Gaia:

Orion's Integral Shaped Filament is a Standing Wave

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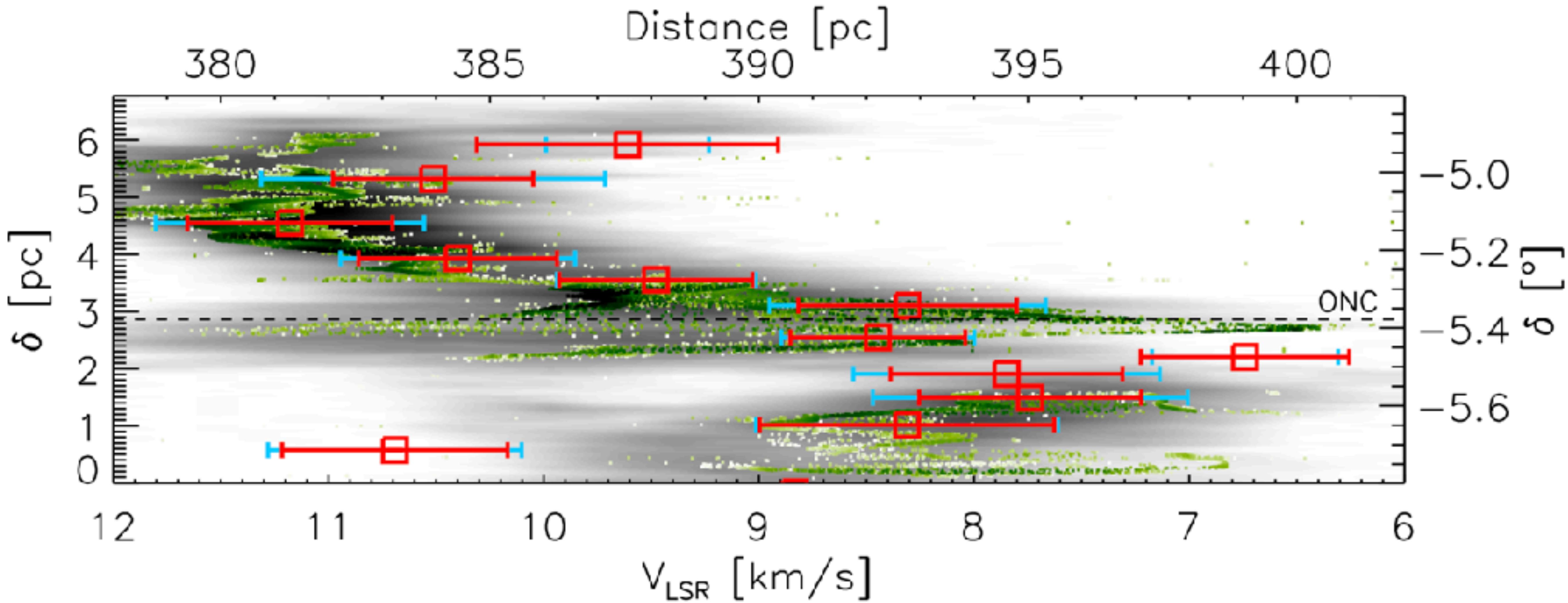
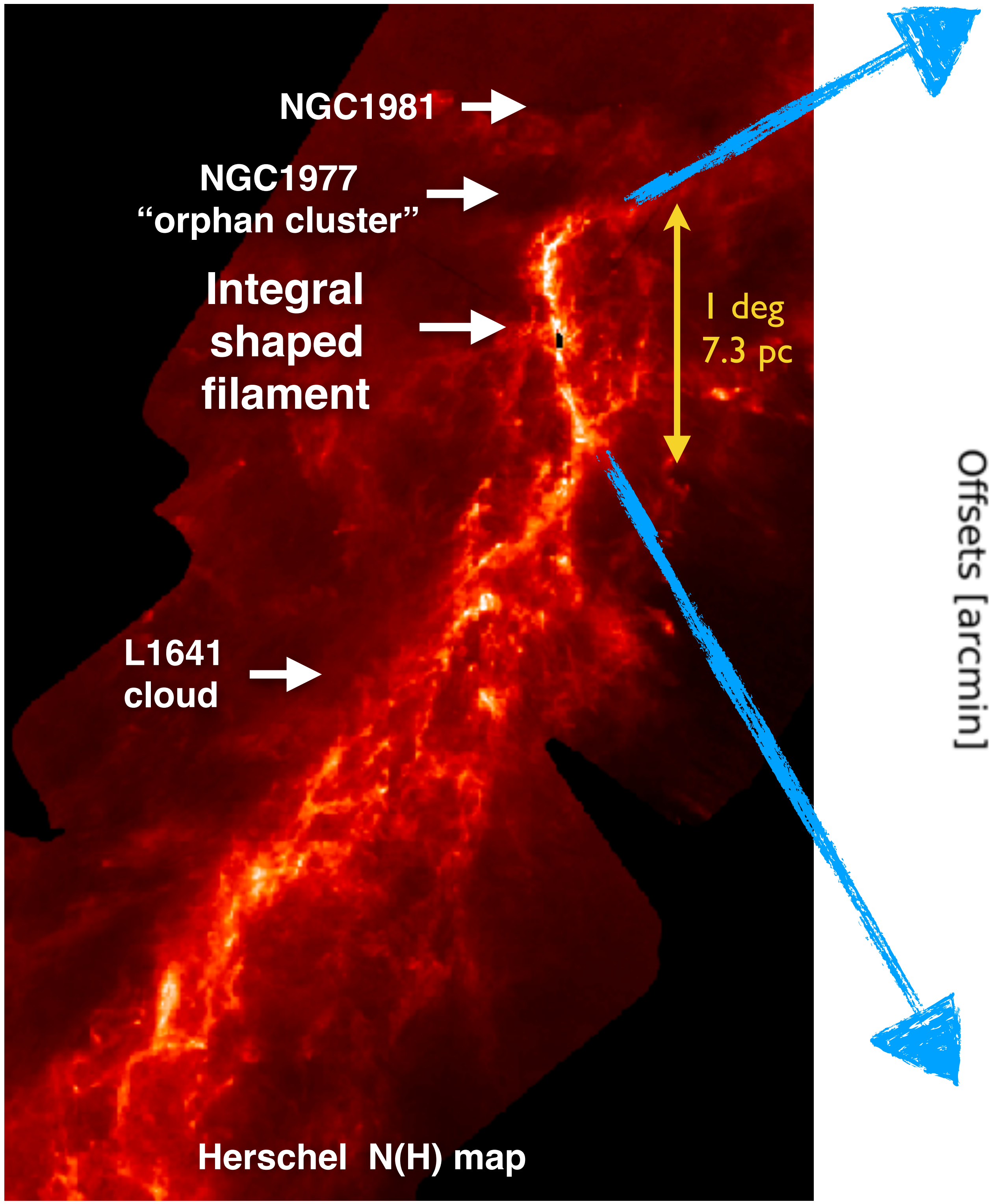
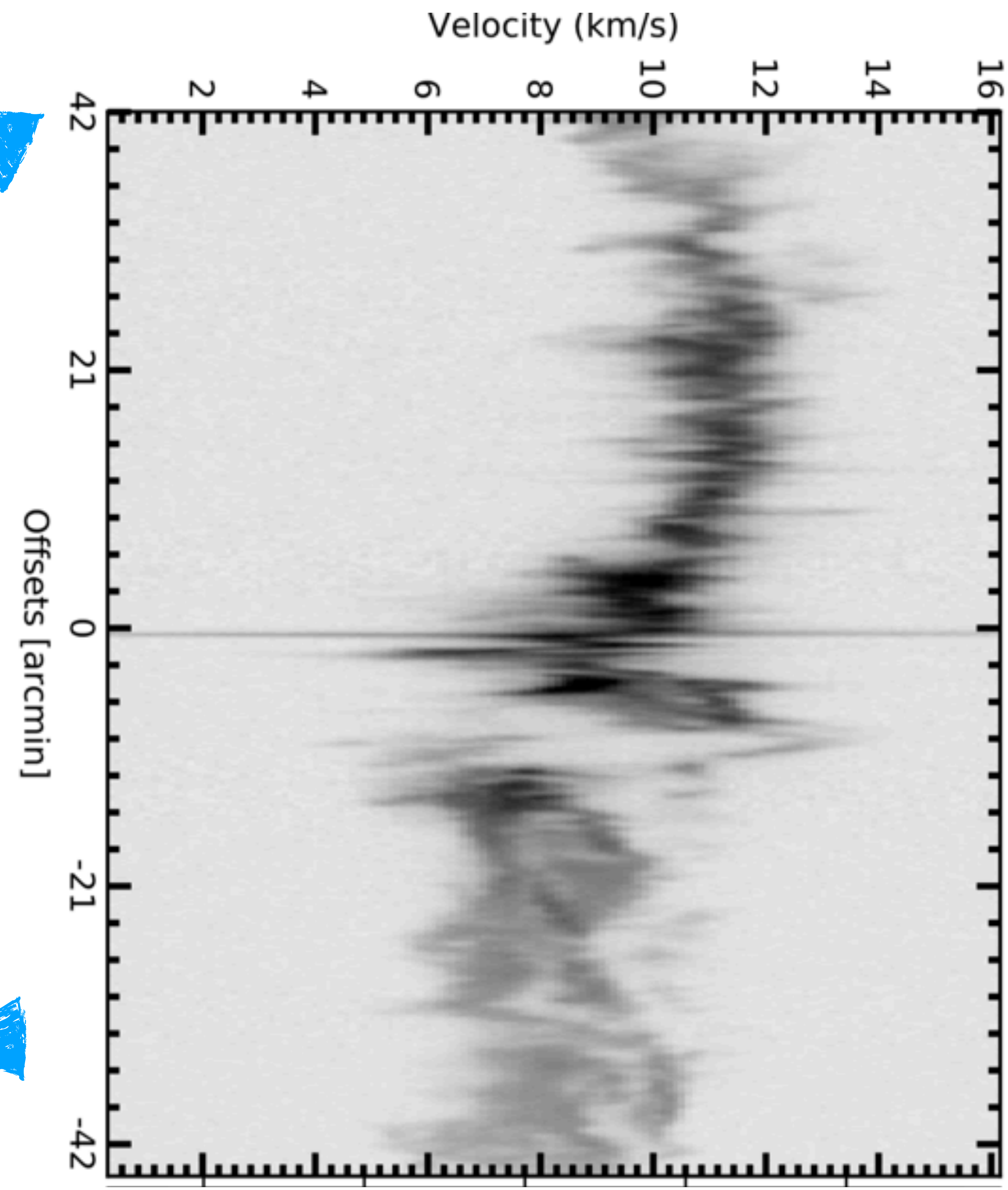


Stutz, Gonzalez-Lobos, & Gould (2018): arXiv:1807.11496

Integral Shaped Filament (ISF) gas & ^{13}CO PV diagram

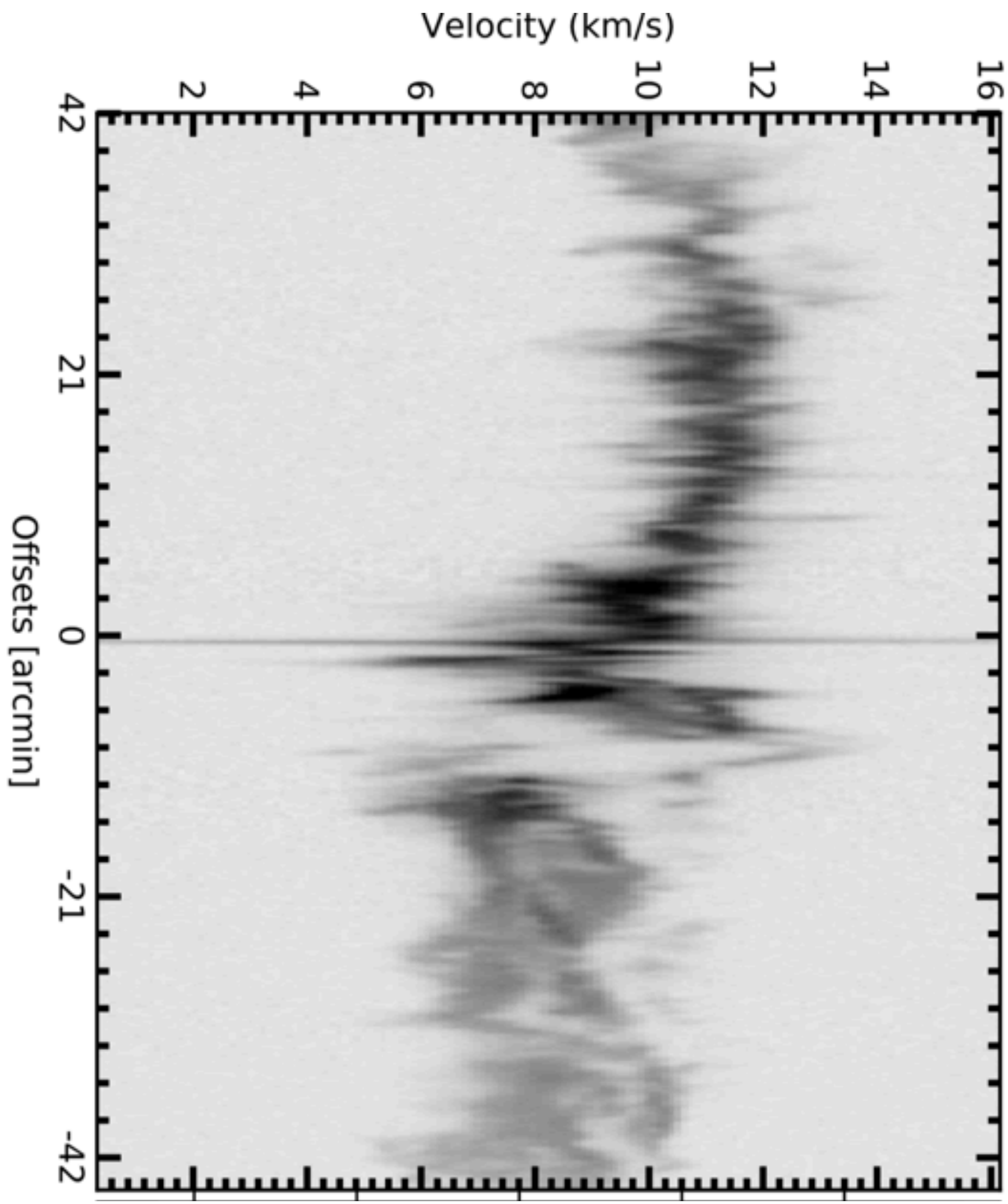




Stutz & Kainulainen (2015); Stutz & Gould (2016)

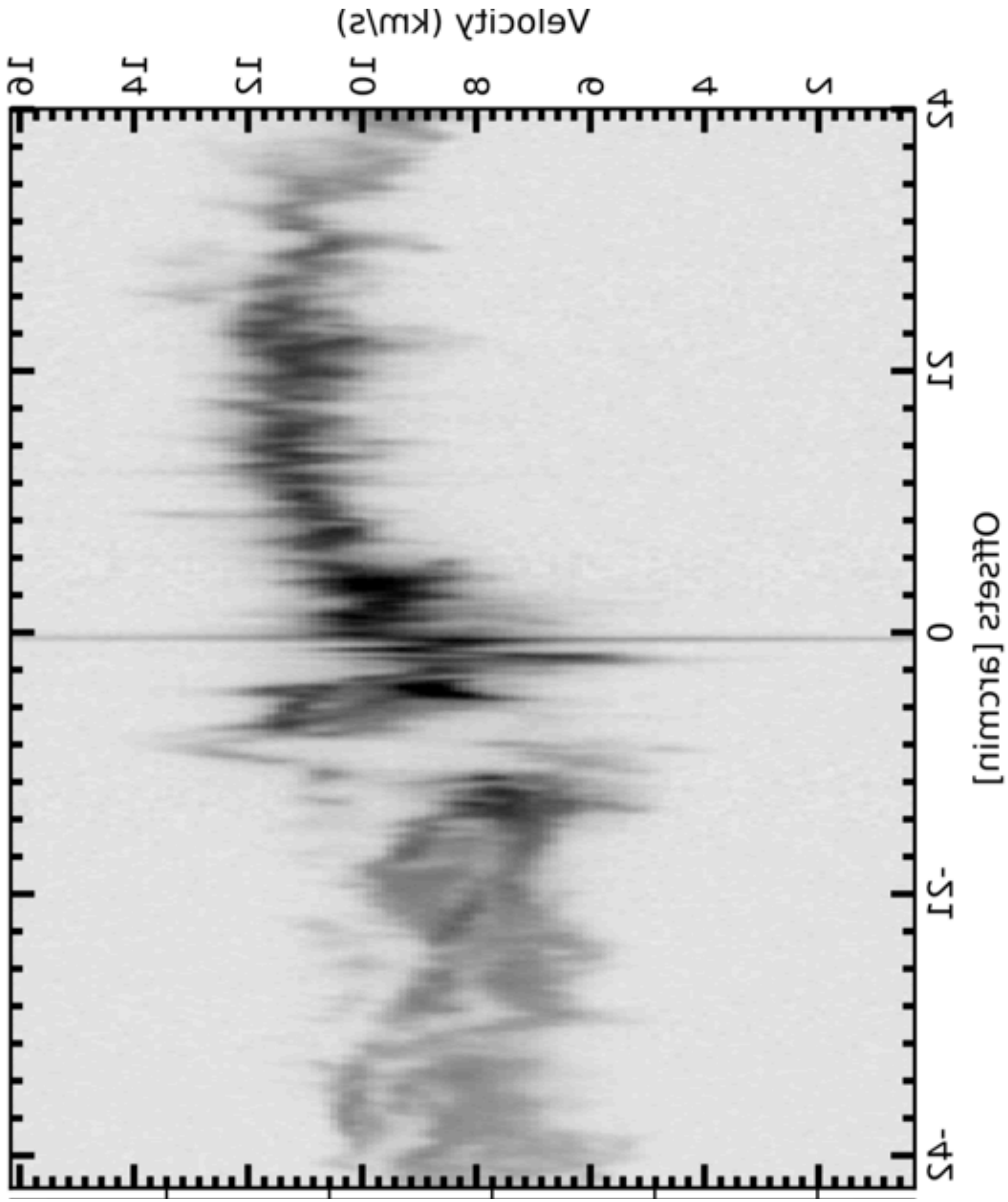
Kong et al. (2018)

Integral Shaped Filament (ISF) ^{13}CO PV diagram



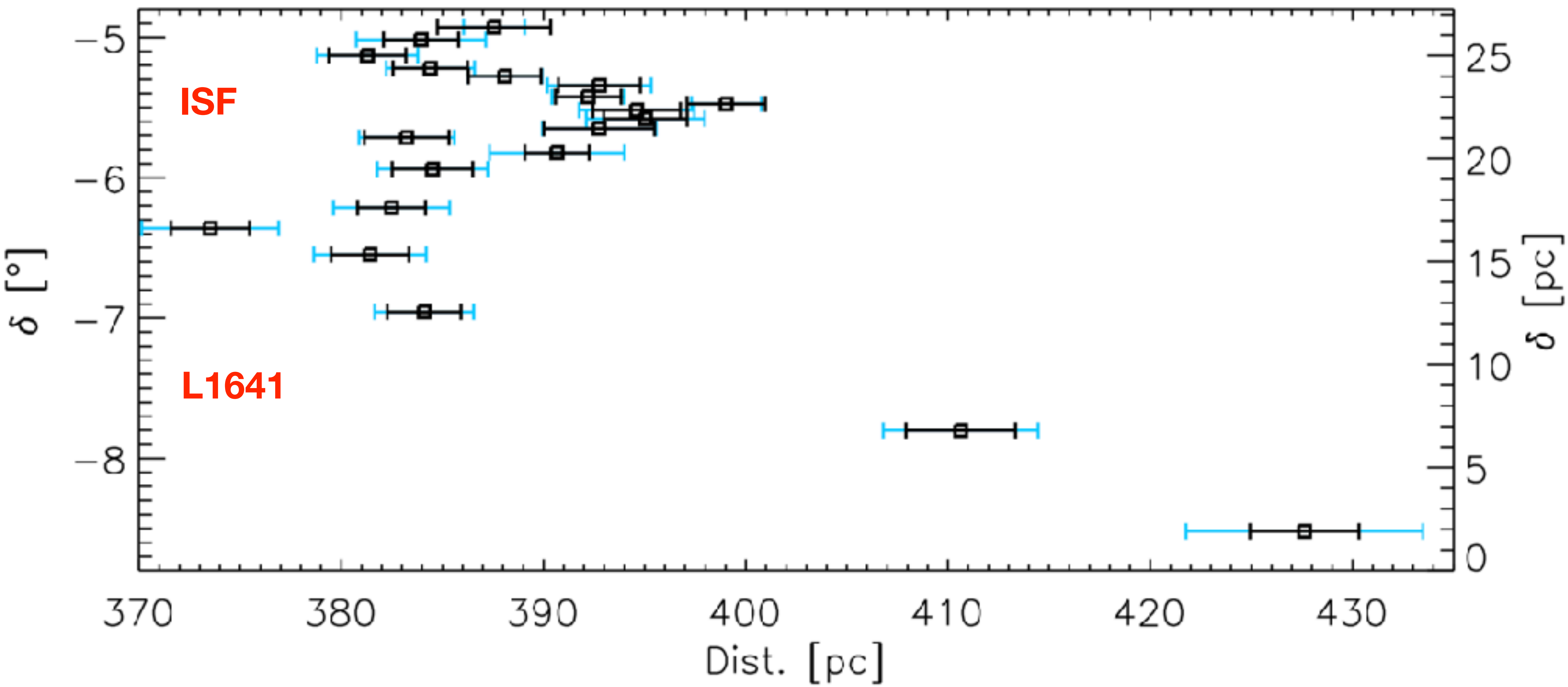
Kong et al. (2018)

Integral Shaped Filament (ISF) ^{13}CO PV diagram



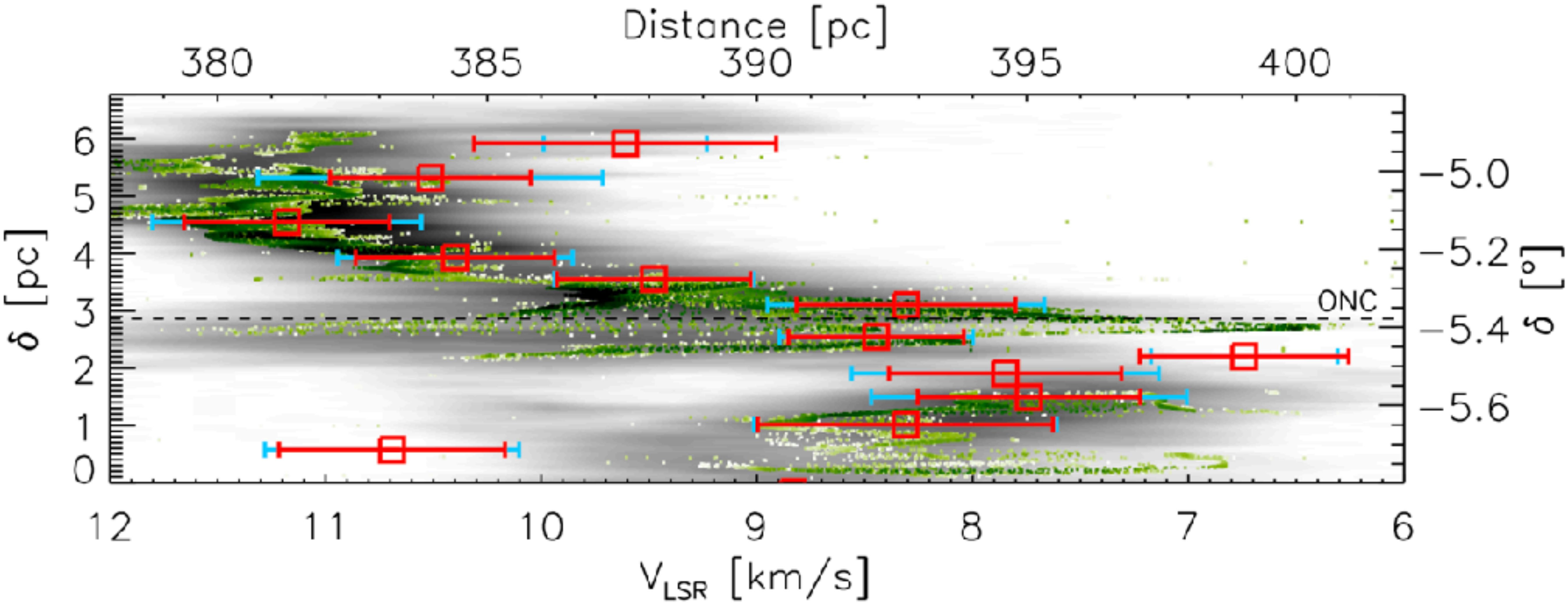
Kong et al. (2018)

Binned Gaia parallaxes of YSO's



Distances of bins of 25 Class II young stars (YSO's) in Orion A drawn from the Megeath+2012 catalog with good Gaia parallaxes.
Comparing to the PV diagram yields a timescale τ = 4 pc/(1 km/s) ~ 4 Myr.

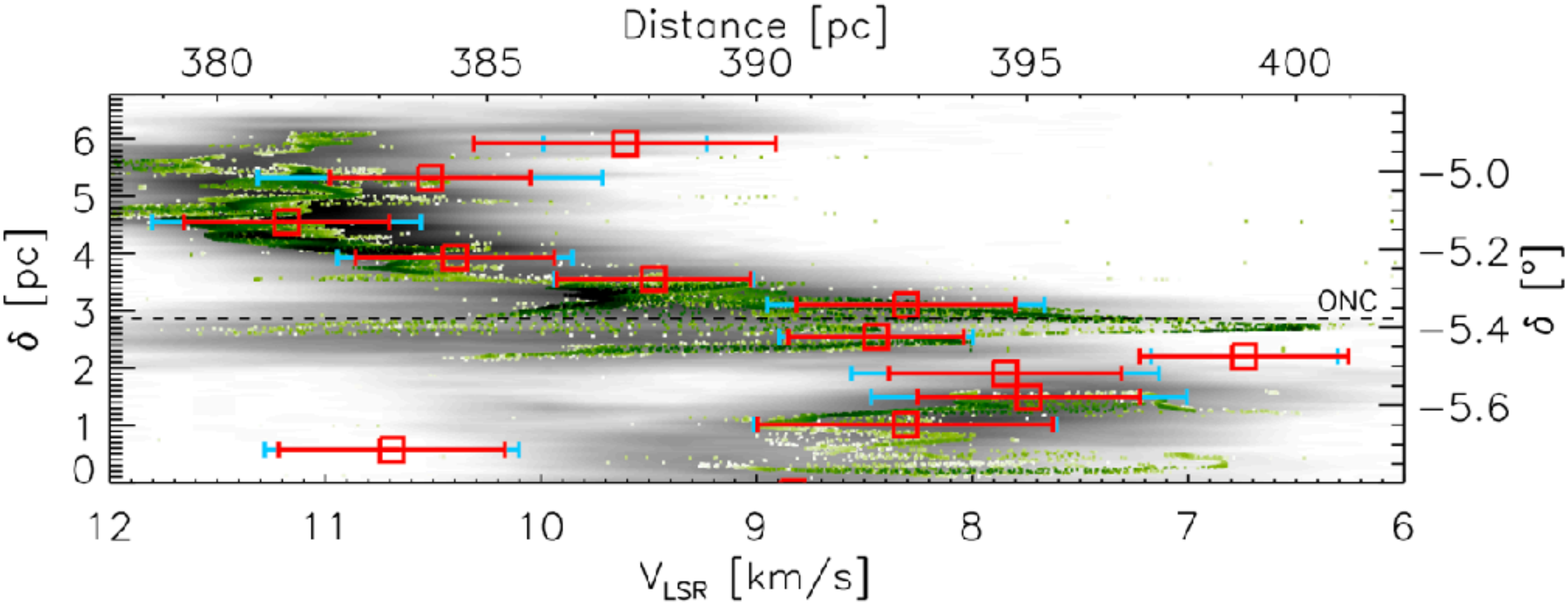
ISF zoom:
Gaia parallaxes + ^{13}CO and N_2H^+ PV diagram



^{13}CO (grey; Ripple+2013) and N_2H^+ (green shade; Tatematsu+2008) reversed PV diagram.

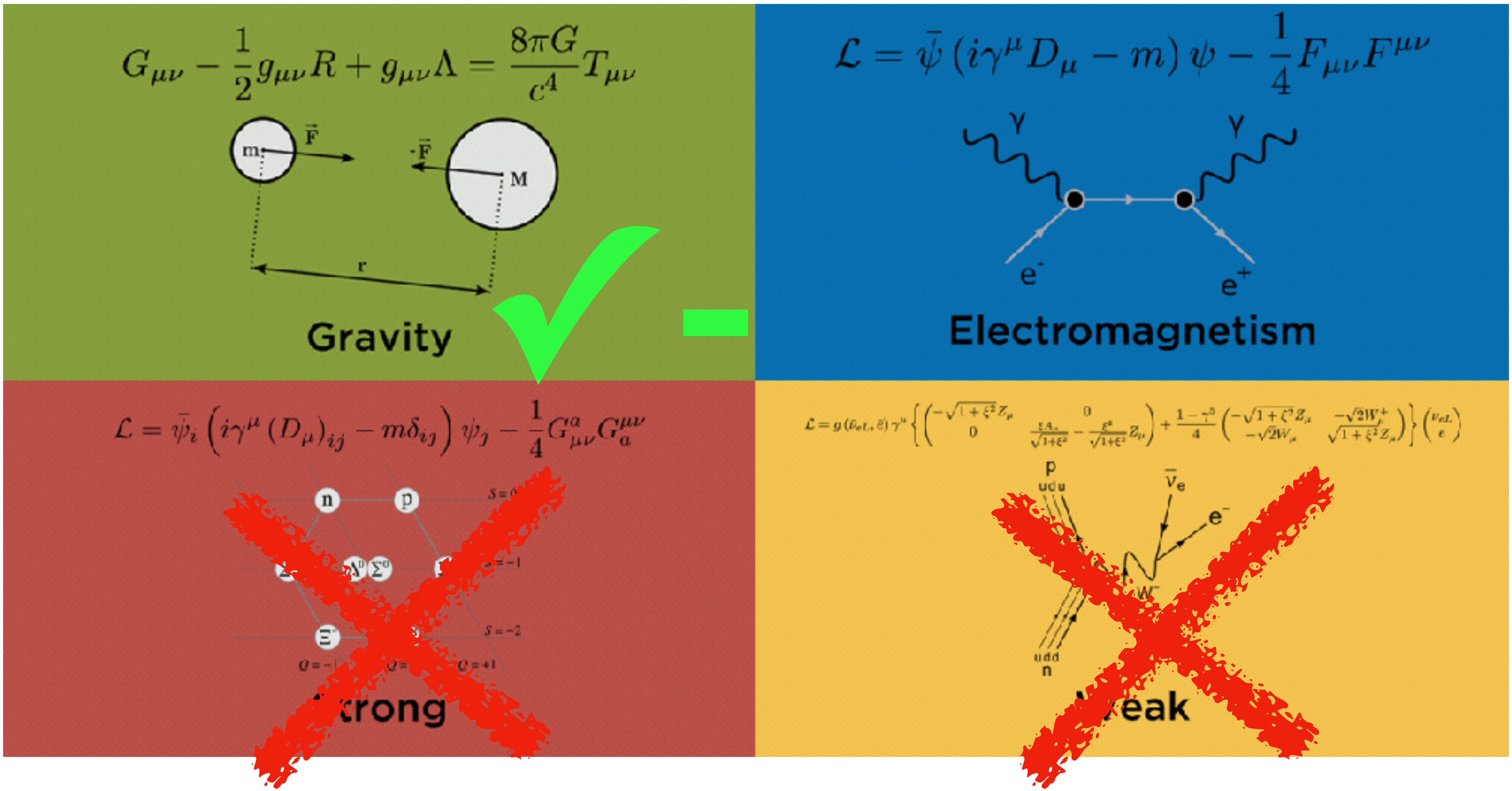
Comparison of completely independent measurements (optical / radio, space / ground, astrometric / heterodyne), with no connection except physics, yields a timescale of τ =~ 4 Myr.

ISF zoom:
Gaia parallaxes + ^{13}CO and N_2H^+ PV diagram

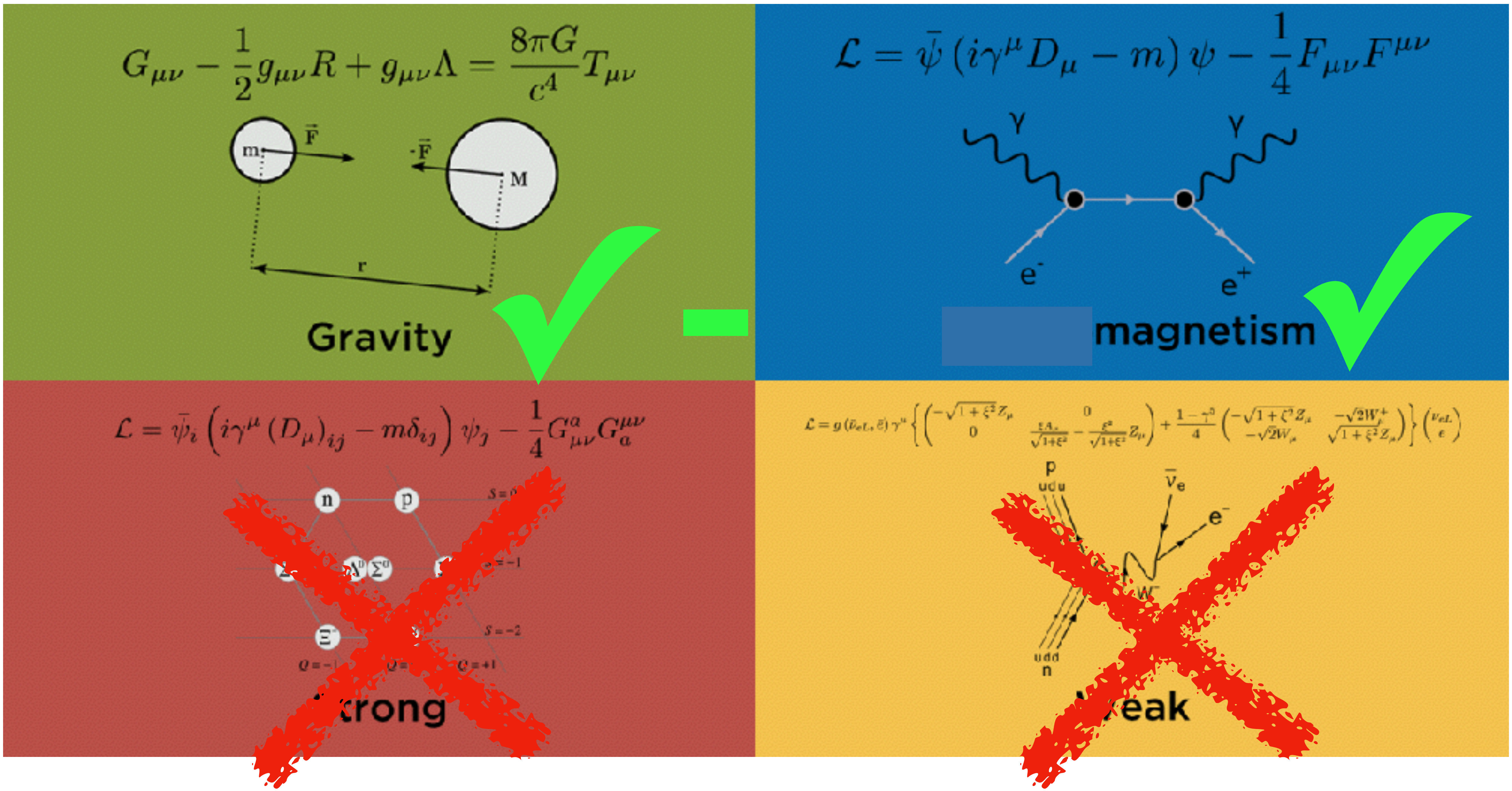


$$v = -\frac{D}{\tau} + K; \qquad \tau = 4\,\mathrm{Myr}.$$

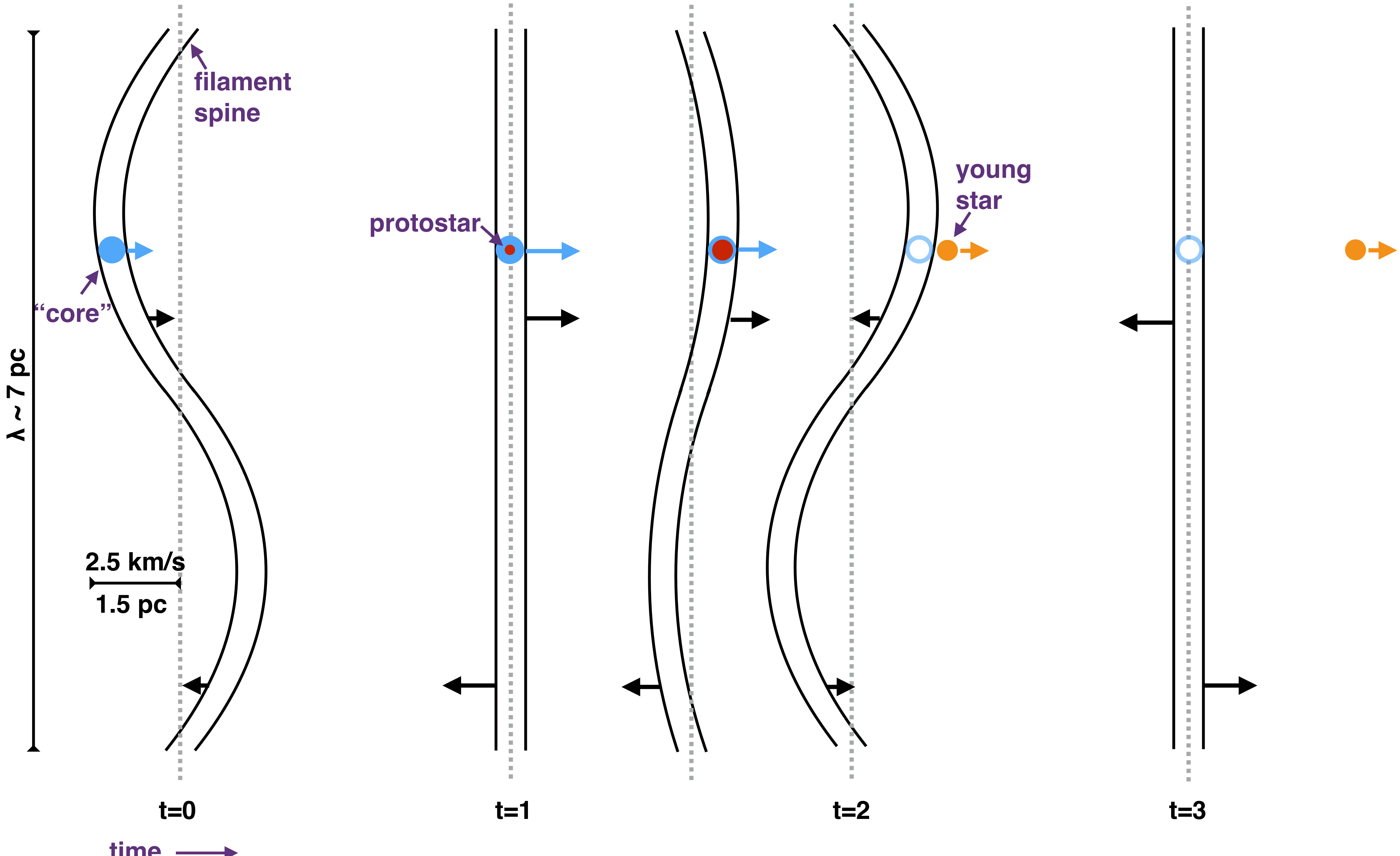
The Four Forces of Nature



The Four Forces of Nature



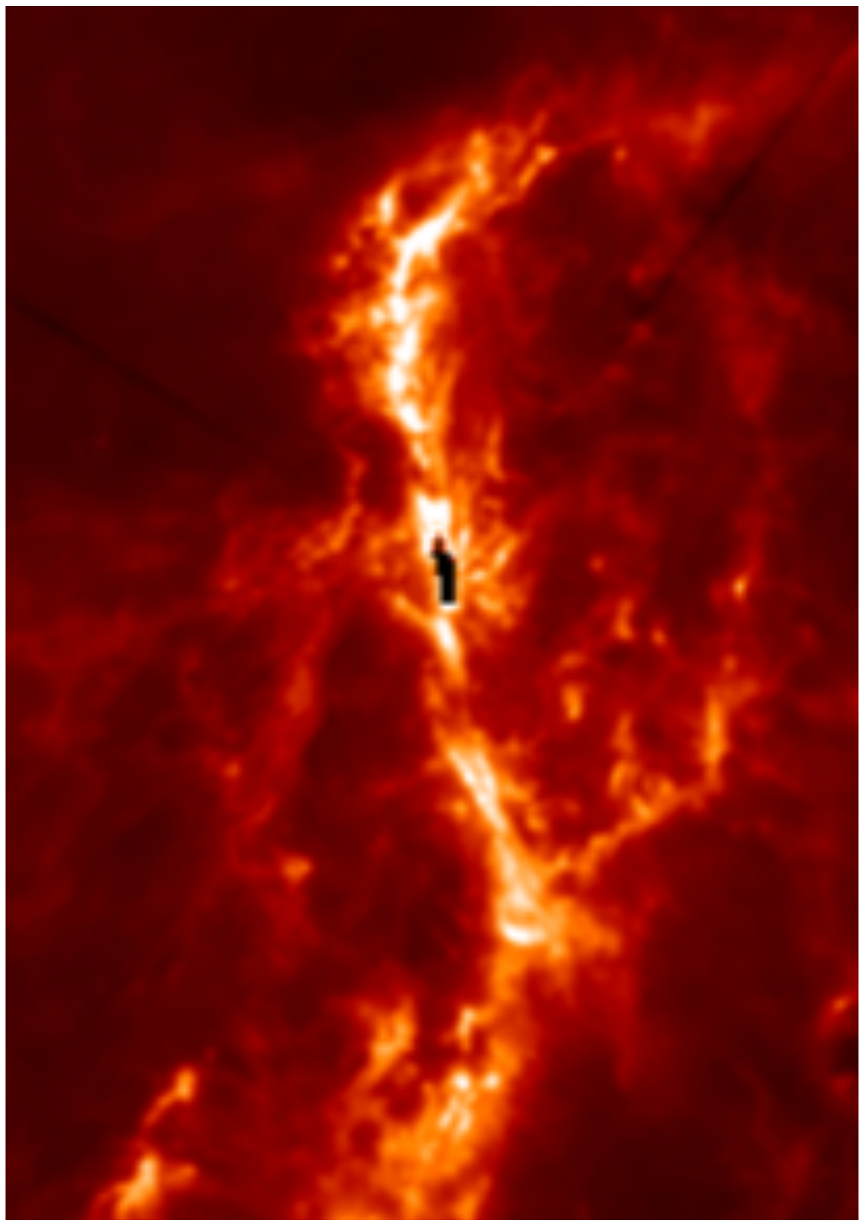
Slingshot: oscillating filament "ejects" stars



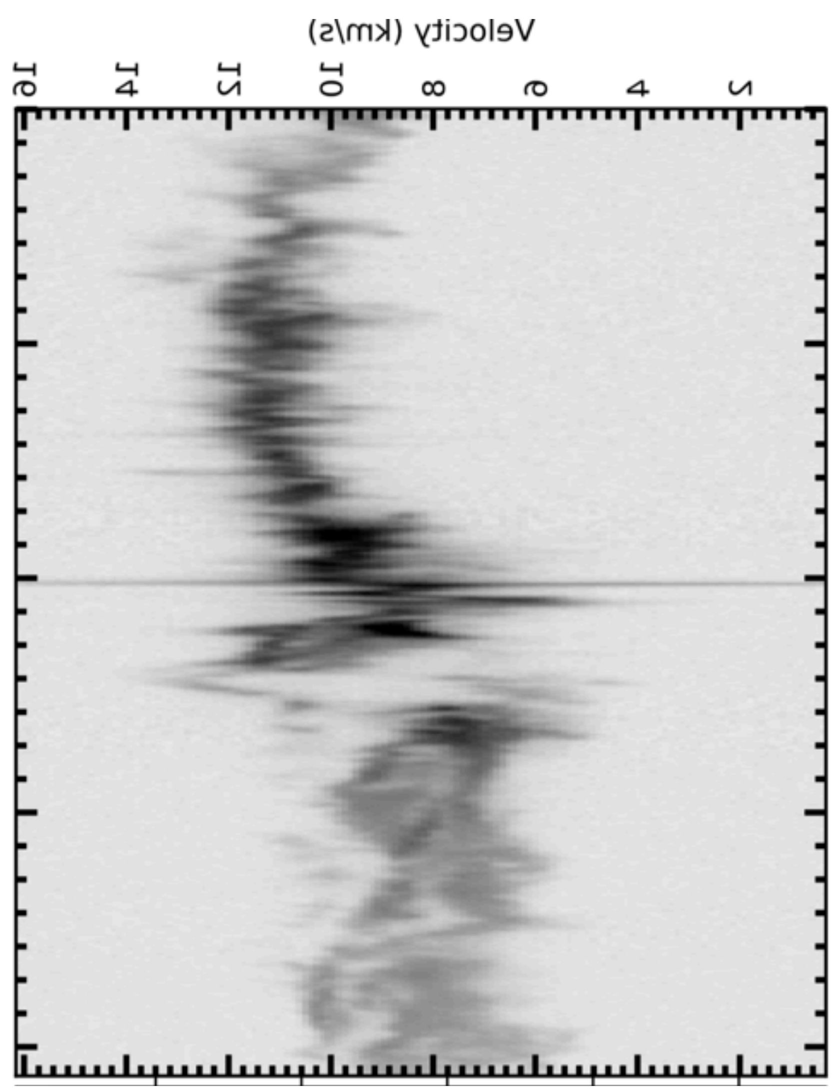
Stutz & Gould (2016); Stutz (2018)

Slingshot basis

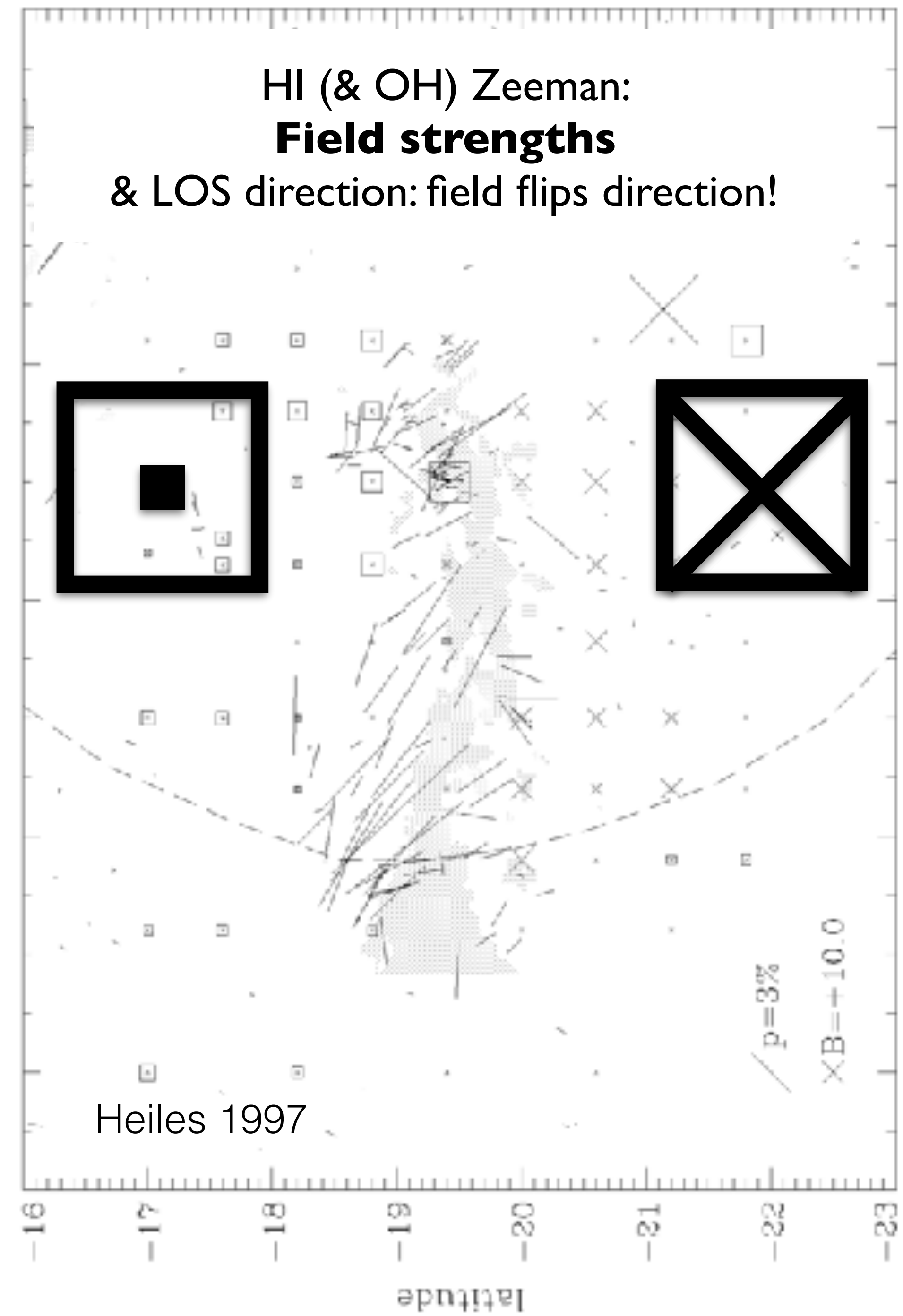
“Integral” or wave shape



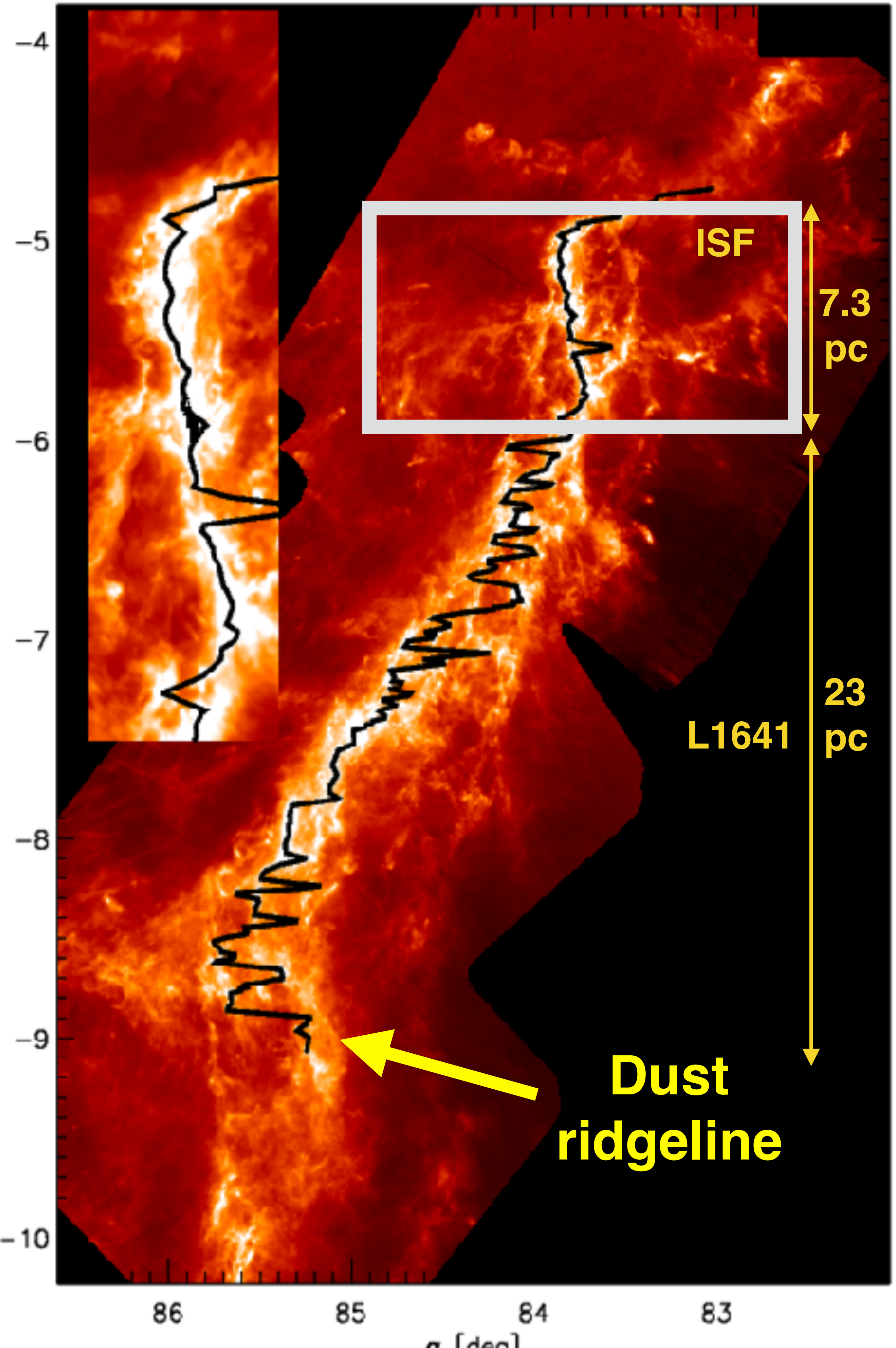
Velocity gradients

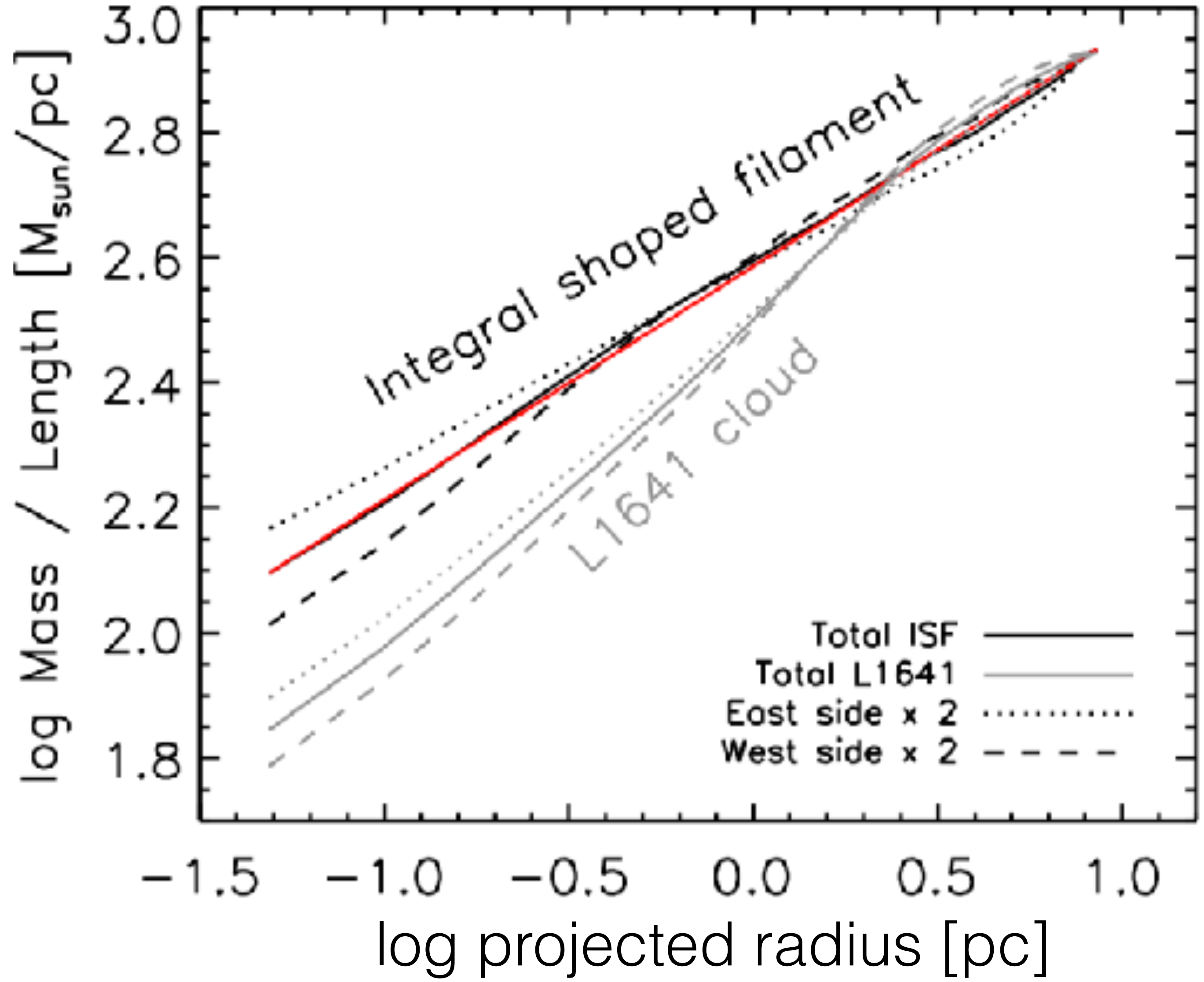


B-field strengths



Line mass, density, and gravitational potential

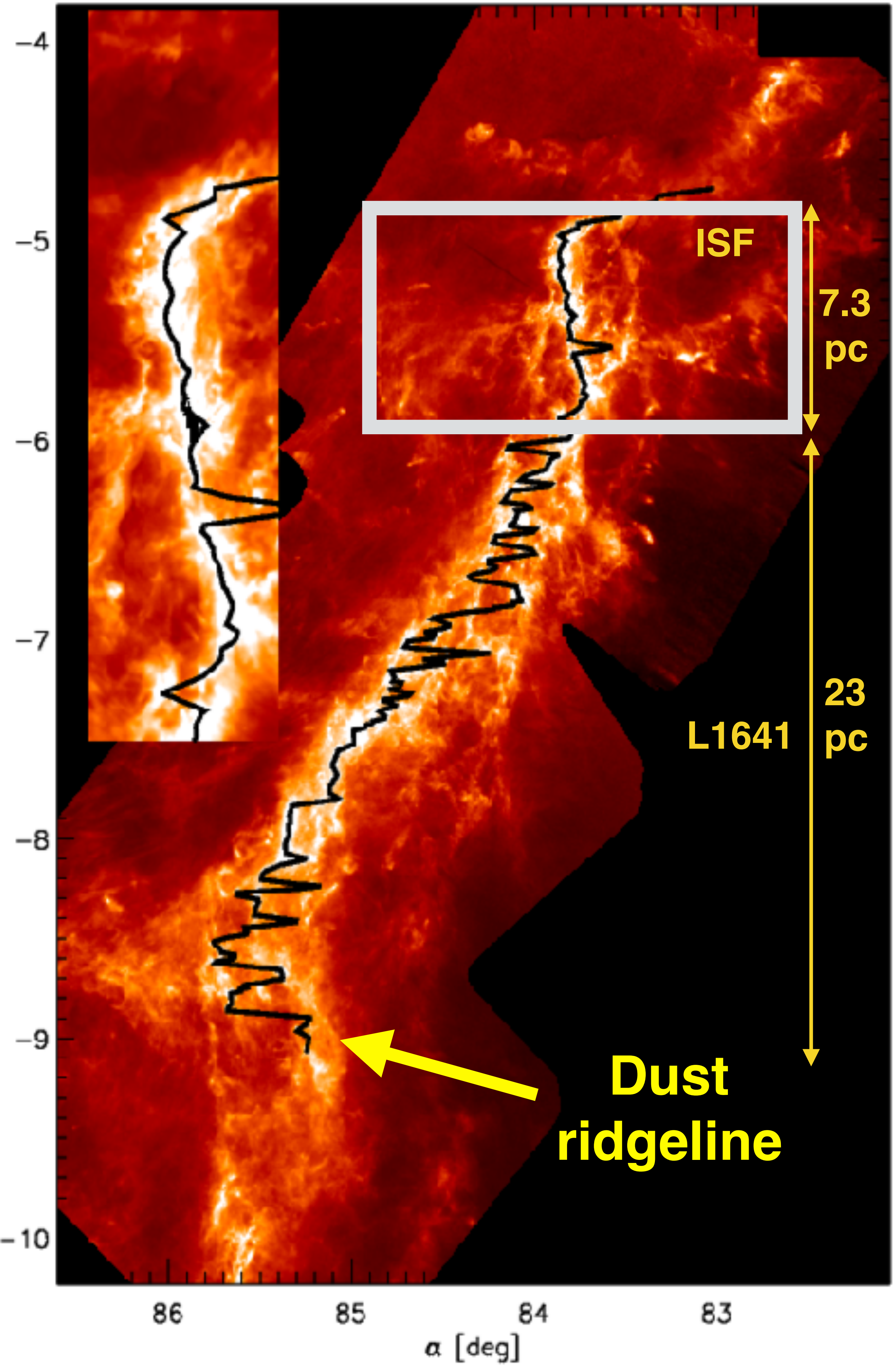


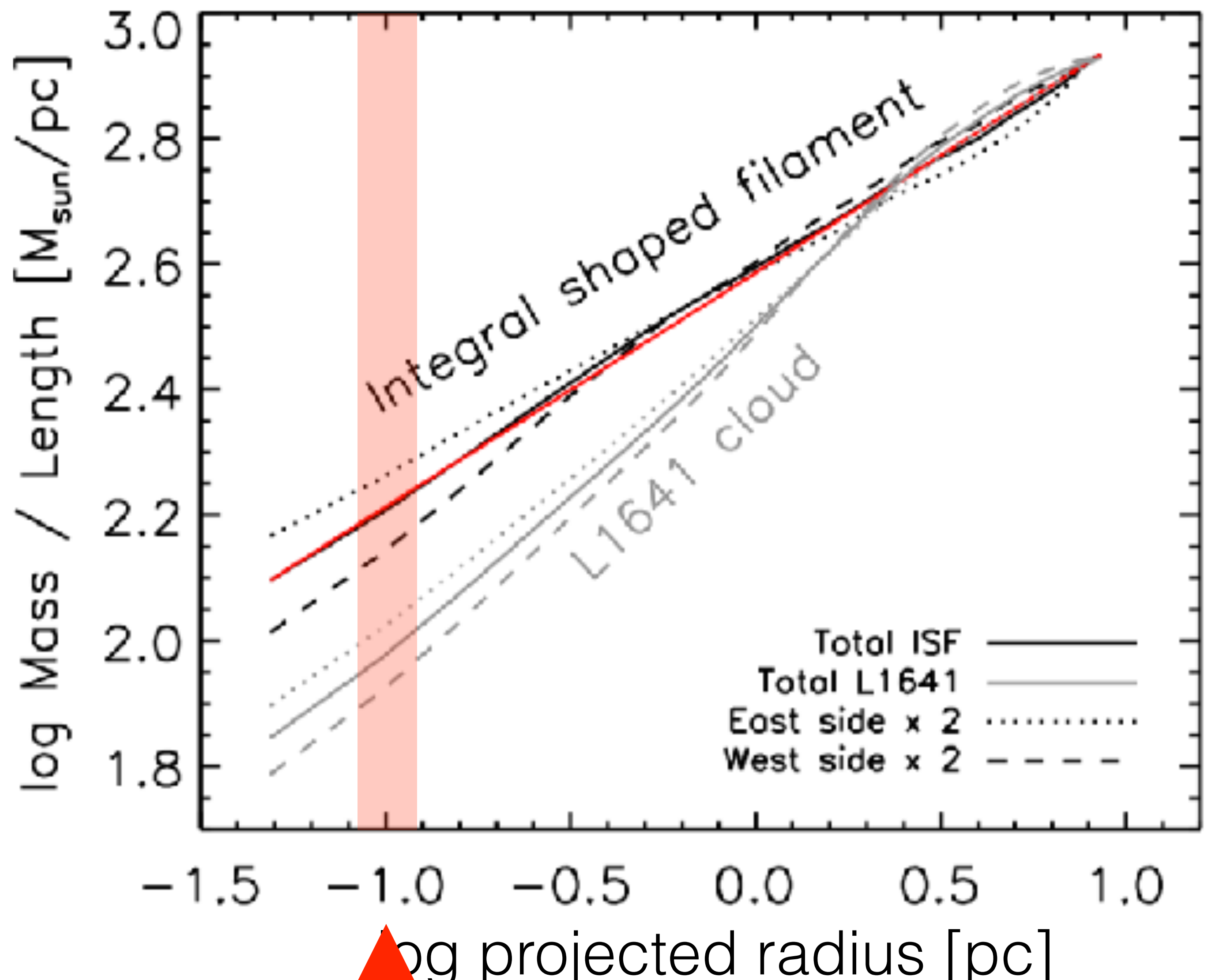


ISF mass per unit length profile:
$$\lambda(r) = 385\ M_{sun}/pc\ (r/pc)^{-3/8}$$

Stutz & Gould (2016); see also Stutz (2018)

Line mass, density, and gravitational potential

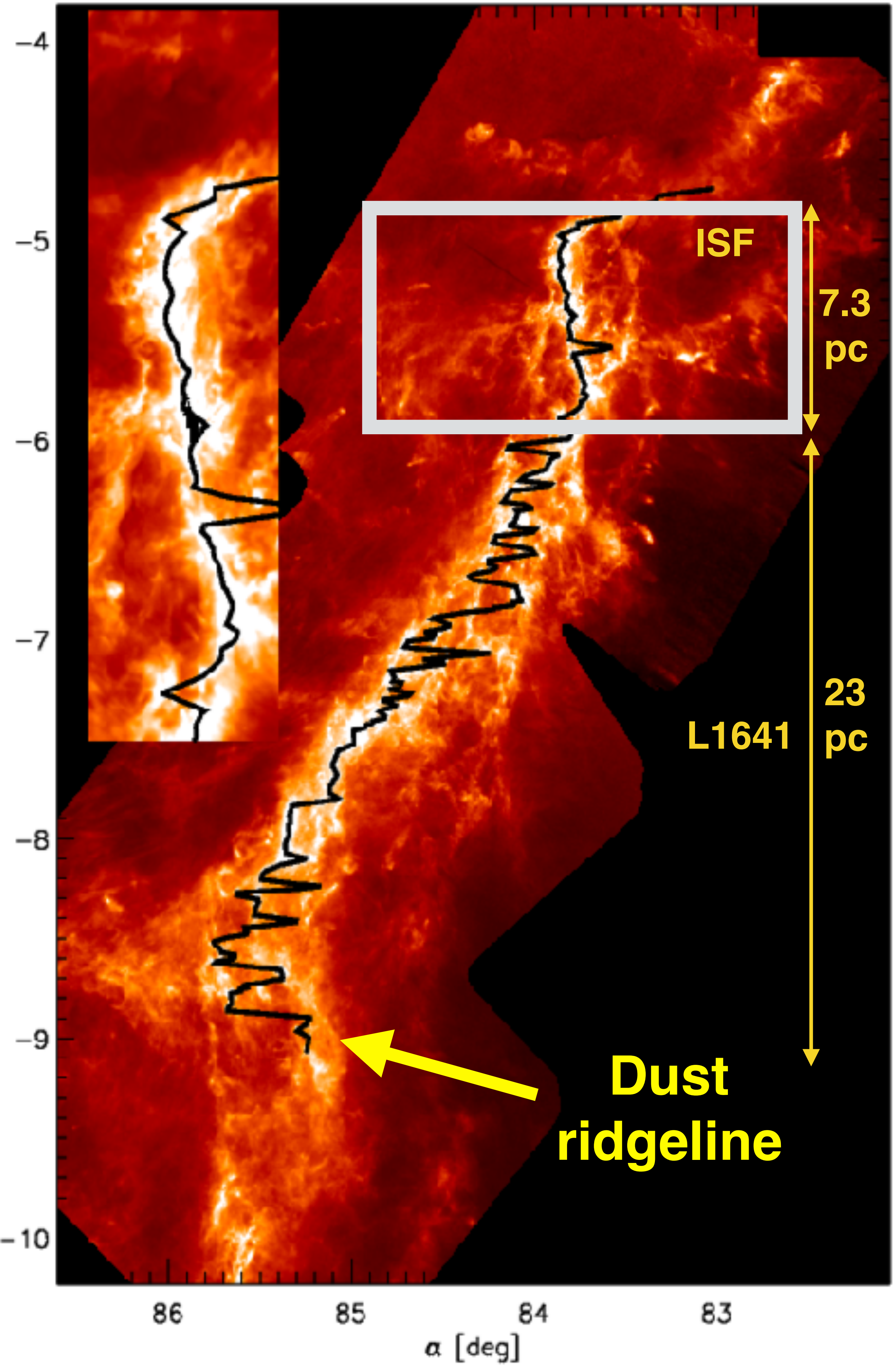


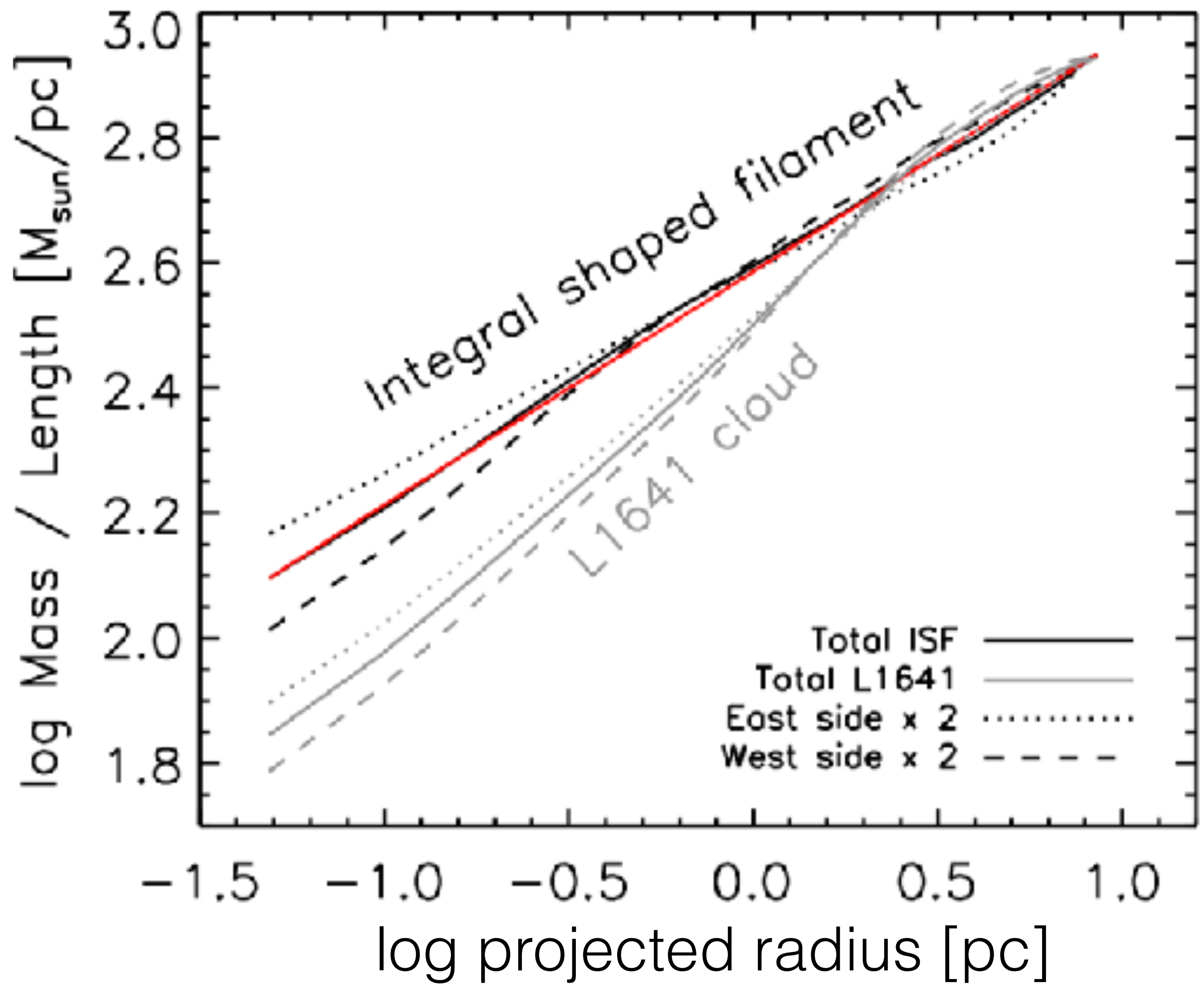


ISF has scale free power law: no break at 0.1 pc

Stutz & Gould (2016); see also Stutz (2018)

Line mass, density, and gravitational potential



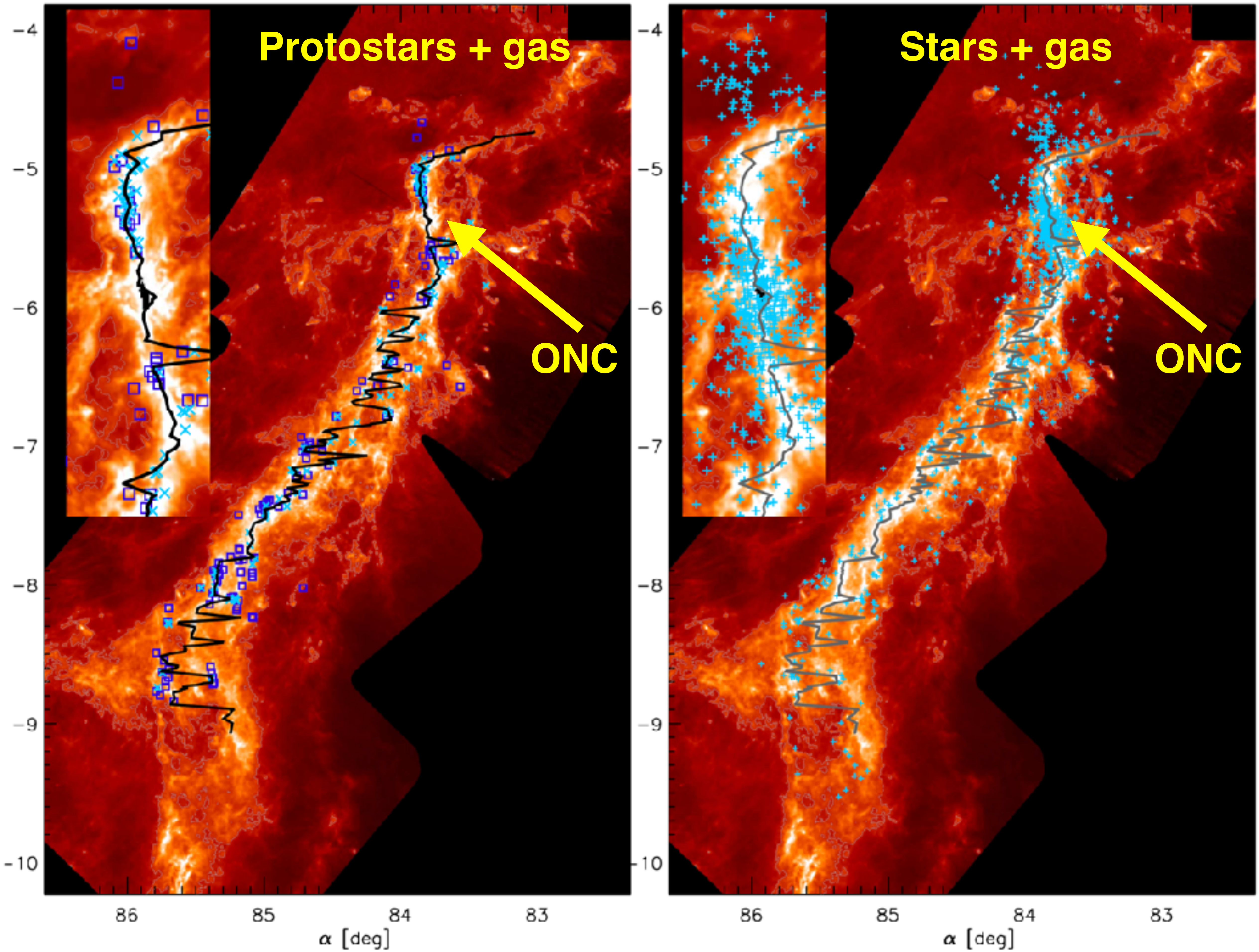


ISF radial profiles:

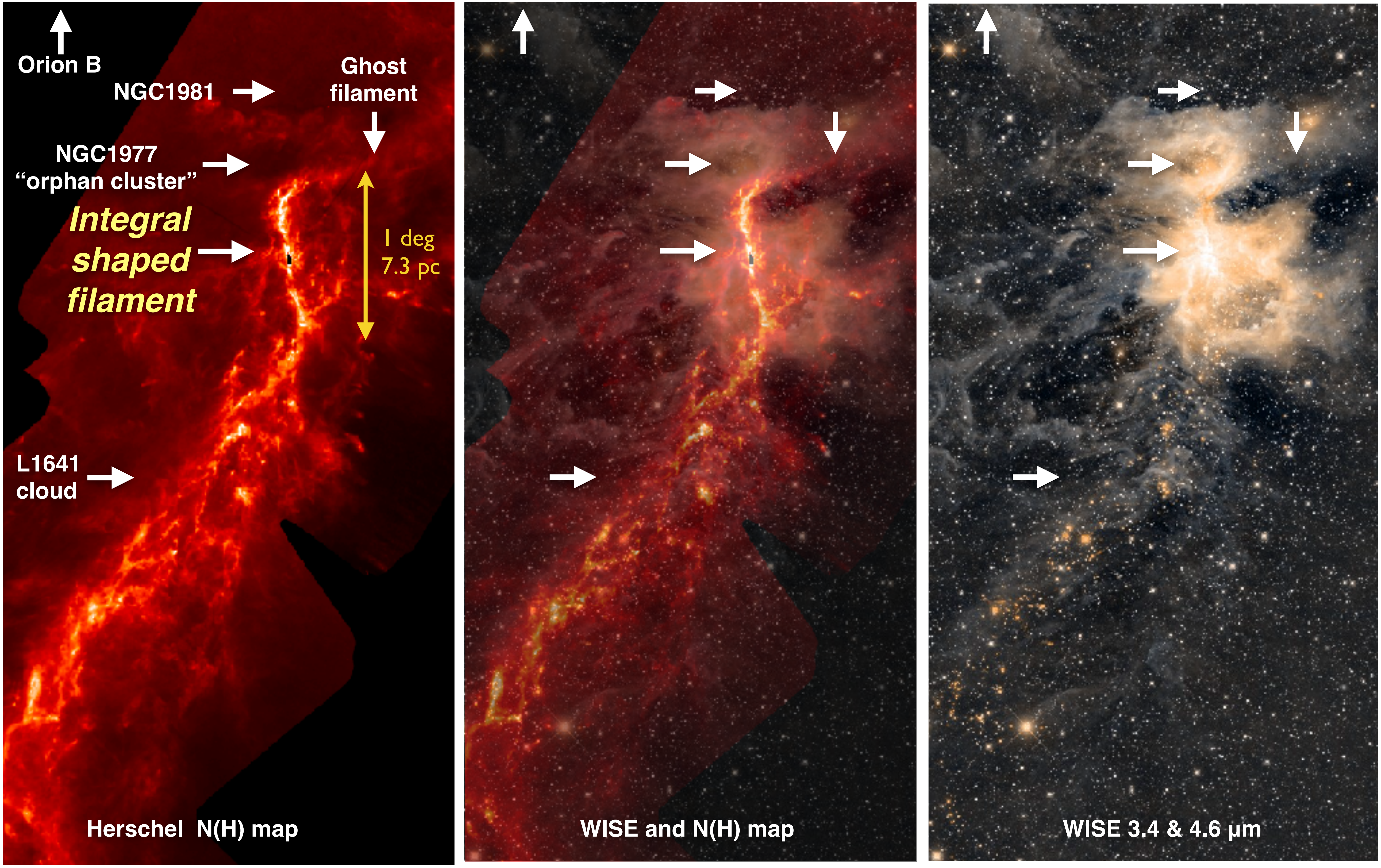
$\rho(r) = 16.4\ M_{sun}\ pc^{-3}\ (r/pc)^{-13/8}$

$\Phi(r) = 6.3\ (km\ s^{-1})^2\ (r/pc)^{3/8}$

Stutz & Gould (2016); see also Stutz (2018)

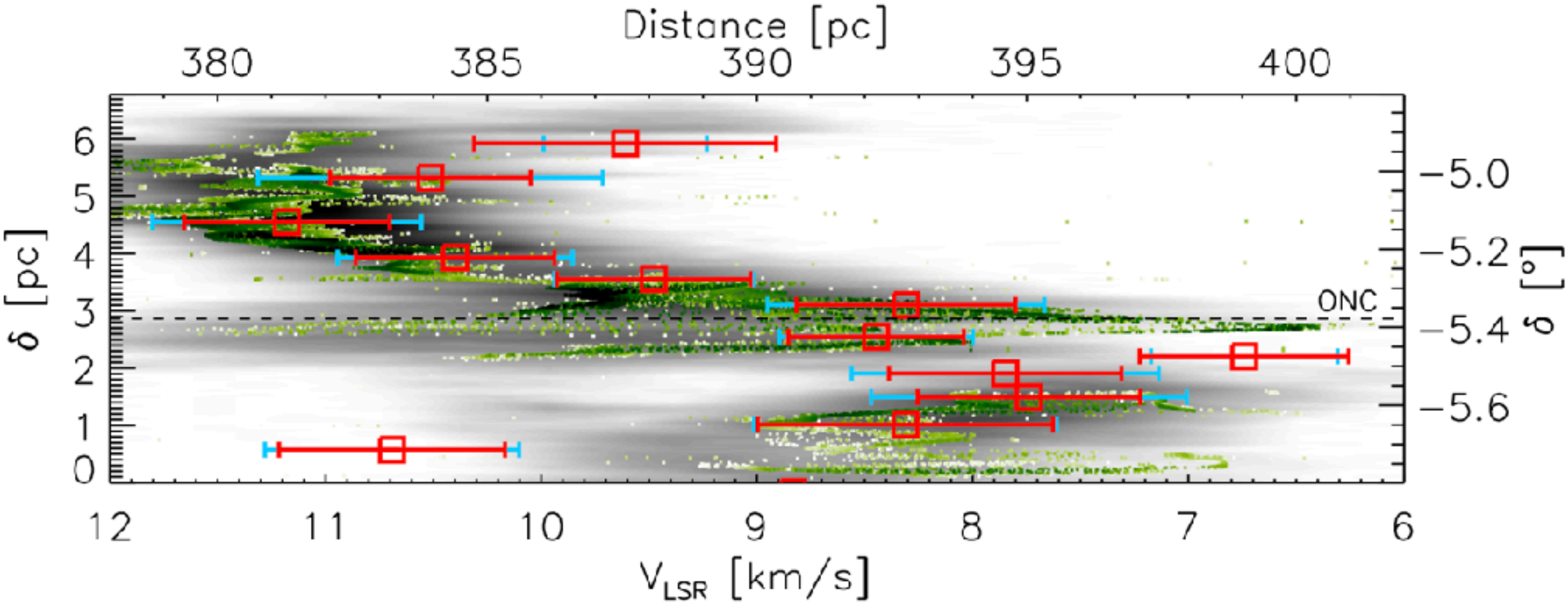


Protostars + gas
Stars + gas
ONC
ONC
−4
−5
−6
−7
−8
−9
−10
86
85
84
83
α [deg]



Orion B
NGC1981
Ghost filament
NGC1977 "orphan cluster"
Integral shaped filament
1 deg
7.3 pc
L1641 cloud
Herschel N(H) map
WISE and N(H) map
WISE 3.4 & 4.6 μm

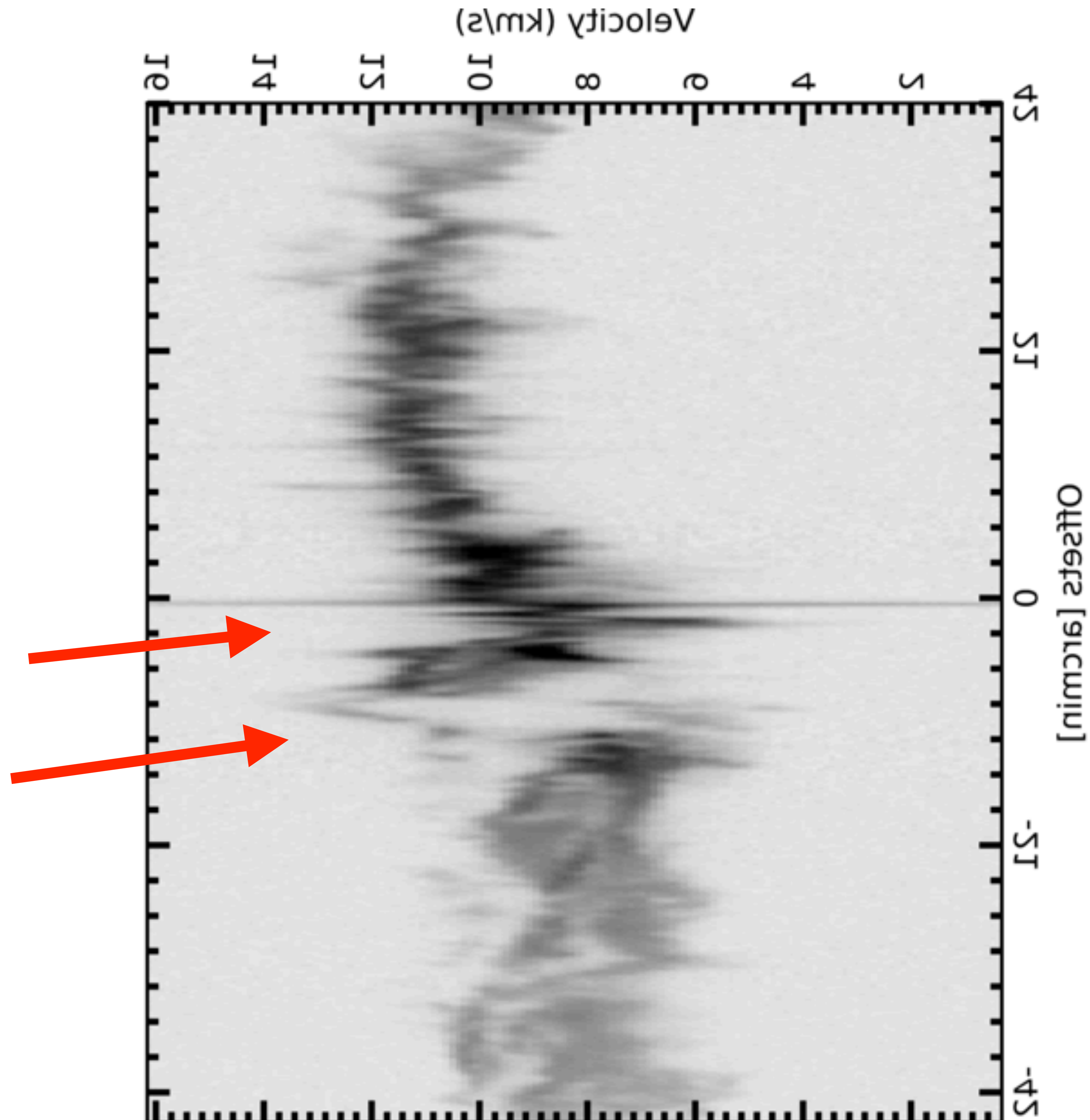
ISF zoom:
Gaia parallaxes + ^{13}CO and N_2H^+ PV diagram



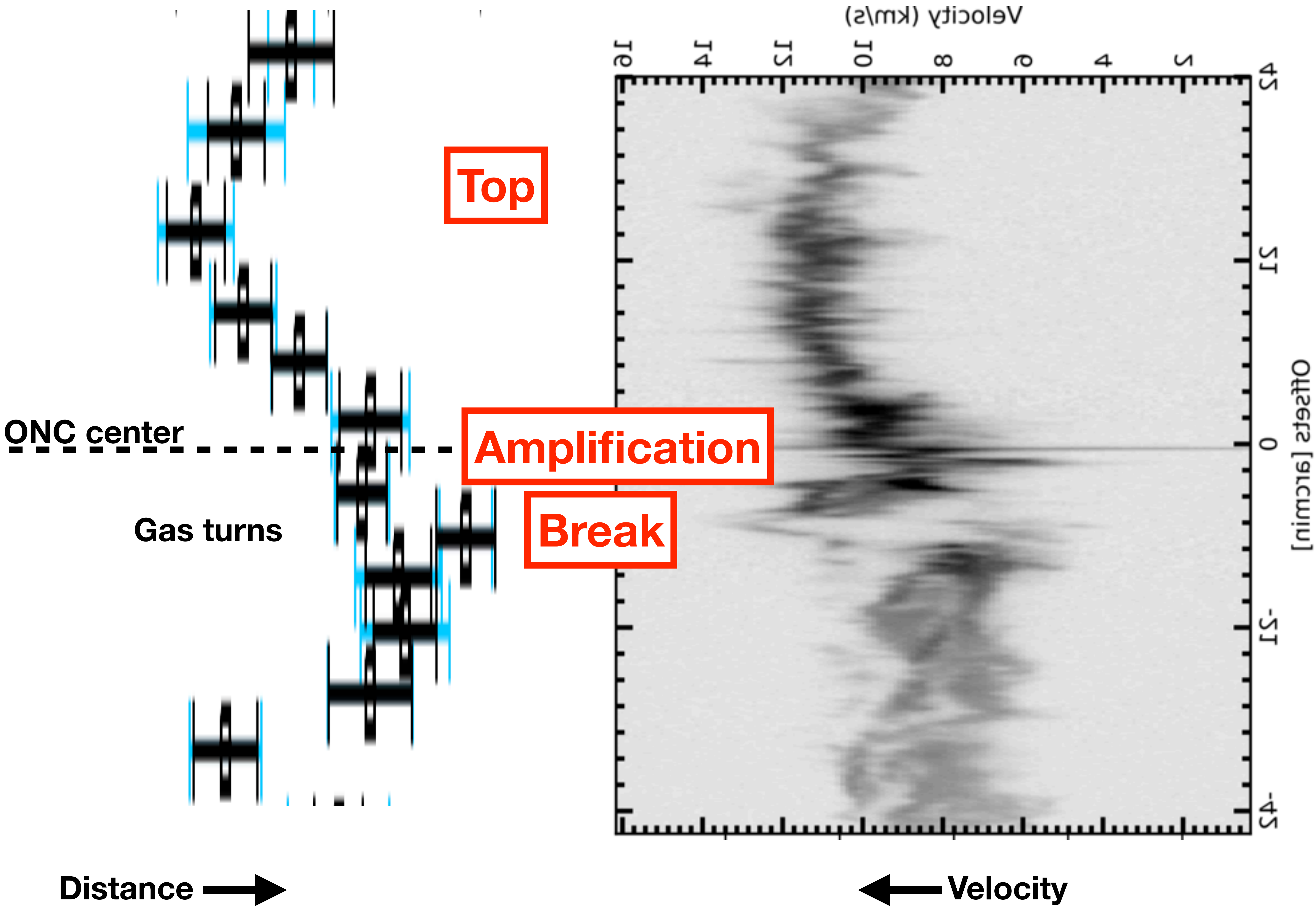
$$v = -\frac{D}{\tau} + K; \qquad \tau = 4\,\mathrm{Myr.}$$

Very obvious that there is a wave with a much shorter wavelength and shorter timescale.

The amplitude increases, then finally just after the cluster, this thing just disappears.

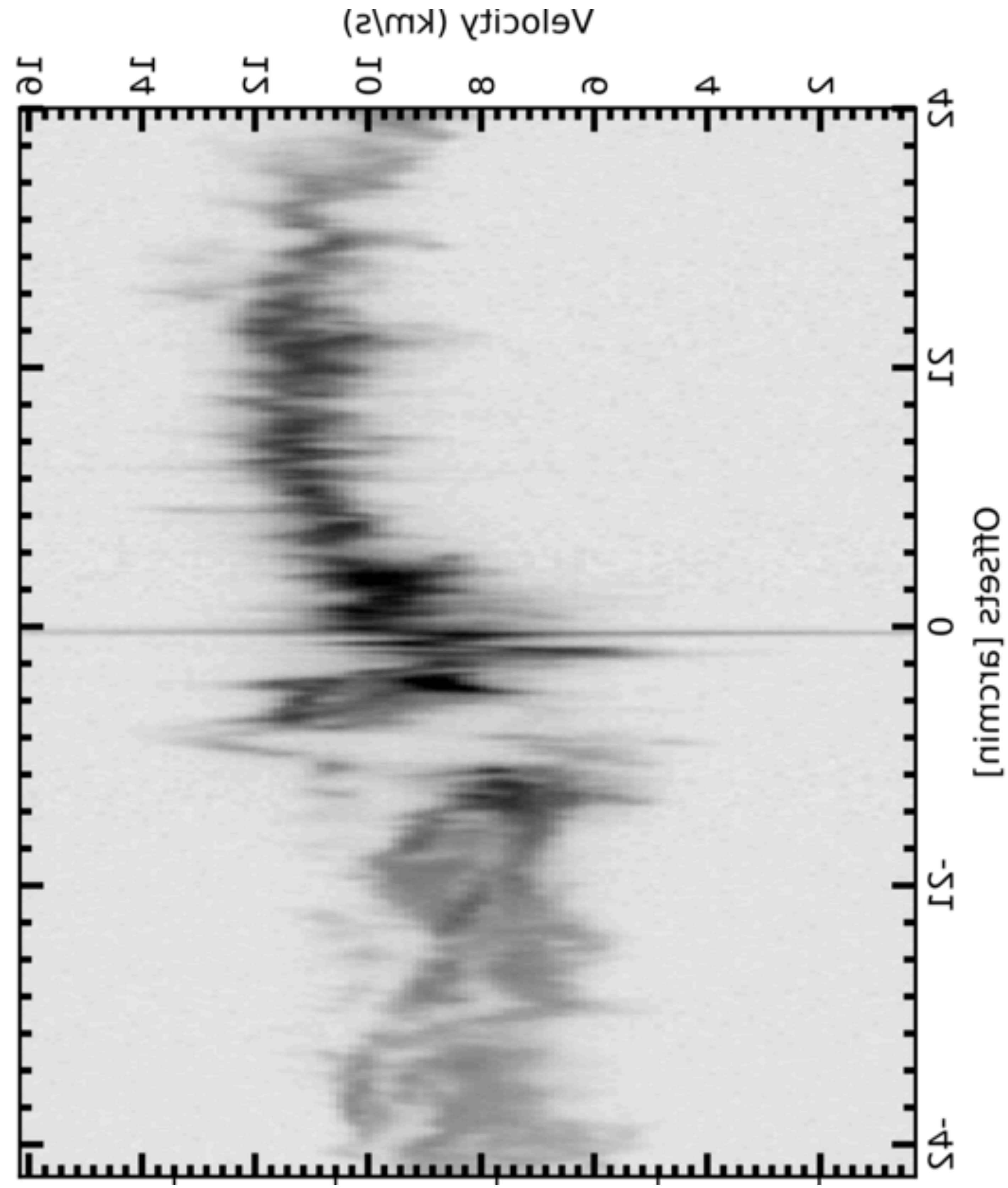


Kong et al. (2018)



Top
ONC center
Amplification
Break
Gas turns
Velocity (km/s)
Offsets [arcmin]
Distance
Velocity

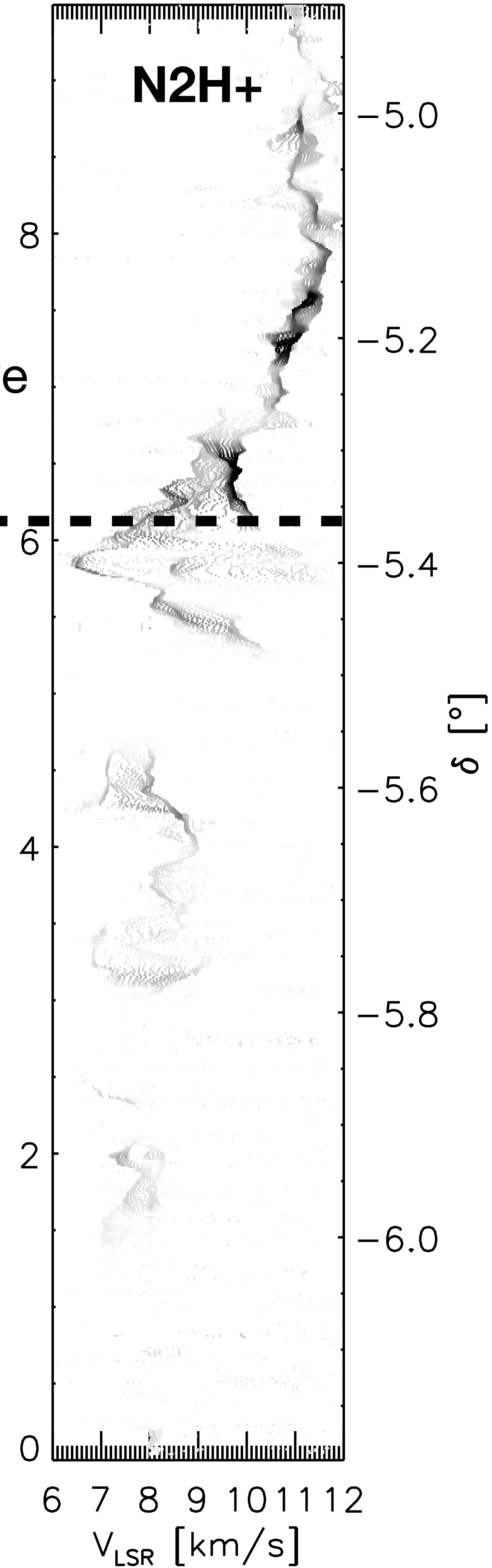
…but from this alone we cannot say much about the nature of these waves.

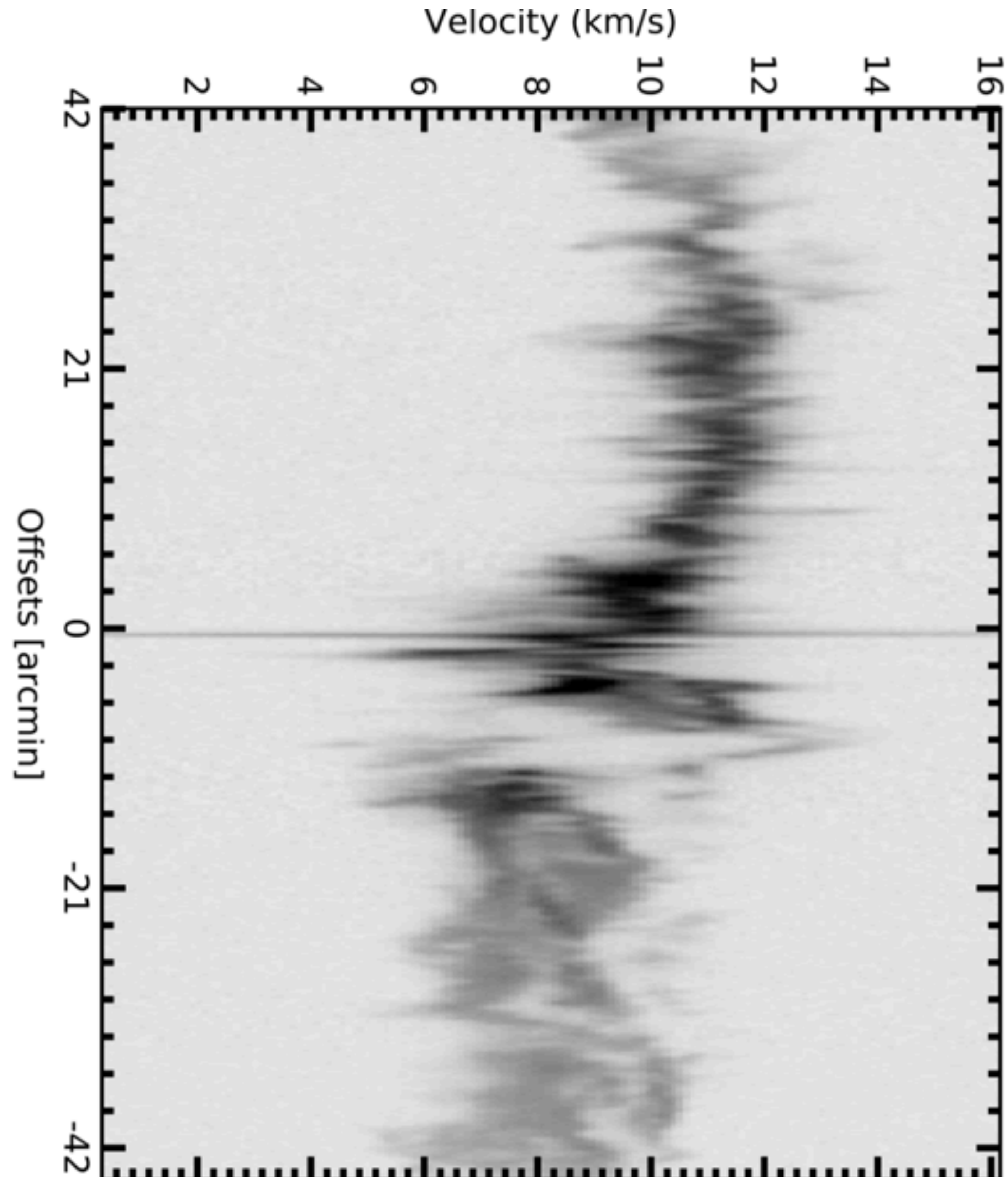


Filament material is wrapping, expected appearance of a torsional wave

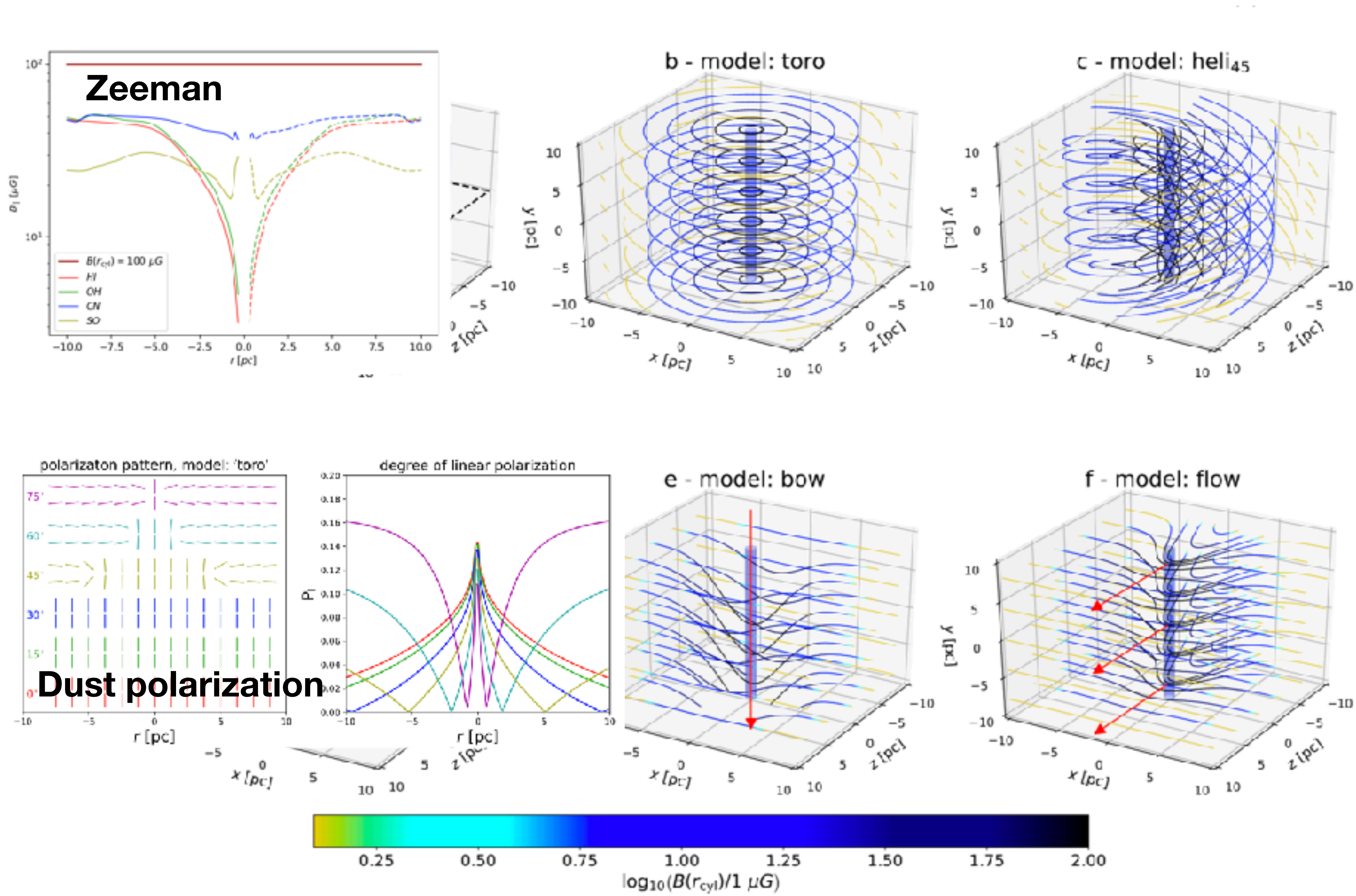
ONC center

Wave appears to be propagating from North to South because it is breaking up in the South.



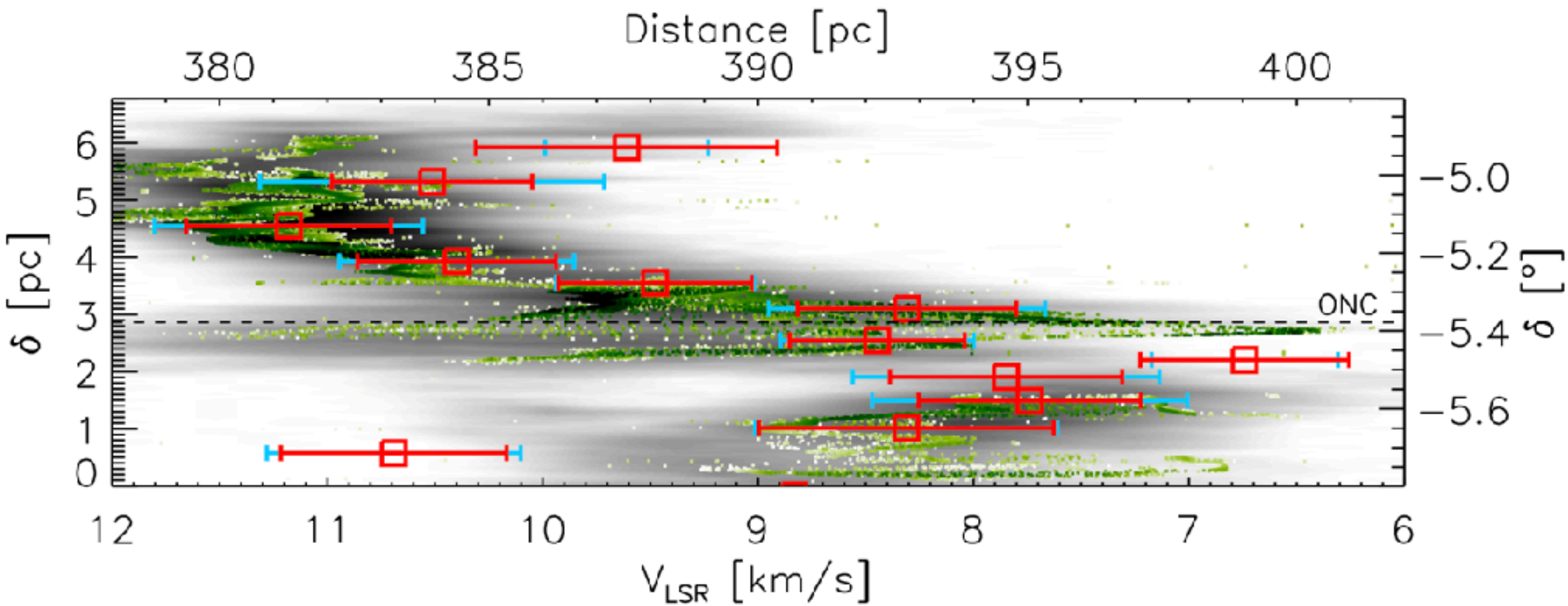


Modeling B-fields in filaments with POLARIS: Reissl et al. (2018), arXiv:1805.02674



Summary:

- Gaia distances combined with gas radial velocities show that the Orion A Integral Shaped Filament is subject to restoring forces consistent with wave propagation, as predicted by the Slingshot (Stutz & Gould 2016).
- The time scale is about 4 Myr.
- The wave appears to propagate from North to South.
- Smaller scale waves (tau ~ 0.5 Myr) appear torsional in nature.



Stutz, Gonzalez-Lobos, & Gould (2018): arXiv:1807.11496