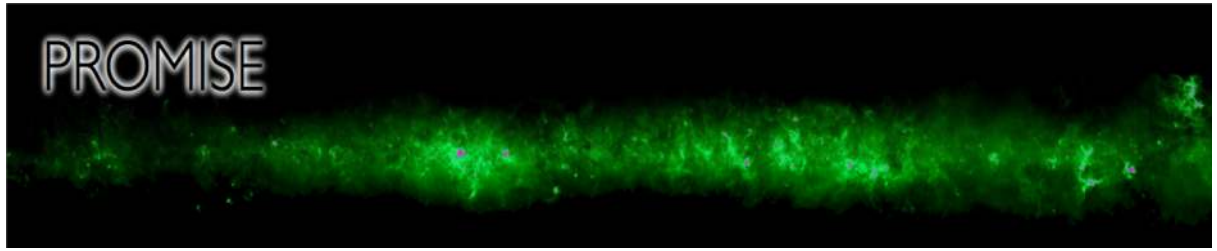
Dynamics and fragmentation in Galactic filamentary structures

Sandra Patricia Treviño-Morales

Treviño-Morales S. P., Pilleri P., Fuente A., et al. 2014, A&A, 569, A19
Treviño-Morales S. P., Fuente A., Sánchez-Monge Á., et al. 2016, A&A, 593, 139 L12 140
Kainulainen J., Stutz A. M., Stanke T., et al. 2017, A&A, 600, A141
Treviño-Morales S. P., Fuente A., Sánchez-Monge A., et al. 2019, A&A, arXiv:1907.03524
Treviño-Morales S. P., Kainulainen J., Orkisz J., et al. 2019, A&A, in prep.

Laboratoire AIM, CEA/IRFU/SAp - CNRS - Universitè Paris Diderot, Paris-Saclay, September, 2019



CHALMERS UNIVERSITY OF TECHNOLOGY

PRobing the Origins of MassIve molecular cloud StructurE

Manuel Riener

PhD student at MPIA
Physical process controlling star formation in molecular clouds; star formation in nerby galaxies

Jouni Kainulainen

Assistant profesor at Chalmers
Observational astronomer in the field of Galactic star formation and interstellar medium

Miaomiao Zhang

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Young stellar objects; jets and outflows, Galactic star formation and ISM

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Molecular cloud structure, star formation in the Milky Way

Sara Rezaeikhoshbakht

Postdoc at Chalmers
3D distribution of dust in the Milky Way Galaxy

Jan Orkisz

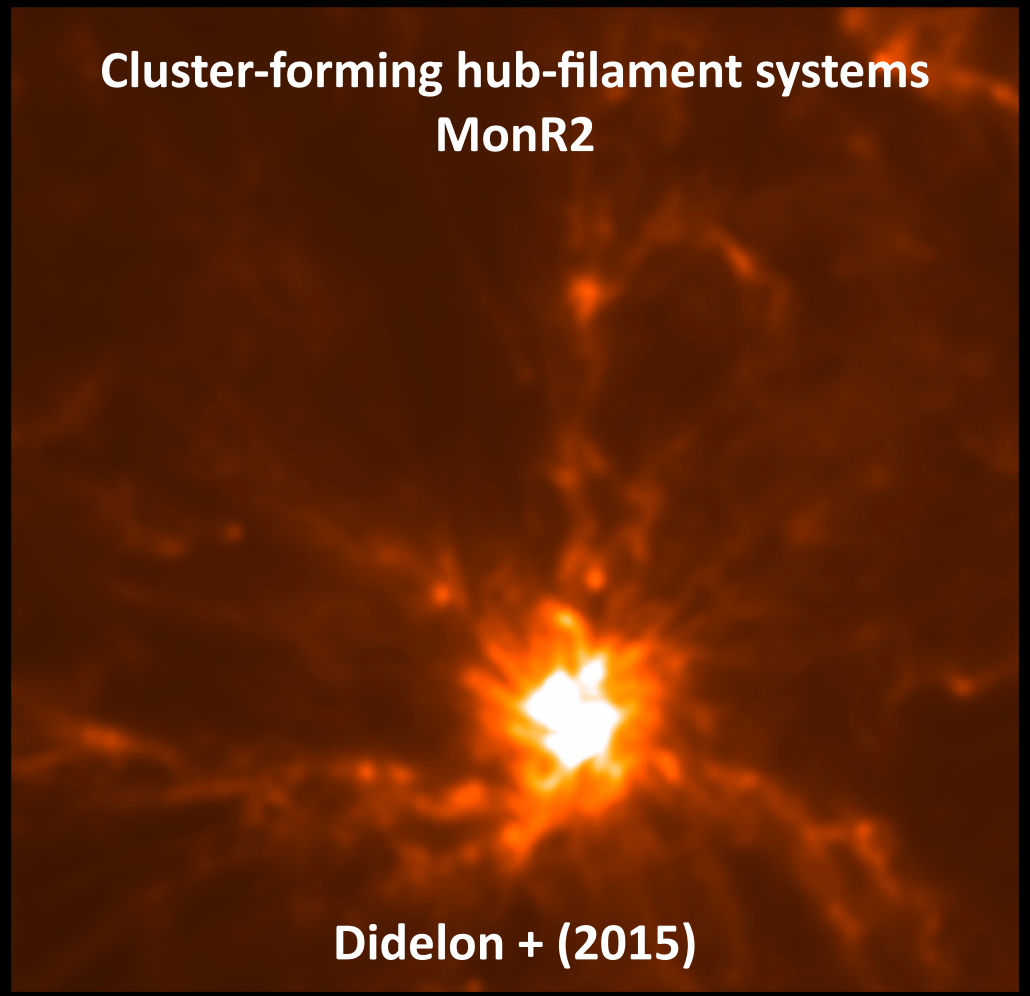
Postdoc at Chalmers
ISM turbulence and magnetic fields, star formation

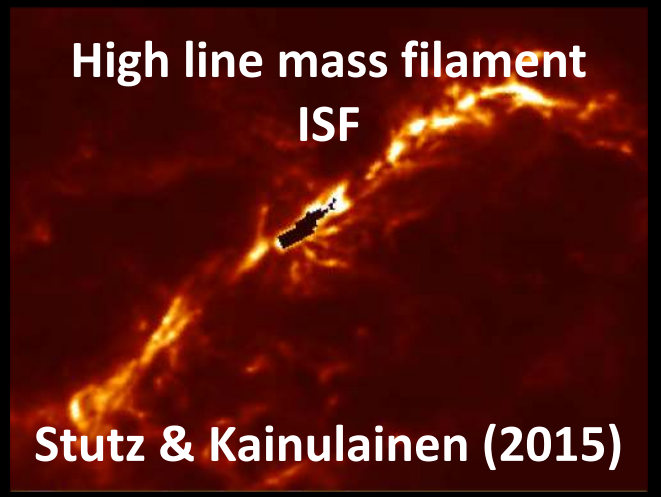
Sandra Treviño-Morales

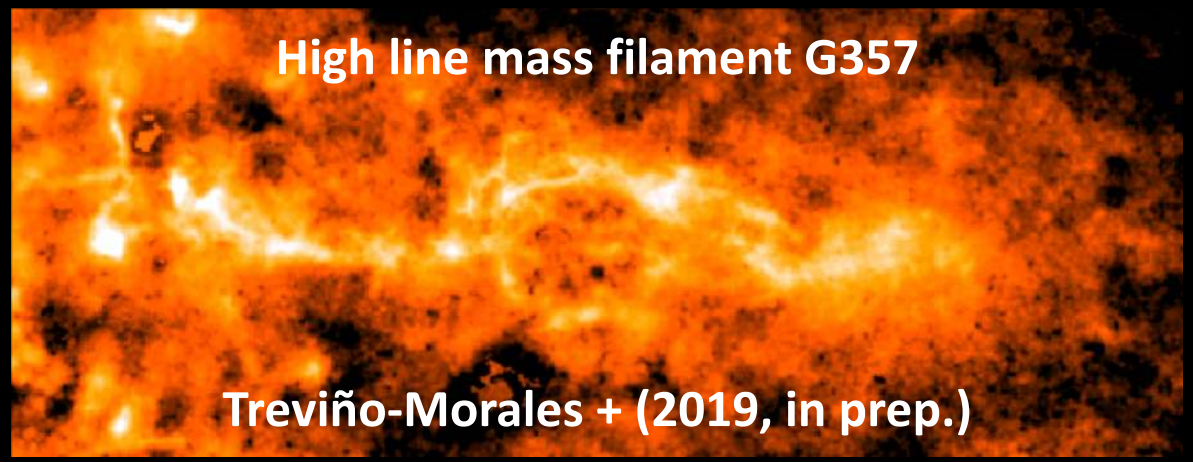
Postdoc at Chalmers
Dynamics and fragmentation in Galactic molecular clouds, astrochemistry in HII and PDR

PROMISE

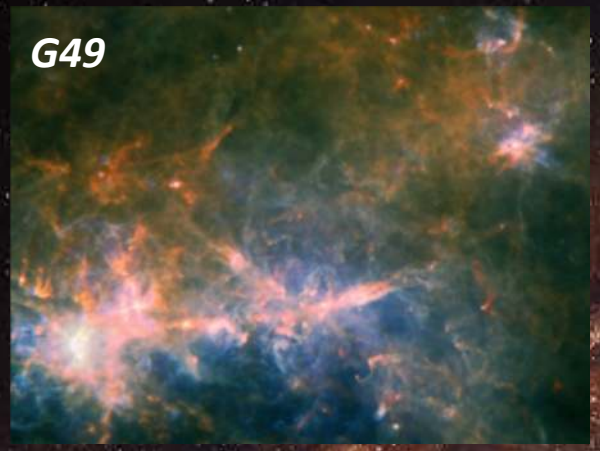
Study of dynamics and fragmentation in filamentary structures







Filaments permeate the ISM on all scales



ESA/Herschel/PACS/SPIRE/Ke
Wang et al. 2015

ESA/Herschel/André, Polychroni, Roy, Könyves, Schneider: Gould Belt survey Key Program

ESA/Herschel/PACS/SPIRE
HOBYS Key Program Consortia

Andre et al. (2010), Molinari et al. (2010), Schneider et al. (2010), Csaengeri et al. (2011), Schneider et al. (2012), Hennemann et al. (2012), Busquet et al. (2013), Hacar et al. (2013), Peretto et al. (2014), Louvet et al. (2014), Tafalla & Hacar (2015), Smith et al. (2014), Henshaw et al. (2014), Tackenberg et al. (2014), Seifried & Walch (2015), Hacar et al. (2018), Arzoumanian et al. (2018), Suri et al. (2019), Trevino-Morales et al. (2019) …

The birthplaces of the stars

Molecular clouds formed by complex networks of filaments intersecting in high-density regions called hub

Unstable against radial collapse and fragmentation (**Inutsuka & Miyama 1997**). Their origin or formation process still unclear. However, turbulence, gravity (**Klessen + 2000**) and magnetic fields (**Molina + 2012; Kirk + 2015**), can produce the observed structures.

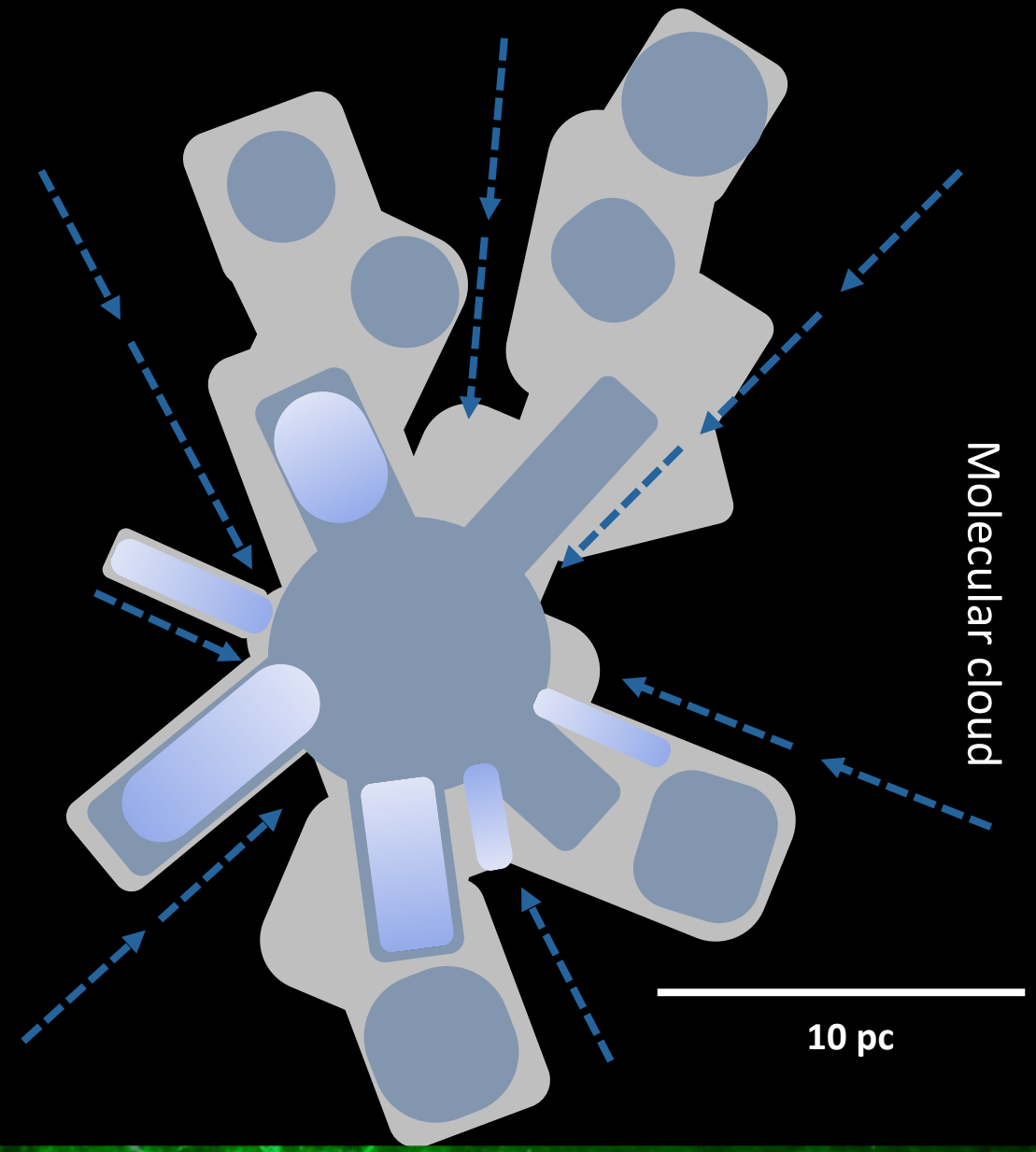


Figure adapted from **Baobab (2010)**

The birthplaces of the stars

Transport of gas along the filaments

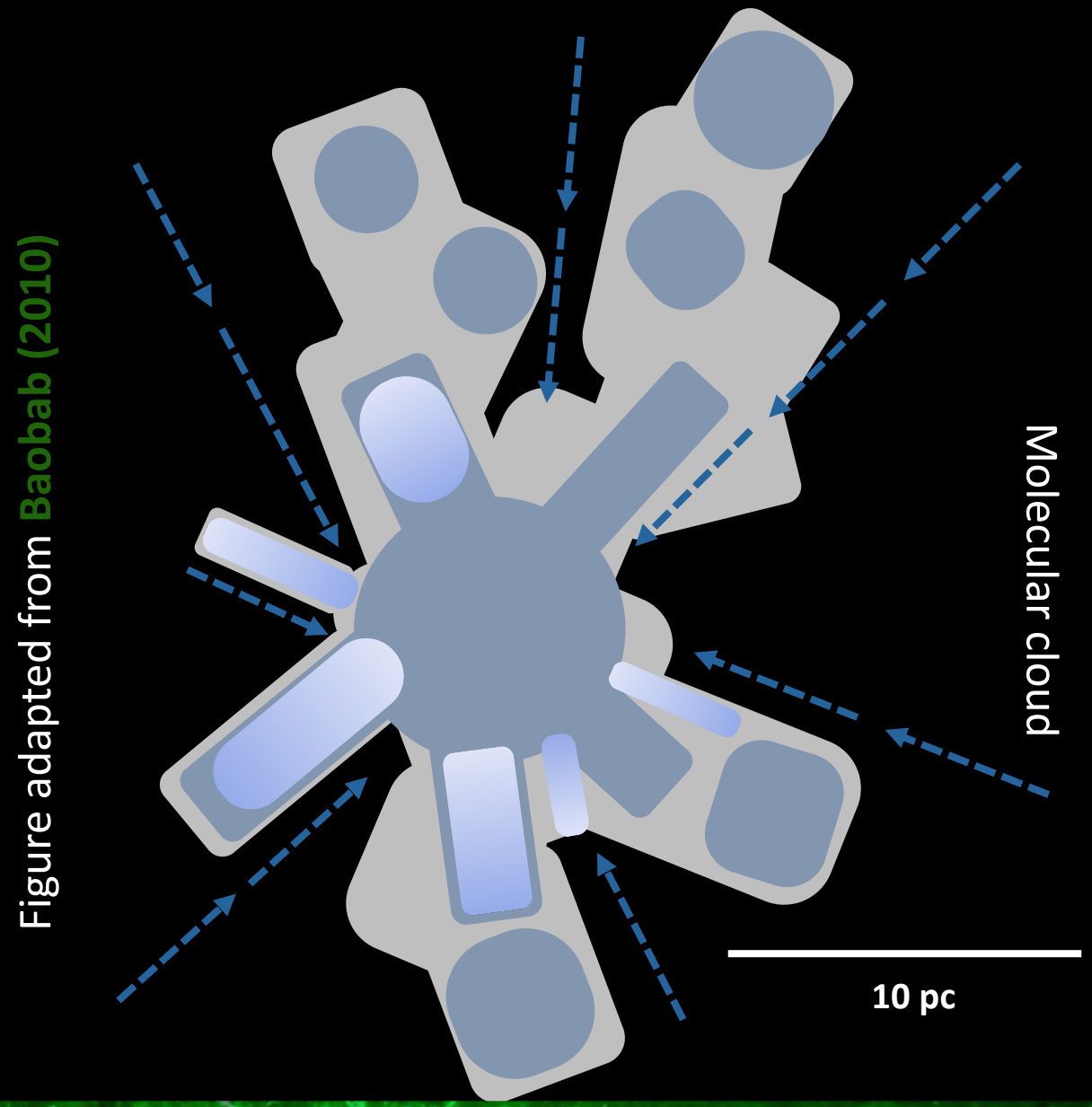
$$M = \frac{N}{X} A(2.8\, m_{\rm H}),$$

N = total column density of the molecule
X = relative abundance with respect to H_2
m_H = hydrogen atom mass

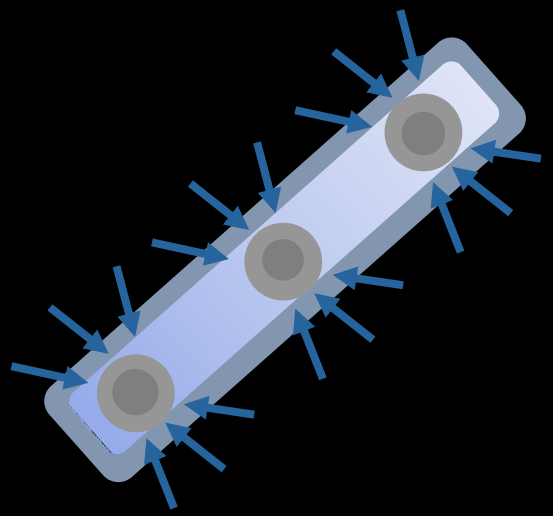
$$\dot{M}_{\rm acc} = \frac{\left(\frac{M}{L_{\rm obs}} V_{\parallel,\rm obs}\right)}{\tan(\alpha)} = \frac{M \nabla V_{\parallel,\rm obs}}{\tan(\alpha)}.$$

M = filament mass
$\nabla V_{\parallel,obs}$ = velocity gradient = $V_{\parallel,obs}/L_{obs}$
Where $L_{obs} = L\cos(\alpha)$ and $V_{\parallel,obs} = V_{\parallel} \sin(\alpha)$

Nagasawa (1987); Kirk + (2013); Wang + (2014)



The birthplaces of the stars



$M_{line} = M/L$

In the case of an **isolated, infinitely long filament** where **gravity and thermal pressure** are the only forces, an equilibrium solution exists at the

$$(M/L)_{\mathrm{crit,O64}} = \frac{2c_s^2}{G} = 16.7\left(\frac{T}{10\ \mathrm{K}}\right) M_\odot\ \mathrm{pc}^{-1},$$

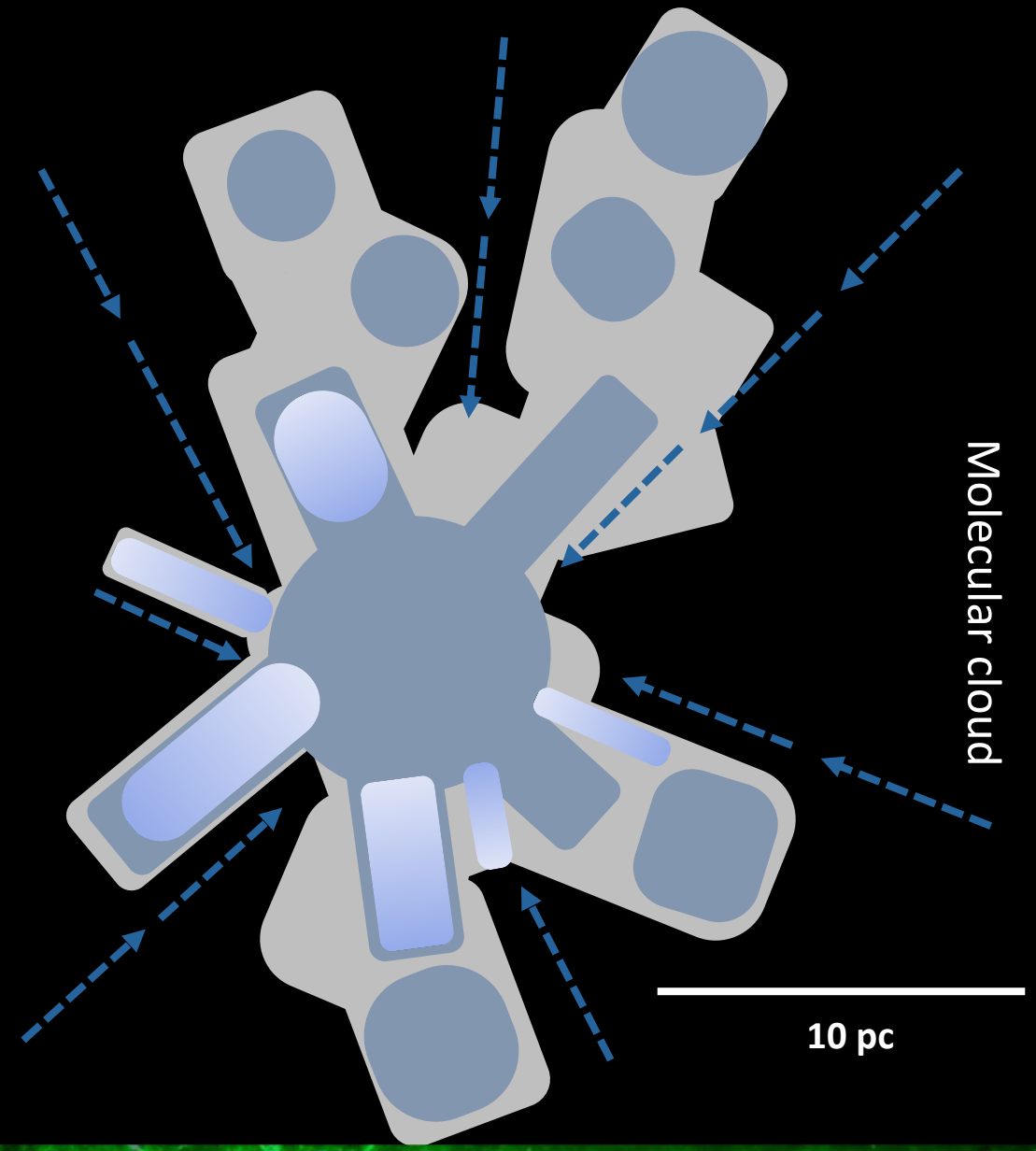
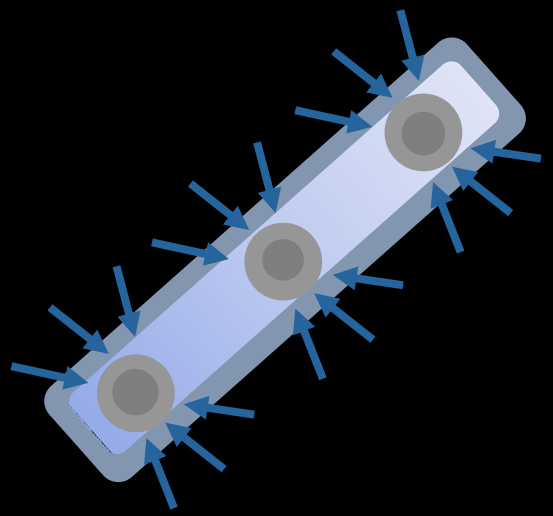


Figure adapted from **Baobab (2010)**

The birthplaces of the stars



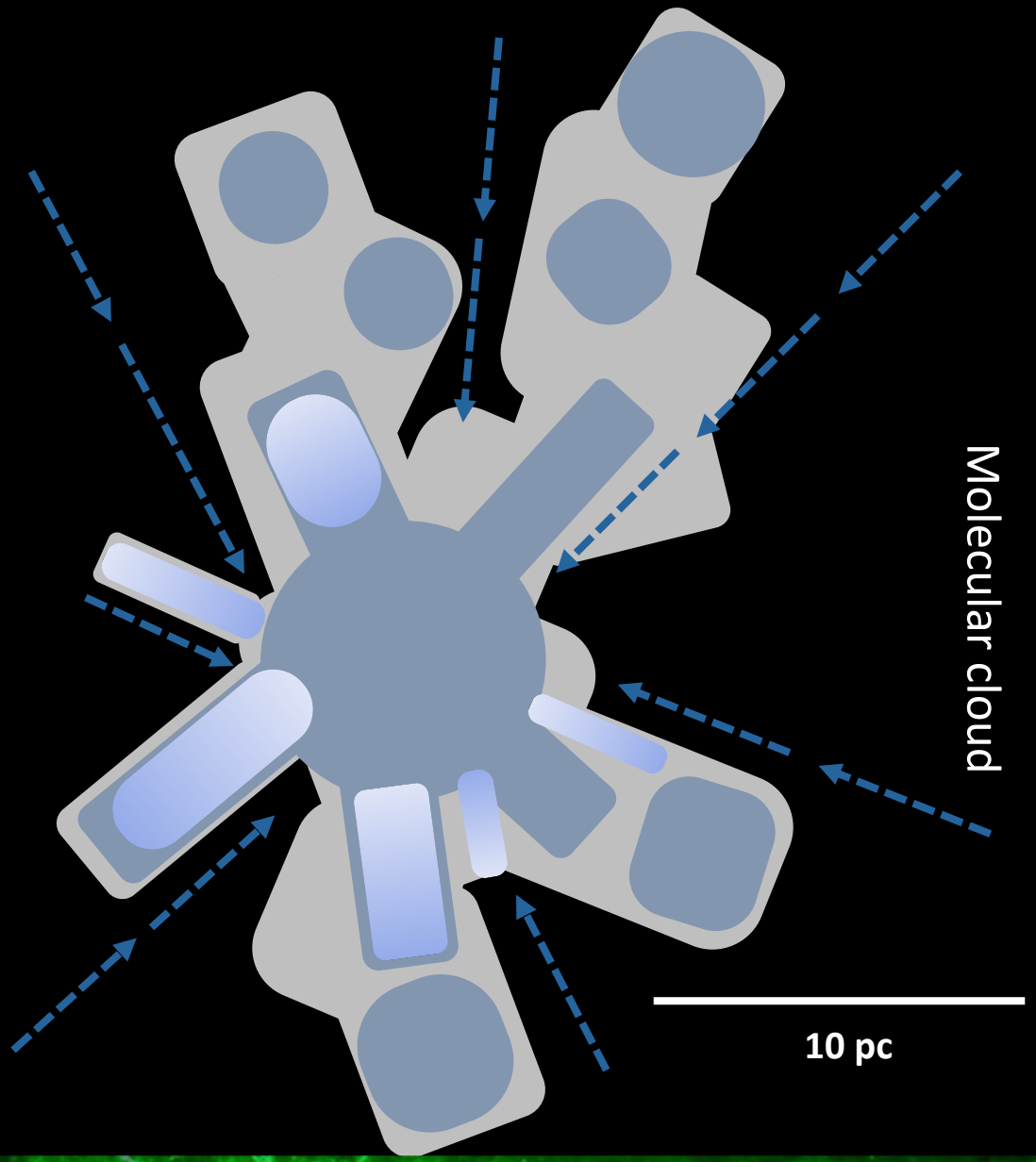
$M_{line} = M/L$

$$(M/L)_{\mathrm{crit,O64}} = \frac{2c_s^2}{G} = 16.7\left(\frac{T}{10\ \mathrm{K}}\right) M_\odot\ \mathrm{pc}^{-1},$$

c_s = sound speed = $(kT/\mu m_H)^{1/2}$
G = gravitational constant.
T = temperature.

Ostriker 1964; Inutsuka & Miyama 1997

Figure adapted from Baobab (2010)



The birthplaces of the stars

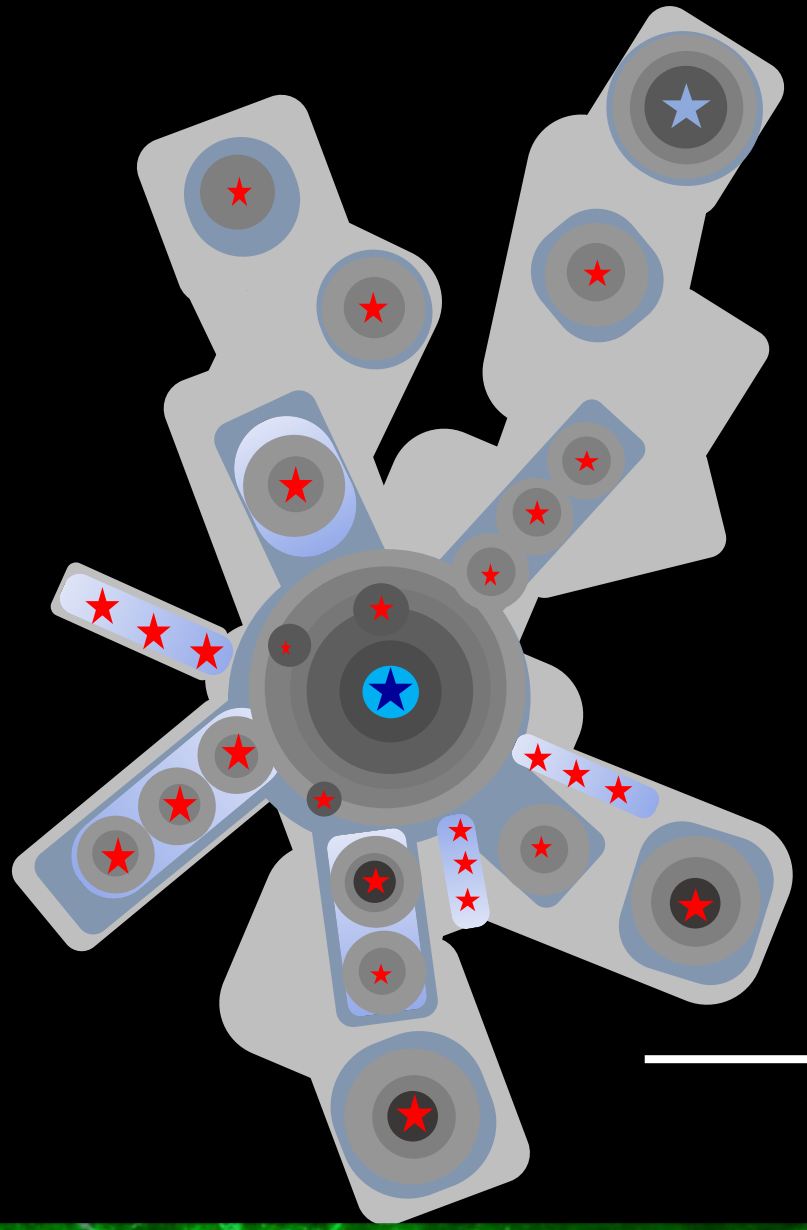
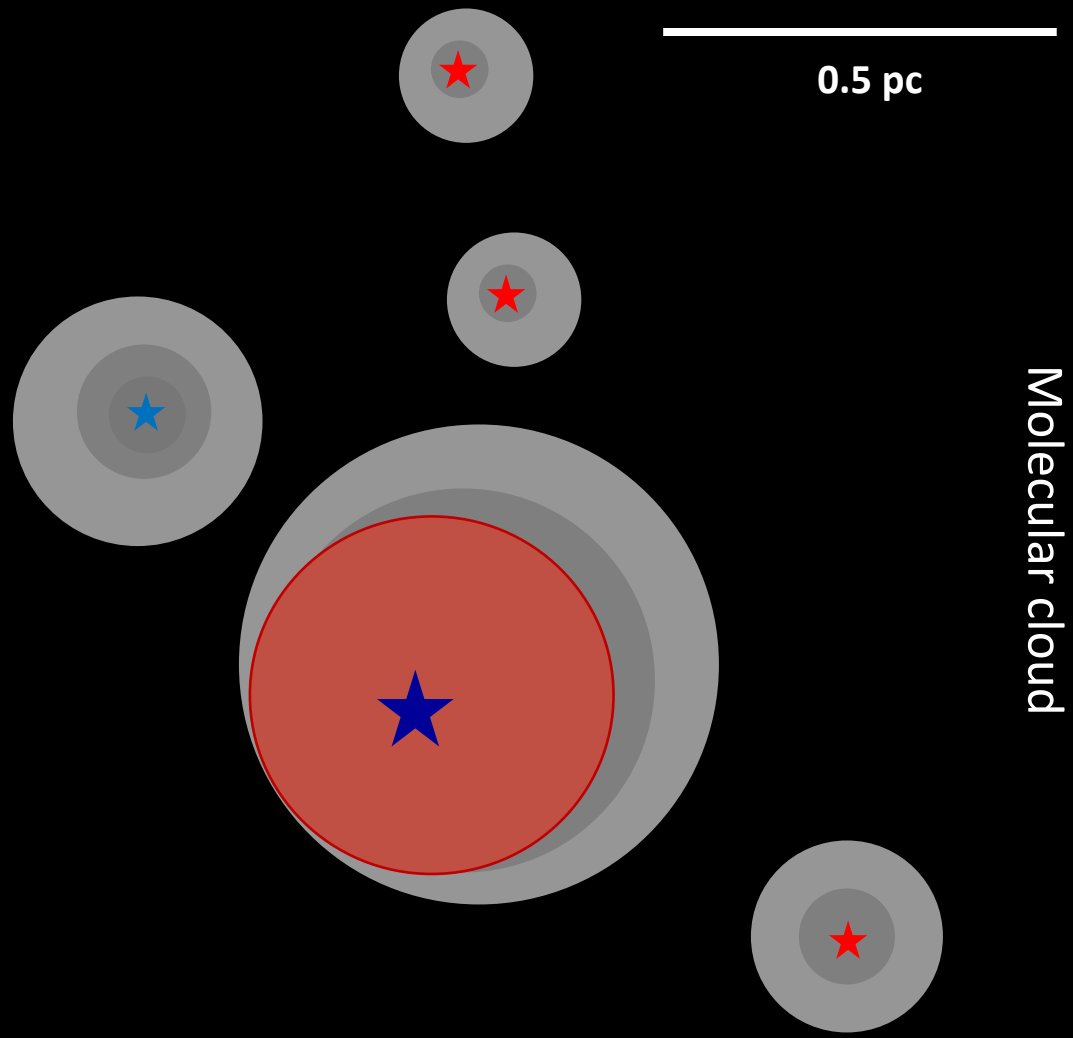


Figure adapted from **Baobab (2010)**

Star formation occurs along the filaments
High-mass stars forming at the hubs

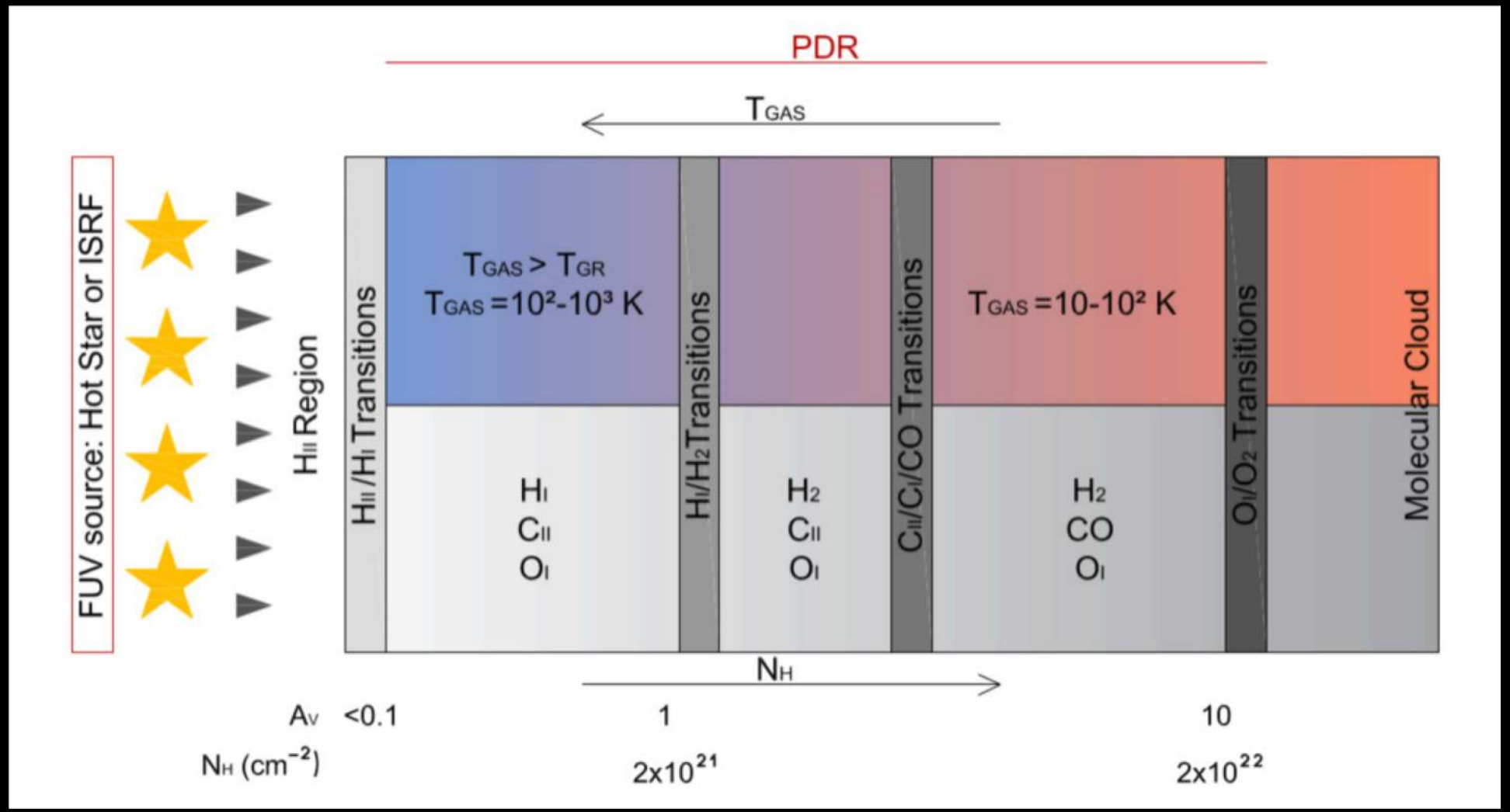
Massive star effects: HII region and Photon-Dominated Region system

A massive star (O & B type) radiates enough **UV photons** with **energies E > 13.6 eV** that ionize the surrounding gas and generate an **HII región** … radiates **photons** with energies **6 < E < 13.6 eV** that **dissociate H_2** and **CO** molecules and generate a **PDR**.



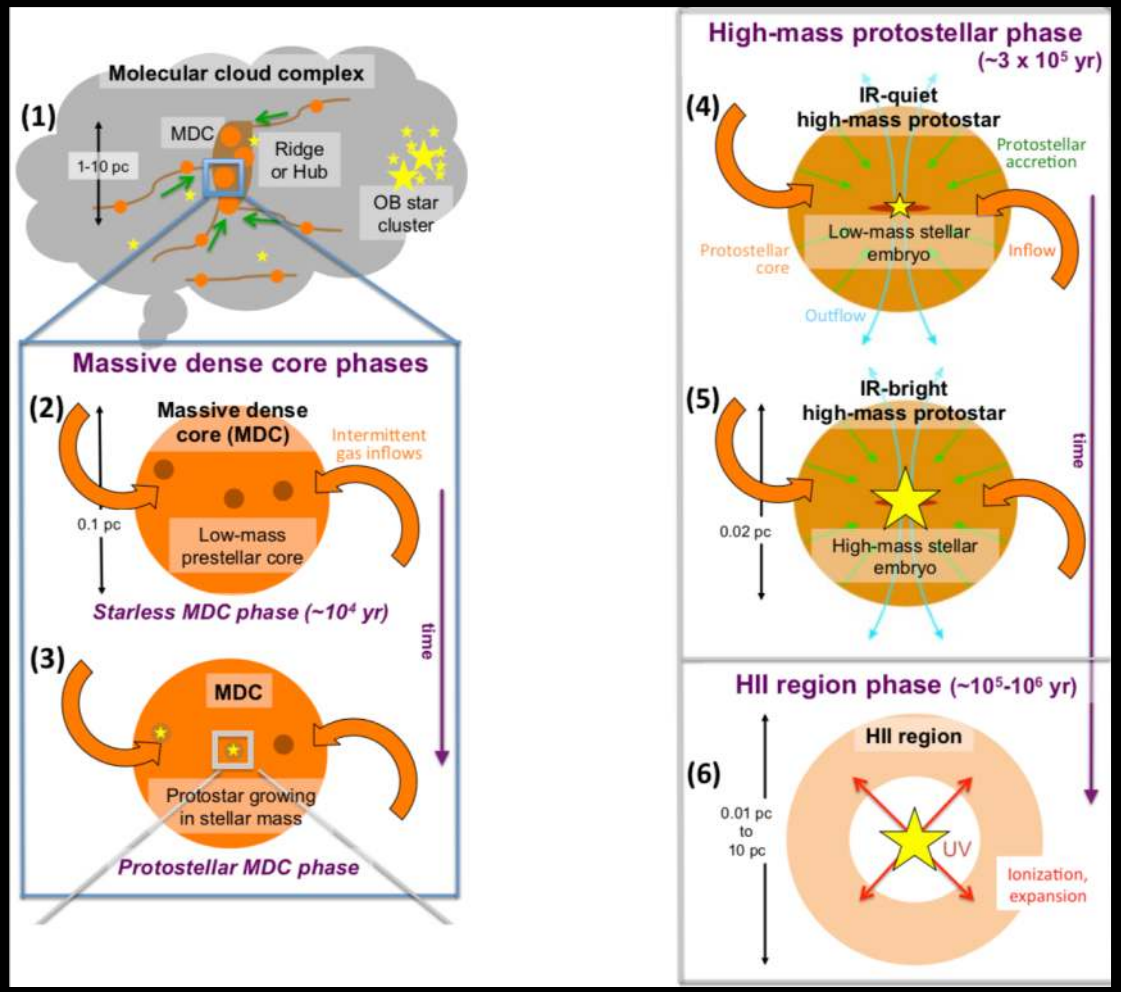
***Link* between HII region and molecular cloud**

What is a Photon-Dominated Region (PDR)?



Adapted from Hollenbach & Tielens (1997)

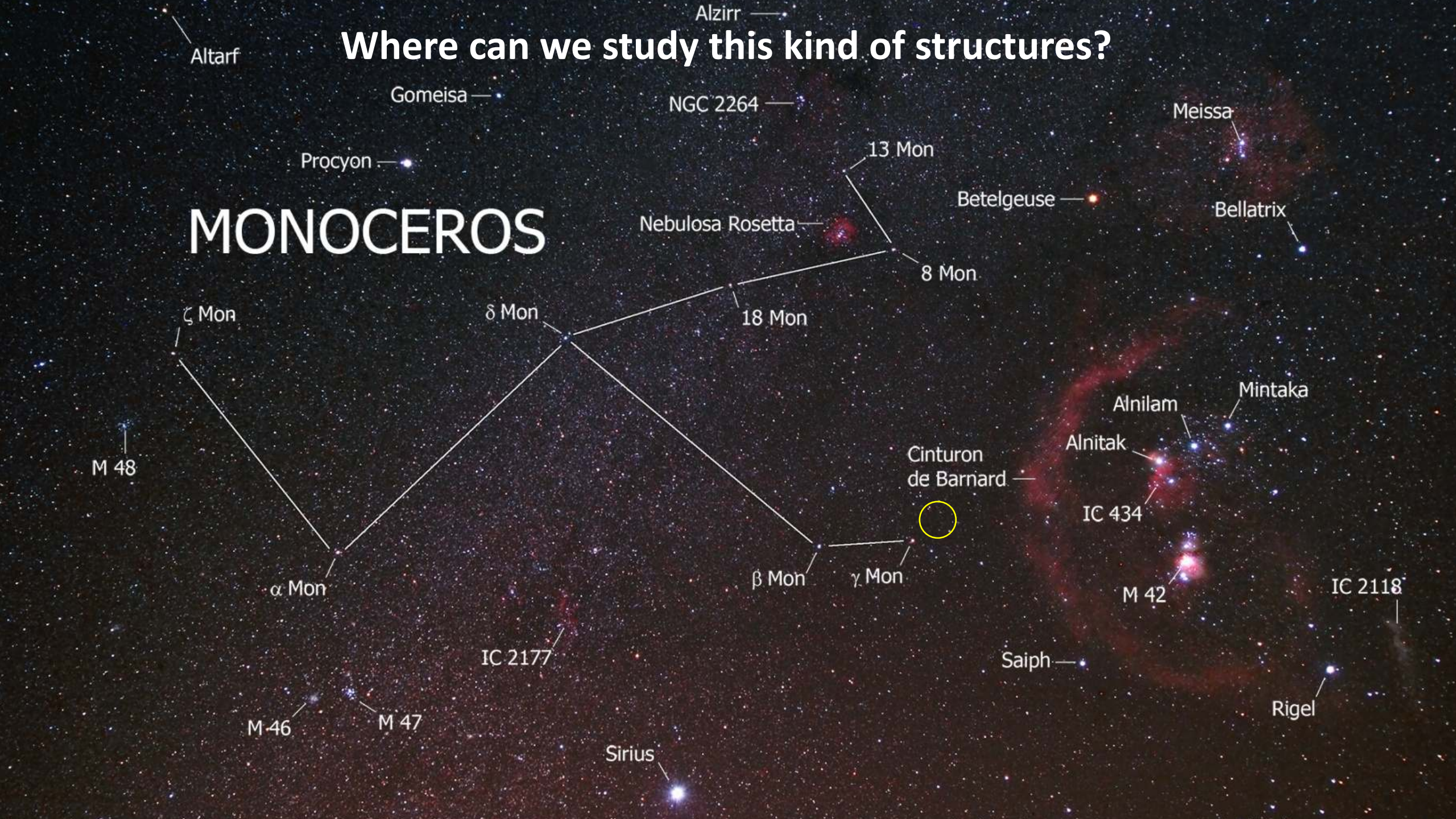
Schematic evolutionary diagram proposed for massive stars formation



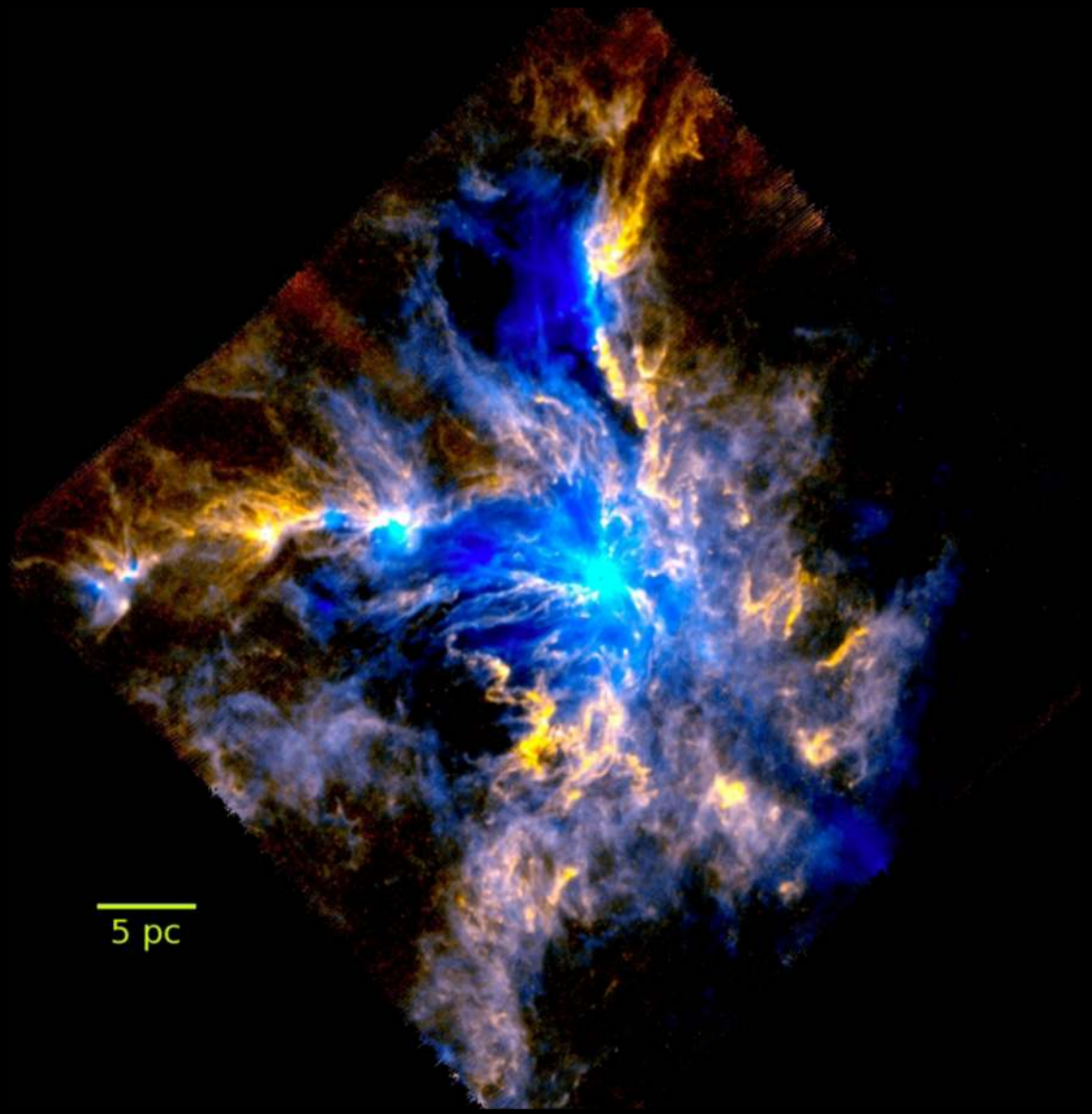
Motte + (2018)

Massive stellar clusters form in extreme clouds called ridges. Unlike the case of low-mass stars which accrete their final mass from well-defined pre-stellar cores, with a mass distribution mimicking the IMF (**Motte +1998; Könyves + 2015**), high-mass stars within ridges should have a complex accretion history.

One should therefore investigate the detailed properties cluster-forming hub-filament system and ridges to constrain the outcome characteristics of massive clusters.


Where can we study this kind of structures?
Alzirr
Altarf
Gomeisa
NGC 2264
Meissa
Procyon
13 Mon
MONOCEROS
Betelgeuse
Bellatrix
Nebulosa Rosetta
8 Mon
18 Mon
δ Mon
ζ Mon
M 48
Mintaka
Alnilam
Alnitak
Cinturon
de Barnard
IC 434
α Mon
β Mon
γ Mon
M 42
IC 2118
IC 2177
Saiph
M 46
M 47
Rigel
Sirius

Monoceros R2 molecular cloud



Pokhrel + (2016)

The **Monoceros molecular cloud** (at **830 pc**) contains several sites of active star formation

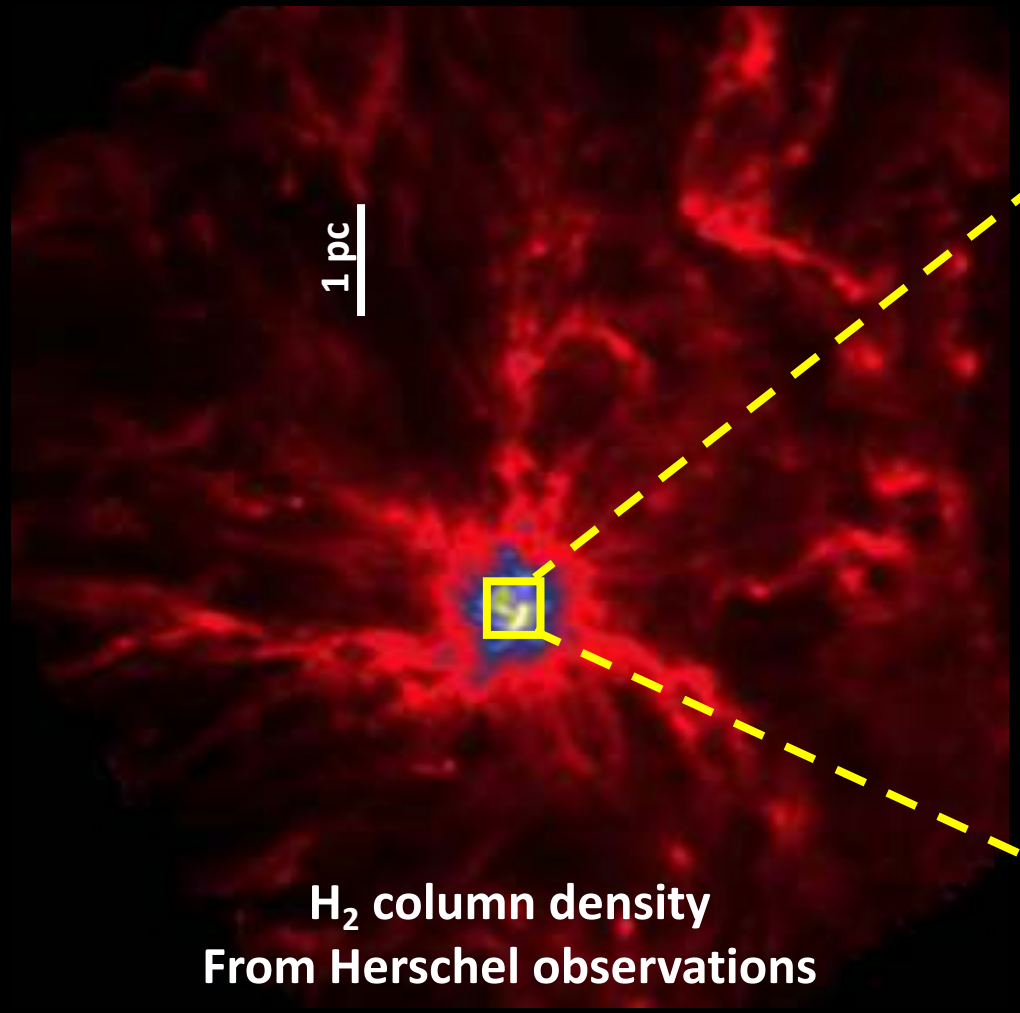
Estimated the mass of 4×10^4 $M_\odot$ in an area of 44pc × 55pc.

- ***Mon R2*** is the most massive and prominent cluster

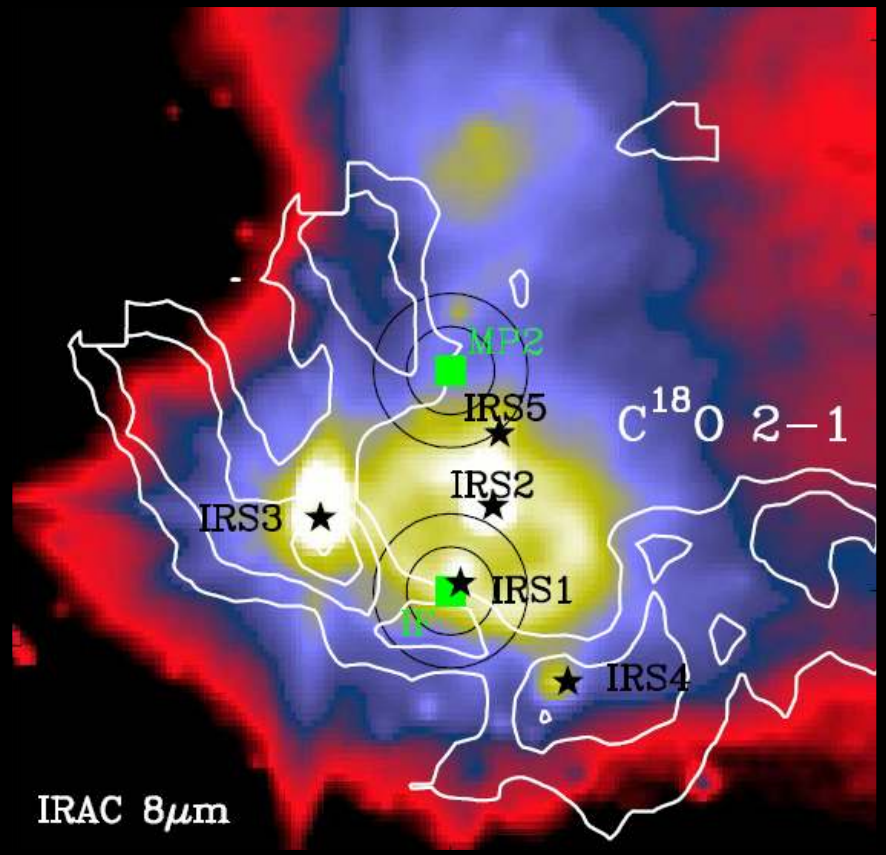
  … rich cluster with 371 objects, including massive (***B-type***) stars
  … large mass reservoir, with a total mass of ~***10 000 $M_\odot$***

Miesch, Scalo & Bally (1999);. Xie (1992); Carpenter (2000); Carpenter & Hodapp (2008)

Monoceros R2 molecular cloud



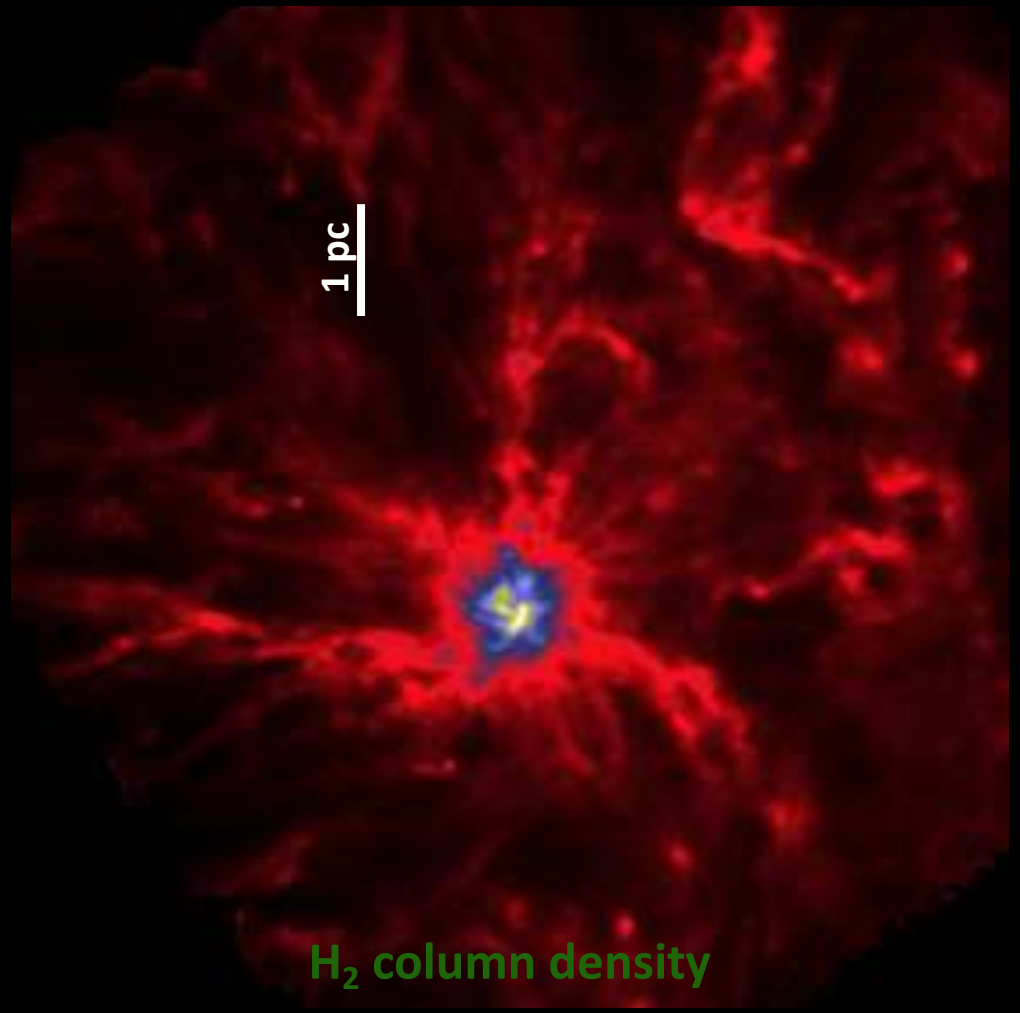
H_2 column density
From Herschel observations



Didelon + (2015)

Pilleri + (2012); Treviño-Morales + (2014)

Monoceros R2 molecular cloud



Didelon + (2015)

Cluster-forming hub-filament system

UC HII region
PDRs with different conditions

Is an excellent target to study

- kinematics,
- dynamics,
- feedback
- chemistry

Pilleri + (2012); Treviño-Morales + (2014)

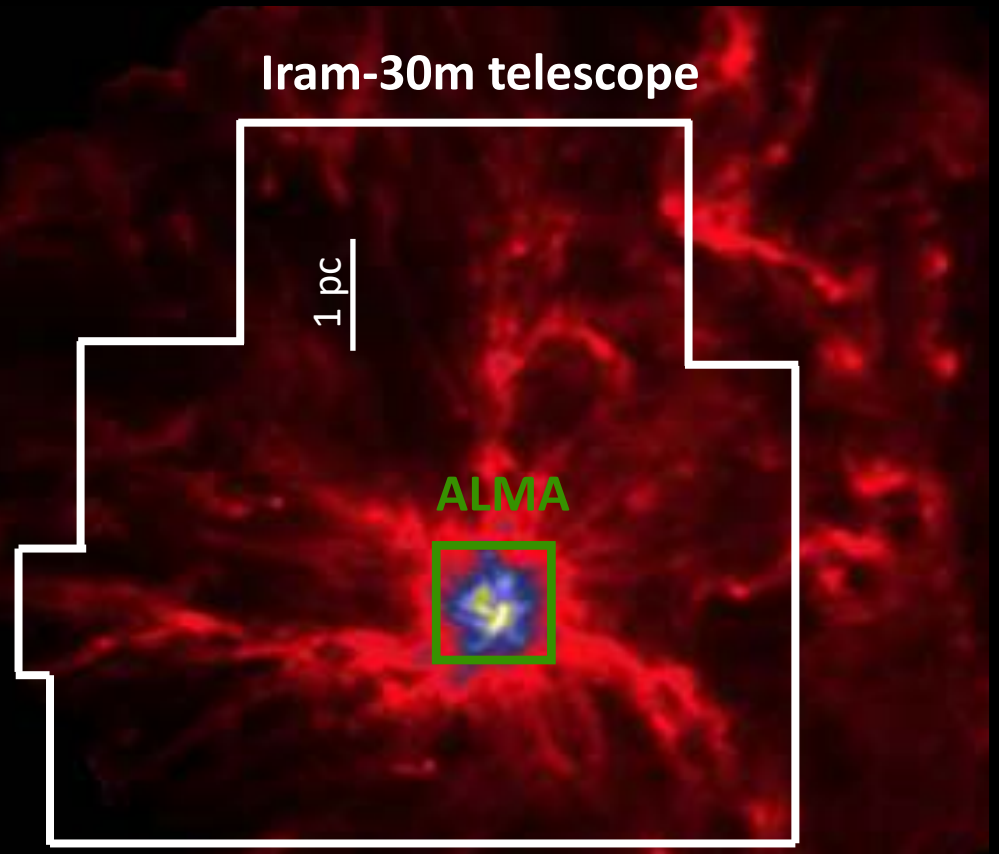
Study of the dynamical properties of Mon R2

Treviño-Morales + (2019)

Large scale observations

- ***IRAM-30m telescope***
- (> 100 hours) at ***3 mm band***

- ^{13}CO
- $C^{18}O$
- HNC
- N_2H^+



H_2 column density
From Herschel observations

Hub observations

- **ALMA**
- (7 hours) at ***3 mm band***

- ^{13}CO
- $C^{18}O$
- CS
- H30α
- SO

Treviño-Morales + (in prep.)

Dynamics of Cluster-forming hub-filament systems: The Mon R2 case

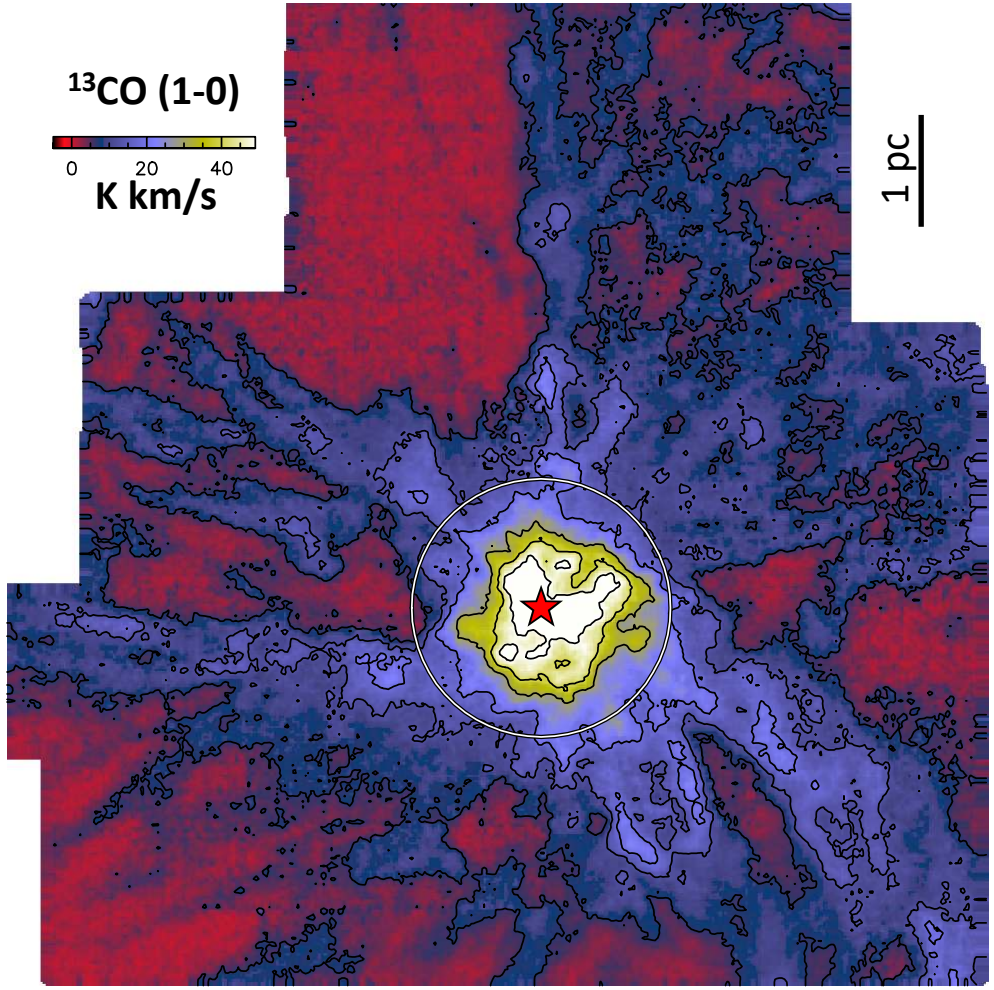
S. P. Treviño-Morales (Chalmers University), A. Fuente (Observatorio Astronómico Nacional), Á. Sánchez-Monge (Universität zu Köln), J. Kainulainen (Chalmers University), P. Didelon (Universitè Paris Diderot), S. Suri (Max-Planck Institute for Astronomy), N. Schneider (Universität zu Köln), J. Ballesteros-Paredes (Instituto de Radioastronomía y Astrofísica), Y. N. Lee (Institut de Physique du Globe de Paris), P. Hennebelle (Laboratoire AIM), P. Pilleri (Universitè de Toulouse), M. González-García (Instituto de Astrofísica de Andalucía), C. Kramer (Institut de Radioastronomie Millimètrique), S. García-Burillo (Observatorio Astronómico Nacional), A. Luna (Instituto Nacional de Astrofísica, Óptica y Electrónica), J. R. Goicoechea (Instituto de Física Fundamental, CSIC), P. Tremblin (Universitè Paris Diderot), and S. Geen (Universität zu Heidelberg)

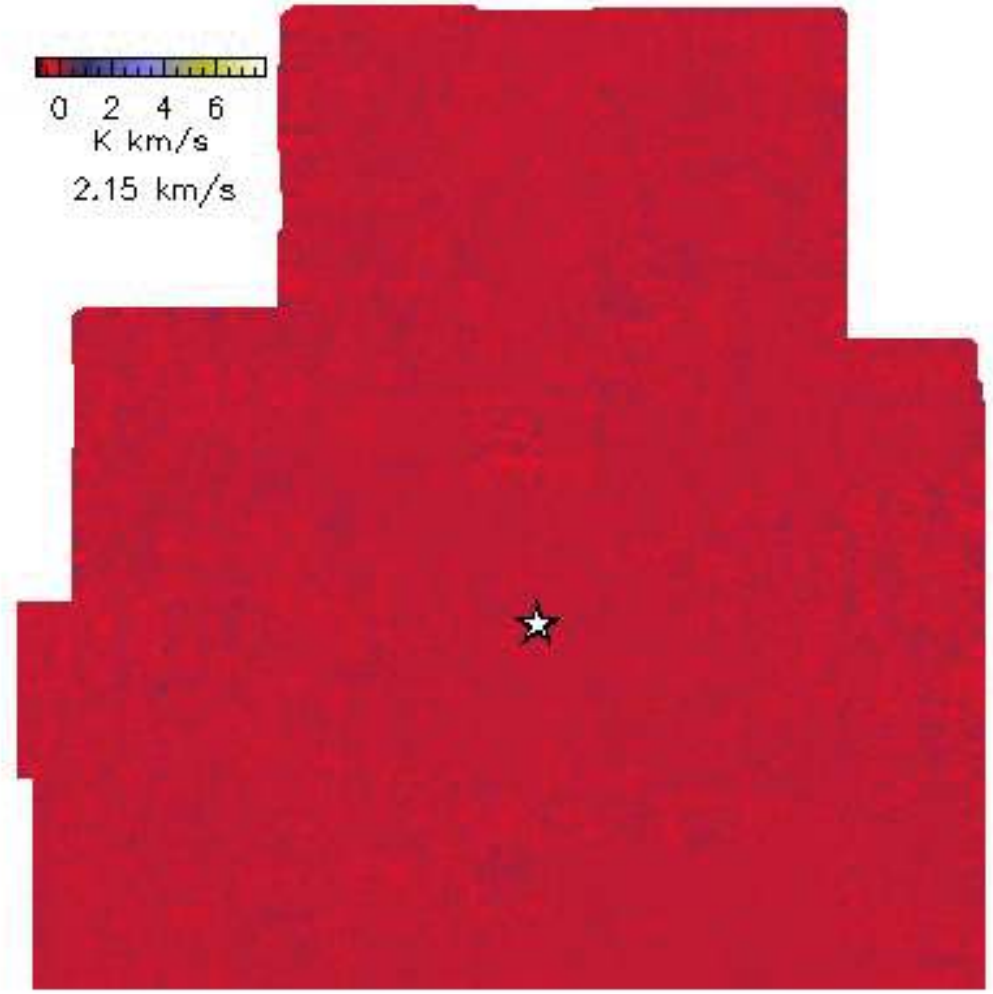
Astronomy & Astrophysics 2019, arXiv e-prints, arXiv:1907.03524

Large-scale emission (30m observations)

Molecular emission is extended and ***well correlated with the dust emission***

Treviño-Morales + (2019)



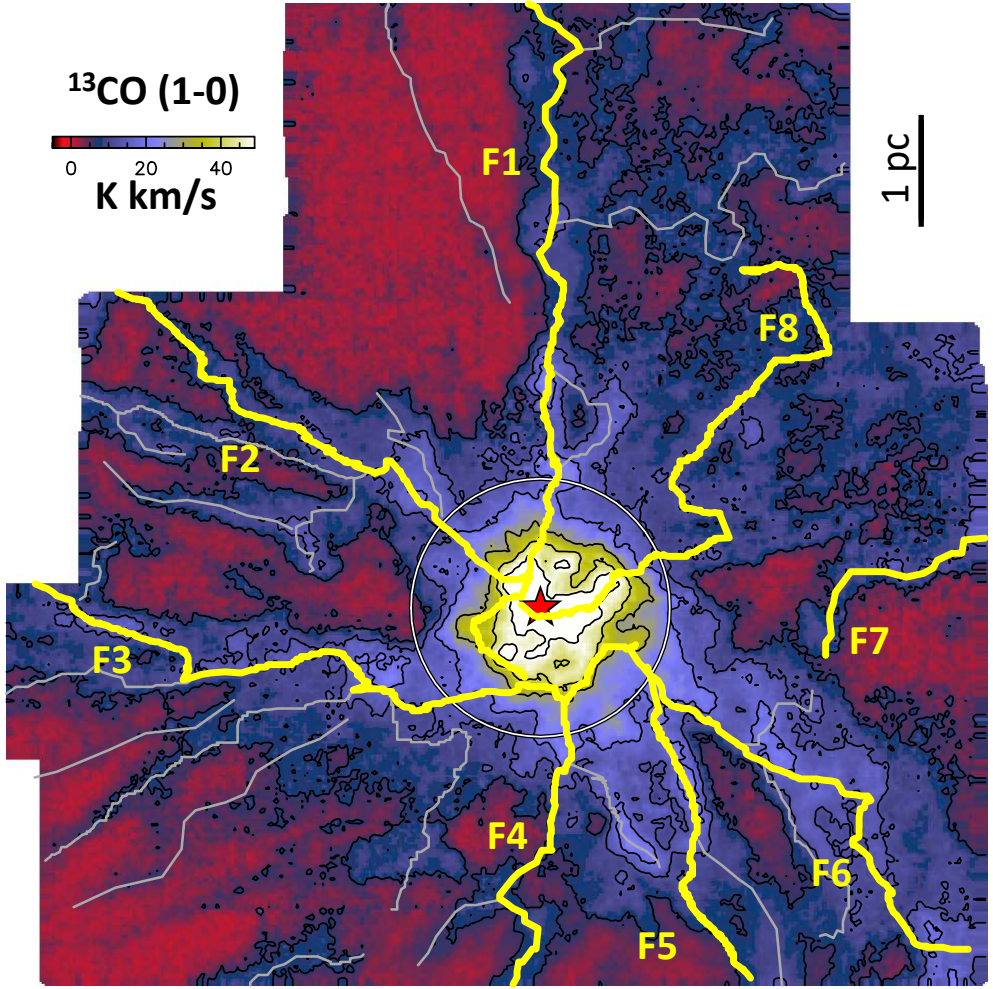


Channel maps from the ^{13}CO emission (intervals of 0.25 km/s)

Filaments: Stability (30m observations)

M_{total} = 8300 $M_\odot$; M_{hub} = 2800 $M_\odot$ (inner 250");
M_{fil} = 2800 $M_\odot$

Treviño-Morales + (2019)



M/L = **50** ($M_\odot$ pc^{-1})

$$(M/L)_{crit} = \frac{2\sigma^2_{ther}}{G} = 16.7\left(\frac{T}{10K}\right) M_\odot\ pc^{-1}$$

with T ~ 15 K

M/L_{crit} = **30** ($M_\odot$ pc^{-1})

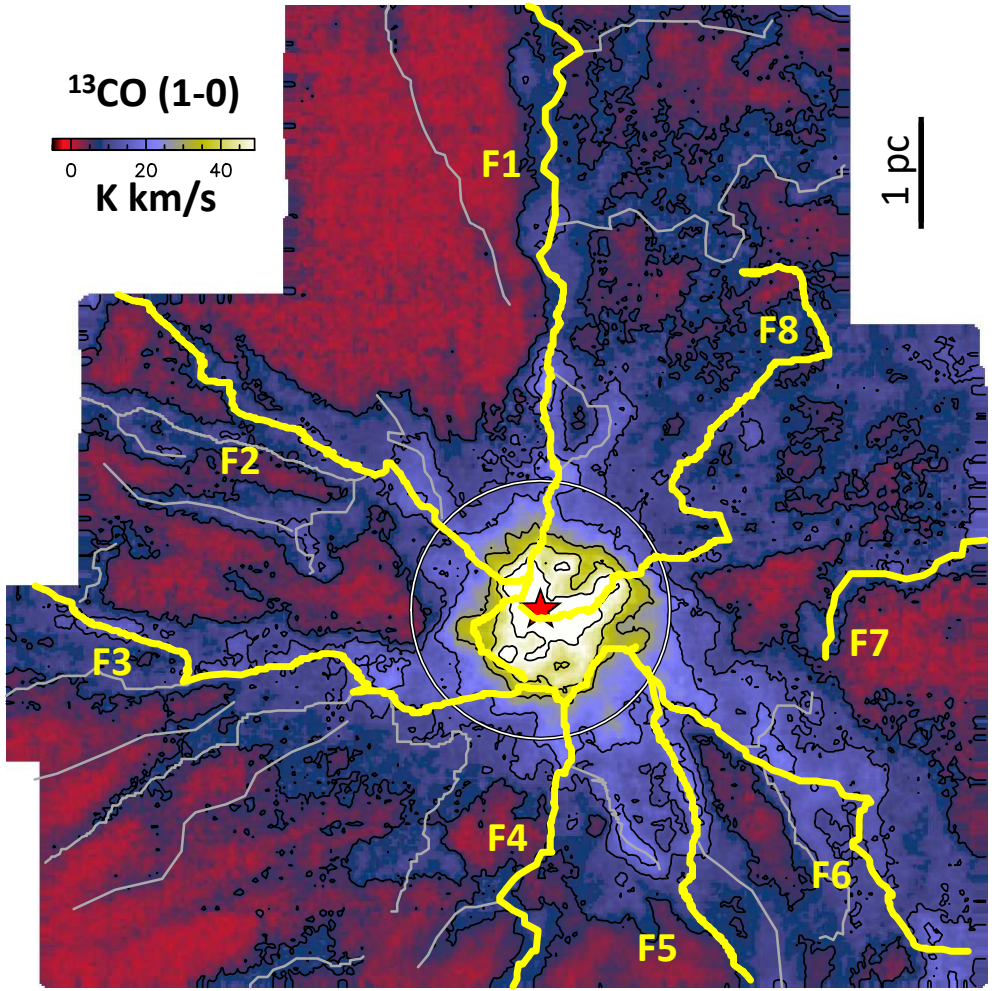
Hints of fragmentation along the filaments

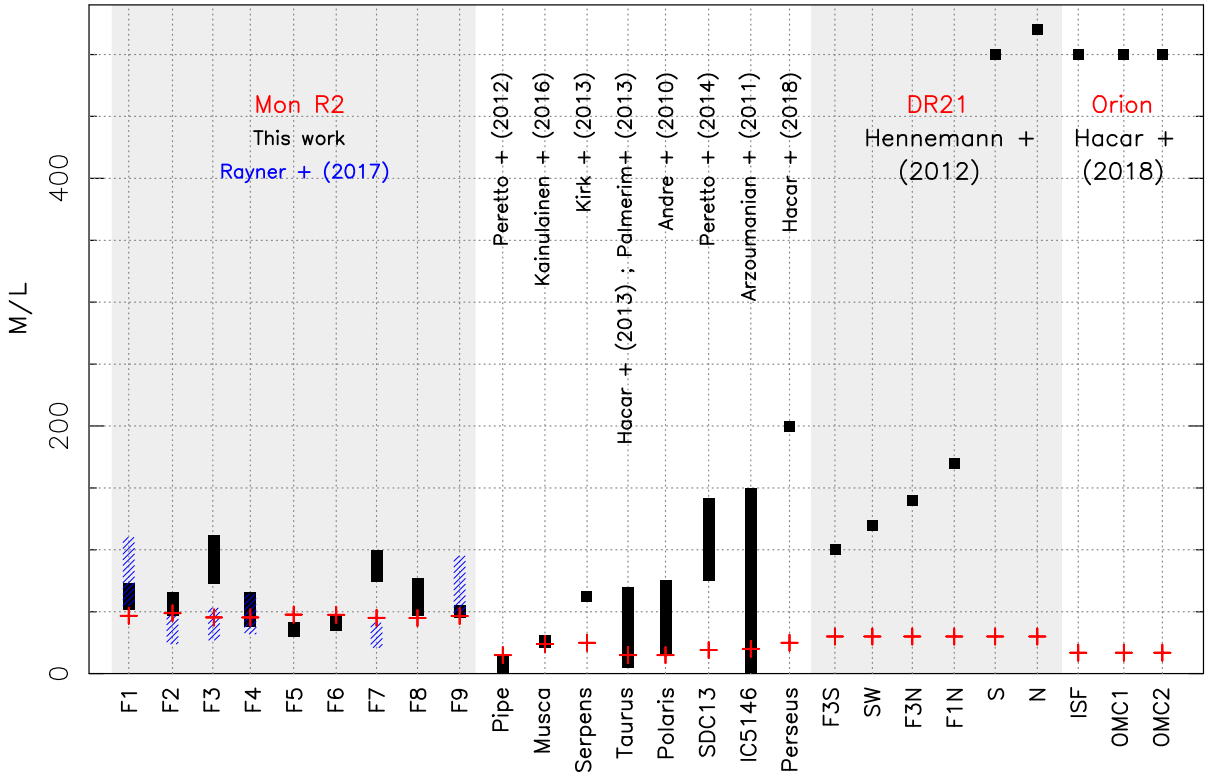
Ostriker (1964); Kirk + (2013); Nagasawa 1987; Wang + 2014

Filaments: Stability (30m observations)

M_{total} = 8300 $M_\odot$; M_{hub} = 2800 $M_\odot$ (inner 250");
M_{fil} = 2800 $M_\odot$

Treviño-Morales + (2019)

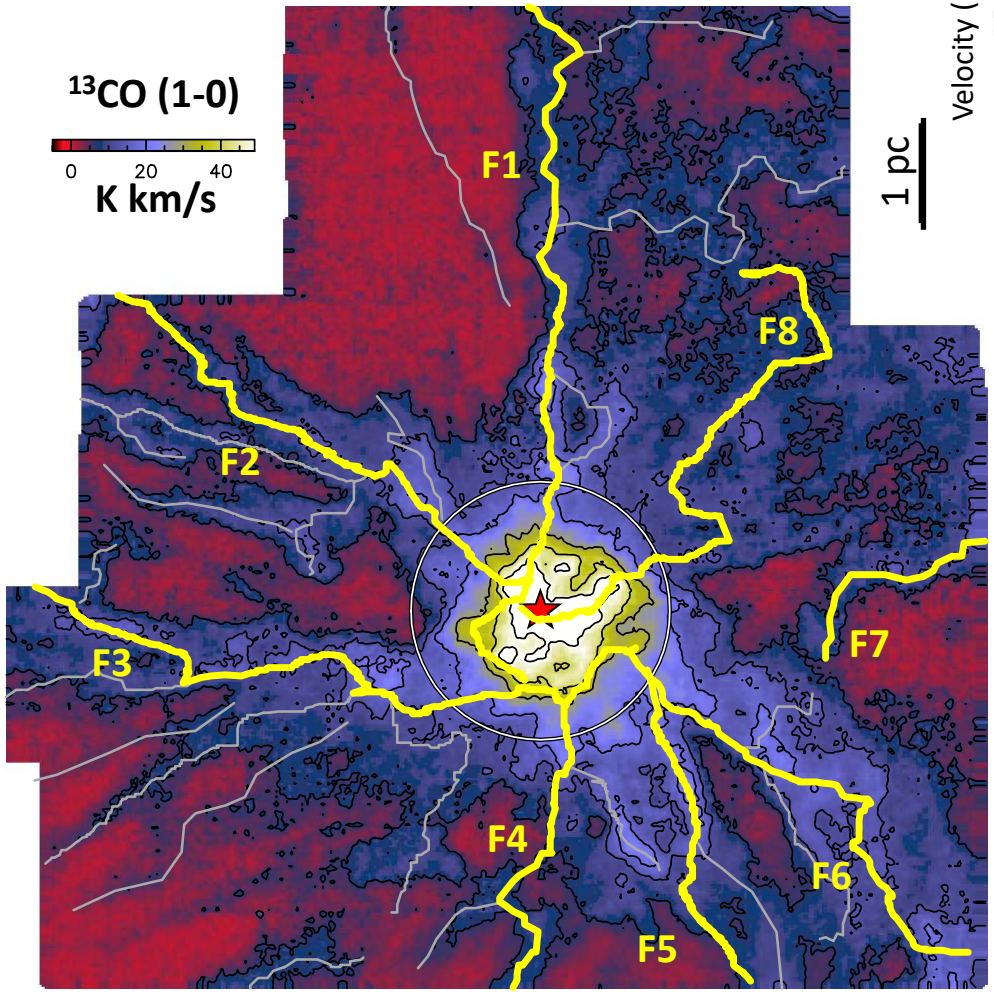


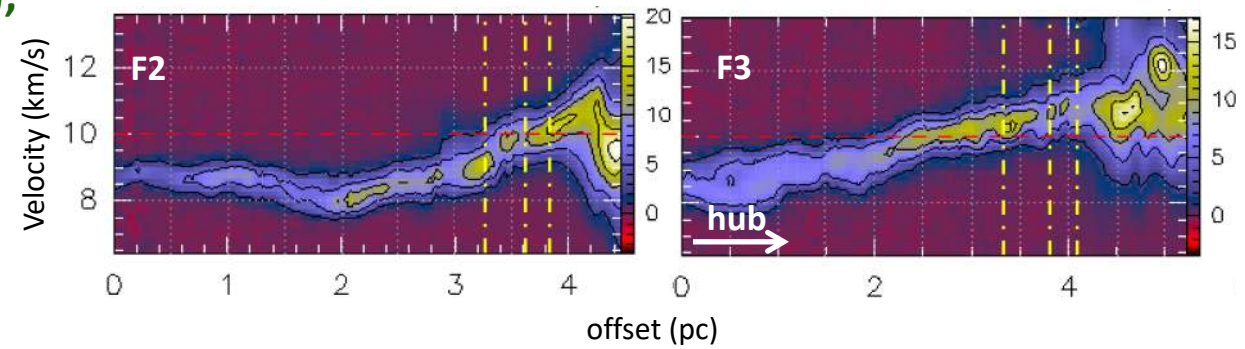


Musca :	M/L = 30 ($M_\odot$ pc^{-1})	**Kainulainen + (2016)**
Taurus (B211)	M/L = 50 ($M_\odot$ pc^{-1})	**Palmeirim +(2013)**
DR21	M/L > 100 ($M_\odot$ pc^{-1})	**Hennemann + (2012)**
Orion A	M/L = 500 ($M_\odot$ pc^{-1})	**Hacar +(2018)**

Filaments: Dynamics (30m observations)

M_{total} = 8300 $M_\odot$; M_{hub} = 2800 $M_\odot$ (inner 250");
M_{fil} = 2800 $M_\odot$





- ***Velocity gradients*** measured as the velocity difference between the extremes of the filament

- ***Mass accretion rates***, assuming 45^o of orientation

$$M_{\rm accr} = \frac{\left(\frac{M}{L_{\rm obs}} V_{\parallel \rm obs}\right)}{\tan\alpha} = \frac{M\,\nabla V_{\parallel \rm obs}}{\tan\alpha}$$

ΔV	=	2 km/s
M_{acc}	=	10^{-4}-10^{-3} $M_\odot$/yr

Treviño-Morales + (2019)

Kirk + (2013); Nagasawa 1987; Wang + 2014

Timing a global collapse

For a hub-filament system presenting a global non-isotropic collapse, the gas flows through the filaments to form the central hub

Treviño-Morales + (2019)

Mass-doubling time = $M(M_\odot)/M_{acc}(M_\odot\,yr^{-1})$

Mass-doubling time = 4-7.5 Myr
M_{hub}~3000 $M_\odot$
Total mass accretion rate = 4-7×10^{-4} $M_\odot yr^{-1}$

For ~ 12×10^{-4} $M_\odot$ yr^{-1} a slightly shorter is mass-doubling time (~2.5 Myr). Considering the gas density of ~10^4 cm^{-3} for Mon R2, the free-fall time is ~3 × 10^5 yr.

$$t_{\rm ff} = (3\pi/(32G\rho))^{-(1/2)}$$

The mass-doubling time derived from the velocity gradients seen in the filaments is one order of magnitude larger than the free-fall time in Mon R2, suggesting a dynamically old region. If the initial density of the cloud is lower, and on the order of ~5 × 10^2 cm^{-3}, the free-fall time is in agreement with the mass-doubling time, suggesting a dynamically young region.

Global collapse!?

Smith et al. 2009; Gómez & Vázquez-Semadeni 2014; Vázquez-Semadeni et al. 2017; Ballesteros-Paredes et al. 2018; Lee & Hennebelle 2016, 2019

Lee & Hennebelle (2019) present simulations of a collapsing molecular cloud and summarize the main features of the process in (i) a global collapse forming a central stellar cluster, (ii) prominent filamentary structures, and (iii) stars forming along the radial filaments that feed the central cluster. The presence of radial filamentary structures like the one seen in MonR2 is more prominent in simulations with a low initial density. In this situation (case A of Lee & Hennebelle 2019) the global collapse precedes the formation of most of the stars. Contrary to that, for initially denser clouds (see case C of Lee & Hennebelle 2019), star formation activity is more widespread and the global collapse is less efficient, resulting in a web-like cloud instead of a radially filamentary cloud. A different interpretation for the generation of a radial filamentary structures in a molecular cloud, is presented in Ballesteros-Paredes et al. (2015), where the turbulent crossing time is ~6-7 times longer than the sound crossing time (consistent with the obtained in the case A of Lee & Hennebelle 2019).

Global collapsing cloud where the filaments feed the central hub

Fragmentation

An expanding HII region braking out the filaments

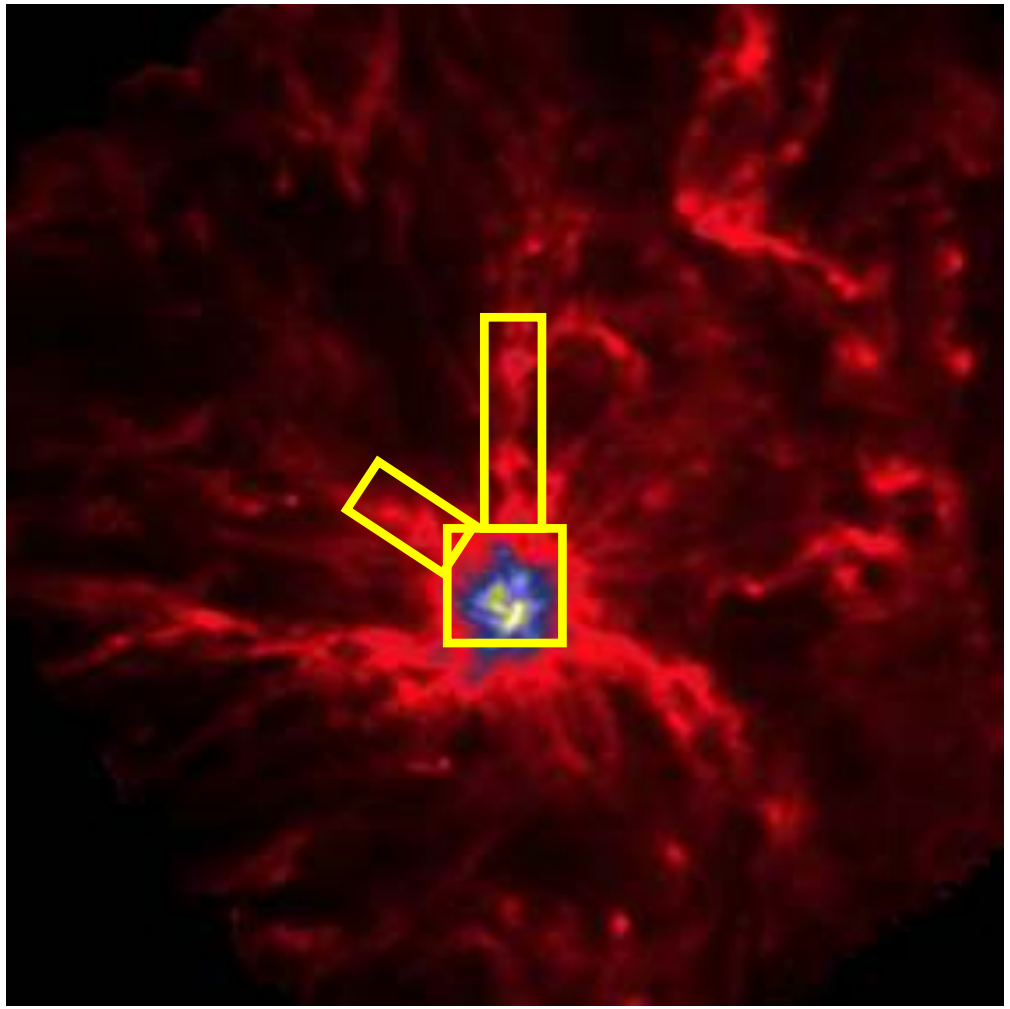
Dynamical signs of a rotating accreting spiral structure

S. P. Treviño-Morales (Chalmers University), Á. Sánchez-Monge (Universität zu Köln), J. Kainulainen (Chalmers University), A. Fuente (Observatorio Astronómico Nacional), S. Suri (Max-Planck Institute for Astronomy), P. Rivière-Marichalar (Observatorio Astronómico Nacional), J. Orkizs (Chalmers University), P. Didelon (Universitè Paris Diderot), N. Schneider (Universität zu Köln), J. Ballesteros-Paredes (Instituto de Radioastronomía y Astrofísica), Y. N. Lee (Institut de Physique du Globe de Paris), P. Hennebelle (Laboratoire AIM), M. González-García (Instituto de Astrofísica de Andalucía), P. Tremblin (Universitè Paris Diderot)

Astronomy & Astrophysics 2019, in preparation.

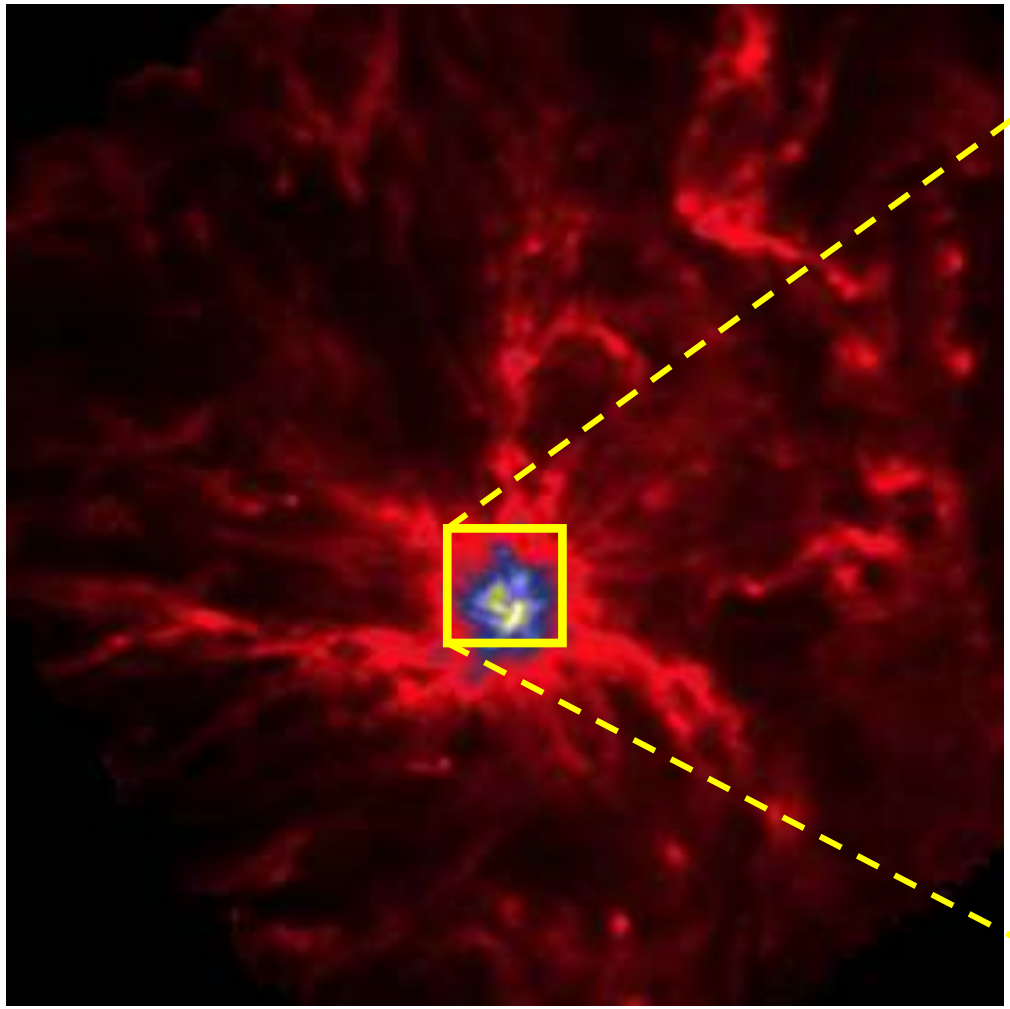
Dynamical signs of a rotating accreting spiral structure

Didelon + (2015)



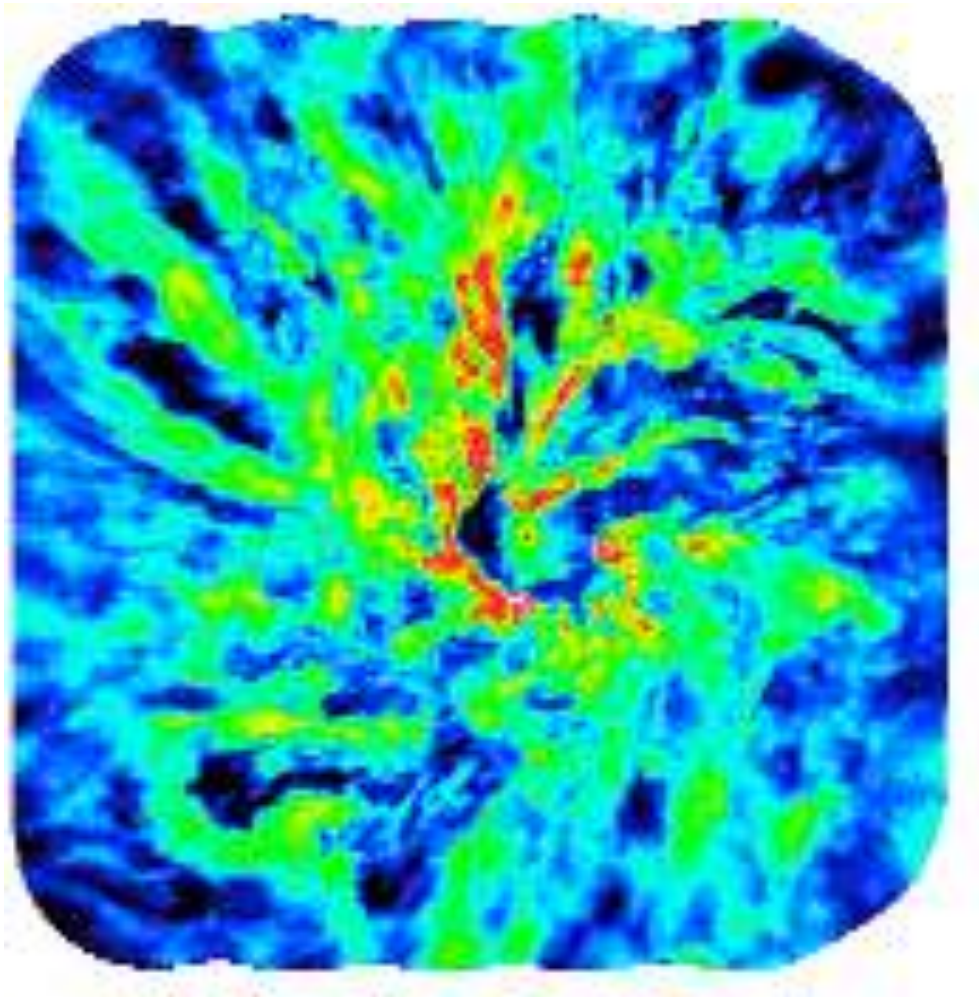
H_2 column density

Dynamical signs of a rotating accreting spiral structure



Didelon + (2015)

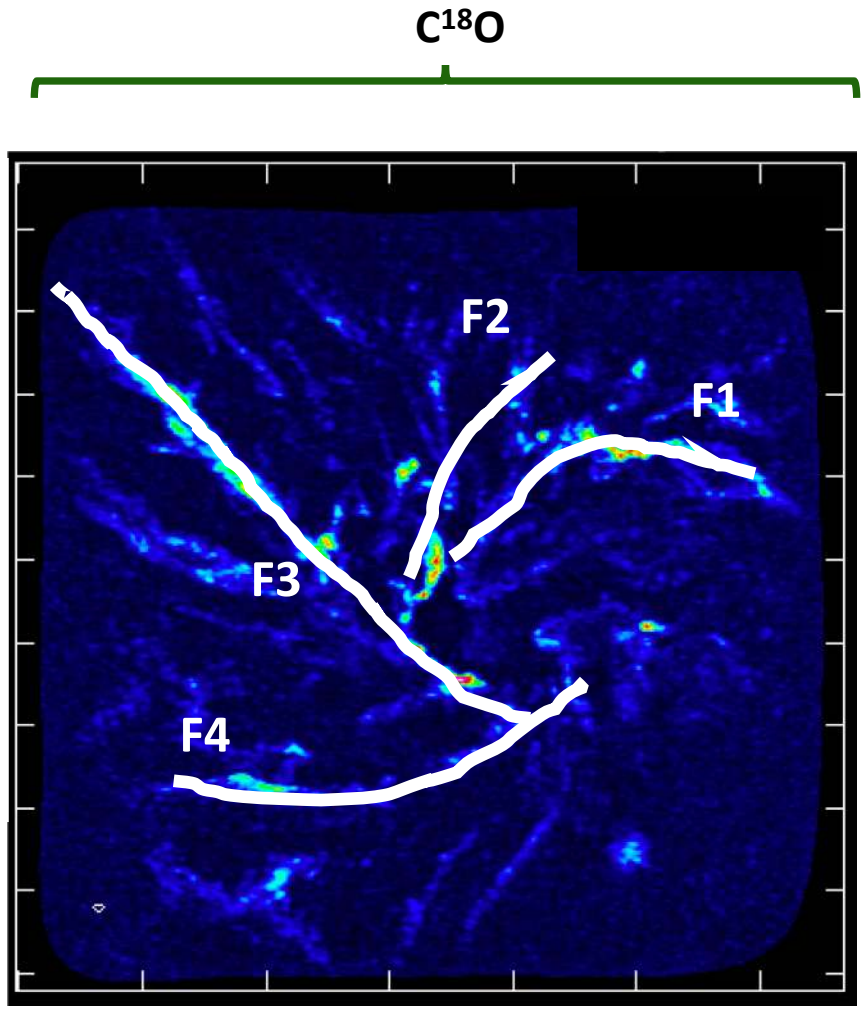
H_2 column density



^{13}CO (1-0)

Treviño-Morales + (in prep.)

Dynamical signs of a rotating accreting spiral structure



Filaments in the central Hub

- $\Delta V \sim 0.5—2$ kms^{-1}/pc
- $M = 100—400\ M_{\odot}$
- $M_{acc} = 0.5—4 \times 10^{-4}$

Filament Identification
Keplerian rotation??
3D structure??

Filaments inside the hub are transonic

Are spiral filamentary structures affecting the star-forming?

MUSCLE W49: A MULTI-SCALE CONTINUUM AND LINE EXPLORATION OF THE MOST LUMINOUS STAR FORMATION REGION IN THE MILKY WAY. I. DATA AND THE MASS STRUCTURE OF THE GIANT MOLECULAR CLOUD

R. Galván-Madrid[1], H. B. Liu[2], Z.-Y. Zhang[3,4], J. E. Pineda[1,5,6], T.-C. Peng[1], Q. Zhang[7], E. R. Keto[7], P. T. P. Ho[2,7], L. F. Rodríguez[8,9], L. Zapata[8], T. Peters[10], and C. G. De Pree[11]

ALMA RESOLVES THE SPIRALING ACCRETION FLOW IN THE LUMINOUS OB CLUSTER-FORMING REGION G33.92+0.11

Hauyu Baobab Liu[1], Roberto Galván-Madrid[2], Izaskun Jiménez-Serra[3], Carlos Román-Zúñiga[4], Qizhou Zhang[5], Zhiyun Li[6], and Huei-R

CLOUD STRUCTURE OF GALACTIC OB CLUSTER-FORMING REGIONS FROM COMBINING GROUND- AND SPACE-BASED BOLOMETRIC OBSERVATIONS

Yuxin Lin[1], Hauyu Baobab Liu[2], Di Li[1,3], Zhi-Yu Zhang[4,2], Adam Ginsburg[2], Jaime E. Pineda[5], Lei Qian[1], Roberto Galván-Madrid[6], Anna Faye McLeod[2], Erik Rosolowsky[7], James E. Dale[8,9], Katharina Immer[2], Eric Koch[7],

Revealing a spiral-shaped molecular cloud in our galaxy – Cloud fragmentation under rotation and gravity

Guang-Xing Li[1,2], Friedrich Wyrowski[2], and Karl Menten[2]

The physical and chemical structure of Sagittarius B2

II. Continuum millimeter emission of Sgr B2(M) and Sgr B2(N) with ALMA

Á. Sánchez-Monge[1], P. Schilke[1], A. Schmiedeke[1,2], A. Ginsburg[3,4], R. Cesaroni[5], D.C. Lis[6,7], S.-L. Qin[8], H.S.P. Müller[1], E. Bergin[9], C. Comito[1], and Th. Möller[1]

A KEPLERIAN-LIKE DISK AROUND THE FORMING O-TYPE STAR AFGL 4176

Katharine G. Johnston[1], Thomas P. Robitaille[2], Henrik Beuther[2], Hendrik Linz[2], Paul Boley[3], Rolf Kuiper[4,2], Eric Keto[5], Melvin G. Hoare[1] and Roy van Boekel[2]

(Accepted October 8, 2018)

FILAMENTS IN SIMULATIONS OF MOLECULAR CLOUD FORMATION

Gilberto C. Gómez and Enrique Vázquez-Semadeni
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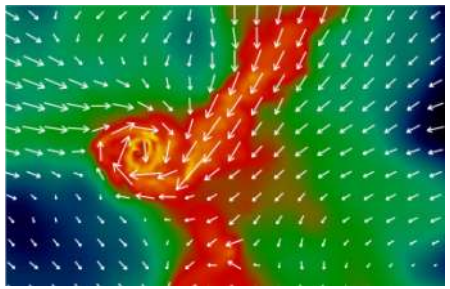
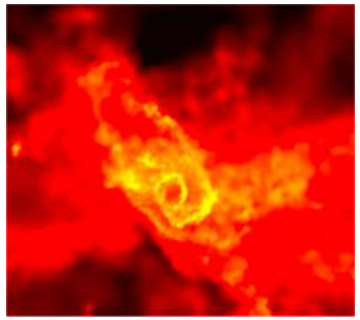
Received 2013 August 26; accepted 2014 July 17; published 2014 August 6



Rotation in young massive star clusters

Michela Mapelli[1⋆]
[1] *INAF-Osservatorio Astronomico di Padova, Vicolo dell'Osservatorio 5, I–35122, Padova, Italy* michela.mapelli@oapd.inaf.it



Spiral features converging in the central cluster

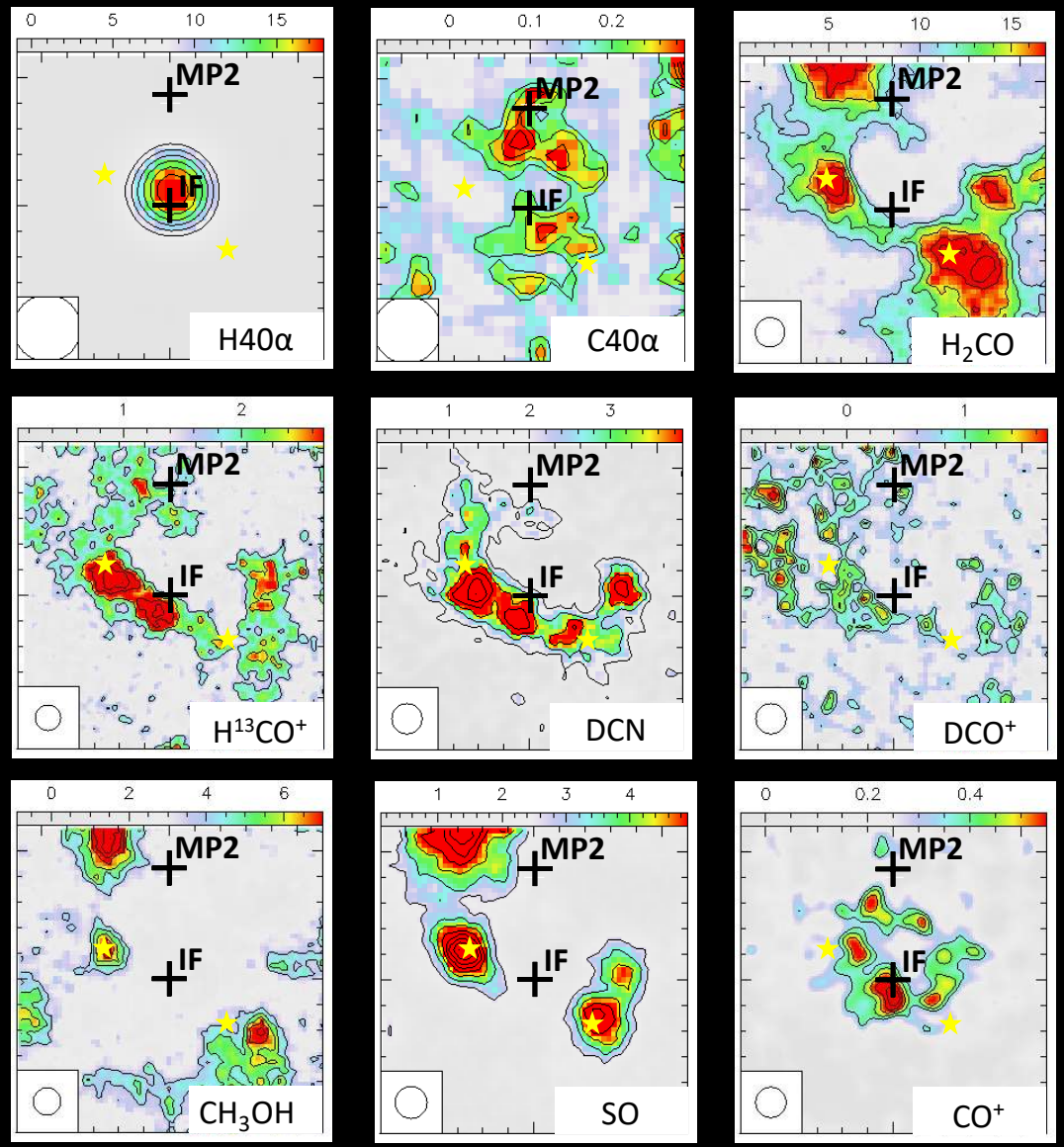
Sub-structures reminiscent to fibers

Similar structures seen in other OB clusters and simulations

A brief view to the chemical complexity

- Radio Recombination Lines
- Deuterated molecules
- Sulphurated molecules
- Complex molecules
- Hydrocarbons
- Nitrogenated species
- Ionic species

≈ 60 different species grouped in ***families***



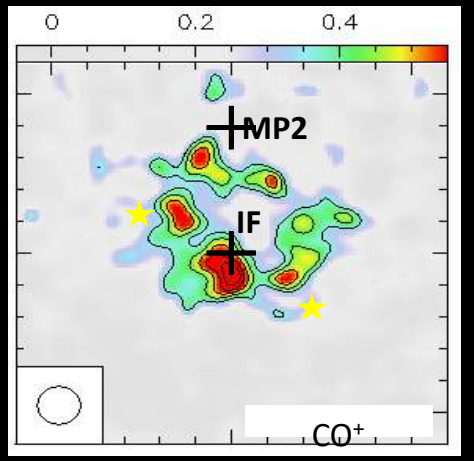
Treviño-Morales et al (2014;2016)

A brief view to the chemical complexity

Reactive ions are destroyed in almost every collision with H and H_2 and recombine rapidly with e^-.

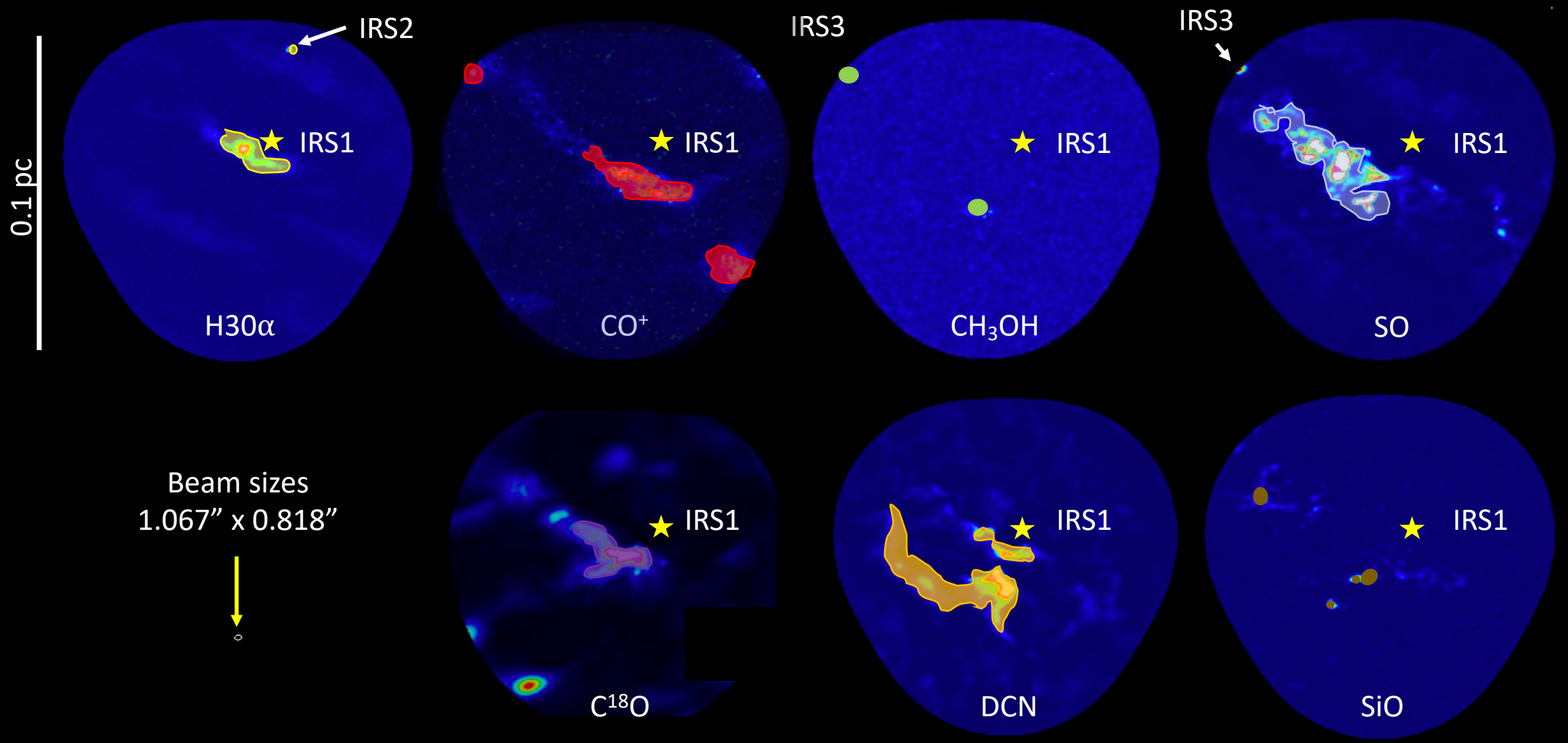
High CO^+ abundance at the HI/H_2 interface ($A_V \approx 1$ mag) of dense PDRs (**Sternberg & Dalgarno 1995**)

Produced by the $C^+ + OH \rightarrow CO^+ + H$ reaction.

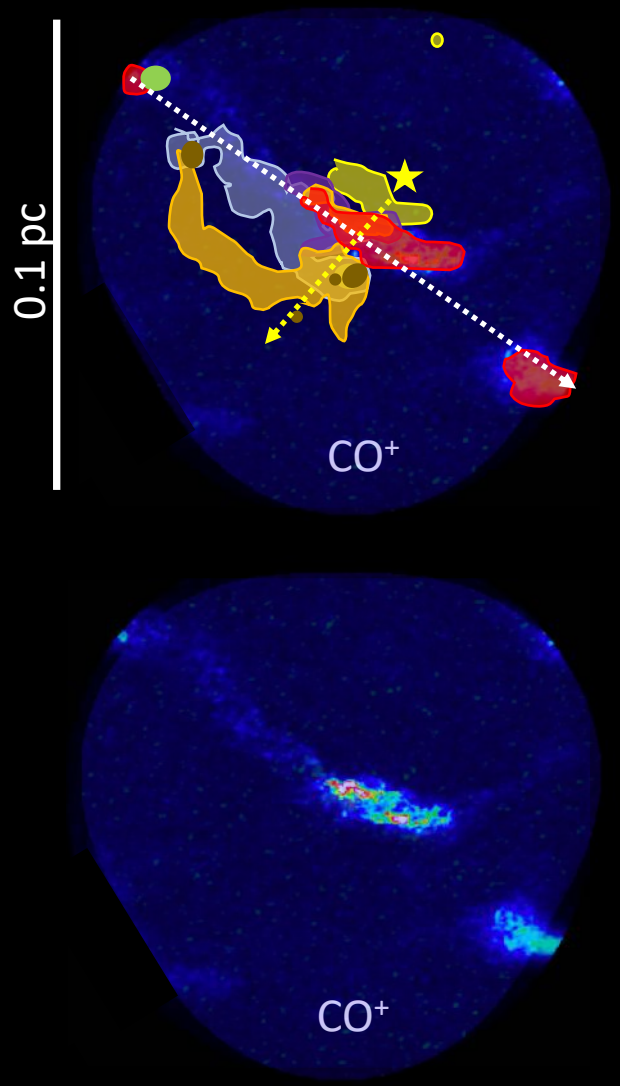


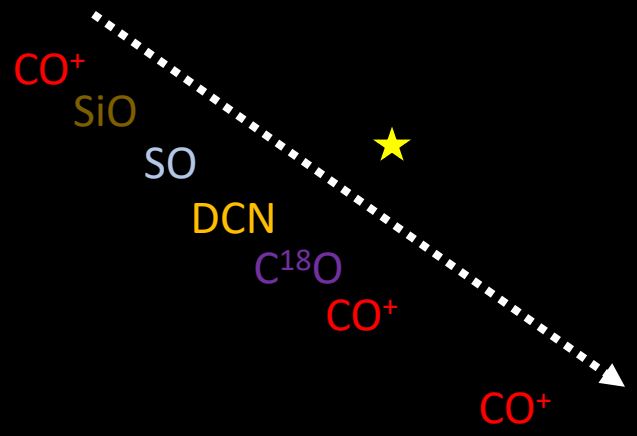
Has been detected in several PDRs, such as the M17SW, Orion Bar, NGC 7027, NGC 7023 (Latter et al. 1993; Stoerzer et al. 1995; Fuente & Martín-Pintado 1997; Fuente et al. 2003), G29.96, MonR2 (Rizzo et al. 2003) and S140 (Savage & Ziurys 2004).

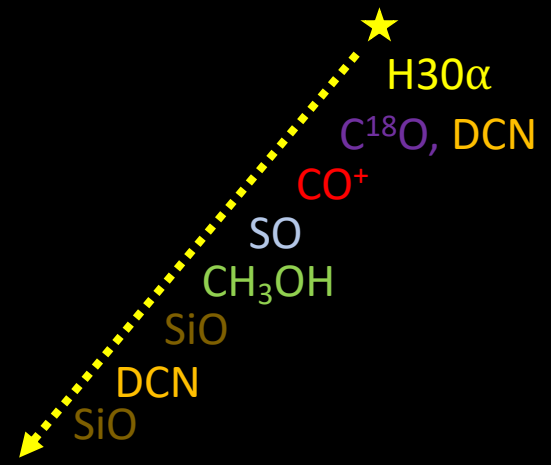
A brief view to the chemical complexity



A brief view to the chemical complexity







Chemical segregation

Beam sizes
1.067” x 0.818”

Treviño-Morales et al (in prep.)

Chemical segregation into the hub

Dense warm clumps

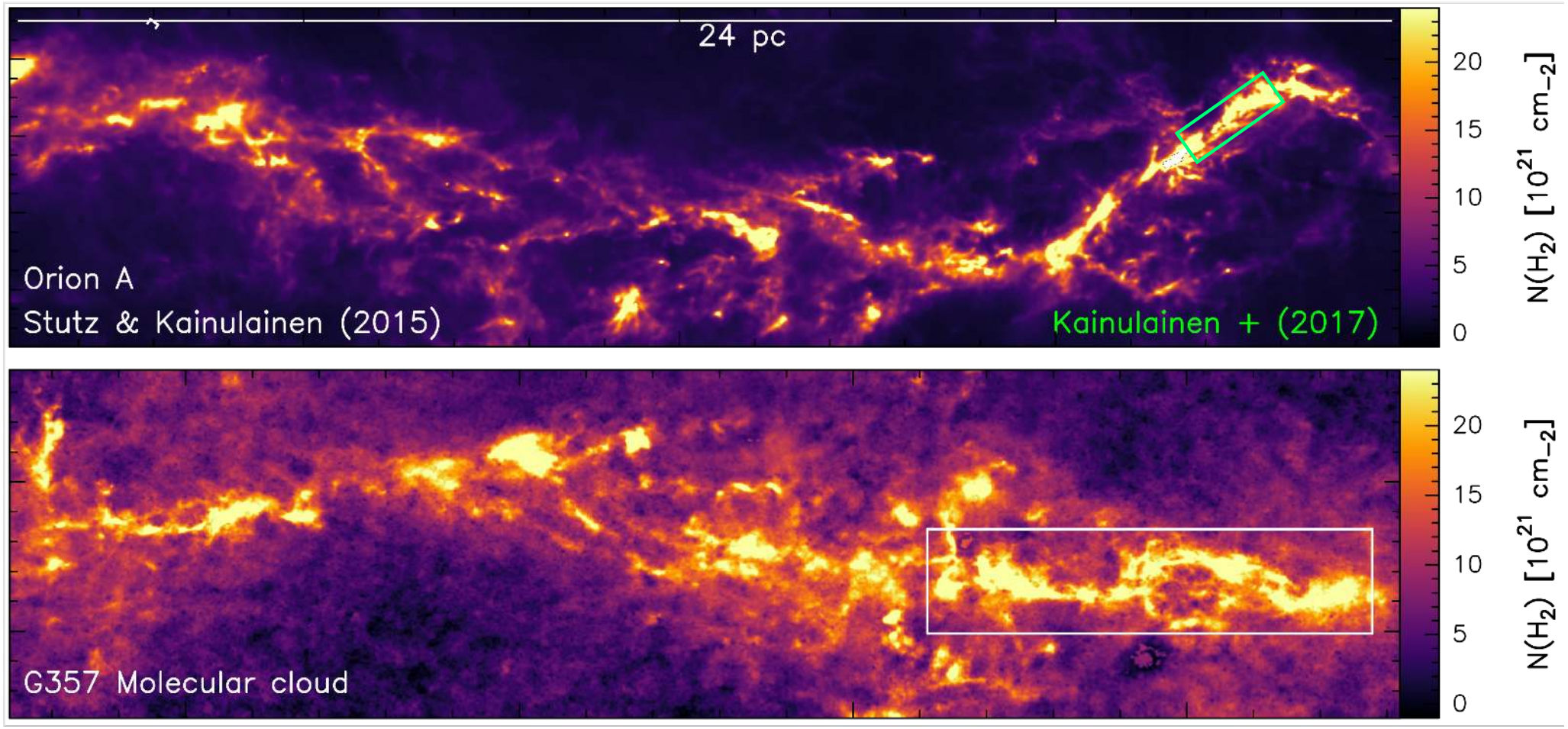
Hints of photoevaporation

Evolutionary sequence for the fragmentation of high line-mass filaments

S. P. Treviño-Morales (Chalmers University), J. Kainulainen (Chalmers University), M. Zhang (), J. Orkizs (Chalmers University), H. Beauter (), S. Clarke (), A. Stutz ()

Astronomy & Astrophysics, in preparation.

Evolutionary sequence for the fragmentation of high line-mass filaments



Aim: Develop an evolutionary sequence for **high line-mass filaments** by characterizing fragmentation of an *early-stage* filament and compare that with the evolved ISF.

Evolutionary sequence for the fragmentation of high line-mass filaments

Integral shaped filament (ISF)

- Located at ~ 420 pc
- Line-mass of 400 $M_{\odot}$/pc
- High-mass star formation
- About 8 pc of longitude

G357

- Located at ~ 3 Kpc (l = 357.7, b= -0.38)
- Line-mass of ~ 300 $M_{\odot}$ /pc
- harbors very few protostars (deficiency of sub-mm sources, 24 µm sources, and red near-infrared sources.)
- Expected to form stars in the future
- Densest filament with about 8 pc of longitude

The G357 cloud morphology and mass are very similar to Orion A

Evolutionary sequence for the fragmentation of high line-mass filaments

Integral shaped filament (ISF)

12marray

- Primary beam ~60’’
- Max recoverable scale 25’’
- Synthesized beam 3.2’’ × 1.7’’
- Achieved rms of 0.14 mJy/beam

ACA

- Primary beam ~105’’
- Max recoverable scale 42’’
- Synthesized beam 19.9’’ × 10’’.3
- Achieved rms 2.3 mJy/beam

G357

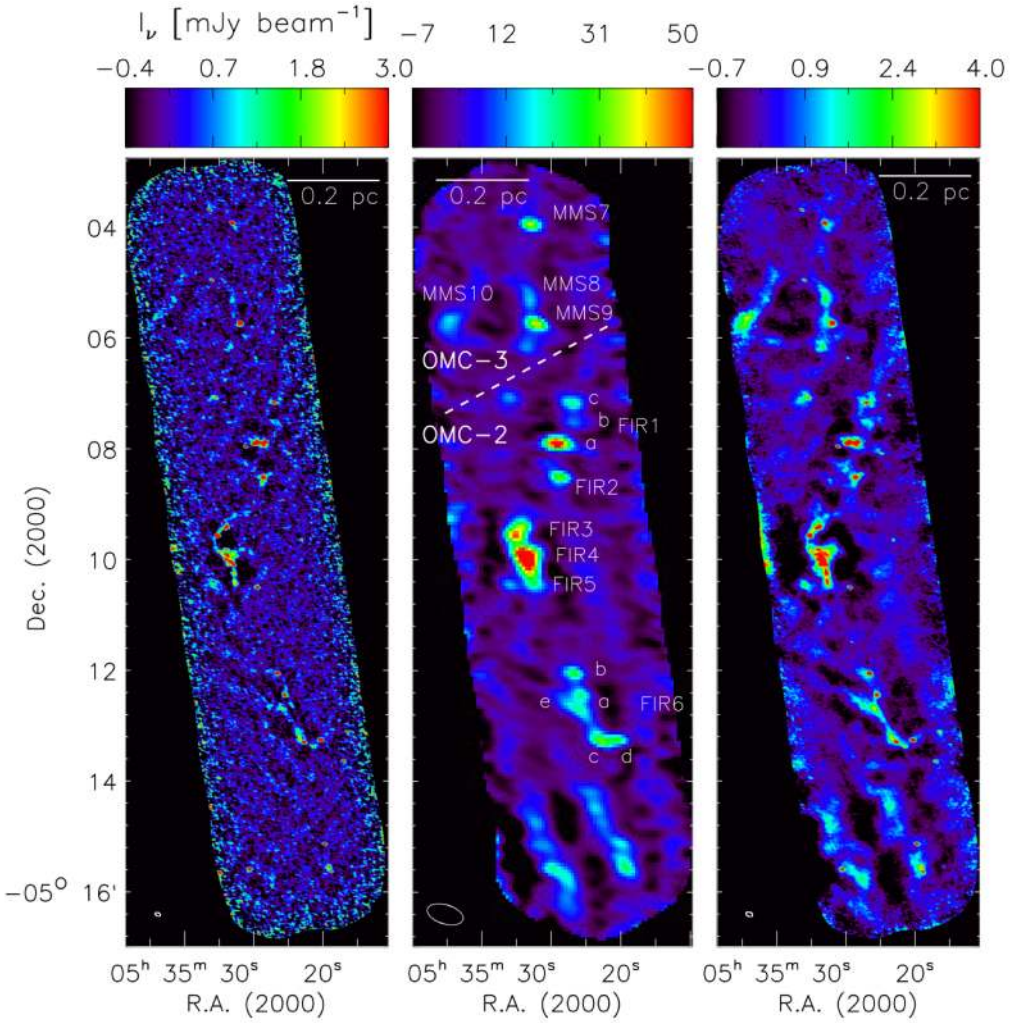
12m array

- Primary beam ~63’’
- Max recoverable scale 32’’
- Synthesized beam 0.34” x 0.32"
- Achieved rms of 0.2 mJy/beam

ACA

- Primary beam ~107’’
- Max recoverable scale 55’’
- Synthesized beam 18’’ × 9’’
- Achieved rms 2.0 mJy/beam

Evolutionary sequence for the fragmentation of high line-mass filaments



- **43 cores** (26 corresponds with protostars)
- **Fluxes between 5 and 40 mJy**
- Starless cores show strong grouping
- **Groups correspond** to the gas morphology traced by the ***Herschel* column density map**
- Density profile along the filament show that the predictions for **Jeans' fragmentation scale is ~10000AU** and for the filamentary **gravitational fragmentation scale is ~40000AU**.
- **Gravitational fragmentation is an important process**, even though our understanding of how exactly it proceeds is incomplete.

(Kainulainen + 2017)

Evolutionary sequence for the fragmentation of high line-mass filaments

Coverage of ALMA Study
3 mm continuum and N_2H^+ emission

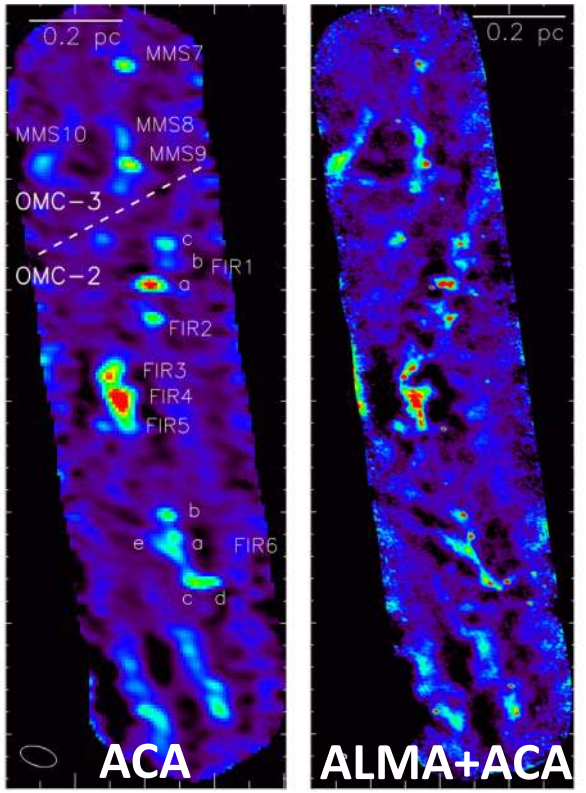
7 pc

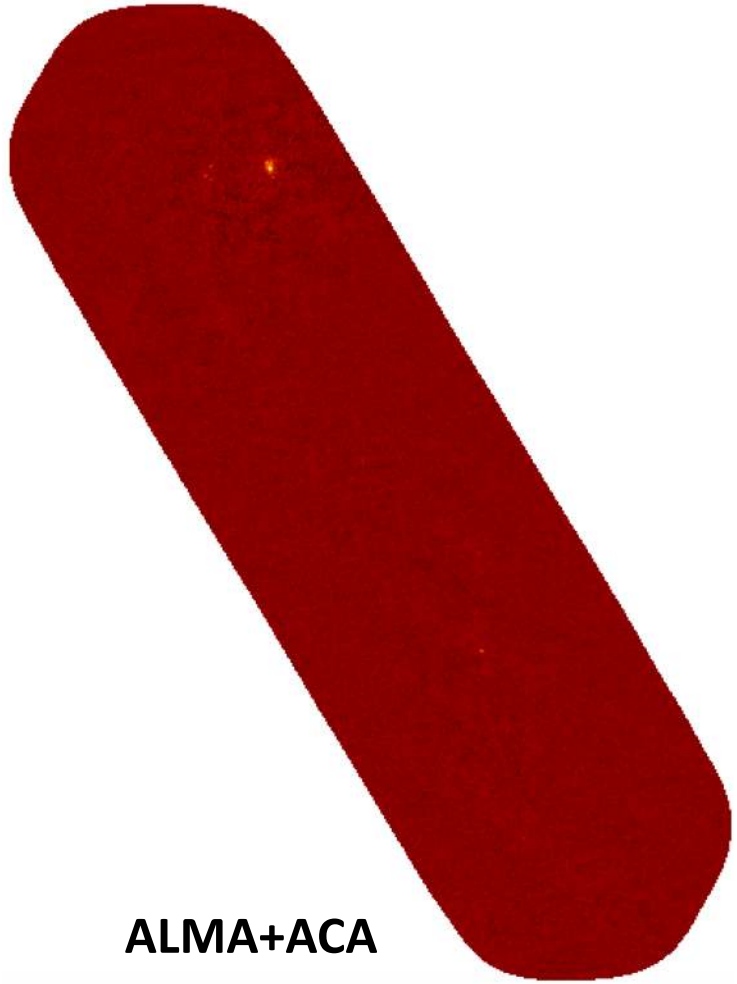
- Located at ~3 Kpc (l = 357.7, b= -0.38)
- Dense cloud with line-mass of **~ 300 $M_\odot$ /pc**
- The cloud morphology and mass is very similar to Orion A
- Deficiency of sub-mm and red near-infrared sources
- Expected to form stars in the future

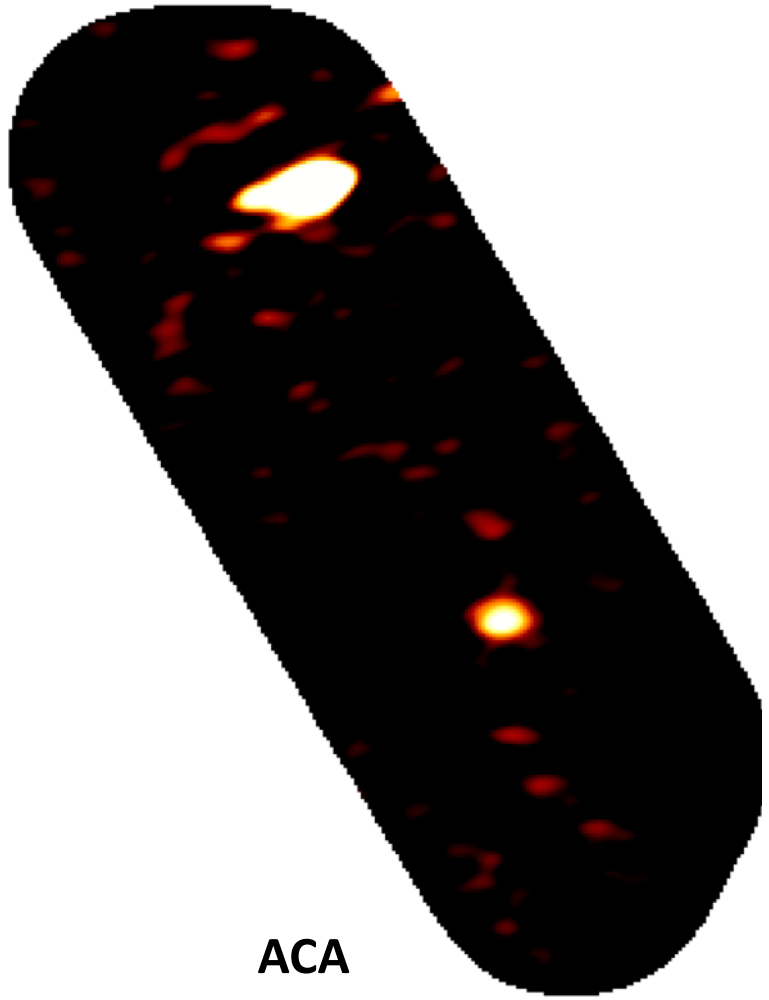
Treviño-Morales, Kainulainen, Orkisz, Zang, Beuther, Stutz

Evolutionary sequence for the fragmentation of high line-mass filaments

ISF

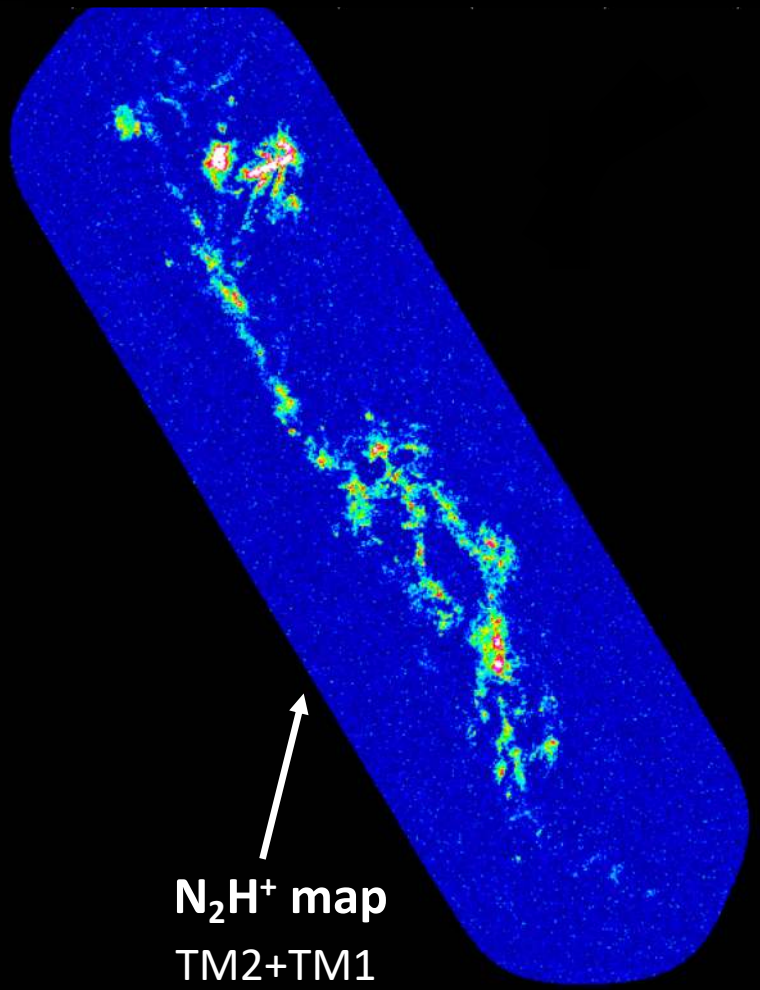






The G357 has a “lack” of continuum extended emission

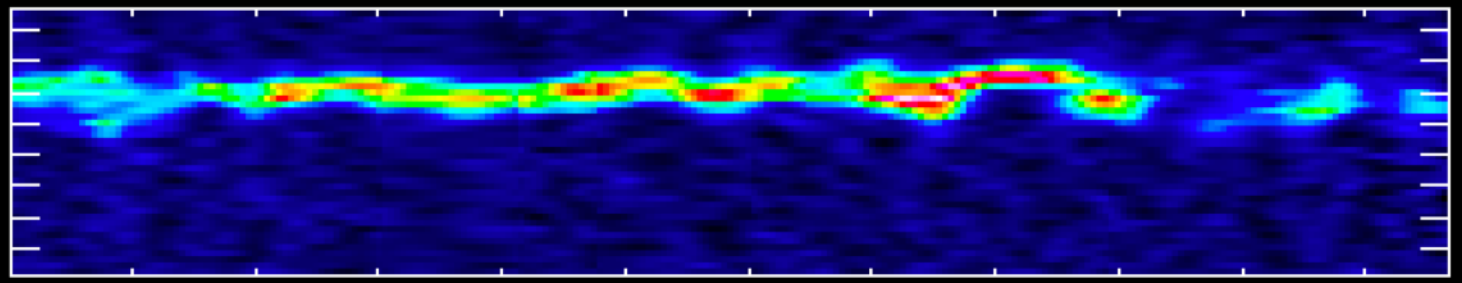
Evolutionary sequence for the fragmentation of high line-mass filaments



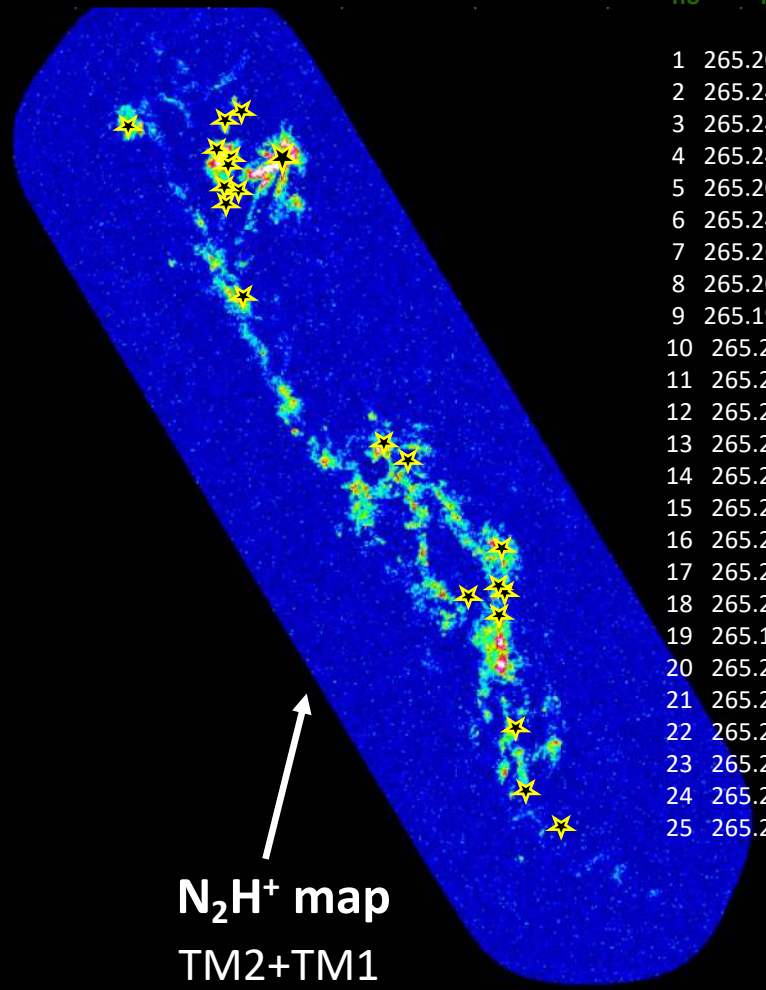
N_2H^+ map
TM2+TM1

Identification of compact objects

- GaussClumps (CUPID)
- 25 objects
- Resolved D of a few 1000 AU
- M=0.3-3.5 $M_\odot$



Evolutionary sequence for the fragmentation of high line-mass filaments



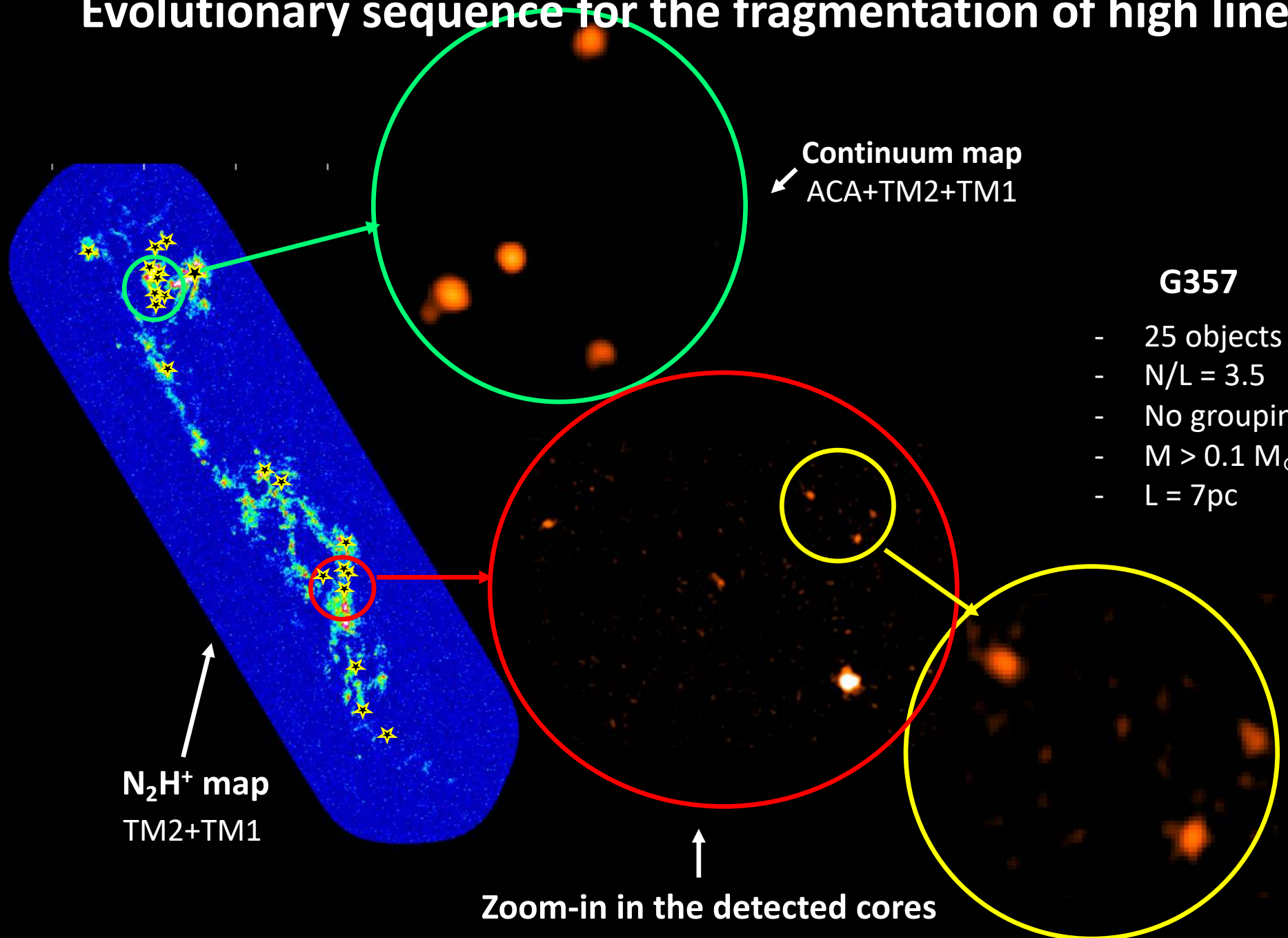
N_2H^+ map

TM2+TM1

no	ra	dec	x	y	fwhm_x	fwhm_y	size_x	size_y	p_flux	totalflux	pa	edge	stdev	snr
1	265.204681	-31.248840	4395.050	2938.180	8.690	7.530	0.250	0.220	0.002714	0.202603	-9.940	0.000	2.420E-05	112.136
2	265.248230	-31.184158	2479.400	6264.490	6.990	7.590	0.190	0.210	0.000627	0.037038	18.790	0.000	3.268E-05	19.189
3	265.248596	-31.184355	2462.380	6254.420	8.320	7.510	0.220	0.210	0.000588	0.040894	-40.540	0.000	3.216E-05	18.281
4	265.247742	-31.182993	2500.500	6324.480	7.970	9.360	0.220	0.250	0.000445	0.036656	-19.260	0.000	3.149E-05	14.133
5	265.204498	-31.248816	4402.520	2939.440	5.210	6.910	0.140	0.180	0.000362	0.014235	-6.510	0.000	2.417E-05	14.978
6	265.247681	-31.184666	2503.480	6238.500	9.220	8.340	0.240	0.220	0.000310	0.026067	-17.750	0.000	3.100E-05	10.002
7	265.263550	-31.178282	1804.510	6566.500	4.910	5.520	0.130	0.130	0.000262	0.007695	42.930	0.000	2.444E-05	10.719
8	265.204468	-31.246325	4404.470	3067.500	6.540	7.650	0.170	0.190	0.000224	0.012062	-4.360	0.000	2.417E-05	9.269
9	265.195007	-31.277824	4819.500	1447.490	7.670	6.940	0.190	0.180	0.000220	0.012632	-11.570	0.000	2.381E-05	9.239
10	265.248749	-31.184469	2456.500	6248.500	6.500	8.380	0.180	0.200	0.000203	0.011913	28.780	0.000	3.210E-05	6.323
11	265.220612	-31.226883	3694.490	4067.500	7.670	7.030	0.190	0.180	0.000215	0.012405	-1.100	0.000	2.416E-05	8.898
12	265.246948	-31.184080	2535.500	6268.500	5.110	9.120	0.140	0.220	0.000197	0.009812	-15.640	0.000	2.918E-05	6.751
13	265.223572	-31.222876	3564.500	4273.500	8.120	9.220	0.220	0.220	0.000199	0.015933	39.640	0.000	2.316E-05	8.592
14	265.210846	-31.246073	4123.500	3080.500	11.240	6.200	0.280	0.160	0.000199	0.014862	9.170	0.000	2.339E-05	8.509
15	265.205017	-31.235689	4379.500	3614.500	8.630	5.100	0.200	0.140	0.000170	0.007985	-21.260	0.000	2.508E-05	6.778
16	265.245972	-31.203720	2578.500	5258.490	8.110	5.260	0.190	0.140	0.000168	0.007587	24.900	0.000	2.428E-05	6.919
17	265.203644	-31.265575	4439.500	2077.490	6.330	6.540	0.160	0.160	0.000172	0.007552	-39.430	0.000	2.509E-05	6.856
18	265.205444	-31.245567	4361.500	3106.490	6.270	8.780	0.180	0.200	0.000170	0.009938	37.950	0.000	2.456E-05	6.921
19	265.197754	-31.274384	4699.500	1624.500	7.860	5.500	0.180	0.160	0.000165	0.007598	-34.390	0.000	2.469E-05	6.683
20	265.204712	-31.248638	4393.500	2948.500	8.770	6.380	0.220	0.160	0.000167	0.009933	-6.010	0.000	2.442E-05	6.839
21	265.246002	-31.176868	2577.500	6639.500	10.480	6.240	0.250	0.150	0.000142	0.009743	1.600	0.000	2.338E-05	6.073
22	265.248993	-31.187366	2445.500	6099.500	5.620	10.480	0.130	0.250	0.000141	0.008736	-2.900	0.000	3.021E-05	4.667
23	265.246887	-31.189623	2538.500	5983.500	4.010	7.000	0.160	0.110	0.000131	0.003839	-63.780	0.000	2.676E-05	4.896
24	265.248535	-31.178326	2465.500	6564.500	7.430	4.360	0.160	0.130	0.000131	0.004405	-35.600	0.000	3.089E-05	4.240
25	265.246368	-31.188768	2561.500	6027.490	7.410	10.590	0.220	0.220	0.000130	0.010655	42.720	0.000	2.500E-05	5.200

Clarke S. +(2019)

Evolutionary sequence for the fragmentation of high line-mass filaments



Continuum map
ACA+TM2+TM1

N_2H^+ map
TM2+TM1

Zoom-in in the detected cores

G357	ISF
- 25 objects	- 43 objects
- N/L = 3.5	- N/L = 27
- No grouping	- Grouping
- M > 0.1 $M_\odot$	- M > 0.1 $M_\odot$
- L = 7pc	- L = 1.6 pc

Evolutionary sequence for the fragmentation of high line-mass filaments

G357

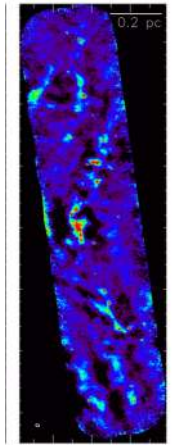
- 25 objects
- N/L = 3.5
- No grouping
- M > 0.3 $M_\odot$

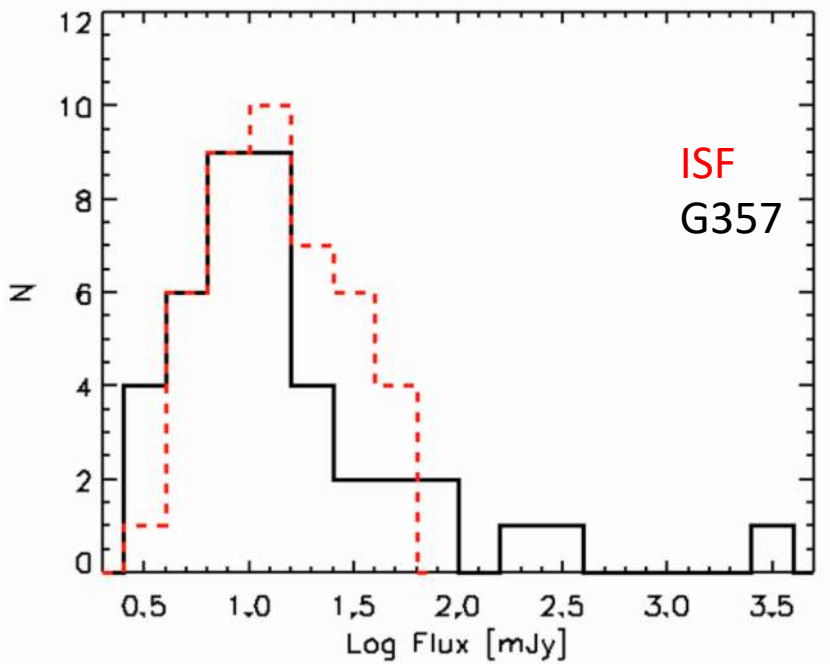
7 pc

ISF

- 43 objects
- N/L = 27
- Grouping
- M > 0.1 $M_\odot$

1.6 pc





Integral shaped filament (ISF) in Orion A

- **43 cores** found in ISF with **fluxes** between **5 and 40 mJy** corresponding with **M = 0.1 -2.6 $M_\odot$**
- Strong grouping where groups correspond to the gas morphology traced by the *Herschel* column density map
- Density profile along the filament show that the predictions for **Jeans' fragmentation scale is ~10000AU** and for the filamentary **gravitational fragmentation scale is ~40000AU**.

G357 Filament

- **25 cores** found in G357 with **fluxes** between **6 and 130 mJy** corresponding with **M > 0.3 $M_\odot$**
- No grouping
- N/L smaller than in the ISF by a factor of 7
- **Complex Kinematics** and **velocity gradients** at the spots of the most massive clumps
- **Younger evolutionary state. It is expected to actively form stars in the future**