Revealing the external gas inflow into Orion-KL region using JCMT

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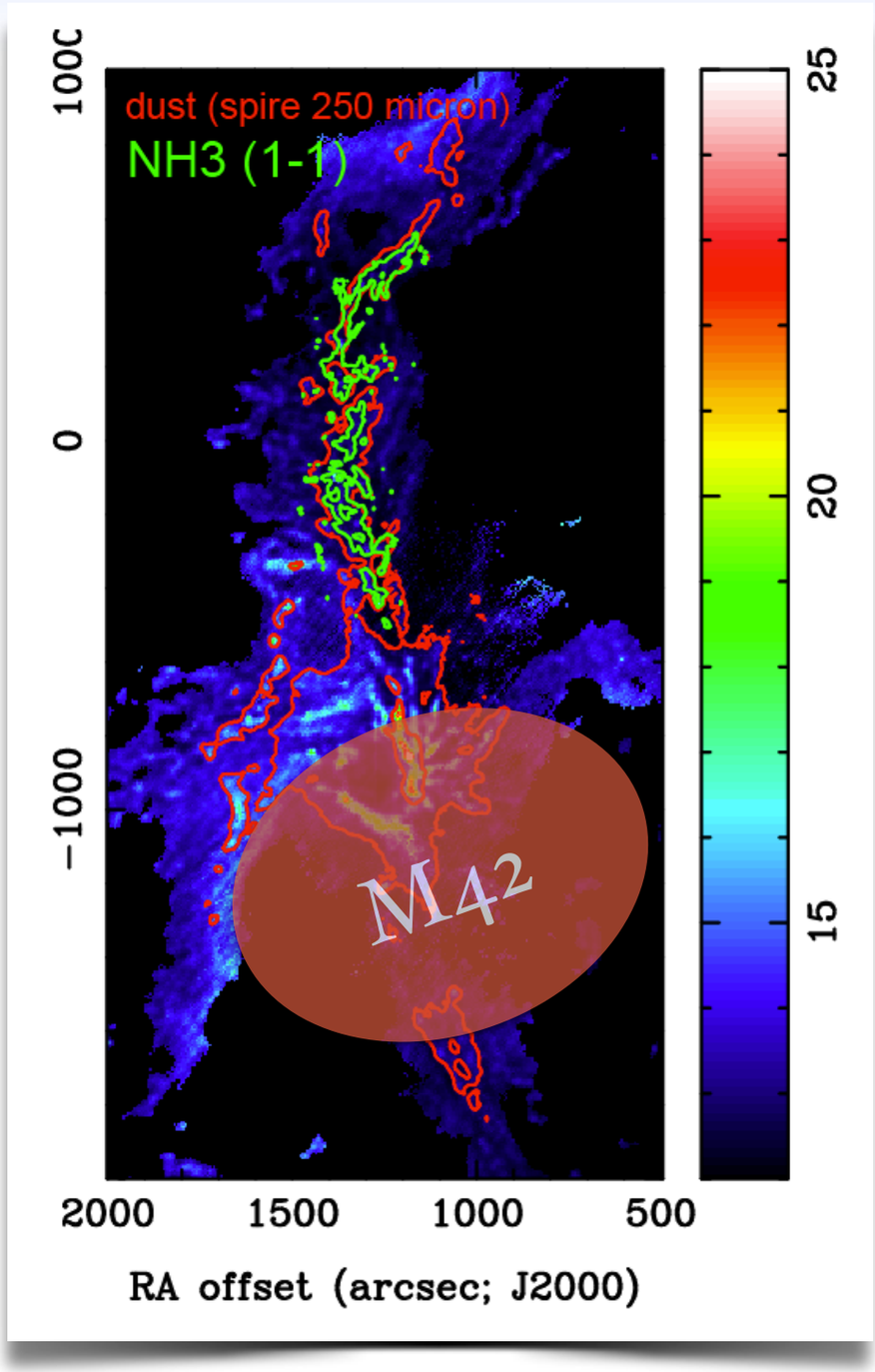
Diego Mardones、Alesso Traficante et al.

Outline

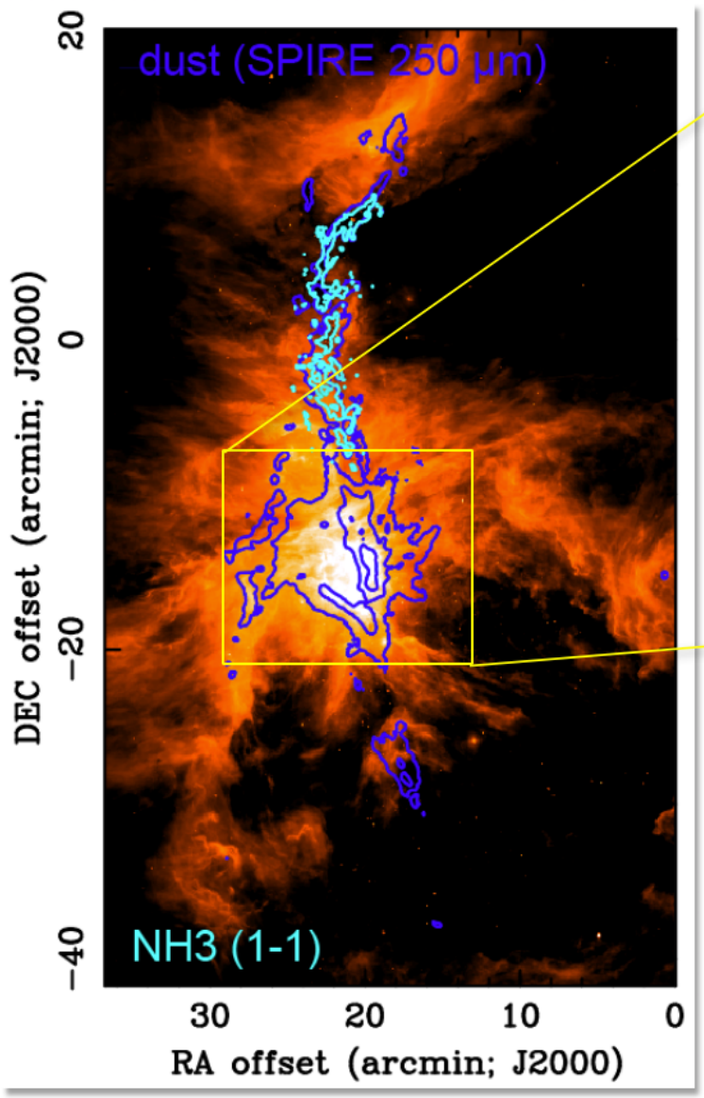
- Gas and dust morphology and temperature field
- One big question: explosive outflow vs ongoing high-mass YSO.

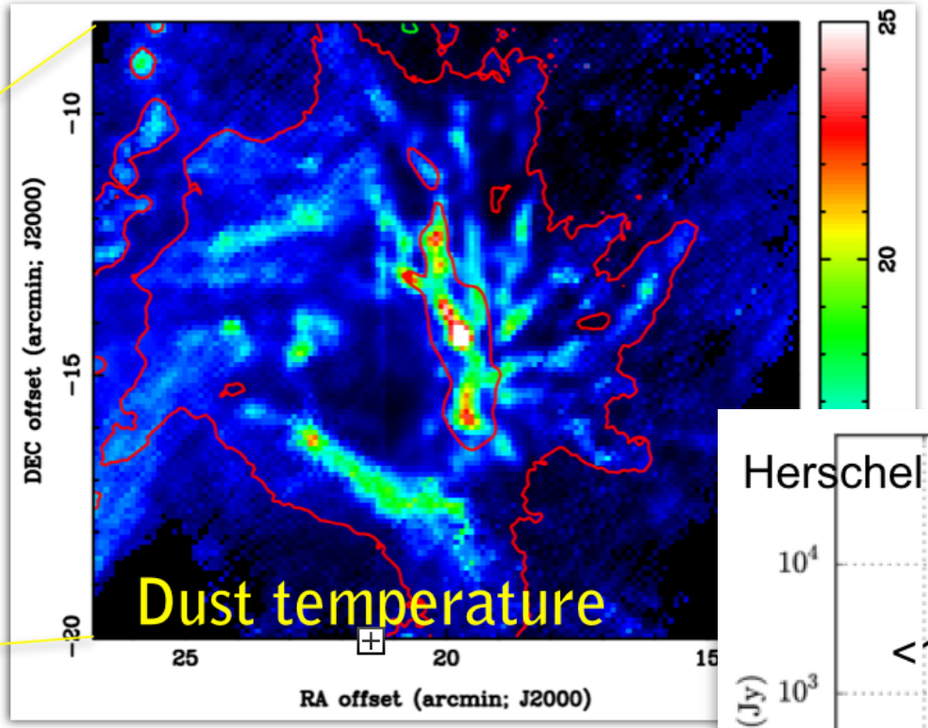


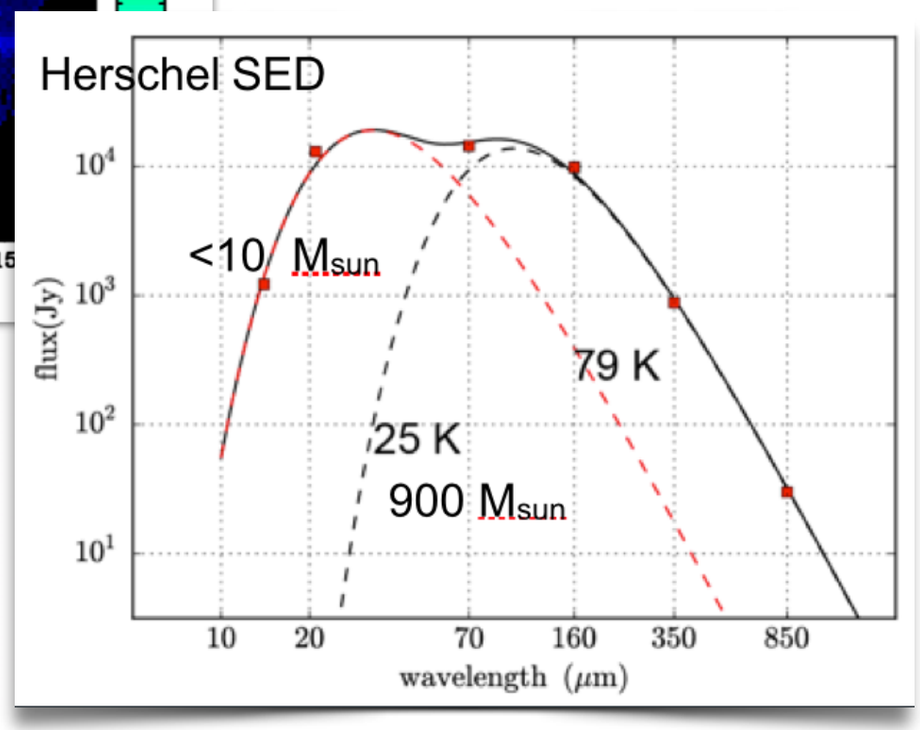
Orion KL: huge amount of cold dense gas

Gas morphology and temperature distribution

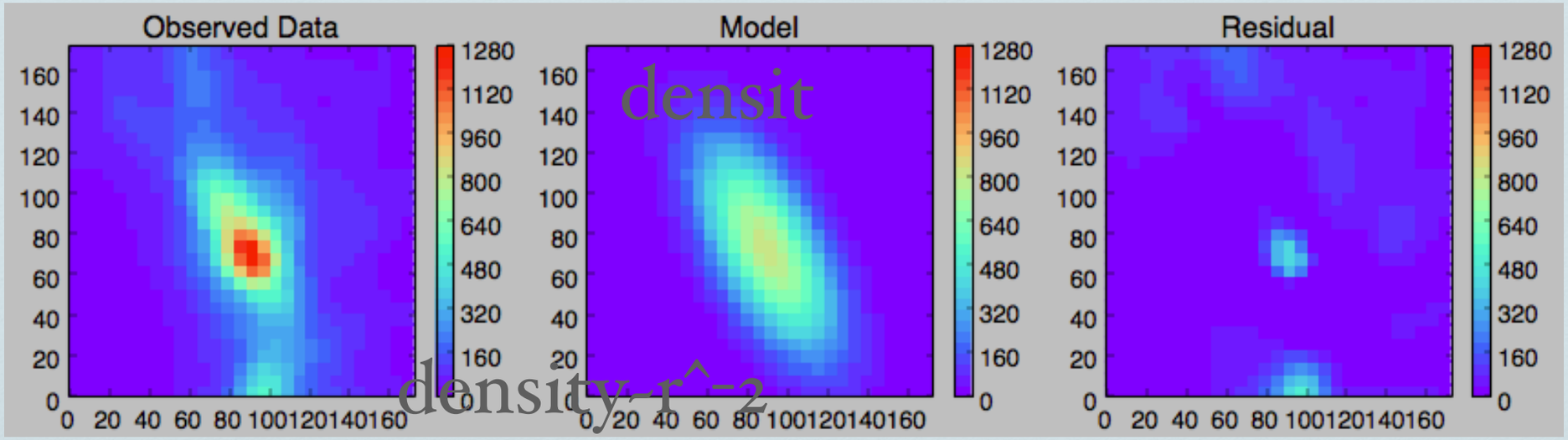
- Multiple filaments converging into the center (Orion hot core).
- Despite the heating from Trapezium stars and Orion hot core, the major fraction of Orion A still has noticeably low temperatures (20-25 K).
- The central region has T~25 K, decreasing to 20 K at the outer part.
- The cold gas has a total mass of ~1800 $M_\odot$, which is huge compared to the Orion hot core (~40 $M_\odot$).



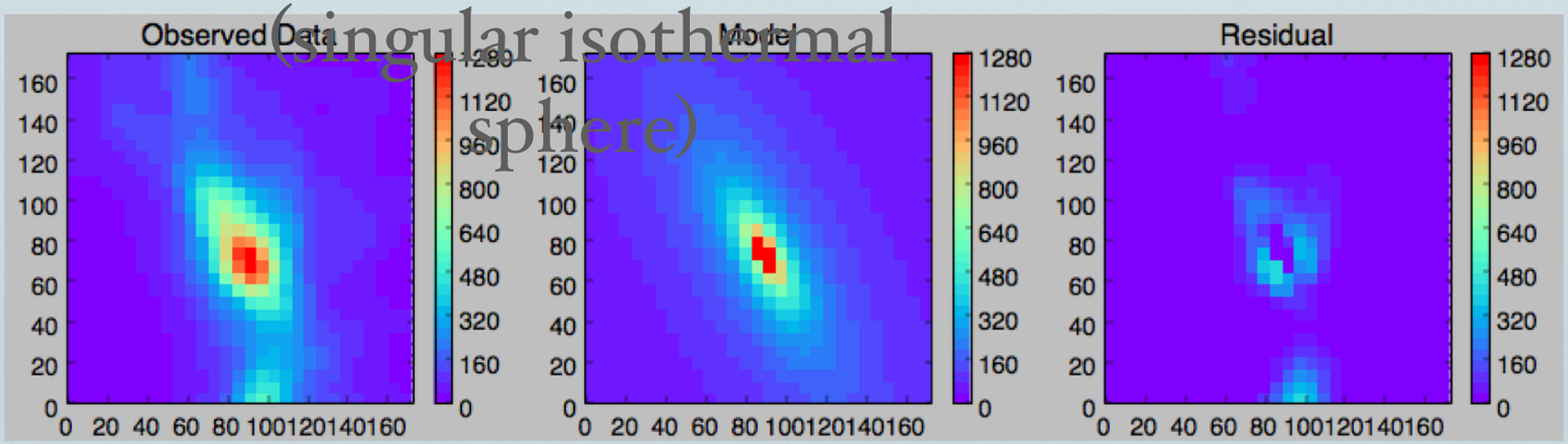




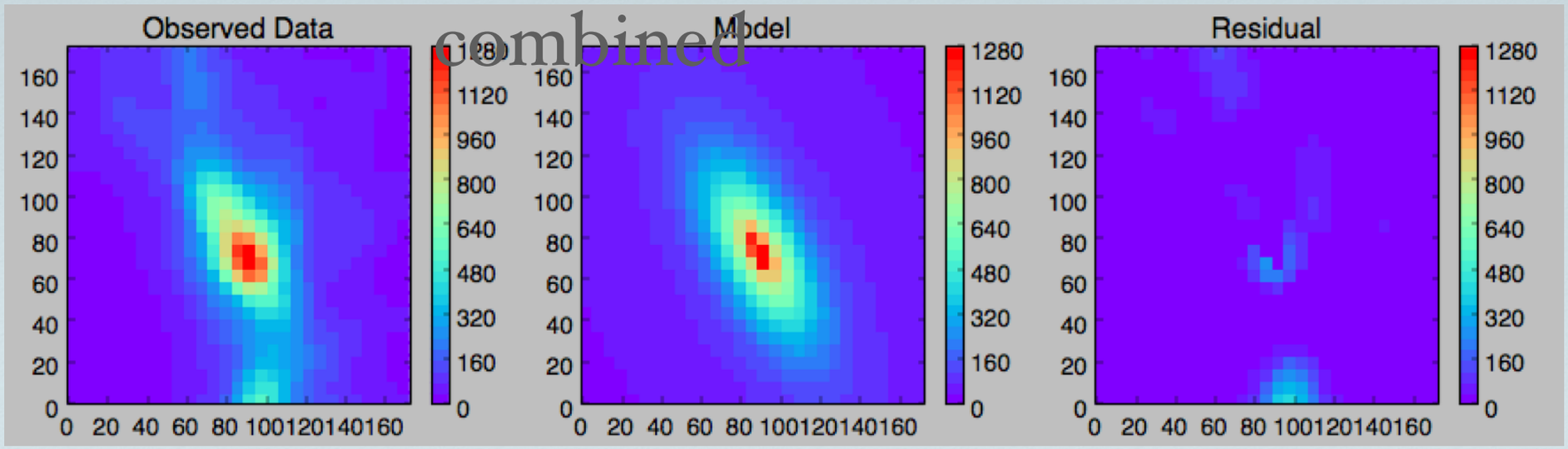
- Density-profile: 3D structure modeling.

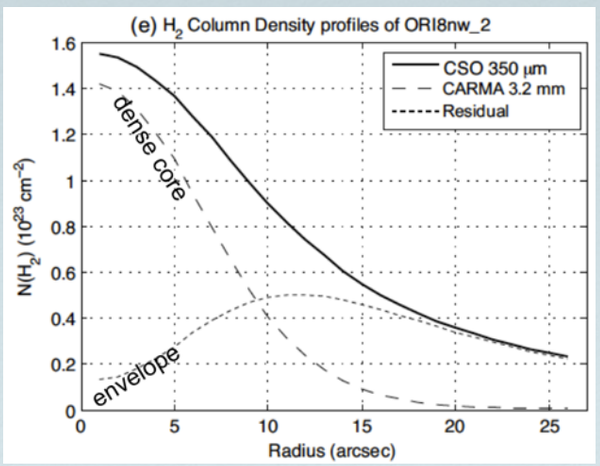


density-r^-2 (singular isothermal sphere)



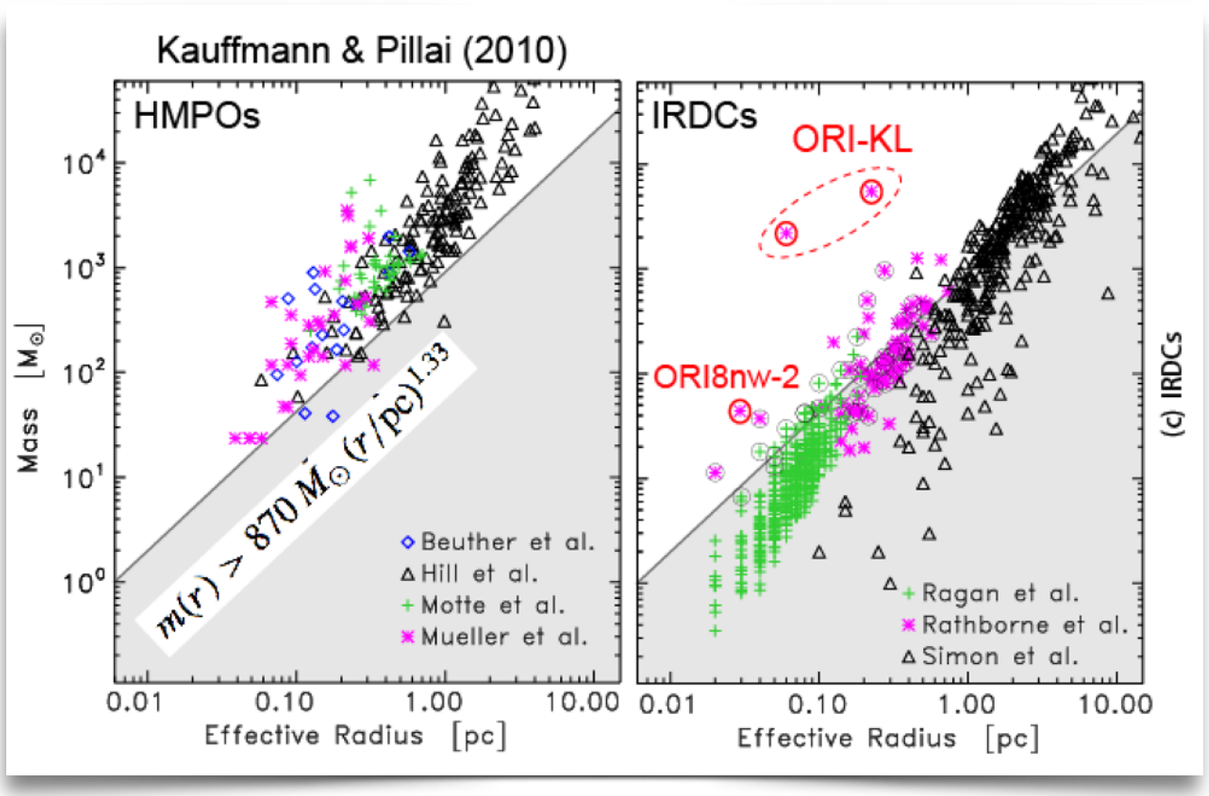
combined



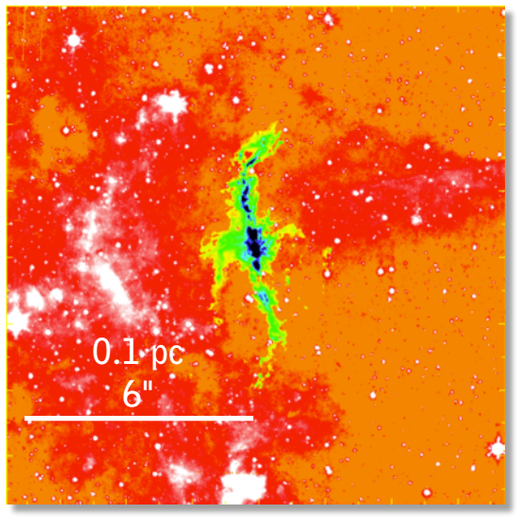


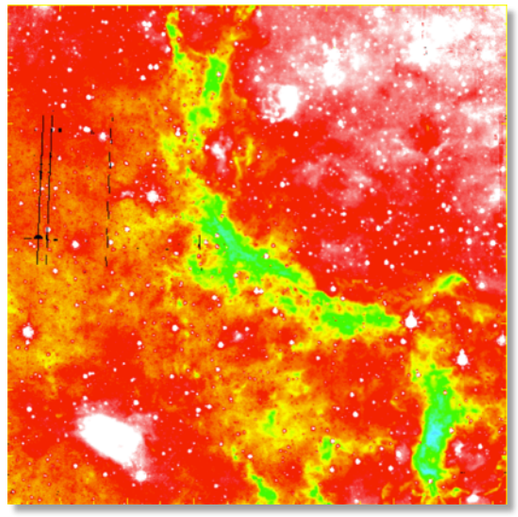
Orion: mass and density

- Compared with the typical filamental IRDC (e.g. G11.11, Wang et al. 2014), Orion A exhibits a similar but more compact structure, while the IRDC has little region with $N(H_2) > 10^{24}$ cm^{-2}.
- Orion and G11.11 have similar total masses. But the central clump in Orion A (cold gas) is much more massive than the gas clumps within G11.11 at similar spatial scales ⇒ tendency to form higher-mass stars.



Parameter	Average IRDC clump	G11-clump (3.6 kpc)	G11-cores	Ori-KL (if 3.6 kpc)	Ori8(L1641-N) (if 3.6kpc)
Size	0.05-0.7pc (3"-38")	0.75×0.4pc (40×25")	(0.02pc) (1.0")	0.07×0.05pc (4×3")	0.1×0.08pc (5×4")
T_{SED}(K)	22	15	10-20	25	24
Mass($M_\odot$)	10-10^3	930	10-92	1800	10-40
N(H2)(cm^{-2})	10^{22}-10^{23}	1.0×10^{23}	7.9×10^{23}	2.6×10^{24}	5×10^{23}
n(H2)(cm^{-3})	10^4-10^5	8×10^4	7.5×10^6	1.0×10^7	2.0×10^5
Line width (km s^{-1})	0.8-3.0	~1.0	~1.0	1-5 (various lines)	1.2

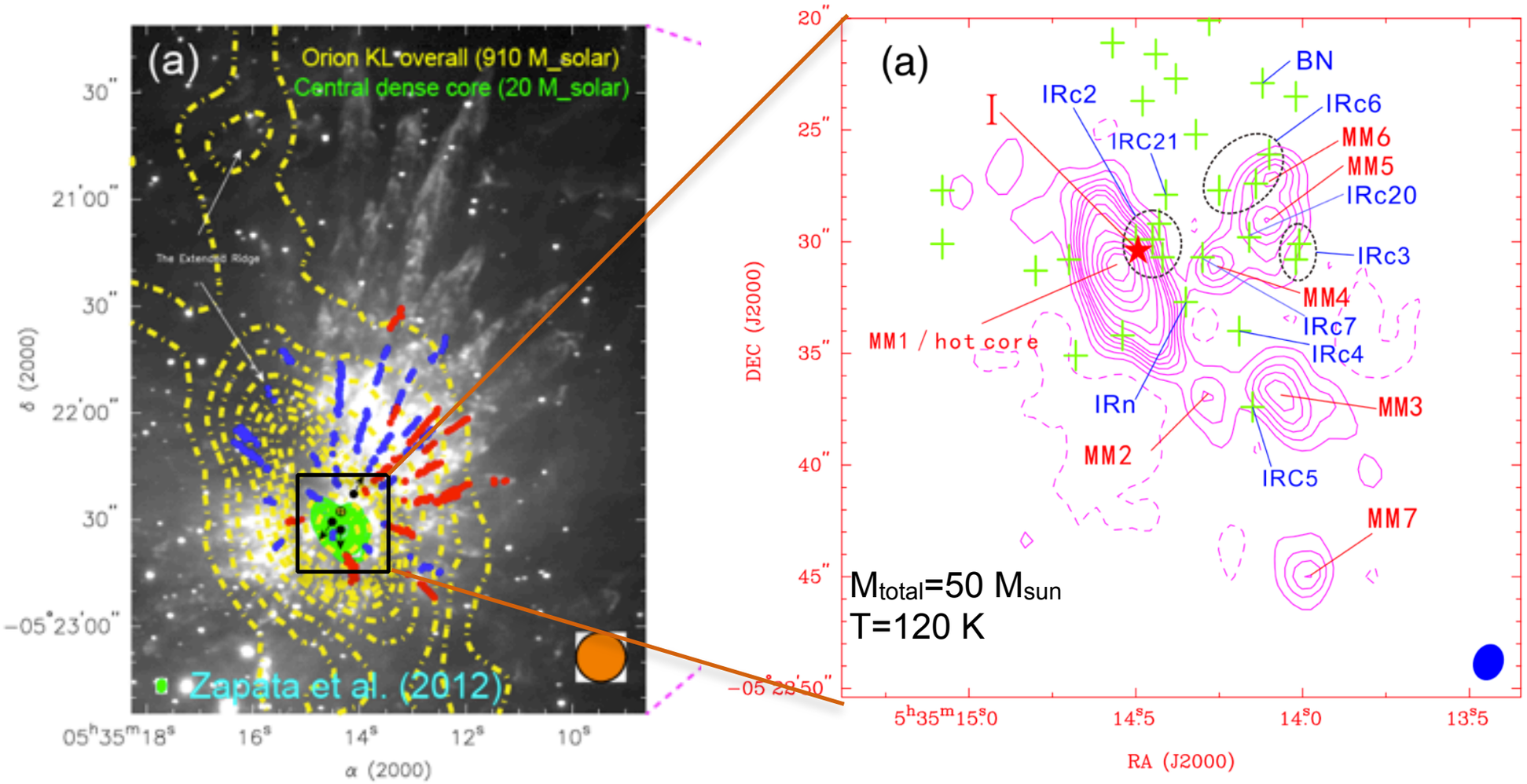




simulated extinction map

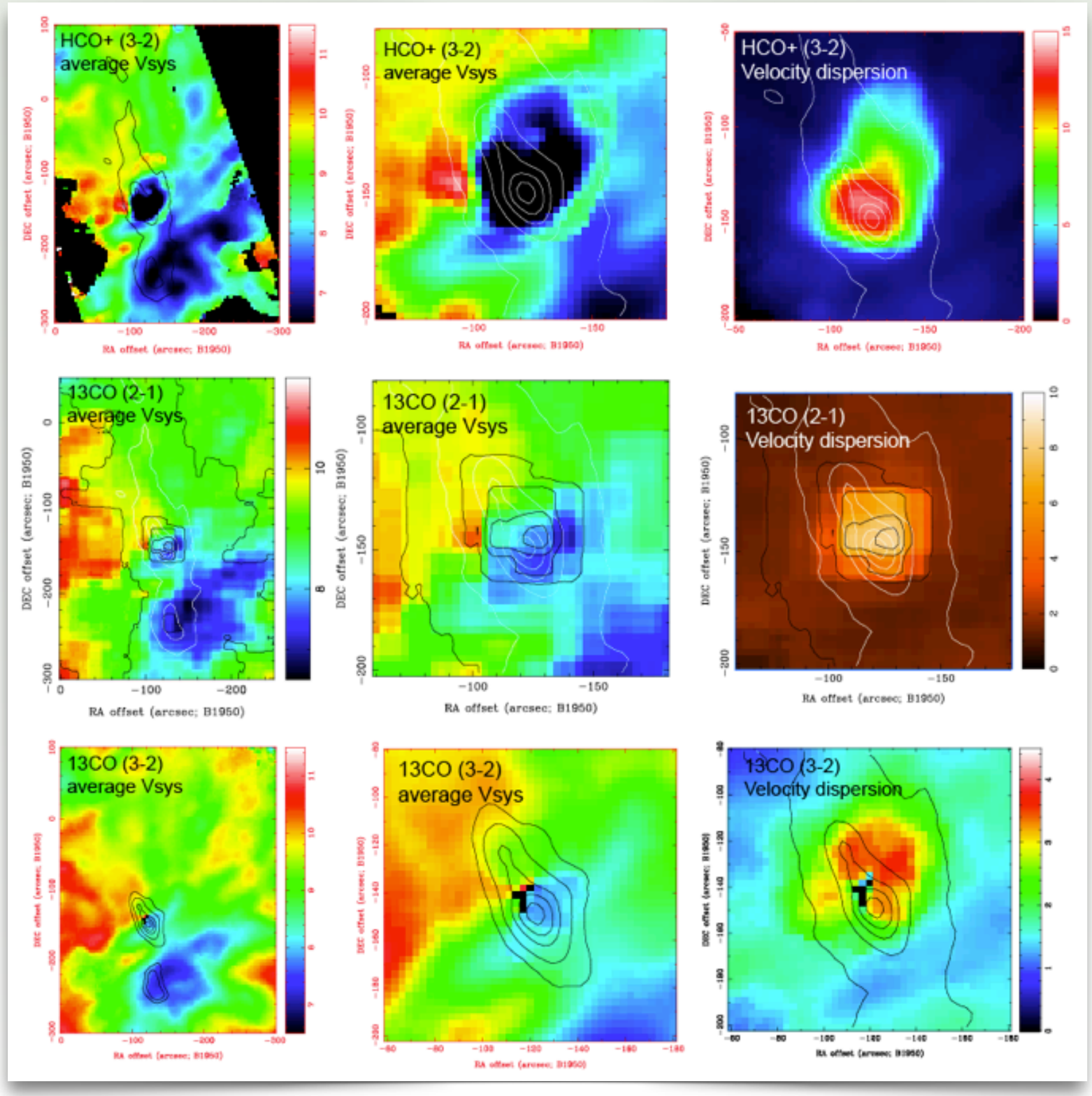
Orion KL: explosive outflow + ongoing massive star formation

- An extended explosive outflow over a large opening angle, with strong shock emission.
- central dense core MM1 : 6.7 GHz CH_3OH maser.
- The outflow is originated almost from MM1, although not fully overlapped.

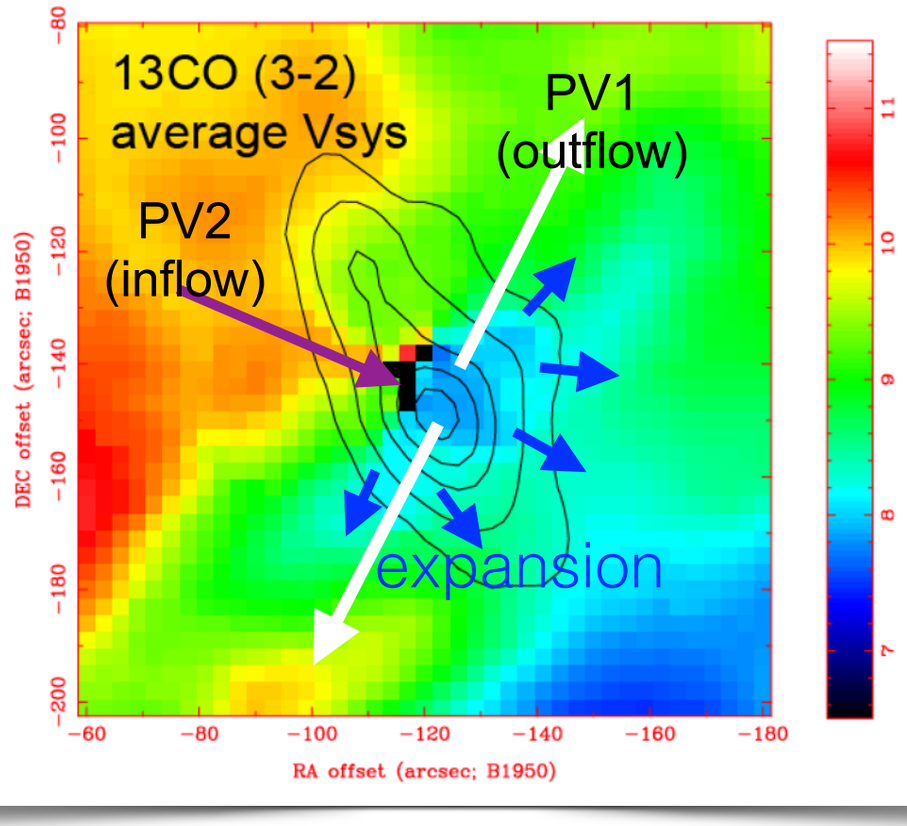


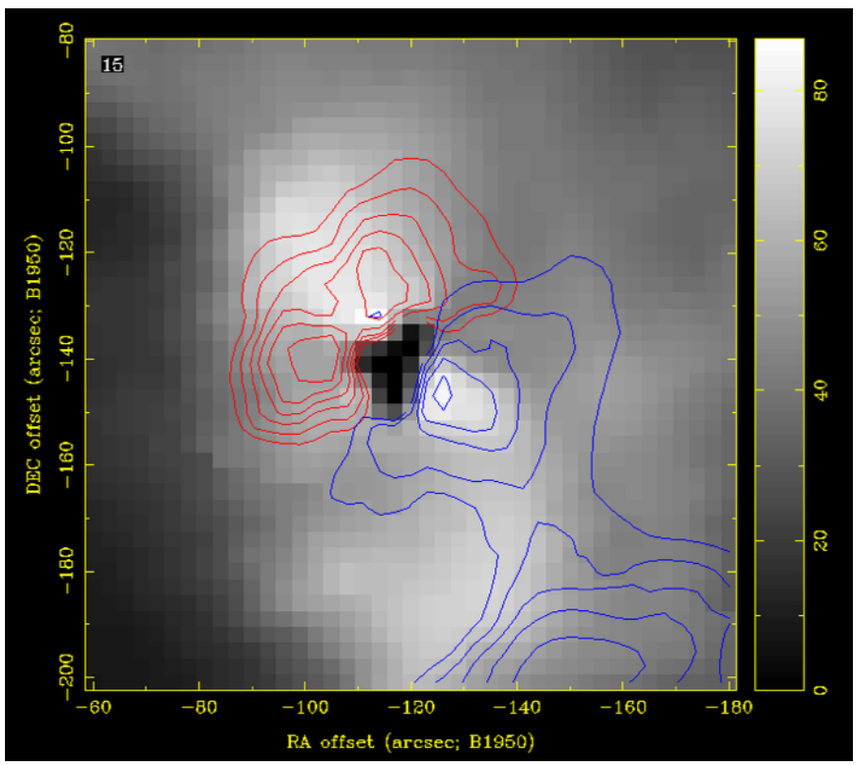
Wu & Liu et al. (2016)

Orion–KL: explosive outflow vs ongoing massive star formation

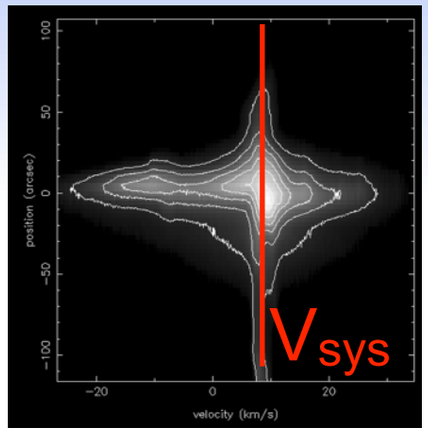


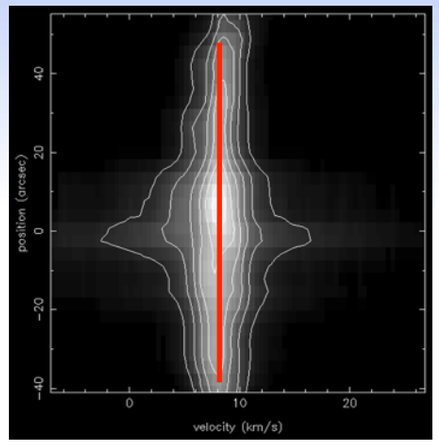
Inflow into Orion–KL hot core

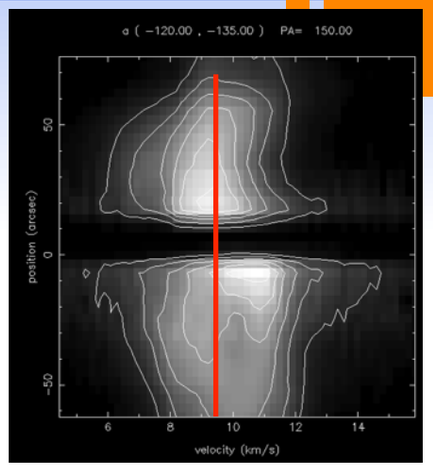




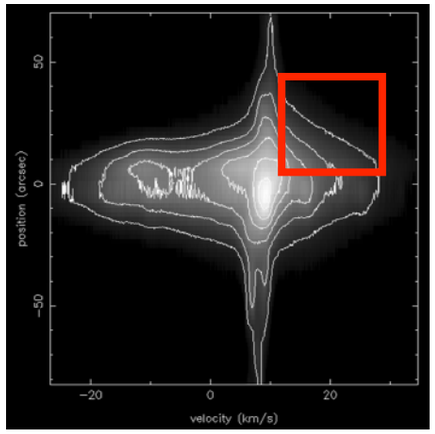
PV1

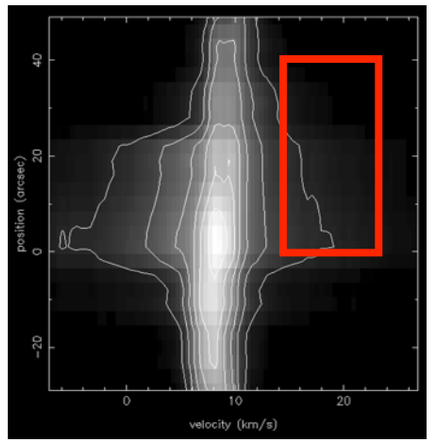


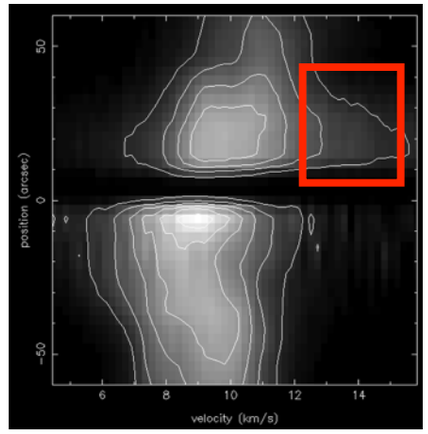




PV2





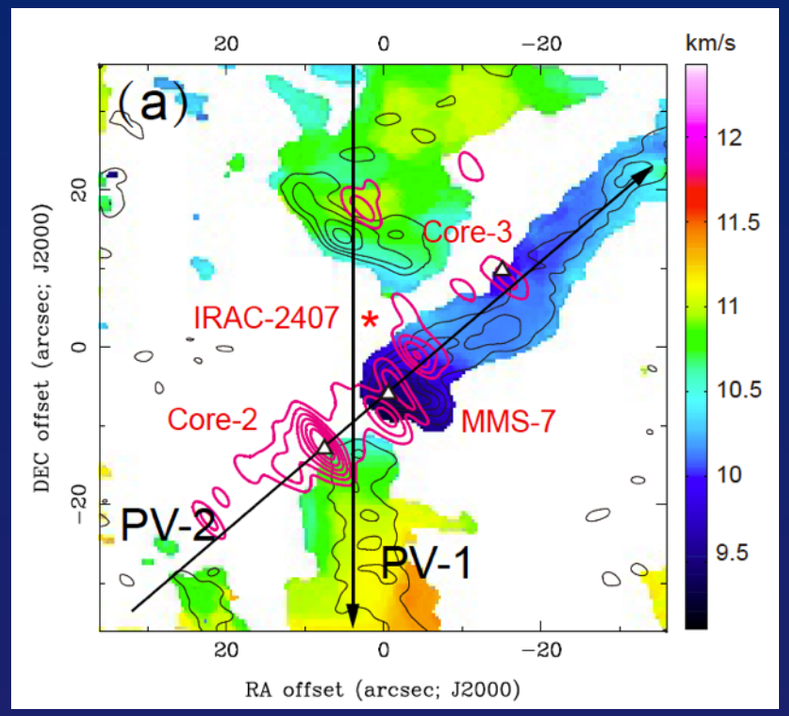


HCO^+ (3-2) ^{13}CO (2-1) ^{13}CO (3-2)

Red shift excess towards east

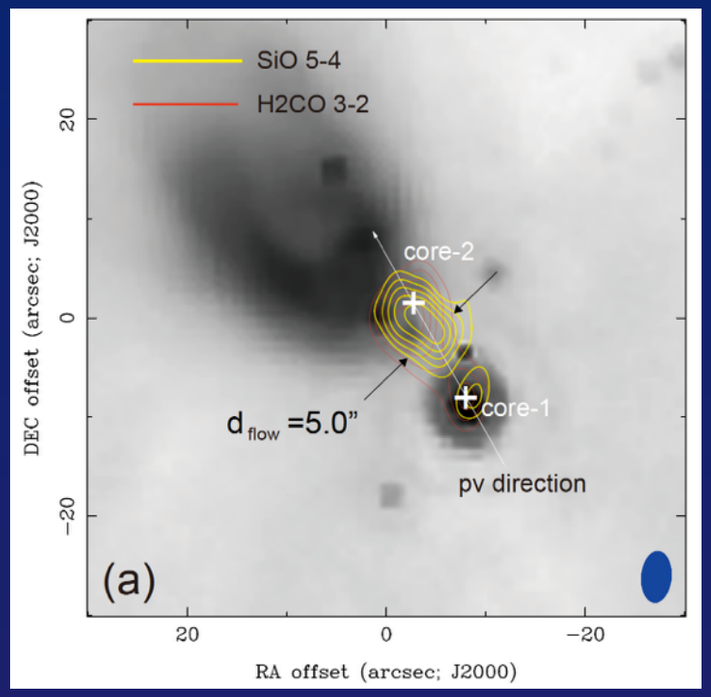
- Redshifted gas indicating a likely inflow
- $(dM/dt)_{inflow} = \Delta V\ L\ N(H_2) \sim 5\times10^{-4}\ M_\odot$/year

Conclusion



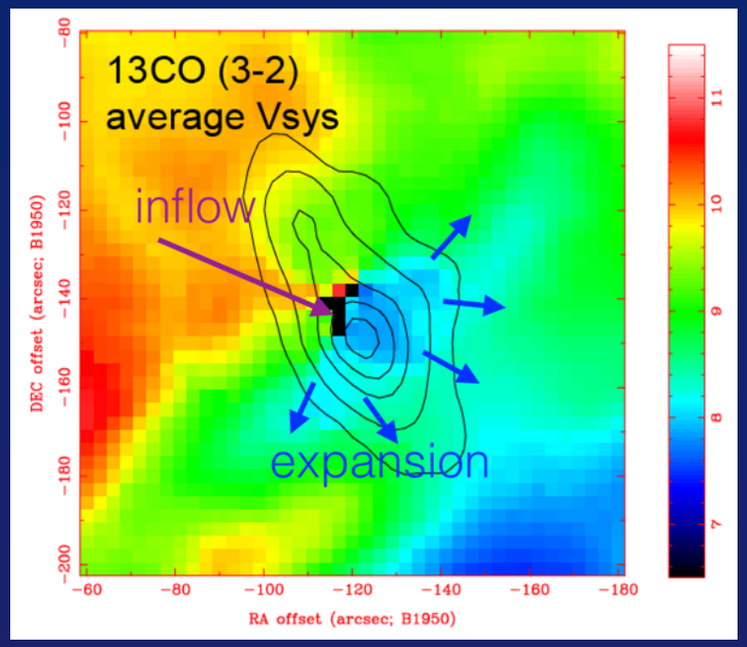
- OMC-3 MMS-7
  inflow along the filament

Ren & LI (2016), to be submitted



- G350.69-0.39
  transfer flow in binary cores

Chen, Ren, Qiu et al. (2016), ApJ

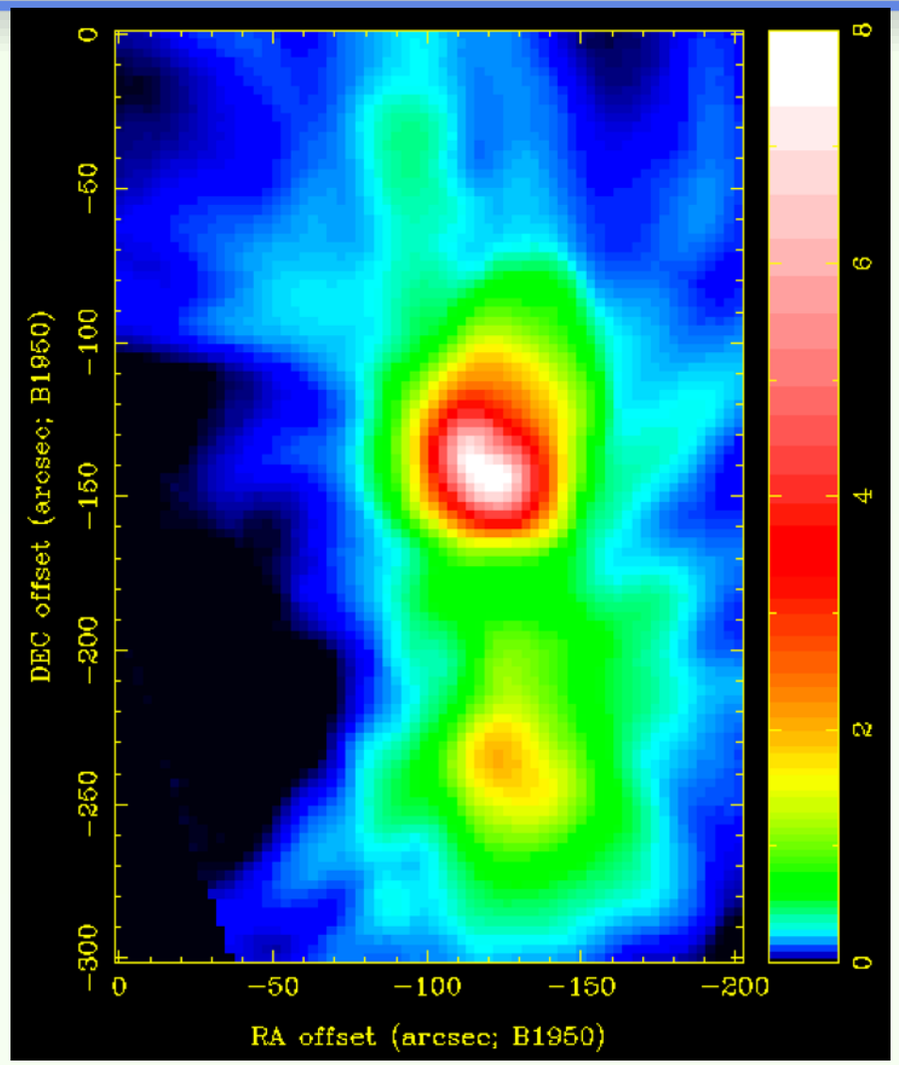


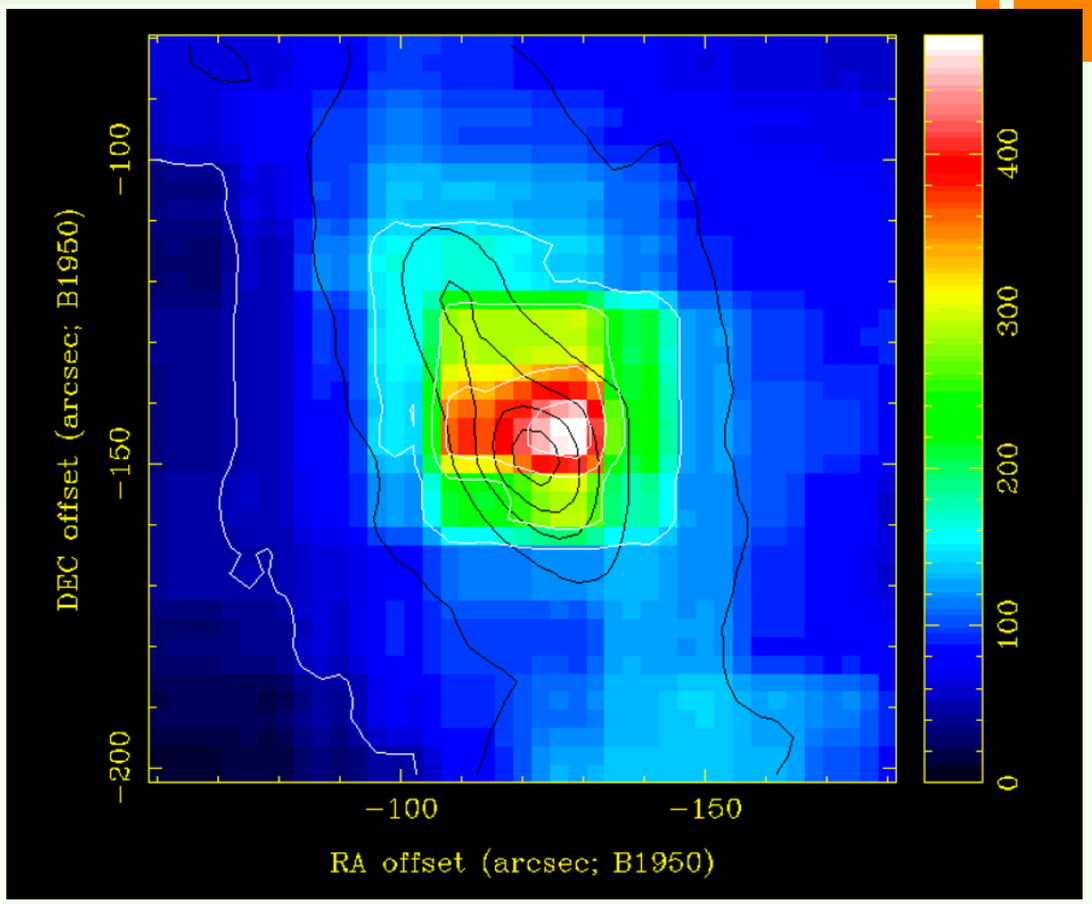
- Orion KL
  Expanding clump
  + inflow injection

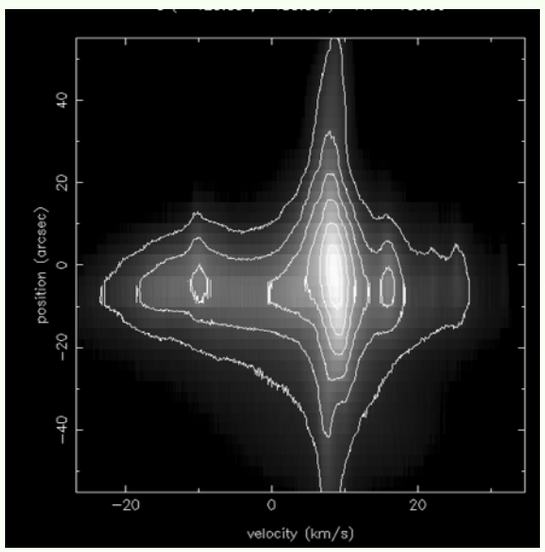
Ren & LI (2017), to be submitted

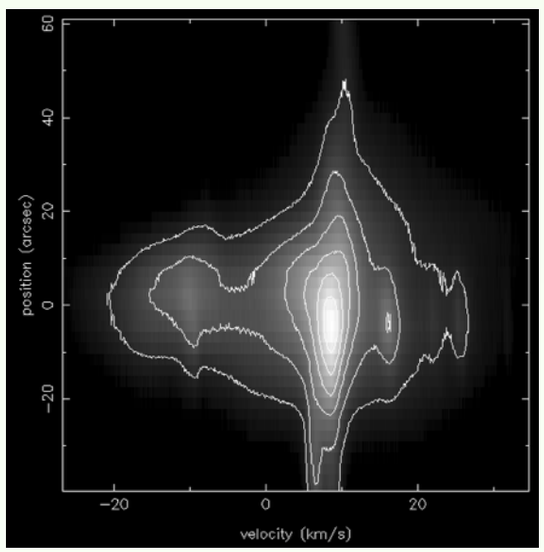
- External Inflow into individual cores are observed in different types of star–forming regions.
- "Even" the JCMT archive data can present useful information.

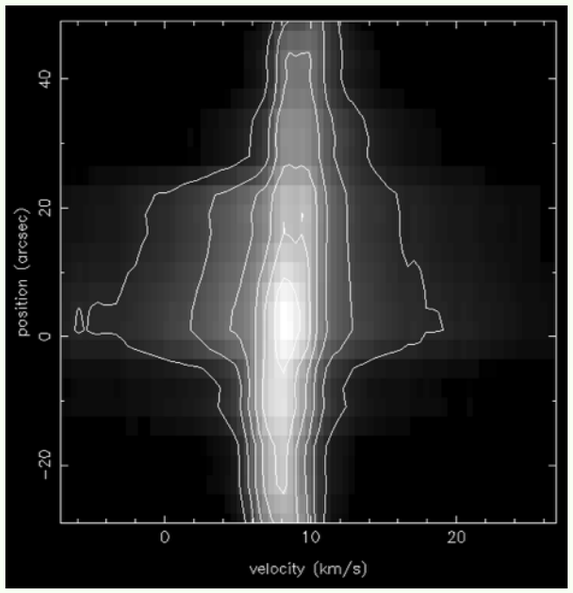
Gas expansion in Orion–KL

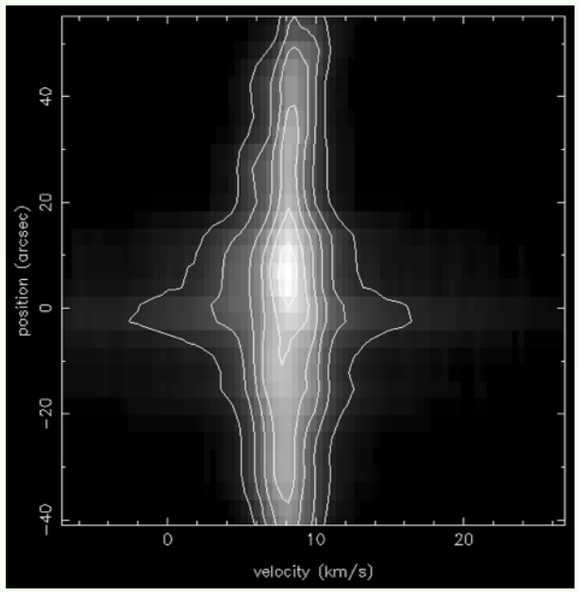




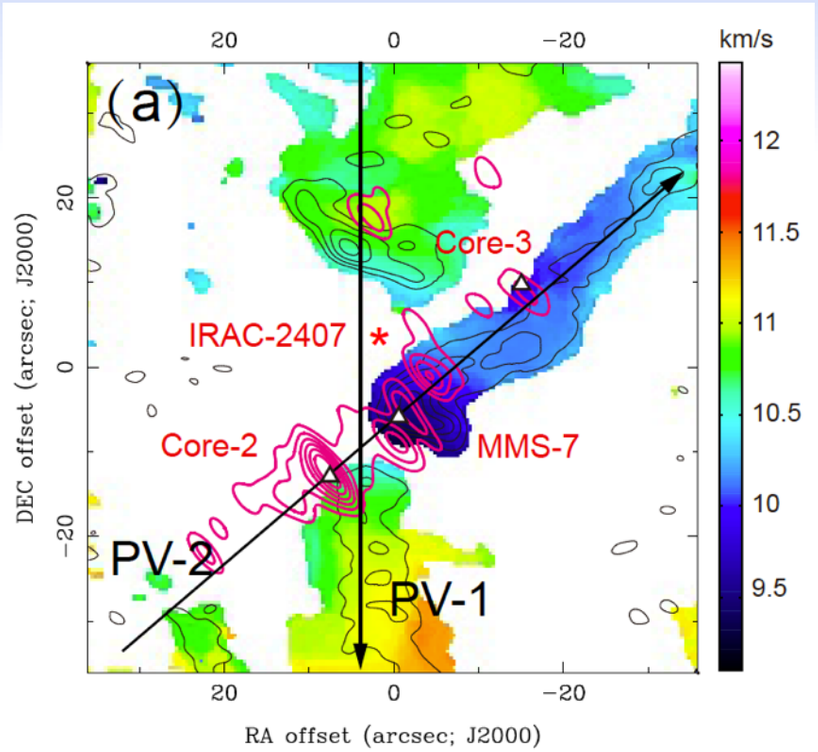


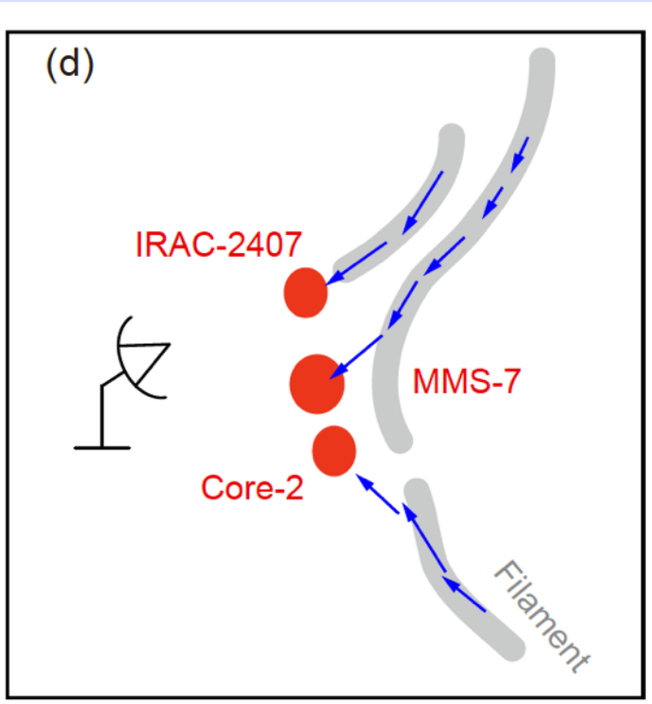


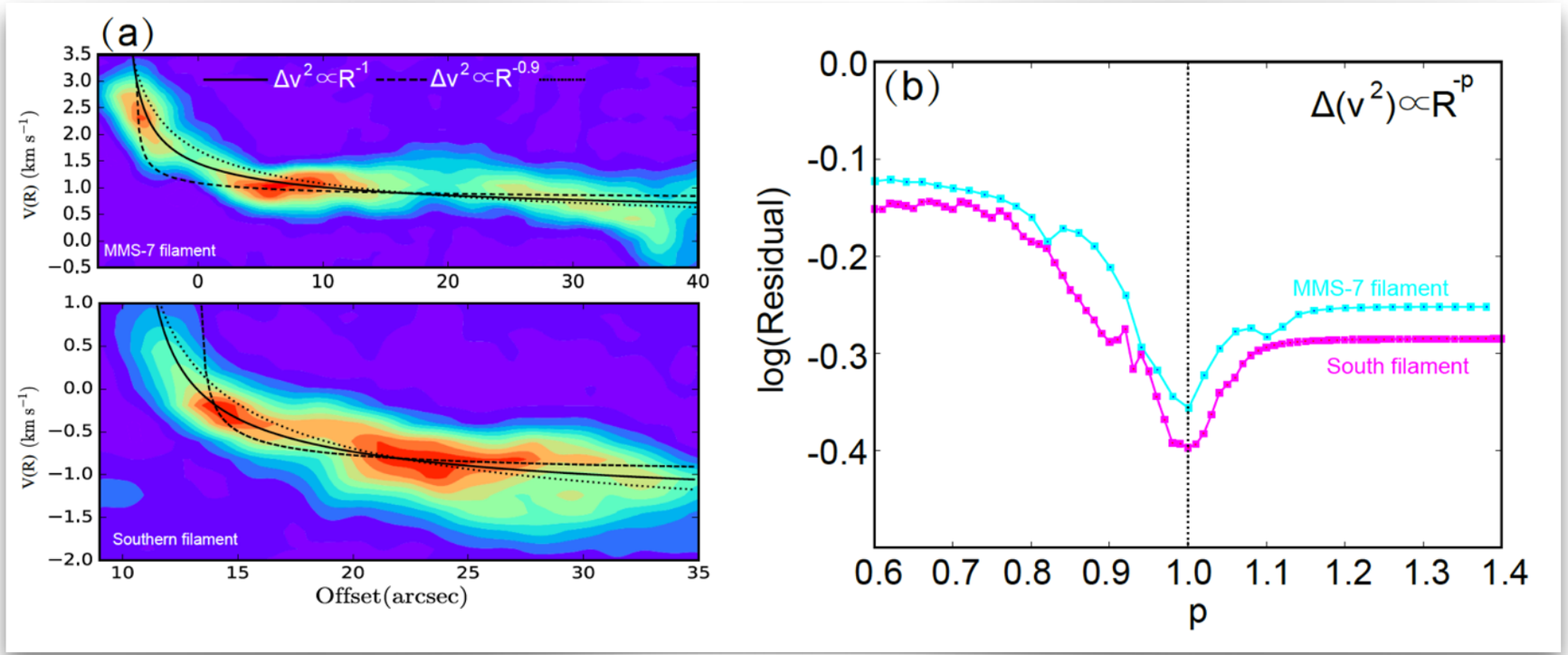


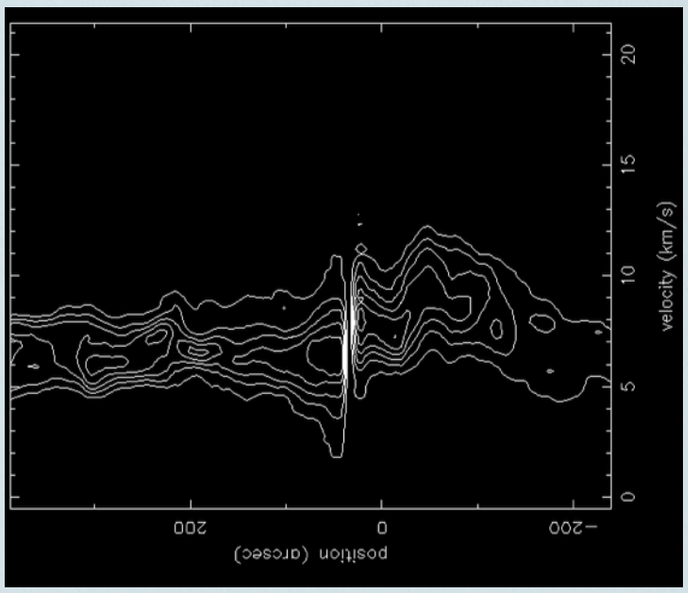


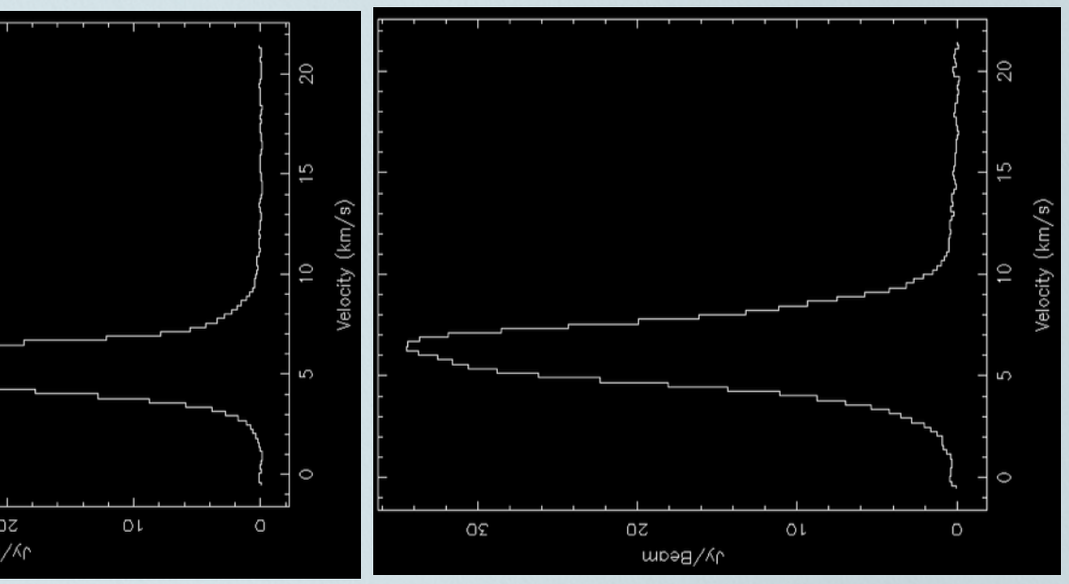
Outline


(a)
km/s
12
11.5
11
10.5
10
9.5
Core-3
IRAC-2407
Core-2
MMS-7
PV-2
PV-1
DEC offset (arcsec; J2000)
RA offset (arcsec; J2000)

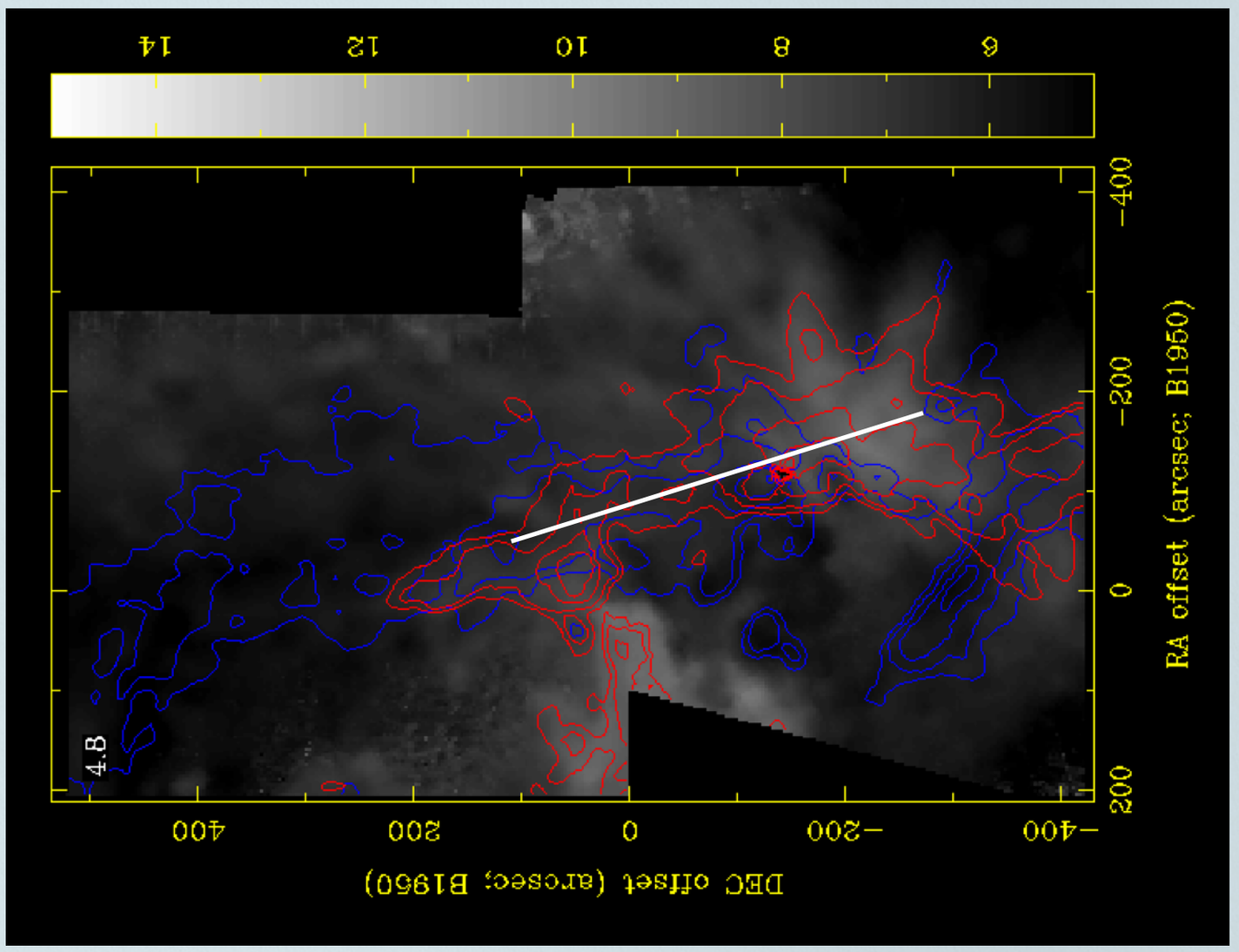

(d)
IRAC-2407
MMS-7
Core-2
Filament

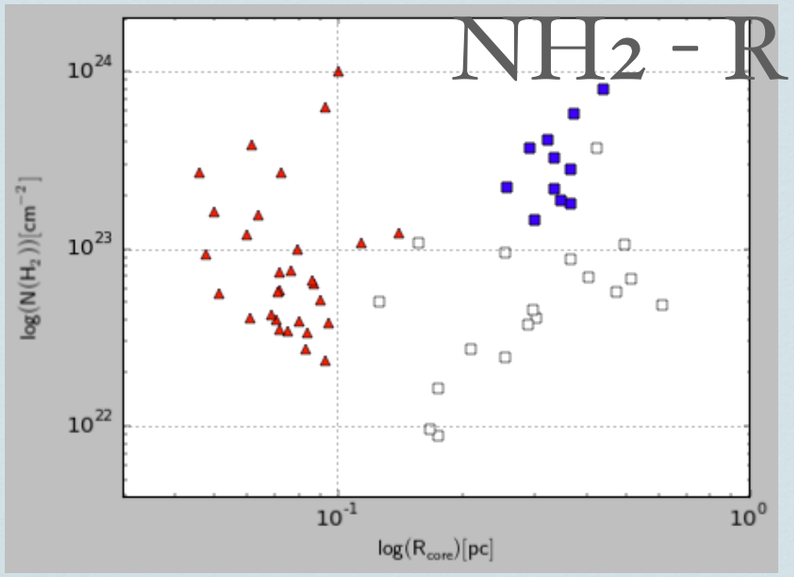

(a)
$\Delta v^2 \propto R^{-1}$
$\Delta v^2 \propto R^{-0.9}$
V(R) (km s^{-1})
MMS-7 filament
Southern filament
Offset(arcsec)
(b)
$\Delta(v^2) \propto R^{-p}$
log(Residual)
MMS-7 filament
South filament
p

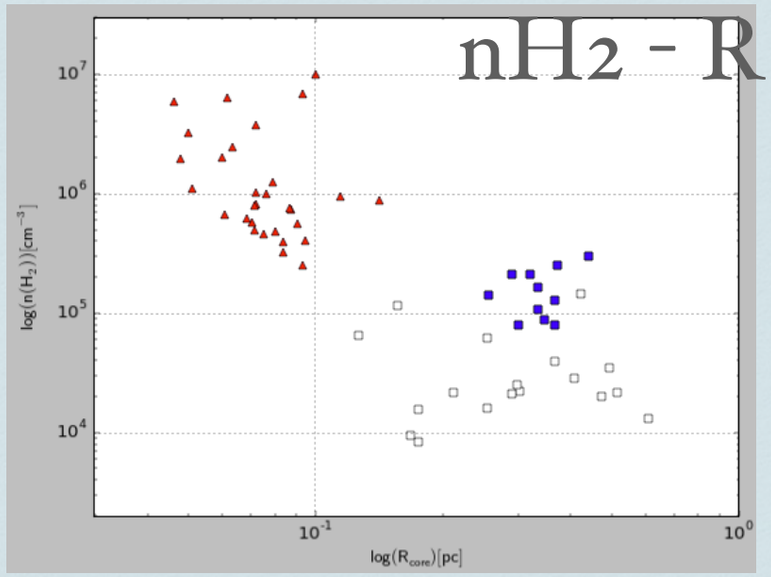

position (arcsec)
−200
0
200
velocity (km/s)
0
5
10
15
20

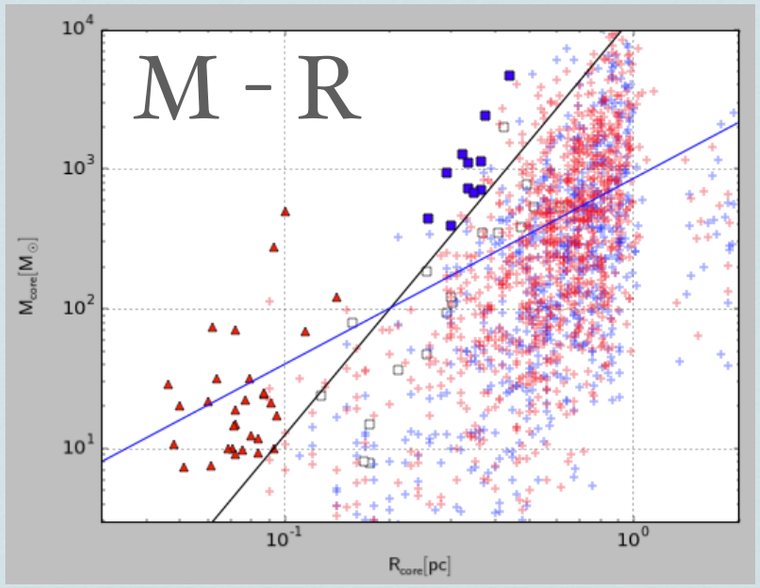

Velocity (km/s)
0
5
10
15
20
0
10
20
30
Jy/Beam

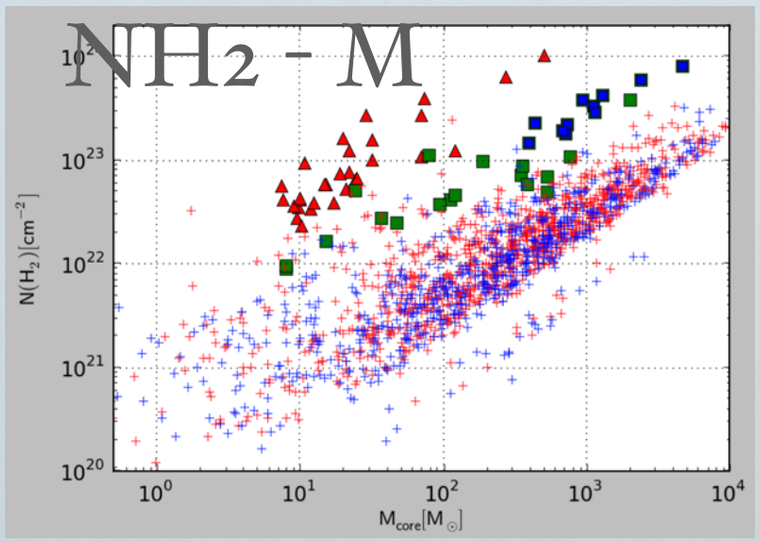
Velocity (km/s)
0
5
10
15
20
0
10
20
30
40
Jy/Beam

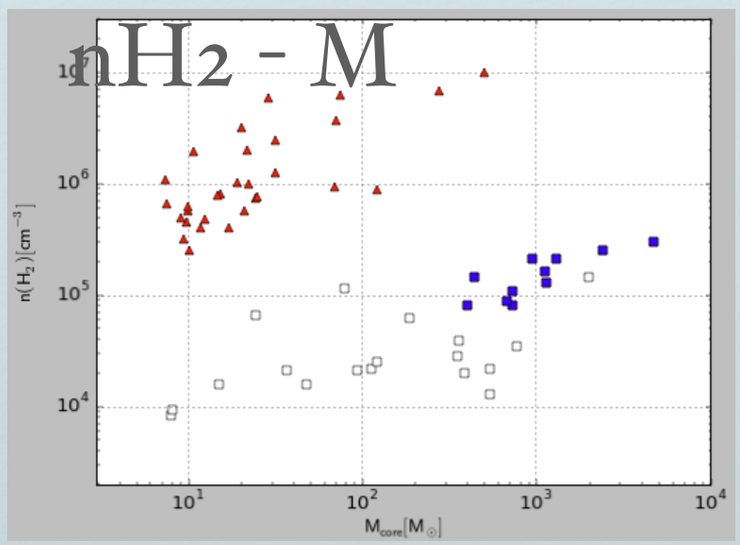

DEC offset (arcsec; B1950)
−400
−200
0
200
400
RA offset (arcsec; B1950)
200
0
−200
−400
4.8
6
8
10
12
14

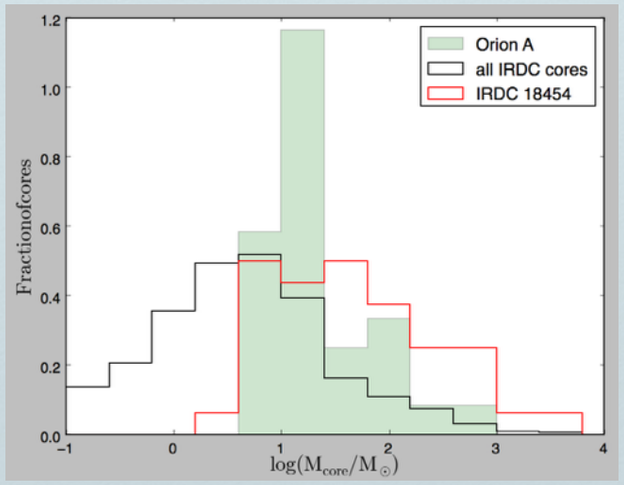

NH2 - R
log(N(H2))[cm−2]
log(Rcore)[pc]

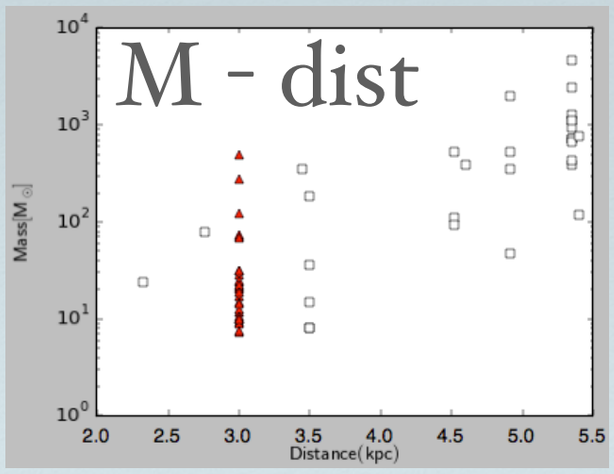

nH2 - R
log(n(H2))[cm−3]
log(Rcore)[pc]

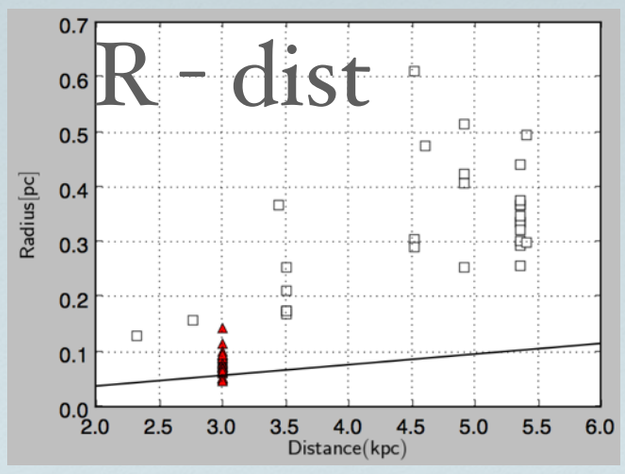

M - R
Mcore[M⊙]
Rcore[pc]

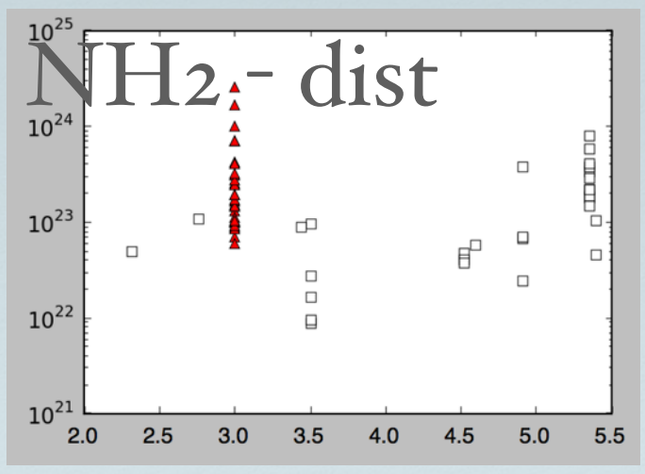

NH2 - M
N(H2)[cm−2]
Mcore[M⊙]

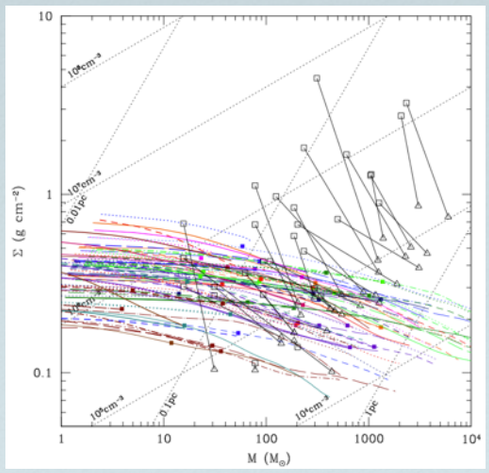

nH2 - M
n(H2)[cm−3]
Mcore[M⊙]


Orion A
all IRDC cores
IRDC 18454
Fractionofcores
log(Mcore/M⊙)

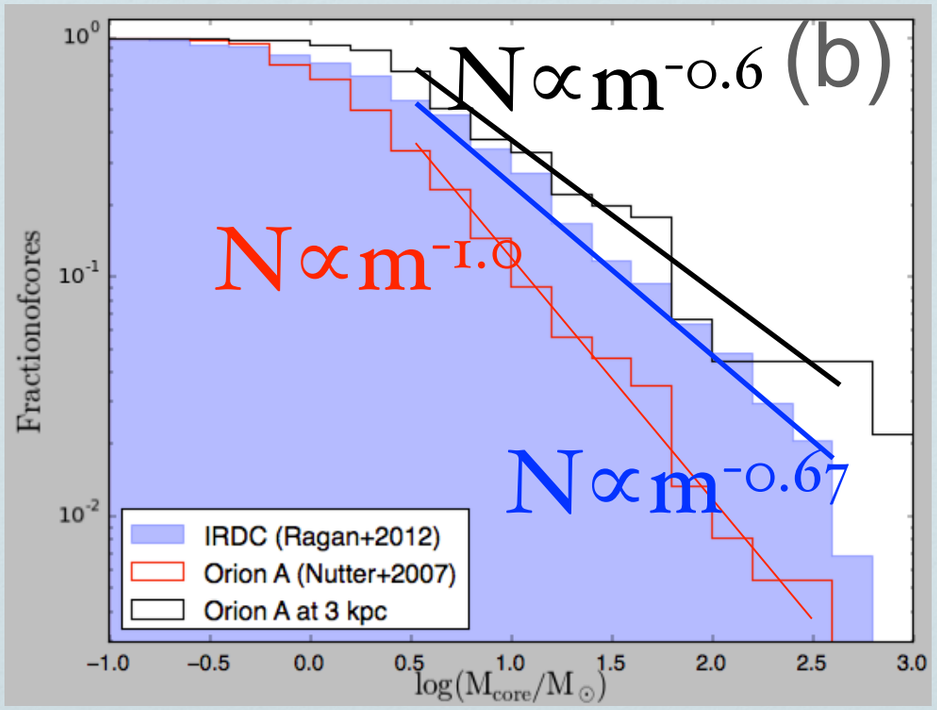

M - dist
Mass[M⊙]
Distance(kpc)

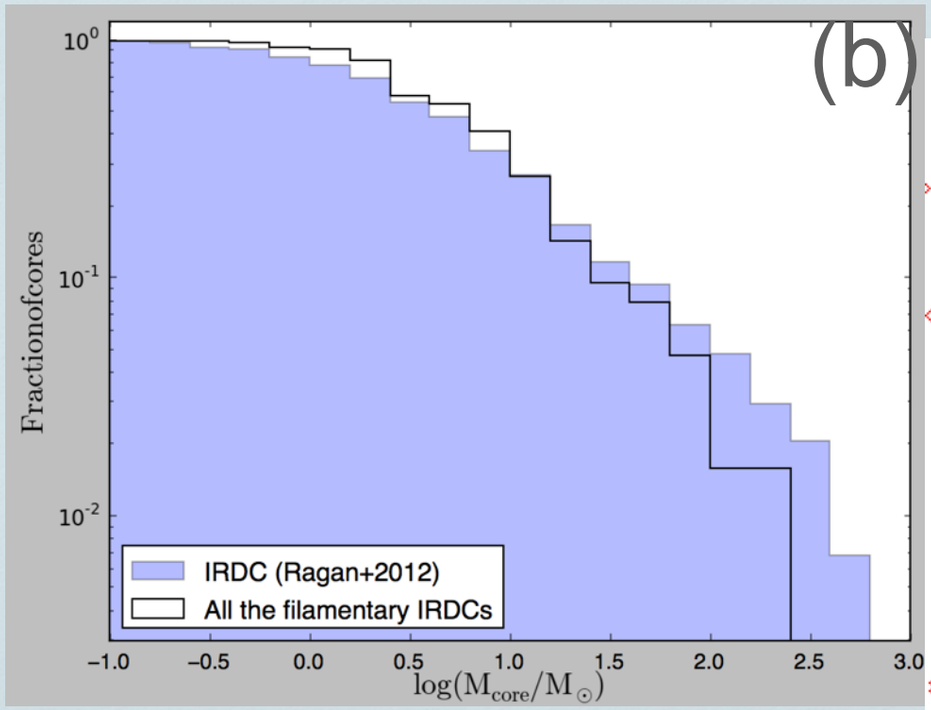

R - dist
Radius[pc]
Distance(kpc)

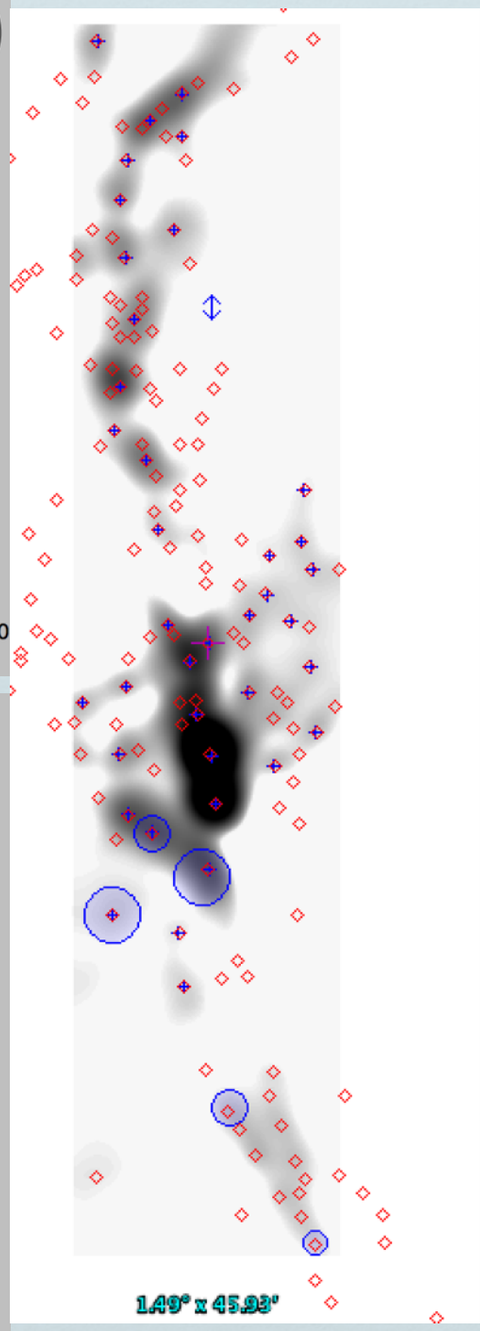

NH2 - dist

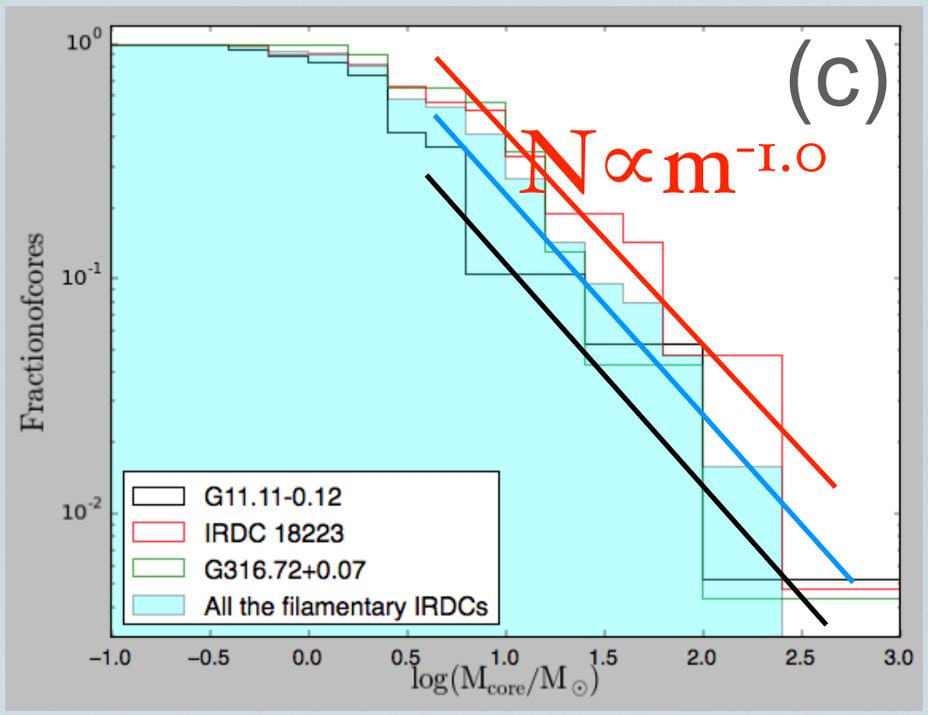

Σ (g cm−2)
M (M⊙)

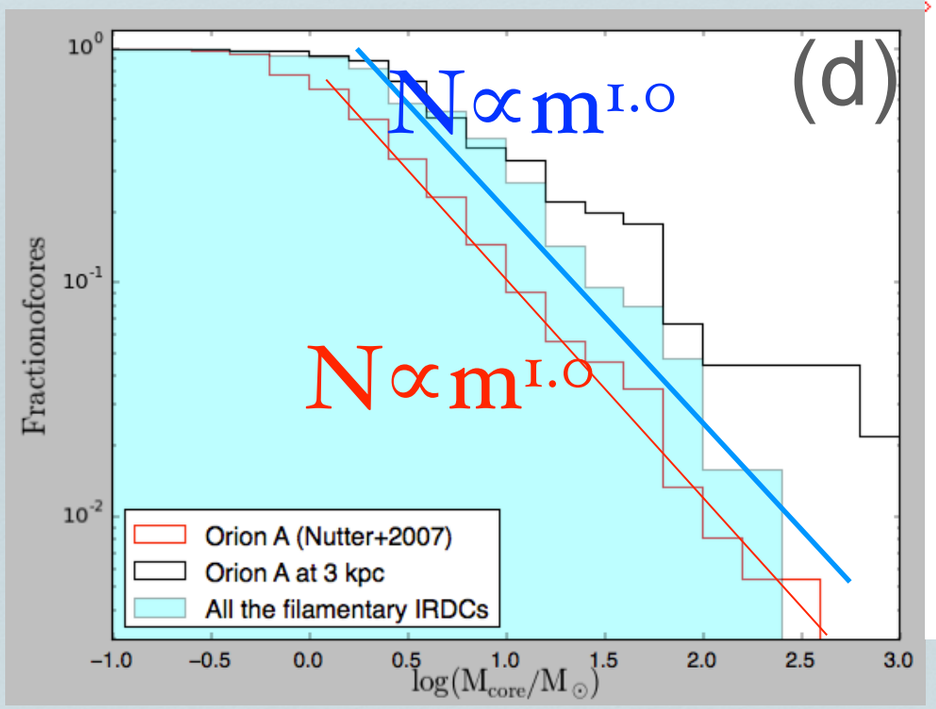
Cumulated Core Mass Function: N(>m)

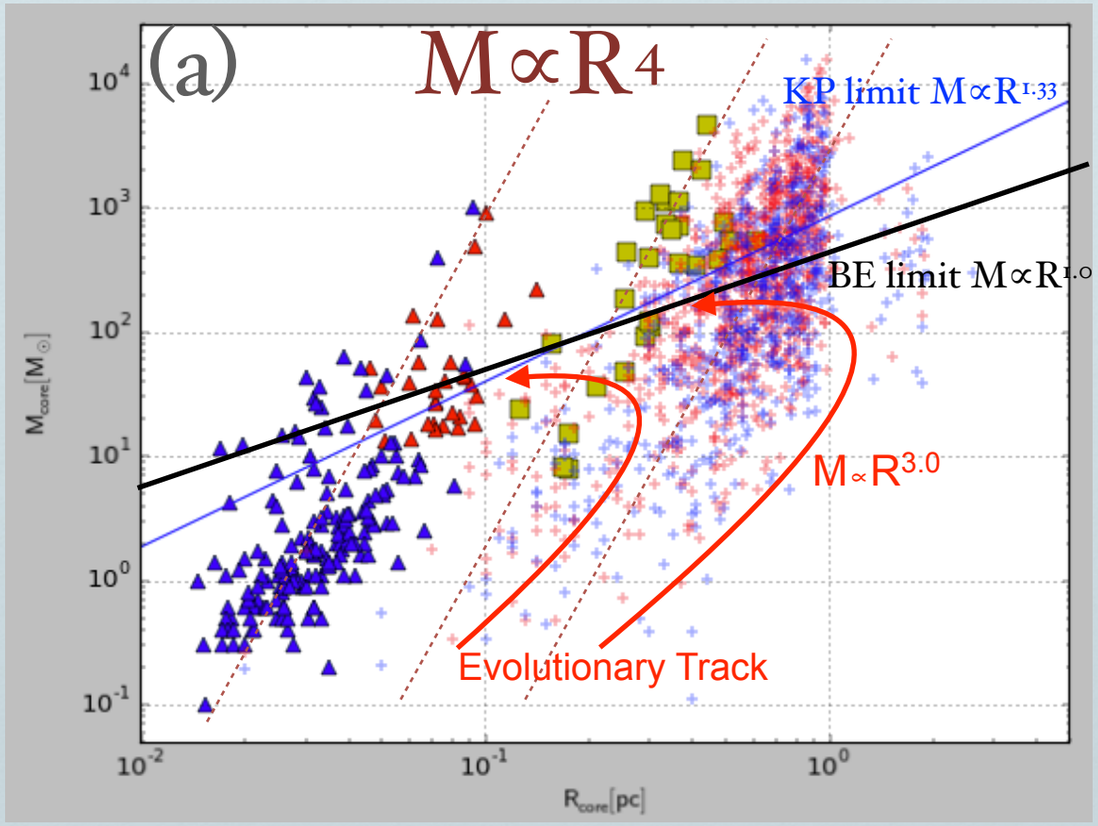


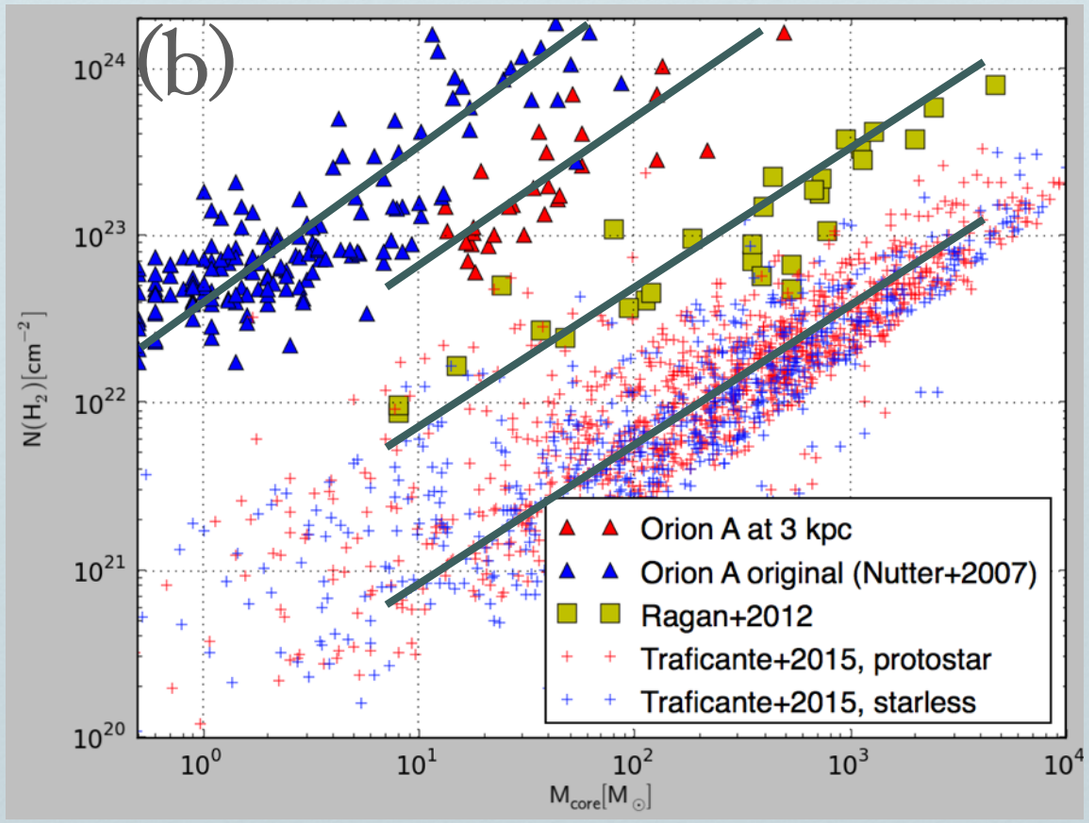









(a)
M∝R4
KP limit M∝R1.33
BE limit M∝R1.0
M∝R3.0
Evolutionary Track
Mcore[M⊙]
Rcore[pc]


(b)
N(H2)[cm−2]
Mcore[M⊙]
Orion A at 3 kpc
Orion A original (Nutter+2007)
Ragan+2012
Traficante+2015, protostar
Traficante+2015, starless