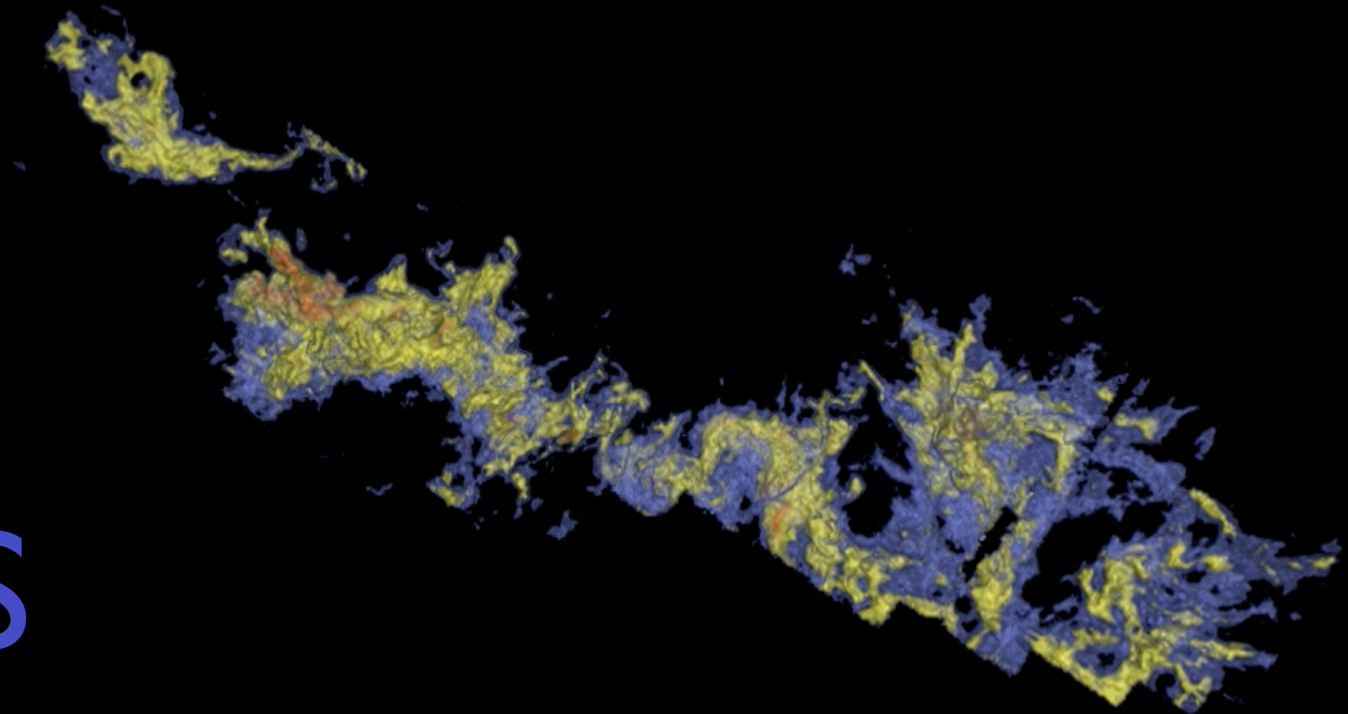
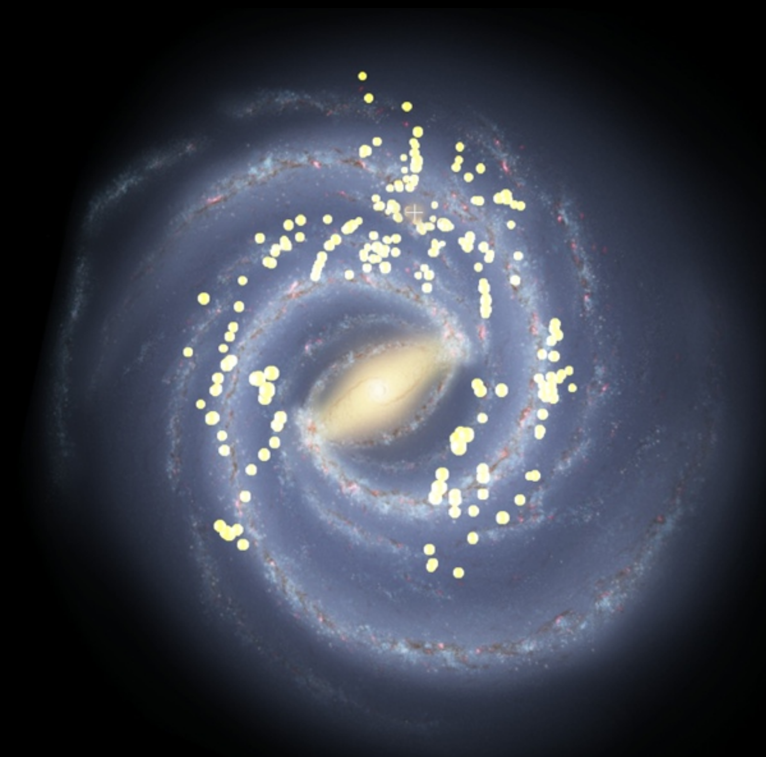

Adam Block, APOD, 29 June 2012: Dark Clouds in Aquila

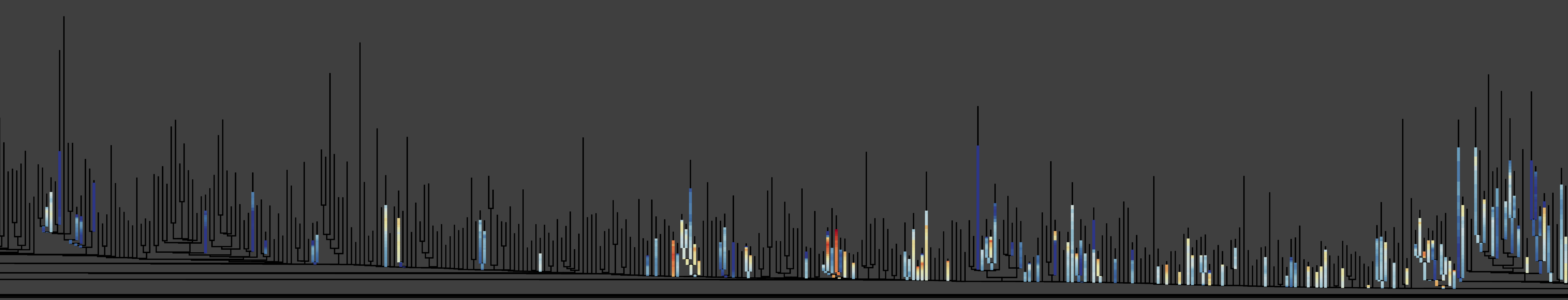


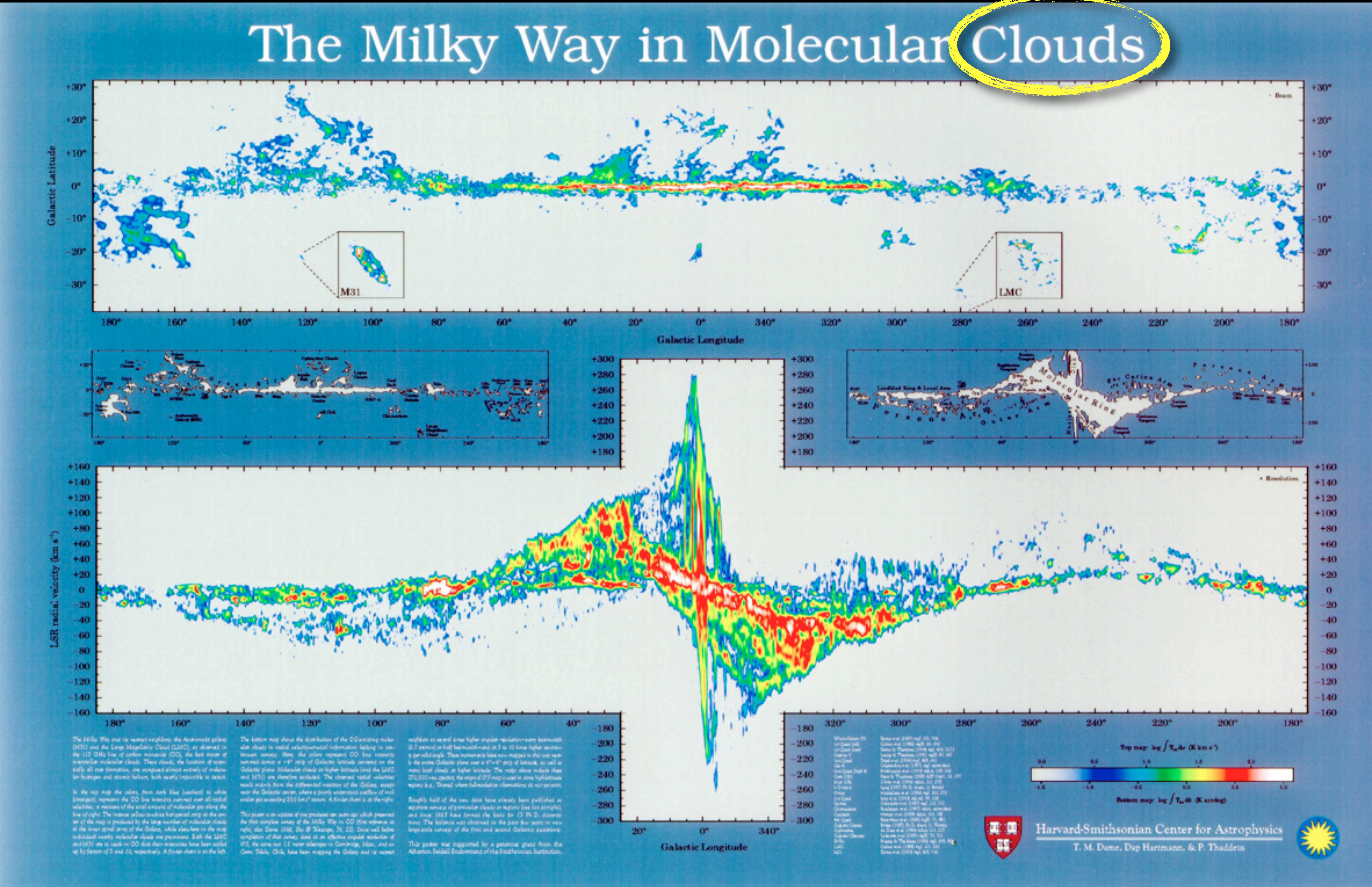


EPoS

Under Pressure

Alyssa**Goodman**, Chris **Beaumont**, Tom Dame, Chris **Faesi**, Stella **Offner,** Mark Reid &
Tom **Rice** (Harvard-Smithsonian Center For Astrophysics) &
Joao Alves (U.Vienna), Bob Benjamin (U. Wisconsin), Erik Rosolowsky (U. British Columbia)





Dame et al. 2001

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What is Universe3D.org?

The intention of Universe3D.org is to host links to web content that enable the enhancement of our three-dimensional view of the Universe.

Recently added Dataset

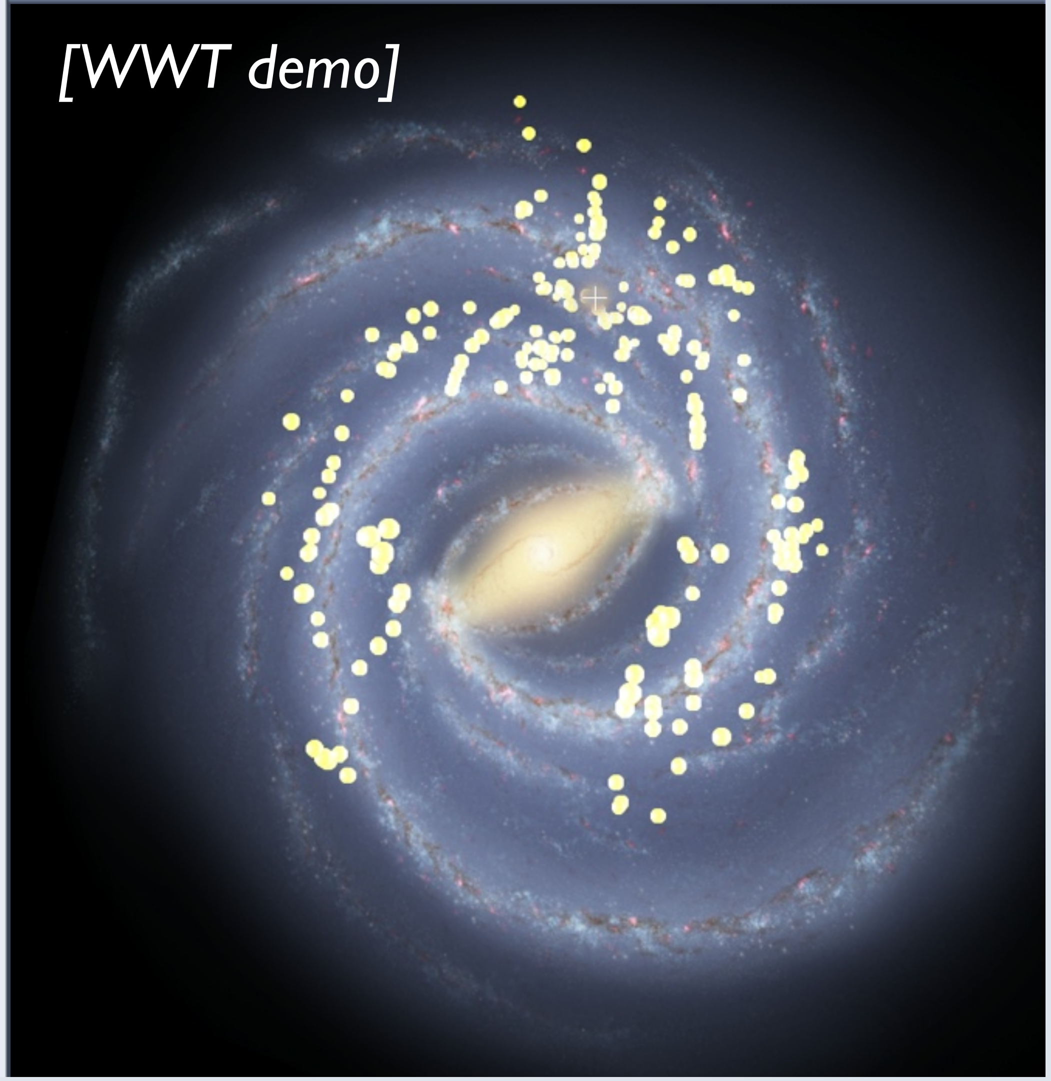
SLOAN Digital Sky Survey The Sloan Digital Sky Survey or SDSS is a major multi-filter imaging and spectroscopic redshift survey using a dedicated 2.5-m wide-angle optical telescope at Apache Point Observatory in New Mexico, United States. The main galaxy sample has a median redshift of $z = 0.1$; there are redshifts for luminous red galaxies as far as $z = 0.7$, and for quasars as far as $z = 5$; and the imaging survey has been involved in the detection of quasars beyond a redshift $z = 6$.

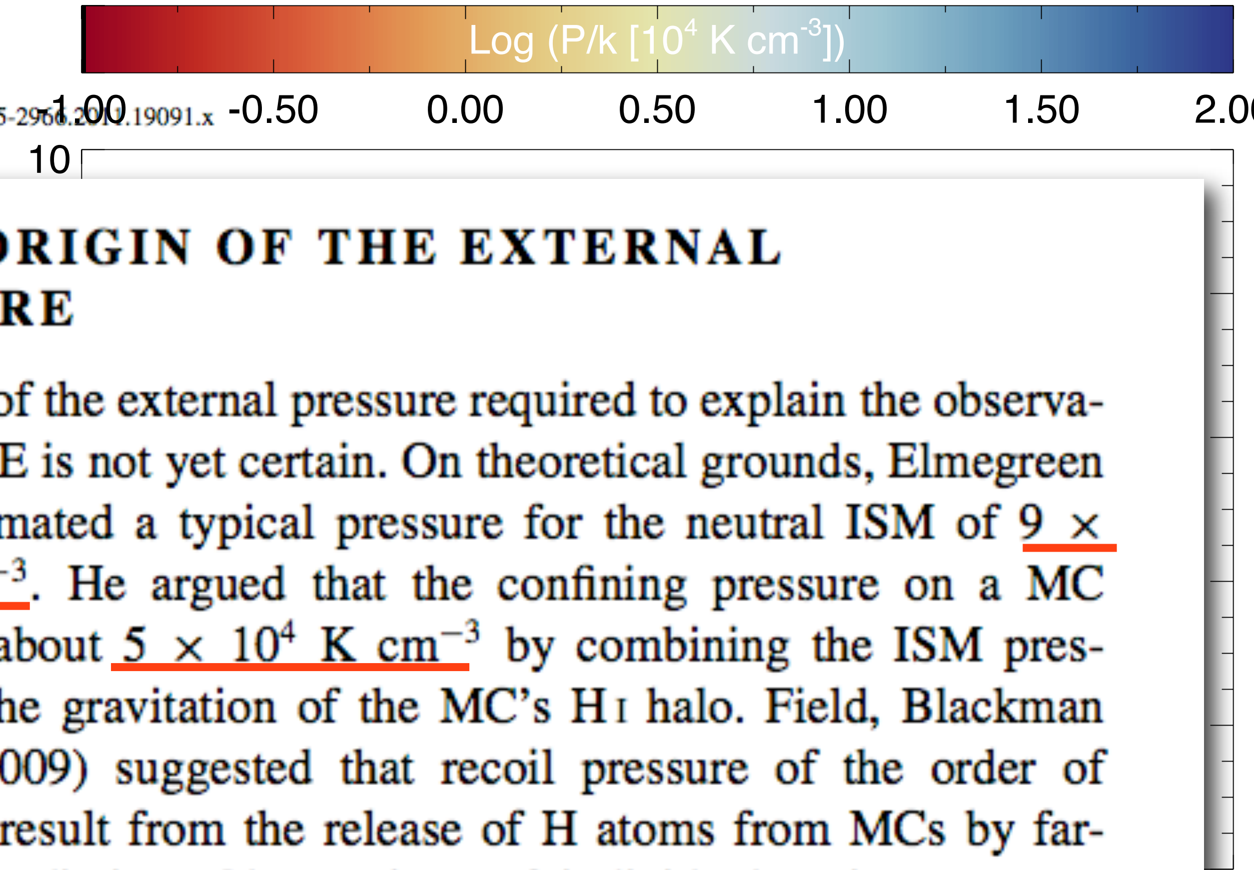
Astronomy News

- *June 26, 2012:* Astronomers use supercomputer to explore role of dark matter in galaxy formation
- *June 25, 2012:* Moon to pass by Mars tonight
- *June 24, 2012:* Astronomers find planets so close they 'see' each other in night sky
- *June 14, 2012:* Huge Asteroid to fly by Earth
- *June 13, 2012:* Astronomers may have discovered the oldest galaxy in the Universe
- *June 5, 2012:* Last Transit of Venus for the 21st century

Announcements

The Milky Way

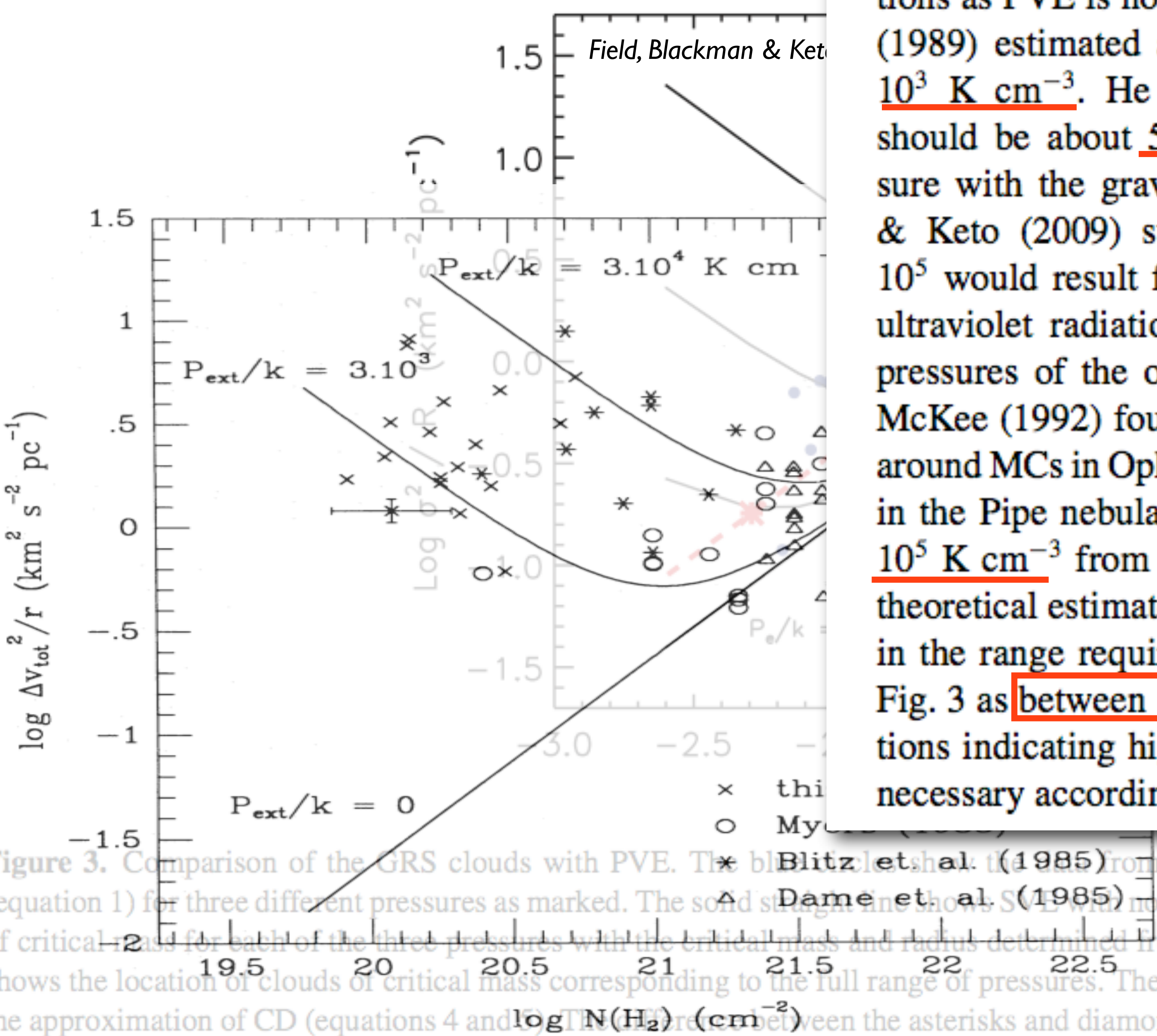




Mon. Not. R. Astron. Soc. **416,** 710–714 (2011)   doi:10.1111/j.1365-2966.2011.19091.x

Does external pressure explain recent results for m

George B. Field,[1] Eric G. Blackman[2] and Eric R. Keto[1★]
[1]Harvard–Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
[2]Department of Physics and Astronomy, University of Rochester, Rochester, NY 14627-0171, USA



4 THE ORIGIN OF THE EXTERNAL PRESSURE

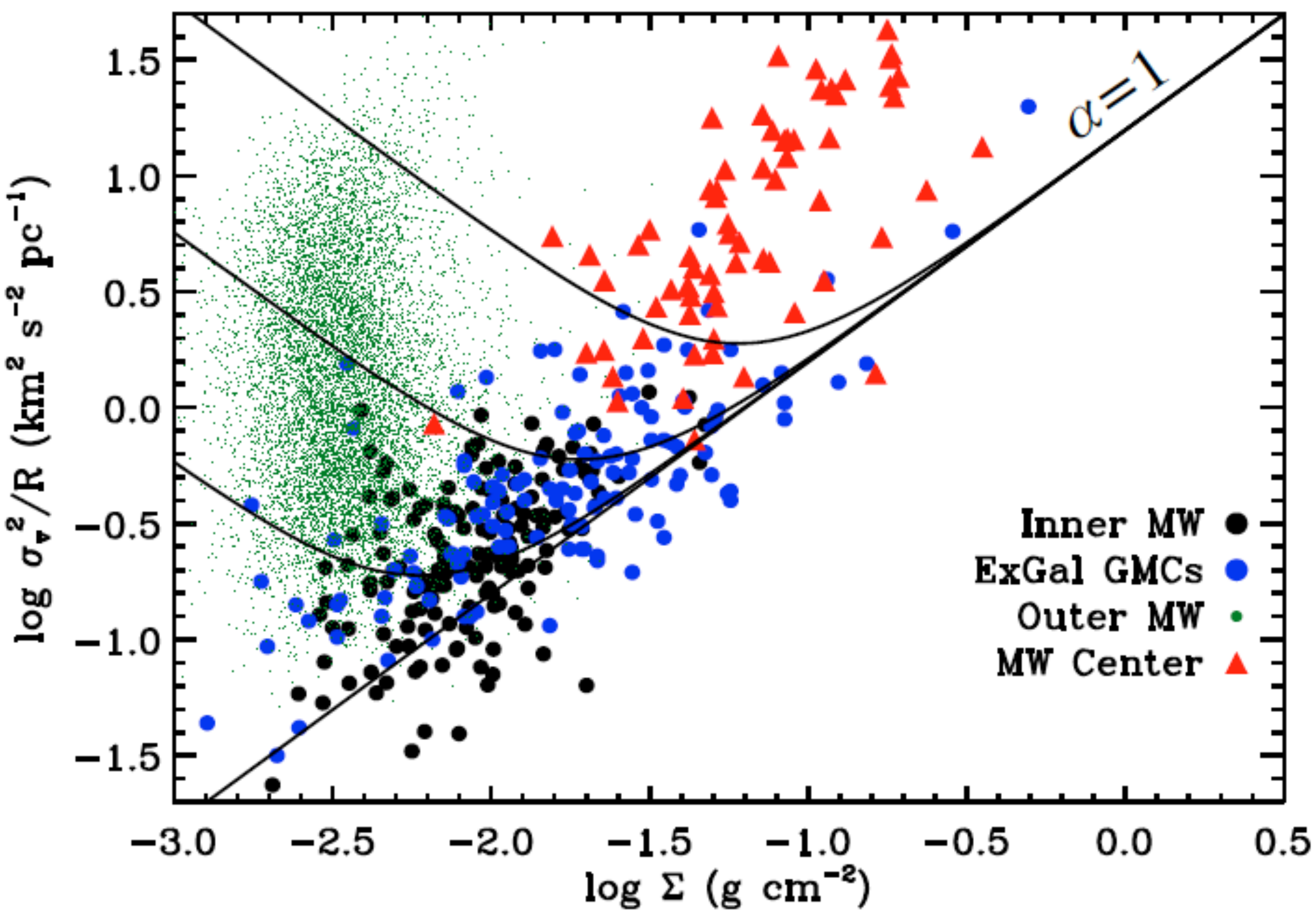
The origin of the external pressure required to explain the observations as PVE is not yet certain. On theoretical grounds, Elmegreen (1989) estimated a typical pressure for the neutral ISM of 9×10^3 K cm^{-3}. He argued that the confining pressure on a MC should be about 5×10^4 K cm^{-3} by combining the ISM pressure with the gravitation of the MC's H I halo. Field, Blackman & Keto (2009) suggested that recoil pressure of the order of 10^5 would result from the release of H atoms from MCs by far-ultraviolet radiation. Observations of individual regions suggest pressures of the order of 10^5 K cm^{-3}. For example, Bertoldi & McKee (1992) found pressures of $P_e/k = (0.5–2) \times 10^5$ K cm^{-3} around MCs in Ophiuchus, Lada et al. (2008) found 7×10^4 K cm^{-3} in the Pipe nebula and Belloche et al. (2011) found $P_e/k = 5 \times 10^5$ K cm^{-3} from observations of 60 nearby starless cores. These theoretical estimates and observations suggest intercloud pressures in the range required to confine most of the clouds, indicated by Fig. 3 as between 10^4 and 10^6. We are not aware of other observations indicating higher pressures in the neutral ISM that might be necessary according to Fig. 3.

Figure 3. Comparison of the GRS clouds with PVE. The bl… from Heyer09. The three v-shaped curves are the solutions of PVE (equation 1) for three different pressures as marked. The solid straight line shows SVE with no external pressure. The three asterisks show the location of clouds of critical mass for each of the three pressures with the critical mass and radius determined from the LE equation (equations 6 and 7). The dashed straight line shows the location of clouds of critical mass corresponding to the full range of pressures. The diamonds correspond to clouds of critical mass determined with the approximation of CD (equations 4 and 5). The difference between the asterisks and diamonds shows the difference between the CD and LE approximations in this analysis.

…ntity $[\Delta v_{tot}(^{12}CO)]^2/r$ where $\Delta v_{tot}(^{12}CO)$ is the corrected FWHM line width of ^{12}CO and r is the radius as measured by the FWHM contour of …mperature is plotted vs. column density of H_2 for several types of clouds in the galaxy. The straight line is the location of points of virial … with no external pressure. Upper and lower curved lines show locations of virial equilibrium for clouds in an intercloud medium with uniform … 10^4 and 3×10^3 K cm^{-3}.

FYI...

including extragalactic data, the outer Milky Way, and the Galactic Center <u>does</u> change this picture...



Putting the inner Milky Way data (Heyer et al. 2009) into context with data from: the outer Milky Way (Heyer, Carpenter, & Snell 2001); extragalactic GMCs (Rosolowsky & Blitz 2005; Bolatto et al. 2008); and the Galactic center (Oka et al. 2001). Notice how the outer MW clouds appear much more unbound (**α**>>1) than those in the inner MW, and how very unbound the Galactic Center clouds appear (Spergel & Blitz 1992).

figure courtesy of E. Rosolowsky, reproduced from Goodman et al. 2011 NSF proposal

Theory & Semantics

The virial theorem that applies to an isolated self-gravitating isothermal spherical cloud immersed in a uniform external pressure, P_e, is (Spitzer 1978)

$$\frac{\ddot{I}}{2M} = 3\sigma^2 - \frac{\Gamma G M}{R} - \frac{4\pi P_e R^3}{M}, \quad (1)$$

What does "bound" mean?

Object will not expand (and it could collapse).

What does "pressure-confined" mean?

Cloud of gas would expand if not for external pressure.

What does "weight of the envelope" mean?

Gravity of material <u>beyond a boundary</u> pushing "down" on what's interior to the bounding surface can be thought of as external pressure... this distinction depends on surface's meaning...

cf., re: large scales....Ostriker, McKee & Leroy 2010; Ostriker & Shetty 2011; Krumholz, McKee & Tumlinson 2009...

Observations & Semantics

How can observers measure "internal" and "external" pressures?

1-D velocity dispersion & "density" are all we can offer.

What are the meanings of "internal" and "external"?

Boundary definitions are largely arbitary (and not in 3D real space), so must be clearly defined & understood.

Can we separate gravity and pressure observationally?

e.g. *what does "weight of the envelope" mean?!*

cf., Rosolowsky & Blitz 2005; Lada et al. 2008; Oka et al. 2011...

OBSERVED Pressure = $P = \rho\sigma_v^2$

density (r) is derived from column density (*N*), which is derived from CO luminosity & "X-factor" assumptions

1-D **velocity dispersion** (sv) is taken to be 2nd moment of velocity along the line of sight. (Can also assume 3D=3$^{1/2}$ sv.)

Dendrogram Refresher

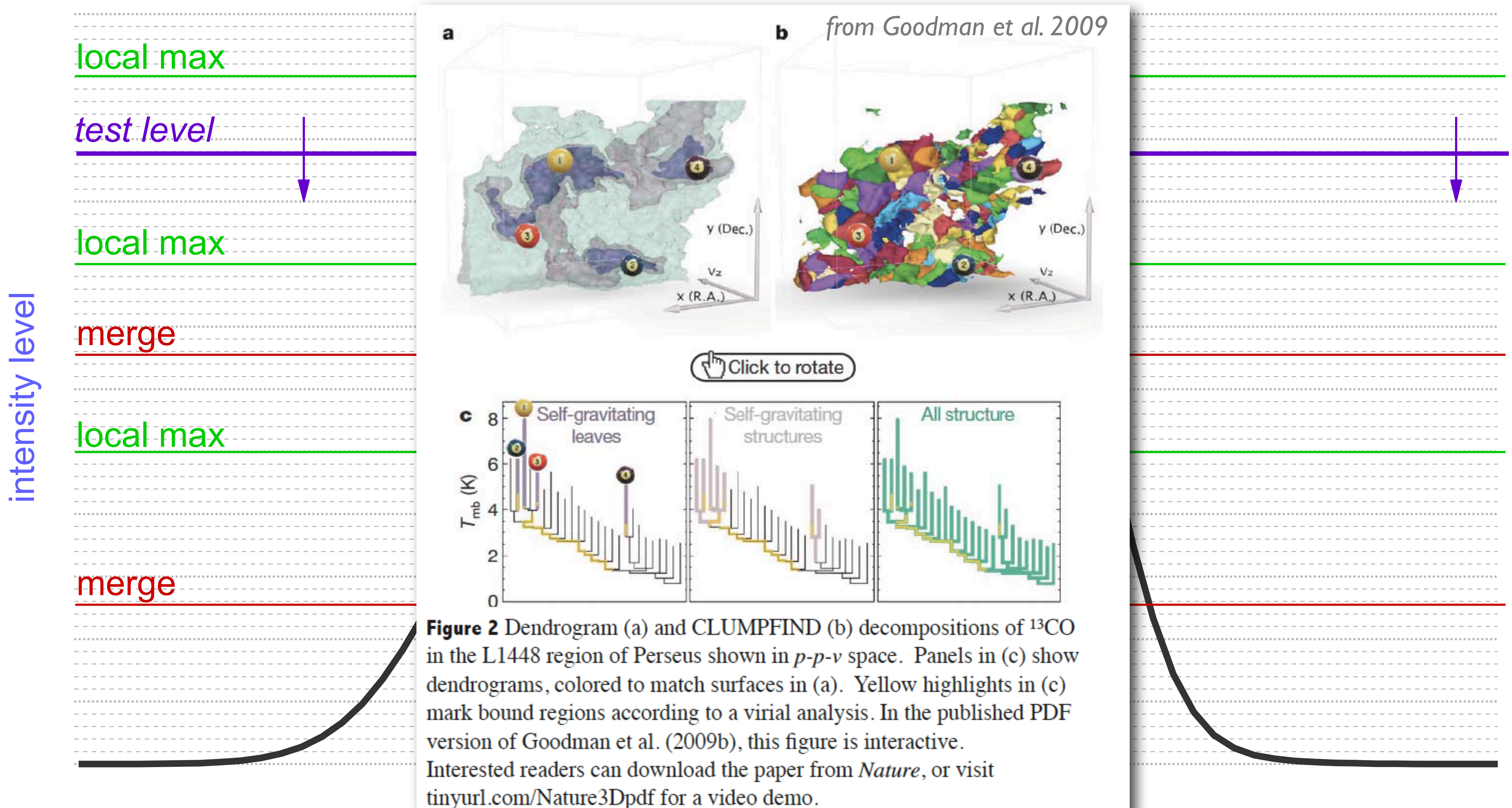


Figure 2 Dendrogram (a) and CLUMPFIND (b) decompositions of ^{13}CO in the L1448 region of Perseus shown in *p-p-v* space. Panels in (c) show dendrograms, colored to match surfaces in (a). Yellow highlights in (c) mark bound regions according to a virial analysis. In the published PDF version of Goodman et al. (2009b), this figure is interactive. Interested readers can download the paper from *Nature*, or visit tinyurl.com/Nature3Dpdf for a video demo.

Hierarchical "Segmentation"

Rosolowsky, Pineda, Kauffmann & Goodman 2008

How **real** are *p-p-v* clumps (& boundaries!) in real (*p-p-p*) space?

THE ASTROPHYSICAL JOURNAL, 570:734–748, 2002 May 10

PHYSICAL VERSUS OBSERVATIONAL PROPERTIES OF CLOUDS IN TURBULENT MOLECULAR CLOUD MODELS

J
Department of Astrophysic

We examine the quest
be determined by measu
tions of three-dimensio
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Subject headings: ISM: c

Mon. Not. R. Astron. Soc. **391,** 1091–1099 (2008) doi:10.1111/j.1365-2966.2008.13970.x

The structure of molecular clouds and the universality of the clump mass function

Rowan J. Smith,[1★] Pa
[1] *Scottish Universities Physics Allianc*
[2] *Zentrum für Astronomie der Universi*

Accepted 2008 September 16. Receive

THE ASTROPHYSICAL JOURNAL, 712:1049–1056, 2010 April 1 doi:10.1088/0004-637X/712/2/1049

THE EFFECT OF PROJECTION ON DERIVED MASS–SIZE AND LINEWIDTH–SIZE RELATIONSHIPS

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[4] University of British Columbia Okanagan, 3333 Univers
Received 2009 September 23; accepted 2010 Janu

ABSTRACT

Power-law mass–size and linewidth–size correlations, two of "
namical state of clumps within molecular clouds. Using the r
cloud, we investigate how geometric projection may affect the d
structures in the column density map have similar masses and
(position–position–position, PPP). Smaller scale clumps in the
sive than the PPP clumps, due to the projection of all emitting
effects, structures in a synthetic spectral observation (position
relate with physical structures in the simulation. In considerin
relationship in the PPV cube is appreciably different from that
pressure in the simulated line widths imposes a minimum line
slopes of the linewidth–size relationships, though there are still
scatter. Employing commonly used assumptions in a virial an
parameters of the structures in the PPV and PPP cubes. Howeve
mass–size relationships in the PPP and PPV cubes, we caution th
be misleading due to geometric projection effects. We specula
kinetic and gravitational pressure would be required for accurate
with highly filamentary structure, are bound.

Key words: ISM: clouds – ISM: structure – methods: analytical
Online-only material: color figures

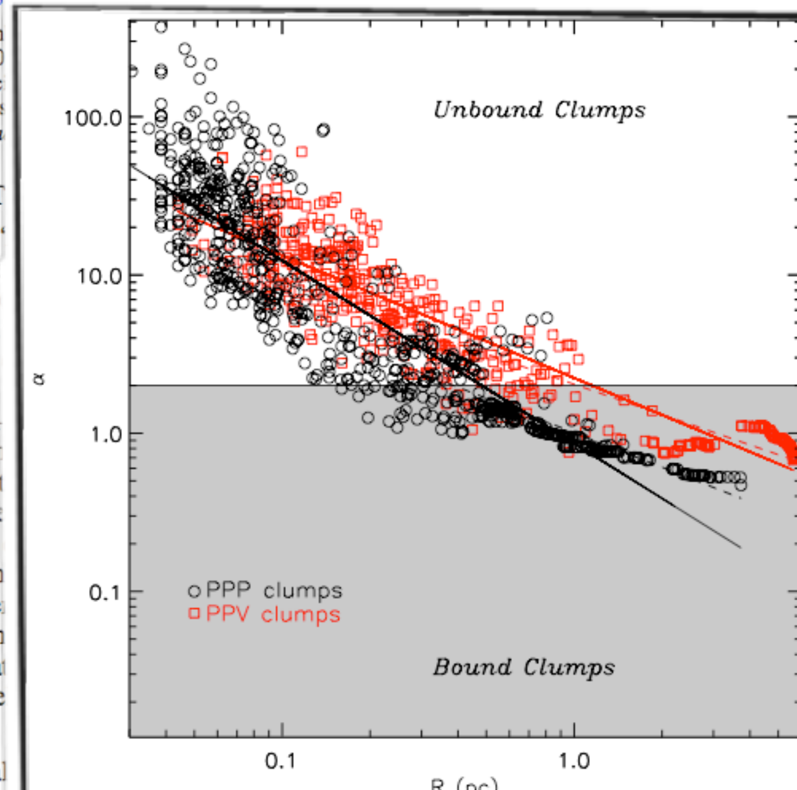
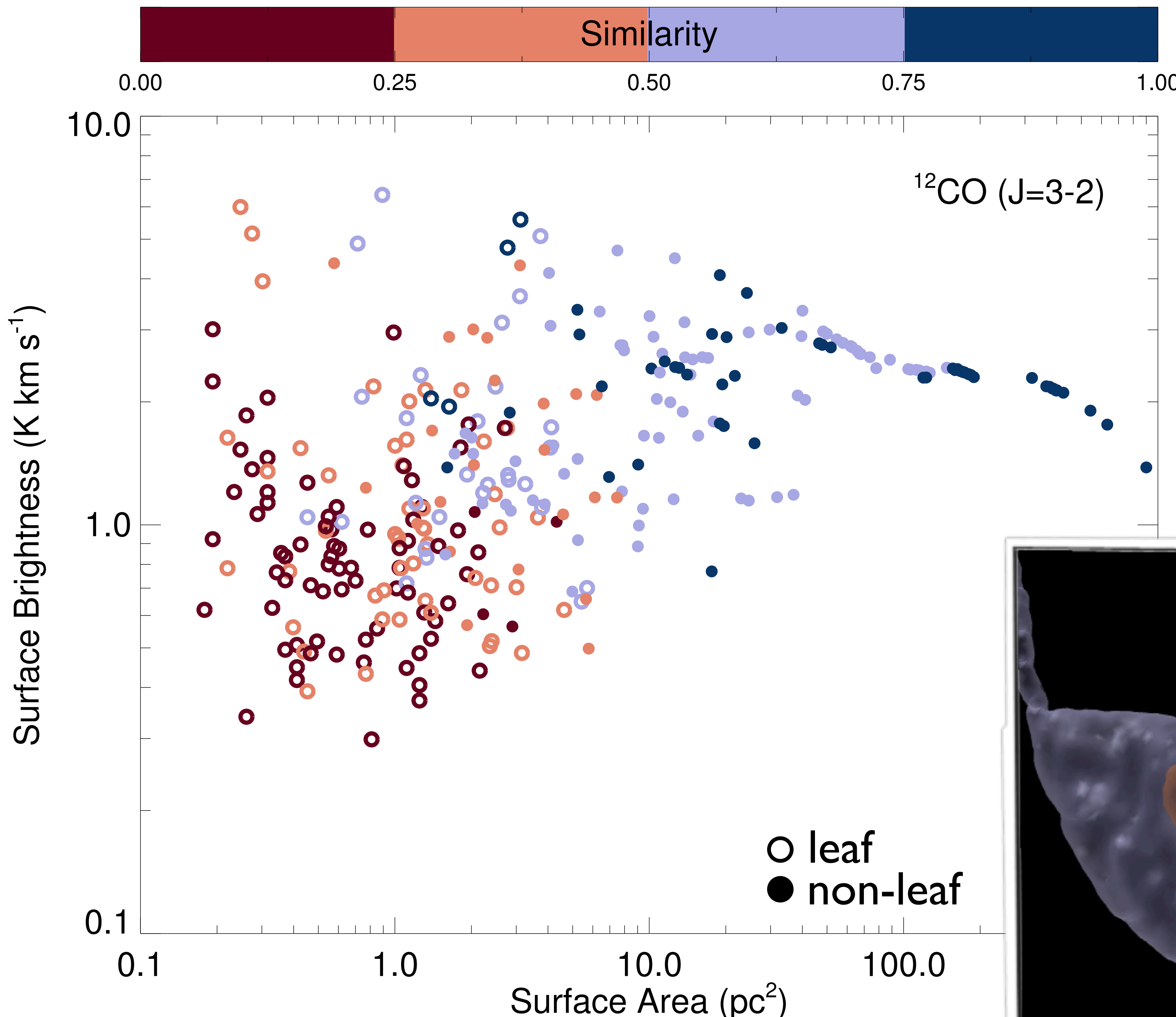
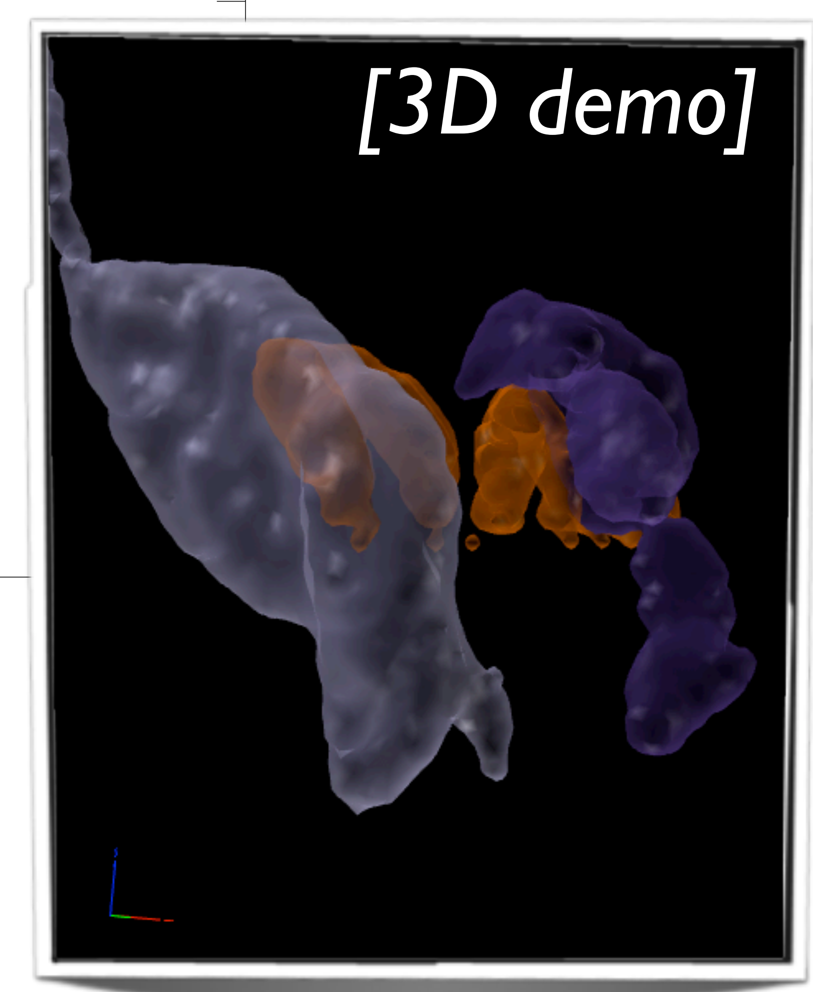


Figure 5. Virial parameter (α)–size relation for clumps found in the 3D simulation (circles) and synthetic PPV cube (squares). Best-fit lines are also shown, with slopes of −1.1 and −0.8 for the 3D simulation and the PPV clumps, respectively. Horizontal line shows $\alpha = 2$, indicating virialized clumps.

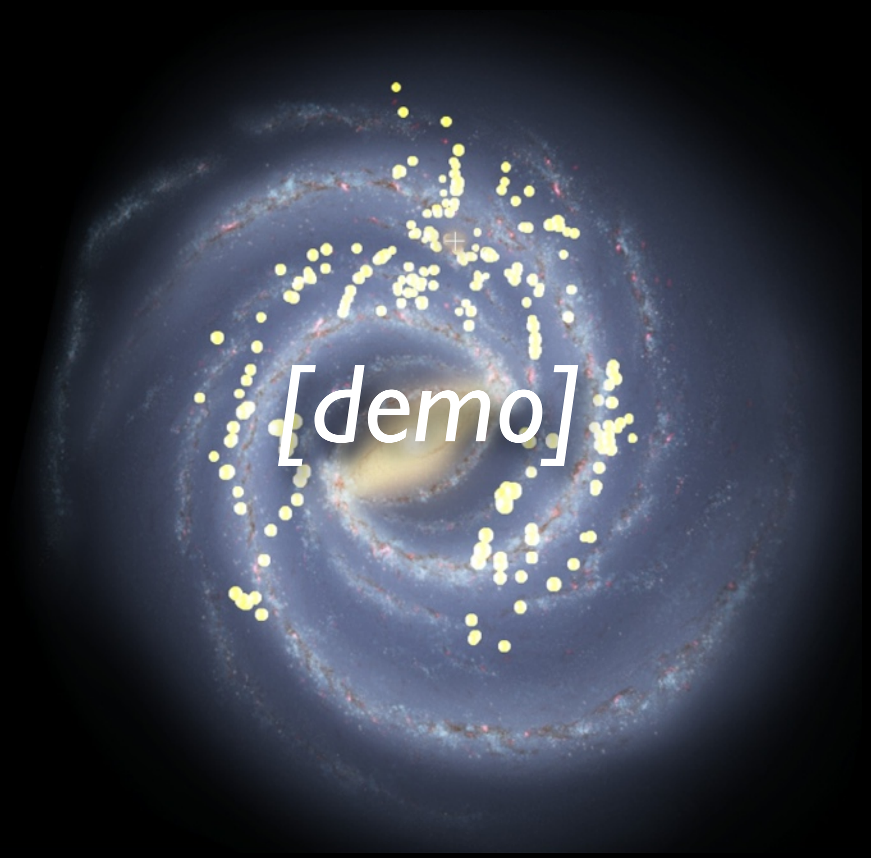
Dendrogram-based *p-p-v* to *p-p-p* "reality" measures



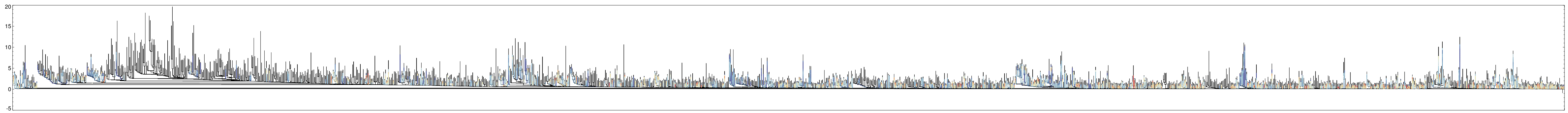


Beaumont, Offner & Goodman 2012, in prep. (uses simulated CO(3-2))

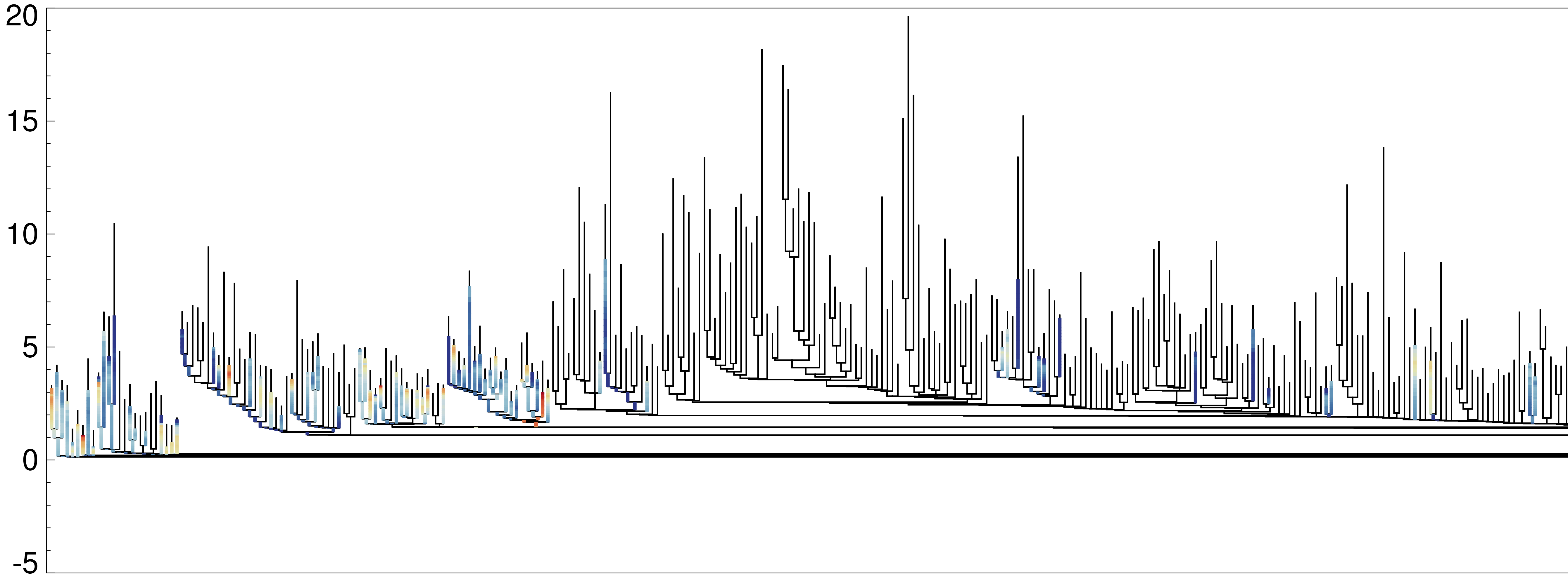
Pressure Structure of Milky Way Clouds



[2012 Harvard Senior Thesis of Tom Rice, using Dame 2011 CO data & Reid model of Milky Way]

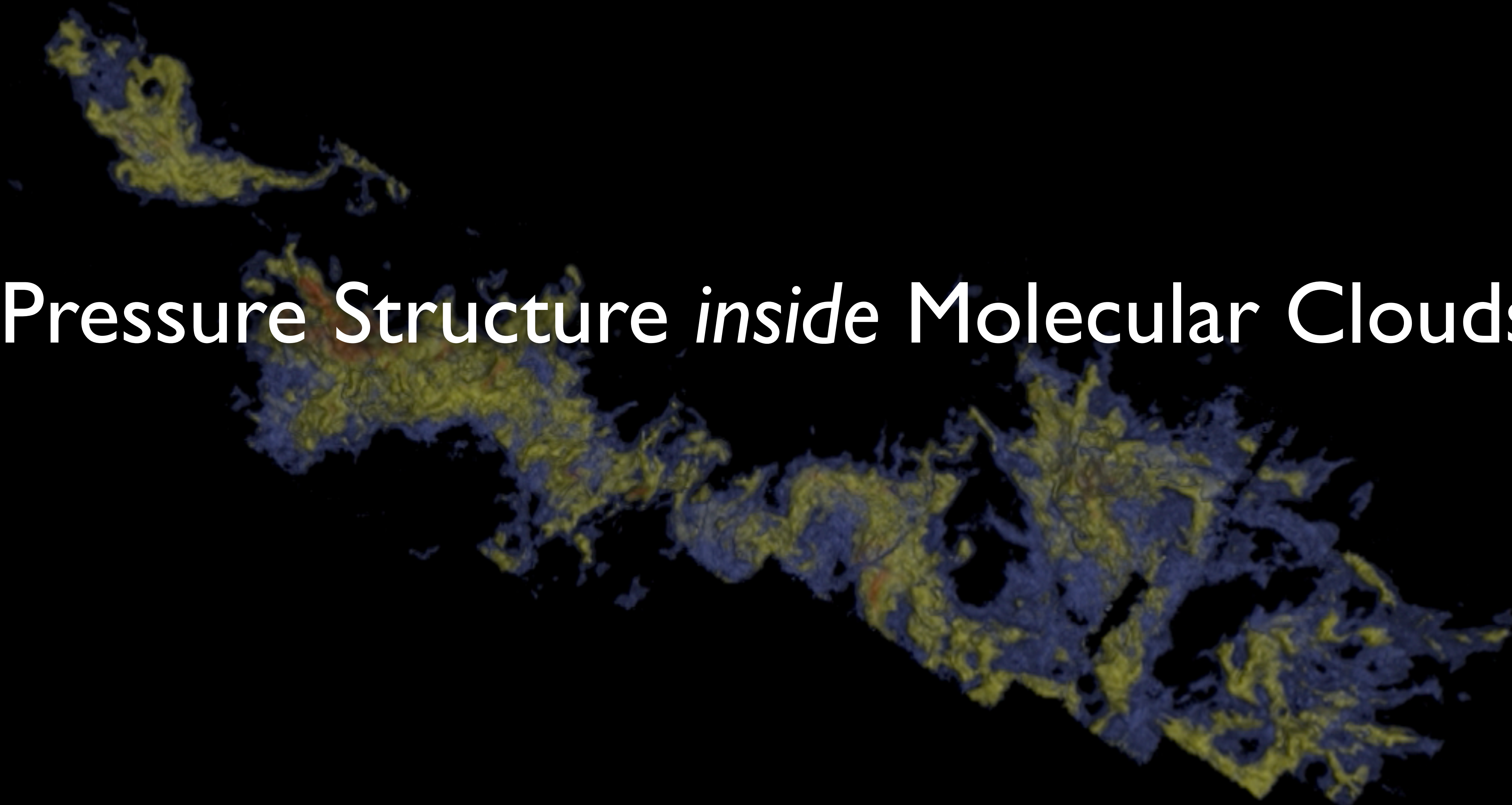


Pressure Structure of Milky Way Clouds

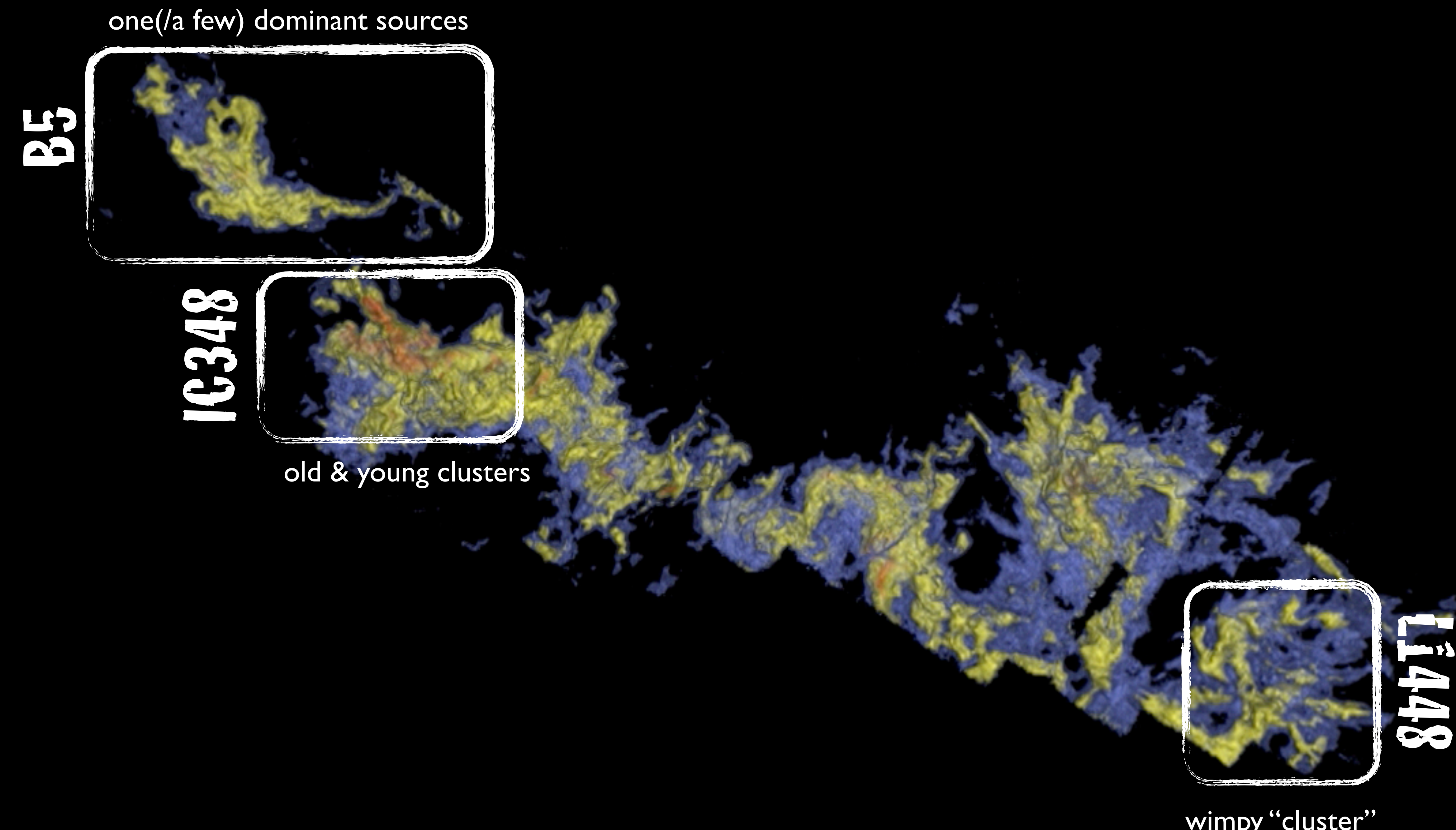


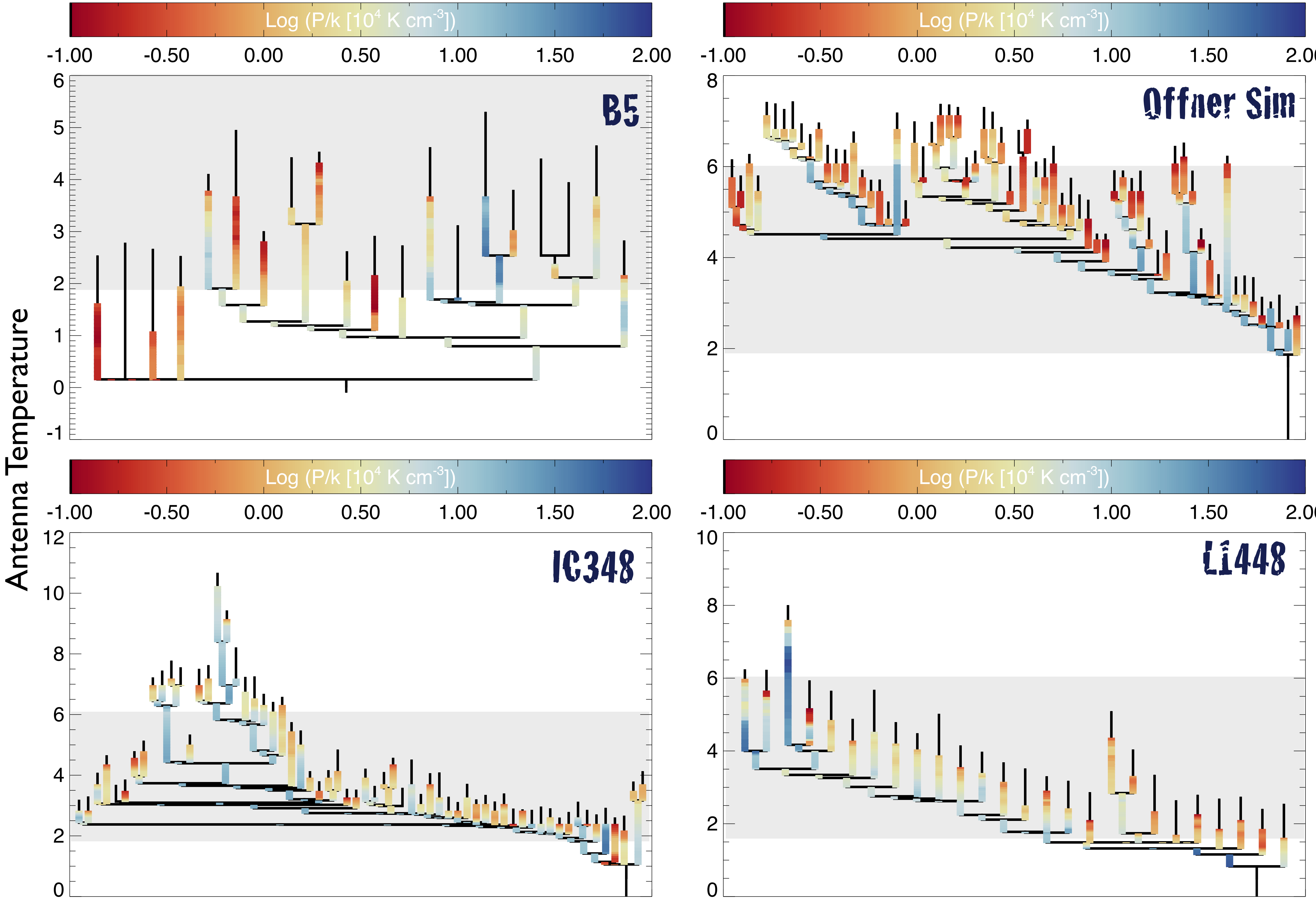
Goodman, Beaumont, Dame, Offner, Rice, Rosolowsky et al. 2012, in prep
(includes distance estimates & correlation with dust & star-formation tracers)

Pressure Structure *inside* Molecular Clouds



Regions (approximately)



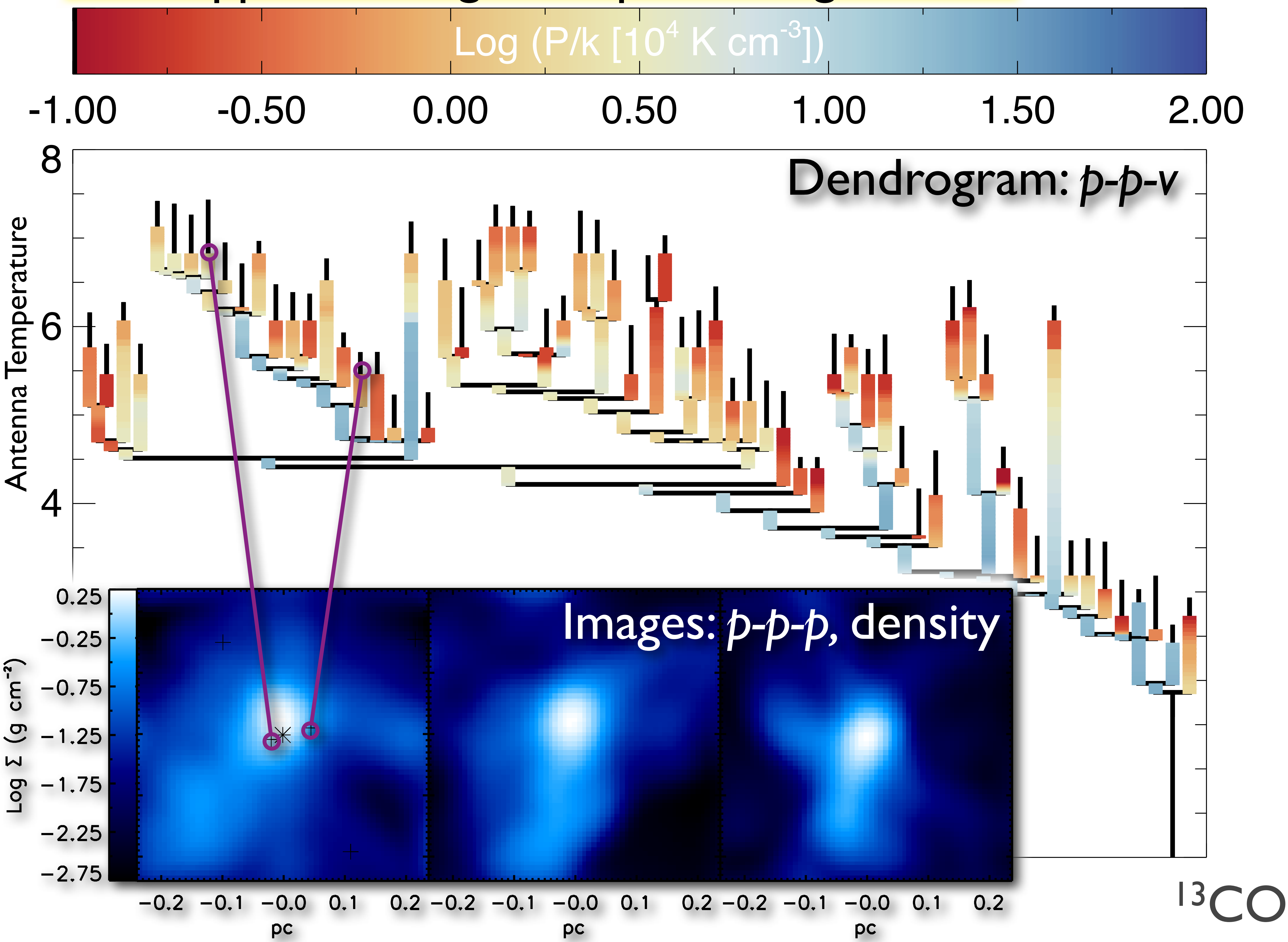


"Pressure" according to ^{13}CO

Faesi, Beaumont, Offner, Goodman 2012, in prep

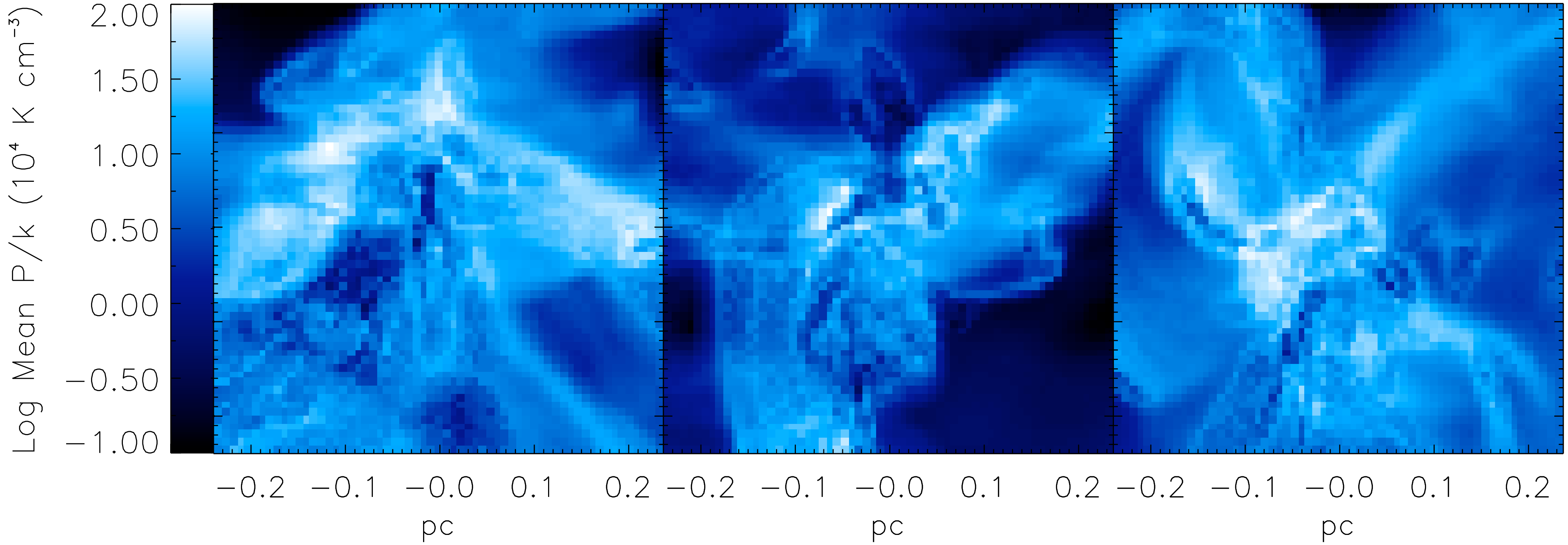
Note apparent "negative" pressure gradients!

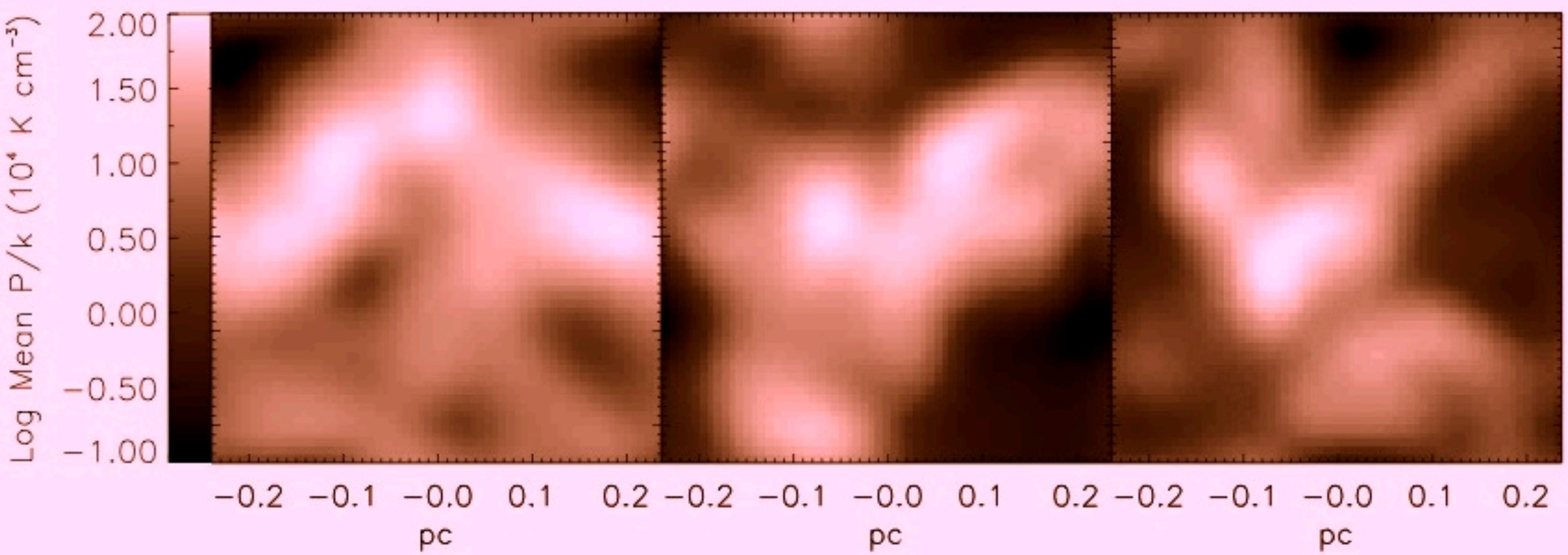
Offner Sim



Offner Sim

Pressure

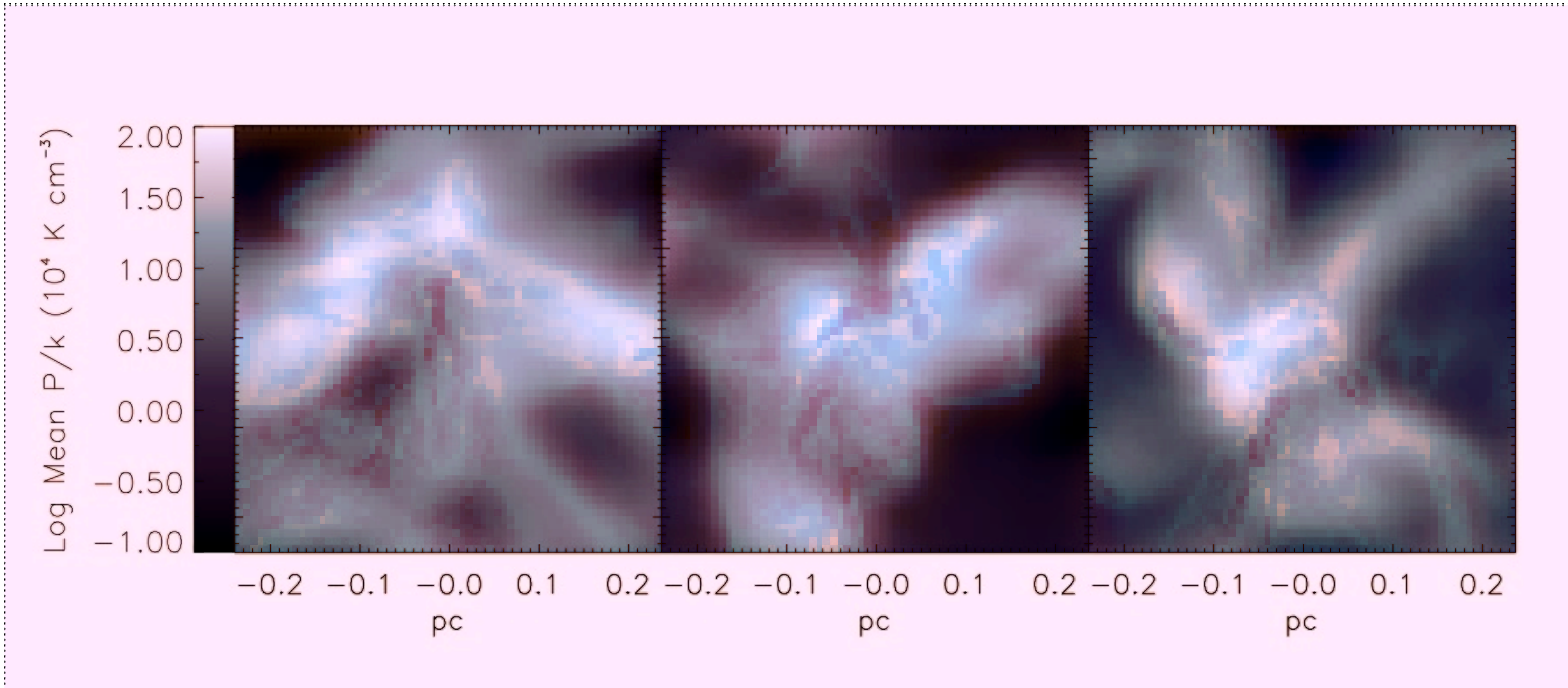




^{13}CO

Offner Sim

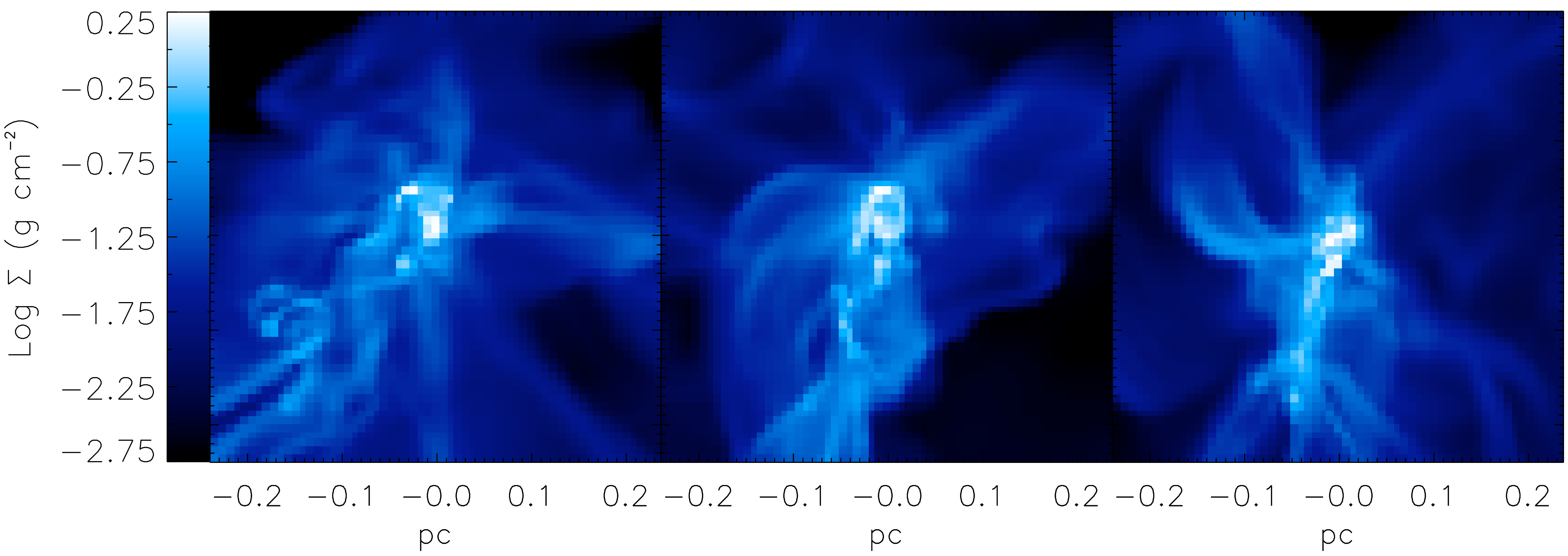
Pressure

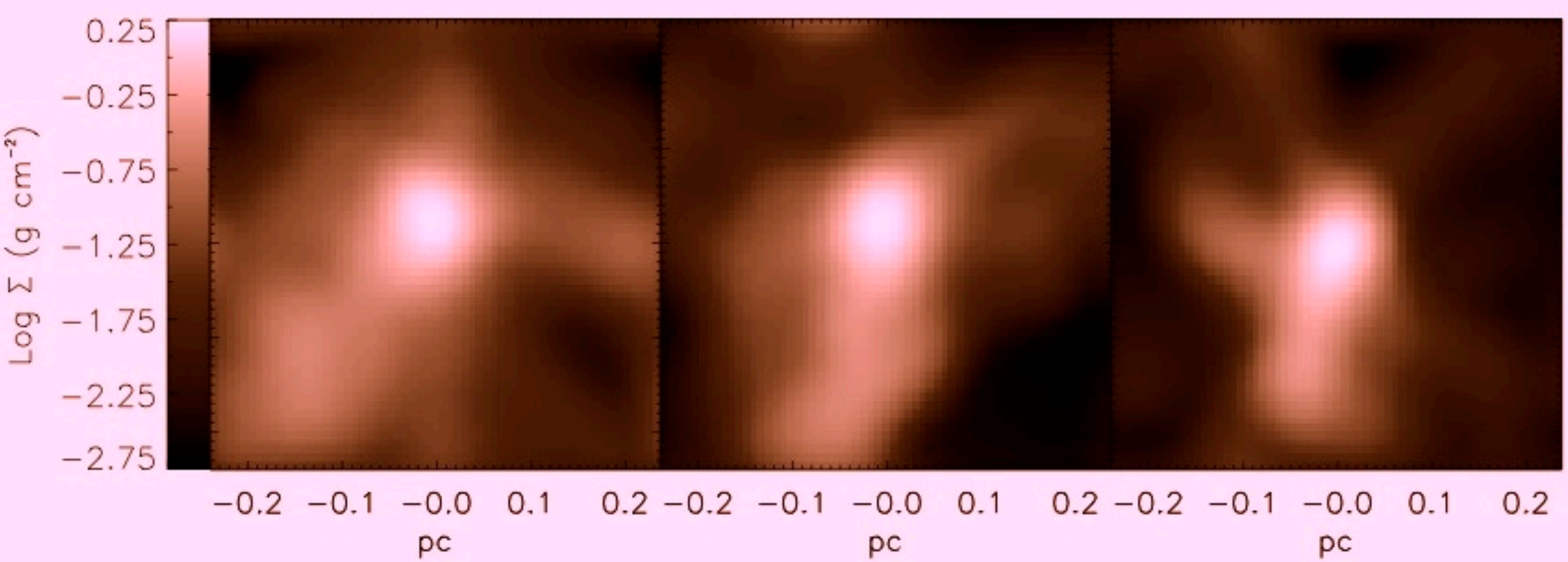


^{13}CO

Offner Sim

Column Density

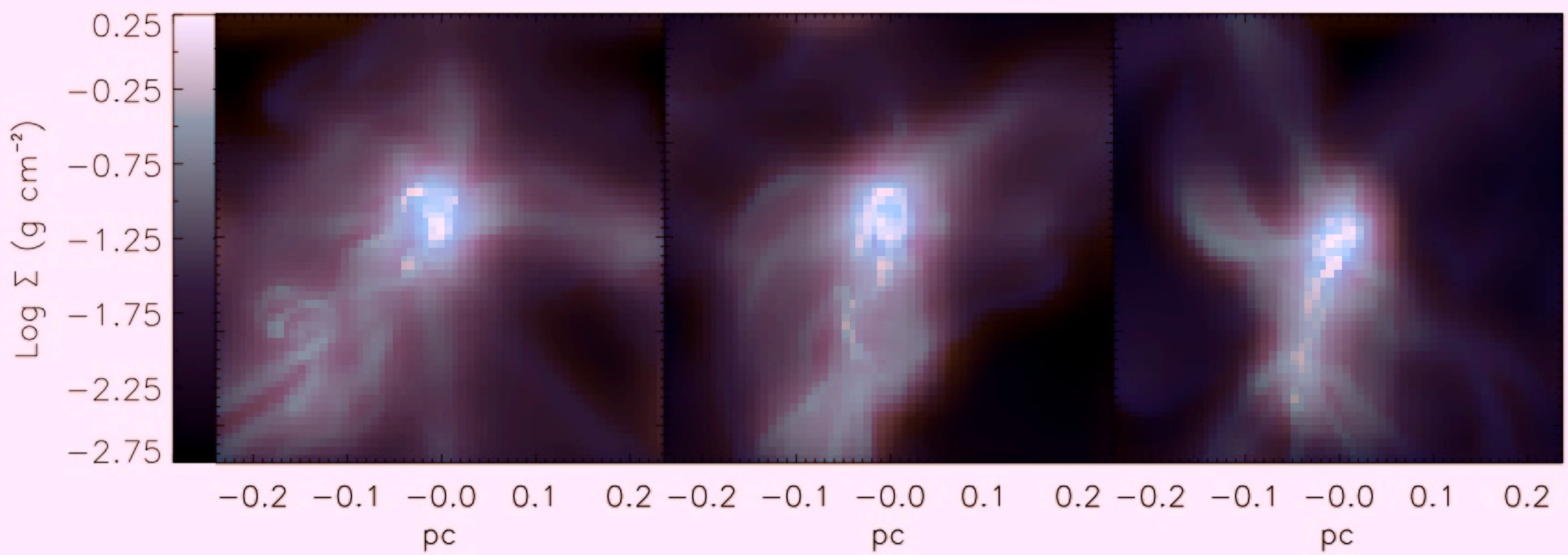




^{13}CO

Offner Sim

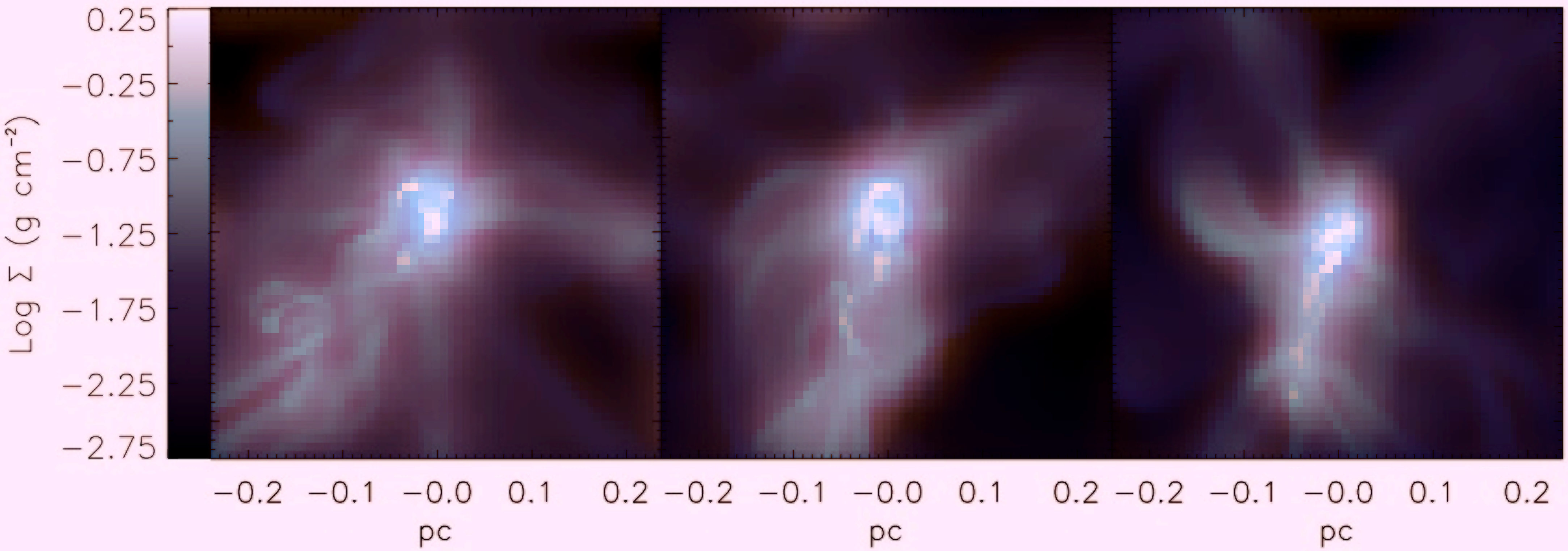
Column Density



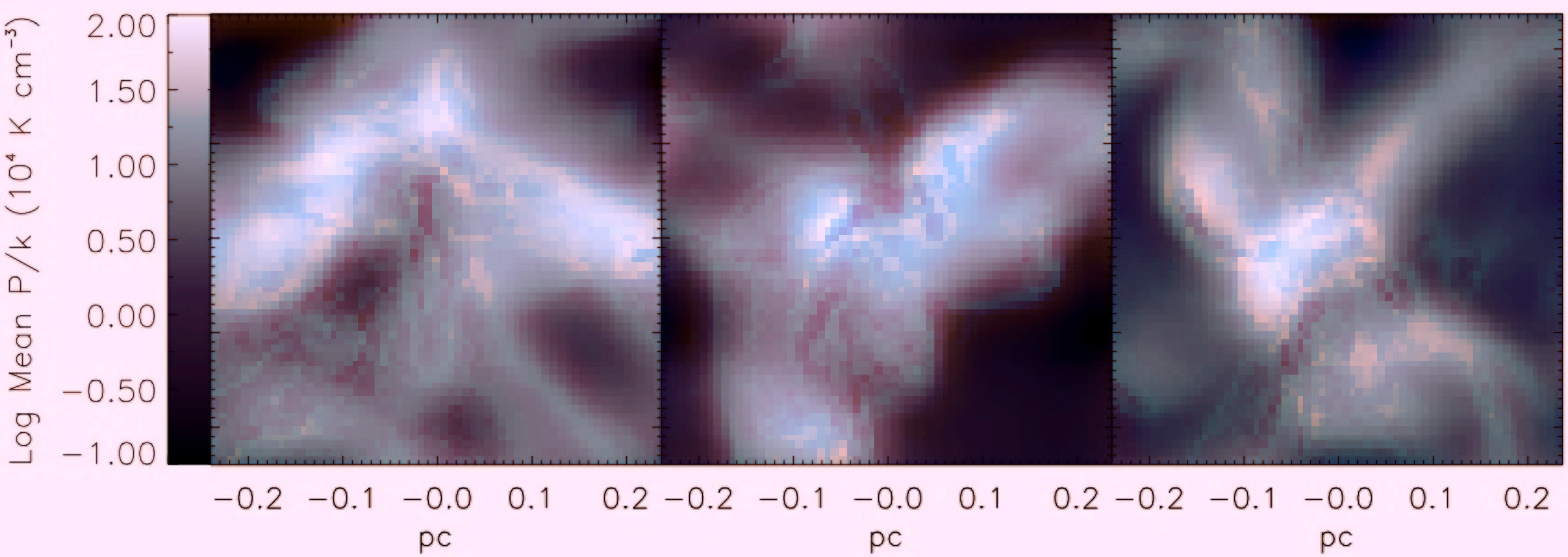
^{13}CO

Offner Sim

Column Density



Pressure

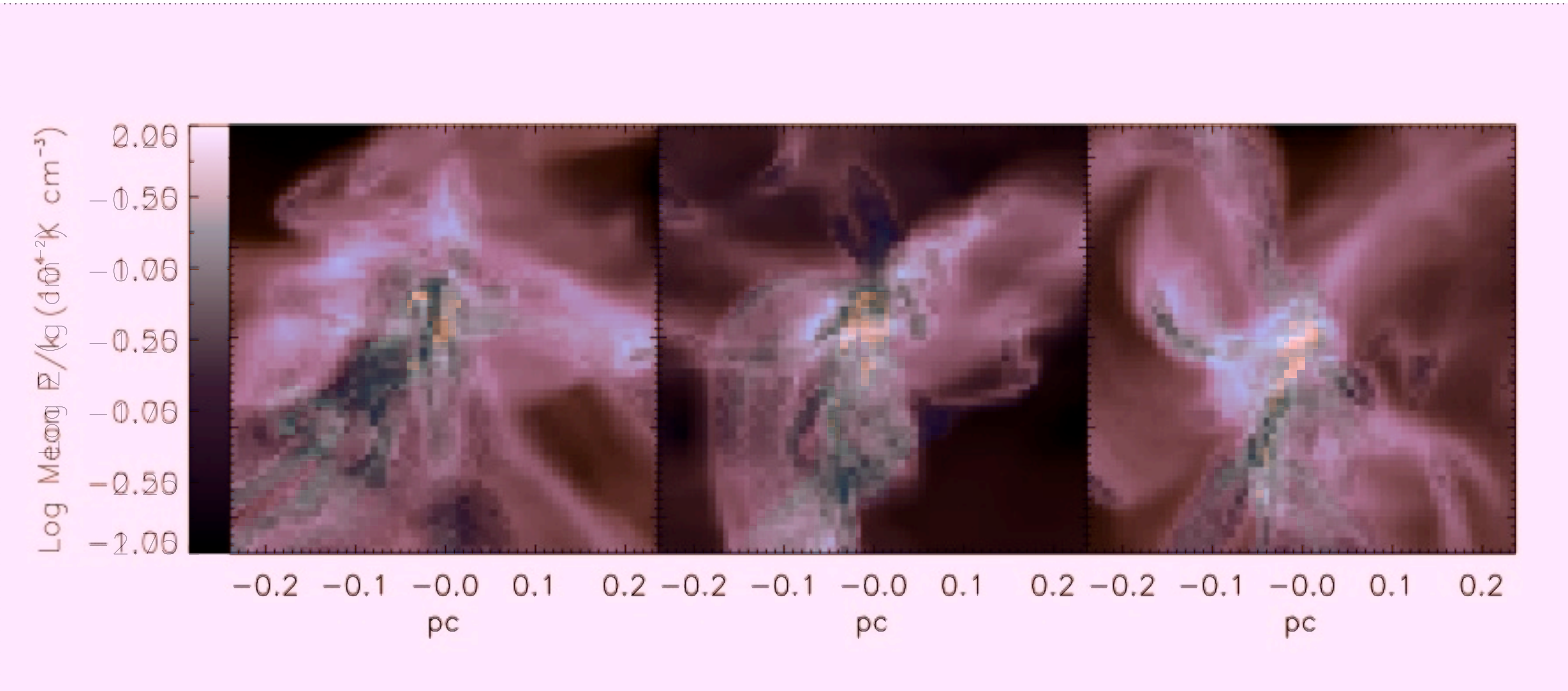


^{13}CO

Offner Sim

Pressure
(full res)

Column Density
(full res)

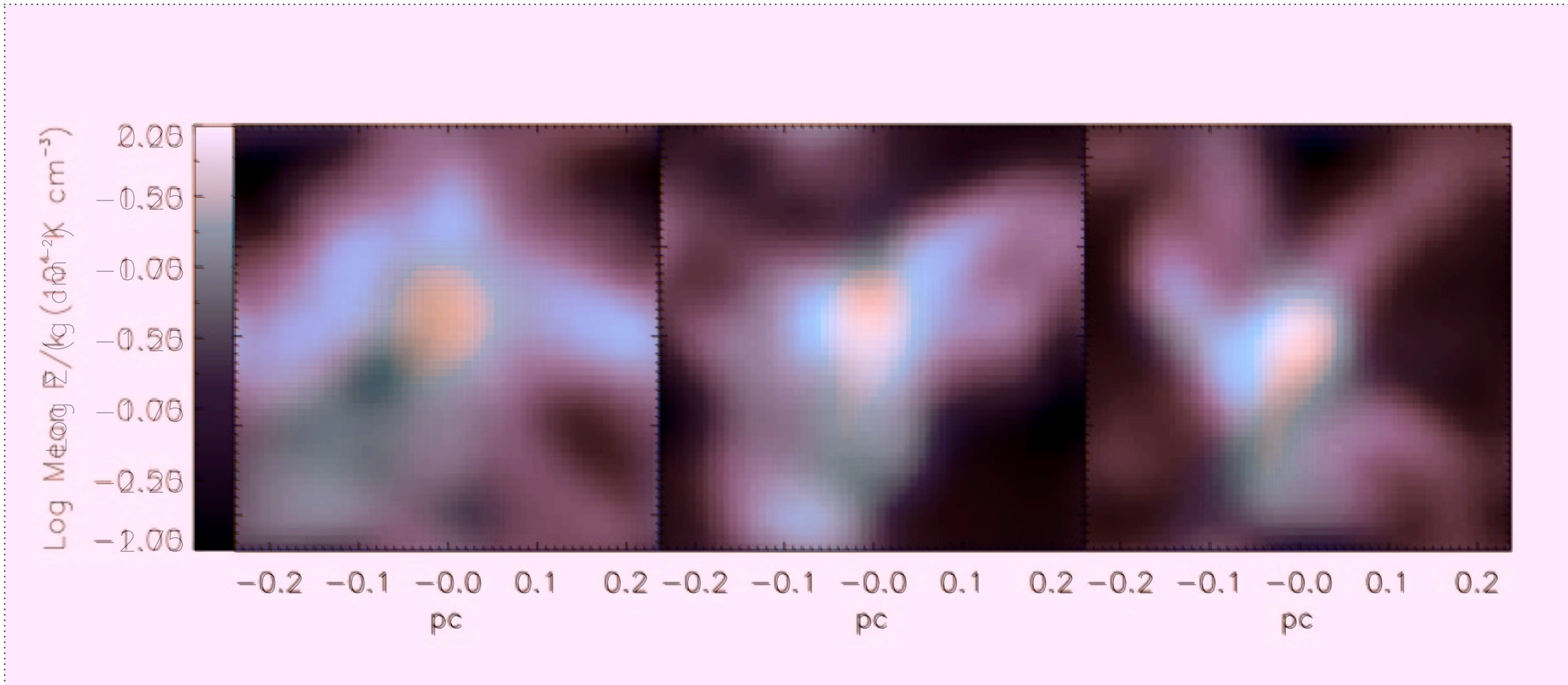


^{13}CO

Offner Sim

Pressure
(low res)

Column Density
(low res)

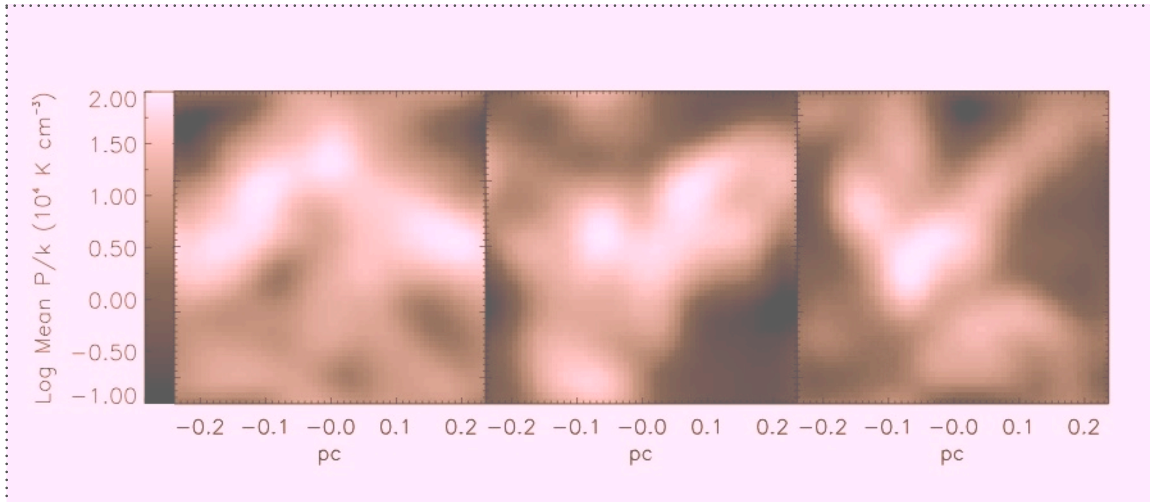


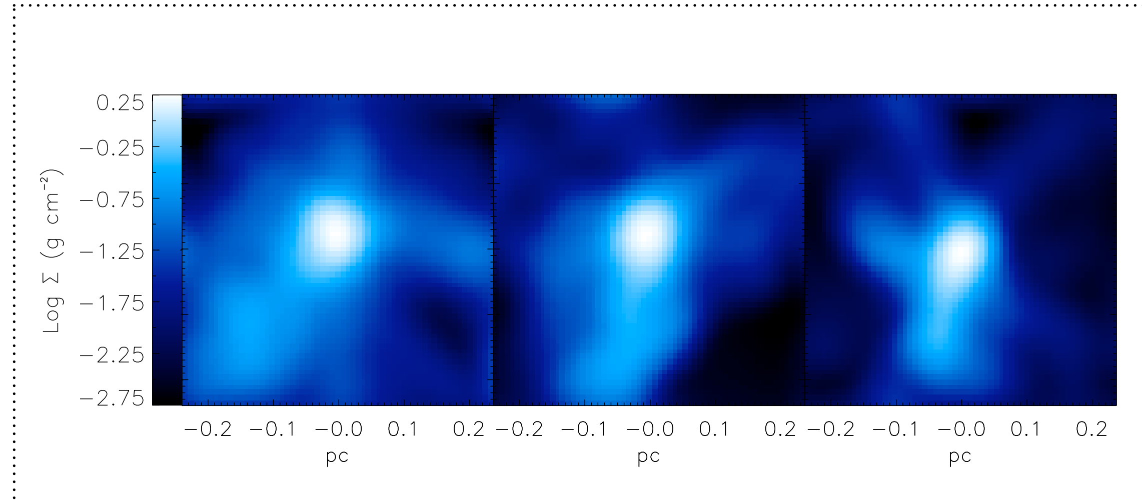
^{13}CO

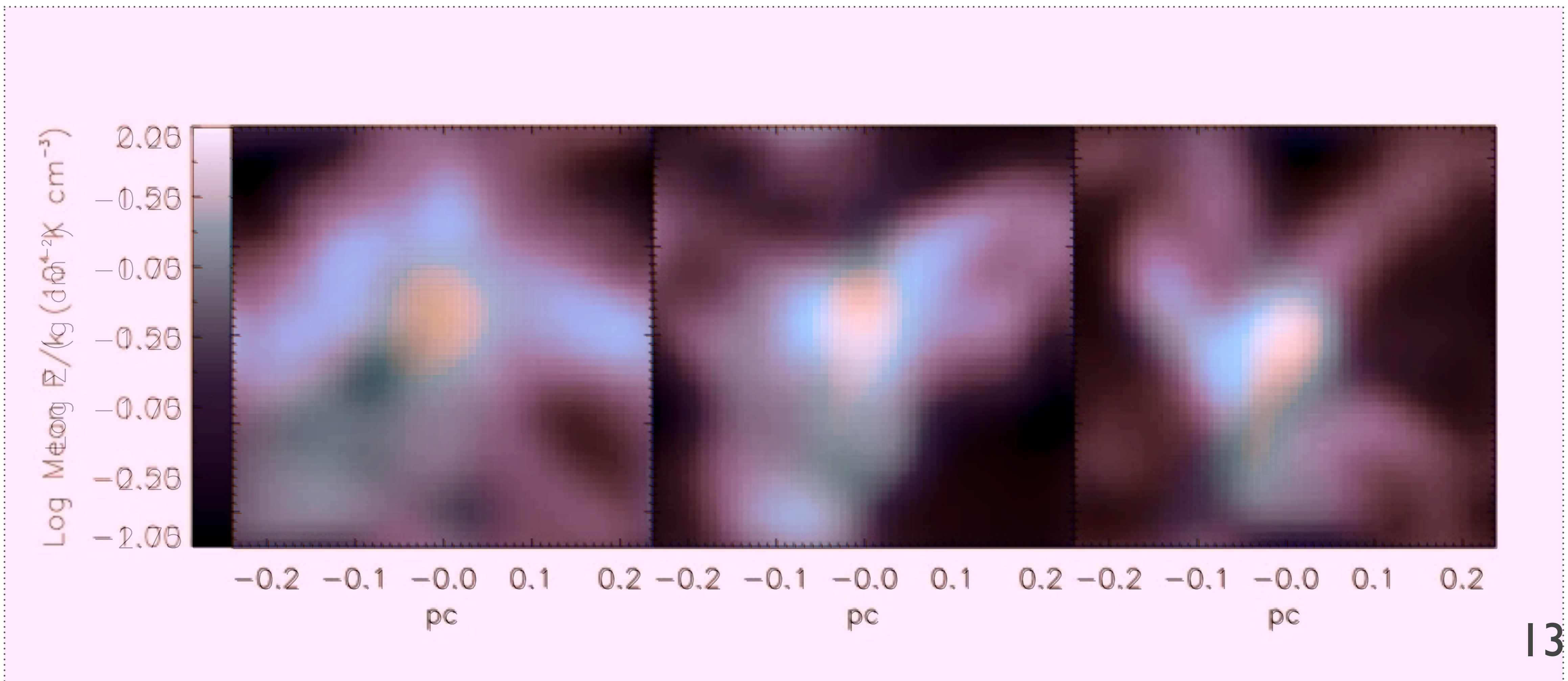
Offner Sim

Pressure
(low res)

Column Density
(low res)



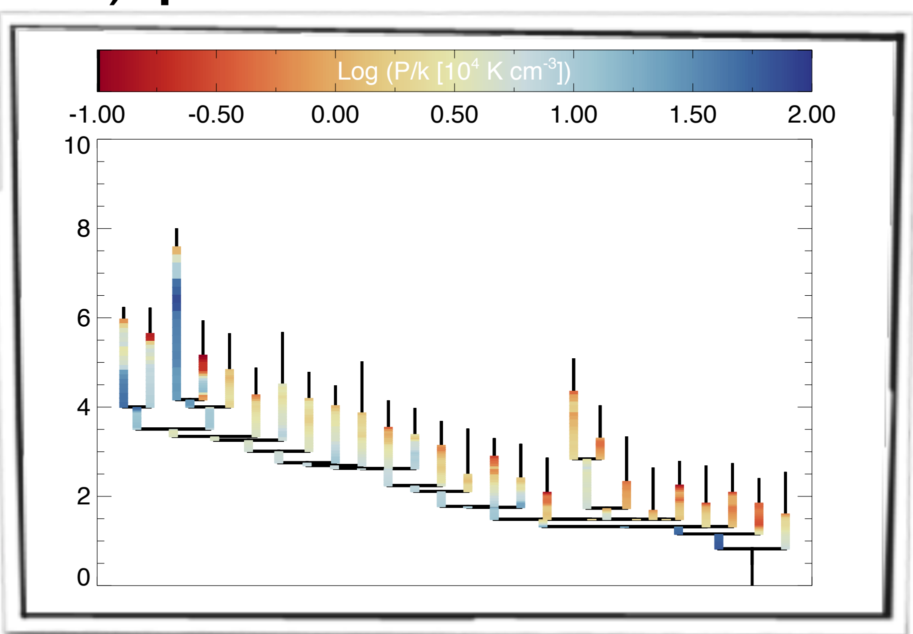




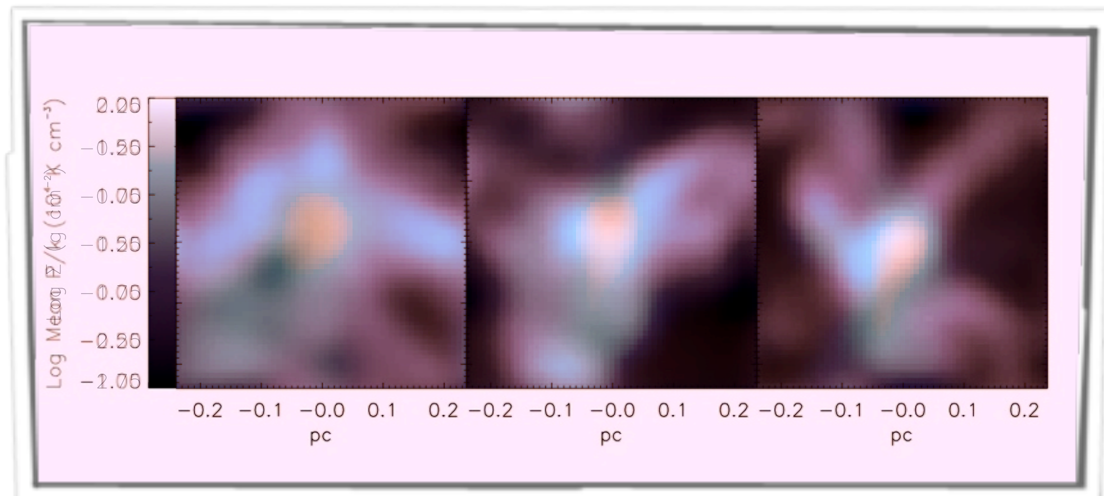
^{13}CO

To remember under pressure...

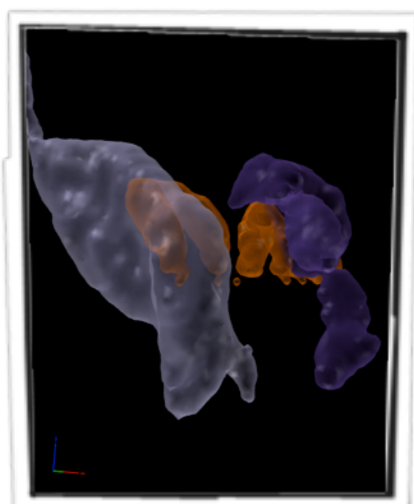
We can *measure* (proxies for) pressure "structure."



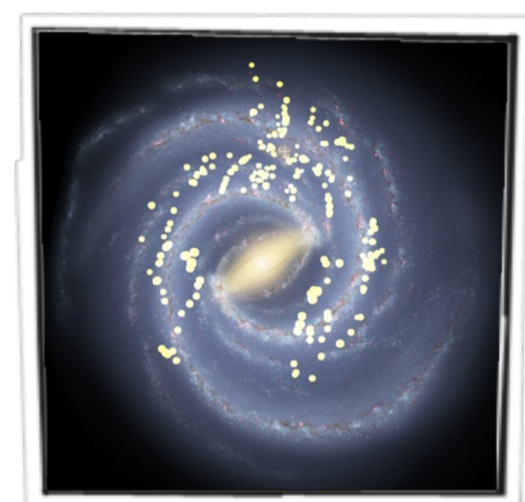
Simulated observations to calculate "theoretical" pressure proxies are proving key.



Equilibrium formulations (e.g. SVE, PVE) may not apply, and many *p-p-v* structures should not be interpreted as real in *p-p-p*.



A hierarchical catalog of Milky Way clouds & properties will soon be found at UNIVERSE3D.org



More discussion...

Are there "critical" pressure-boundaries? (a la Chieze '87)

On what scale is it relevant to think of an equation of state, P(r, T)?

Can we really separate "internal" and "external" pressure? (Enrique, Eric, Chris...?)

UNIVERSE3D.org

&

"The Proposal that Nobody Read"

(a warning about the NSF for Americans)

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 11-1 **NSF 05-608** **11/15/11**	FOR NSF USE ONLY
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NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
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CO-PI/PD **Erik W Rosolowsky**	PhD	2005	250-807-9623	erik.rosolowsky@ubc.ca

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TITLE OF PROPOSED PROJECT **The Hierarchical Structure of Star-Forming Regions in the Milky Way**