Dense gas flows and feedback in the Serpens South protocluster

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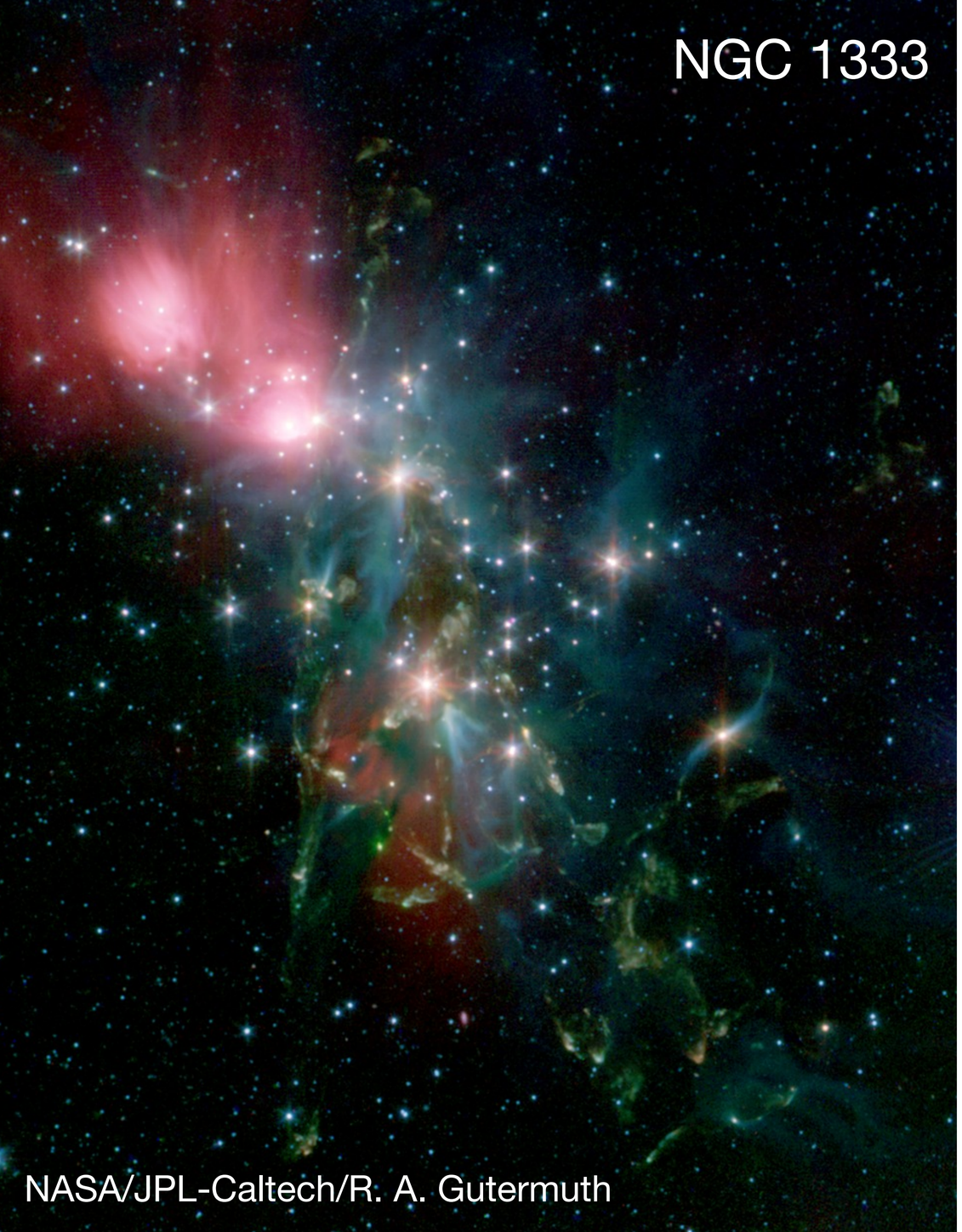
low mass

What is the impact of star formation on nearby dense gas?

cluster-forming

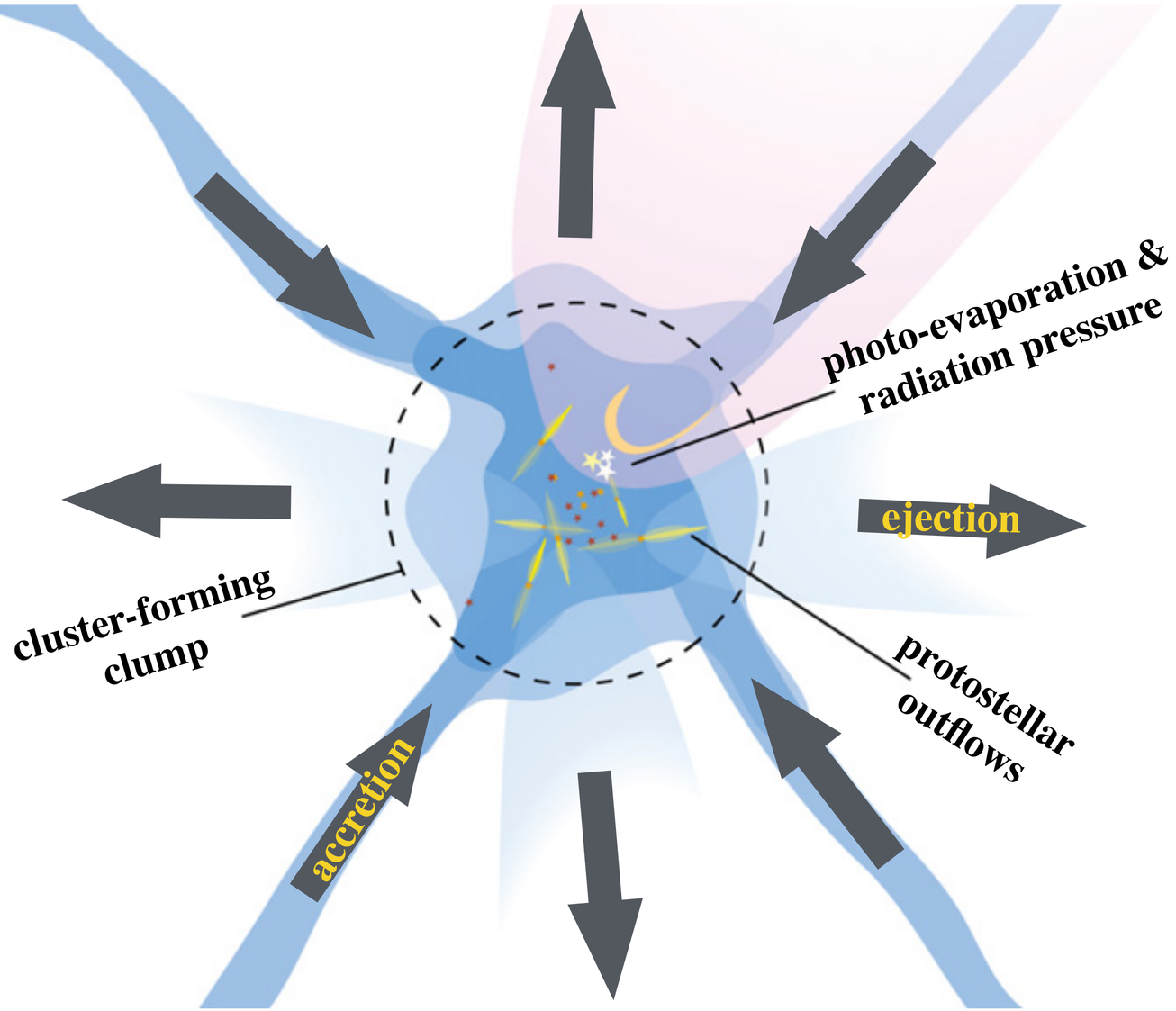


How well do pc-scale outflows couple with dense gas?

- Protostellar cores: mass loss in envelope via entrainment (e.g. Arce & Sargent 2006, Offner & Chaban 2017)
- Seamus Clarke's talk - outflows largely directed away from filaments, little impact?
- Low-mass protostellar clusters:
  - outflows can maintain clump turbulence (?)
  - injected energy insufficient to unbind clump

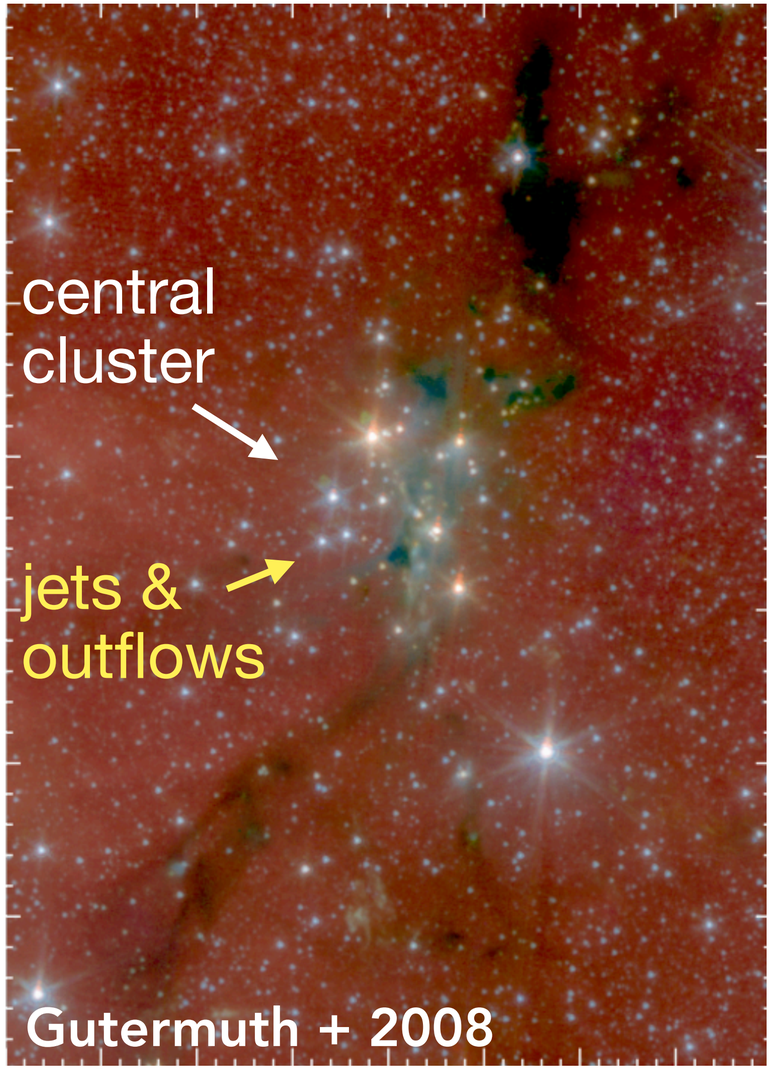
(e.g. . Li and Nakamura 2006, Arce + 2010, Duarte-Cabral + 2012, Plunkett + 2015, Feddersen + 2020, many others!)

Cluster evolution is driven by a mix of processes

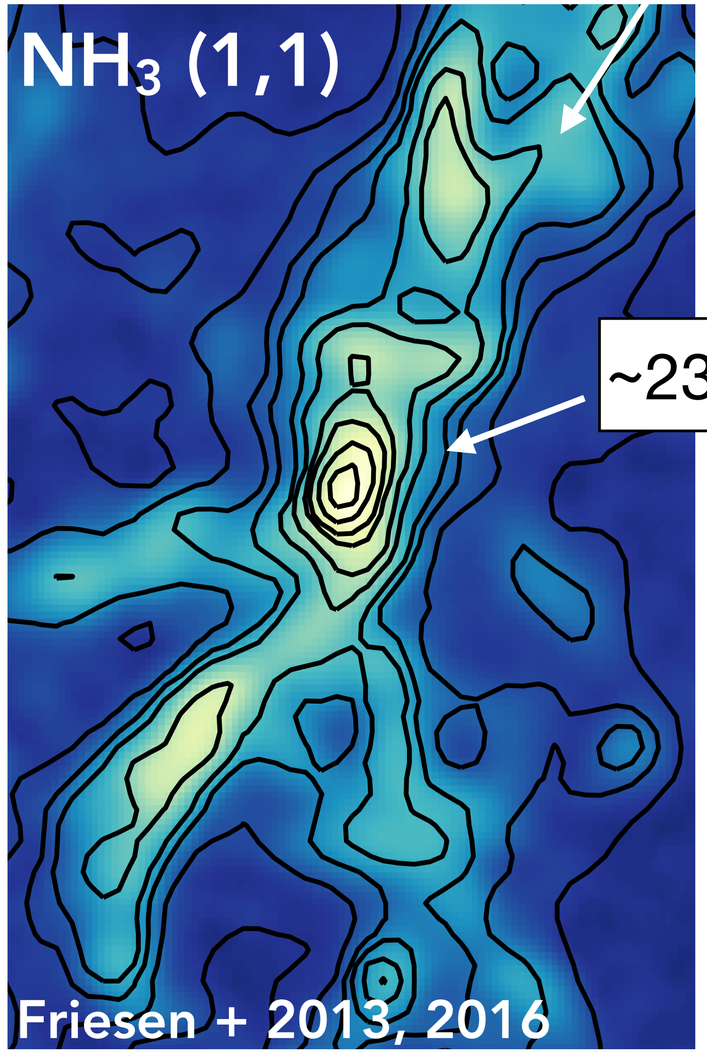


- In low mass clusters, outflows are the dominant feedback mechanism (e.g., Matzner & Jumper 2015)
- Hub-filament systems accrete mass via filaments

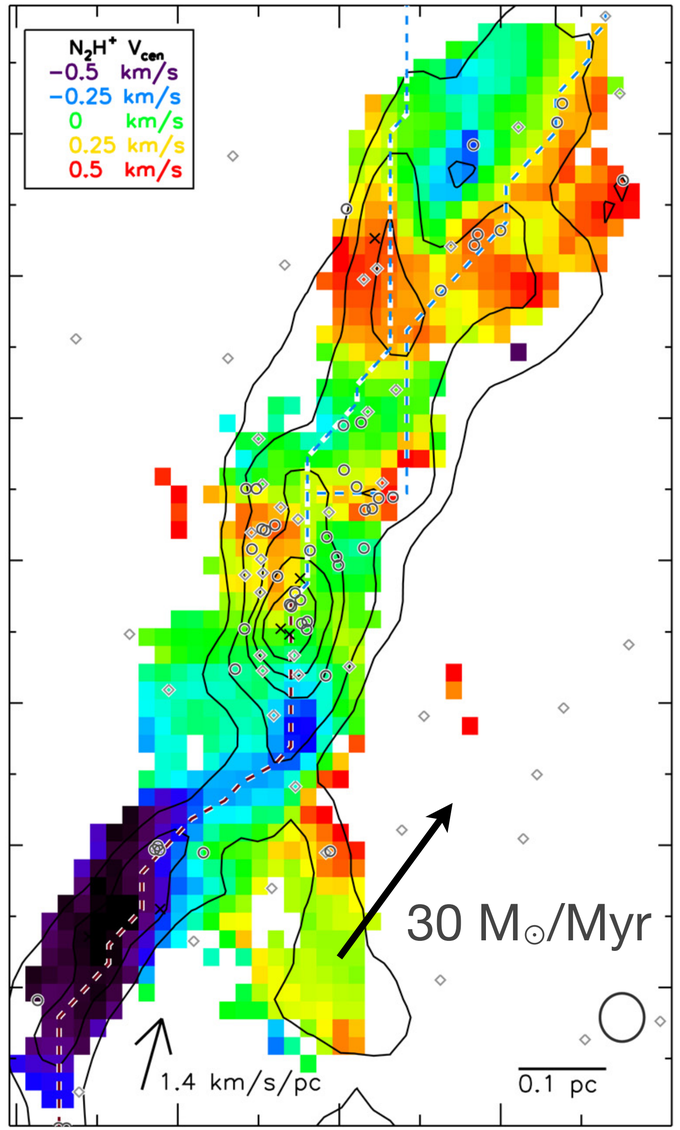
Serpens South: a young protocluster with accretion flows



Nakamura + 2011,
Plunkett + 2015, 2018

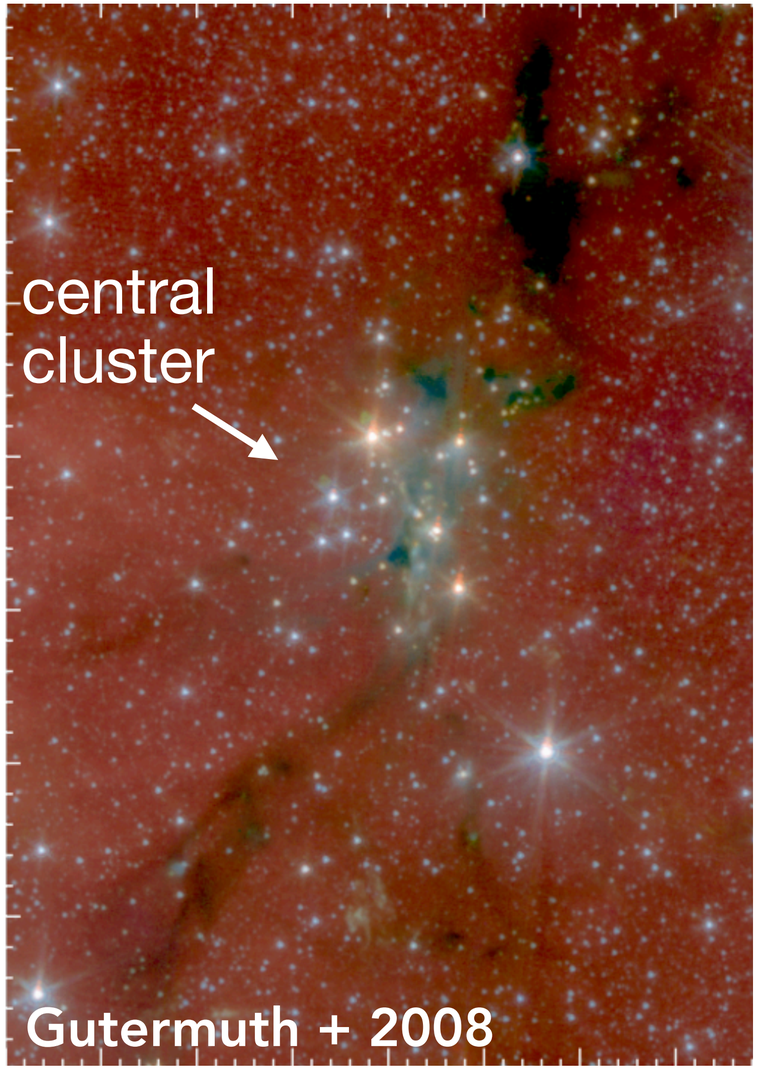


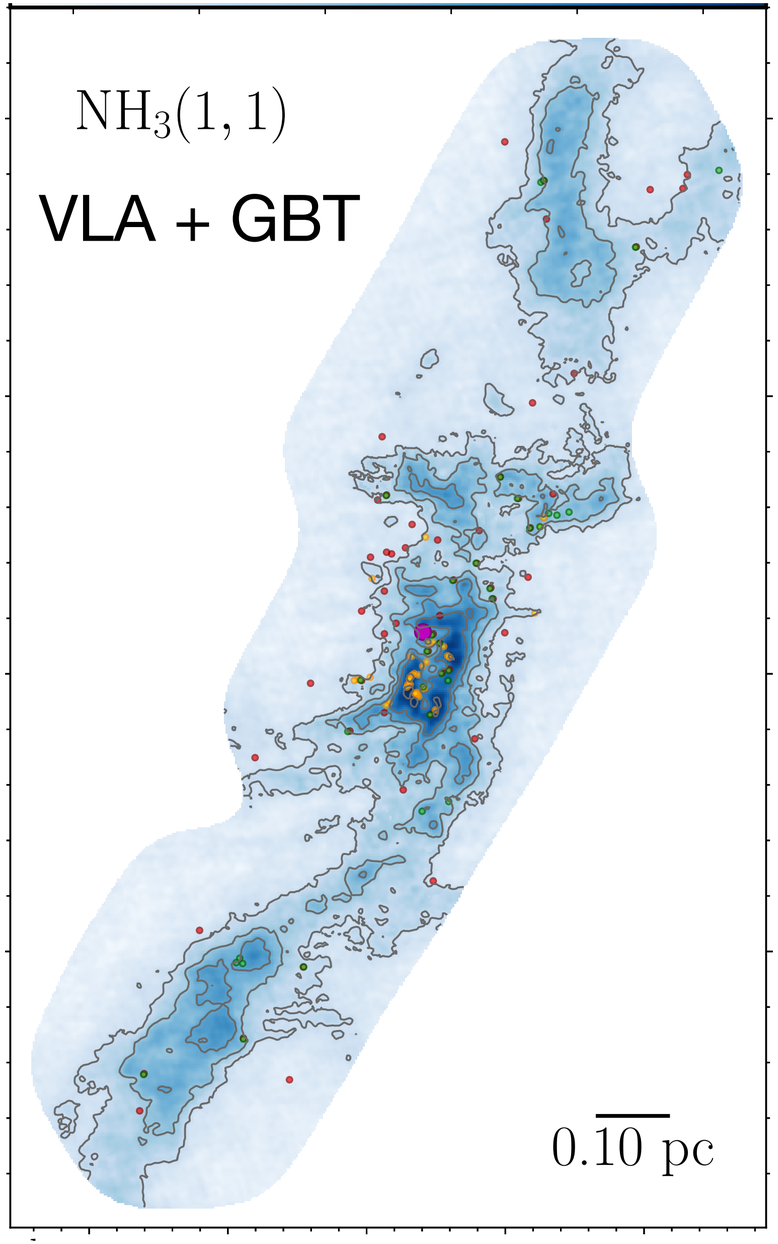
Tanaka + 2013



Kirk + 2013

How does the cluster impact the dense gas?





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VLA mosaic

NH_3 (1,1), (2,2), (3,3)

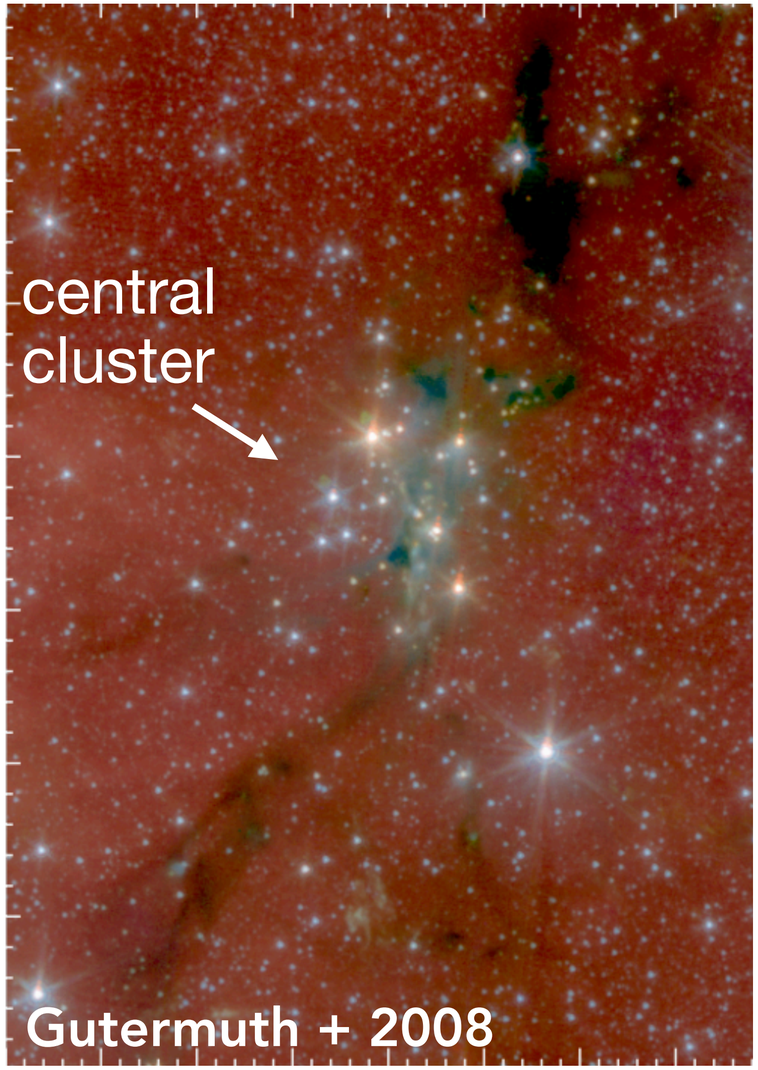
5” angular resolution (0.01 pc)

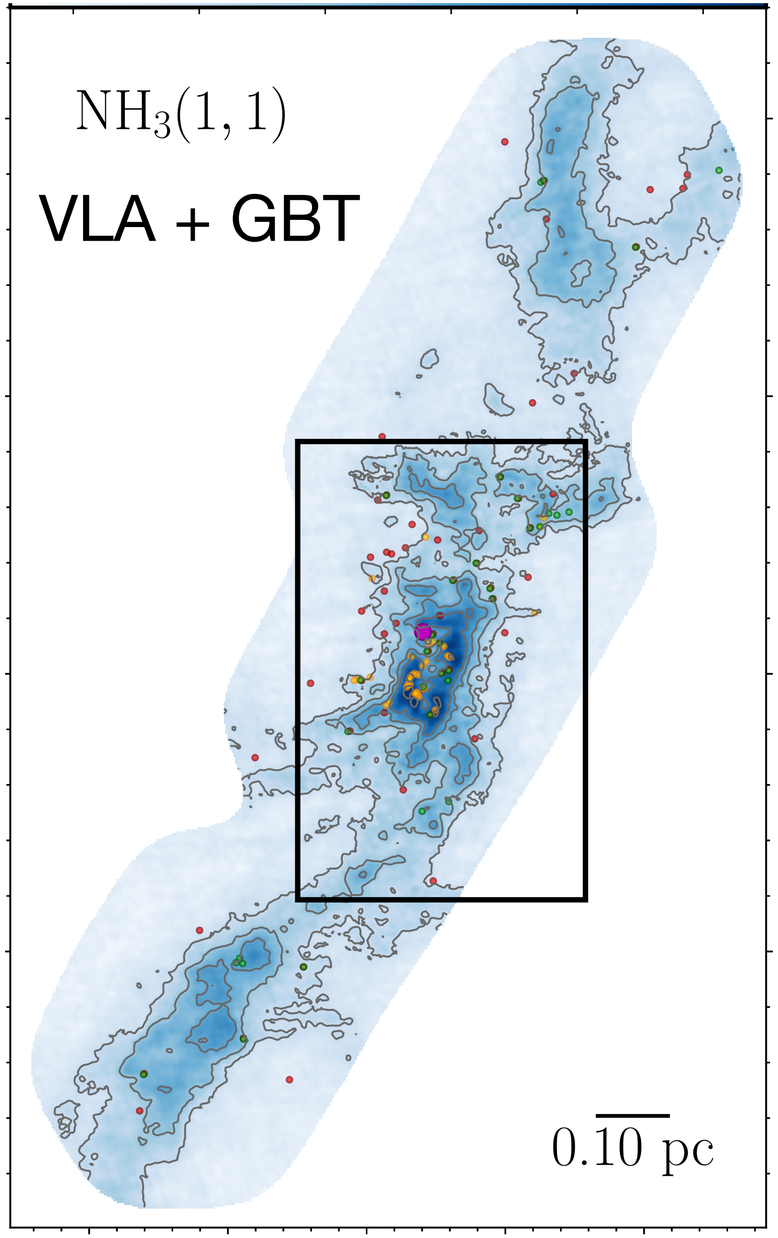
Δv = 0.15 km/s

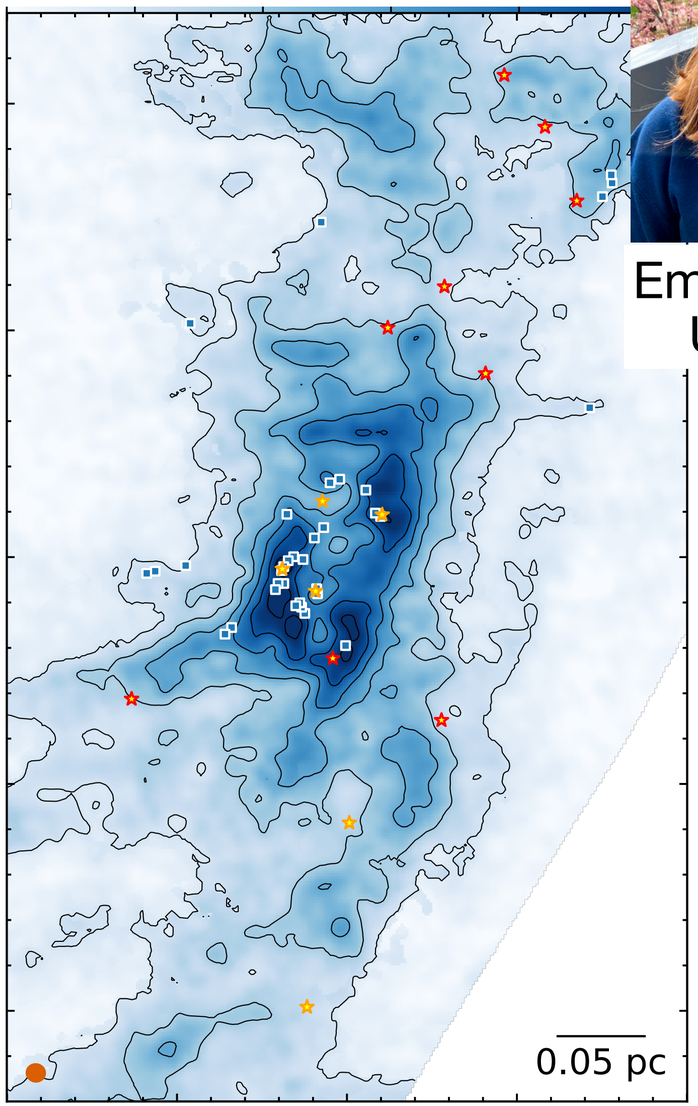
28 pointing mosaic

GBT model & feather

Dense gas is highly fragmented







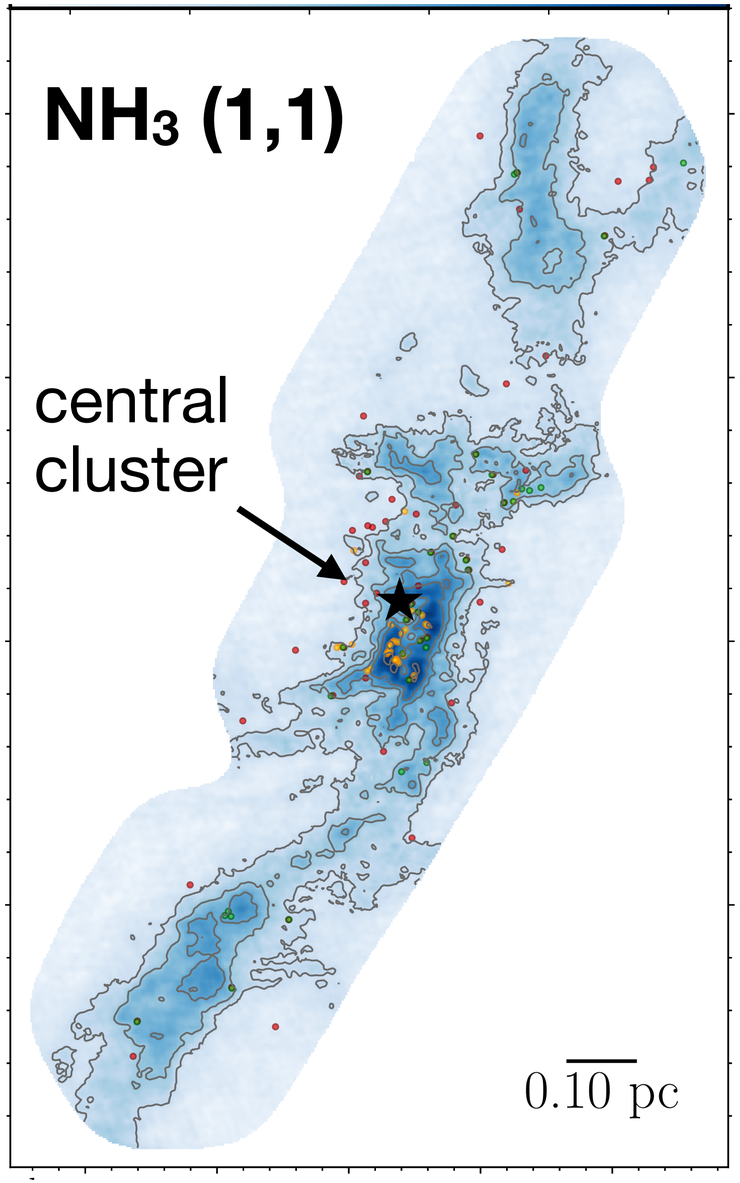
Emma Jarvis
U. Toronto

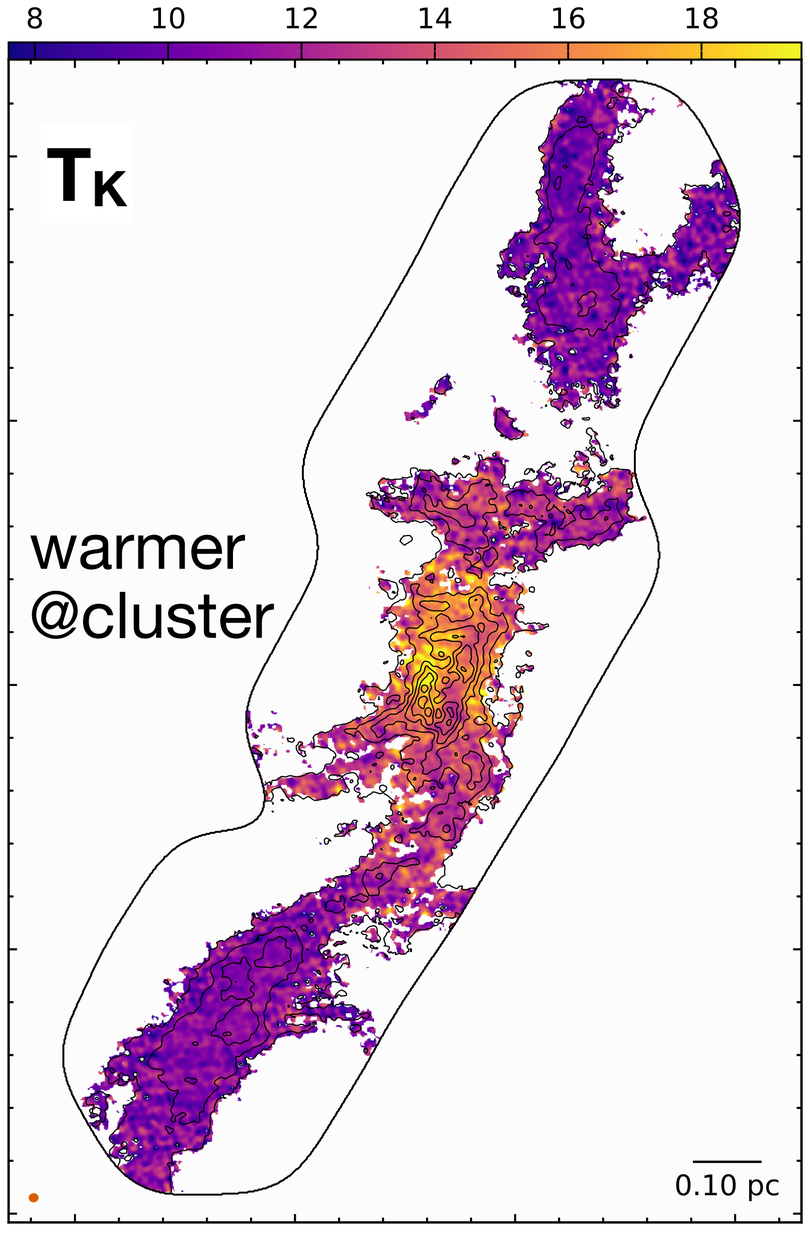
Friesen & Jarvis 2024

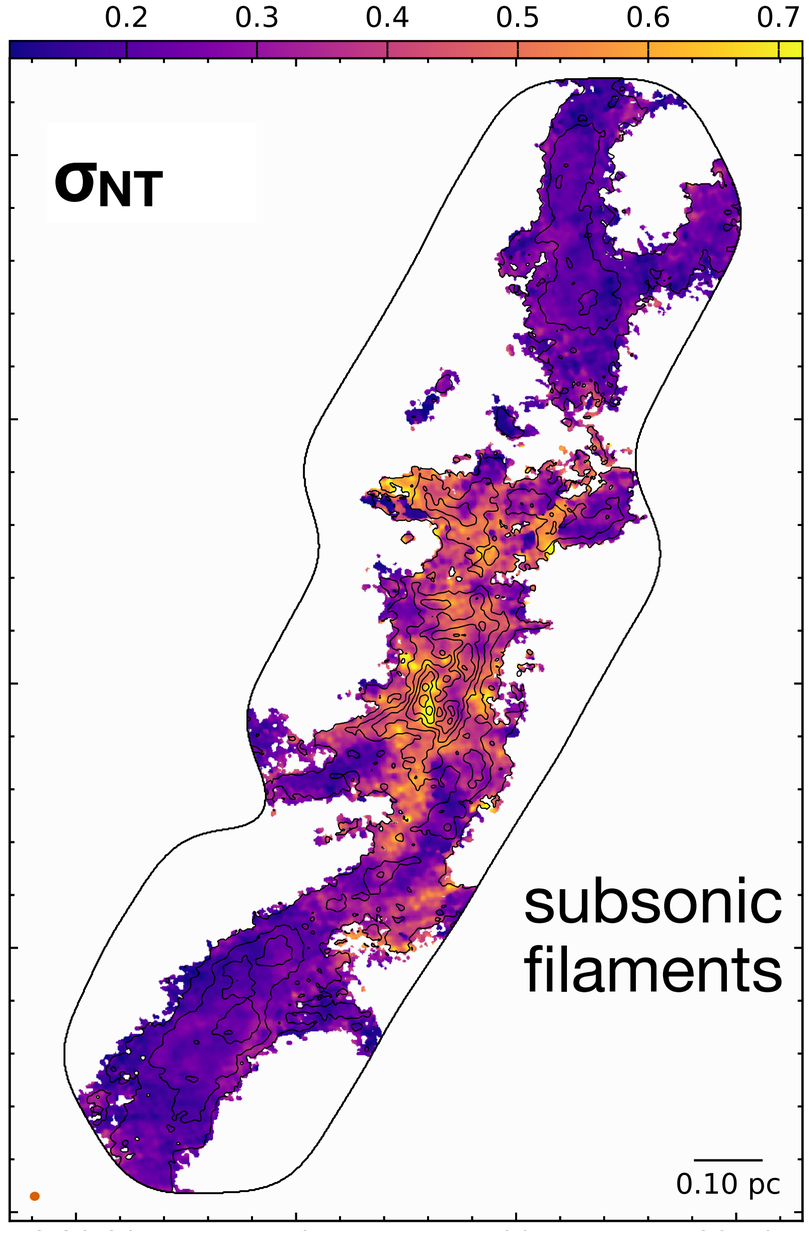
★★ protostars: Sun + 2022

□ mm continuum: Plunkett + 2018

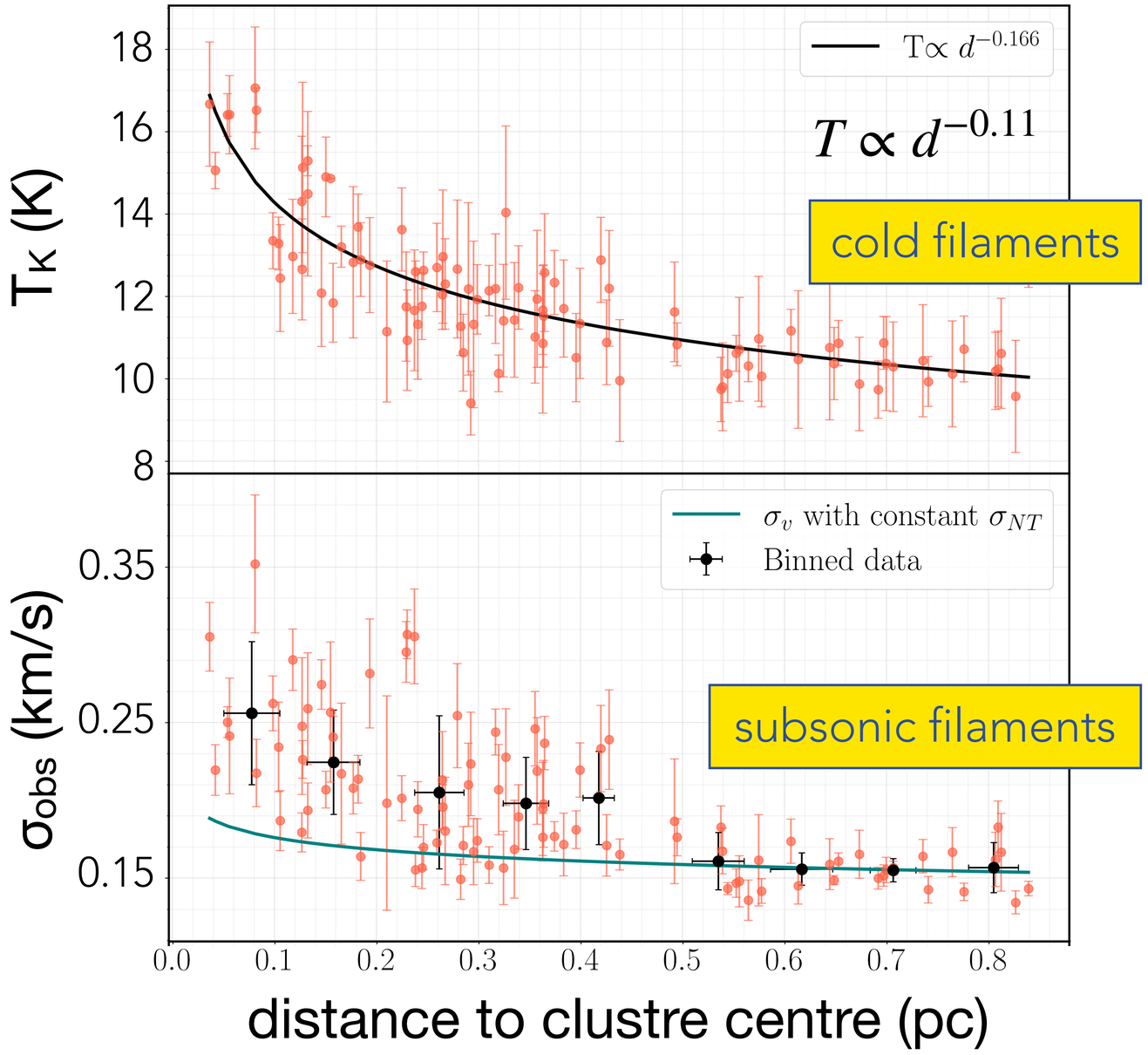
Dense gas is impacted by the cluster







Core gas is impacted by the cluster



Datapoints:

Mean T_K, σ in cores

(identified via *astrodendro*)

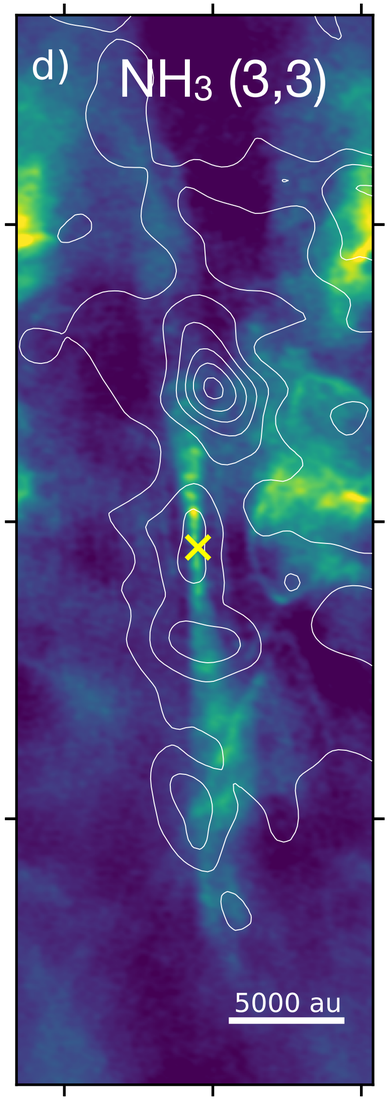
Core T_K, σ_{NT} increase closer to cluster centre

Steeper dependence $T \propto d^{-0.35}$ in high mass regions, theory

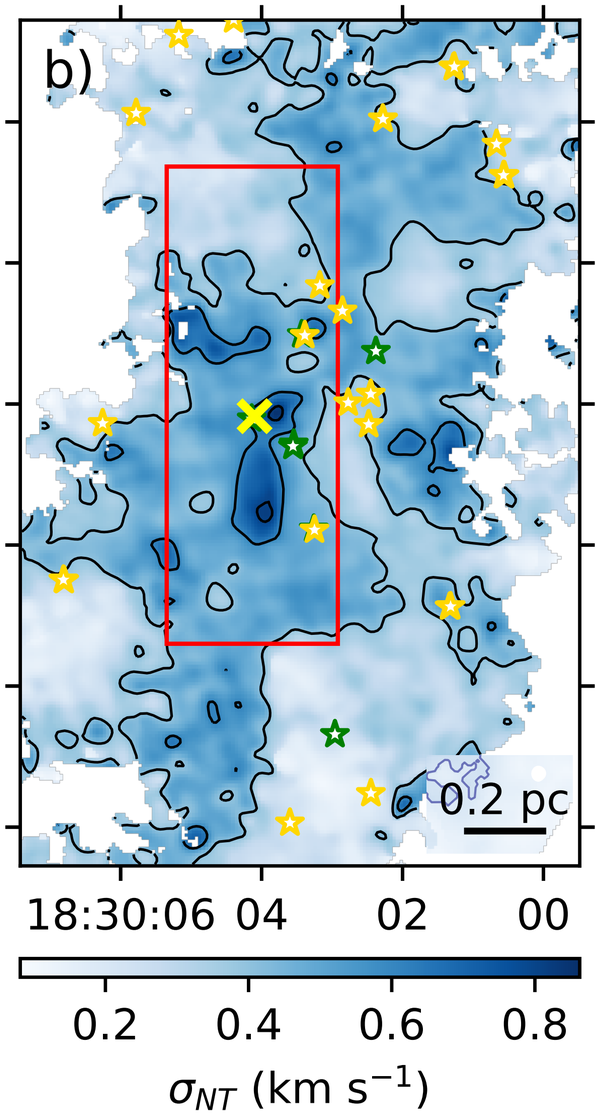
(e.g. Longmore + 2011, Wong + 2012, Scoville & Kwan 1976)

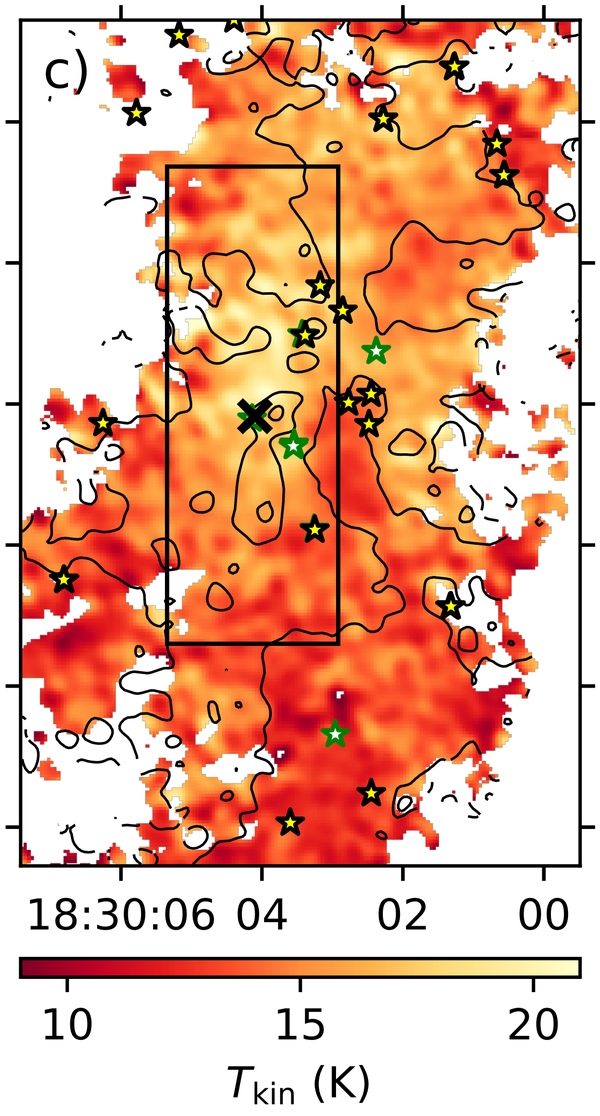
Protostellar jets & outflows: increased σ

- Collimated outflows more efficient in driving turbulence (e.g. Nakamura & Li 2007)
- Energy injection scale ~ few x 0.1 pc (obs/ theory)
- Large σ_{NT} extent matches broader outflows (e.g. Nakamura + 2011)

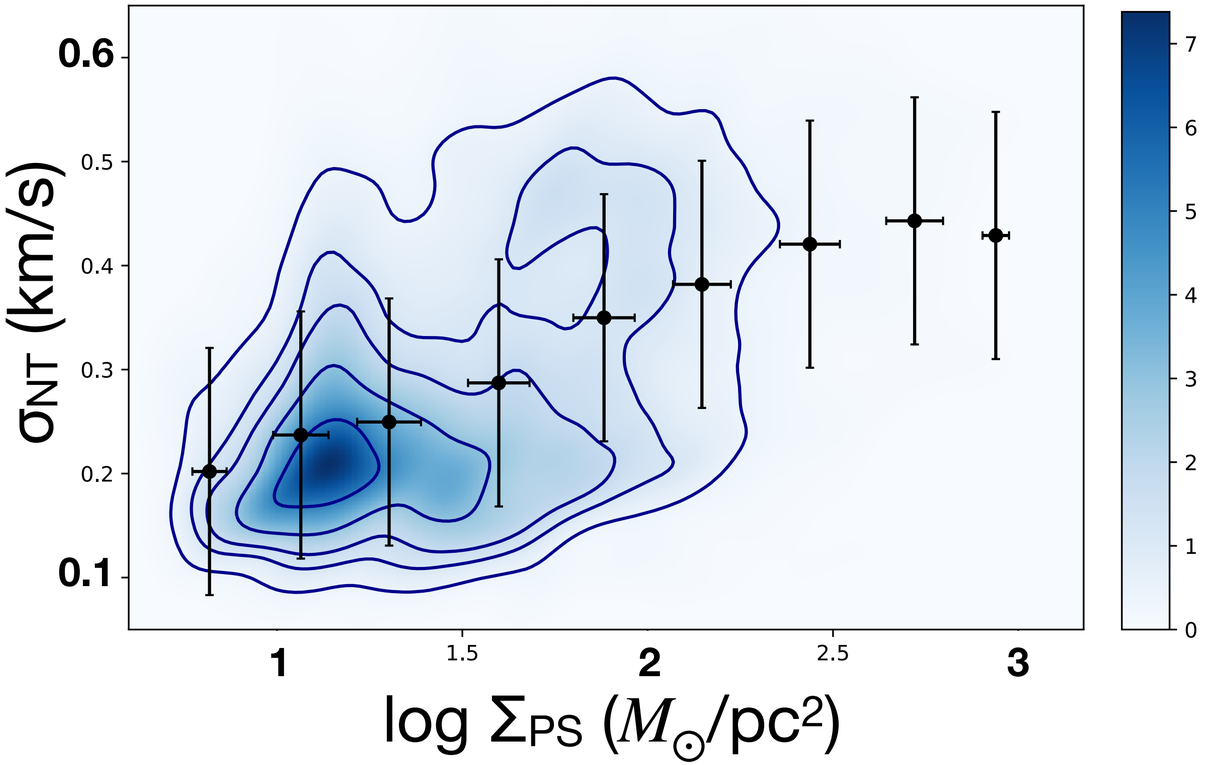


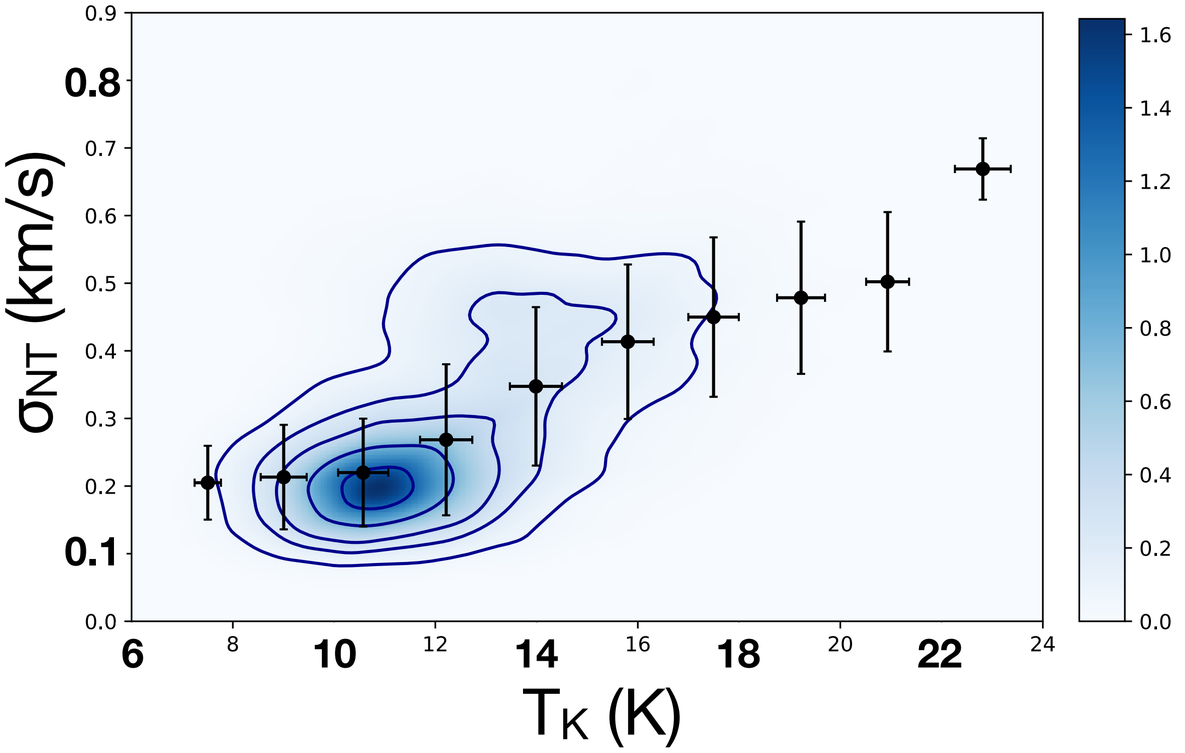
Collimated protostellar jet (Plunkett + 2015)





Σ_{PS}, T_K and σ_{NT} are correlated





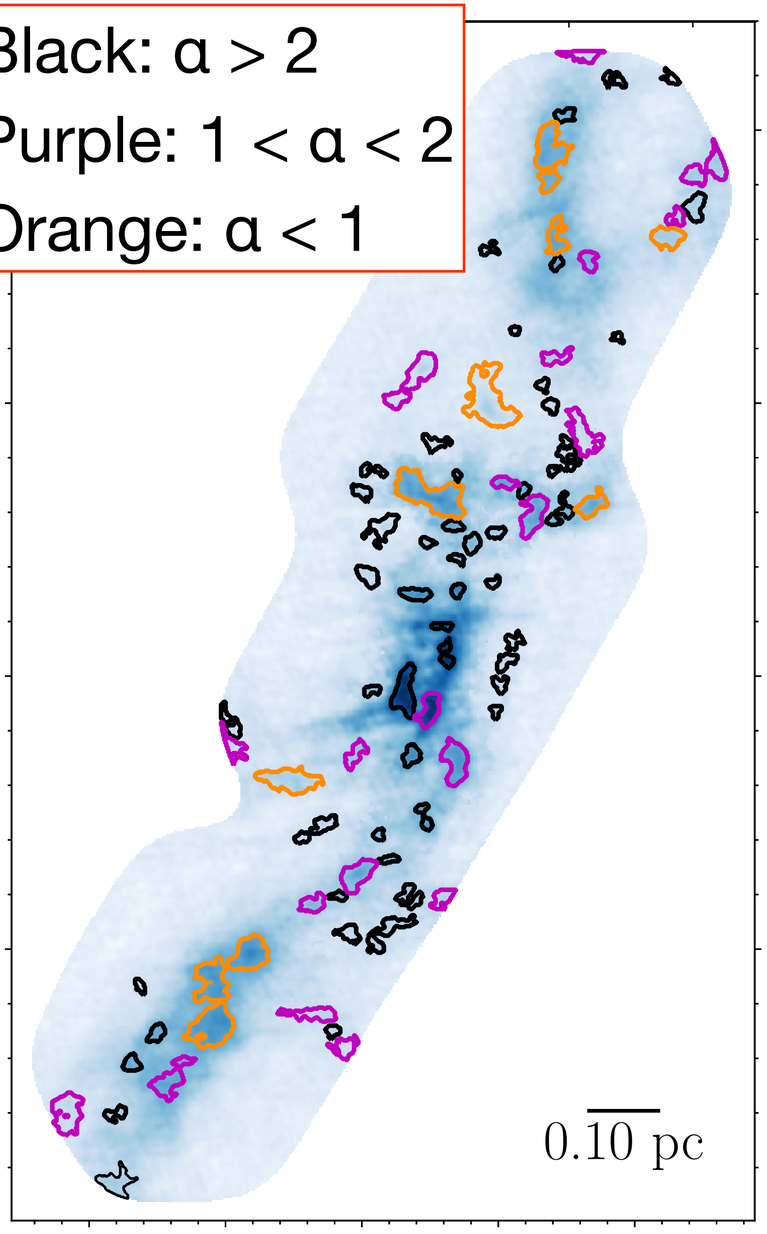
- Both T_K and σ_{NT} increase with protostellar surface density
- Strongest positive correlation between T_K and σ_{NT} themselves
  - Gas heating: radiative + mechanical feedback

Dense cores are less bound near the cluster

Black: α > 2

Purple: 1 < α < 2

Orange: α < 1

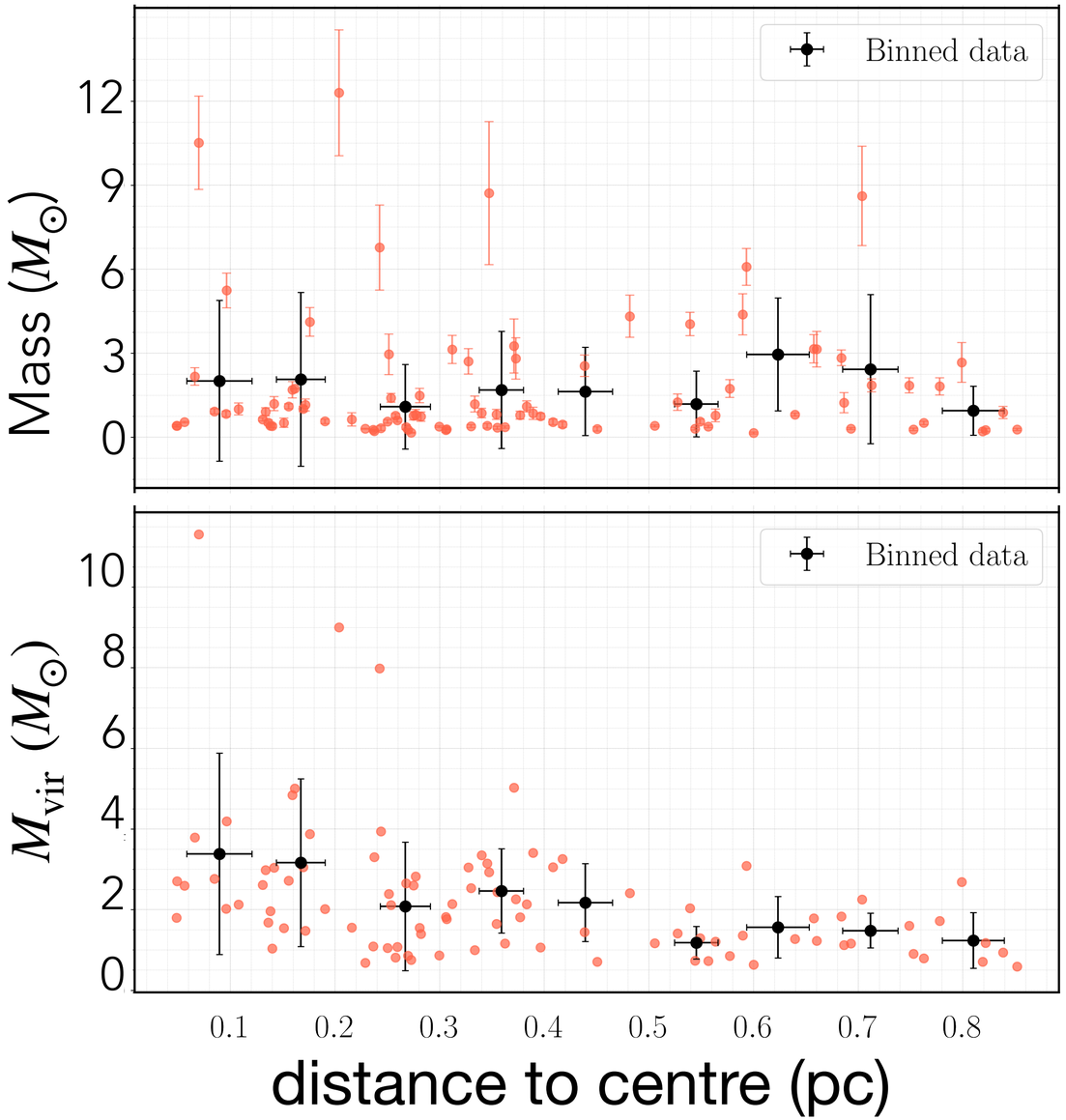


Virial analysis

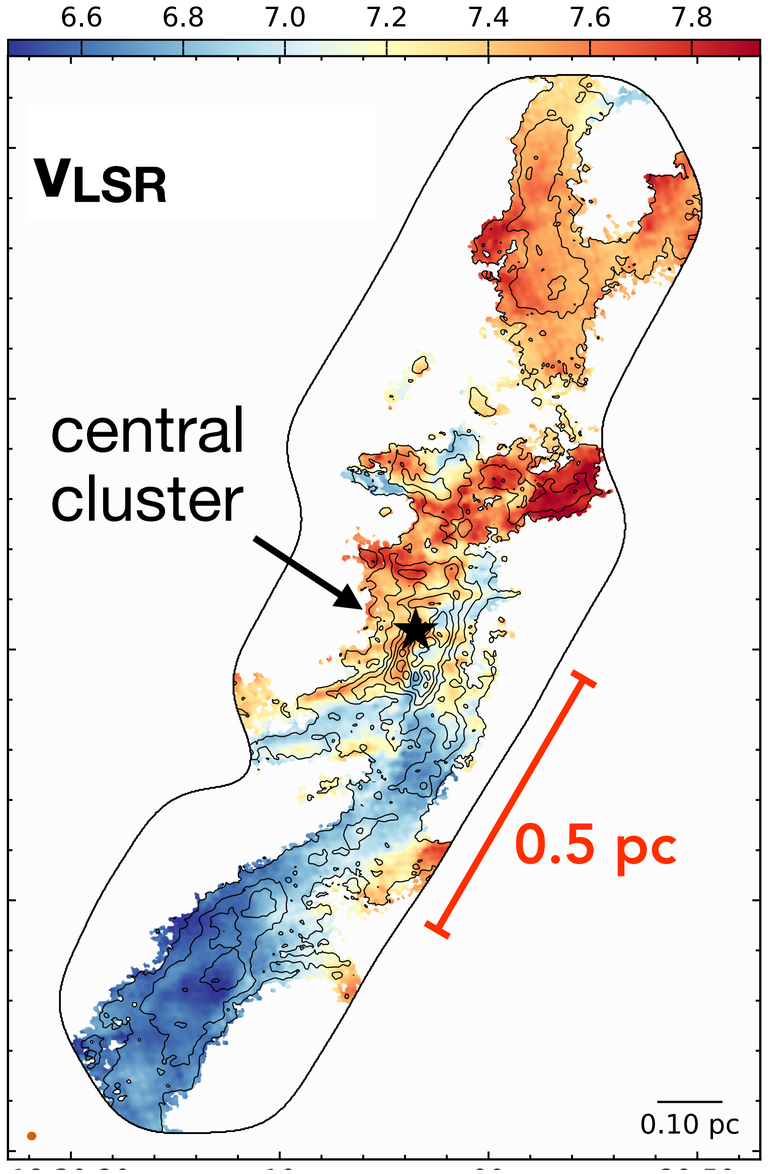
Core masses ~ constant

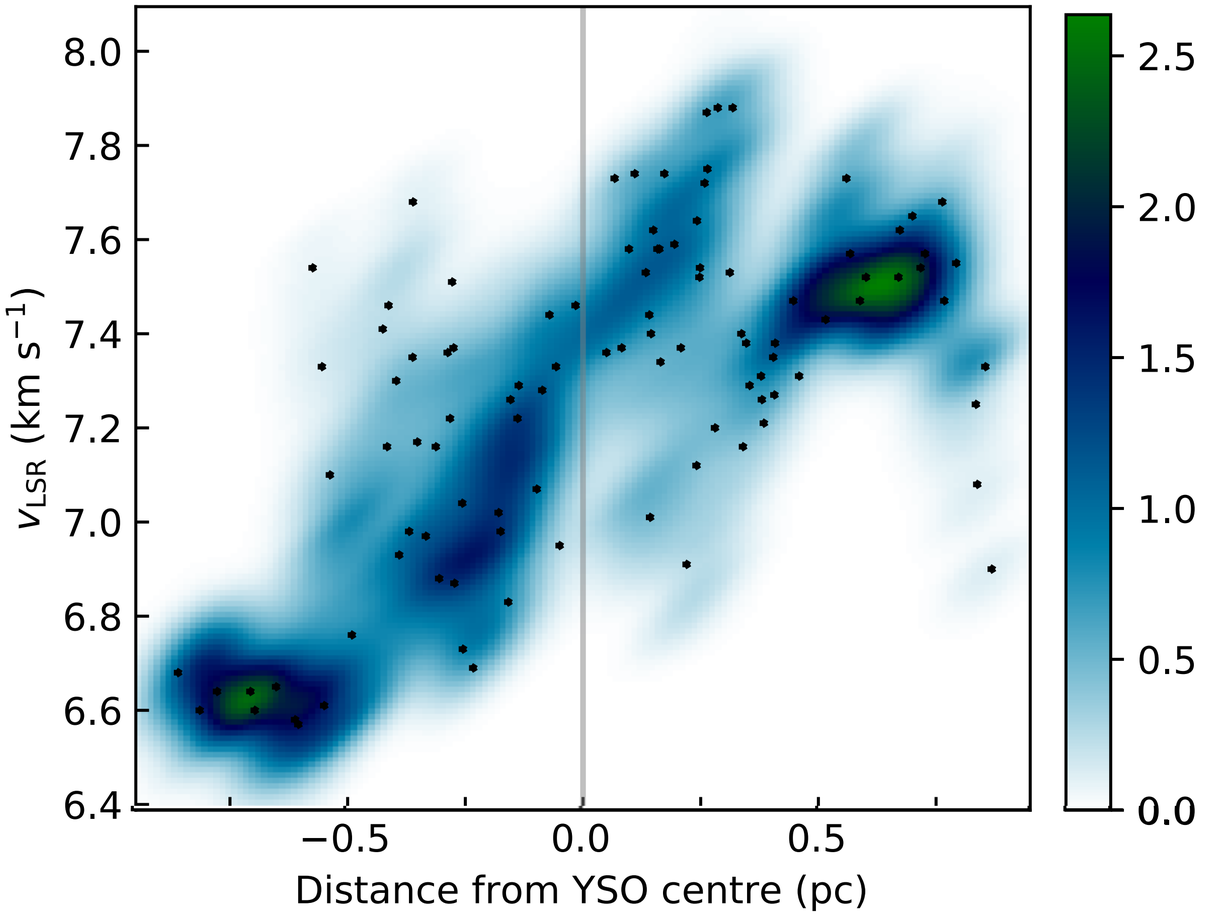
Virial masses increase toward cluster centre

Friesen & Jarvis 2024



Filamentary flows: reservoir for accretion





- Accretion timescale ~ 0.7 - 1.4 Myr at 0.5 pc

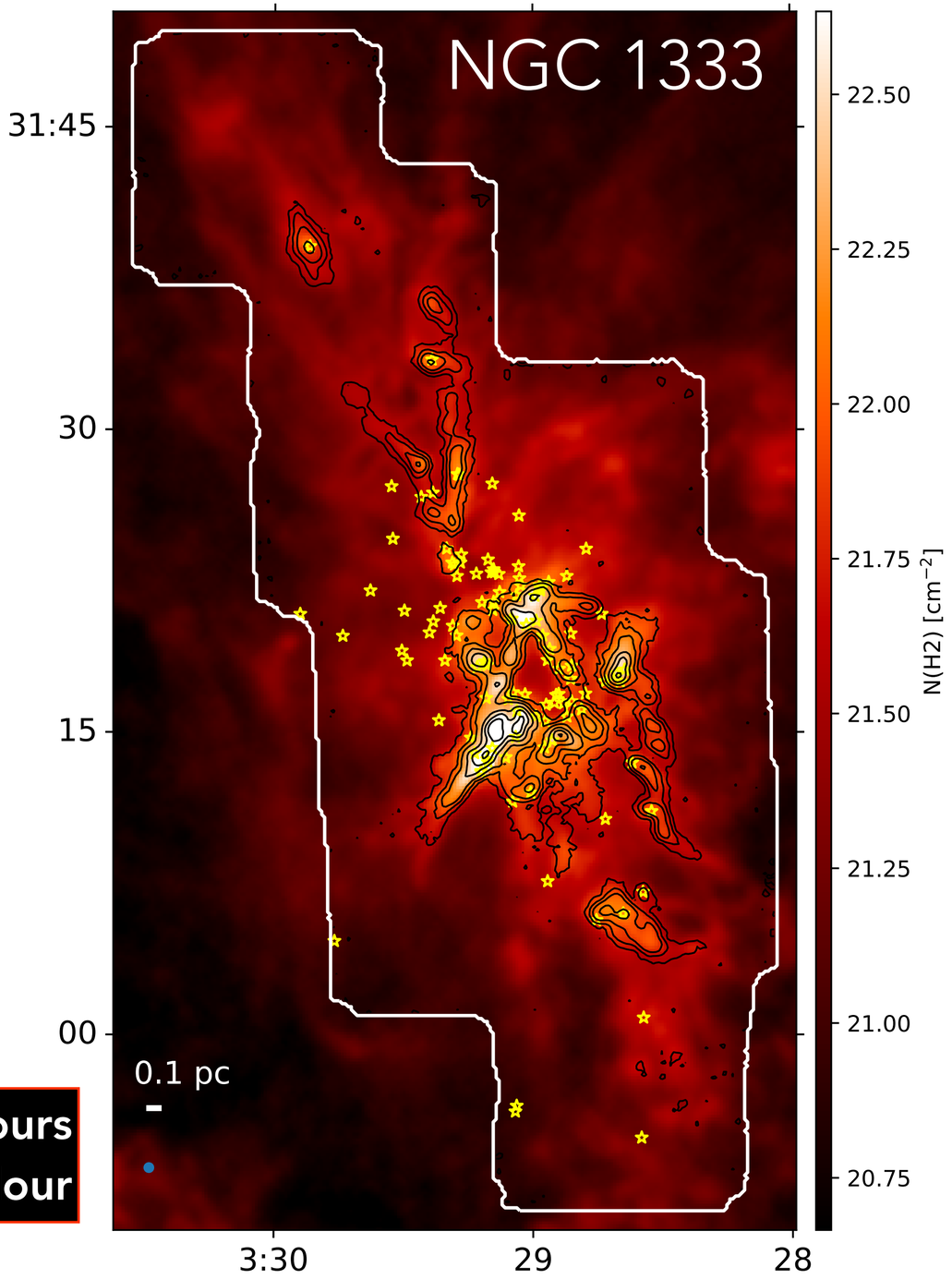
Can we say something more broadly about feedback in low mass star-forming regions?

Green Bank Ammonia Survey (GAS)

Friesen, Pineda + 2017

Pineda, Friesen + in prep

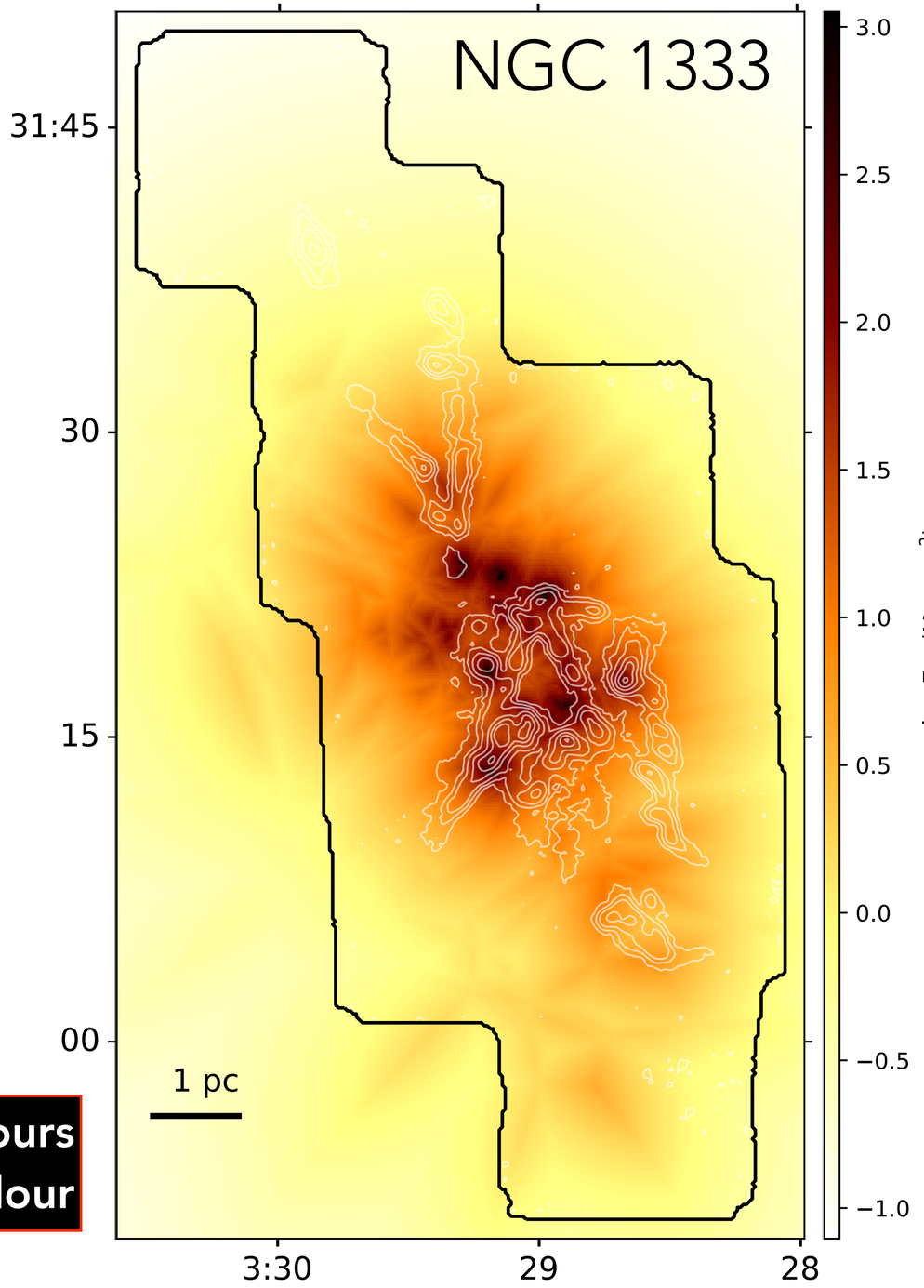
- NH_3 maps toward main Gould Belt star-forming regions
- Mass in mapped regions: $N(H_2)$ from Herschel GBS (Singh & Martin 2022)
- Protostellar catalogs: Class 0/I/II from various sources
  (e.g. NGC 1333: c2d; Dunham + 2015)



NH_3 (1,1) contours
$N(H_2)$ colour

YSO counts & Σ_{PS}

- NH_3 maps toward main Gould Belt star-forming regions
- Mass in mapped regions: $N(H_2)$ from Herschel GBS (Singh & Martin 2022)
- Protostellar catalogs: Class 0/I/II from various sources
  (e.g. NGC 1333: c2d; Dunham + 2015)
- Assume $M_* \sim 0.5\ M_{Sun}$ for Σ_{PS} (following Evans + 2009)

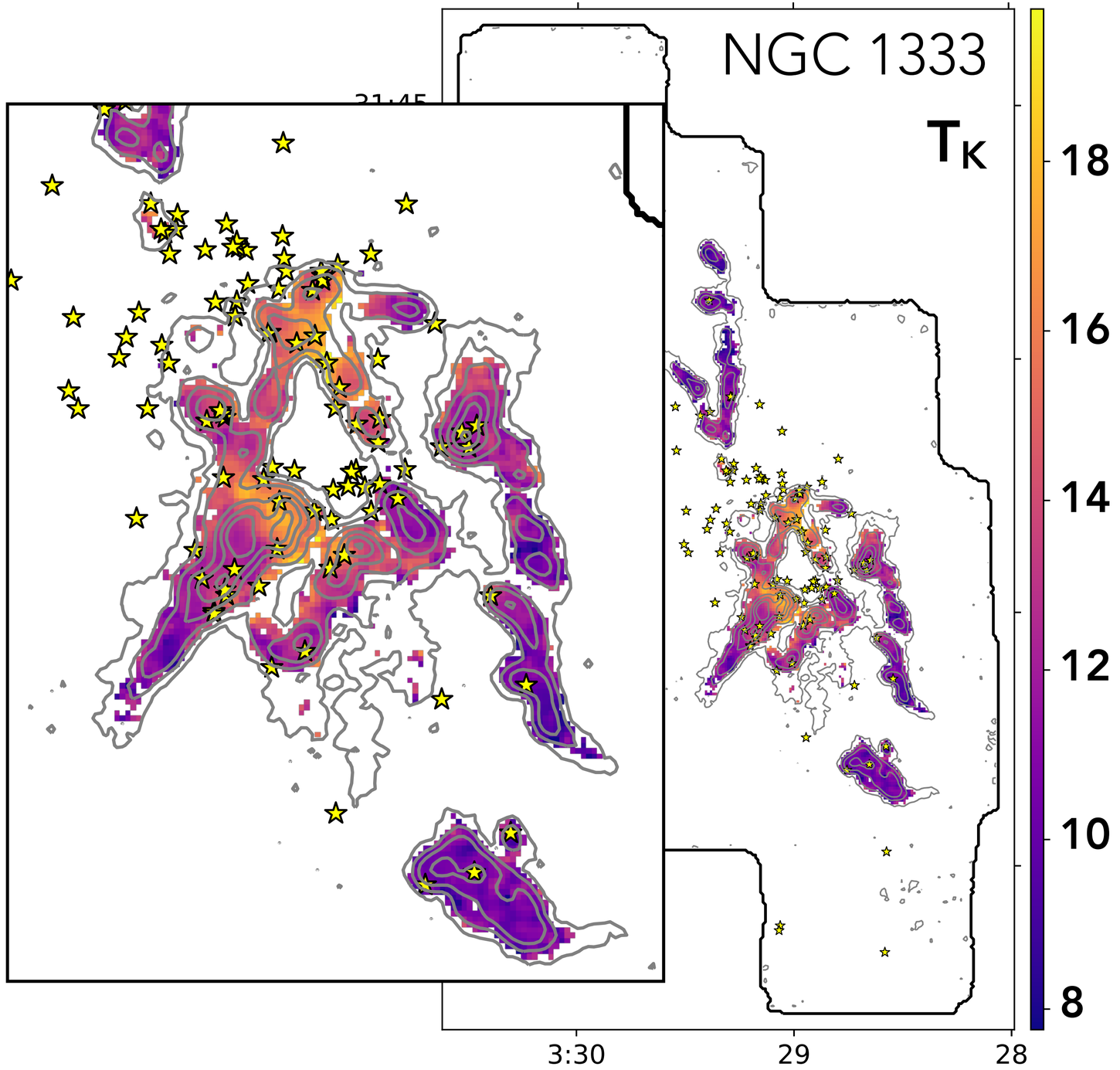


NH_3 (1,1) contours
Σ_{PS} colour

YSO counts & Σ_{PS}

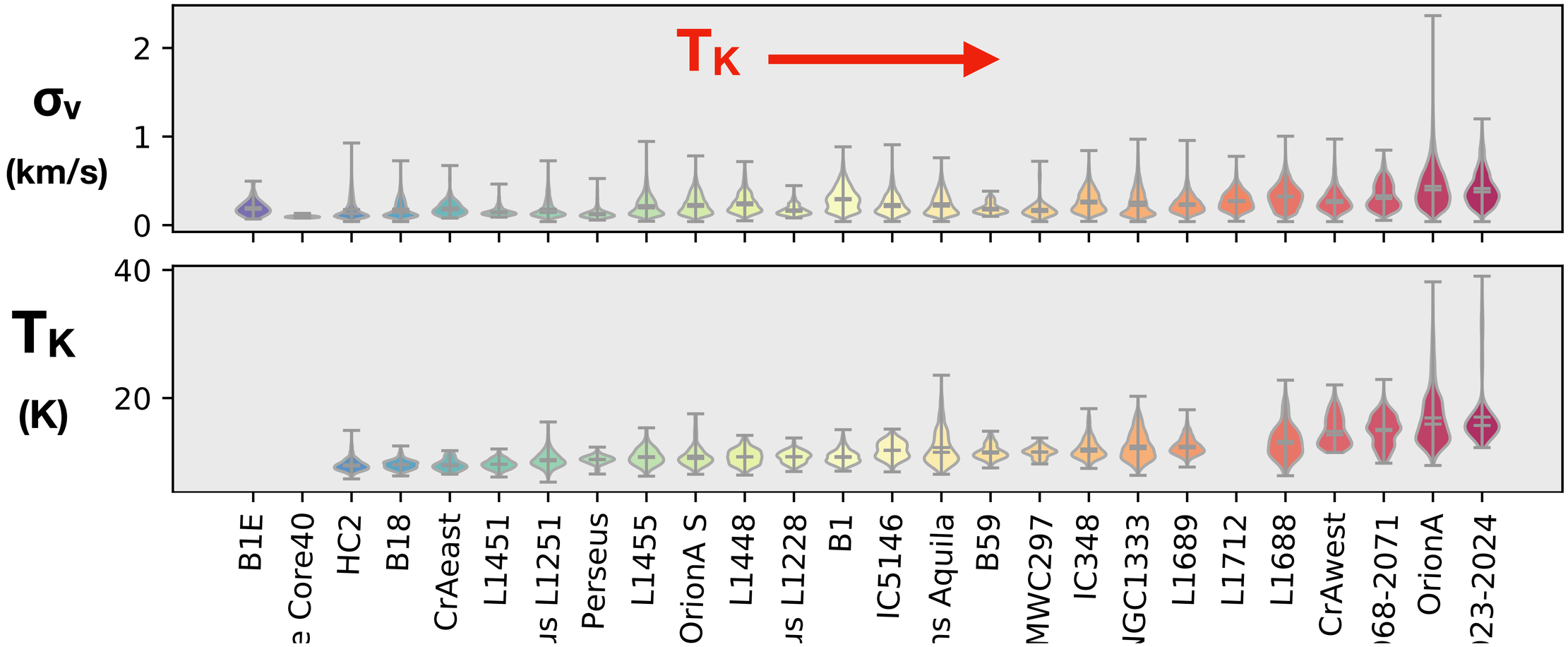
Similar to Serpens South, Σ_{PS}, T_K, and σ_{NT} are positively correlated across GAS clouds

- Median values per region
- pixel-by-pixel correlation



Spread in parameters also increases with Σ_{SFR}

- Narrow (subsonic) lines present in all regions, but with smaller relative fractions as T_K, Σ_{SFR} increase



Pineda, Friesen + in prep

In the Serpens South protocluster:

- Dense cores are warmer with **larger velocity dispersions**
  - Less likely to be gravitationally bound via virial analysis
  - Virial masses larger in the cluster than in the filaments
  - Filamentary flows will deposit gas & protostars within ~1-2 Myr (but may have a natural cutoff)
- Broader lines correlated with protostellar outflows & jets within ~ 0.5 pc
  - Shallow dependence of T_K on r: radiative + mechanical feedback
- Filaments remain subsonic & cores more likely to be gravitationally bound

Gould Belt clouds:

- Similar correlations between Σ_{PS}, T_K, and σ_{NT}: can we use to better quantify low mass feedback effects on dense gas?