While I keep you from this,

I will tell you about this.

+ please see this .

THE ASTROPHYSICAL JOURNAL, 777:173 (20pp), 2013 November 10 doi:10.1088/0004-637X/777/2/173

QUANTIFYING OBSERVATIONAL PROJECTION EFFECTS USING MOLECULAR CLOUD SIMULATIONS

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ABSTRACT

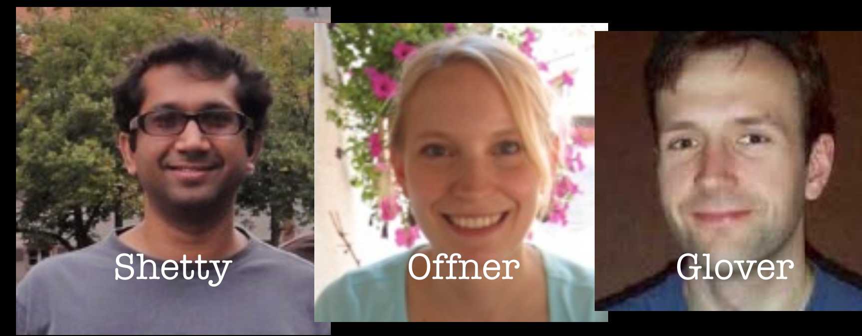
The physical properties of molecular clouds are often measured using spectral-line observations, which provide the only probes of the clouds' velocity structure. It is hard, though, to assess whether and to what extent intensity features in position–position–velocity (PPV) space correspond to "real" density structures in position–position–position (PPP) space. In this paper, we create synthetic molecular cloud spectral-line maps of simulated molecular clouds, and present a new technique for measuring the reality of individual PPV structures. Using a dendrogram algorithm, we identify hierarchical structures in both PPP and PPV space. Our procedure projects density structures identified in PPP space into corresponding intensity structures in PPV space and then measures the geometric overlap of the projected structures with structures identified from the synthetic observation. The fractional overlap between a PPP and PPV structure quantifies how well the synthetic observation recovers information about the three-dimensional structure. Applying this machinery to a set of synthetic observations of CO isotopes, we measure how well spectral-line measurements recover mass, size, velocity dispersion, and virial parameter for a simulated star-forming region. By disabling various steps of our analysis, we investigate how much opacity, chemistry, and gravity affect measurements of physical properties extracted from PPV cubes. For the simulations used here, which offer a decent, but not perfect, match to the properties of a star-forming region like Perseus, our results suggest that superposition induces a ~40% uncertainty in masses, sizes, and velocity dispersions derived from ^{13}CO ($J = 1$–0). As would be expected, superposition and confusion is worst in regions where the filling factor of emitting material is large. The virial parameter is most affected by superposition, such that estimates of the virial parameter derived from PPV and PPP information typically disagree by a factor of ~2. This uncertainty makes it particularly difficult to judge whether gravitational or kinetic energy dominate a given region, since the majority of virial parameter measurements fall within a factor of two of the equipartition level $\alpha \sim 2$.

Key words: ISM: clouds – radiative transfer – techniques: image processing – techniques: spectroscopic

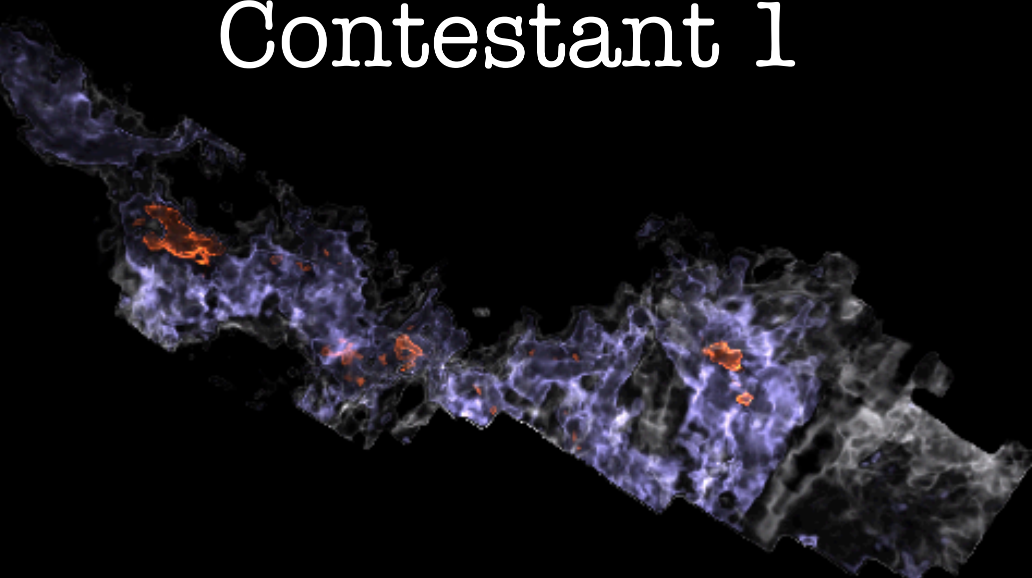
Online-only material: color figures

Will the Real Universe Please Stand Up?

Alyssa A. Goodman
Harvard-Smithsonian Center for Astrophysics



Contestant 1



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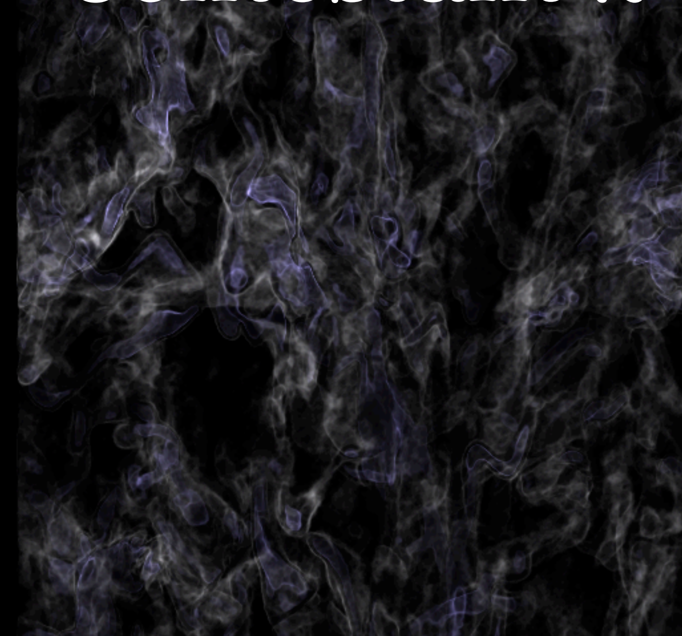

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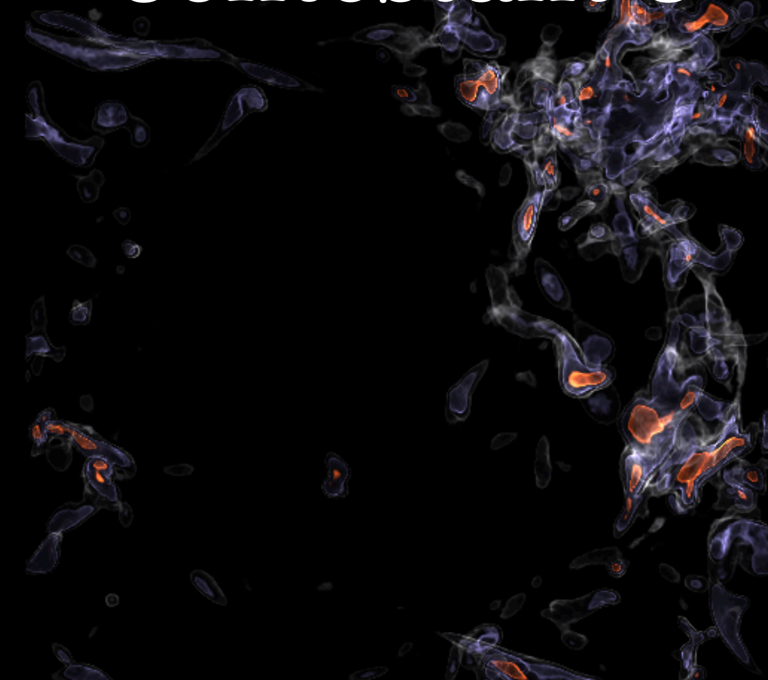
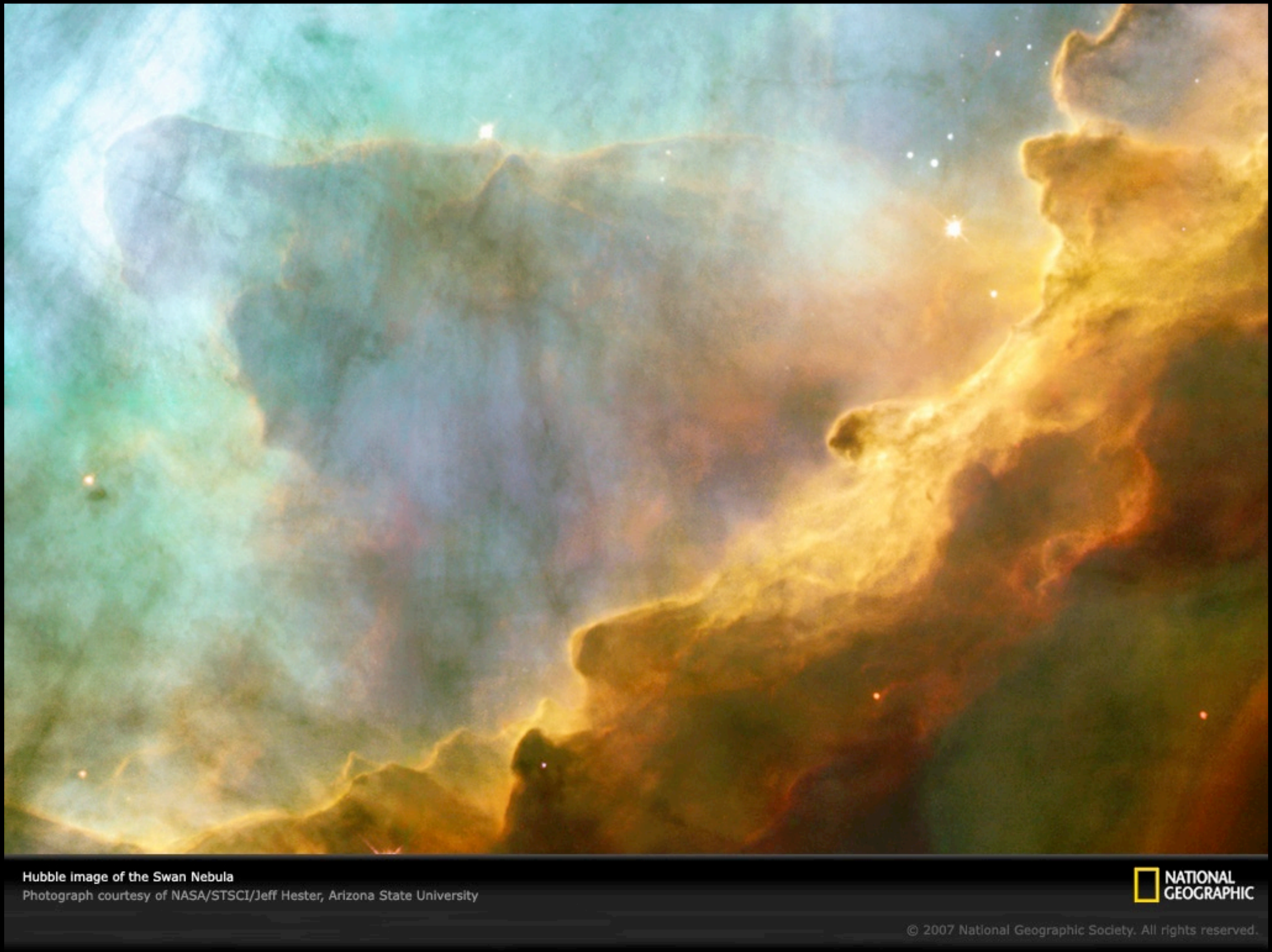


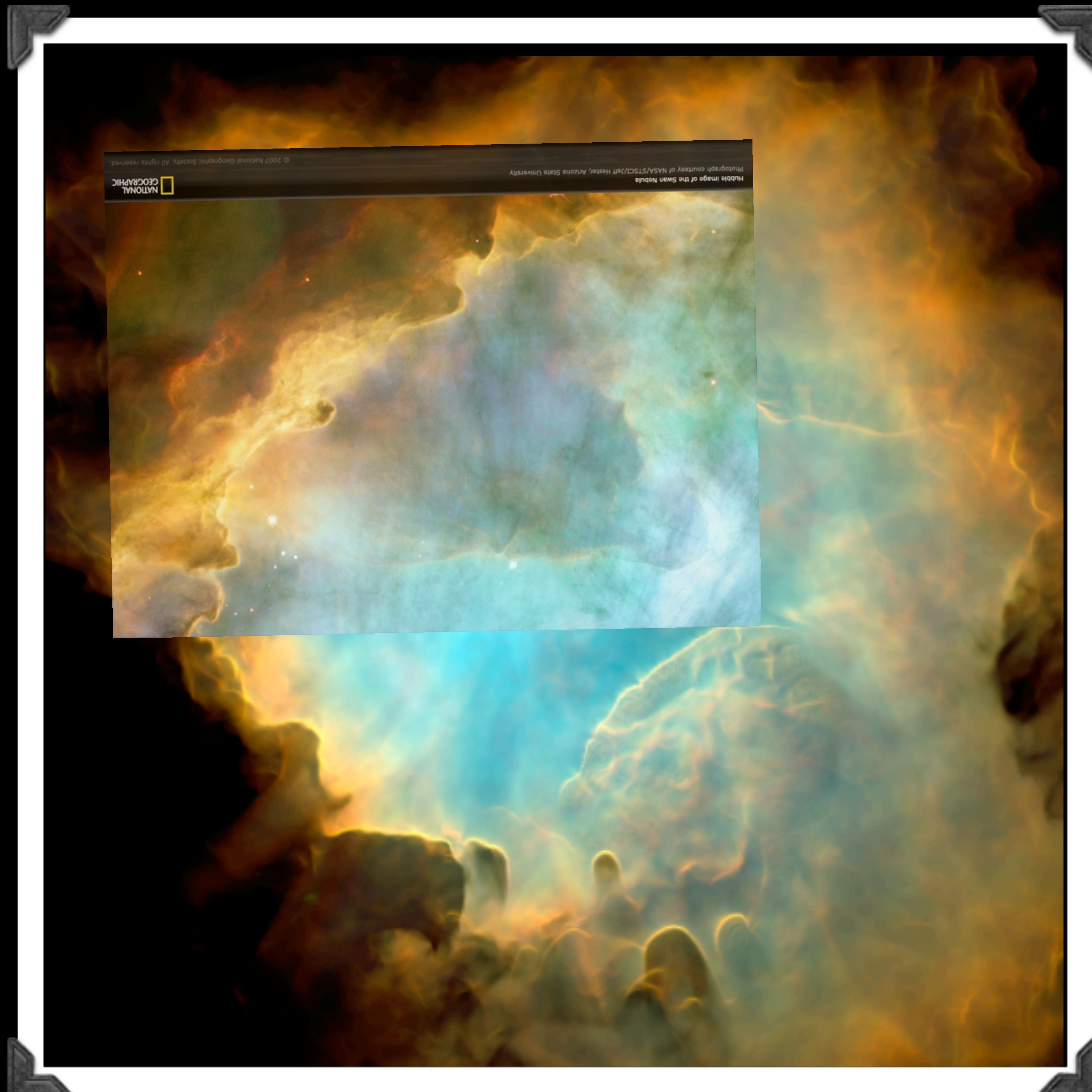
The "Real" M17



HST [OIII], Hα and [NII] emission-line image from Hester et al.

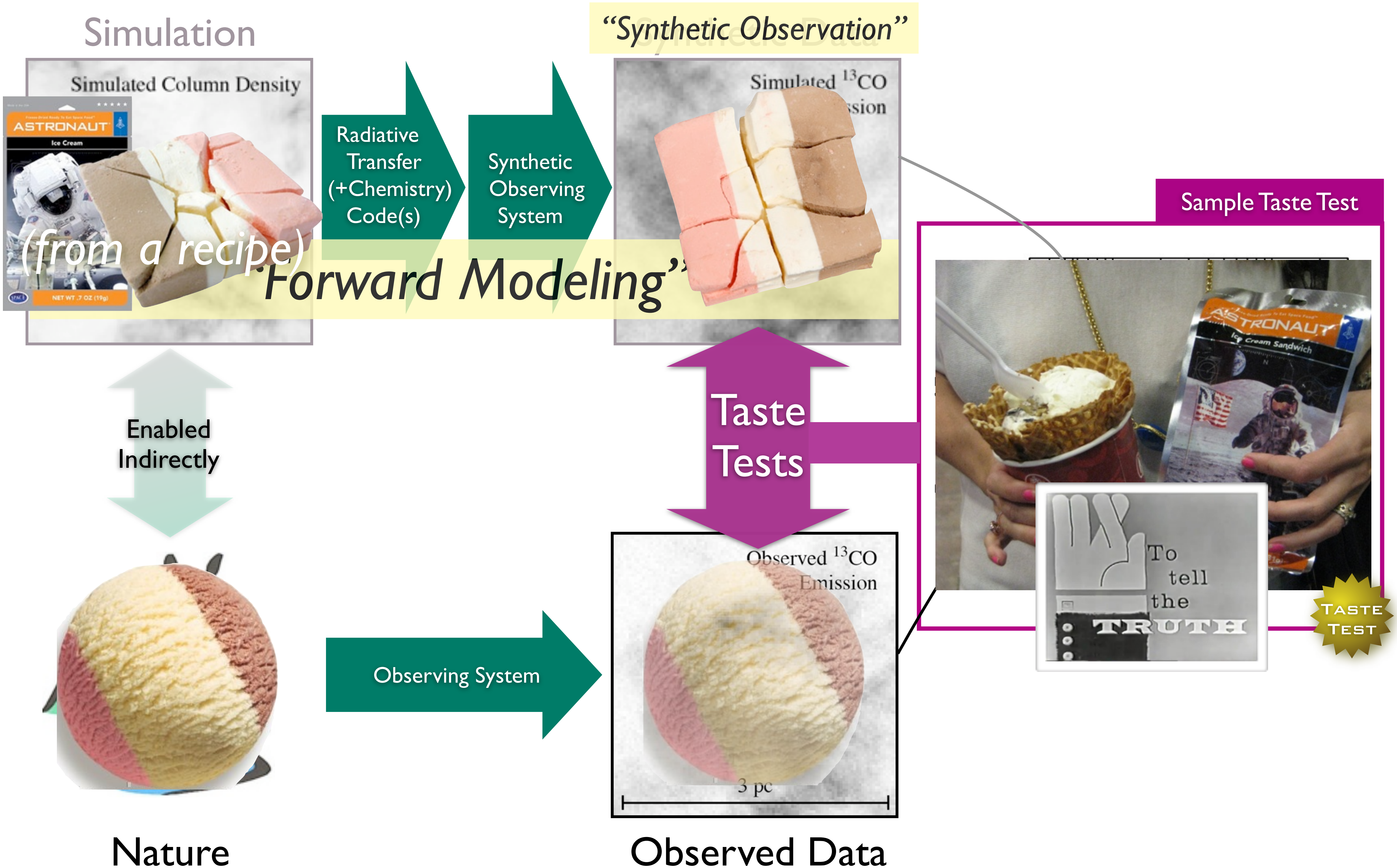
FANTASTIC! How do we “Taste” it?

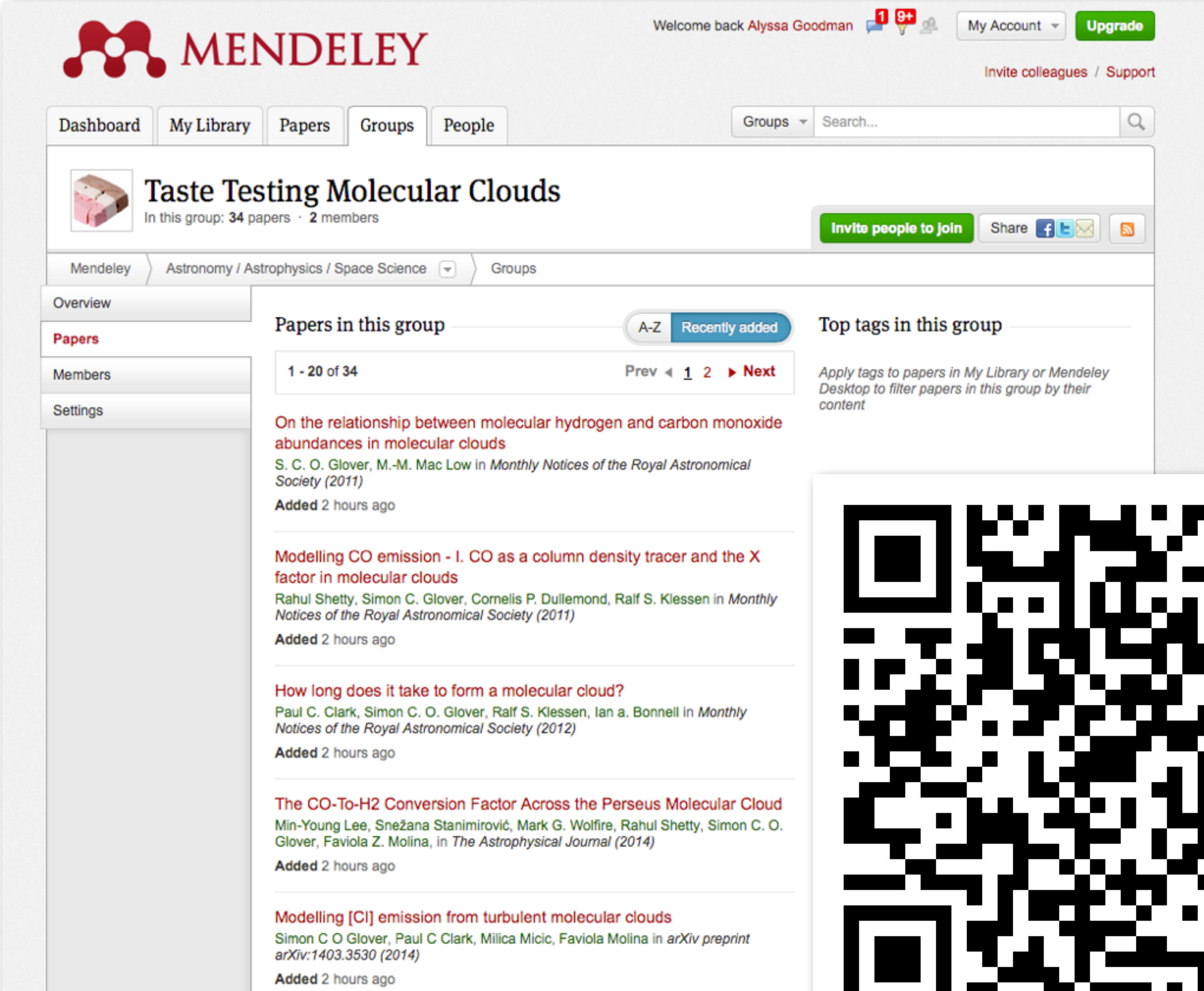
TASTE TEST



*Synthetic [OIII], Hα and [NII] emission-line image from a 512^3 numerical simulation: Mellema, Henney, **Arthur** & **Vàzquez-Semadeni** 2009*

“Taste-Testing”



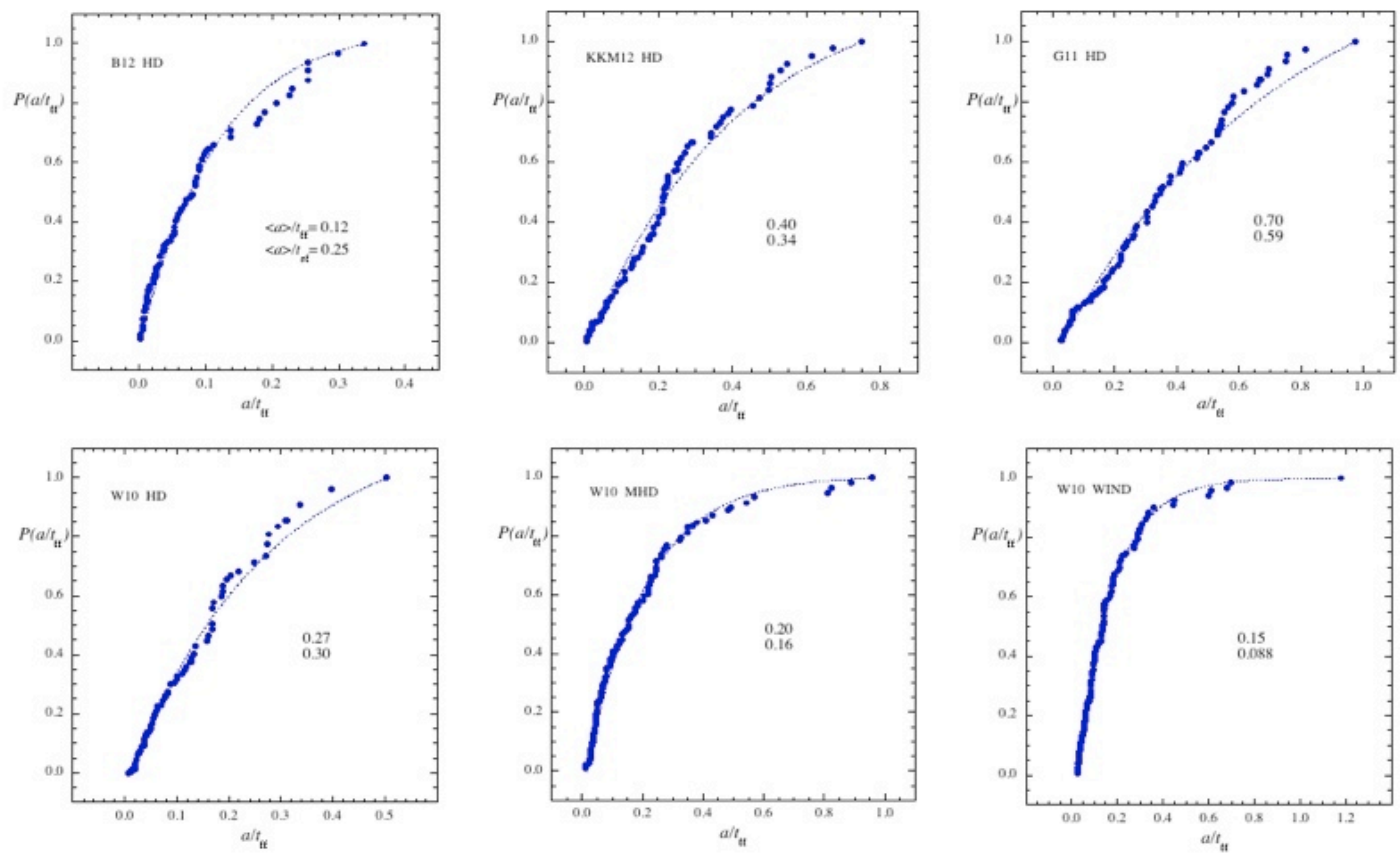


Ask
Simon
Glover

www.mendeley.com/groups/2515761/taste-testing-molecular-clouds/papers/
or, tweet ADS link to #OSSF14

also, ask Stella Offner, Christoph Federrath, Rowan Smith & others “in the know” about Myers et al. 2014

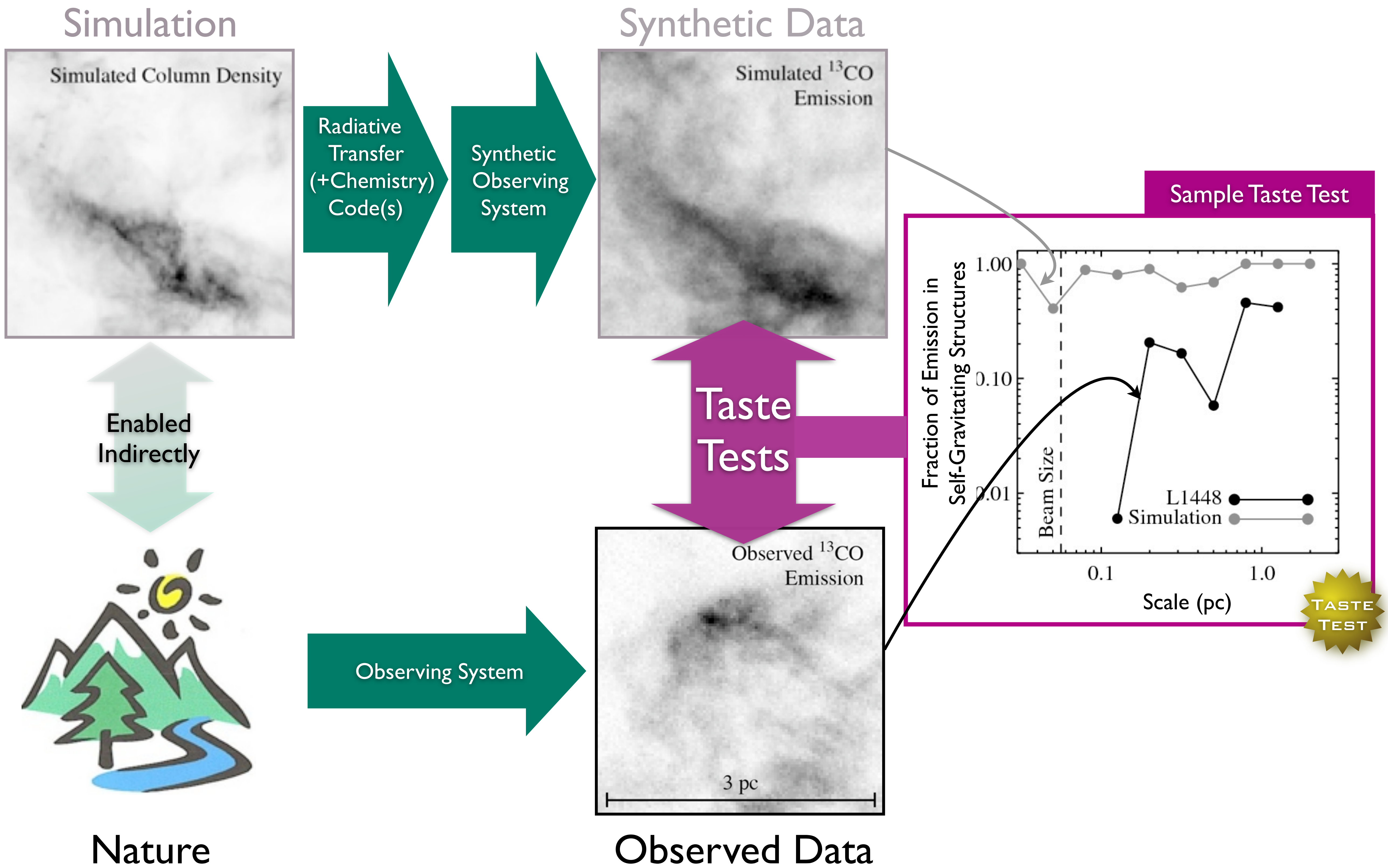
PMS accretion durations are fit by model of random accretion stopping

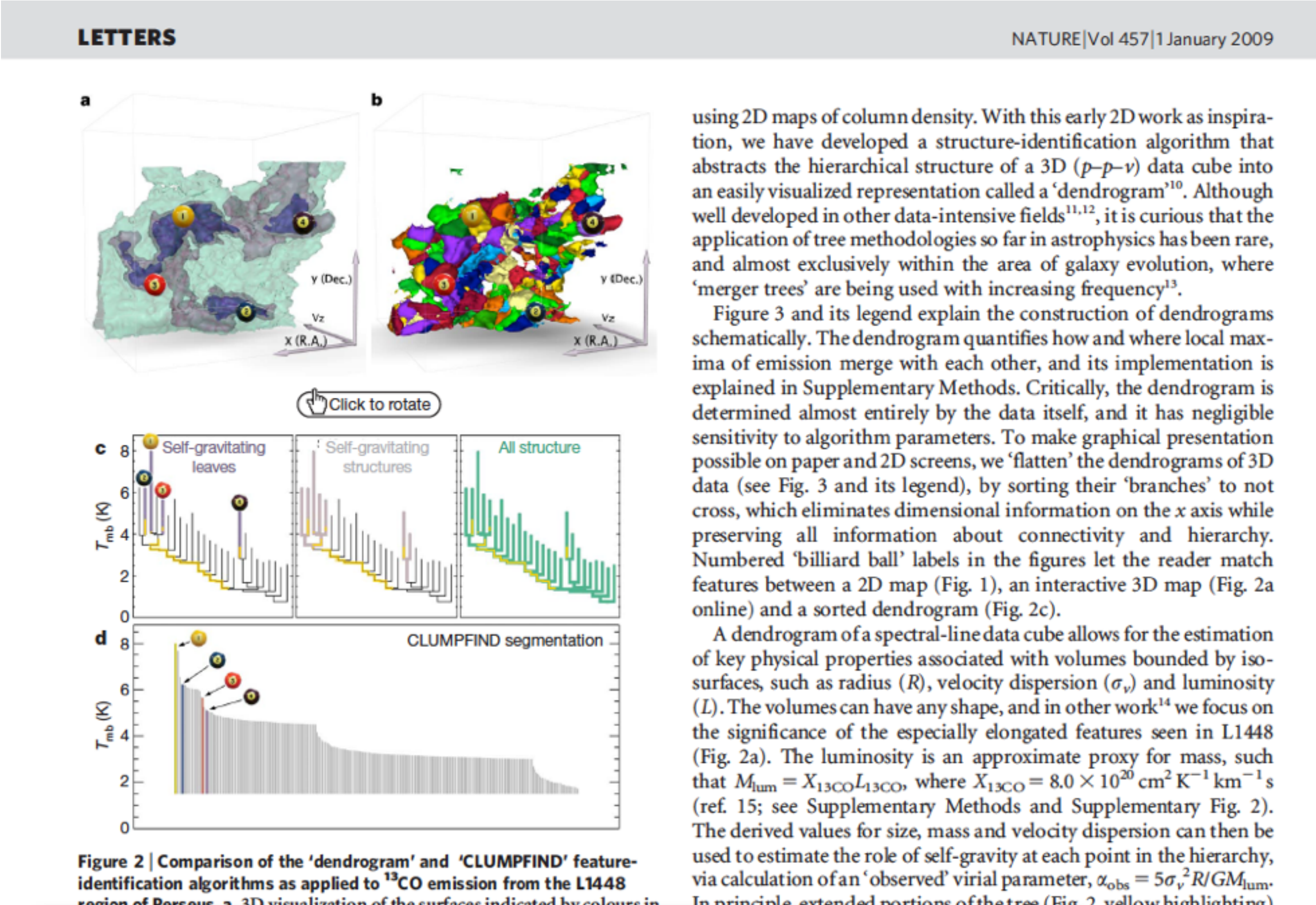


Cumulative distributions of the probability that the accretion duration is less than *a*, for six simulations. Each distribution is weighted to reduce a sampling bias which limits late starts to short durations. In these figures the spacing of points increases for long durations, indicating that the chance of accreting for *a* decreases with *a*.

Each distribution is fit with a random stopping function of form $P(a) = 1 - \exp(-a/\langle a\rangle)$, with mean duration $\langle a\rangle$. Each fit is labelled with the ratio of $\langle a\rangle$ to the initial free fall time and to the star-forming duration of the simulation. The fit quality and the curvature of the distribution tend to increase as the star-forming duration spans a greater number of mean accretion durations. In the W10 simulations, introducing magnetic fields and winds tends to decrease the mean accretion duration.

“Taste-Testing”





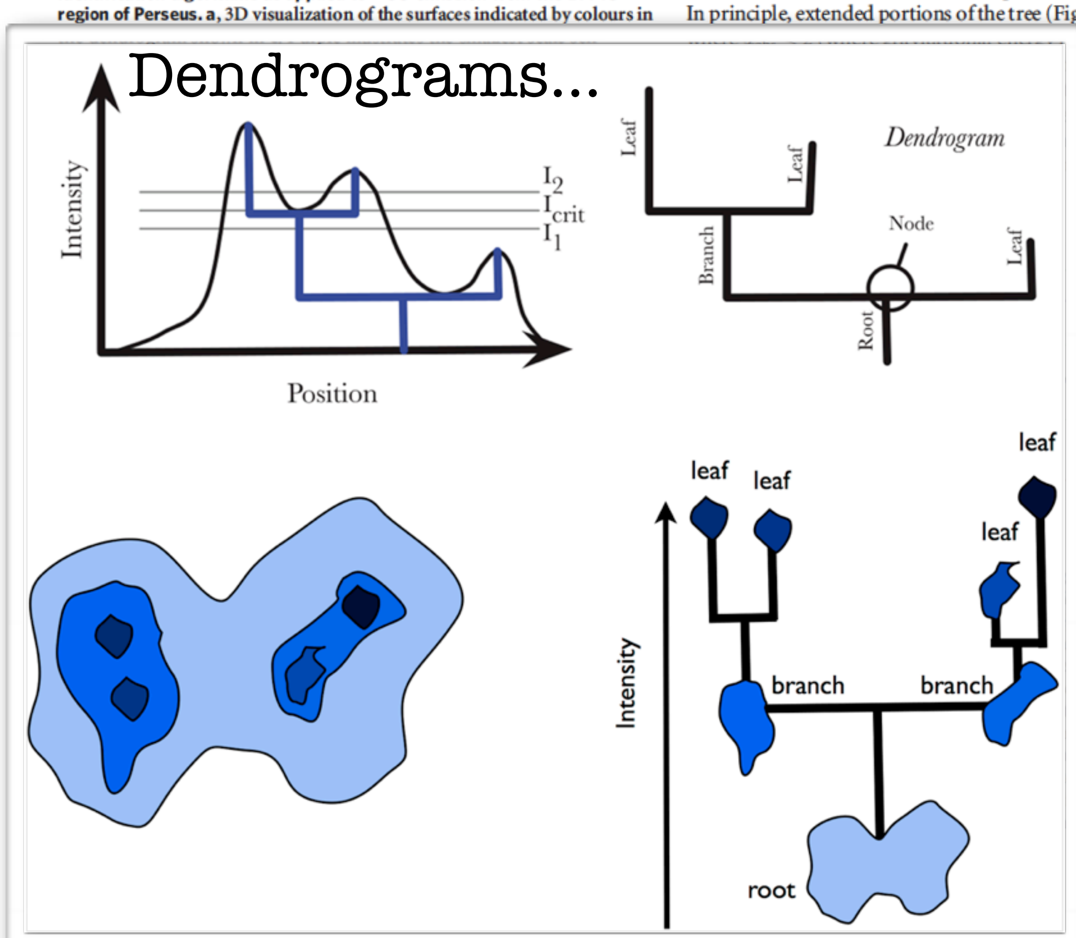
using 2D maps of column density. With this early 2D work as inspiration, we have developed a structure-identification algorithm that abstracts the hierarchical structure of a 3D (*p*–*p*–*v*) data cube into an easily visualized representation called a 'dendrogram'[10]. Although well developed in other data-intensive fields[11,12], it is curious that the application of tree methodologies so far in astrophysics has been rare, and almost exclusively within the area of galaxy evolution, where 'merger trees' are being used with increasing frequency[13].

Figure 3 and its legend explain the construction of dendrograms schematically. The dendrogram quantifies how and where local maxima of emission merge with each other, and its implementation is explained in Supplementary Methods. Critically, the dendrogram is determined almost entirely by the data itself, and it has negligible sensitivity to algorithm parameters. To make graphical presentation possible on paper and 2D screens, we 'flatten' the dendrograms of 3D data (see Fig. 3 and its legend), by sorting their 'branches' to not cross, which eliminates dimensional information on the *x* axis while preserving all information about connectivity and hierarchy. Numbered 'billiard ball' labels in the figures let the reader match features between a 2D map (Fig. 1), an interactive 3D map (Fig. 2a online) and a sorted dendrogram (Fig. 2c).

A dendrogram of a spectral-line data cube allows for the estimation of key physical properties associated with volumes bounded by isosurfaces, such as radius (R), velocity dispersion (σ_v) and luminosity (L). The volumes can have any shape, and in other work[14] we focus on the significance of the especially elongated features seen in L1448 (Fig. 2a). The luminosity is an approximate proxy for mass, such that $M_{lum} = X_{13CO} L_{13CO}$, where $X_{13CO} = 8.0 \times 10^{20}$ cm^2 K^{-1} km^{-1} s (ref. 15; see Supplementary Methods and Supplementary Fig. 2). The derived values for size, mass and velocity dispersion can then be used to estimate the role of self-gravity at each point in the hierarchy, via calculation of an 'observed' virial parameter, $\alpha_{obs} = 5\sigma_v^2 R/GM_{lum}$. In principle, extended portions of the tree (Fig. 2, yellow highlighting)
omparable to or larger
p–p–v space where self-
ratio of kinetic energy
and does not explicitly
ic fields[16], its measured
evity (boundedness) of

Figure 2 | Comparison of the 'dendrogram' and 'CLUMPFIND' feature-identification algorithms as applied to ^{13}CO emission from the L1448 region of Perseus. **a**, 3D visualization of the surfaces indicated by colours in

m process. Shown is the
one-dimensional
an be constructed by
from above in tiny steps
ocal maxima and mergers
on of a test level with the
urple dots) in one
an isosurface in three
Fig. 2c is the direct
from 'isosurface' rather
ttened for representation
or 3D data cubes would



Goodman et al. 2009; cf. Rosolowsky et al. 2008.

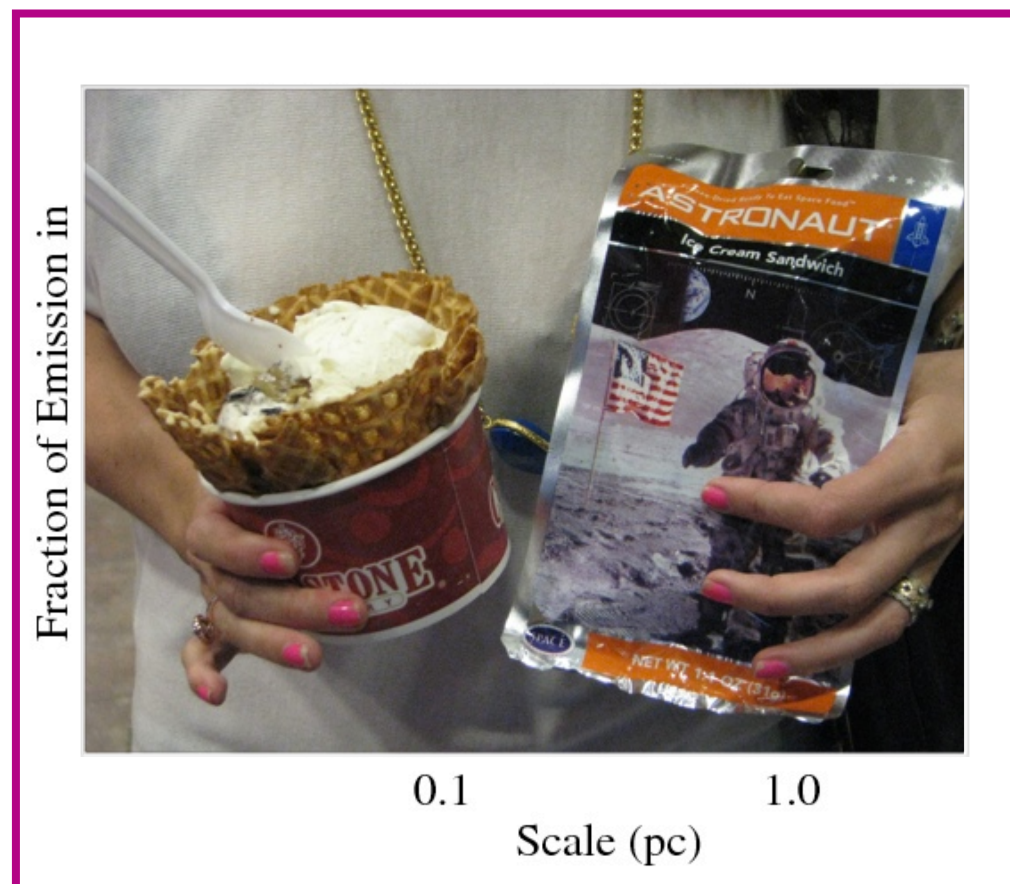
A Curious Taste

(that Frank Shu wasn't sure he liked)

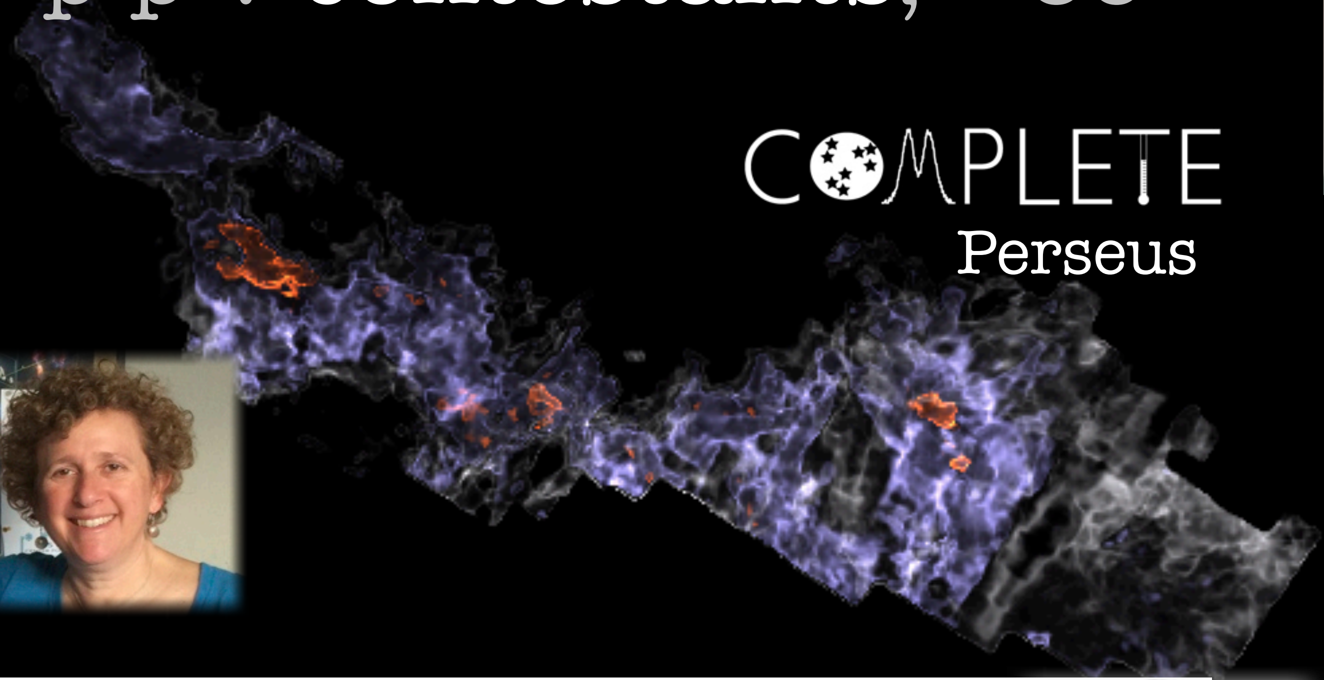
LETTERS

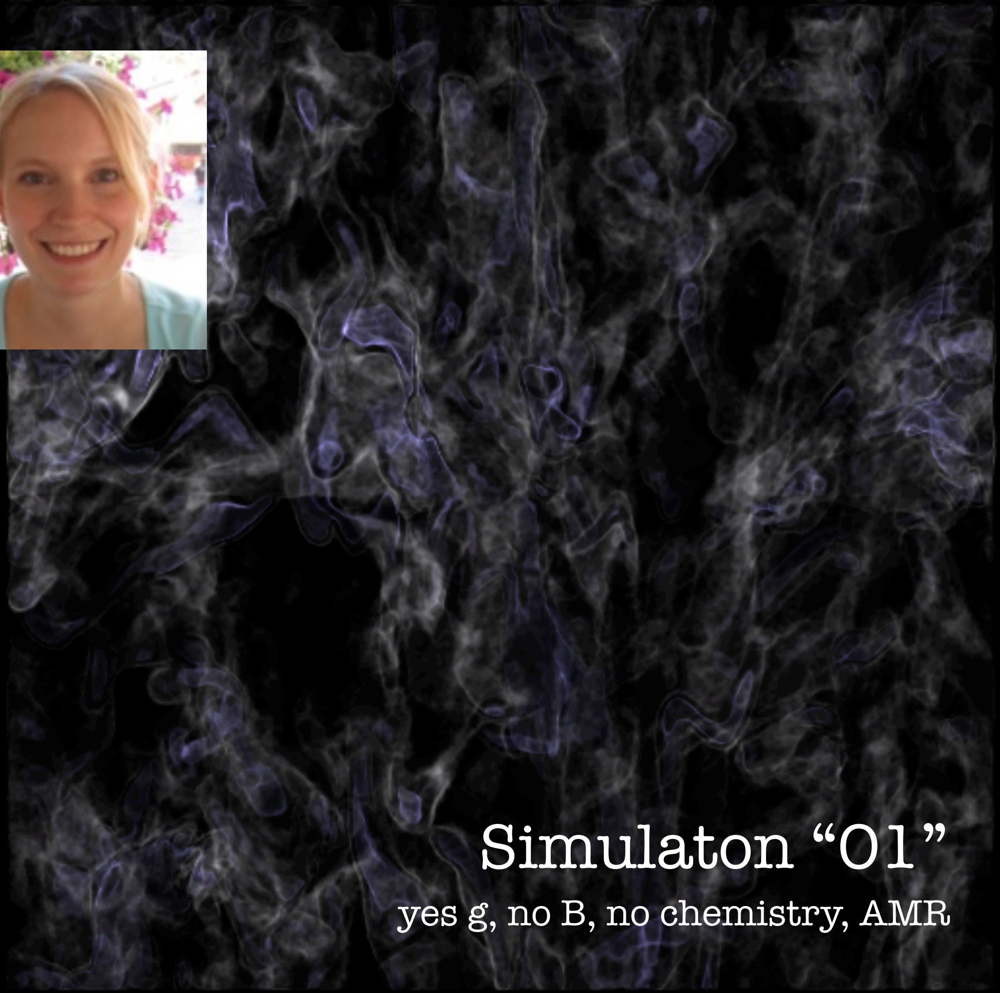
A role for self-gravity at multiple length scales in the process of star formation

Alyssa A. Goodman[1,2], Erik W. Rosolowsky[2,3], Michelle A. Borkin[1]†, Jonathan B. Foster[2], Michael Halle[1,4], Jens Kauffmann[1,2] & Jaime E. Pineda[2]



p-p-v contestants, ^{13}CO



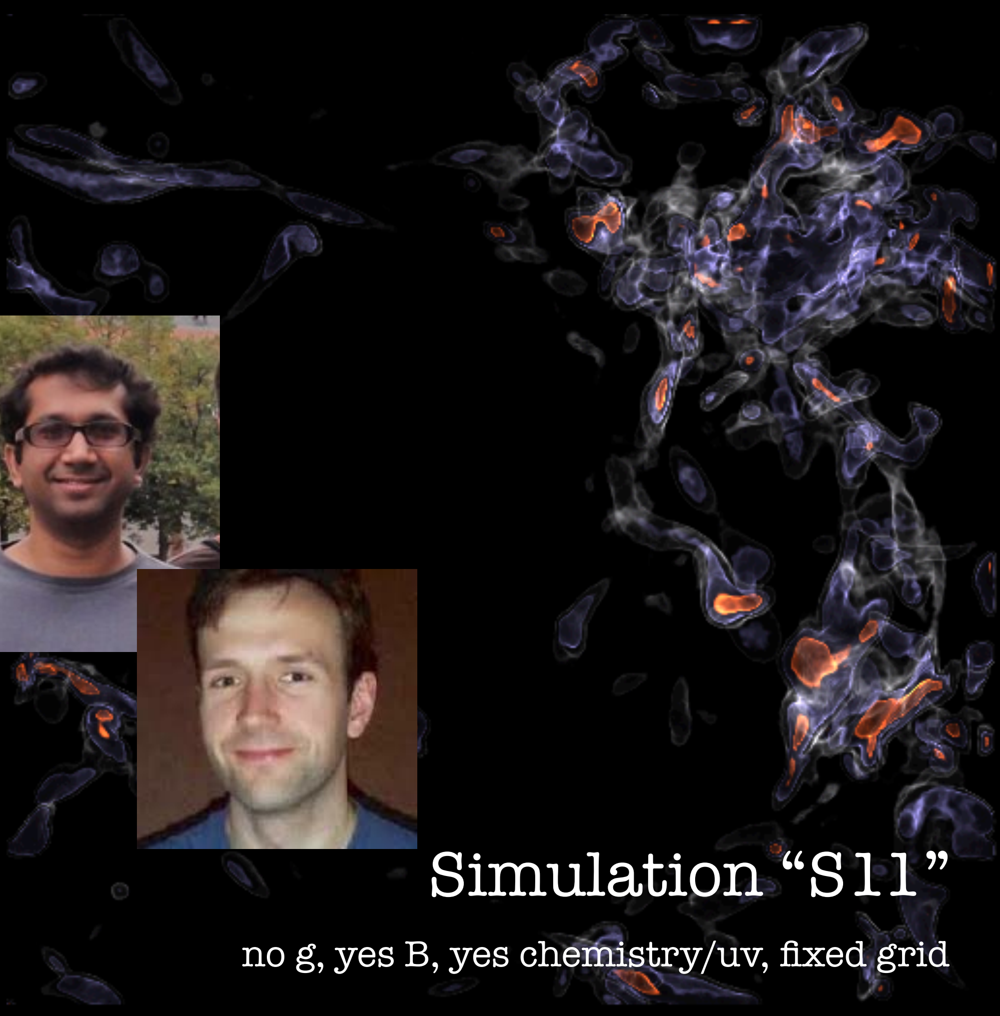


Simulaton “O1”

yes g, no B, no chemistry, AMR

Table 2. Summary of each simulation

	S11	O1
Box Size	20 pc	25 pc
Simulation Code	Zeus-MP	ORION
Gridding	256^3	256^3 + 4 levels of AMR refinement
Driven Turbulence?	Yes	Yes
Driving Power Spectrum	Uniform $1 < k < 2$	Uniform $1 < k < 2$
Gravity?	No	Yes
B field?	5.85 uG	0
Gas Temperature	Variable (10-200K)	15K
Chemistry	H, O, C	None
Background UV	2.7e-3 erg cm^{-2} s^{-1}	No
Constant CO Abundance	No	1.75 e-4
$^{12}CO/^{13}CO$ abundance	70	70
Radiative Transfer Code	RADMC 3D	RADMC 3D
Microturbulence	0.2 km s^{-1}	0.2 km s^{-1}
Metallicity	Solar	N/A
Mean number density (nH)	100 cm^{-3}	58 cm−3
Mach Number	~ 6	22
Isothermal?	No	Yes
Output time(s)	5.7 Myr	2.5 Myr
Mass in stars	N/A	722 Msun (2.4%)



Simulation “S11”

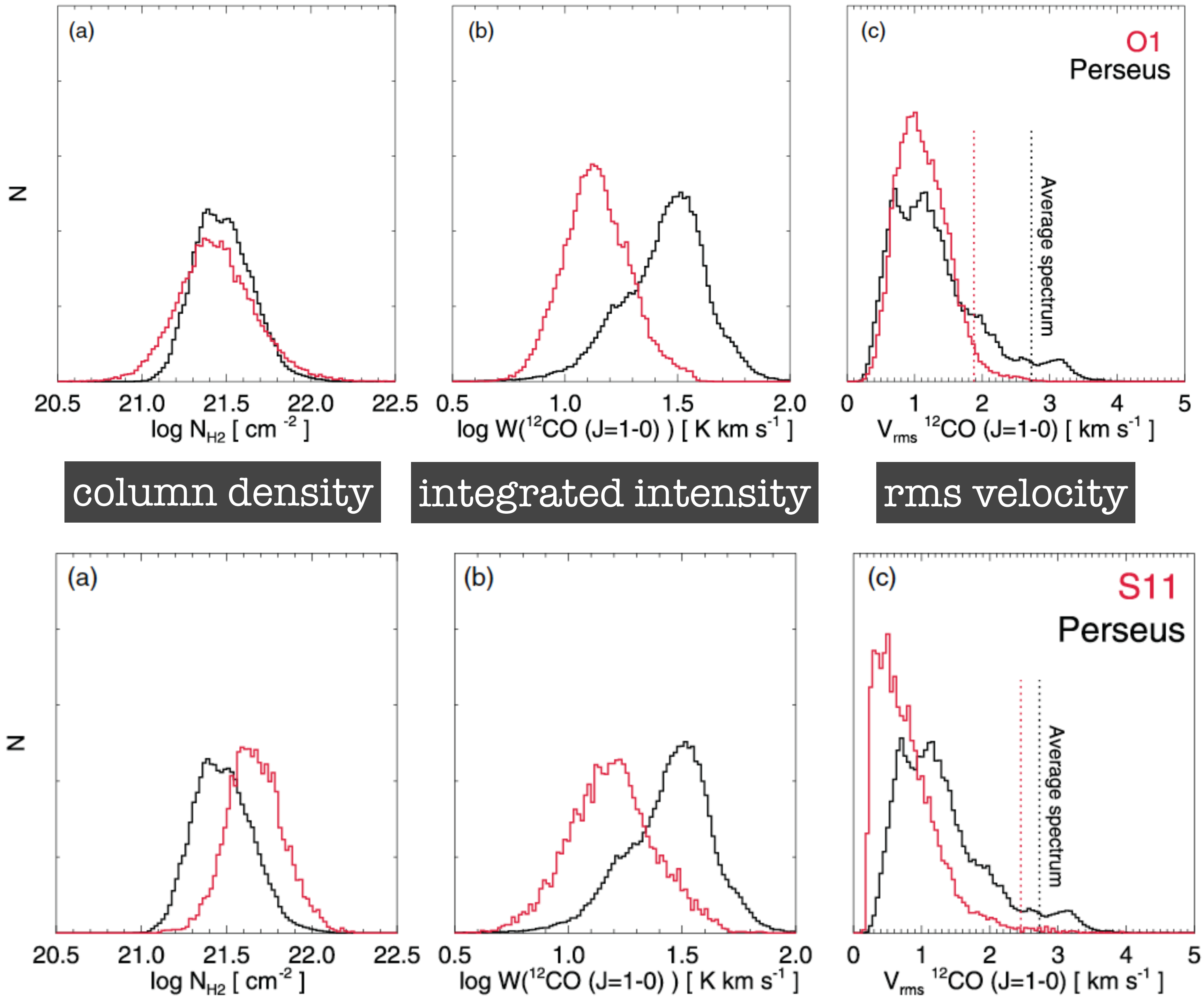
no g, yes B, yes chemistry/uv, fixed grid

Beaumont, Offner, Shetty, Glover & Goodman 2013

Neither simulation is “truthful.”

But, they might be good enough to Taste.

Neither simulation is “truthful.”



Beaumont et al. 2013

Tastemaker 1: Chemistry

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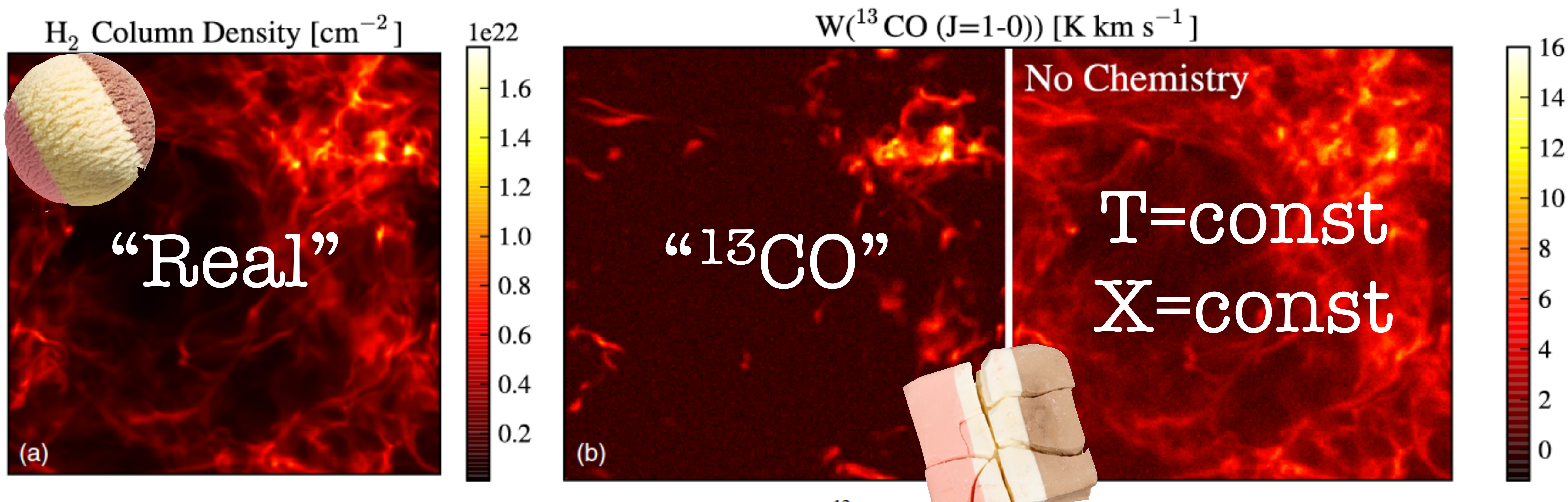

Figure 18. H_2 column density map of S11 (a), and the integrated ^{13}CO (J = … maps with and without chemistry (b, c).

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QUANTIFYING OBSERVATIONAL PROJECTION EFFECTS USING MOLECULAR CLOUD SIMULATIONS

Christopher N. **Beaumont**[1,2], Stella S. R. **Offner**[3,5], Rahul **Shetty**[4], Simon C. O. **Glover**[4], and Alyssa A. **Goodman**[2]

Tastemaker 2: Projection

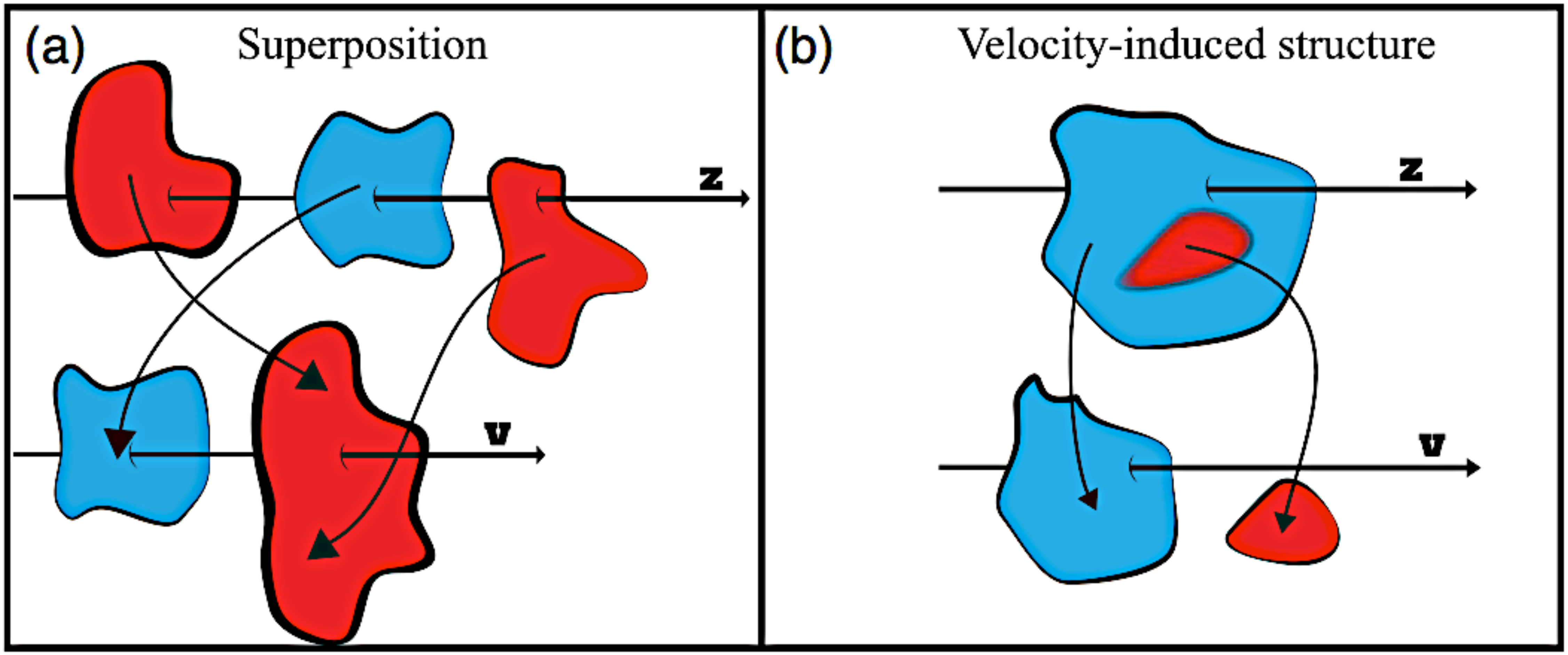


Figure 1. Schematic representation of superposition and velocity-induced structures. Colors indicate velocity. Left: three PPP structures (top) merge into 2 PPV structures (bottom), due to the similar velocity of the front and back structures. Right: a single density structure with internal velocity gradients (top) splits into two PPV structures (bottom).

Beaumont et al. 2013

Tastemaker Part 2: Projection

“PPP” to “PPV”

“Destruction” of Real Structures | “Creation” of Unreal Structures

Real space “PPP”

Observer Space “PPV”

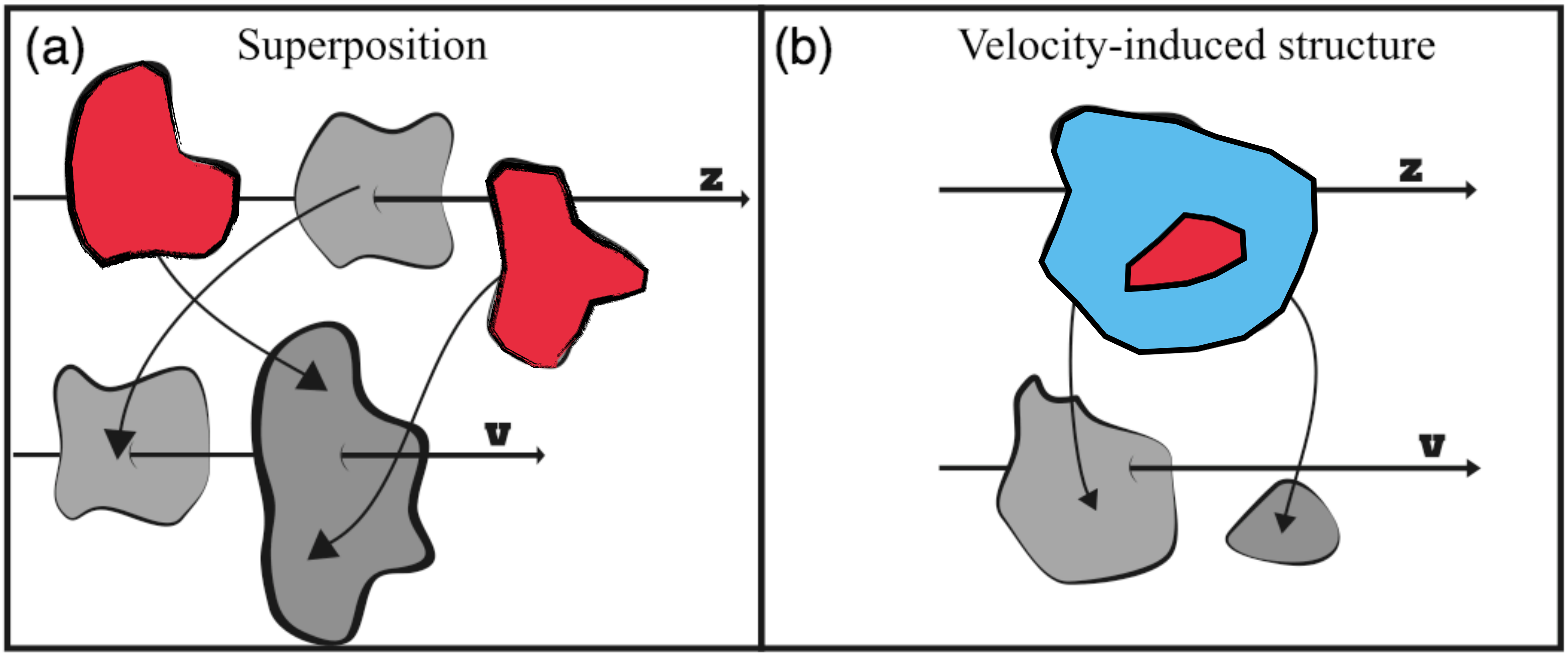


Figure 1. Schematic representation of superposition and velocity-induced structures. Colors indicate velocity. Left: three PPP structures (top) merge into 2 PPV structures (bottom), due to the similar velocity of the front and back structures. Right: a single density structure with internal velocity gradients (top) splits into two PPV structures (bottom).

Beaumont et al. 2013

Tastemaker 3: Opacity

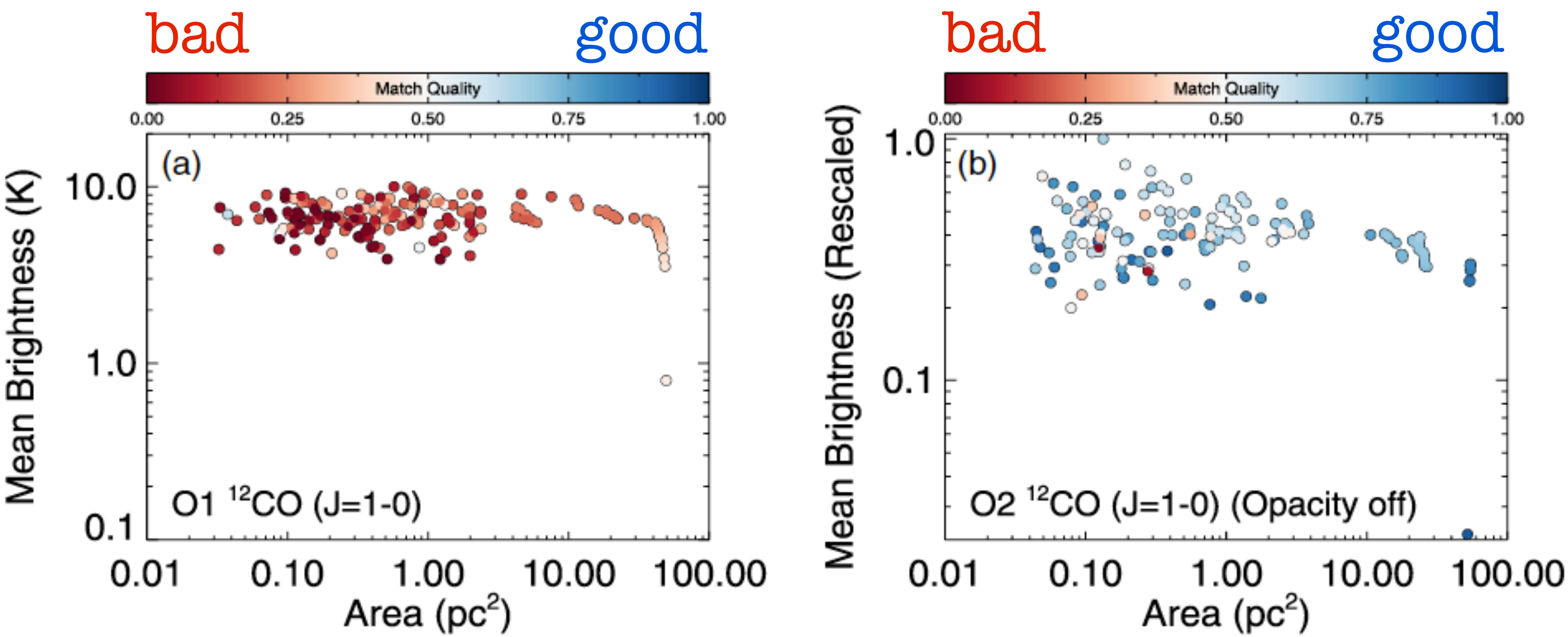
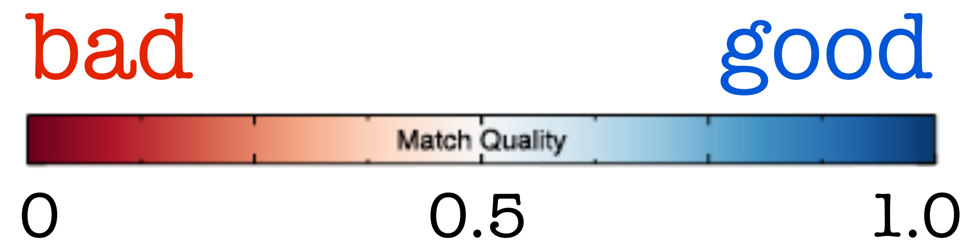
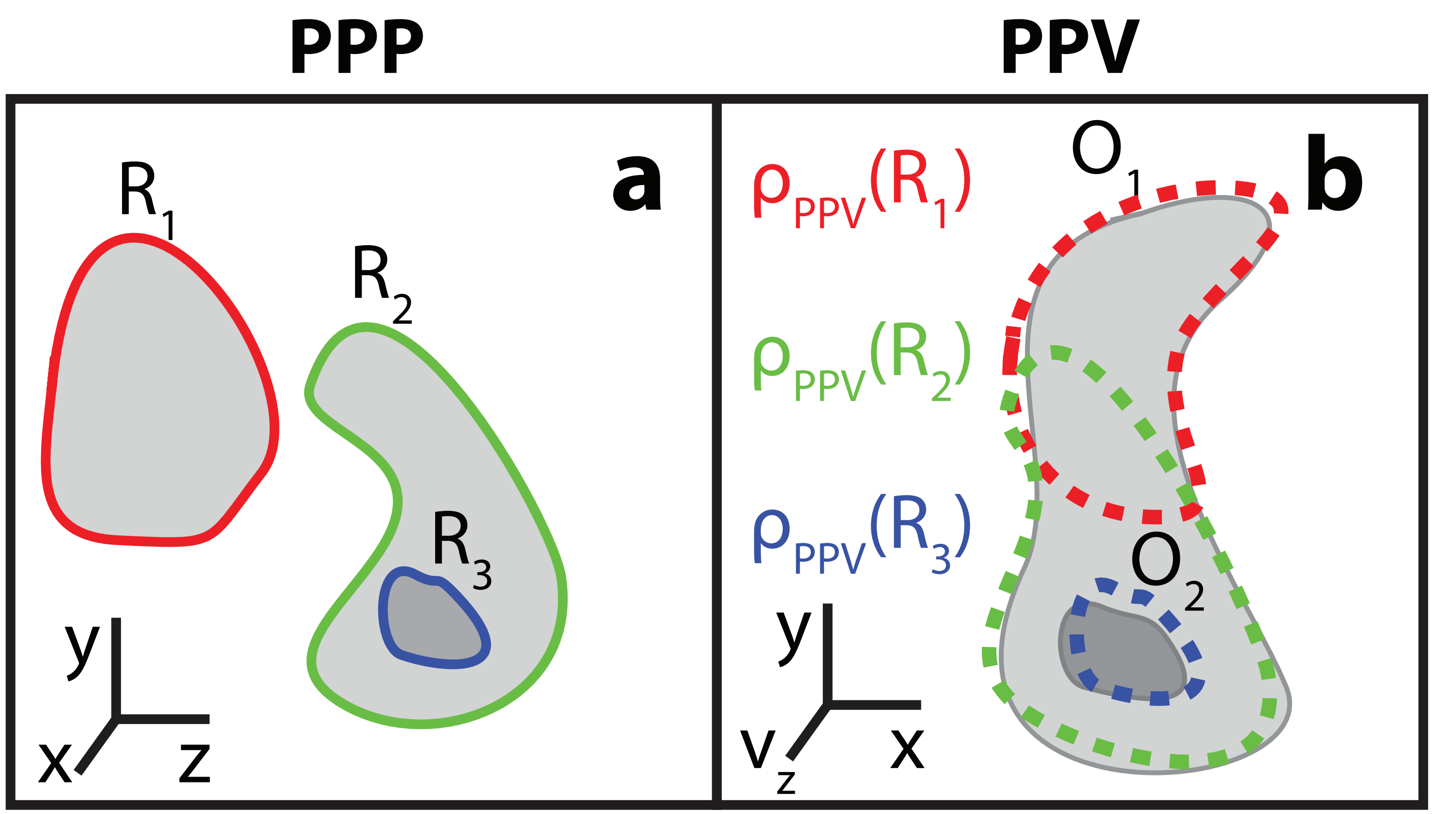


Figure 11. Same as Figure 7, but for the O2 simulation where opacity was disabled during radiative transfer.

Beaumont et al. 2013

Defining “Match Quality”, q=





	Similarity R_1	R_2	R_3	M	q
O_1	0.4	**0.5**	0	R_2	0.5
O_2	0	0.3	**0.9**	R_3	0.9

1. extract features “R” from ppp dendrogram
2. extract features “O” from ppv dendrogram
3. project features R to ppv, find best matches to “O”
4. measure overlap of best match, assign $0<q<1$ quality

Match Quality

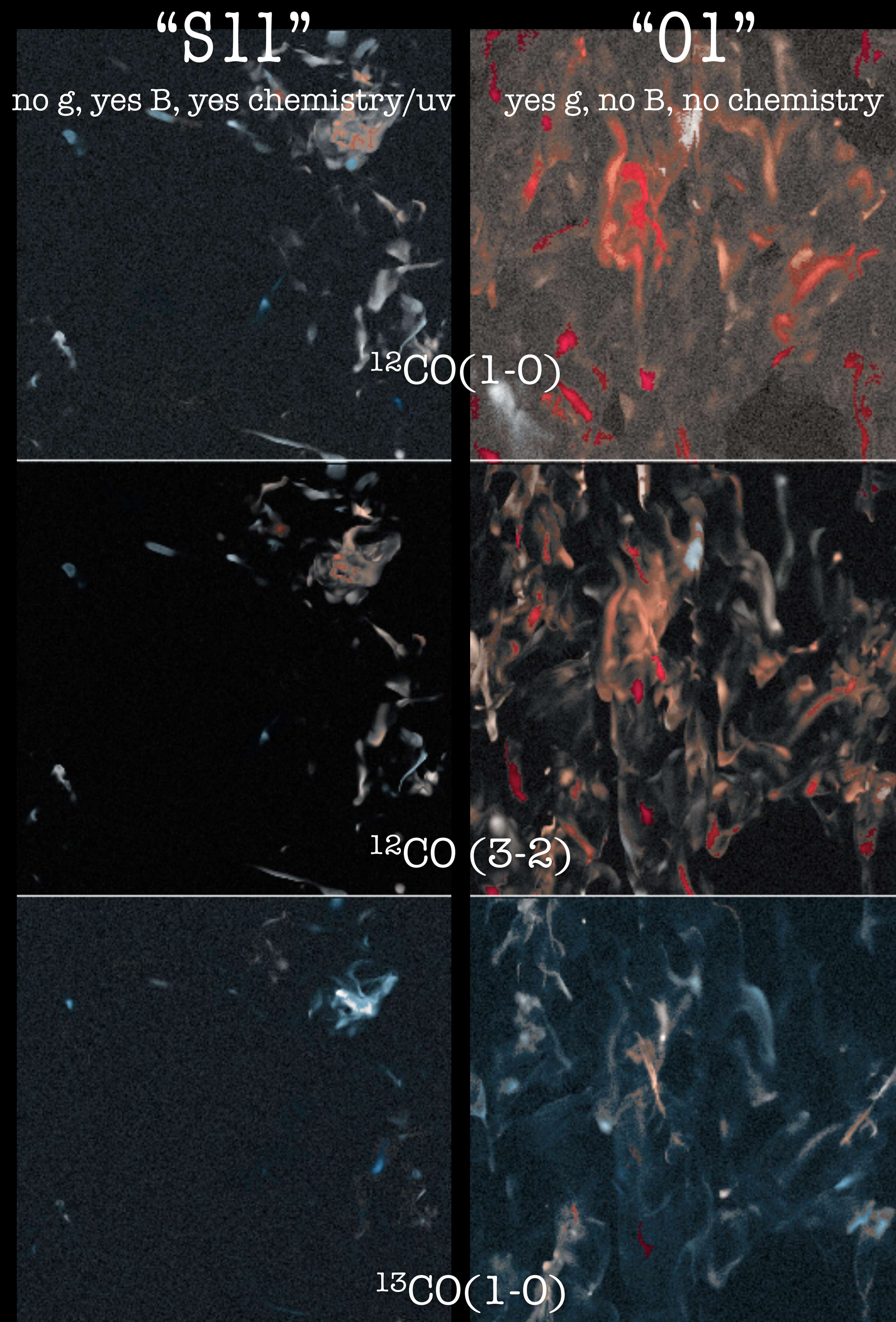
good
bad

movies include a noise model, in both cases

Table 2. Summary of each simulation

	S11	O1
Box Size	20 pc	25 pc
Simulation Code	Zeus-MP	ORION
Gridding	256^3	256^3 + 4 levels of AMR refinement
Driven Turbulence?	Yes	Yes
Driving Power Spectrum	Uniform $1 < k < 2$	Uniform $1 < k < 2$
Gravity?	No	Yes
B field?	5.85 uG	0
Gas Temperature	Variable (10-200K)	15K
Chemistry	H, O, C	None
Background UV	2.7e-3 erg cm^{-2} s^{-1}	No
Constant CO Abundance	No	1.75 e-4
$^{12}CO/^{13}CO$ abundance	70	70
Radiative Transfer Code	RADMC 3D	RADMC 3D
Microturbulence	0.2 km s^{-1}	0.2 km s^{-1}
Metallicity	Solar	N/A
Mean number density (nH)	100 cm^{-3}	58 cm^{-3}
Mach Number	~ 6	22
Isothermal?	No	Yes
Output time(s)	5.7 Myr	2.5 Myr
Mass in stars	N/A	722 Msun (2.4%)

Beaumont, Offner, Shetty, Glover & Goodman 2013

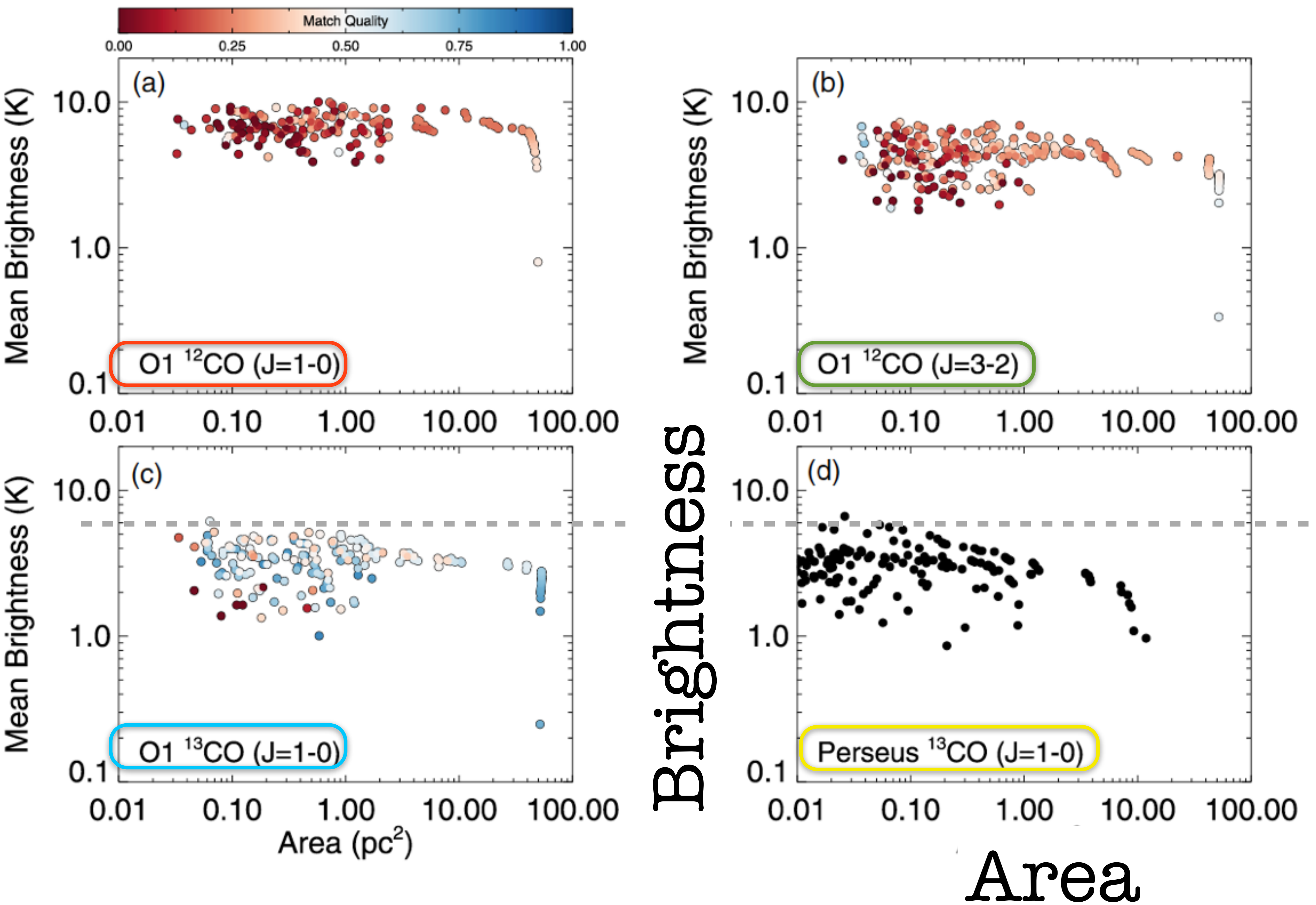


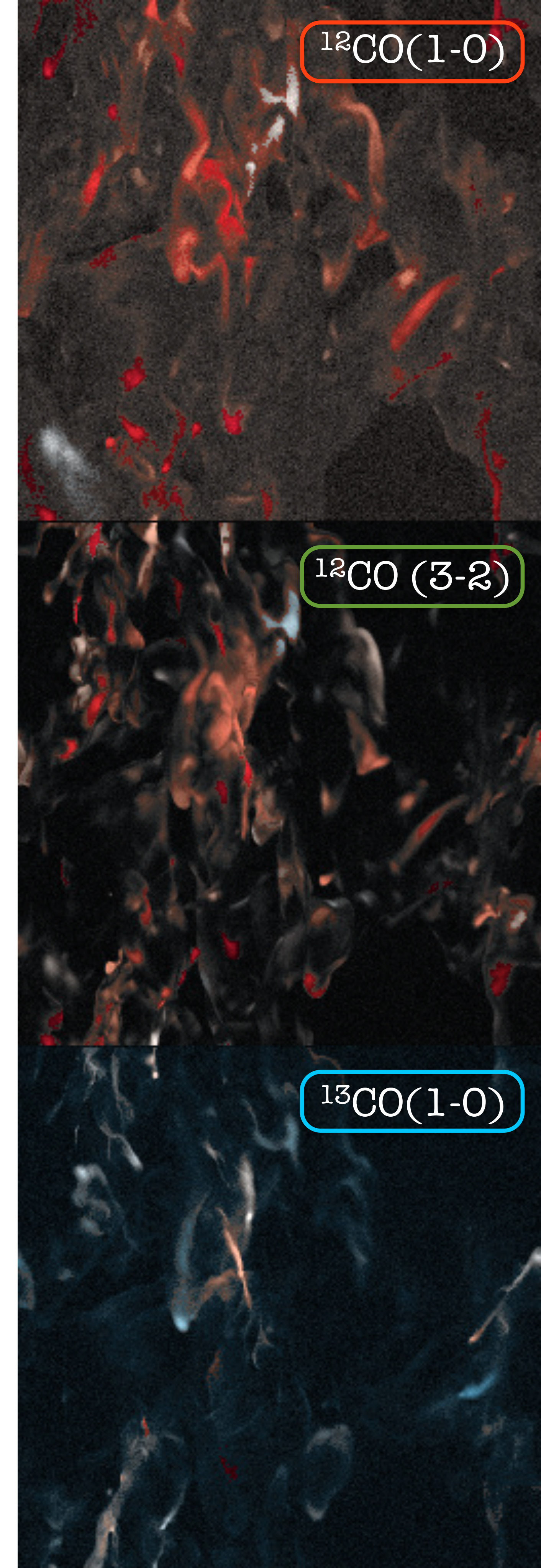
Match Quality

good
bad

"01"

yes g, no B, no chemistry



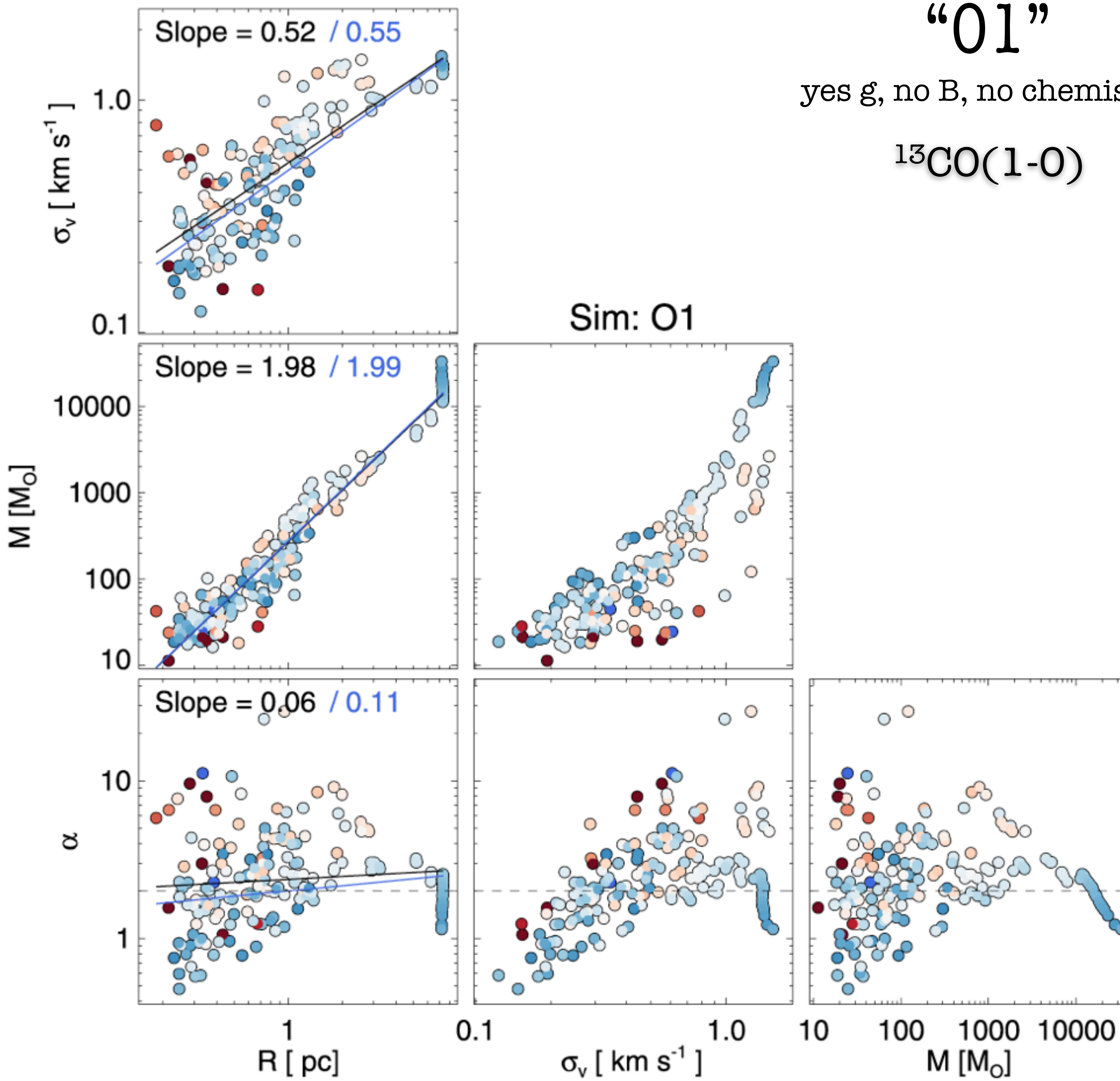


Beaumont, Offner, Shetty, Glover & Goodman 2013

good
bad

Match Quality

"Larson Relations"



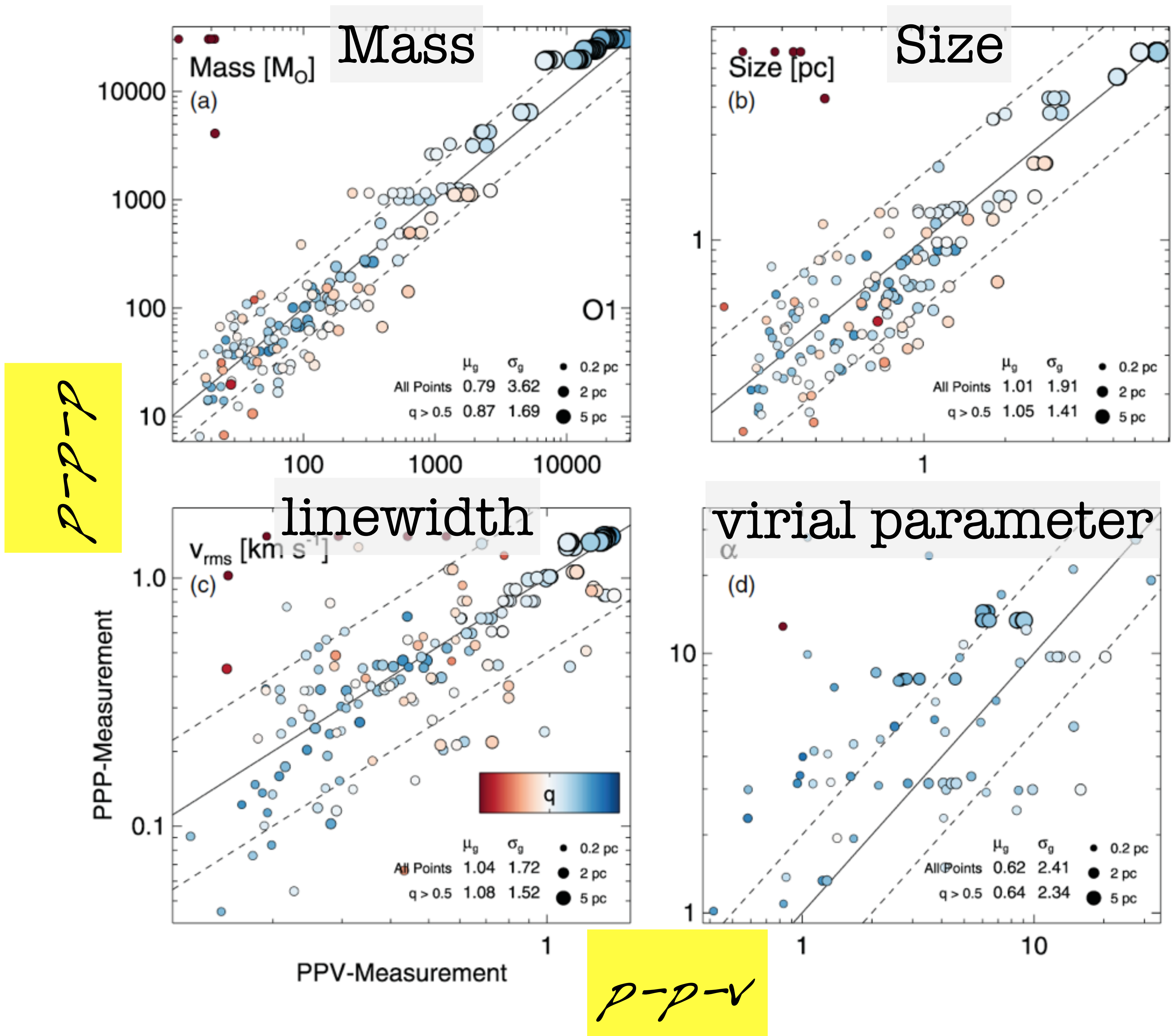
"01"

yes g, no B, no chemistry

$^{13}CO(1\text{-}0)$

Match Quality

$^{13}CO(1\text{-}0)$



"01"

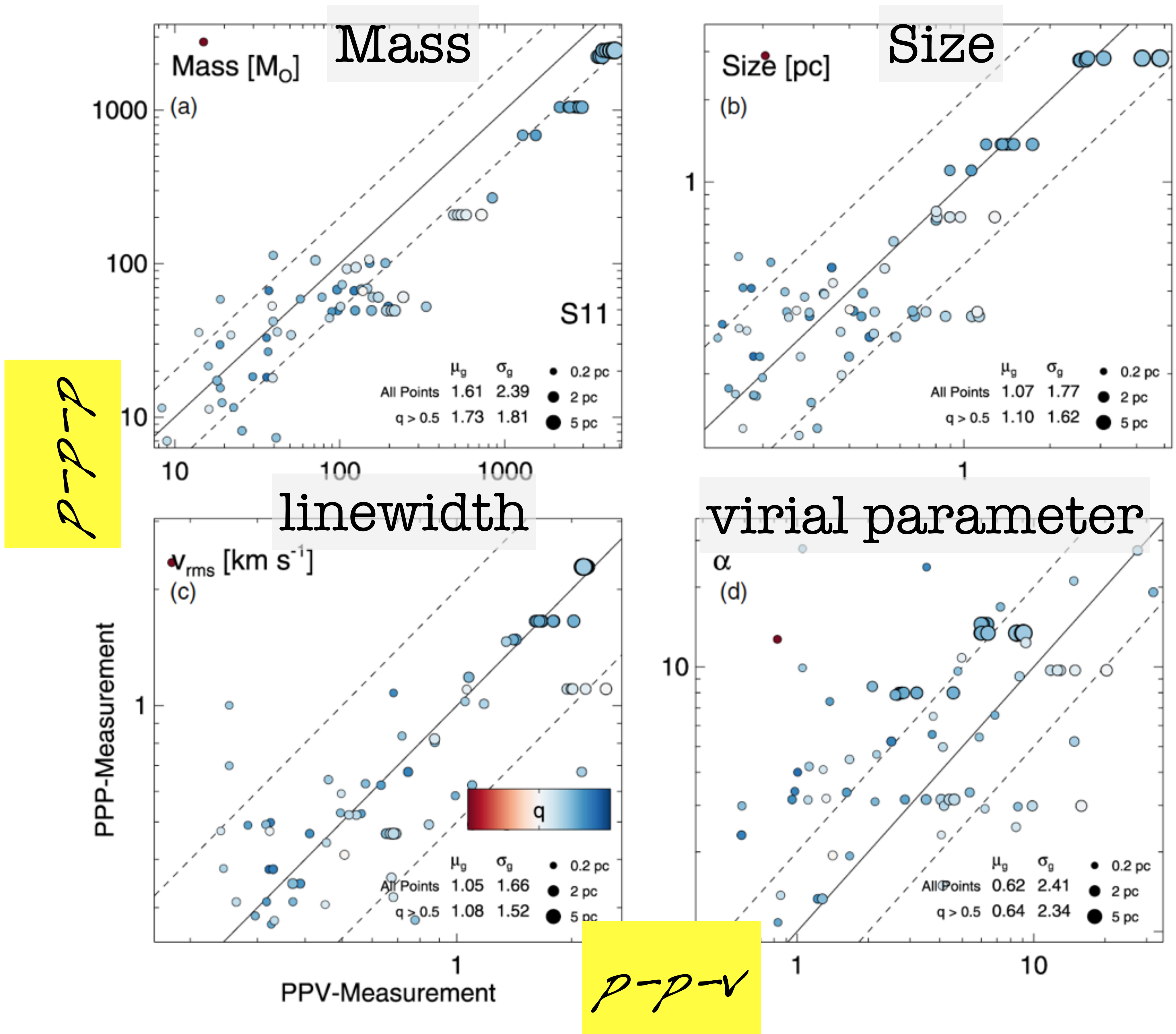
yes g, no B, no chemistry

good

bad

Match Quality

$^{13}CO(1\text{-}0)$

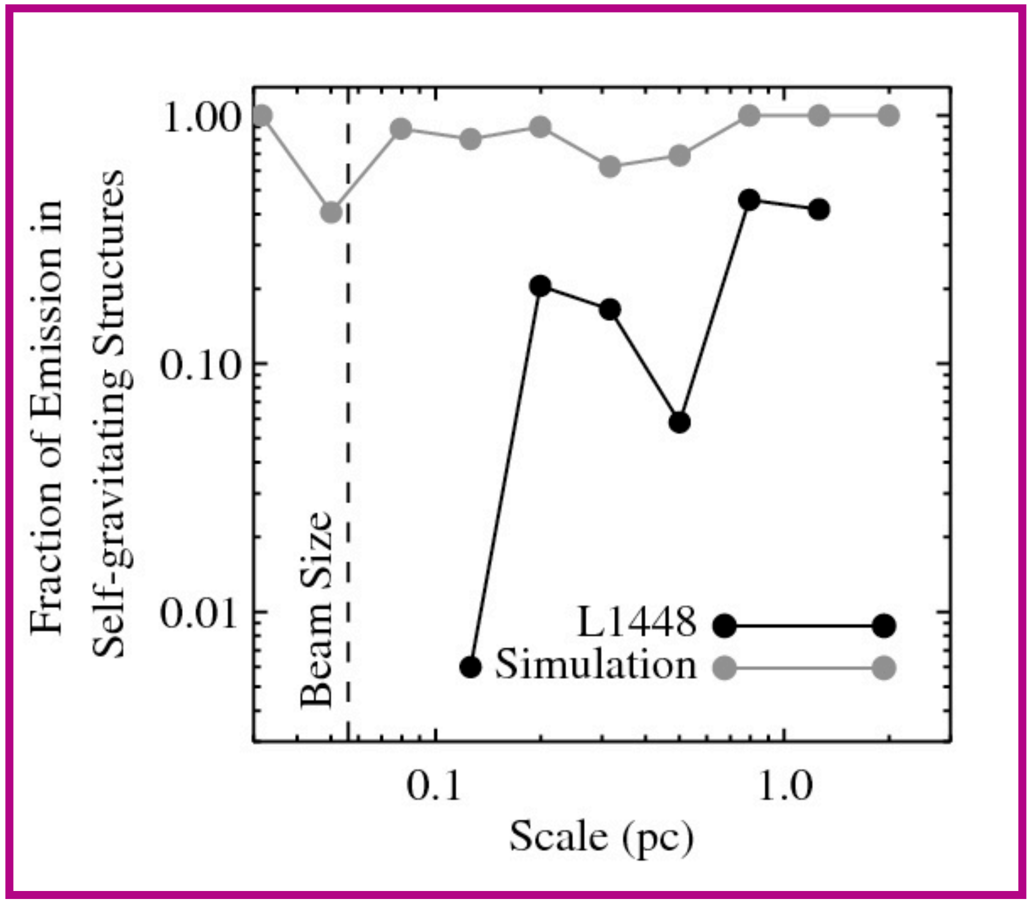


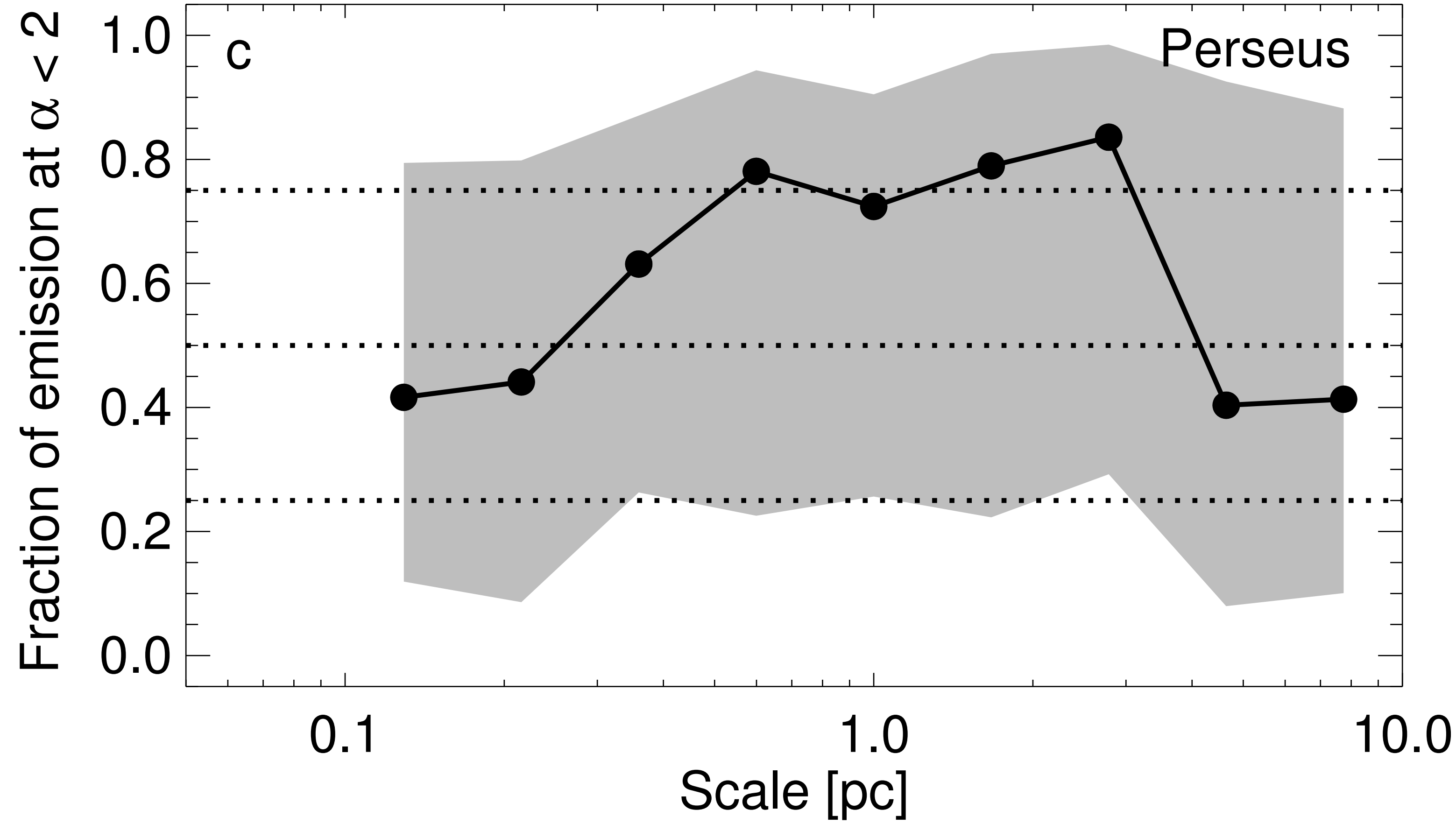
"S11"

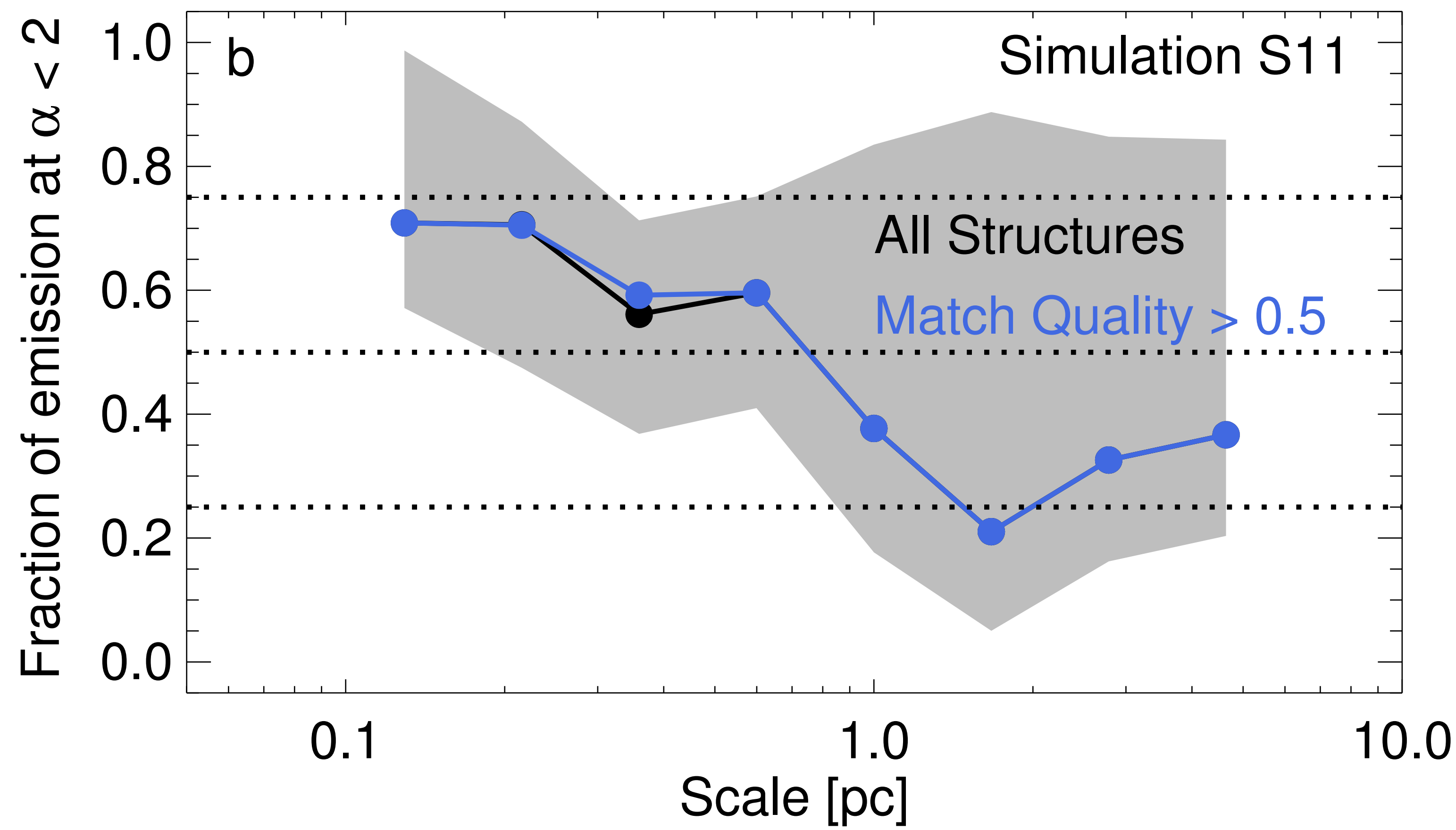
no g, yes B, yes chemistry/uv

good
bad

Frank Shu & the Curious Taste of a

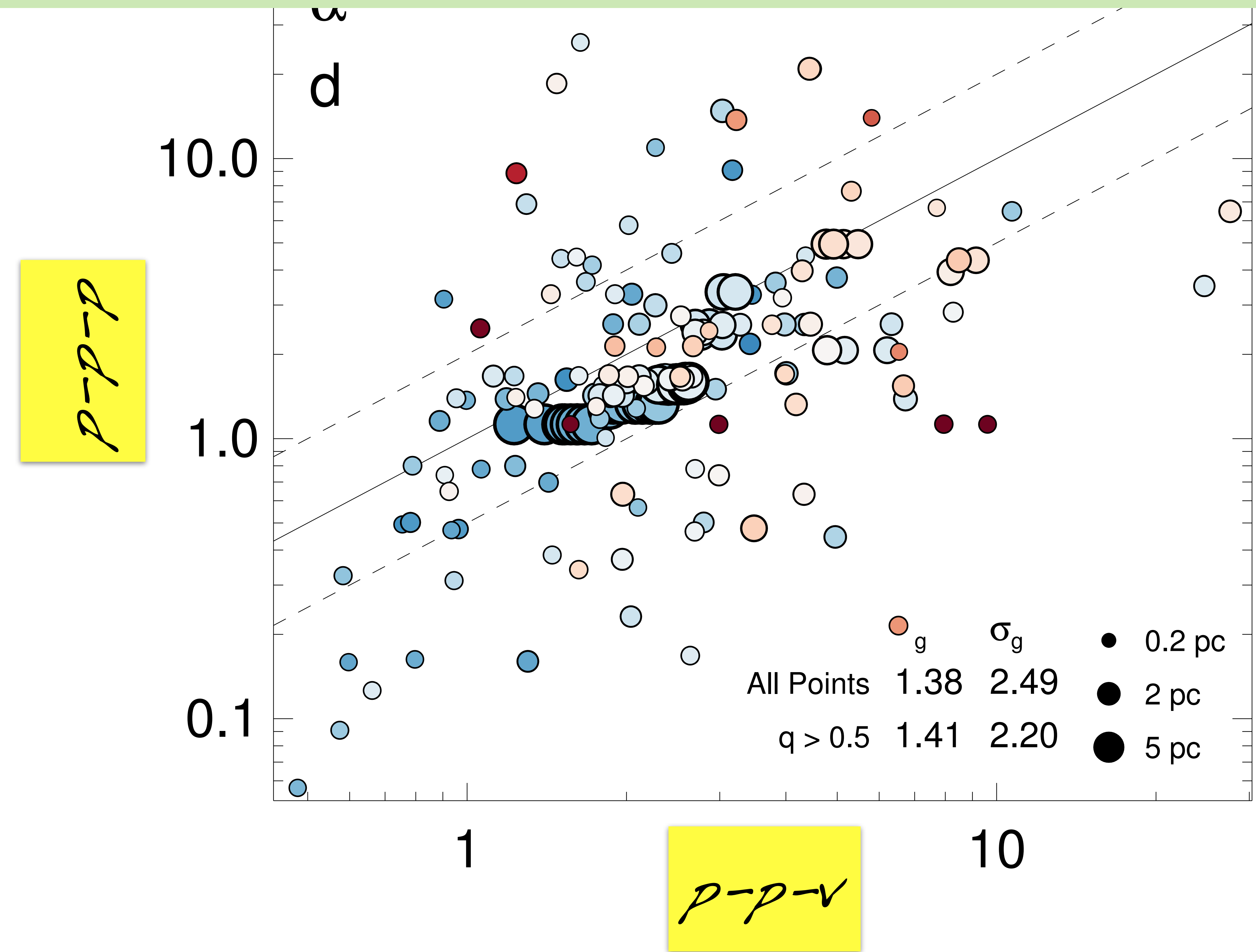






Frank Shu & the Curious Taste of a

The Virial Parameter in p-p-v, using even ^{13}CO, may not be a great test of boundedness

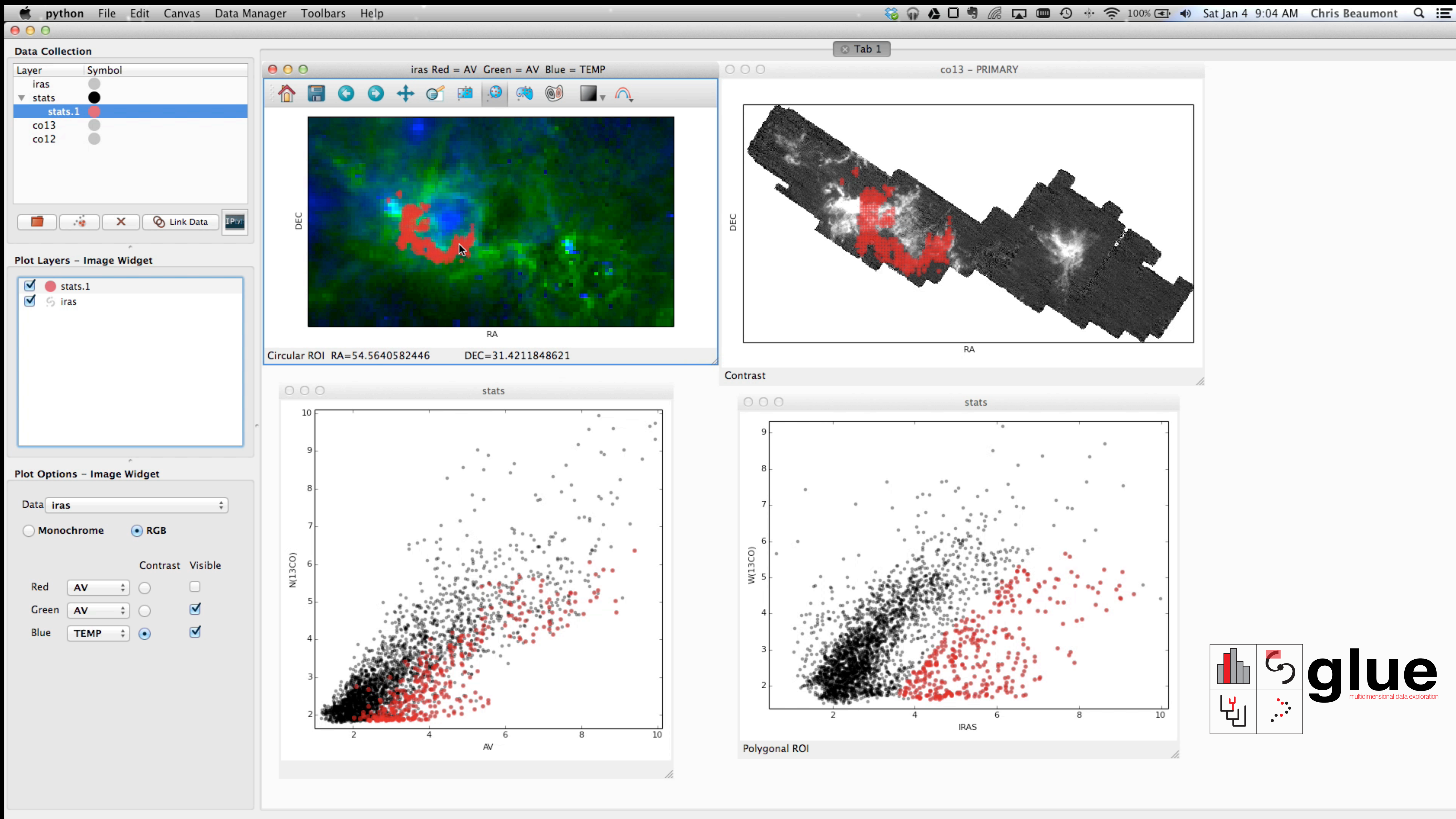


"01, before gravity" as in Padoan 2006

NO g, no B, no chemistry

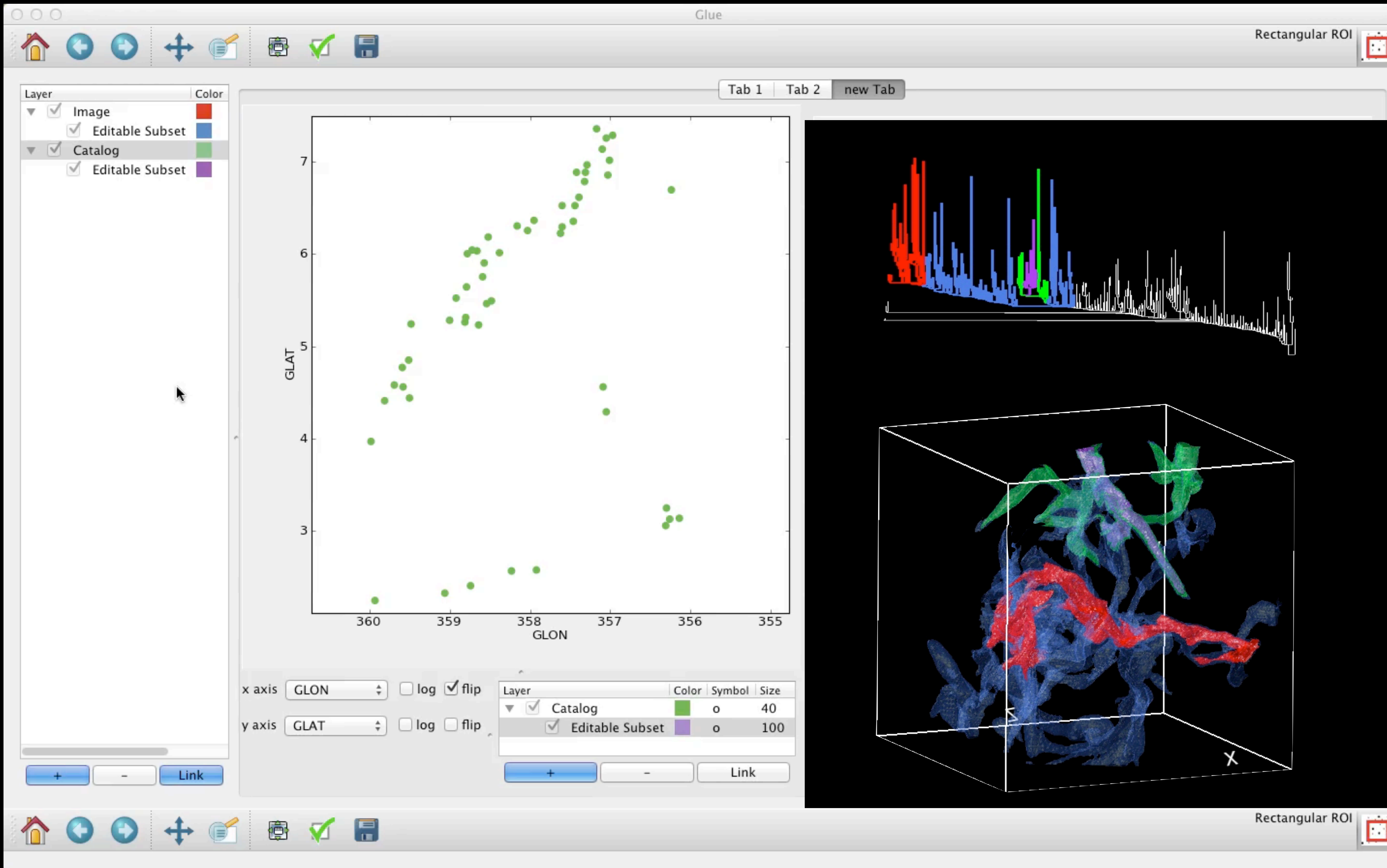
And now, a word from our Sponsors...

Glue



Beaumont, w/Goodman, Robitaille, Borkin

glueviz.org + dendrograms.org



Beaumont, Borkin, Goodman, Rice, Robitaille++
cf. dendroviz, in IDL

Will the Real Universe Please Stand Up?

Many contributors to projects highlighted here include: Ahmed, Alves, Beaumont, Benjamin, Borkin, Burkert, Dame, Duval, Faesi, Glover, Goodman, Hurt, Jackson, Kauffmann, Offner, Reid, Rice, Robitaille, Rosolowsky, Shetty

If I could join you for dinner, I would tell you about our new

ADS
All Sky
Survey,

but the internet's not that good, so please try

adsass.org.

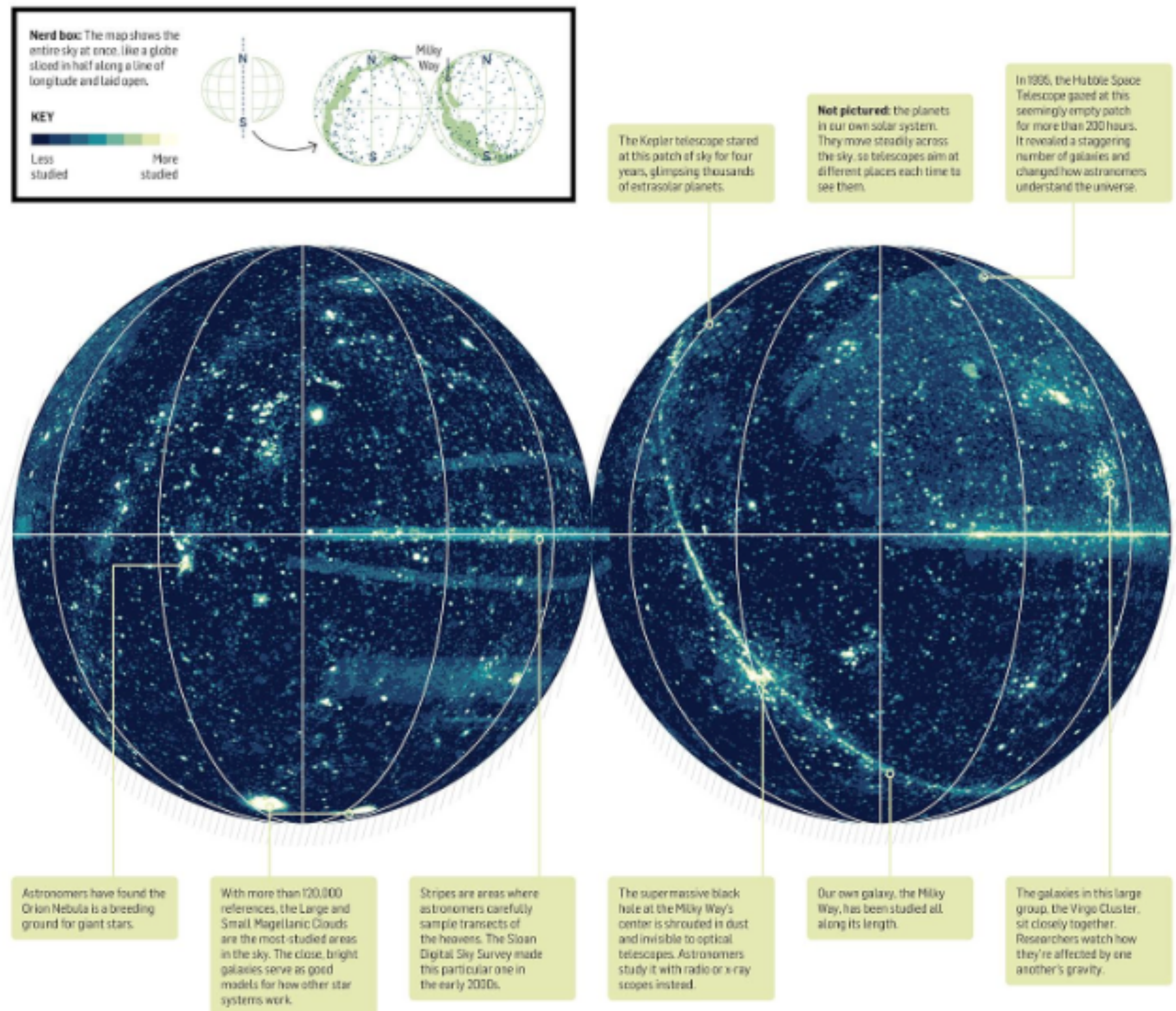
Made possible by: NASA, ADS, CDS, Seamless Astronomy & Microsoft Research.
Created by: Alberto Pepe, Gus Muench, Thomas Boch, Chris Beaumont, Jonathan Fay, Max Lu, Alberto Accomazzi, Sarah Block & Alyssa Goodman.
Infographic at right: Popular Science Magazine, June 2014, created by Katie Peek.

The Most Intriguing Stars In The Universe [Infographic]

Here are the stars that get the closest scrutiny from scientists

By Katie Peek Posted 05.19.2014 at 11:42 am

10

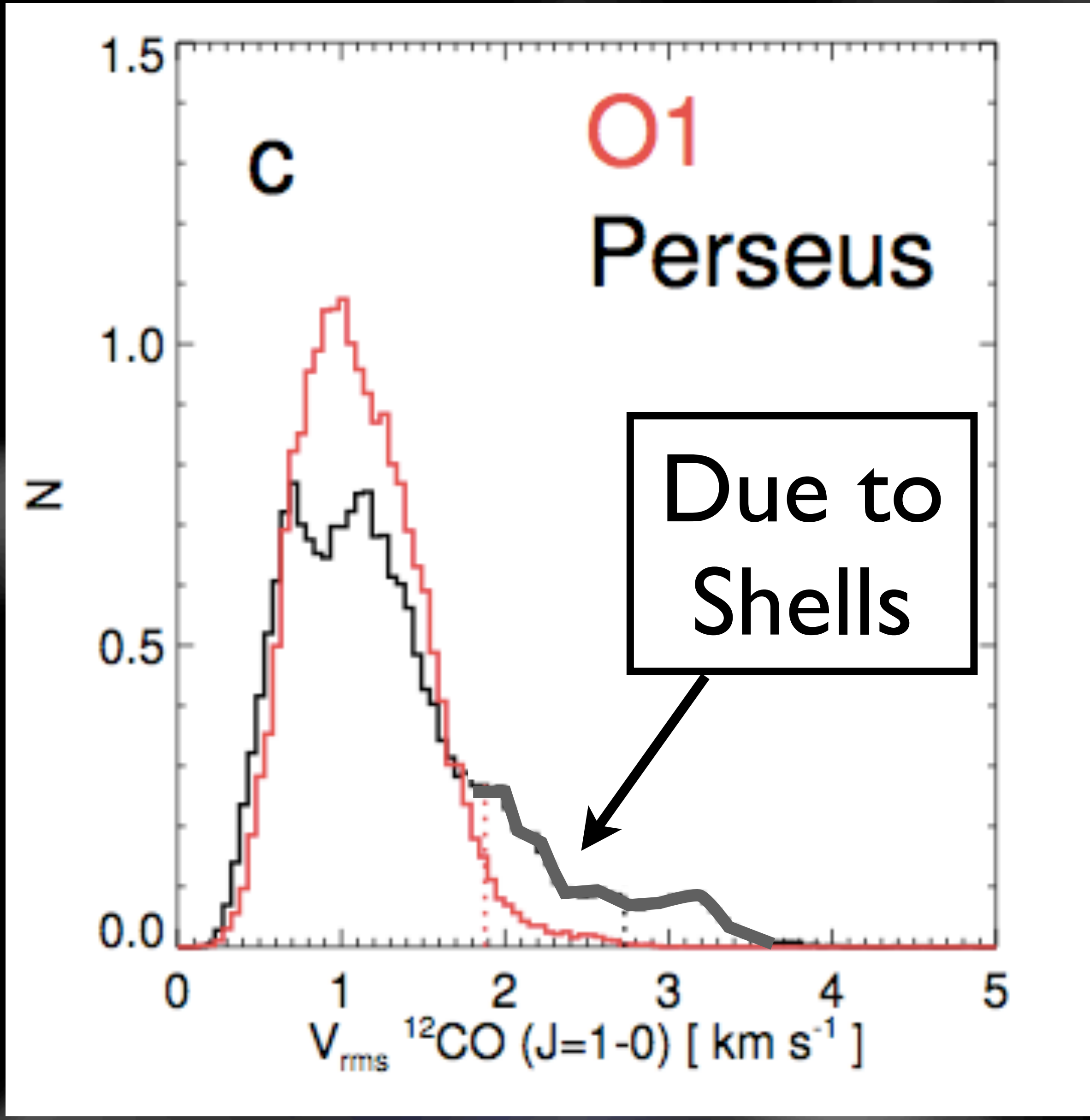


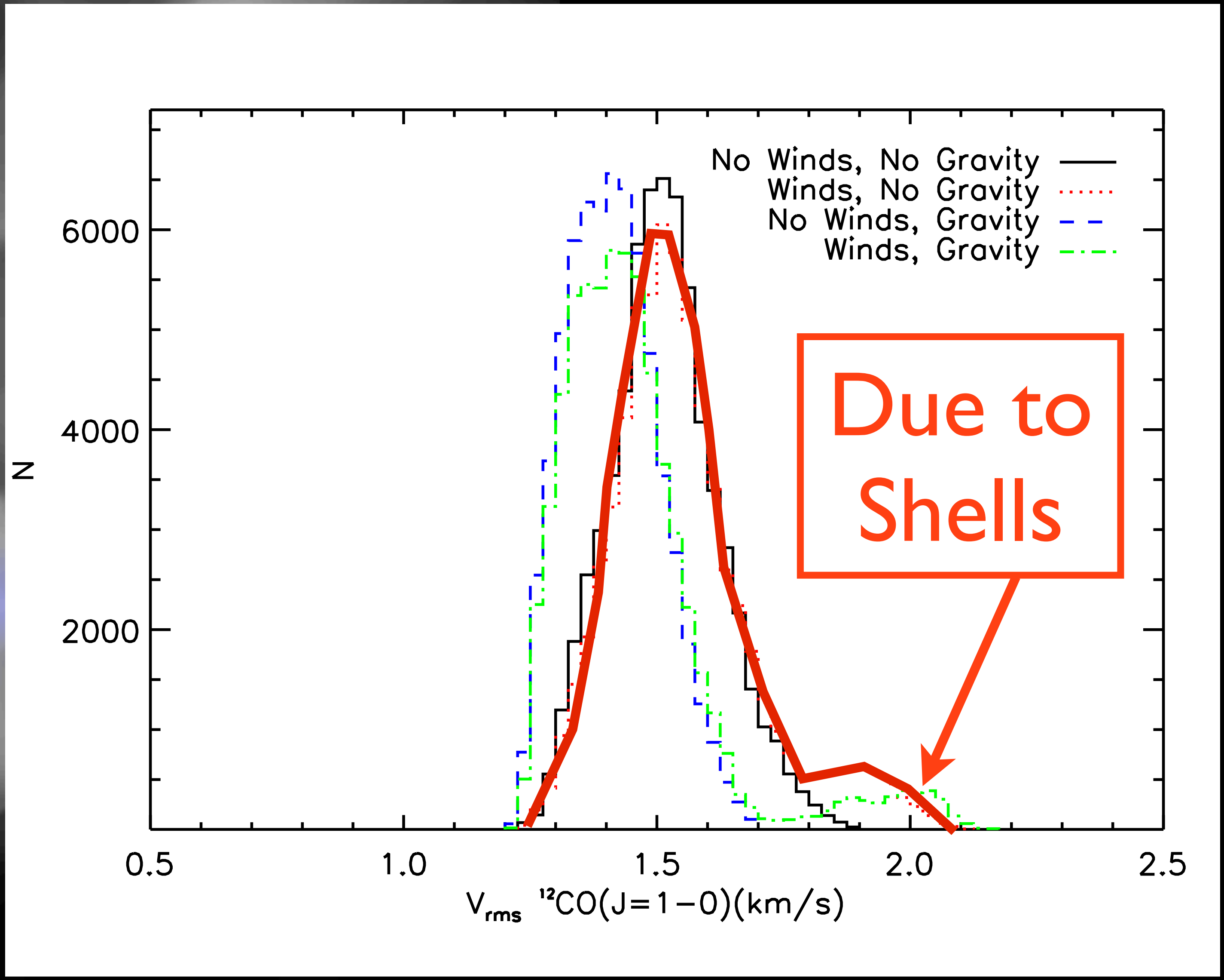
Star map *Illustration by Katie Peek; Original maps courtesy ADS All-Sky Survey, ADSASS.org*

In late 2013, a group of astronomers in the U.S. and France made a new kind of sky map, which charts the how intensely scientists have studied features in the heavens. To build the map, they analyzed a million references to celestial objects in a NASA database of journal articles. Astronomers can use the online version—Astrophysics Data System All-Sky Survey—find data on their targets. The team is also launching a citizen science project later this year to incorporate archival images in the interactive tool. In the meantime, the map already reveals the most intriguing parts of the universe.

This article originally appeared in the June 2014 issue of Popular Science.

Improving Simulations





Offner et al. in prep