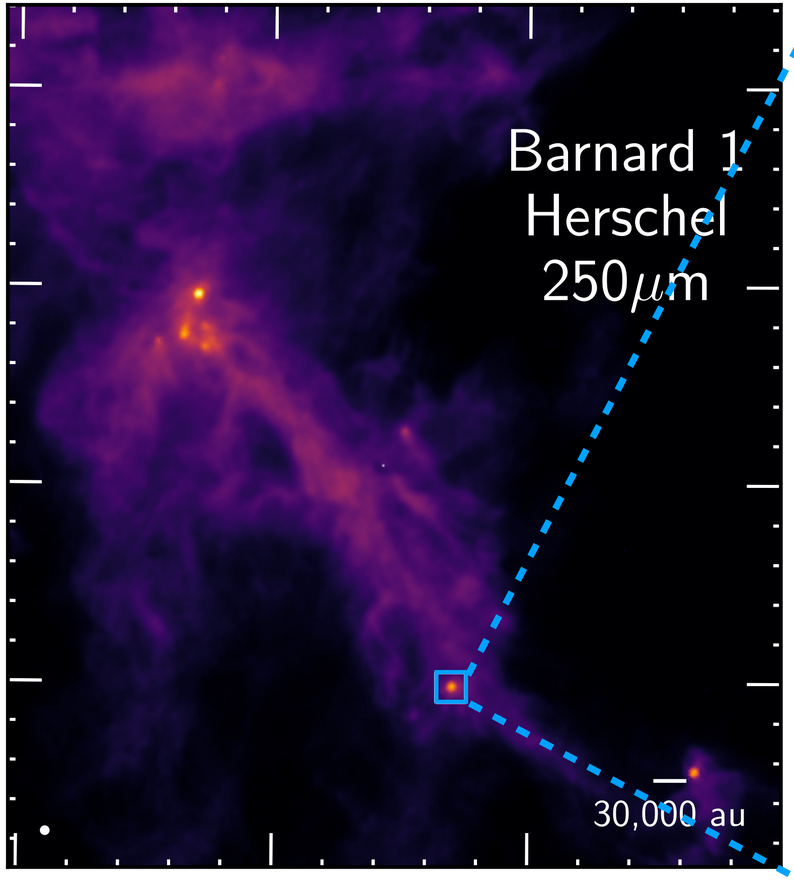


Reprocessed from Tobin et al. (2018)

Streamers Bridge the Gap

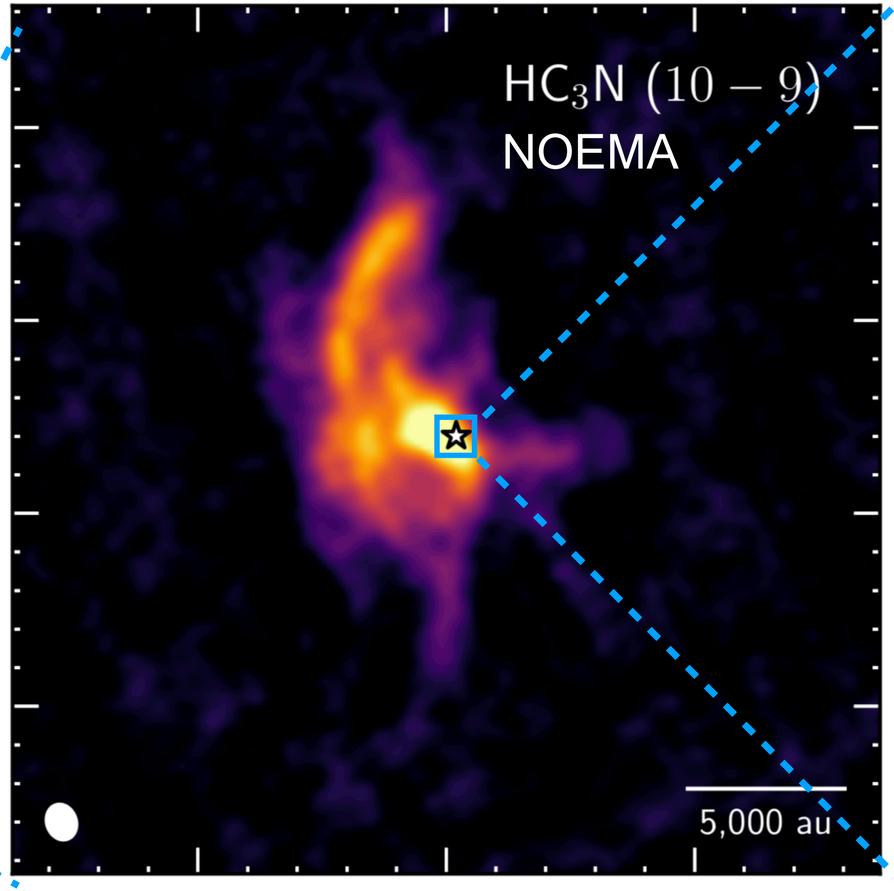
Per-emb-2 (Class 0)

Filament Scale



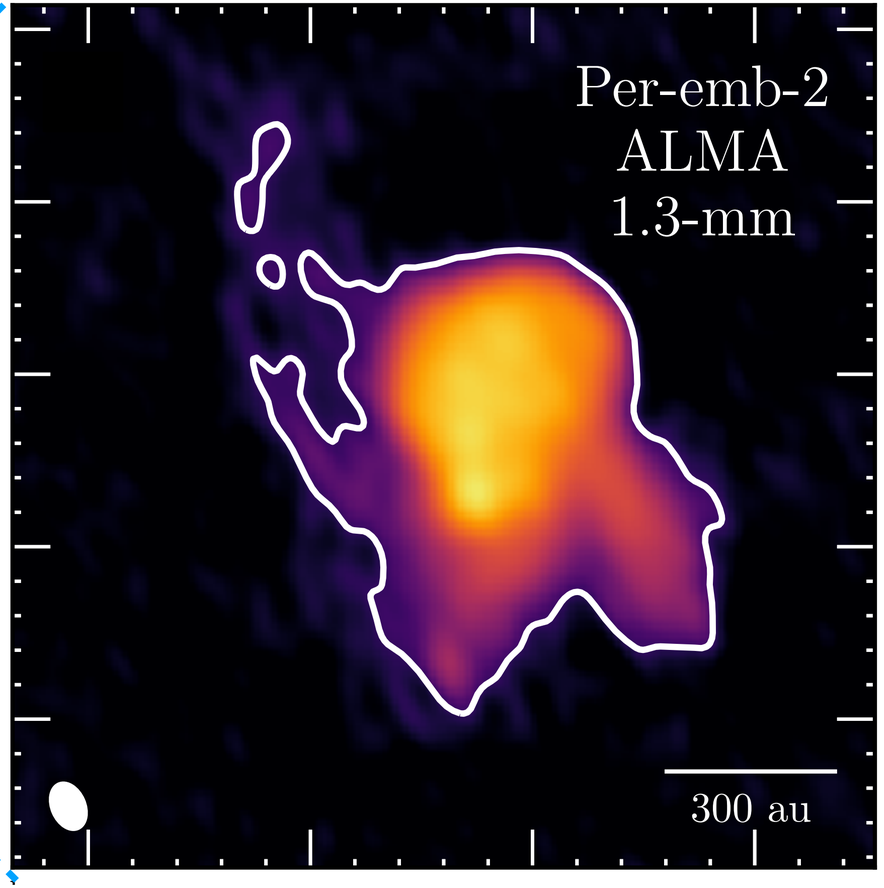
Sadavoy et al. (2012, 2014)

Core/Envelope Scale



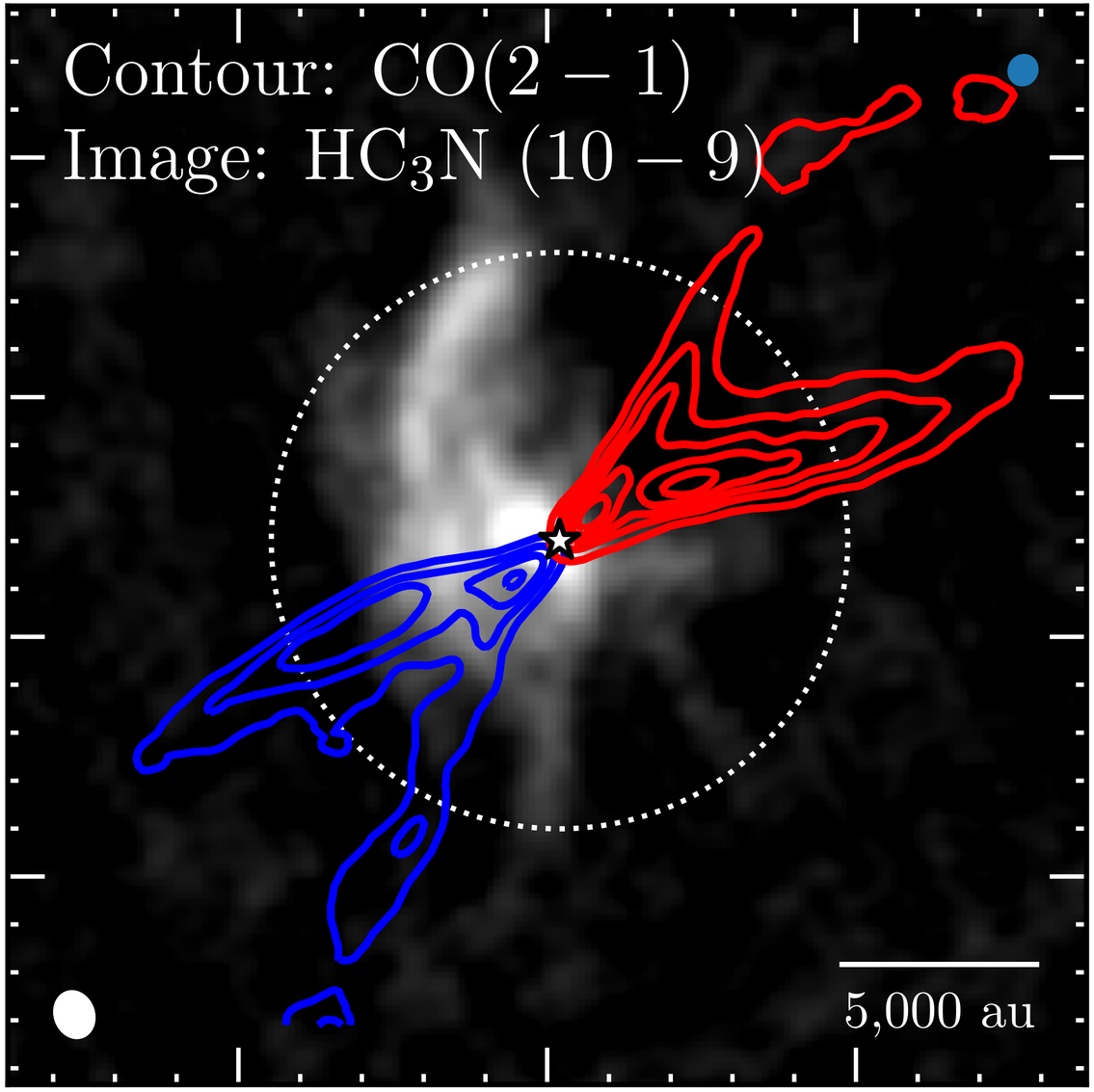
Pineda et al. (2020)

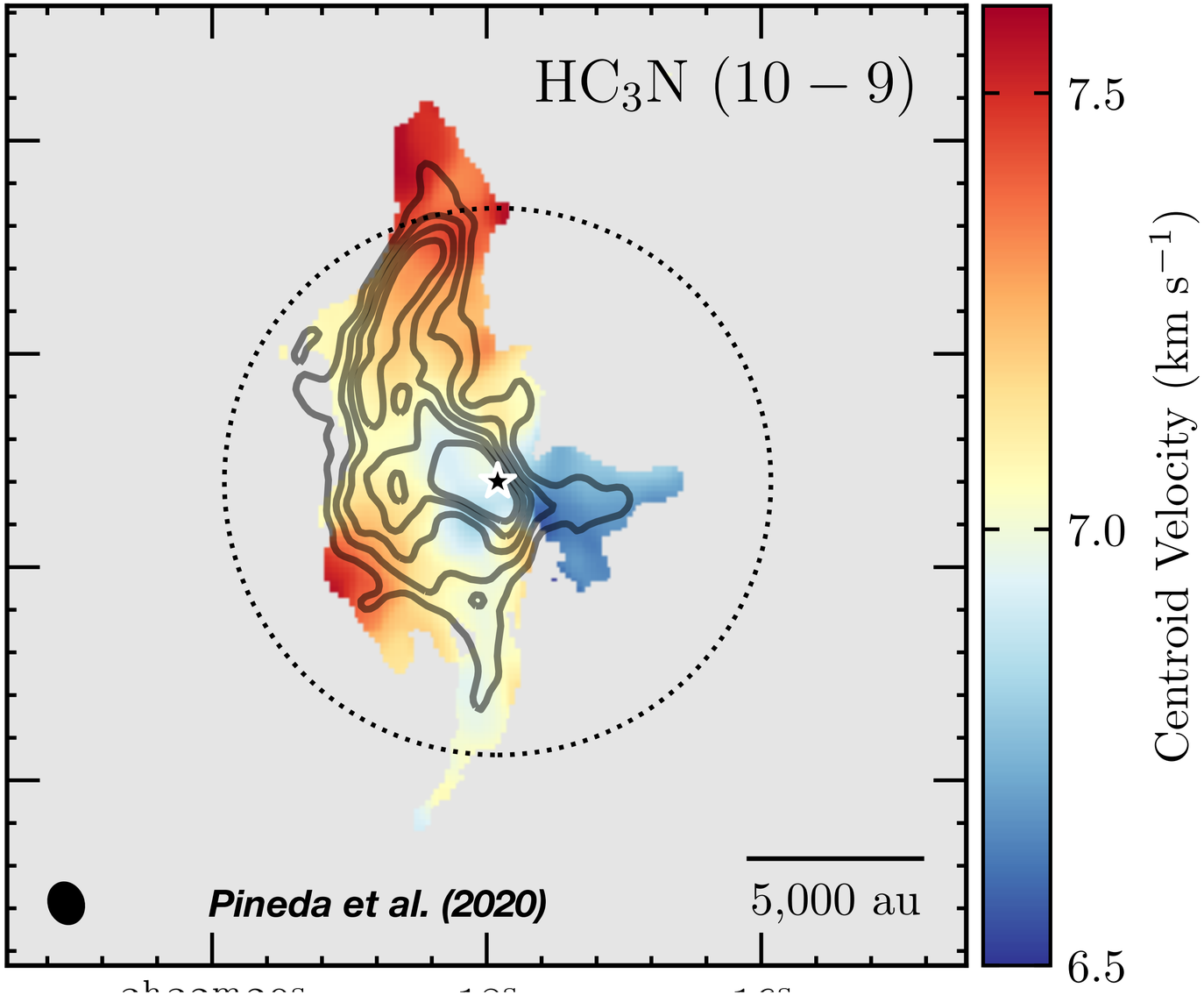
Disk Scale



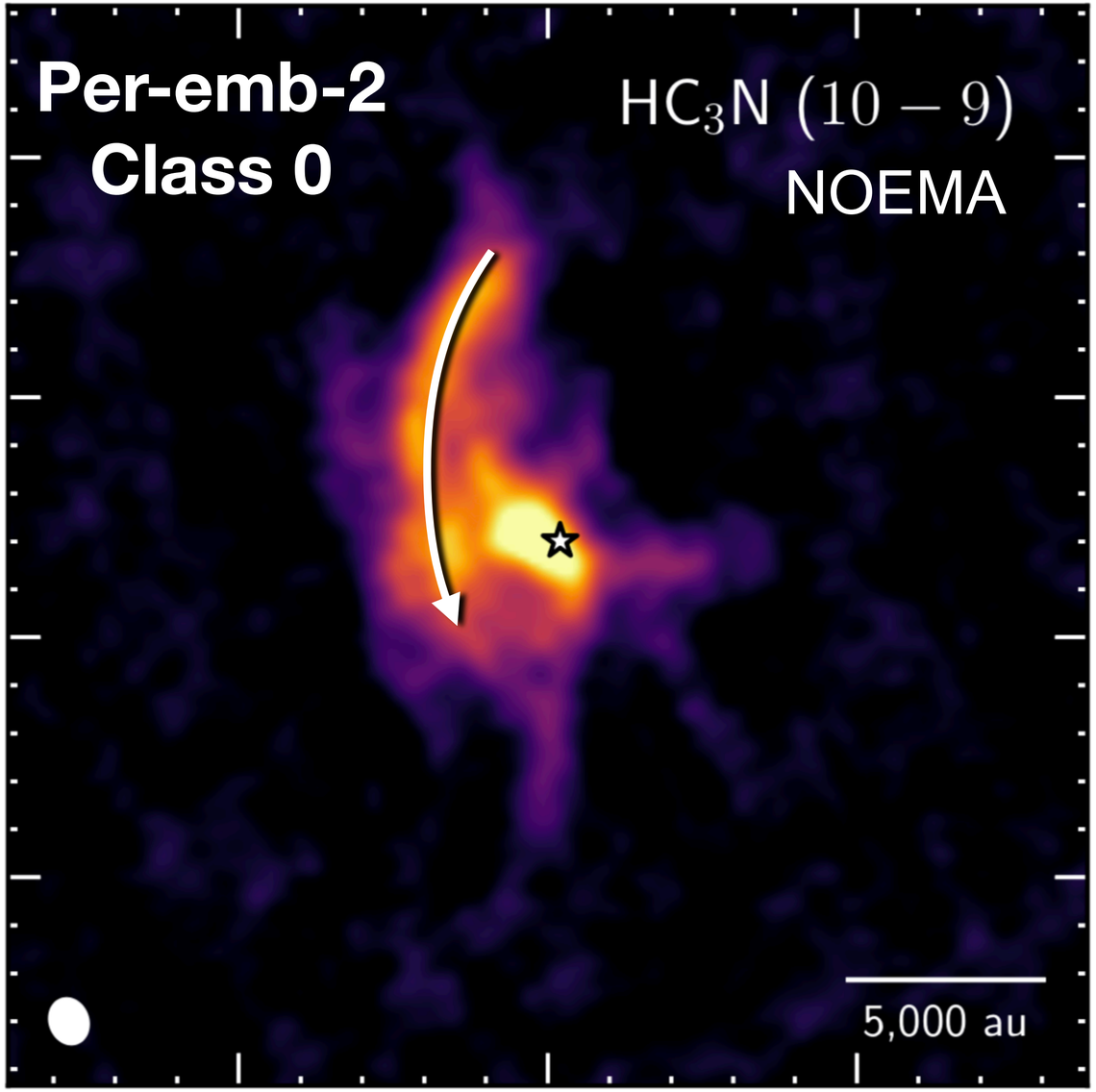
Reprocessed from Tobin et al. (2018)

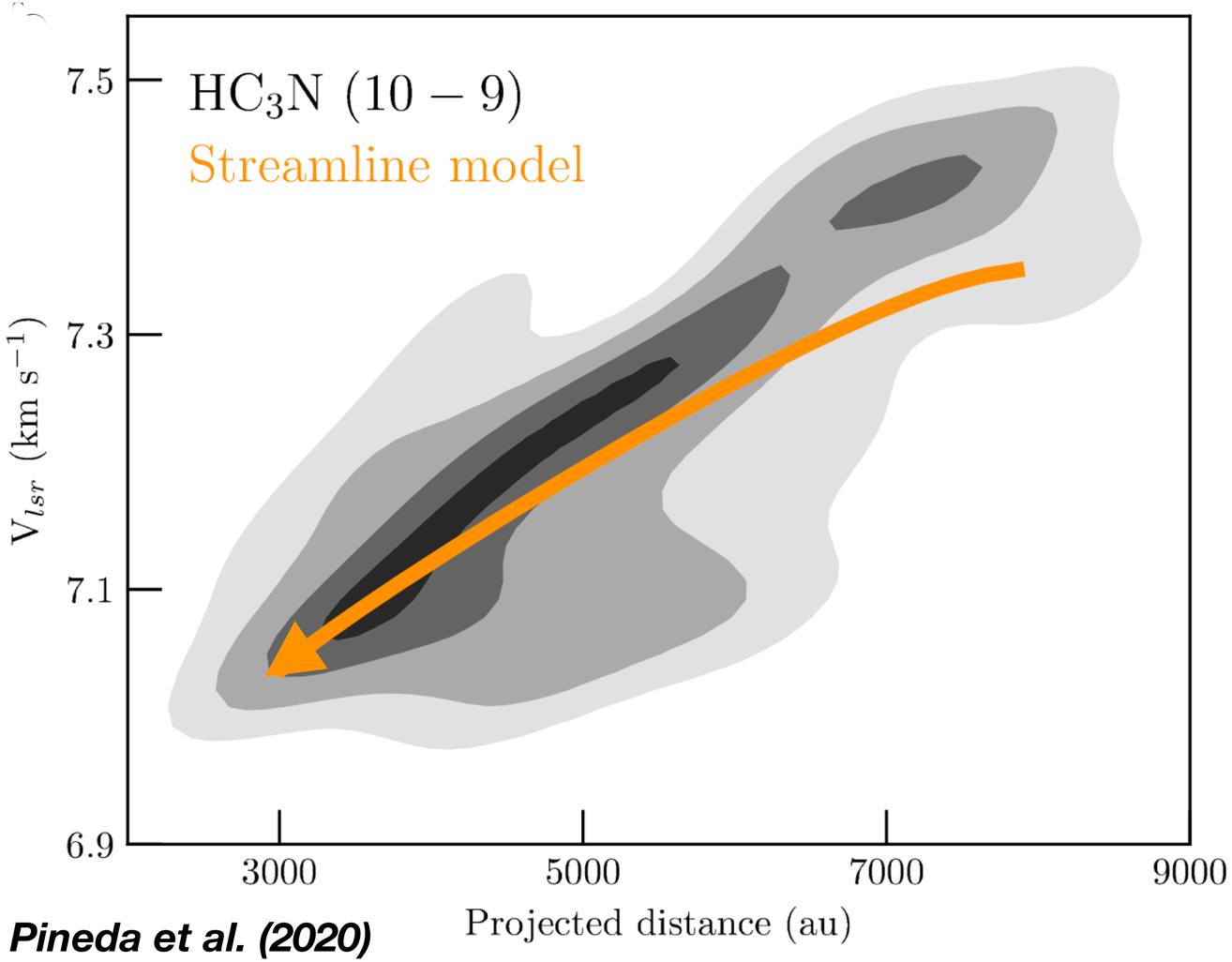
Streamer: Unrelated to Outflow





Class 0 Streamer: Infalling Motion

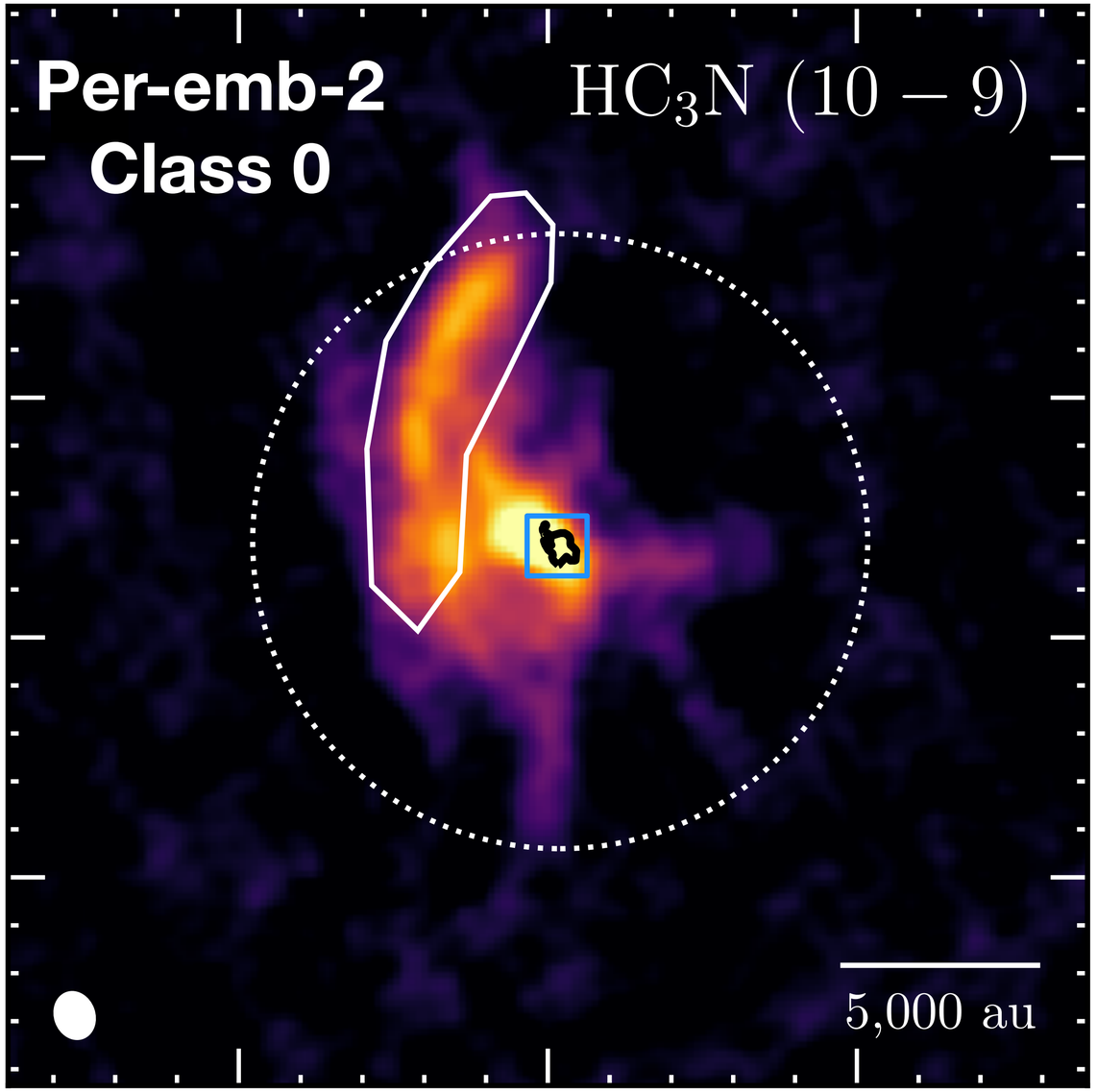


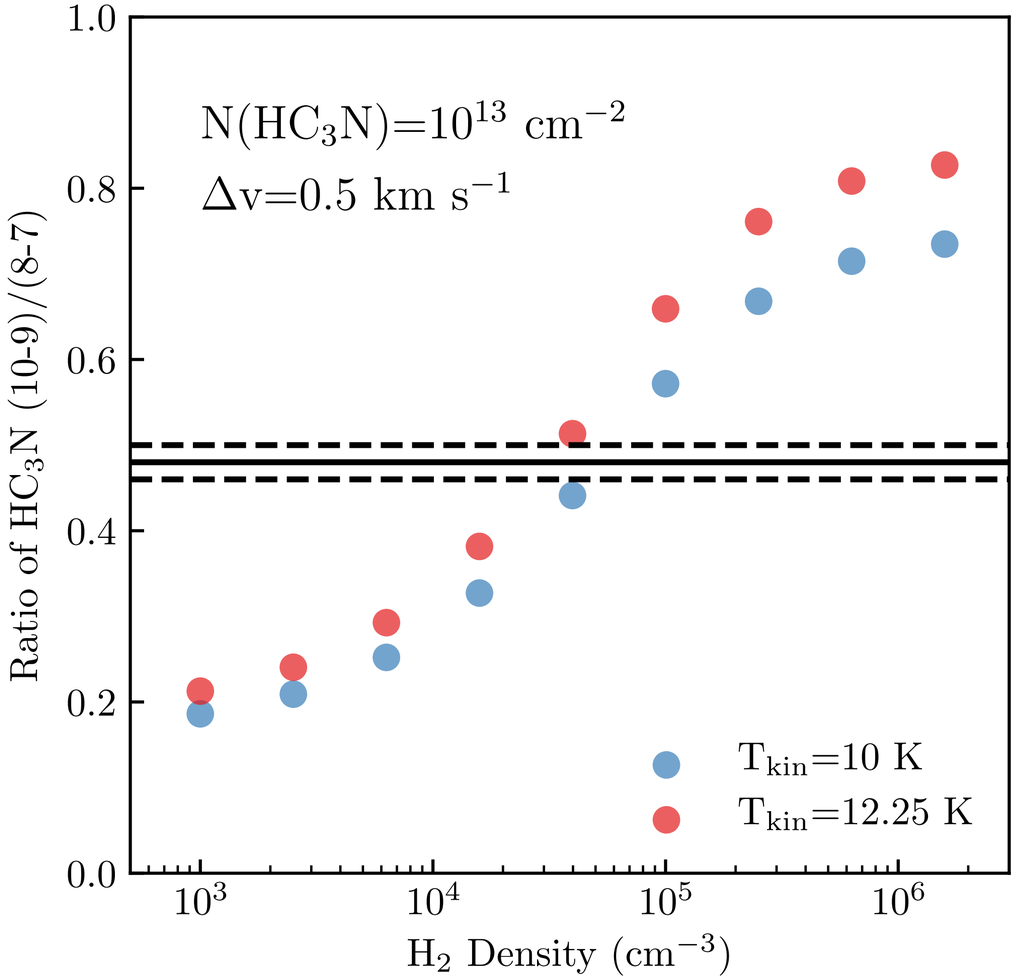


Pineda et al. (2020)

Analytic streamline prescription: *Mendoza et al. (2009)*

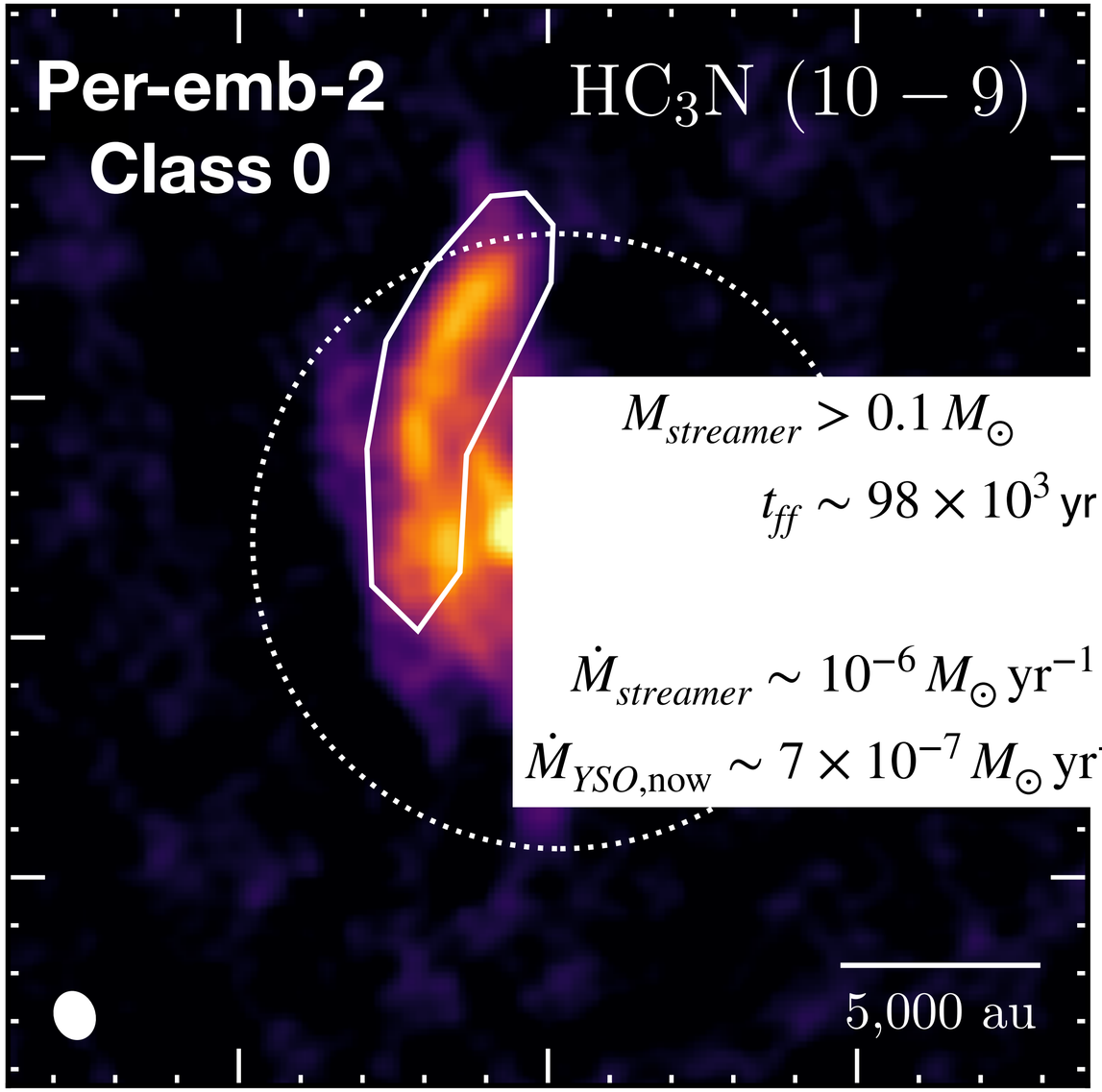
Streamer Infall rate is important

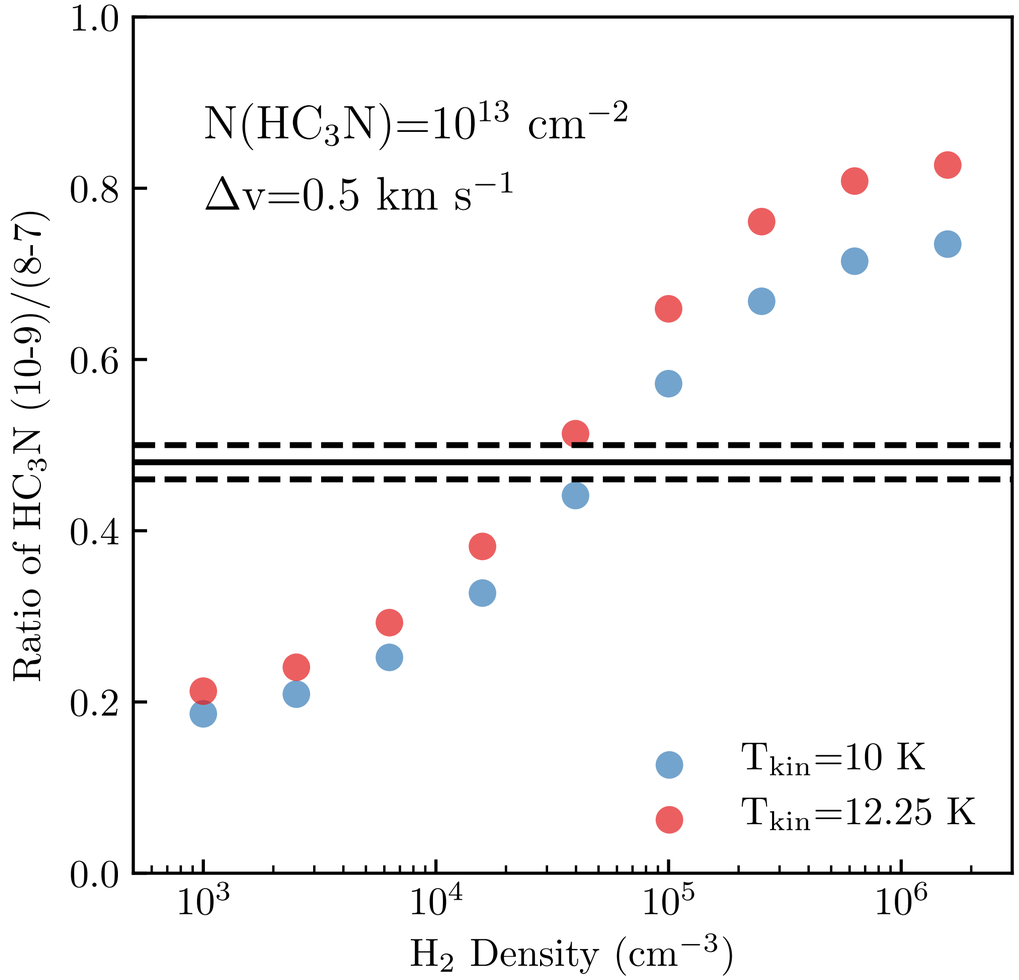




Pineda et al. (2020)

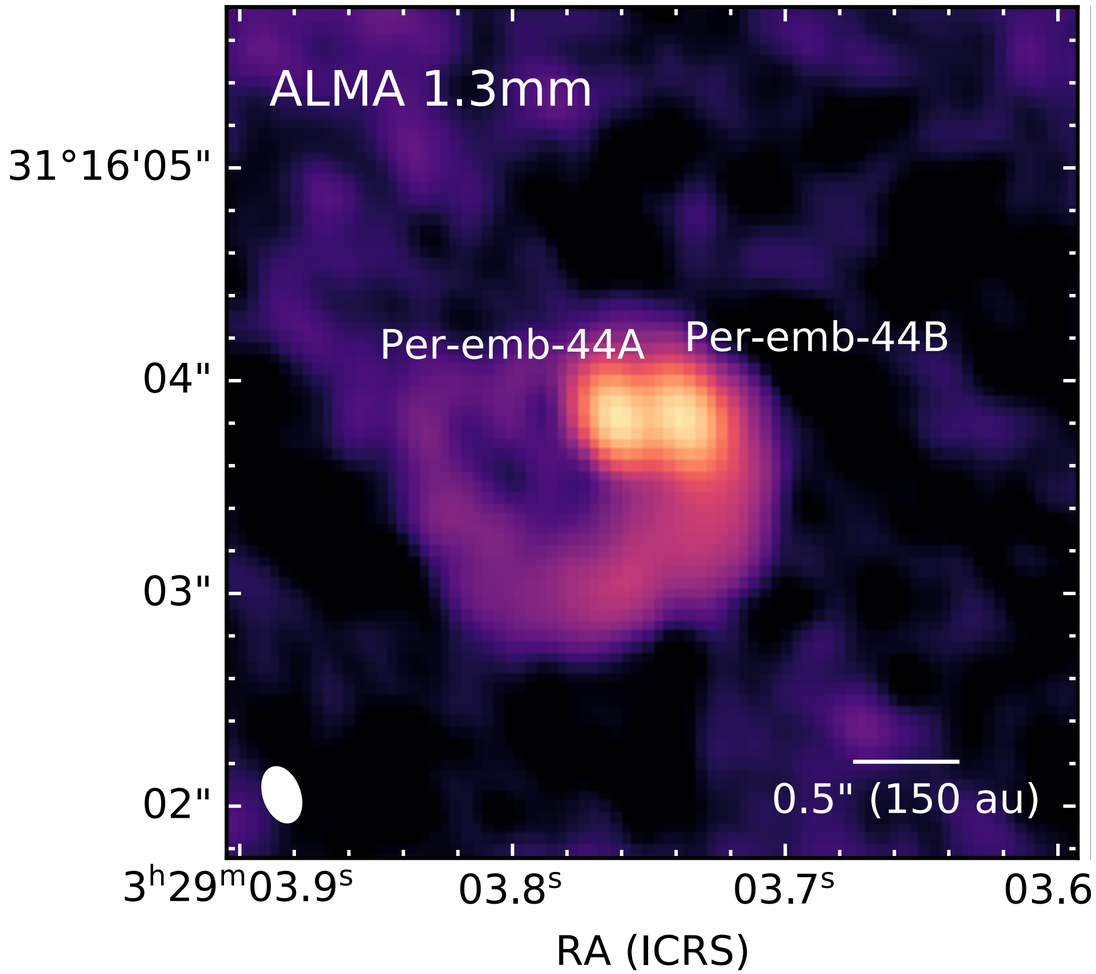
Streamer Infall rate is important





Pineda et al. (2020)

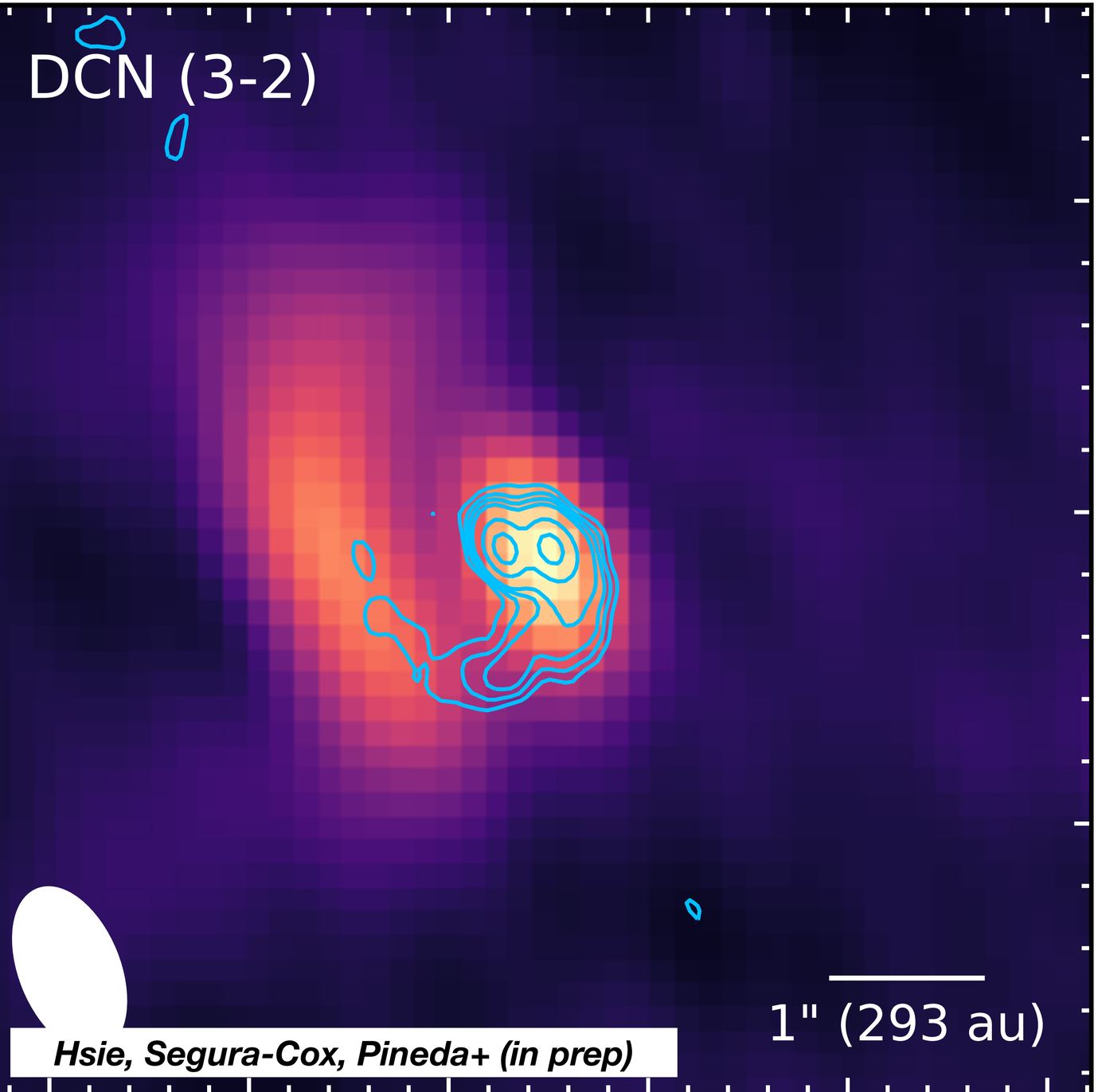
Class I: Streamer or GI disk?

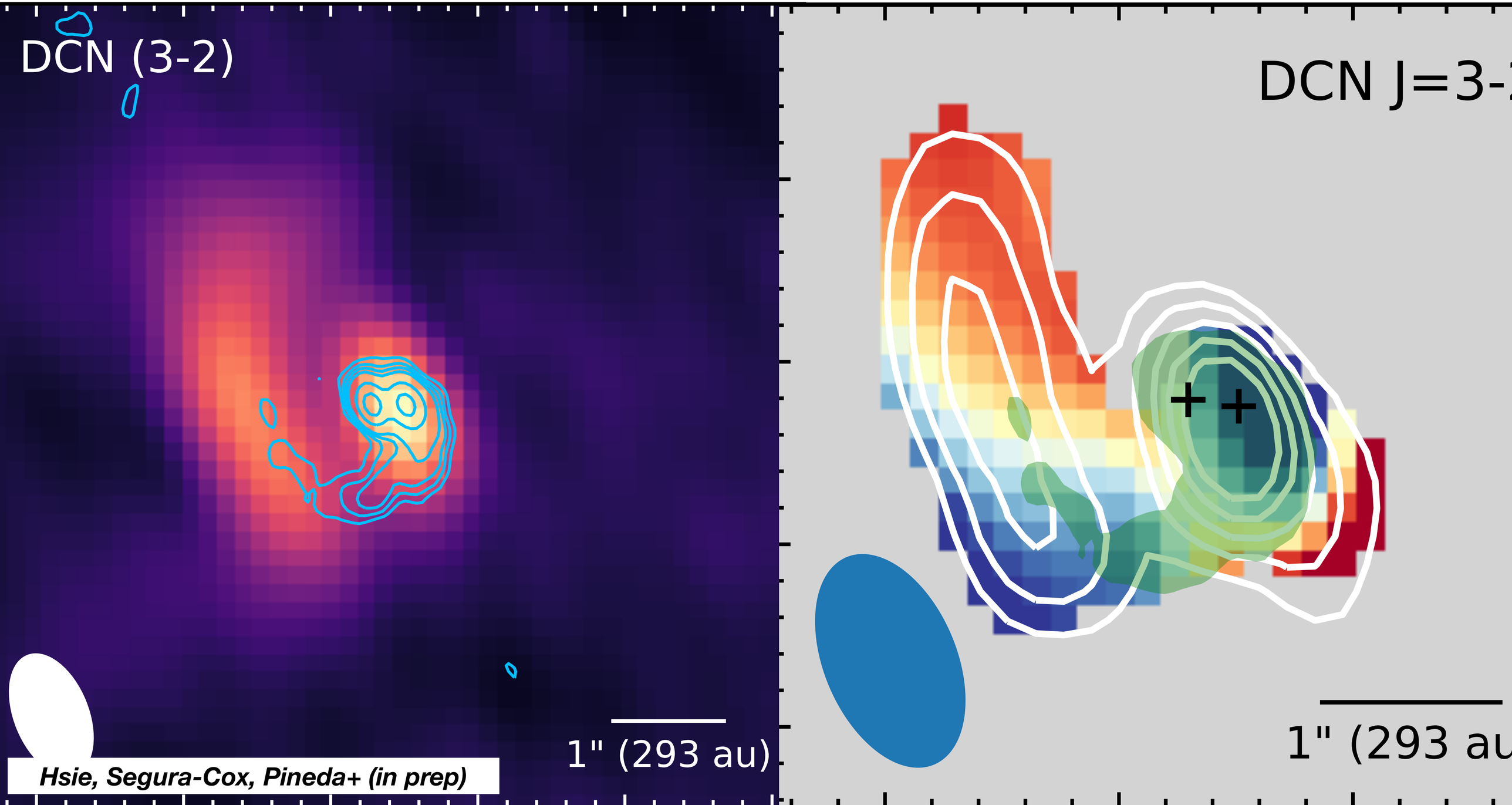


SVS13A (Class I)

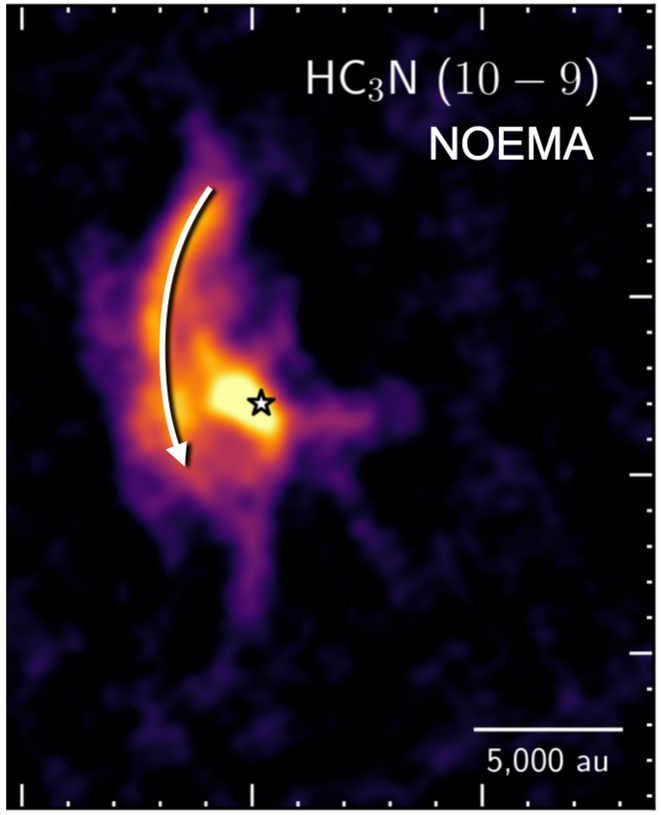
Evidence for fragmenting disk (Tobin+2018)

Hsie, Segura-Cox, Pineda+ (in prep)


DCN (3-2)
1" (293 au)
Hsie, Segura-Cox, Pineda+ (in prep)


DCN (3-2)
1" (293 au)
Hsie, Segura-Cox, Pineda+ (in prep)
DCN J=3-
1" (293 au

Streamers important over multiple phases



Pineda+2020

Per-emb-2 (Class 0)

Length of 10 500 au

$\dot{M}_{in} \approx 10^{-6}\, M_\odot\, yr^{-1}$

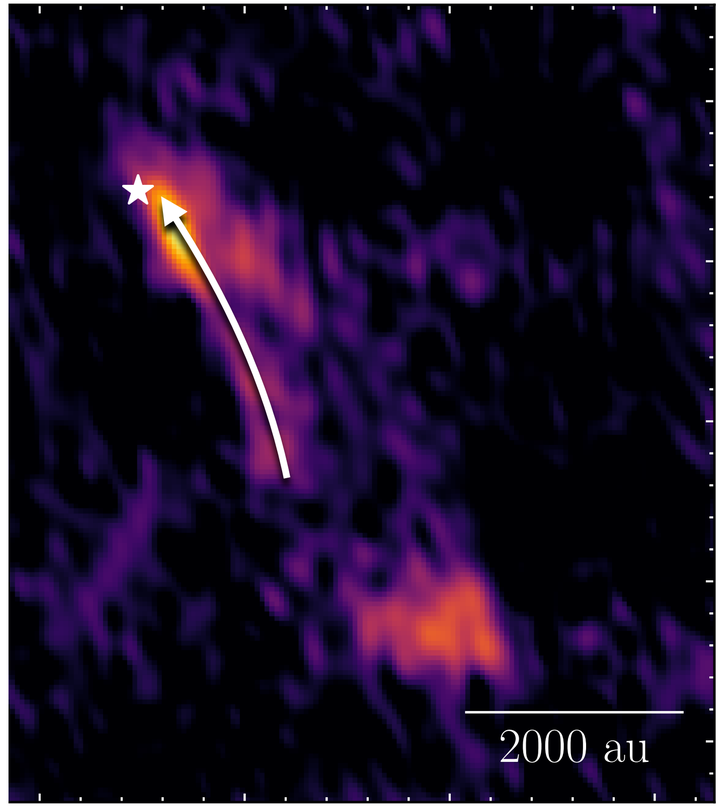
$\dot{M}_{in}/\dot{M}_{acc} \approx 1.4$

Per-emb-50 (Class I)

Length of ~ 3000 au

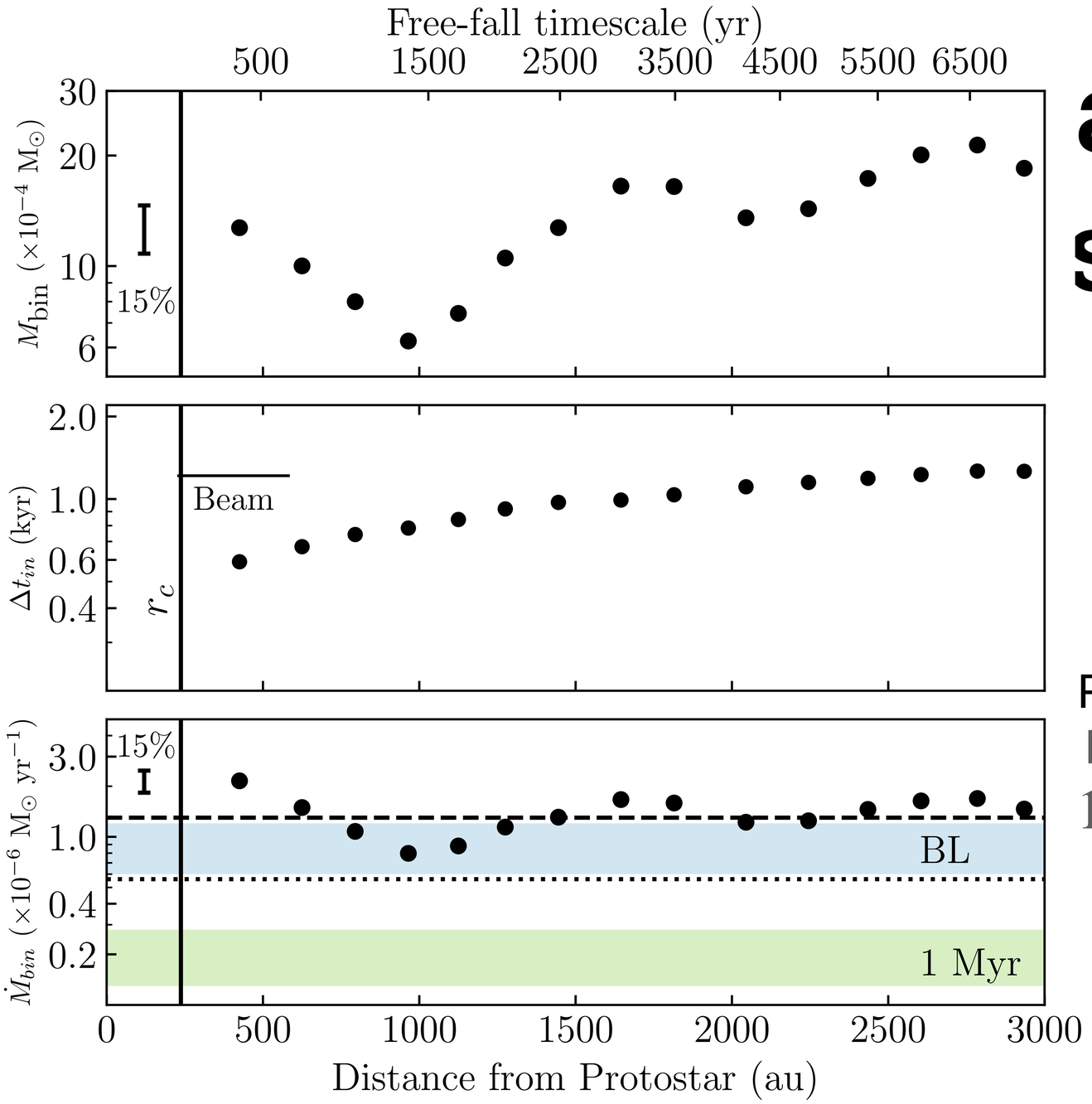
$\dot{M}_{in} \approx 1.3 \times 10^{-6}\, M_\odot\, yr^{-1}$

$\dot{M}_{in}/\dot{M}_{acc} \approx 1 - 2$

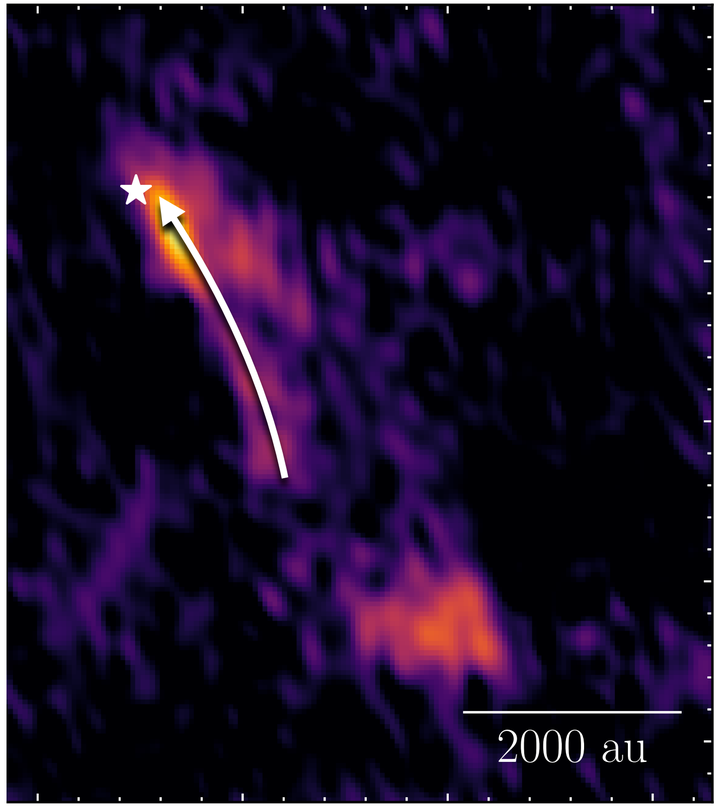


Valdivia-Mena+in prep

See Tomorrow's talk by Valdivia-Mena



ant over multiple ses



Per-emb-50 (Class I)

Length of ~ 3000 au

$1.3 \times 10^{-6}\, M_\odot\, yr^{-1}$

$\dot{M}_{in}/\dot{M}_{acc} \approx 1 - 2$

See Tomorrow's talk by Valdivia-Mena

Valdivia-Mena+in prep

Questions about Streamers

How common are they?

How dominant are they in the mass accretion process?

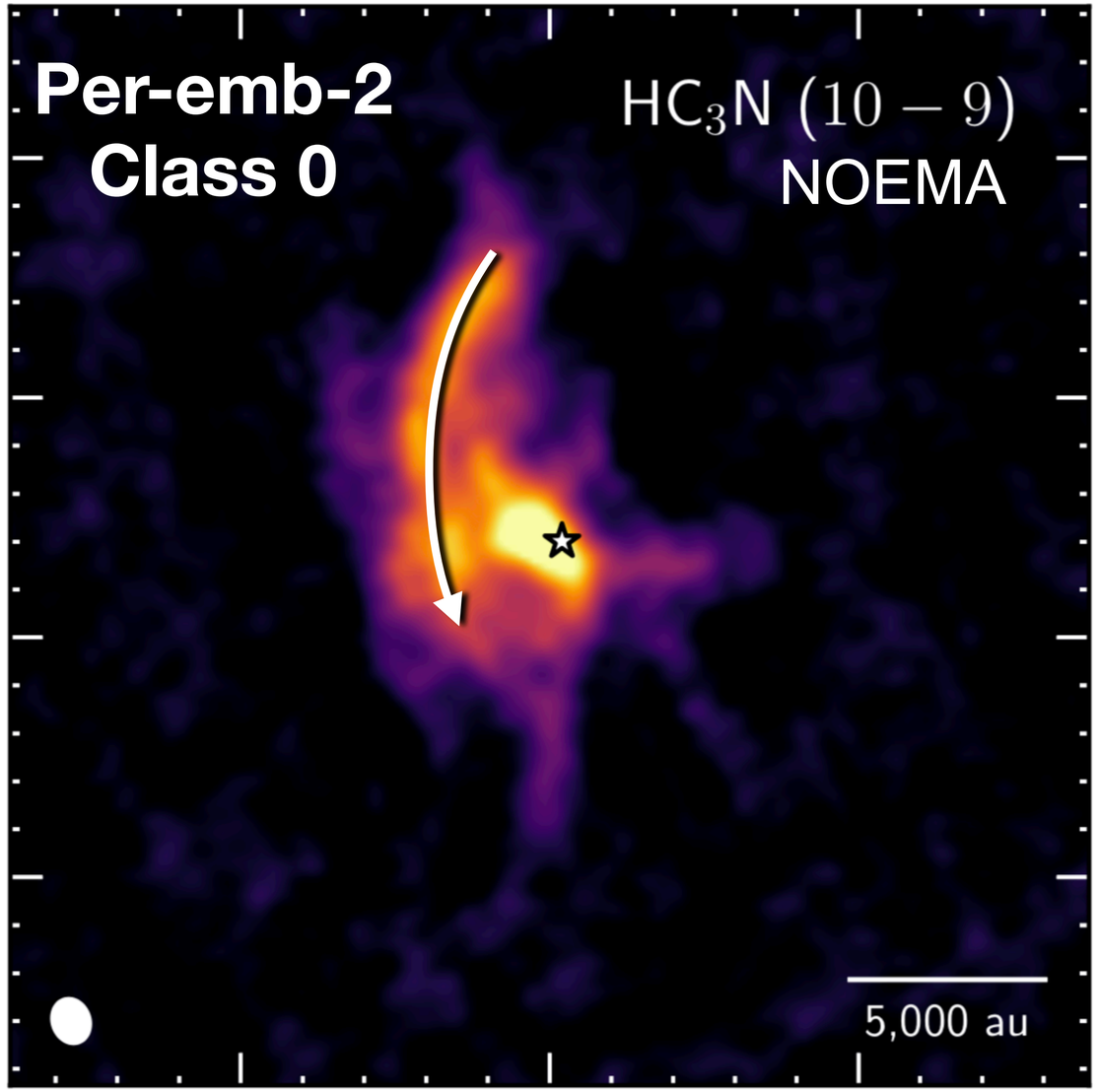
How long are streamers?

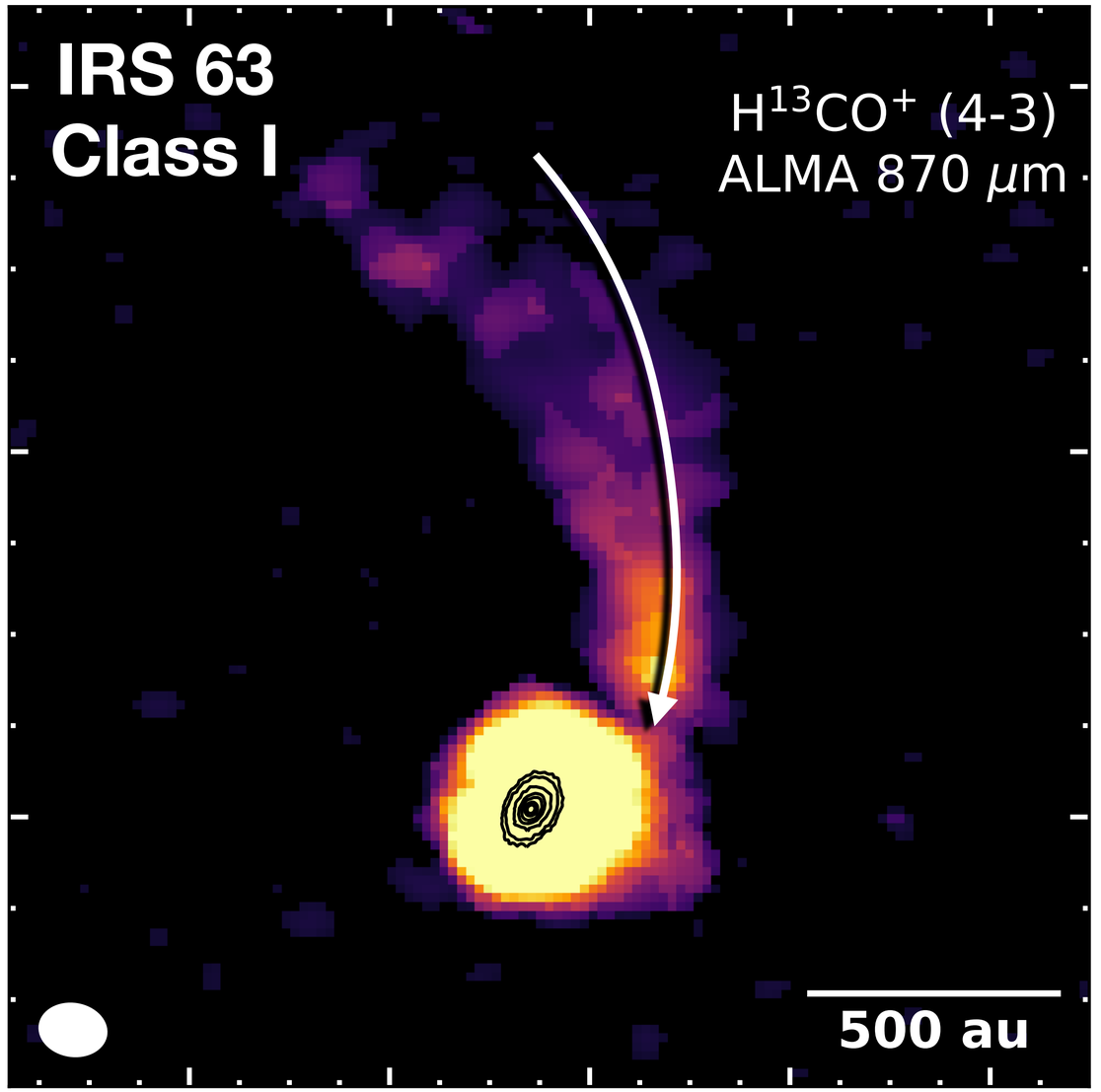
Do they modify the chemical composition of the disk?

What are the best tracers to find streamers?

Are streamers present in previous numerical simulations?

Different Streamer Lengths

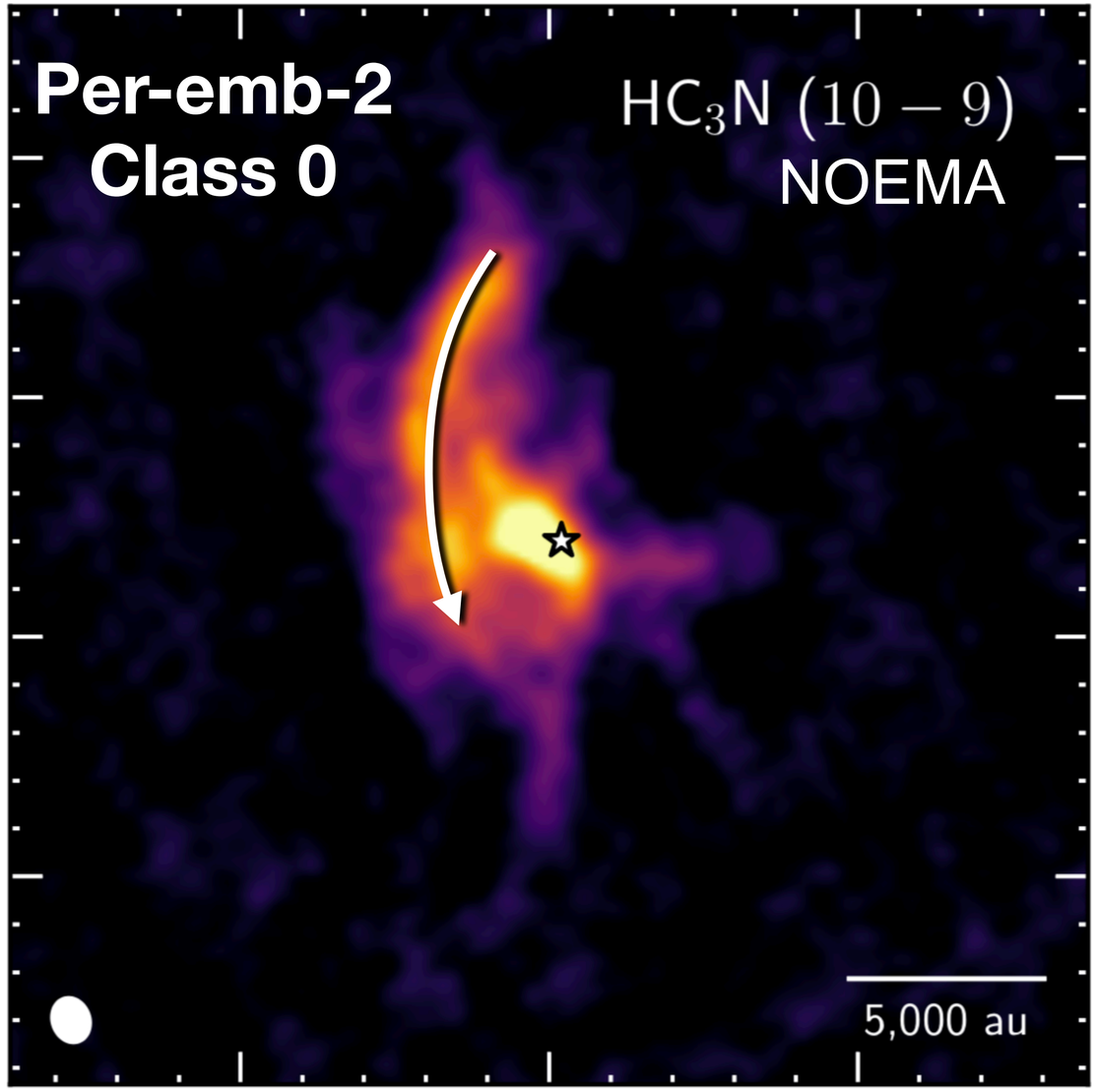




Pineda et al. (2020)

Segura-Cox et al. in prep

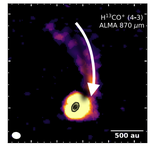
Different Streamer Lengths



~10,000 au streamer

Pineda et al. (2020)

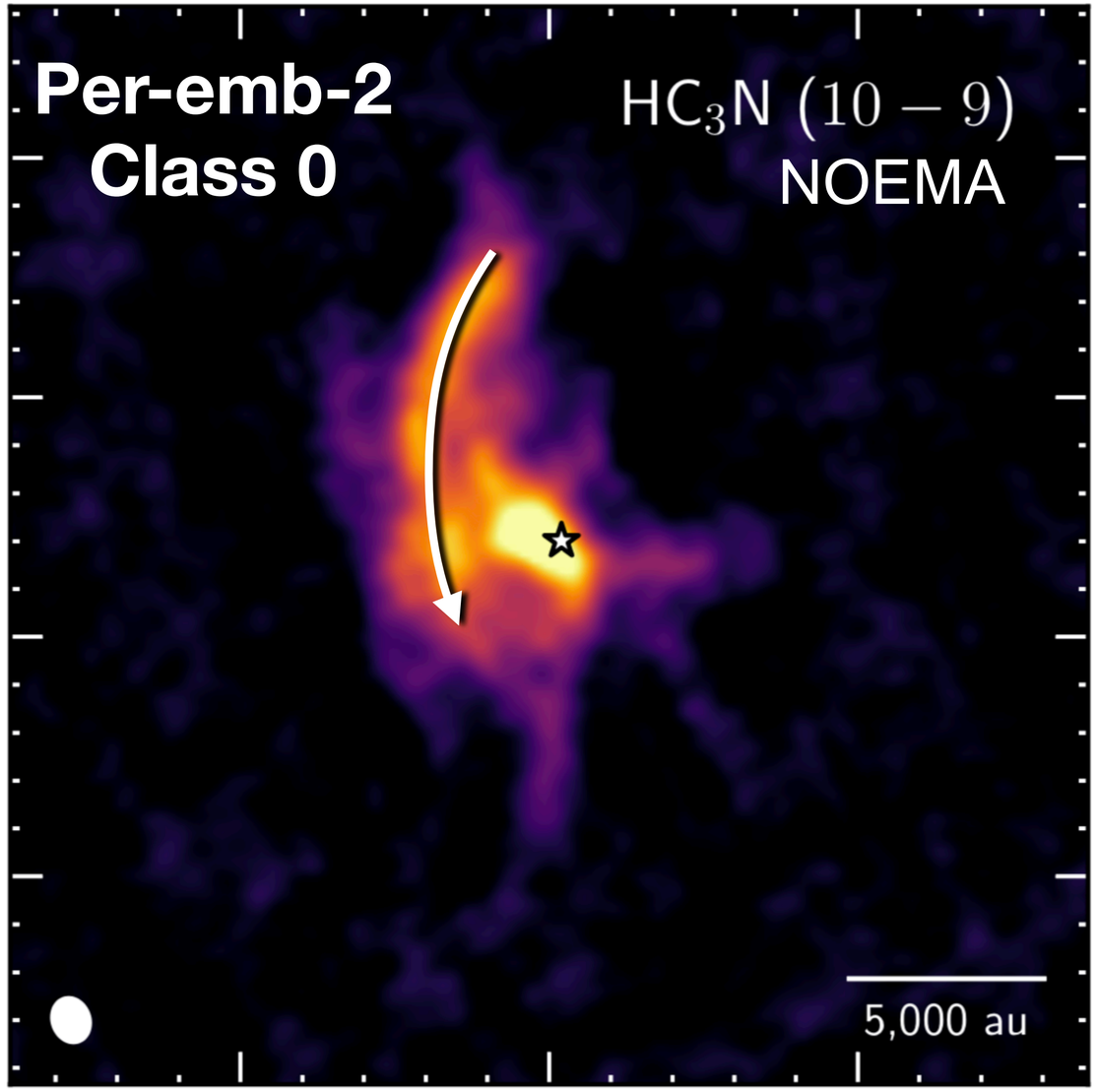
IRS 63
Class I



~1,500 au streamer

Segura-Cox et al. in prep

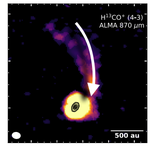
Different Streamer Lengths



~10,000 au streamer

Pineda et al. (2020)

IRS 63
Class I



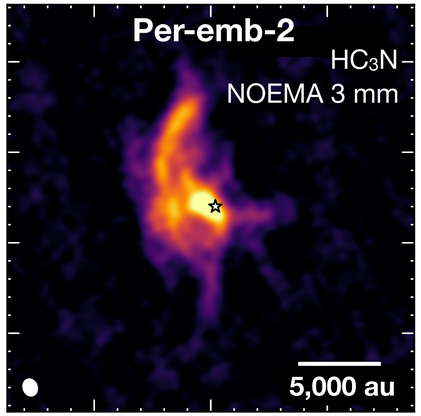
~1,500 au streamer

An evolutionary trend?
Or due to observational limitations?

Segura-Cox et al. in prep

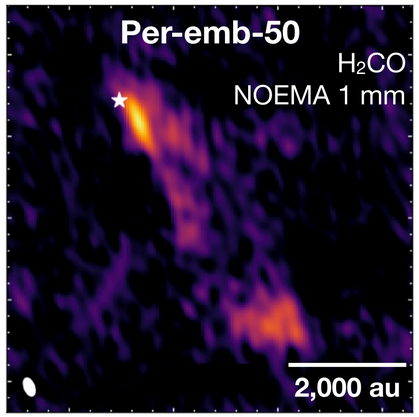
Counting Up the Streamers

Class 0



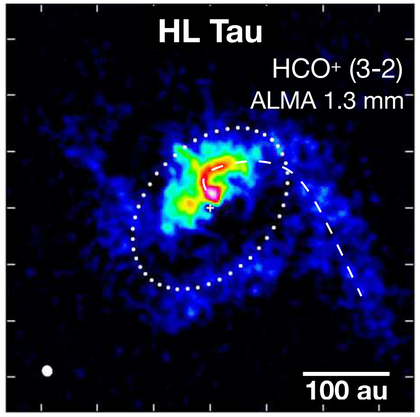
Pineda et al. (2020)

Class I



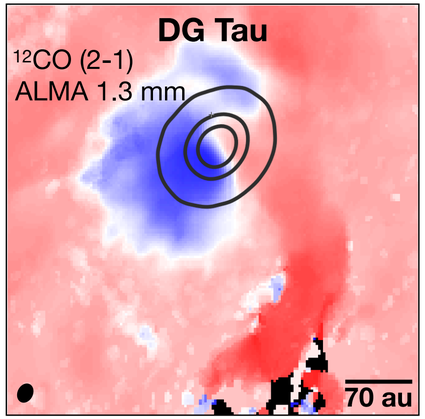
Valdivia-Mena et al. in prep

Class I/II



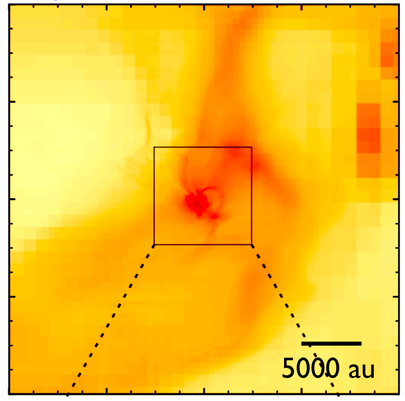
Yen et al. (2019)

Class I/II



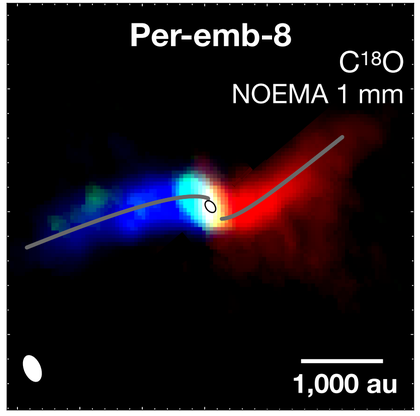
Garufi et al. (2021)

Simulation



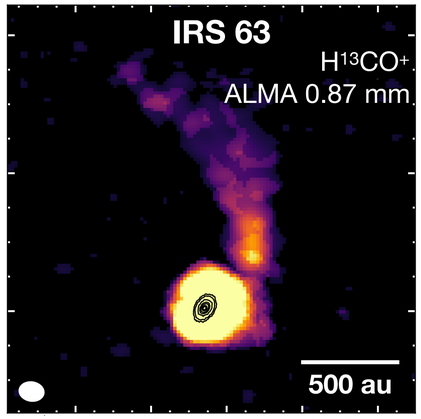
Küffmeier et al. (2019)

Class 0



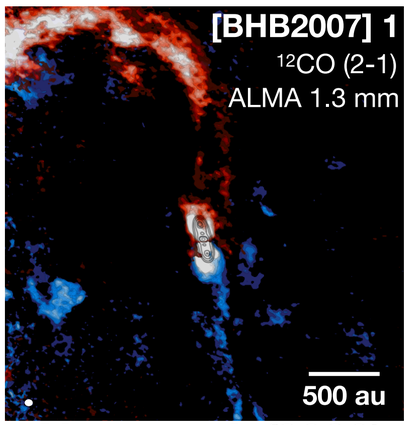
Segura-Cox et al. in prep

Class I



Segura-Cox et al. in prep

Class I/II

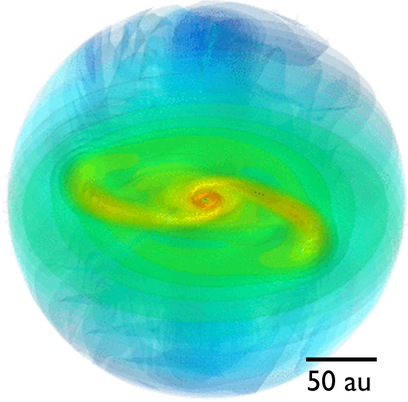


Alves et al. (2020)

Class II

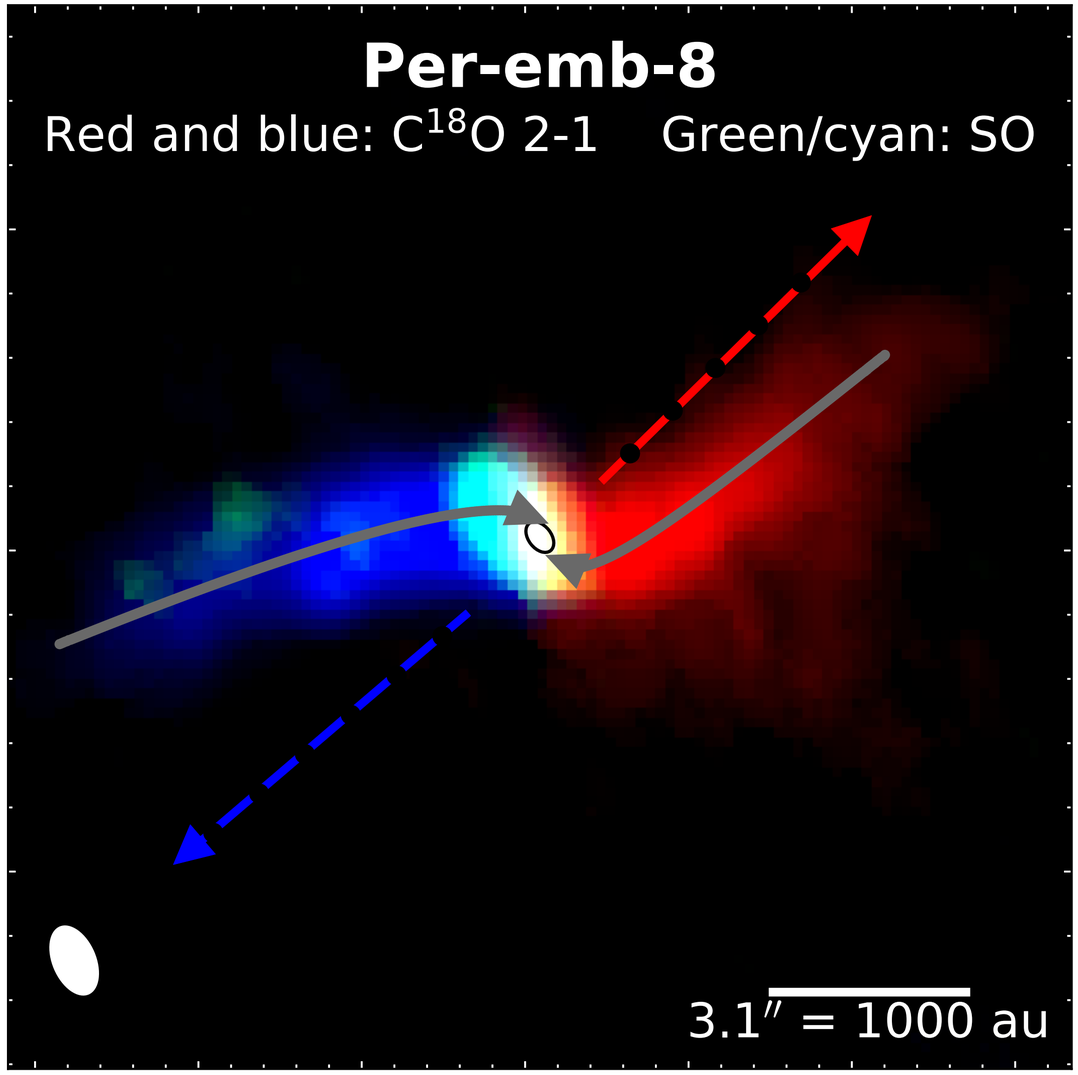
Ginski et al. (2021)

Simulation

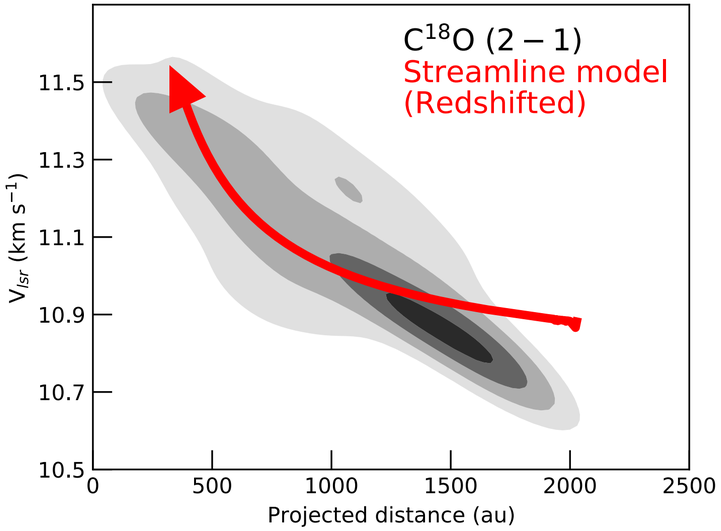


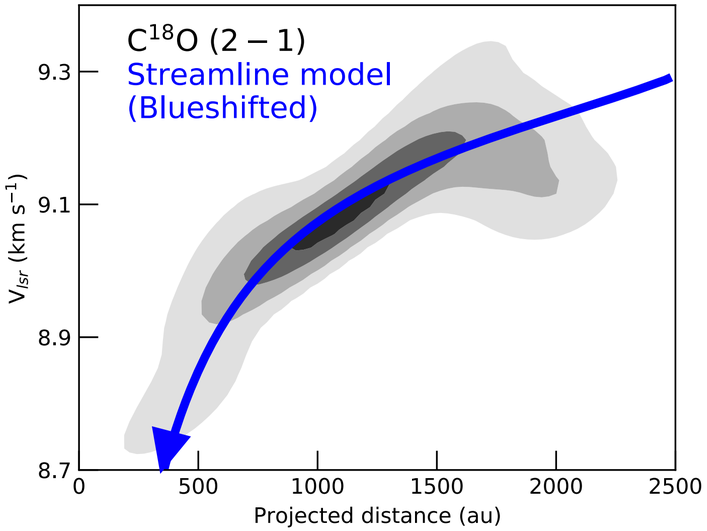
Zhao et al. (2018)

Streamer Statistics with NOEMA



Segura-Cox, Pineda et al. in prep



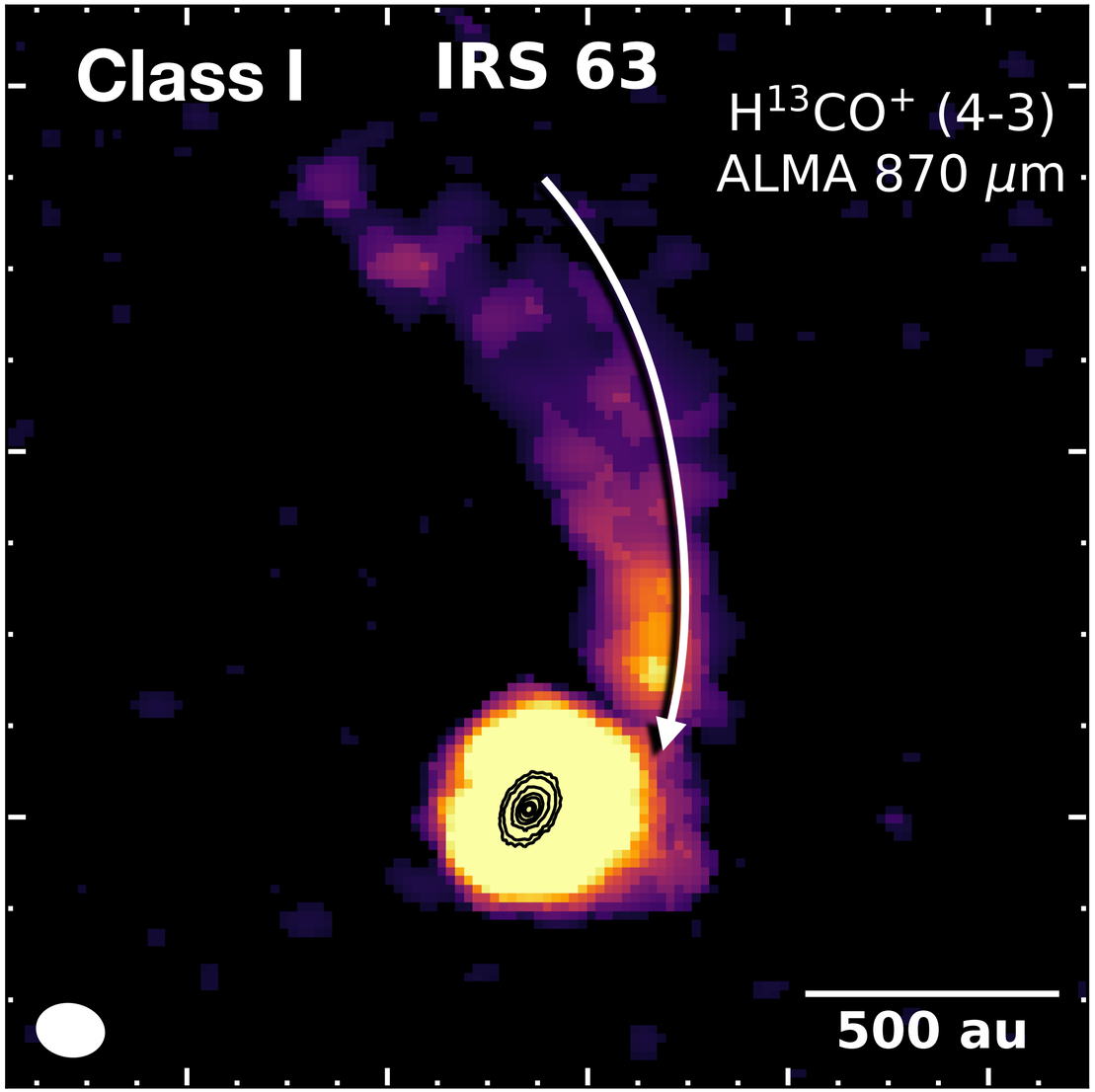


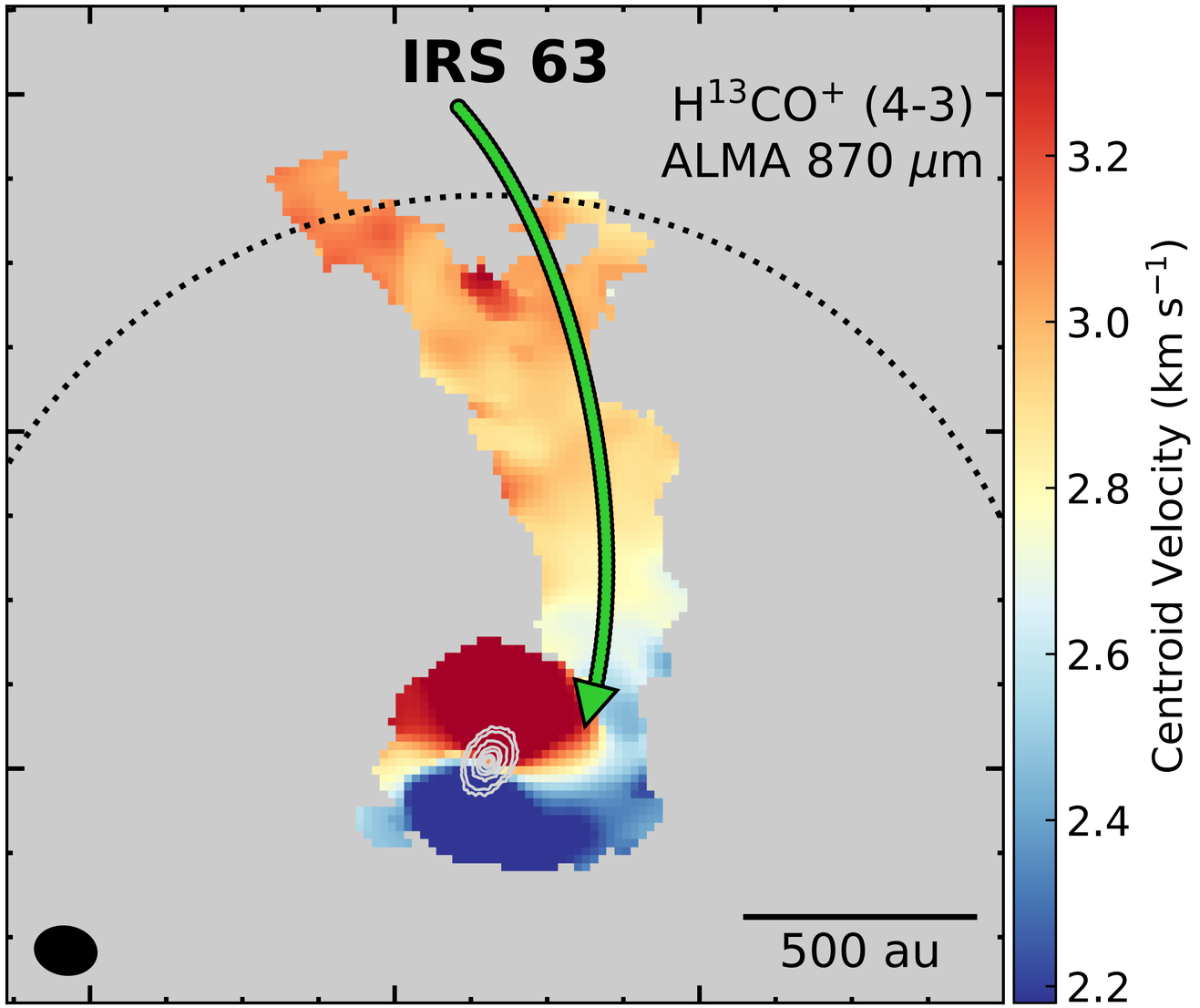
PIs: Paola Caselli & Thomas Henning

Covers 32 Class 0/I and 8 Class II

520 hours observed over 4 years

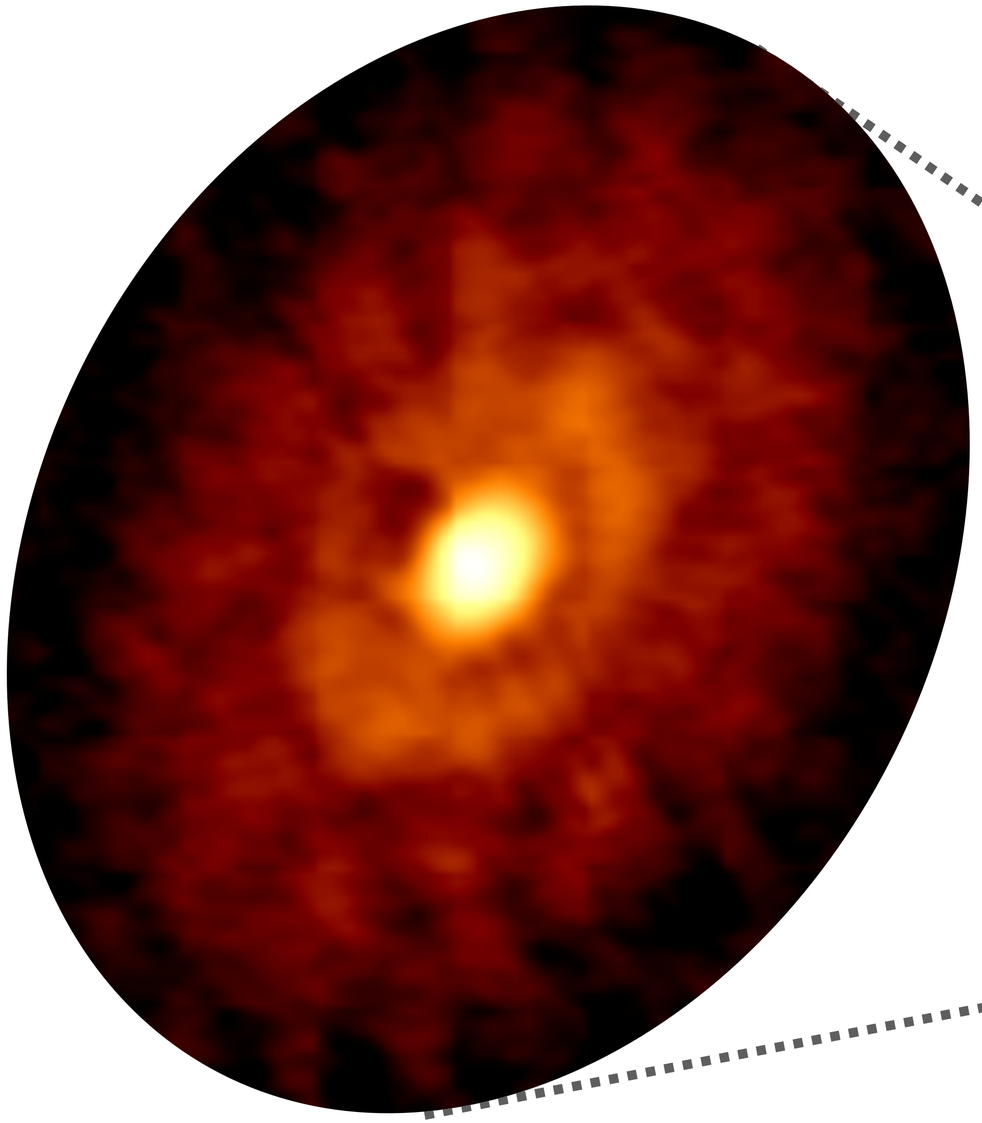
Class I Streamer

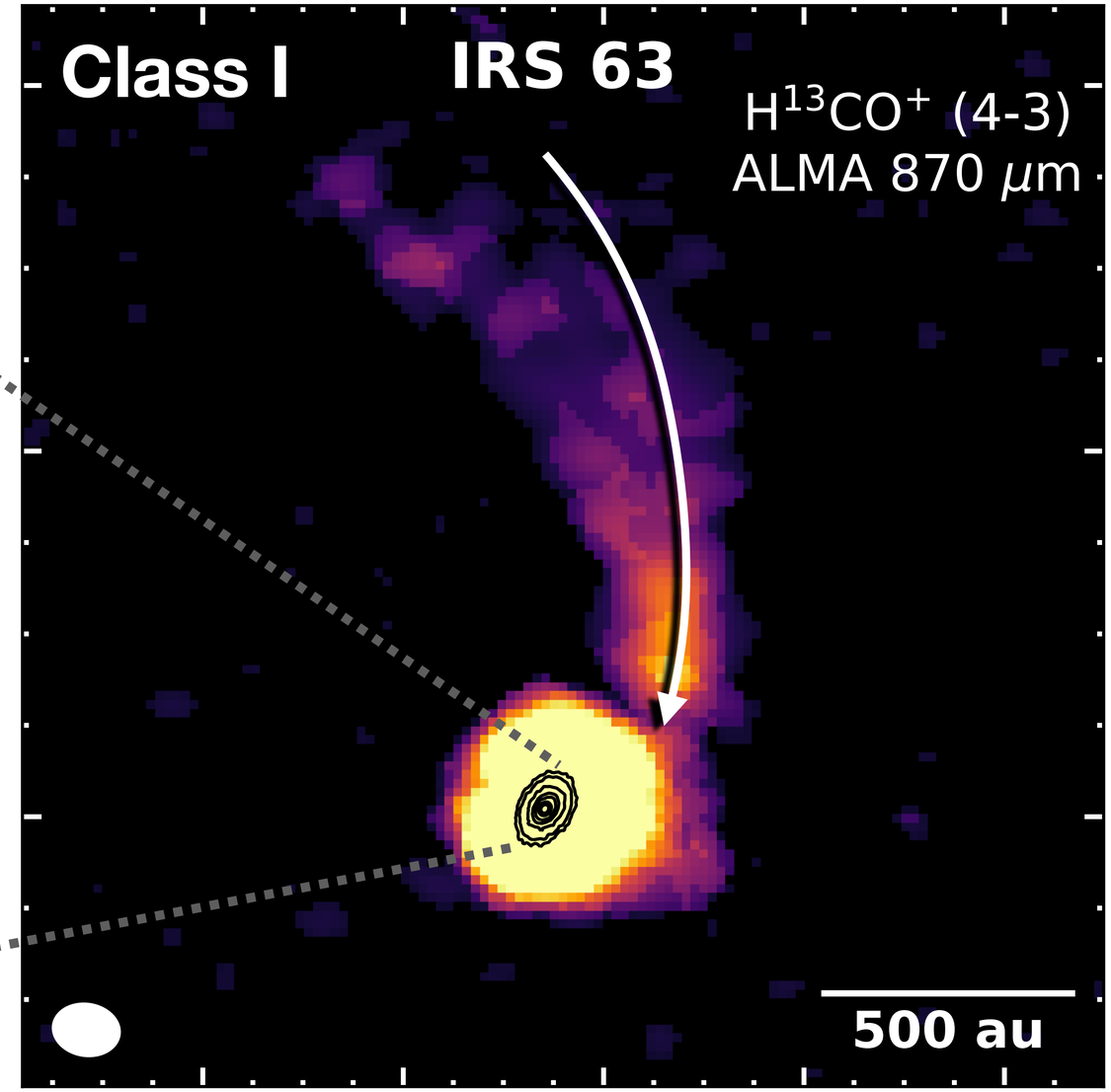




Segura-Cox et al. in prep

Streamer Feeding a Ringed Disk





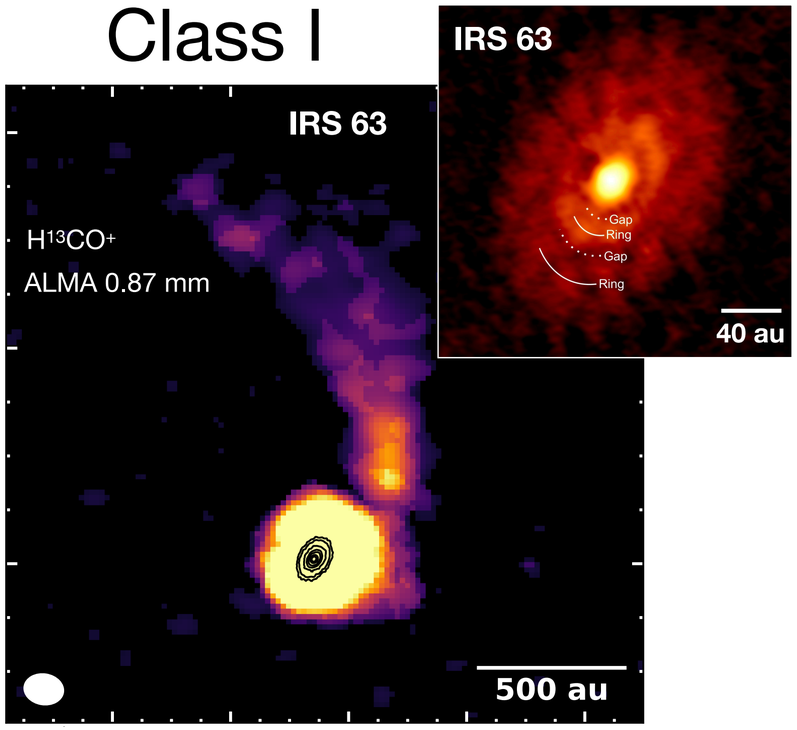
Segura-Cox et al. (2020)

Segura-Cox et al. in prep

More Young Rings & Streamers

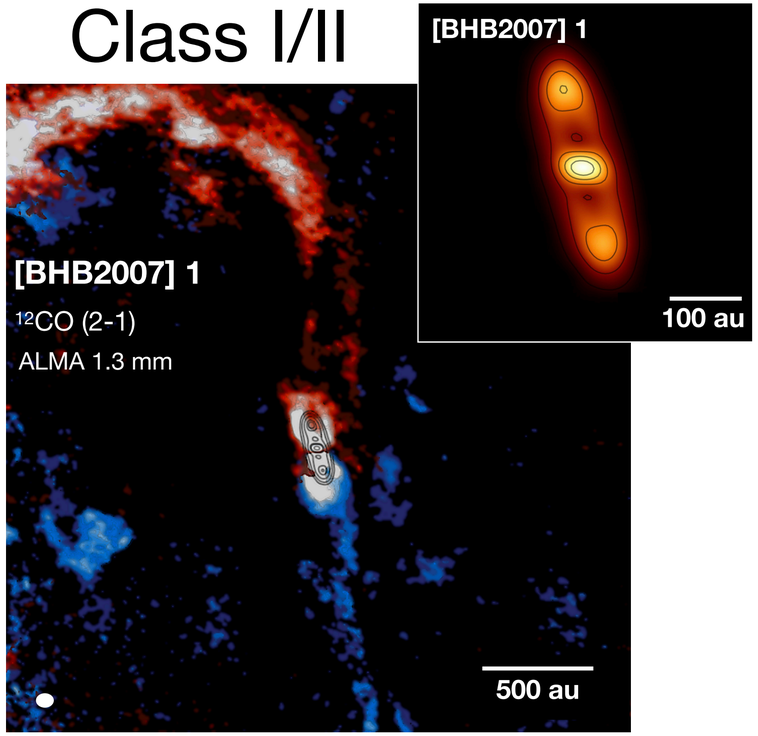
Could these streamers help form the young dust rings?

Class I



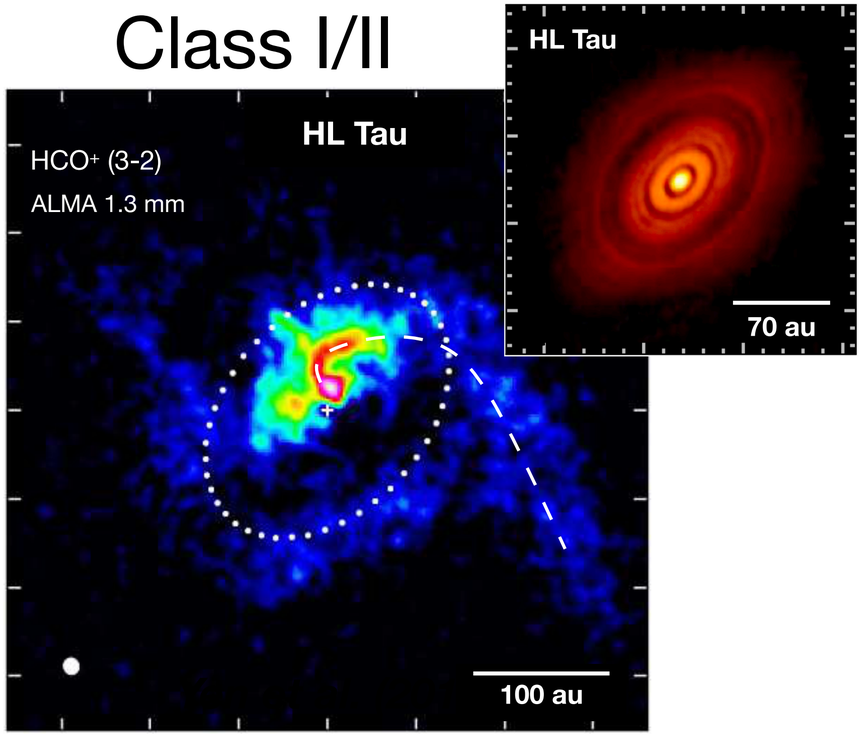
Segura-Cox et al. in prep
Segura-Cox et al. (2020)

Class I/II



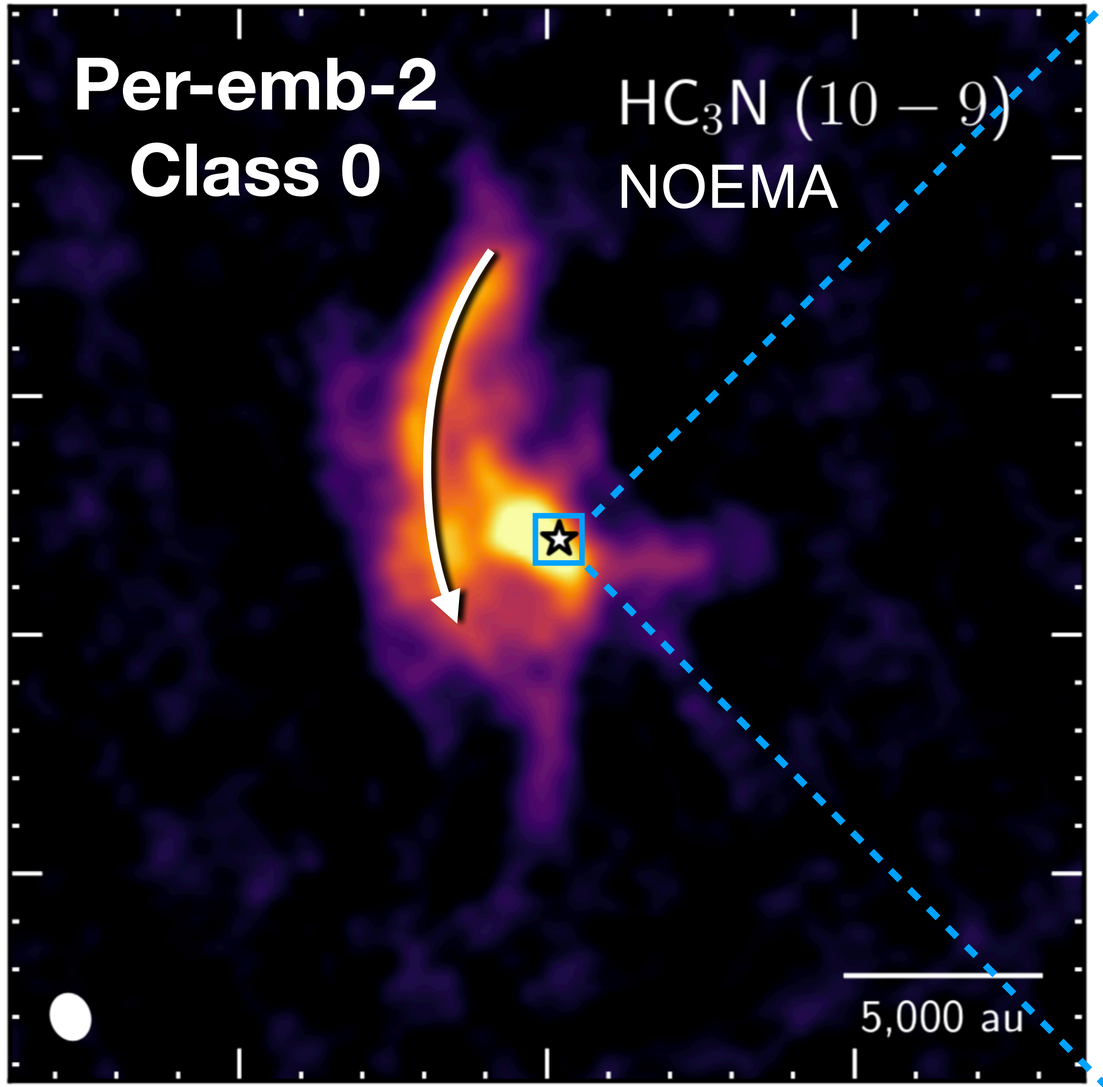
Alves et al. (2020)

Class I/II

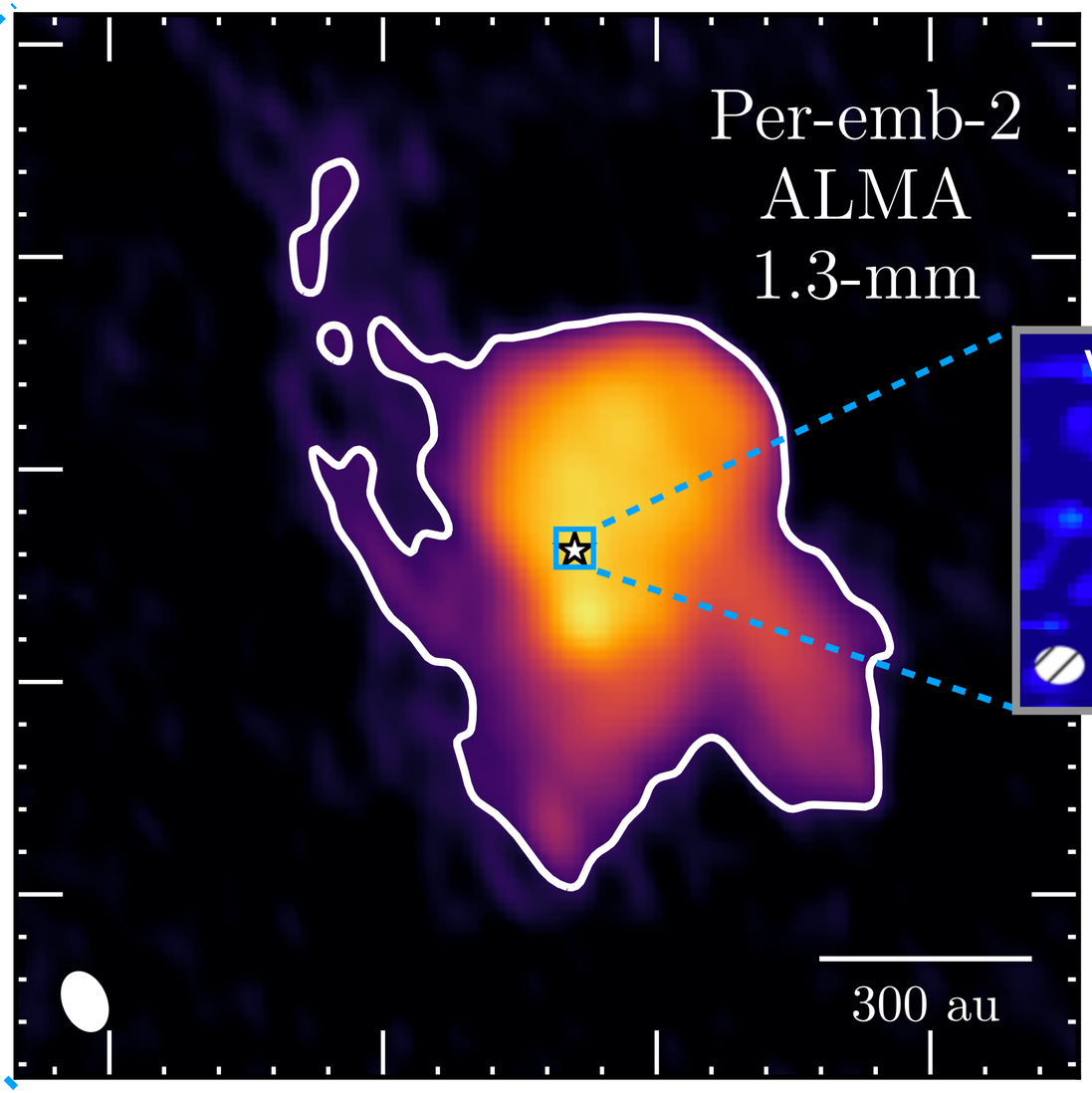


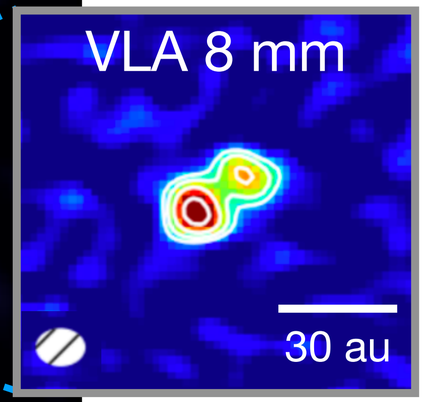
Yen et al. (2019)
ALMA Partnership et al. (2015)

Not Always a Well-Formed Disk



Pineda et al. (2020)

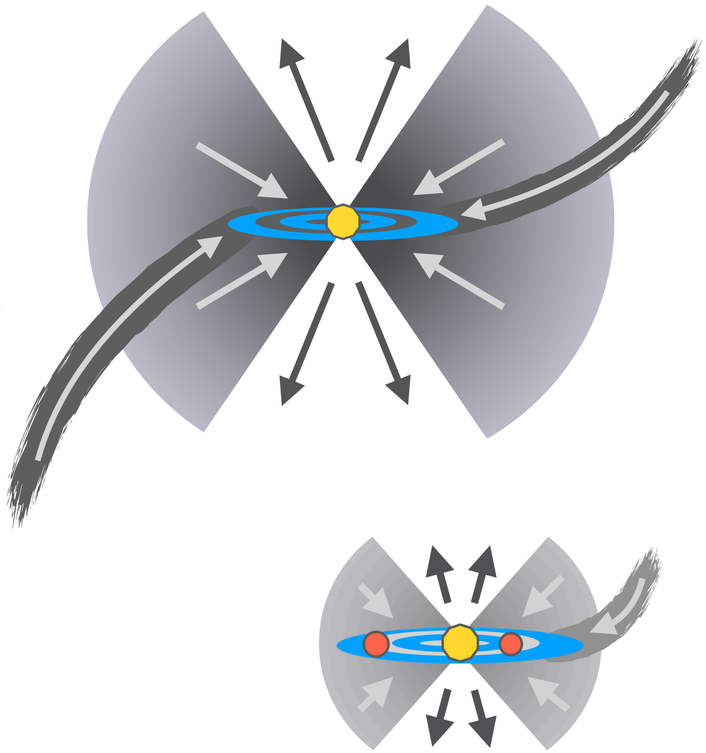




Segura-Cox et al. (2018)

Reprocessed from Tobin et al. (2018)

Questions about Streamers



How common are they?

What are the best tracers to find streamers?

How long are streamers?

How dominant are they in the mass accretion process?

Do they reset the chemical composition of the disk?

Do streamers form rings or make disks gravitationally unstable?

Do streamers cause gas disks to spread?