

Microsoft[®] Research WorldWide Telescope

Experience WWT at worldwidetelescope.org

The screenshot displays the WorldWide Telescope interface with several key components:

- Navigation Bar:** Includes 'Explore', 'Guided Tours', 'Search', 'View', and 'Settings' tabs.
- Collections:** A row of thumbnails for 'All-Sky Surveys' including 'Digitized Sky Survey', 'VLSS: VLA Low-frequency Sky Survey', 'WMAP ILC 5-Year', 'SFD Dust Map (Infrared)', 'IRIS: Improved Resolution', '2MASS: Two Micron All Sky Survey', and 'Hydrogen Alpha Filter'.
- Main View:** A large field of view showing a starry sky with a central circular field of view (FOV) containing a spiral galaxy.
- Finder Scope:** A pop-up window for the selected object, NGC224, providing classification ('Spiral Galaxy in Andromeda') and coordinates (RA: 00h42m42s, Dec: 41:16:00, etc.).
- Context Bar:** A horizontal bar at the bottom showing 'Look At' (Sky), 'Imagery' (Digitized Sky Survey), and a 'Context globe'.
- Image Credits:** A text box at the bottom center providing information about the data source: 'Data provided by two NASA satellites, the Infrared Astronomy Satellite (IRAS) and the Cosmic Background Explorer (COBE). Processing http://astro.berkeley.edu/~marc/dust/'.

Seamlessly explore imagery from the best ground and space-based telescopes in the world

Expert led tours of the Universe

Control time to study how the night sky changes

View and compare images from across the electromagnetic spectrum

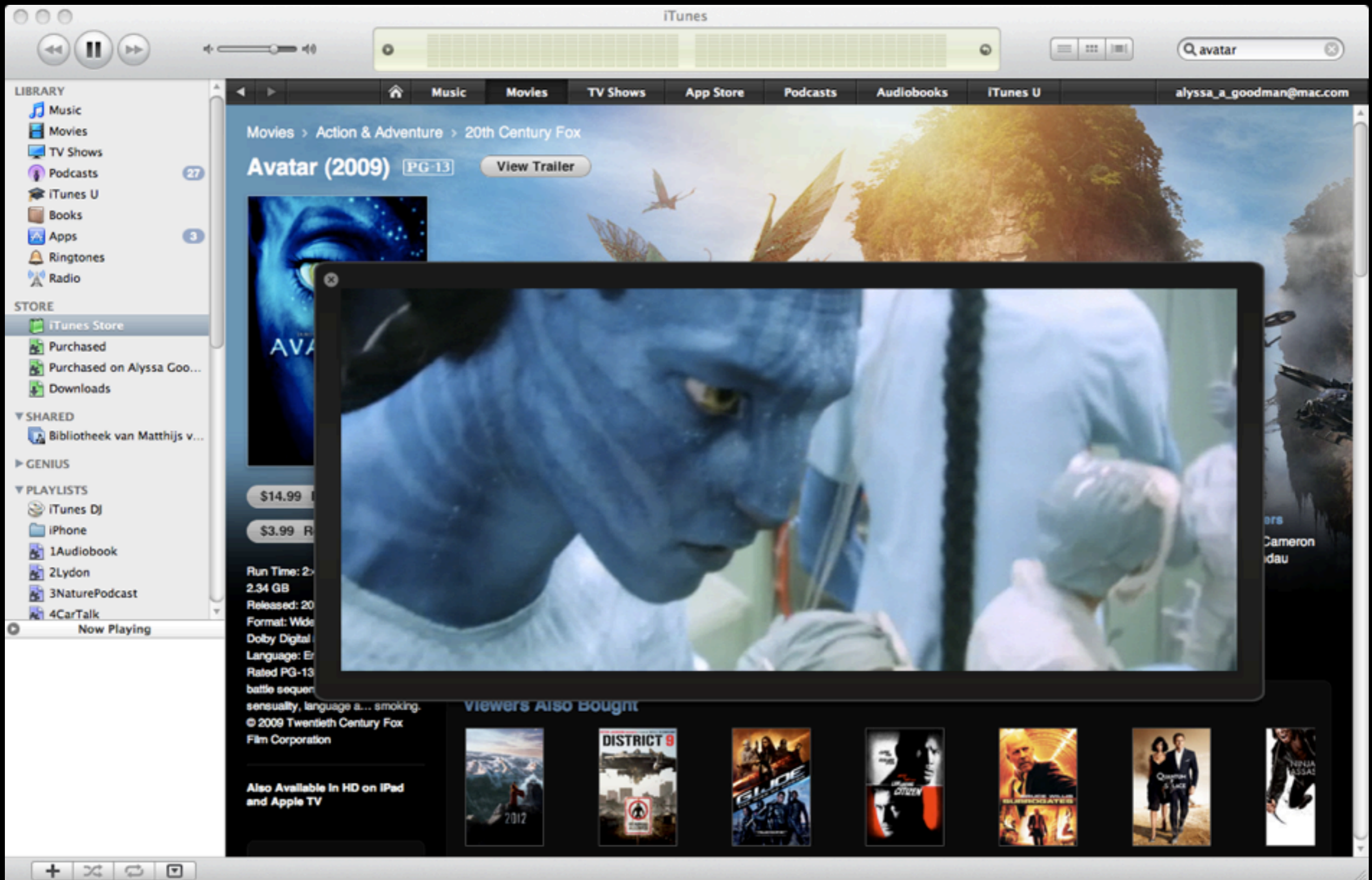
Much more than "just" the sky at night! 3D features can take you to other planets, stars & galaxies.

Finder Scope links to Wikipedia, publications, and data, so you can learn more

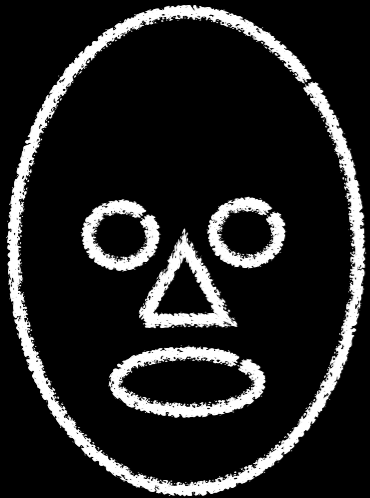
Context bar shows items of interest in current field of view

Context globe shows where you're looking.

Avatar, Another Talk, or Both?

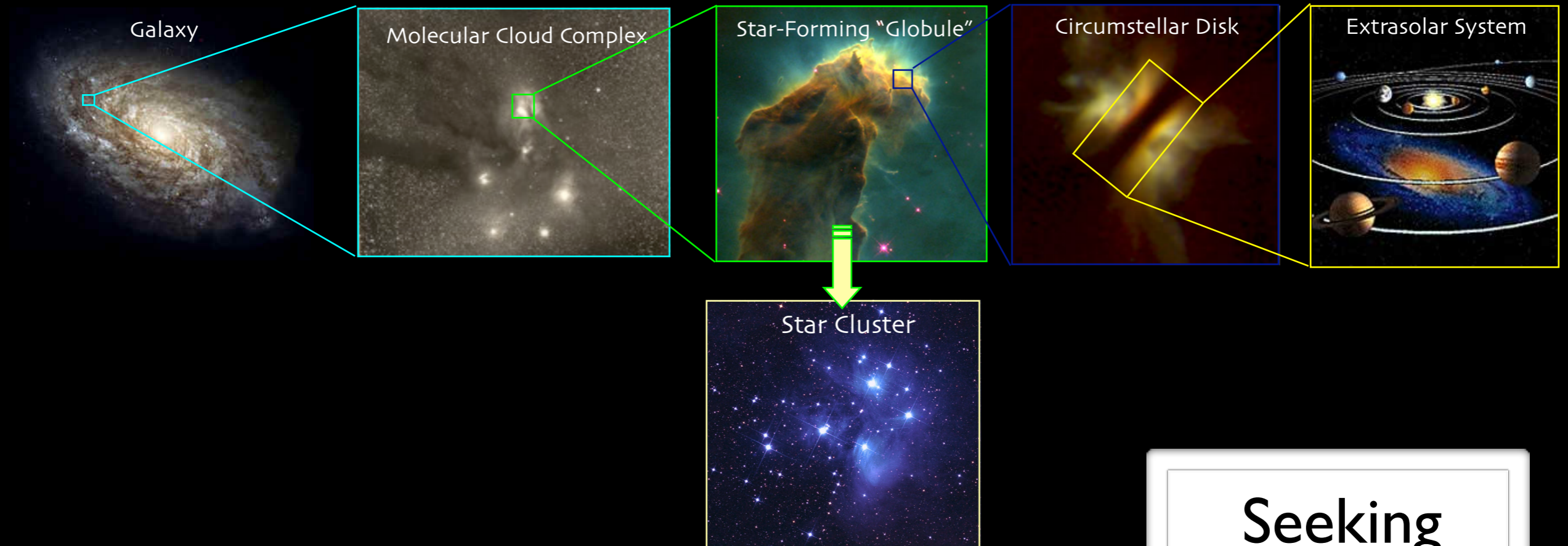


Comparisons between Simulations and Observations... Where we Stand



Alyssa A. Goodman (et al.)
Harvard-Smithsonian Center for Astrophysics

What can be done, where, and how?



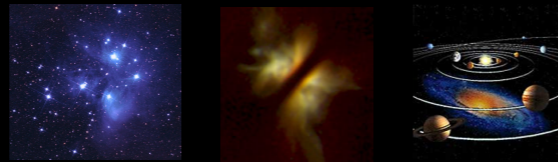
Seeking
 $n, T, \mathbf{v}, X\dots, \mathbf{B}$
of (\mathbf{x}, t)

“UNRESOLVED” measures

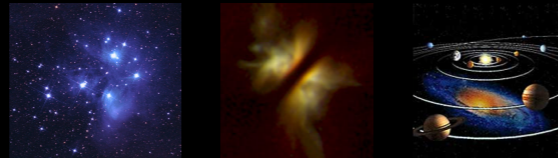
Integrated Intensity Ratios(gas, dust)



counting statistics



★ SED modeling



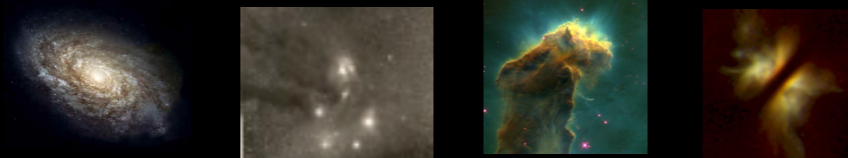
Seeking
 $n, T, v, X..., B$
of (\mathbf{x}, t)

“RESOLVED” measures

★ Dust: Extinction



★ Dust: Emission



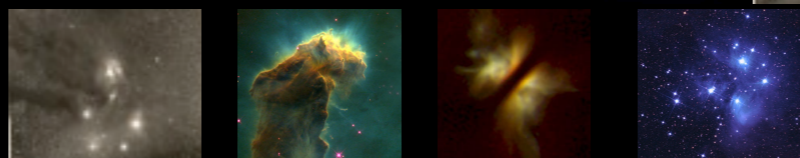
★ Dust: Scattered light



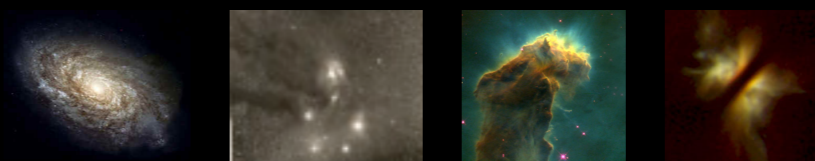
★ Dust/gas: Polarization (abs/scatt/em)



Gas: Zeeman (abs/em)

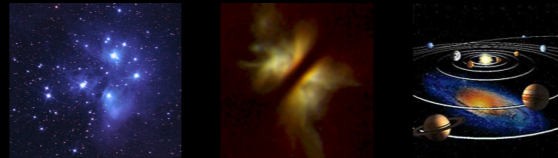


★ Gas: Detailed p - p (- v) maps/analysis



“UNRESOLVED” measures

★ SED modeling

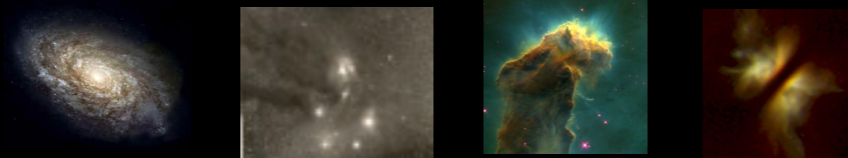


“RESOLVED” measures

★ Dust: Extinction



★ Dust: Emission



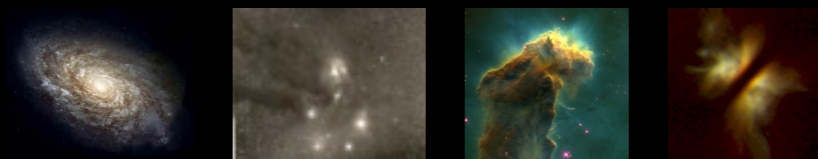
★ Dust: Scattered light



★ Dust/gas: Polarization (abs/scatt/em)



★ Gas: Detailed p - $p(-v)$ maps/analysis



“Review” will note the work of...

Galaxy Scale



Rosolowsky et al.

Dobbs et al.

GMC Scale

Lazarian, Pogosyan, et al.

Heyer, Brunt et al.

E. Ostriker, Stone & Gammie

HII Regions

Jane Arthur et al. (HII regions)...

Clouds/Cores



Rosolowsky et al.

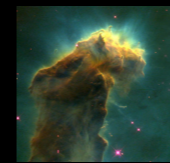
Padoan et al.

Juvela et al.

R. Smith, Bonnell et al.

H. Kirk et al. (including S. Basu)

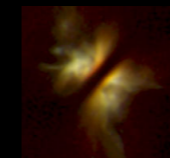
Cores/Disks



Offner, Krumholz, et al.

Schnee, Kauffmann, Shetty et al.

Steinacker et al.



J. Foster et al.

J.E. Pineda et al.

Cores/Clusters



Rundle, Harries, Acreman, Bate

Ayliffe, Bate et al.

Sources

Robitaille et al.

Whitney et al.

...and surely several others!

The “Real” M17



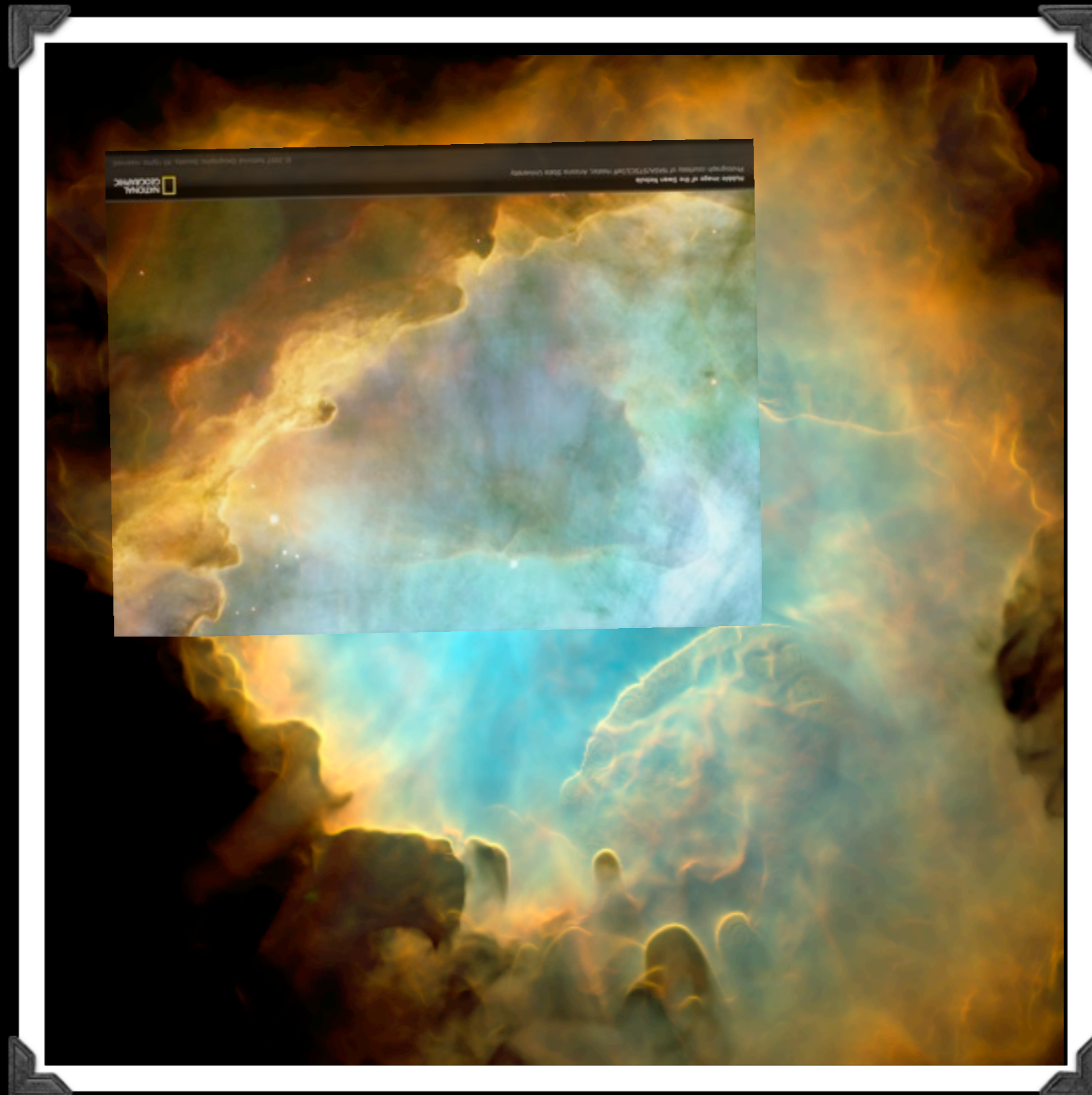
Hubble image of the Swan Nebula
Photograph courtesy of NASA/STSCI/Jeff Hester, Arizona State University



© 2007 National Geographic Society. All rights reserved.

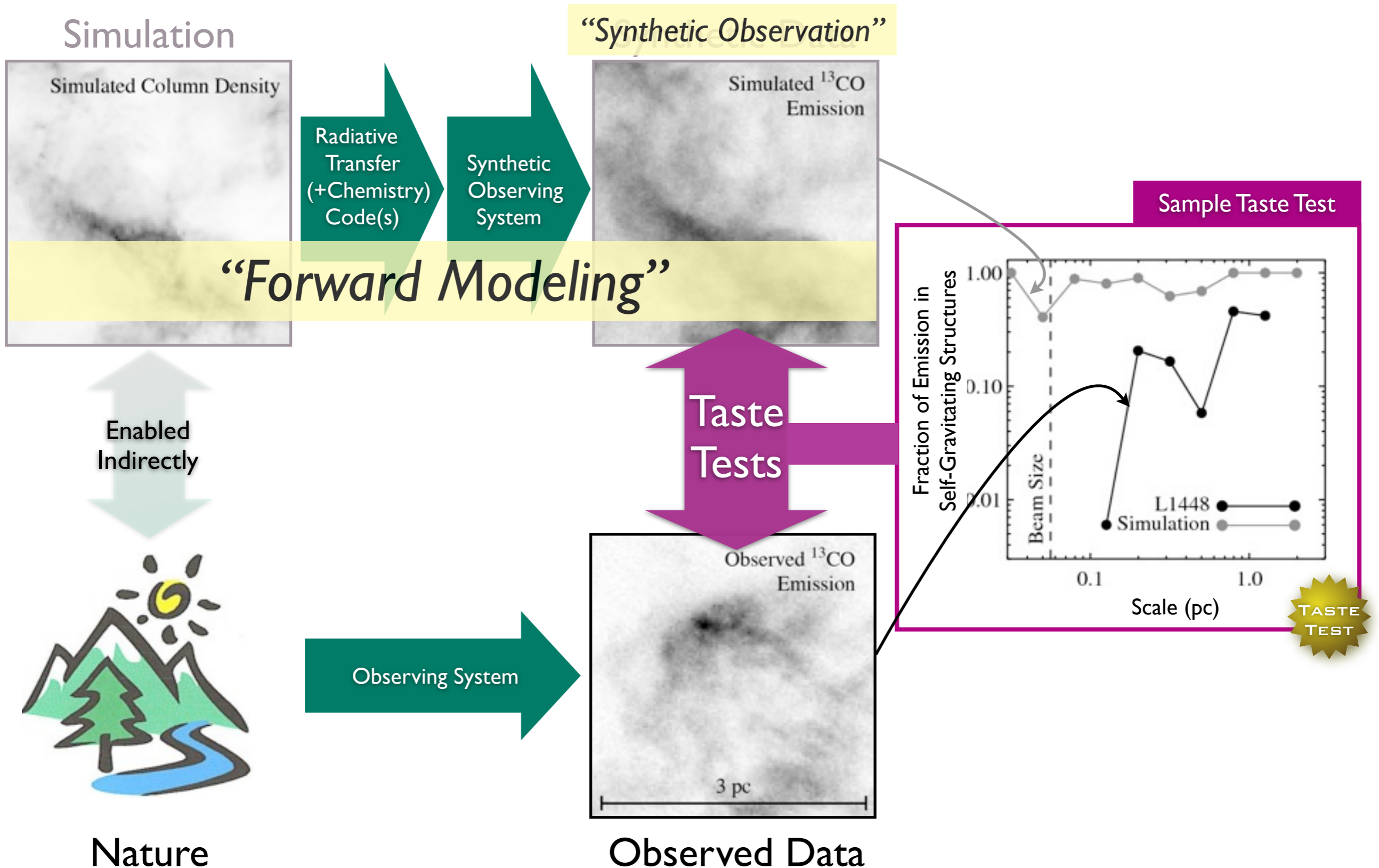
HST [OIII], H α and [NII] emission-line image from Hester et al.

FANTASTIC! Now we need to “Taste” it...



Synthetic [OIII], H α and [NII] emission-line image from a 512³ numerical simulation: Mellema, Henney, Arthur & Vázquez-Semadeni 2009

What is "Taste-Testing"?



Dust: Polarimetry

Synthetic Optical Polarization Map;
Ostriker, Stone & Gammie 2001

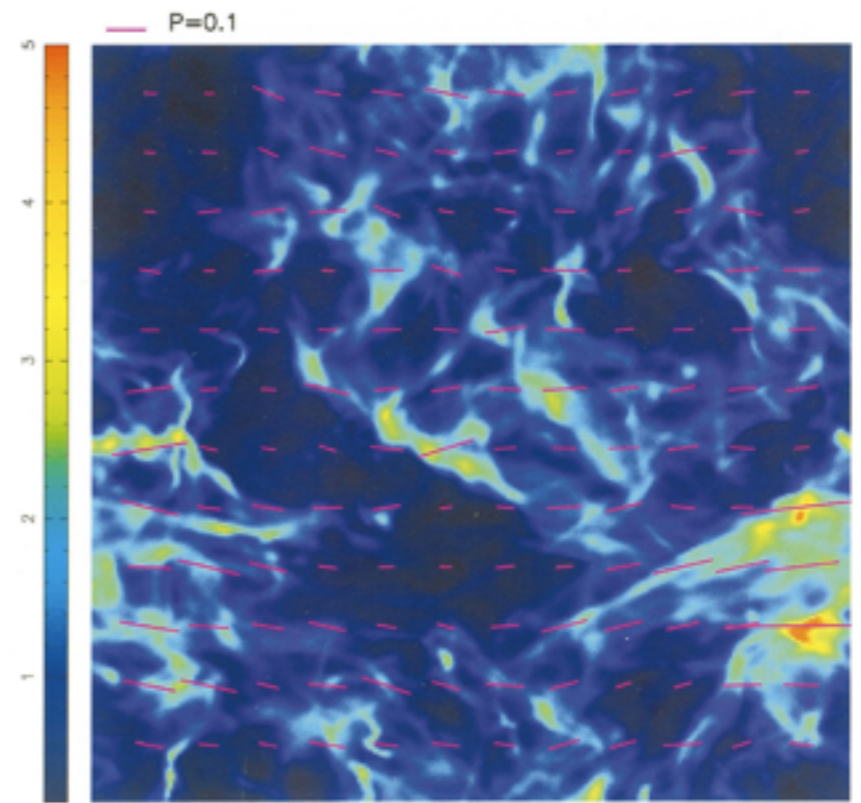
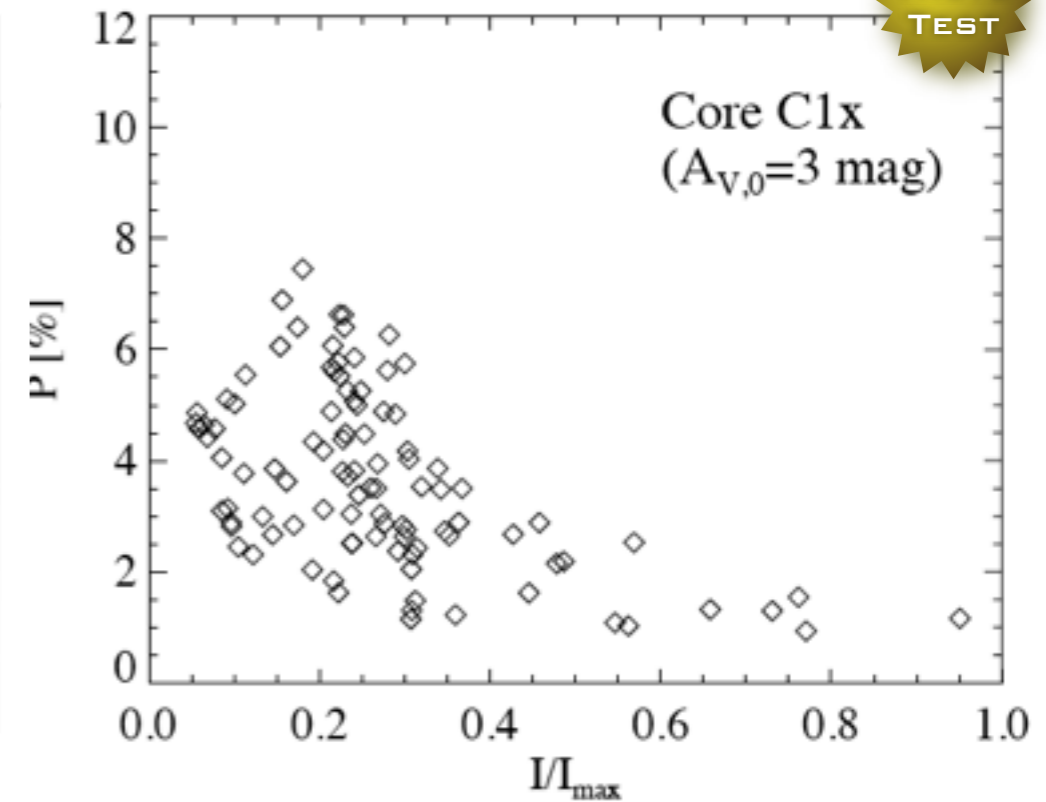
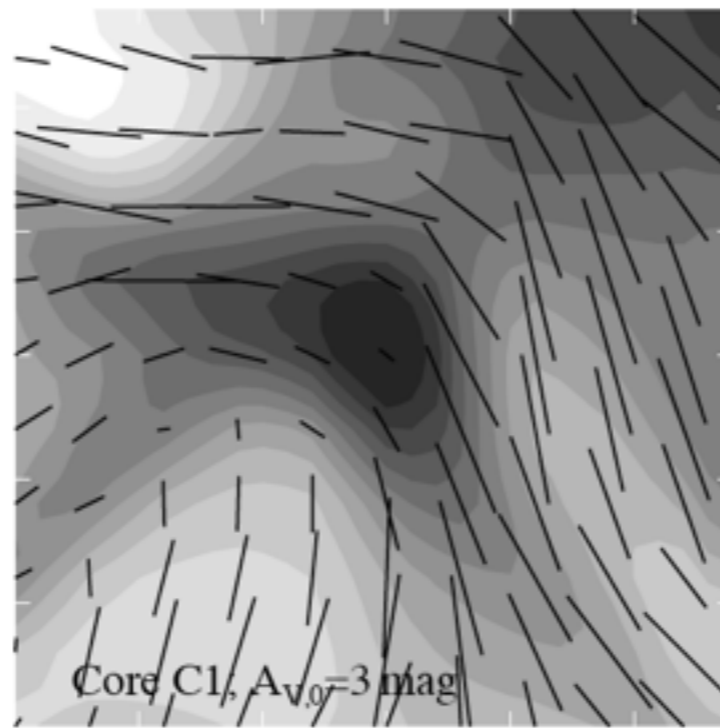
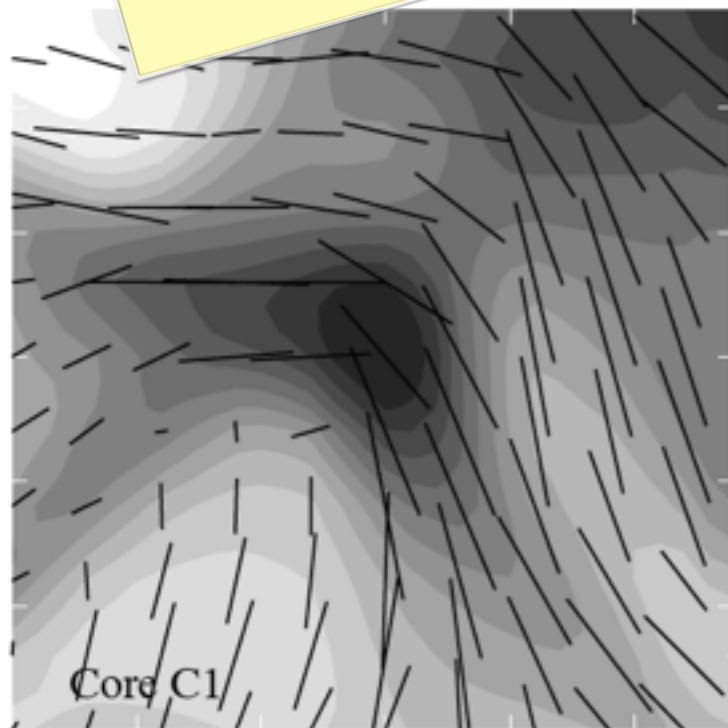


FIG. 22.—Column density (color scale, with units μ_L) and simulated polarization map for model snapshot B2 ($\beta = 0.01$, $\mathcal{M} = 7$), projected along \hat{z} perpendicular to the mean magnetic field. The fractional polarization at each point is proportional to the value of a fiducial polarization P corresponding to a uniform medium and uniform magnetic field perpendicular to the line of sight, arbitrarily set here to $P = 0.1$ as shown in the key.

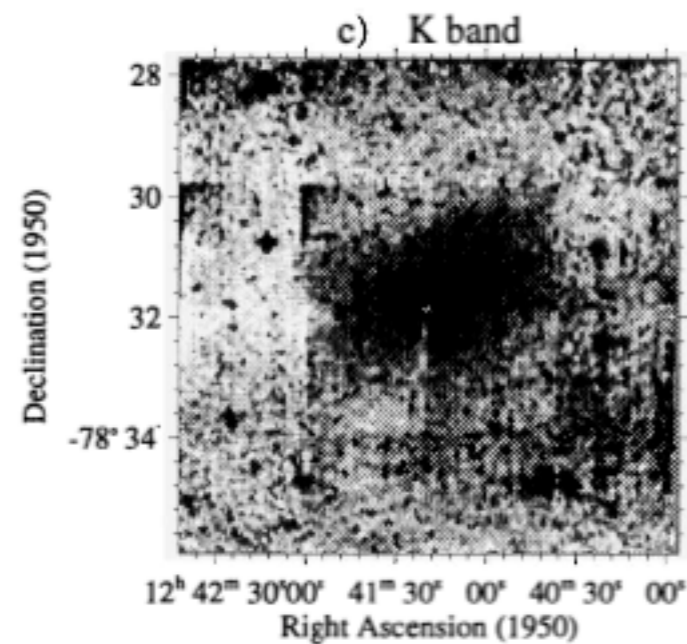
See Ram Rao's talk....



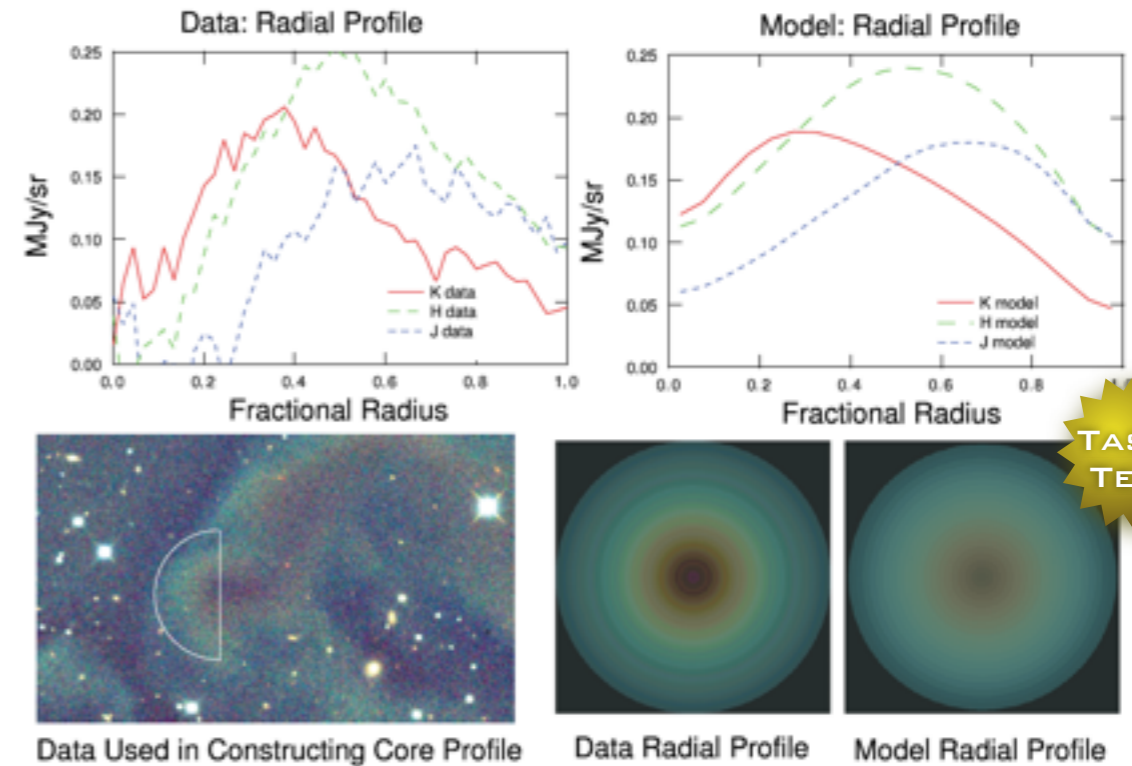
Sub-mm “Polarization Holes” caused by poorly aligned grains; Padoan et al. 2001

Dust: Scattered light

...can give exquisite resolution column density maps



First NIR Detection; *Lehtinen & Mattila 1996*



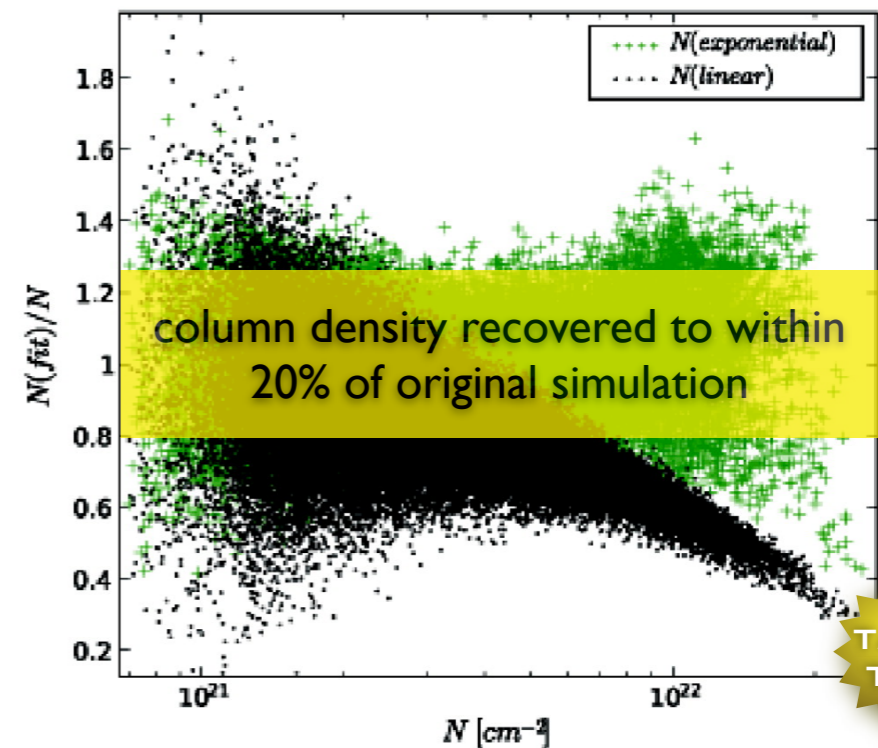
NIR “Cloudshine”; *Foster & Goodman 2006*

See Jurgen Steinacker's talk....



Fig. 8. Comparison of the three Spitzer images at 3.6, 4.5, and 8 μm of the inner 66000 AU of L183 (top) with scattered light models based on grains growing as a function of density (bottom). The underlying 3D structure of the model images is consistent with the measured A_V map. The general pattern of the modeled diffuse emission is similar while, the flux is about a factor of 2 lower in the model.

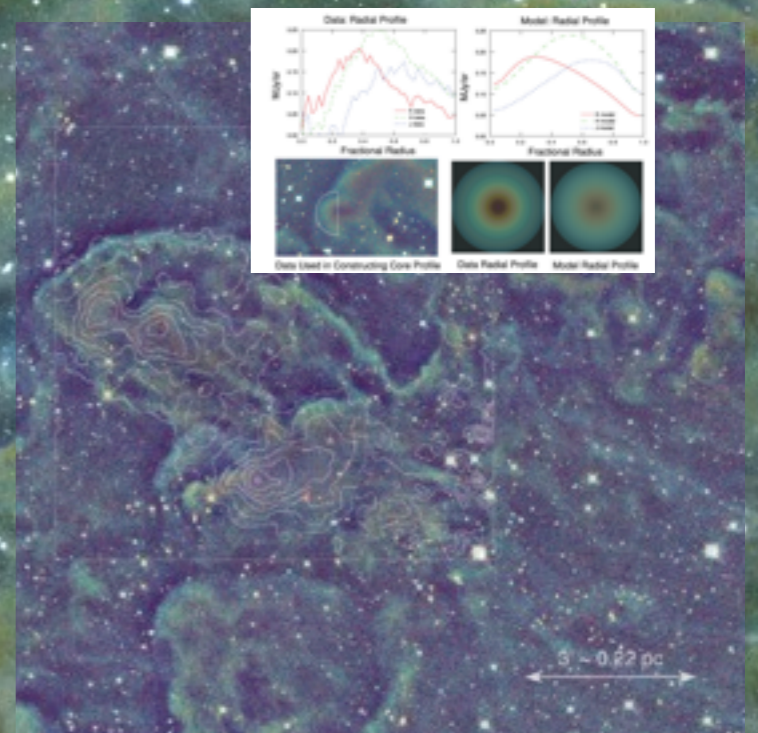
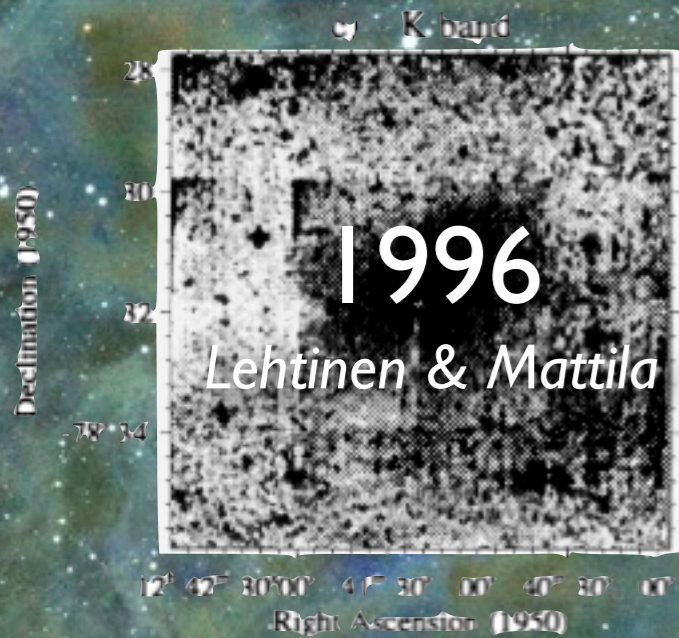
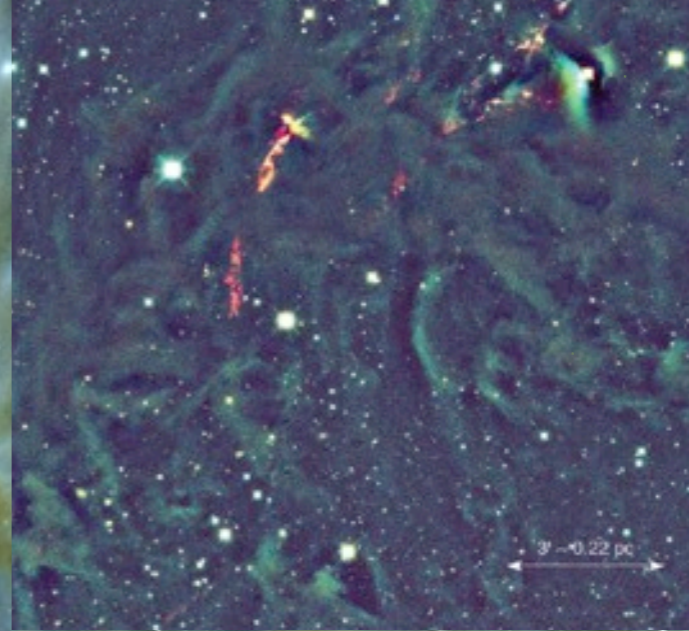
MIR “Coreshine”; *Steinacker et al. 2010*



“Inversion” of Cloudshine: *Padoan, Juvela & Pelkonen 2006; Juvela, Pelkonen, Padoan, Mattila 2006*

“Cloudshine”

(note this image is used to measure **extinction** too!)

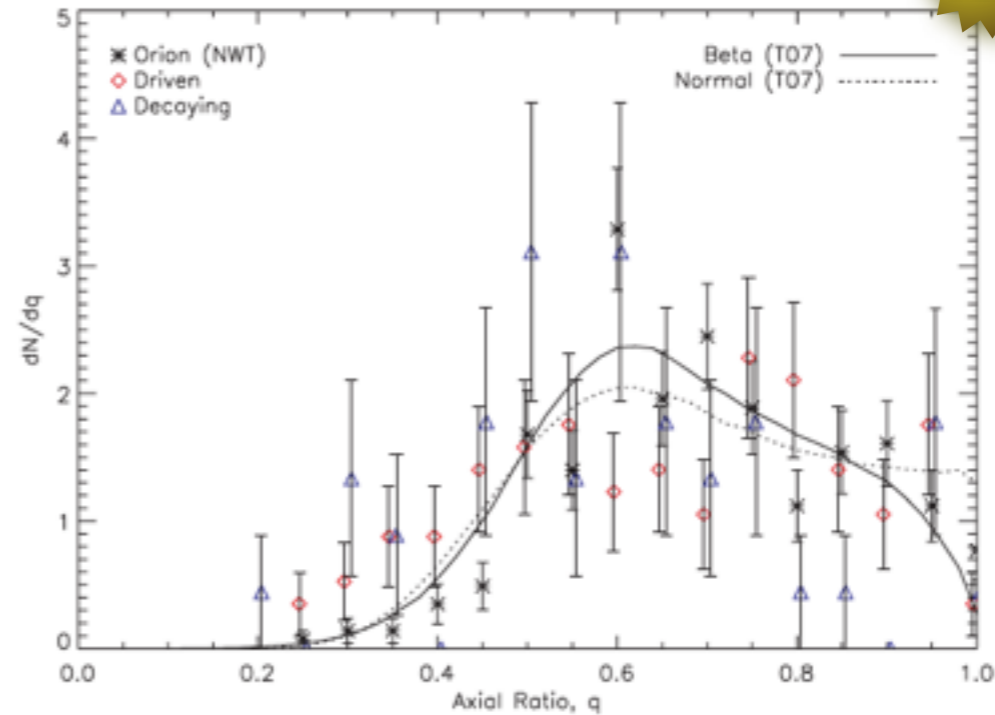


Background: to appear in Foster, Mandel, Pineda, Covey & Goodman 2010
Insets: Foster & Goodman 2006, Calar Alto JHK

Dust: Emission

Orion Core Shapes from AMR Simulations (Offner & Krumholz 2009)

TASTE TEST

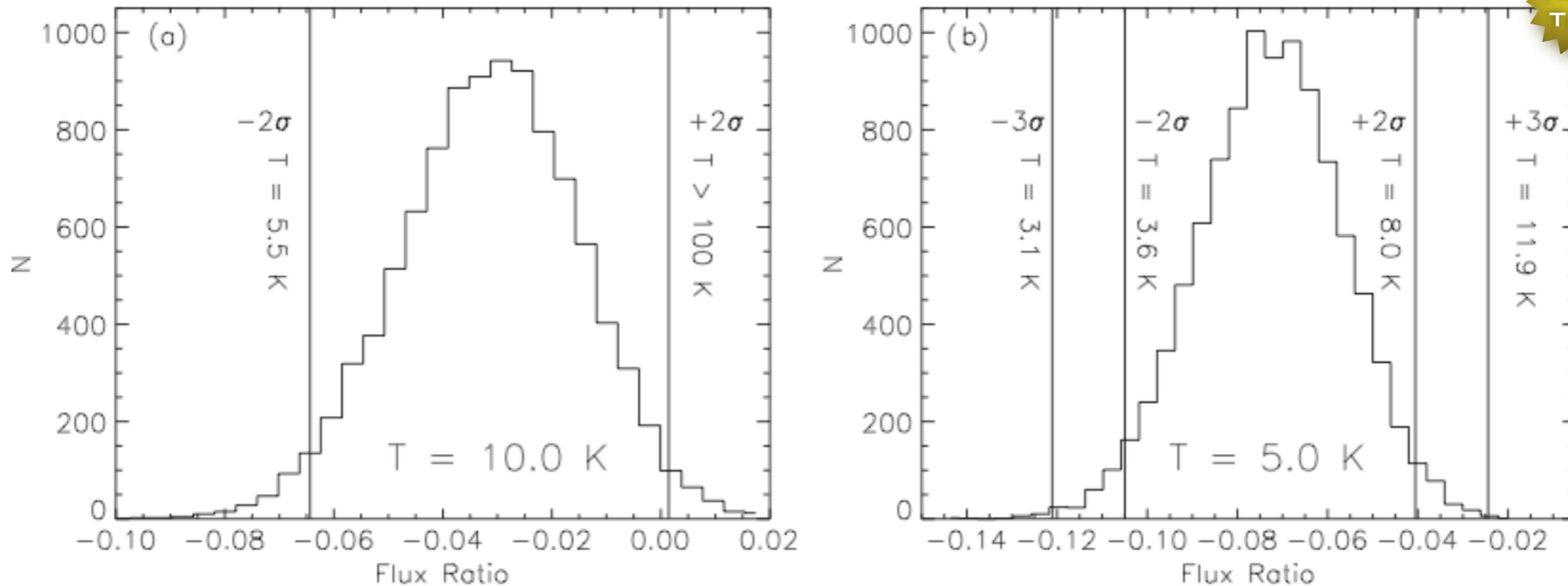


Not enough time for proper discussion, but ask a question about Herschel...

See also Mika Juvela's talk, and poster by J. Malinen et al.

Even the "Column Temperature" is much more uncertain than you would think (even for Herschel) Shetty, Kauffmann, Schnee, Goodman, Ercolano 2009

TASTE TEST

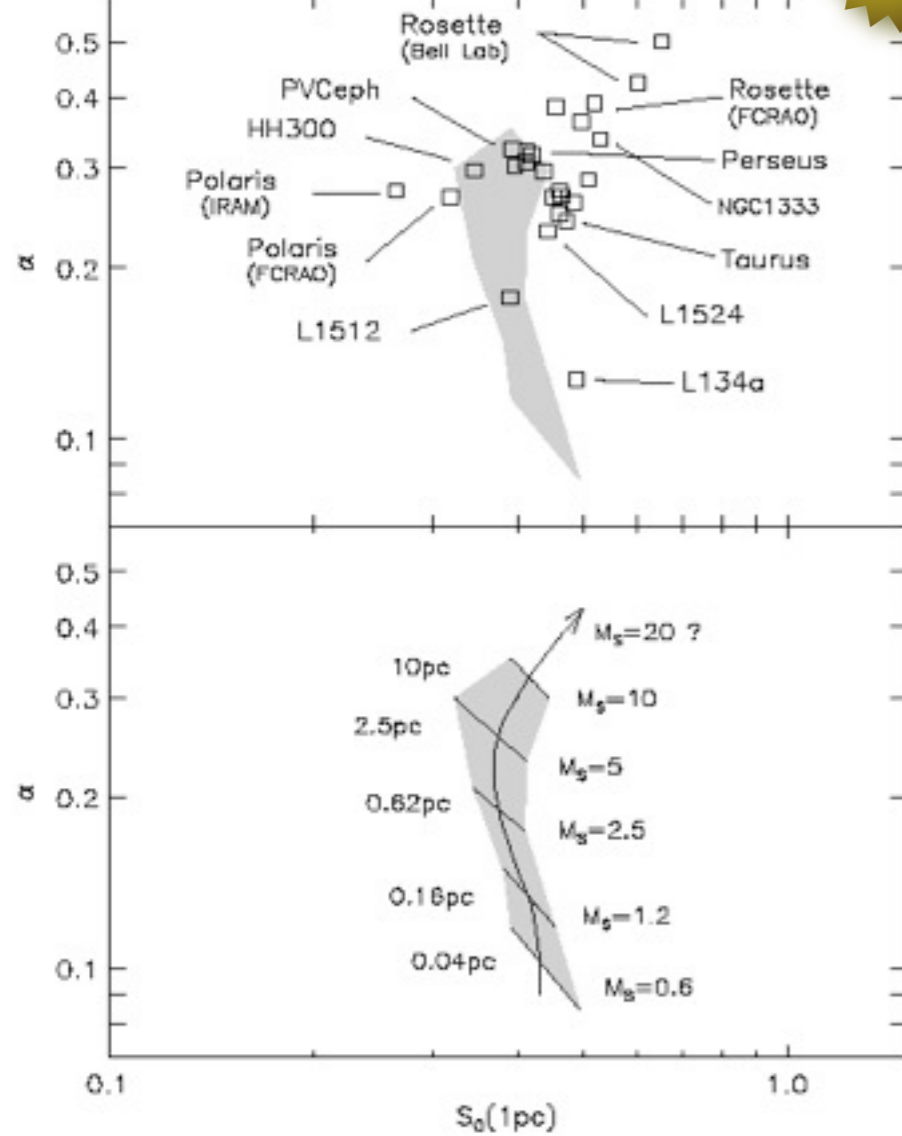


Gas: Detailed p - $p(-v)$ maps/analysis

The Spectral Correlation Function
Need for High Mach Numbers...

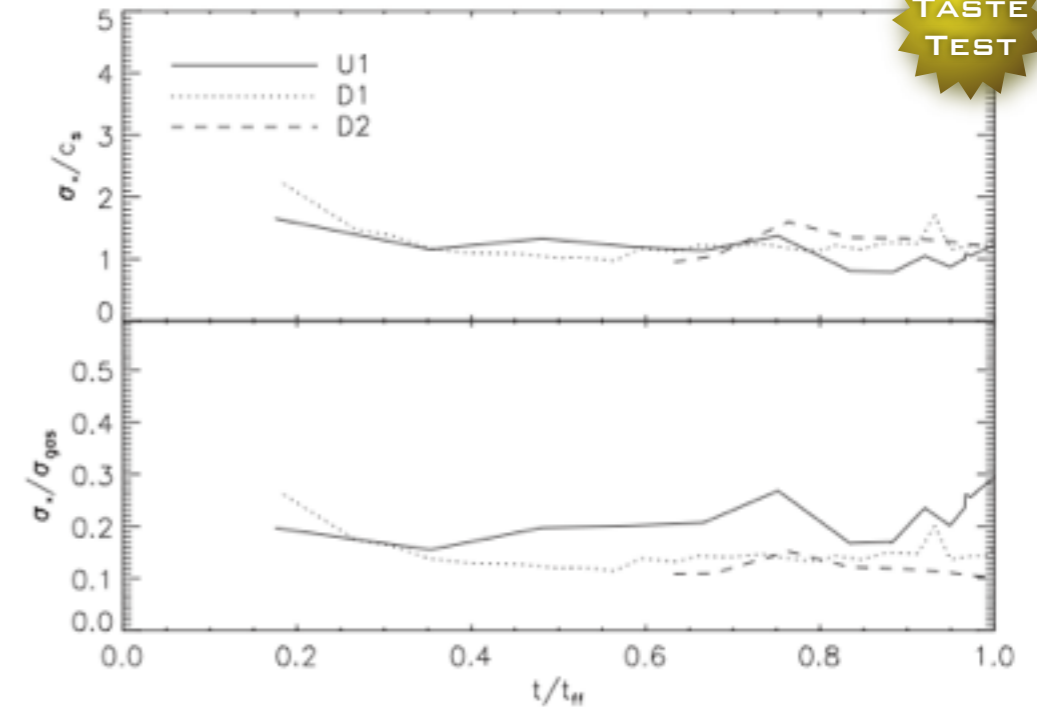
Padoan et al. 2003;
cf. Rosolowsky et al. 1999, etc.

TASTE
TEST

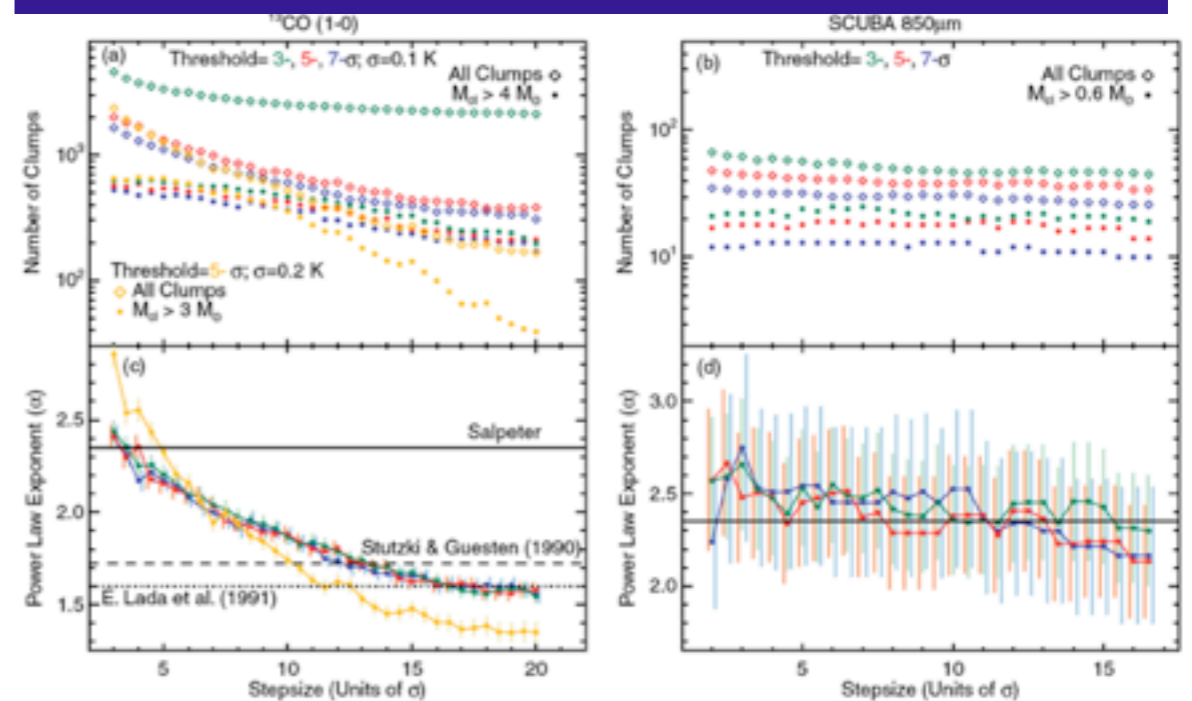


Small Stellar and Core-to-Environment **Velocities**
Offner, Hansen & Krumholz 2009; cf. Ayliffe et al. 2007;
Rundle et al. 2010; Kirk et al. 2010

TASTE
TEST








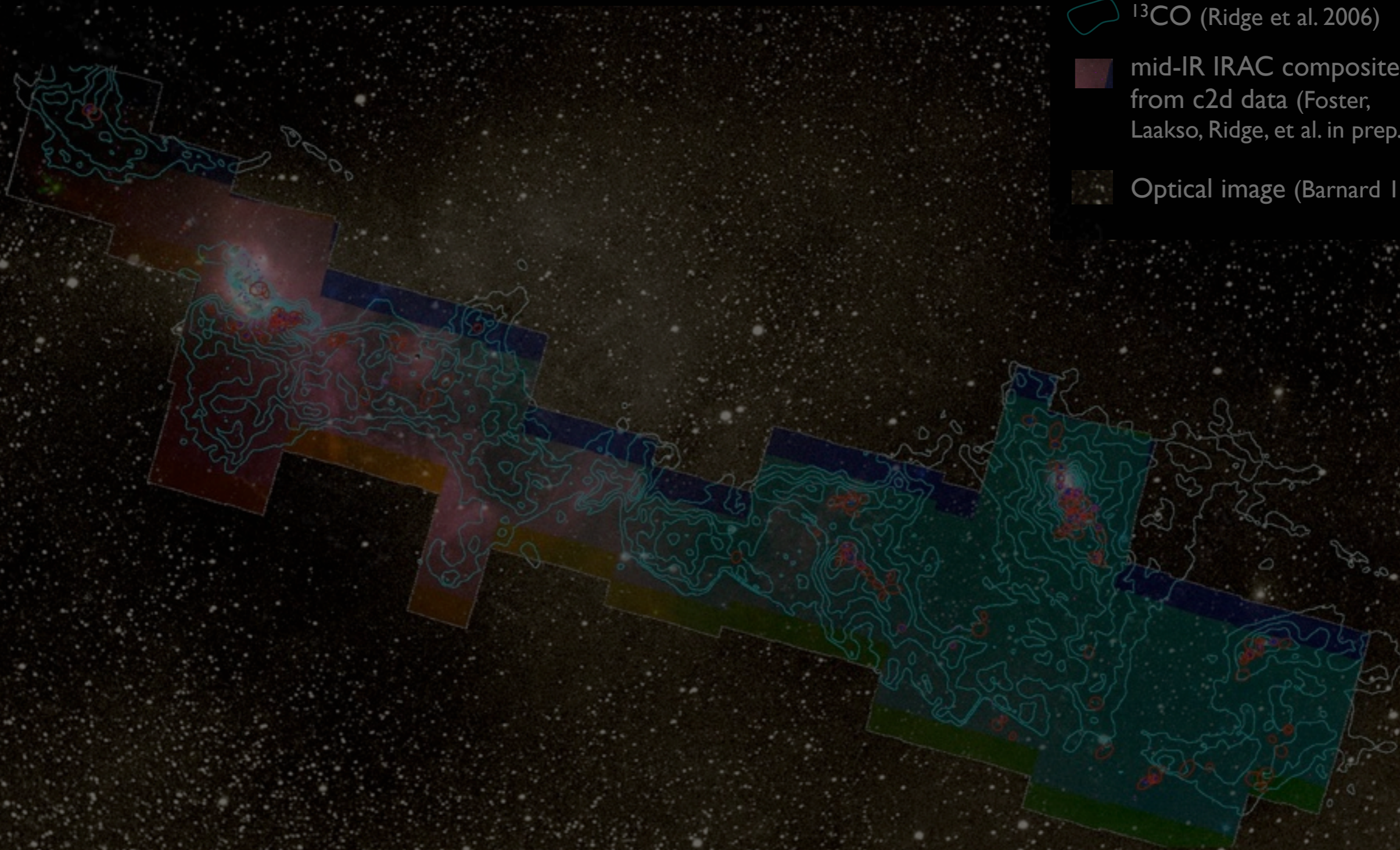
“The Perils of CLUMPFIND” – **Any CMF you want?!**
Pineda, Rosolowsky & Goodman 2009



COMPLETE Perseus

Image size: 1305 x 733
VL: 63 WW: 127

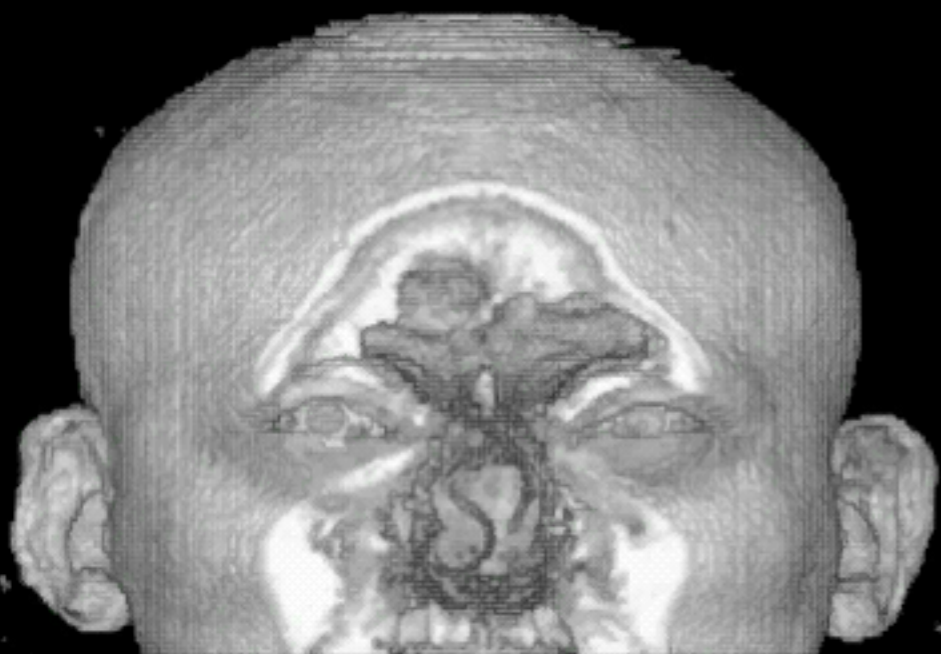
-  mm peak (Enoch et al. 2006)
-  sub-mm peak (Hatchell et al. 2005, Kirk et al. 2006)
-  ^{13}CO (Ridge et al. 2006)
-  mid-IR IRAC composite from c2d data (Foster, Laakso, Ridge, et al. in prep.)
-  Optical image (Barnard 1927)



m: 1/249
Zoom: 227% Angle: 0

“p-p-v” NOT p-p-p (,v-v-v)

“KEITH”



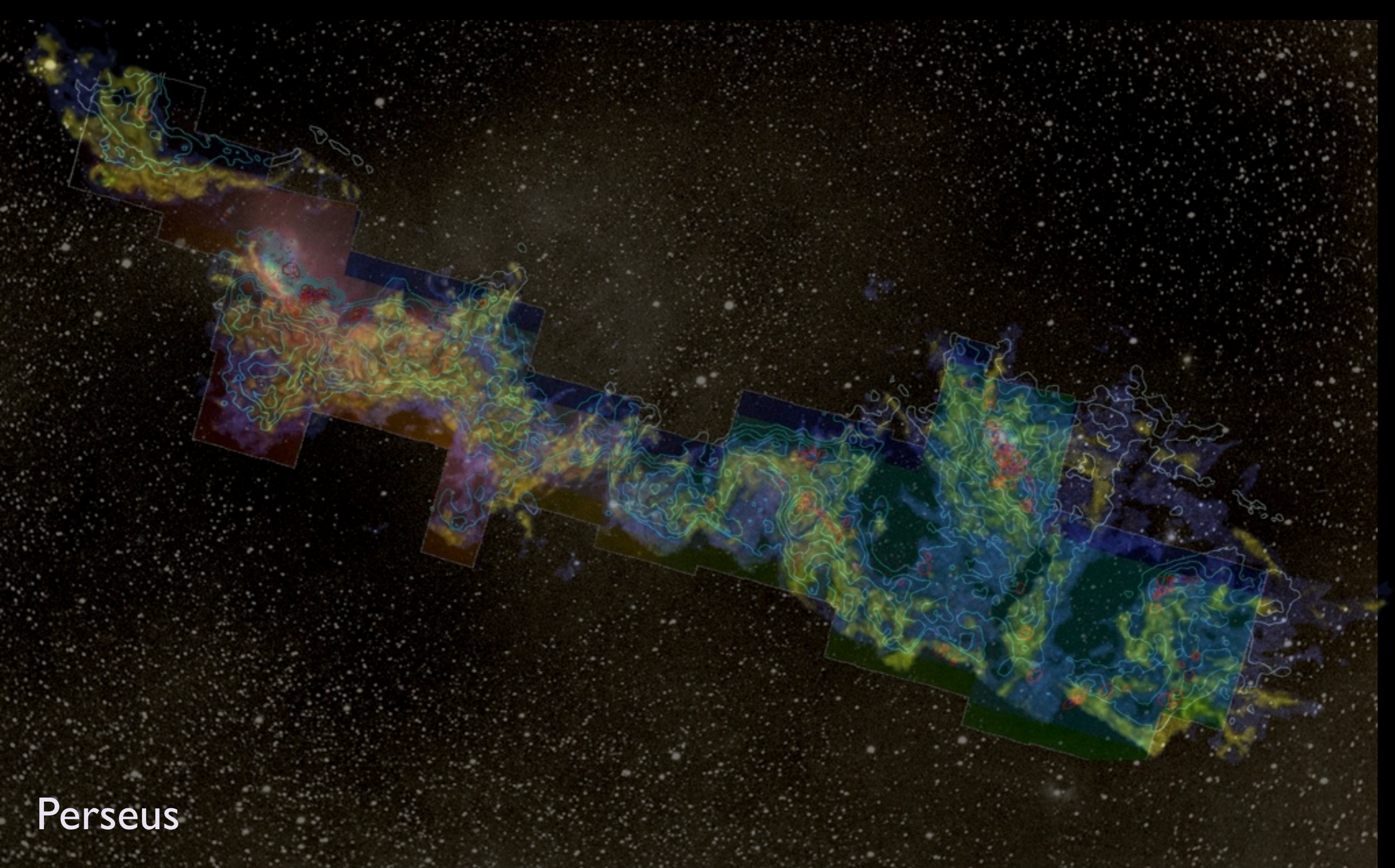
“z” is depth into head

“PERSEUS”



“z” is line-of-sight velocity

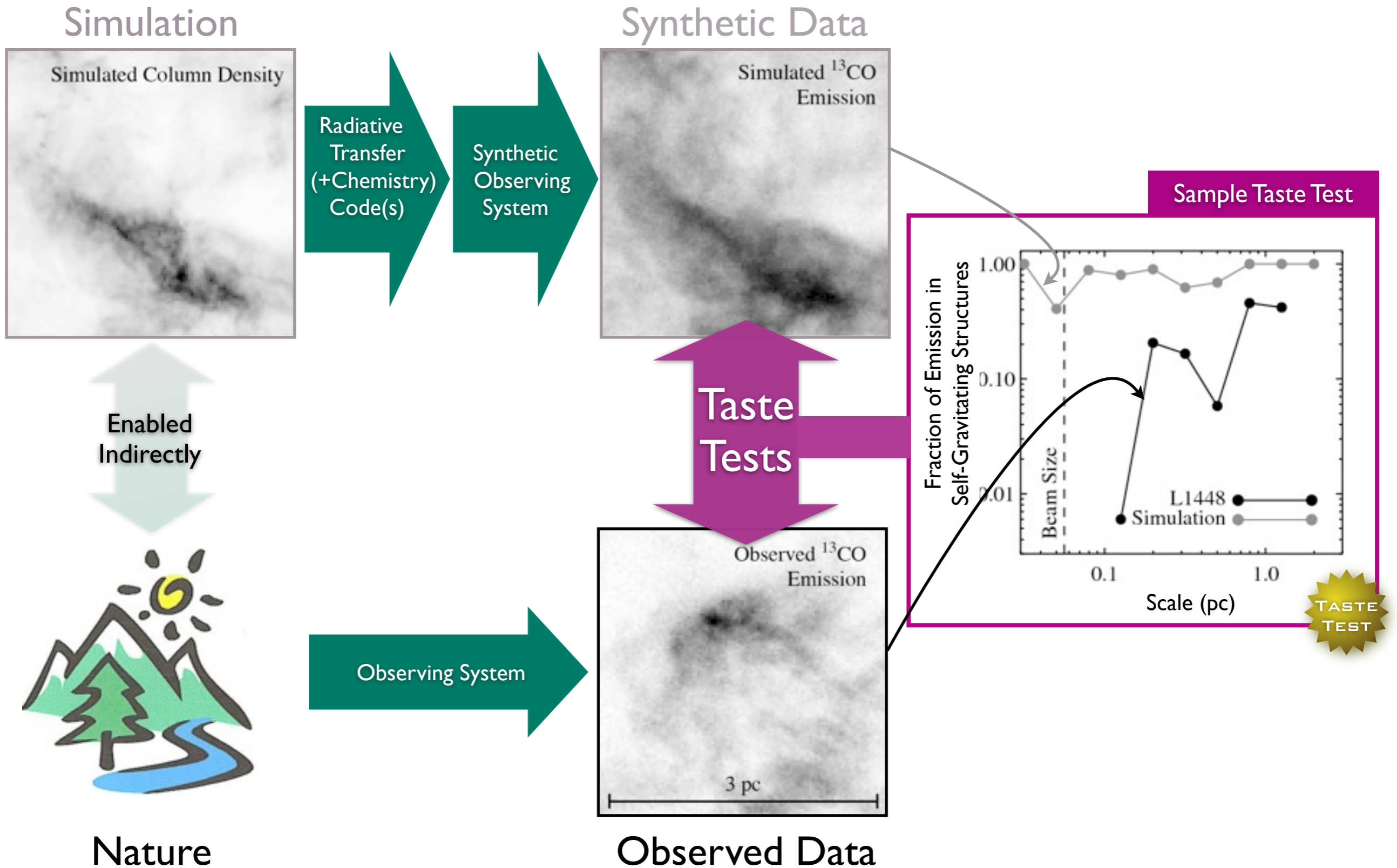


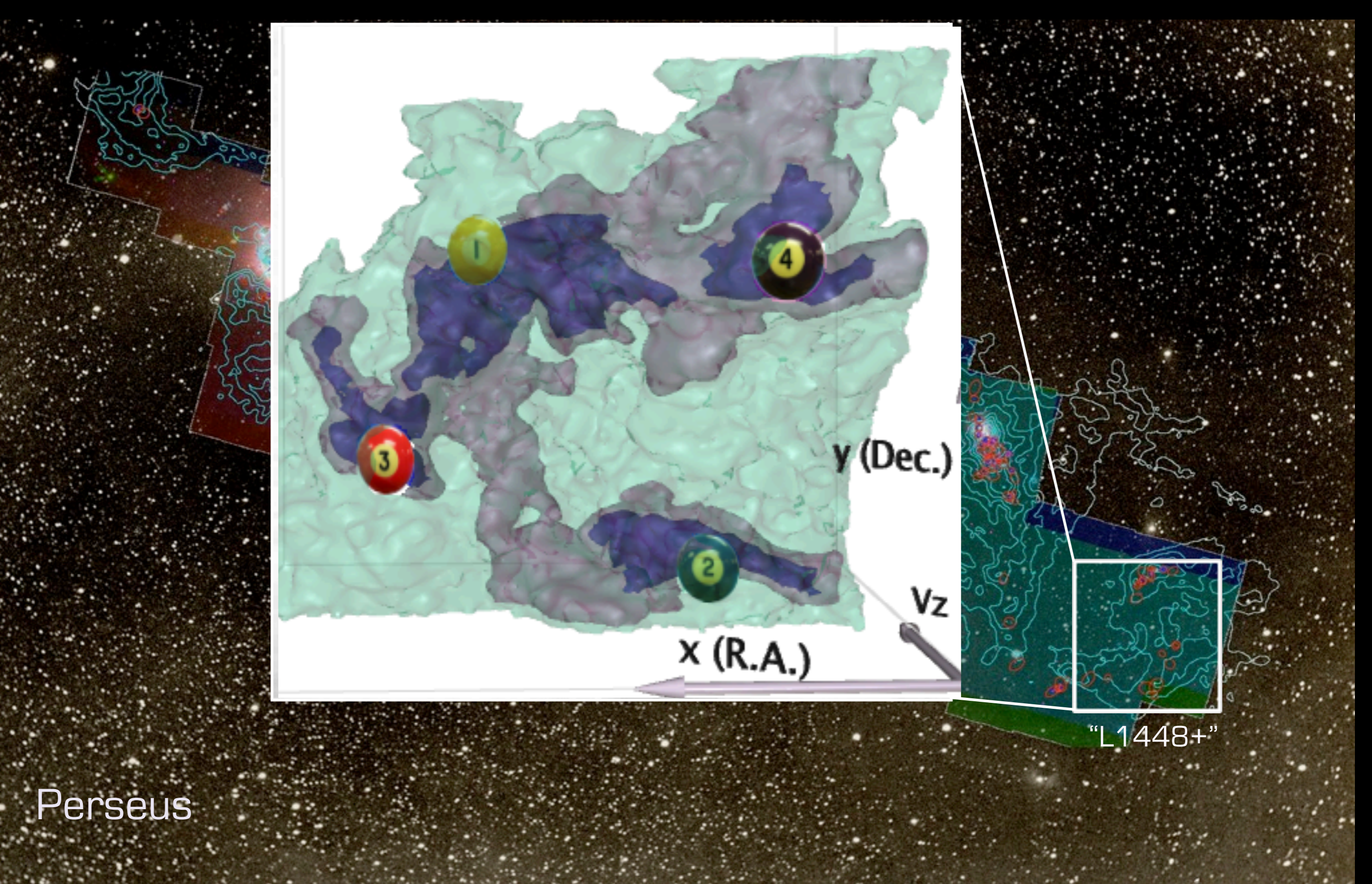


Perseus

3D Viz made with VolView

Taste-Test in p - p - v





Perseus

Conclusion

Dendrogram-based analysis shows that **star formation takes place in self-gravitating “cocoon,”** and some of those **cocoons are likely bound to each other.**

But, that’s not today’s point...

Let’s see how the **Taste Test Works, using 3D PDF...**

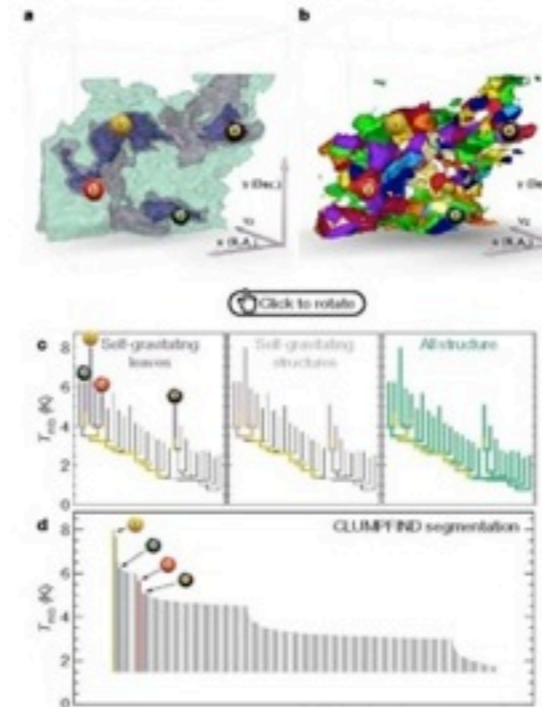


Figure 2 | Comparison of the ‘dendrogram’ and ‘CLUMPFIND’ feature-identification algorithms as applied to ^{13}CO emission from the L1448 region of Perseus. **a**, 3D visualization of the surfaces indicated by colours in the dendrogram shown in **c**. Purple illustrates the smallest scale self-gravitating structures in the region corresponding to the leaves of the dendrogram; pink shows the smallest surfaces that contain distinct self-gravitating leaves within them; and green corresponds to the surface in the data cube containing all the significant emission. Dendrogram branches corresponding to self-gravitating objects have been highlighted in yellow over the range of T_{mb} (main-beam temperature) test-level values for which the virial parameter is less than 2. The x - y locations of the four ‘self-gravitating’ leaves labelled with billiard balls are the same as those shown in Fig. 1. The 3D visualizations show position–position–velocity (p - p - v) space. RA, right ascension; dec., declination. For comparison with the ability of dendrograms (**c**) to track hierarchical structure, **d** shows a pseudo-dendrogram of the CLUMPFIND segmentation (**b**), with the same four labels used in Fig. 1 and in **a**. As ‘clumps’ are not allowed to belong to larger structures, each pseudo-branch in **d** is simply a series of lines connecting the maximum emission value in each clump to the threshold value. A very large number of clumps appears in **b** because of the sensitivity of CLUMPFIND to noise and small-scale structure in the data. In the online PDF version, the 3D cubes (**a** and **b**) can be rotated to any orientation, and surfaces can be turned on and off (interaction requires Adobe Acrobat version 7.0.8 or higher). In the printed version, the front face of each 3D cube (the ‘home’ view in the interactive online version) corresponds exactly to the patch of sky shown in Fig. 1, and velocity with respect to the Local Standard of Rest increases from front (-0.5 km s^{-1}) to back (8 km s^{-1}).

data, CLUMPFIND typically finds features on a limited range of scales, above but close to the physical resolution of the data, and its results can be overly dependent on input parameters. By tuning CLUMPFIND’s two free parameters, the same molecular-line data set⁸ can be used to show either that the frequency distribution of clump mass is the same as the initial mass function of stars or that it follows the much shallower mass function associated with large-scale molecular clouds (Supplementary Fig. 1).

Four years before the advent of CLUMPFIND, ‘structure trees’¹⁰ were proposed as a way to characterize clouds’ hierarchical structure

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’¹¹. Although well developed in other data-intensive fields^{12,13}, 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 frequency¹⁴.

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 setting 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 work¹⁴ 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 $M_{\text{gas}} = X_{13\text{CO}} L_{13\text{CO}}$, where $X_{13\text{CO}} = 8.0 \times 10^{20} \text{ cm}^{-2} \text{ K}^{-1} \text{ s}$ (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, $\alpha_{\text{obs}} = 5\sigma_v^2 R / GM_{\text{gas}}$. In principle, extended portions of the tree (Fig. 2, yellow highlighting) where $\alpha_{\text{obs}} < 2$ (where gravitational energy is comparable to or larger than kinetic energy) correspond to regions of p - p - v space where self-gravity is significant. As α_{obs} only represents the ratio of kinetic energy to gravitational energy at one point in time, and does not explicitly capture external over-pressure and/or magnetic fields¹⁶, its measured value should only be used as a guide to the longevity (boundedness) of any particular feature.

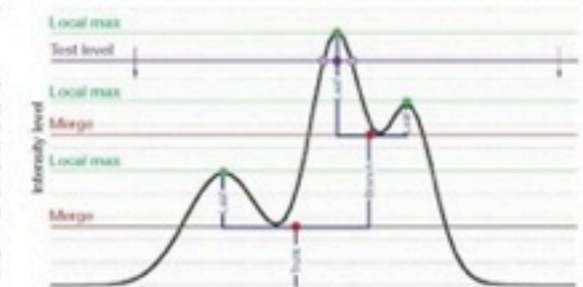
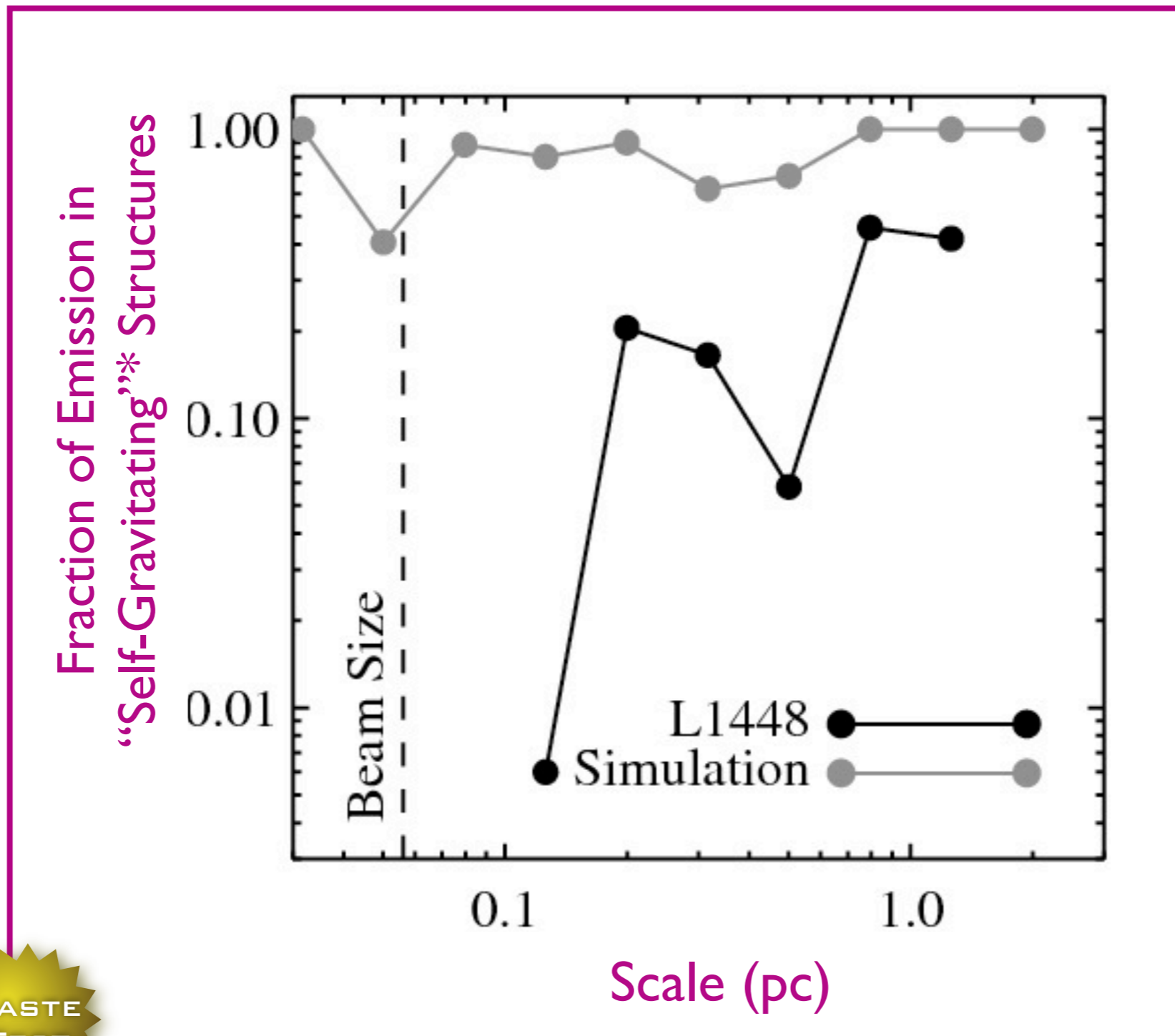


Figure 3 | Schematic illustration of the dendrogram process. Shown is the construction of a dendrogram from a hypothetical one-dimensional emission profile (black). The dendrogram (blue) can be constructed by ‘dropping’ a test constant emission level (purple) from above in tiny steps (exaggerated in size here, light lines) until all the local maxima and mergers are found, and connected as shown. The intersection of a test level with the emission is a set of points (for example the light purple dots) in one dimension, a planar curve in two dimensions, and an isosurface in three dimensions. The dendrogram of 3D data shown in Fig. 2c is the direct analogue of the tree shown here, only constructed from ‘isosurface’ rather than ‘point’ intersections. It has been sorted and flattened for representation on a flat page, as fully representing dendrograms for 3D data cubes would require four dimensions.

Taste-Testing Gravity(?)

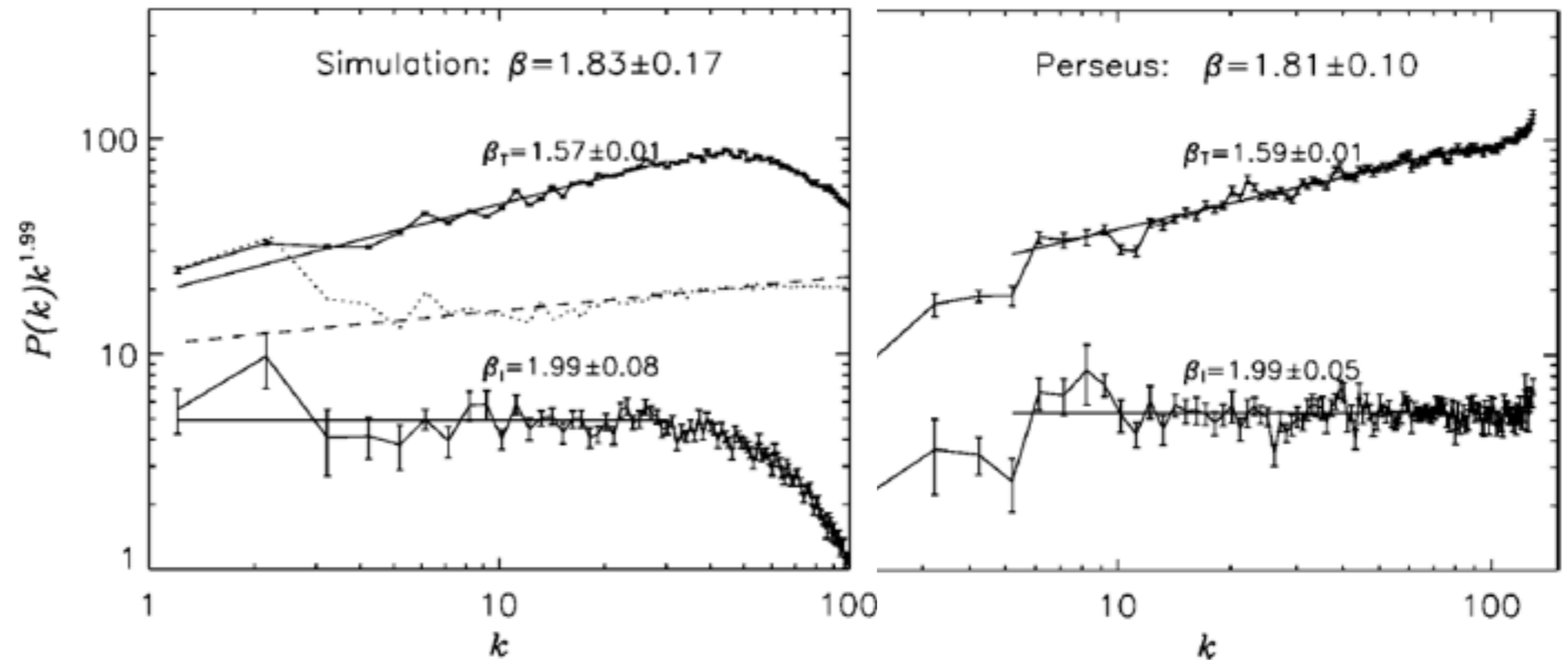


*Gravity-free HD Simulations from Padoan et al. 2006;
L1448 analysis from Rosolowsky et al. 2008
both lines derived from ^{13}CO “observations”*

Matching “Power Spectra” are not enough...

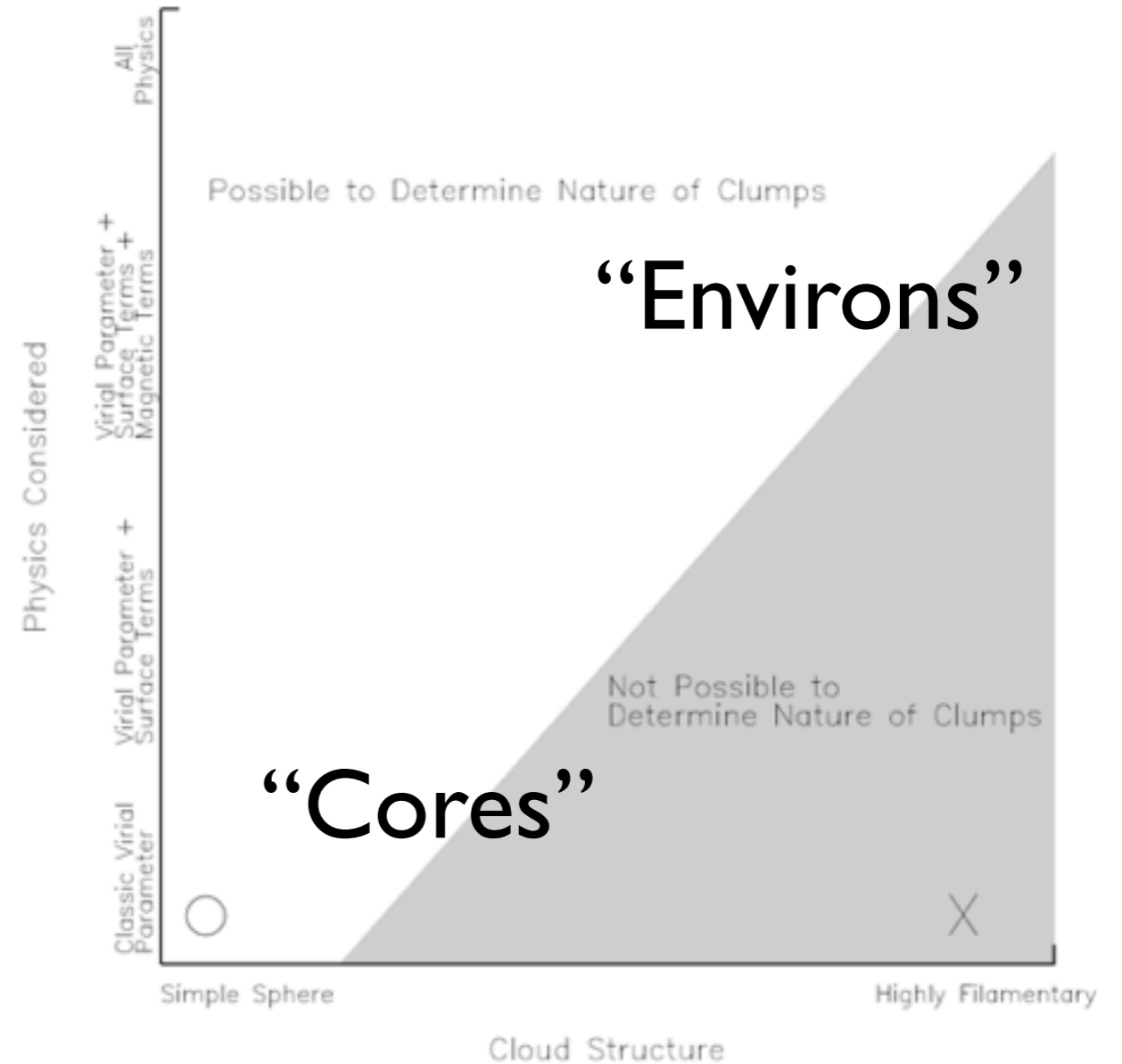
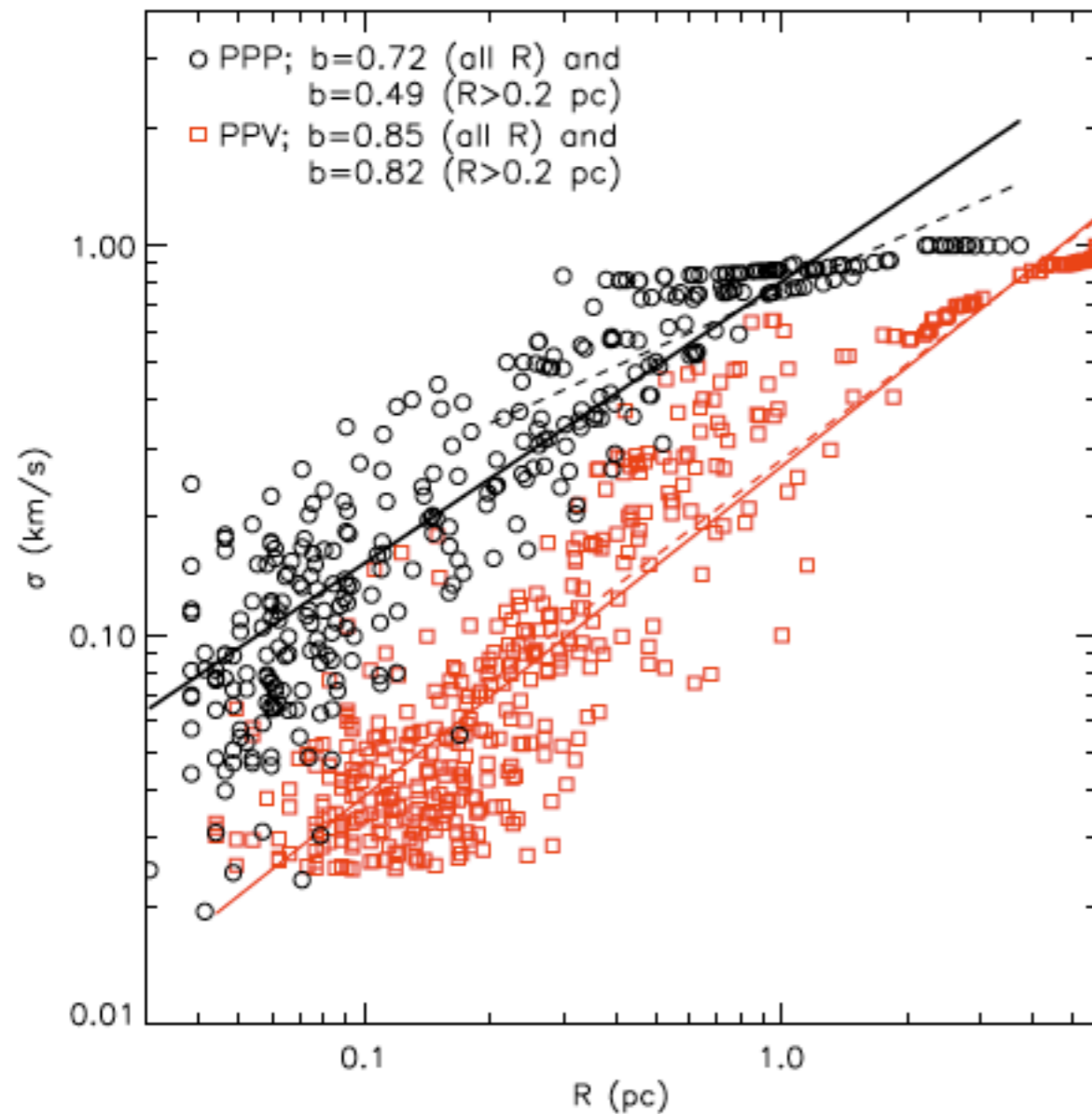


“Perseus-Matching”
Sample Simulation
from Padoan, Juvela,
Kritsuk & Norman 2006
(Mach 6; Enzo; pure hydro)



Note: Padoan et al. 2006 paper was intended to test the VCS method of Lazarian & Pogosyan 2000;
cf. PCA methods of Brunt & Heyer 2002a,b

Caveats/Worries about p - p - v (bijection) ... and the virial parameter



from **Shetty**, Collins, Kauffmann, Goodman, Rosolowsky & M. Norman 2010;

see also recent work of Dib et al., Ostriker et al., Ballesteros-Paredes et al., Myers, and Smith, Clark & Bonnell

Watermelons to Apples to Seeds?

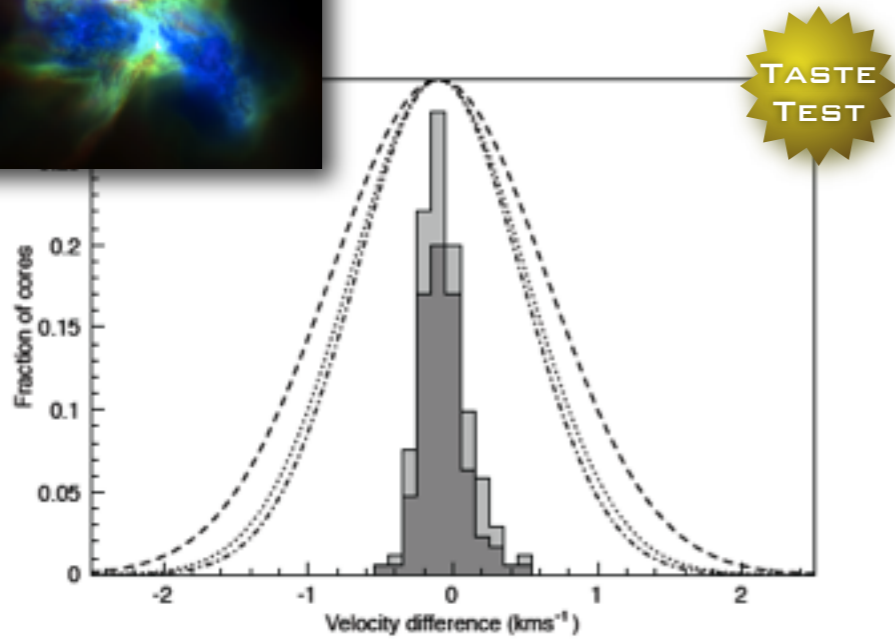
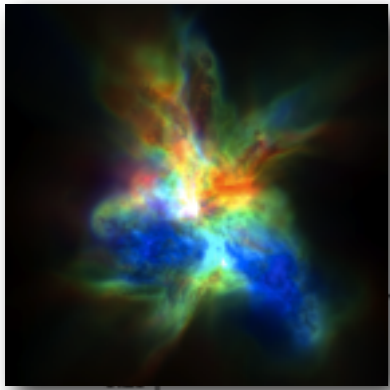
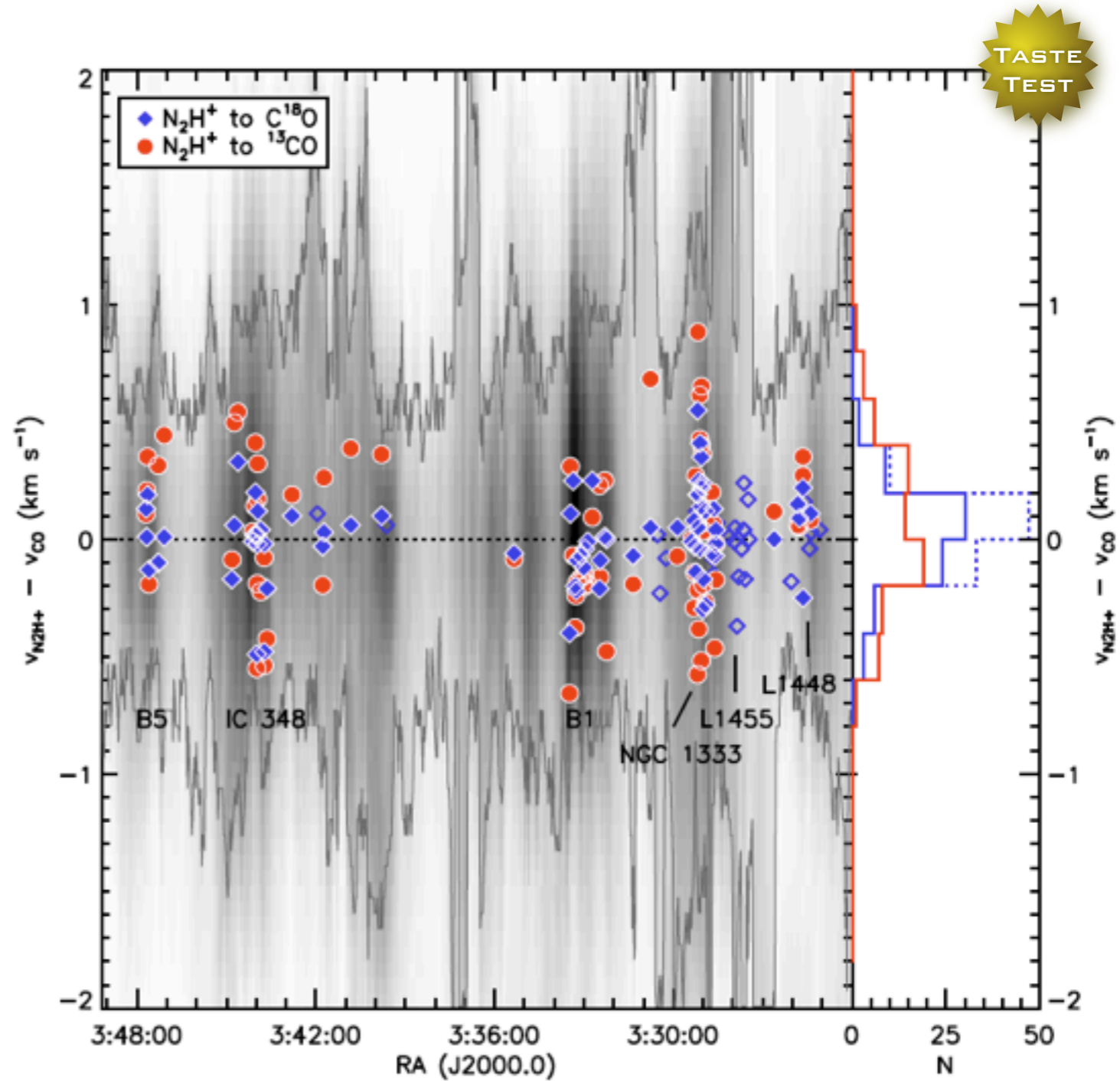
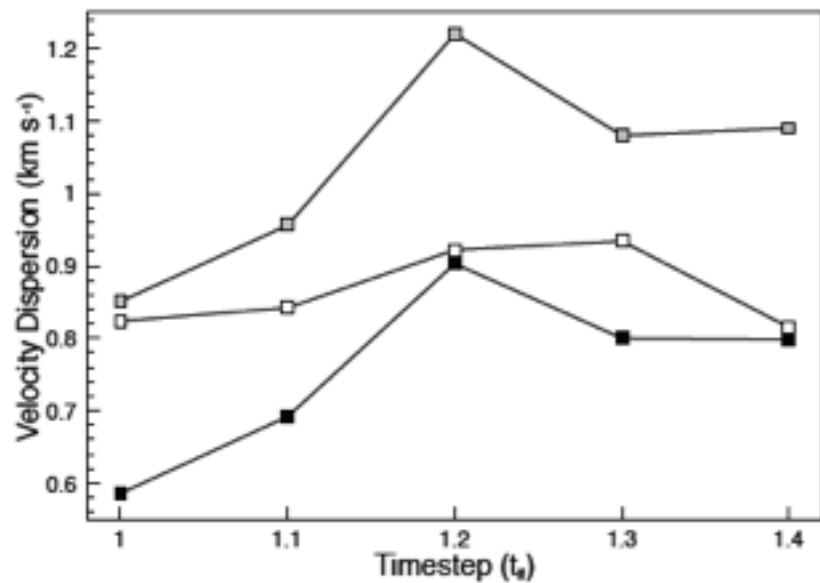


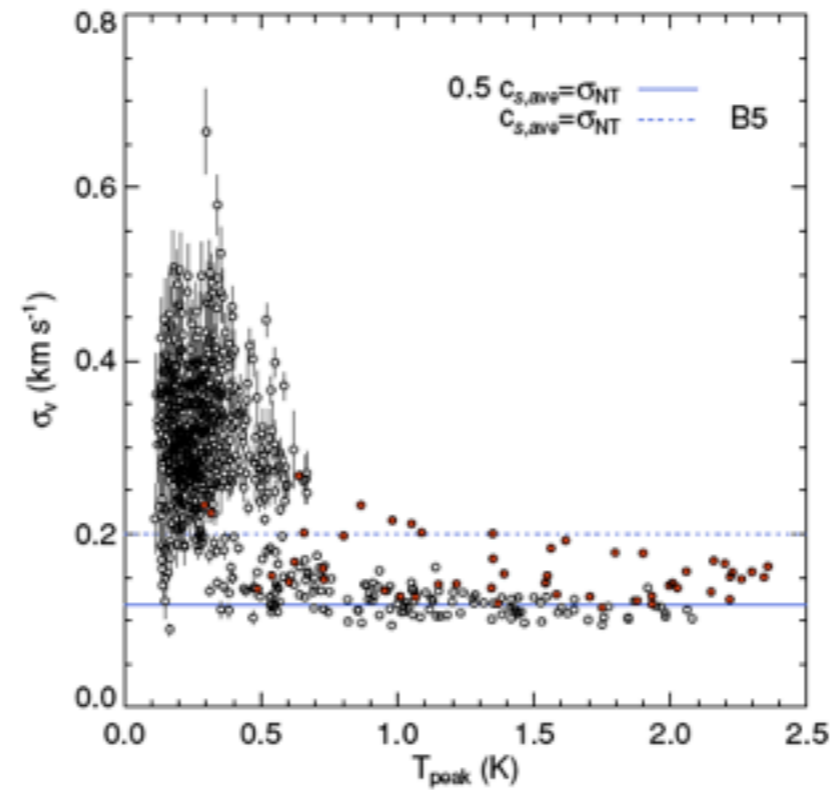
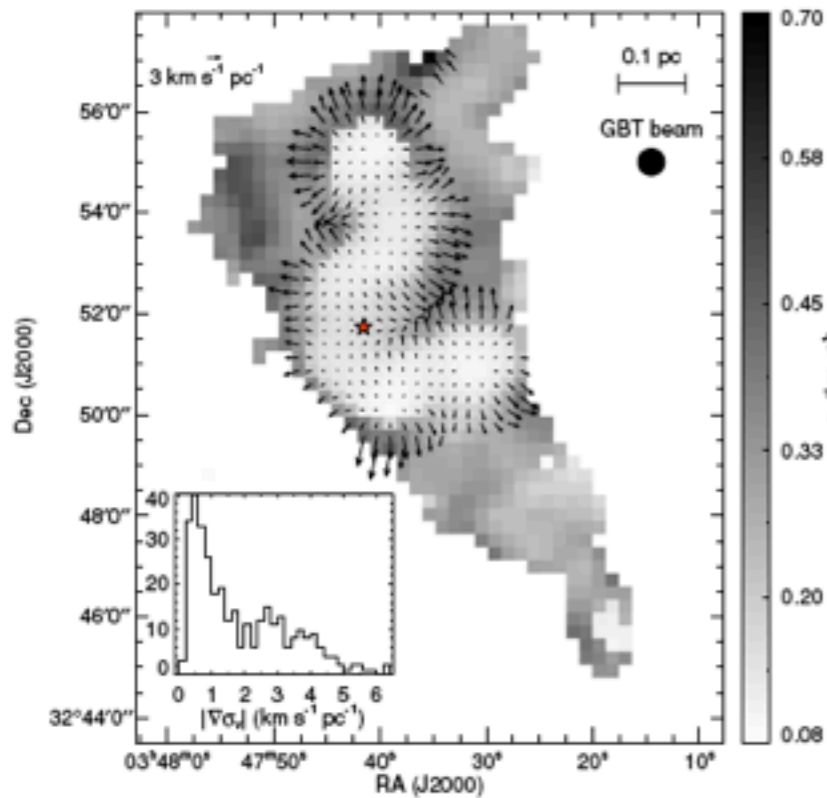
Figure 16. Histogram of velocity difference of all cores (combined starless and protostellar cores) identified at all time steps (light grey, $\sigma = 0.16 \text{ km s}^{-1}$) and protostellar cores (dark grey, $\sigma = 0.18 \text{ km s}^{-1}$). Also plotted are the velocity dispersions for N_2H^+ (dot, $\sigma = 0.861 \text{ km s}^{-1}$), C^{18}O (dot-dash, $\sigma = 0.808 \text{ km s}^{-1}$), ^{13}CO (dash, $\sigma = 1.05 \text{ km s}^{-1}$).



Rundle, Harries, Acreman & Bate 2010
cf. Ayliffe et al. 2007

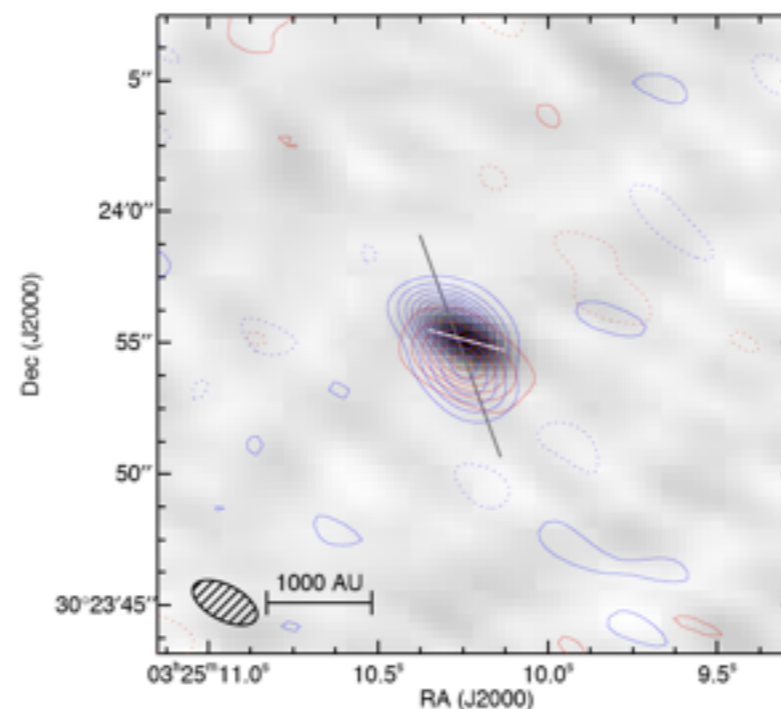
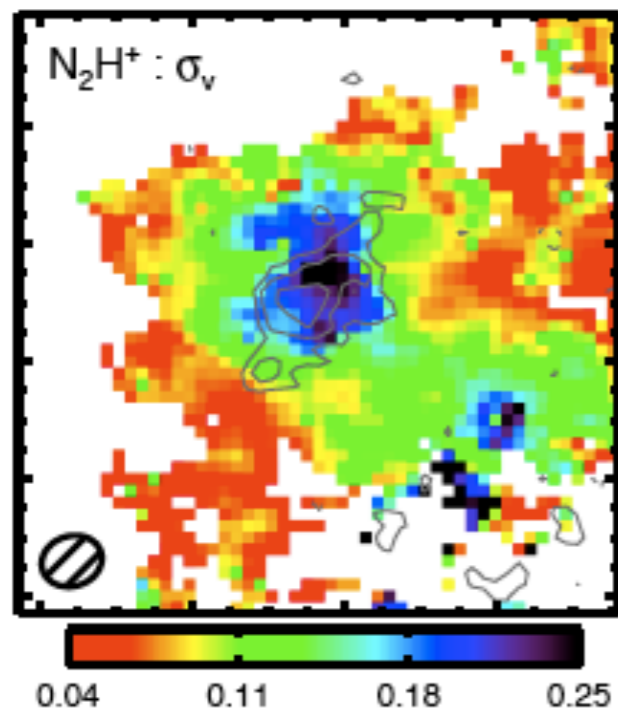
Kirk, Pineda, Johnstone & Goodman 2010;
see also Kirk, Johnstone & Basu 2009

Two Culinary Challenges from Jaime Pineda's Thesis!



Very sharp transition to coherence in cores.
(Chef Ostriker?)

Pineda et al. 2010a



“First Core”
with an outflow
& no Spitzer source
cf. Chen, Arce et al. 2010
(Chef Machida?)

Pineda et al. 2010b

The New Chefs

Modeling CO Observations from Molecular Clouds

Rahul Shetty, Simon Glover, Cornelis Dullemond, Raf Klessen
Institut für Theoretische Astrophysik, Leibniz Universität Hannover, Max-Planck Institut für Astronomie

Introduction
Recent simulations of Giant Molecular Clouds (GMCs) by Glover et al. (2016), which track the hydrodynamics as well as the formation and destruction of molecules, have shown that CO formation is very sensitive to initial properties of the cloud, such as density, metallicity, and the background radiation field. The formation of H₂ on the other hand, is primarily determined by the amount of time available for its formation. We apply radiative transfer calculations (using RADMC-3D, Dullemond et al.) in prep) to these GMC models, in order to investigate the properties of 'CO level emissions'. We use the Large Velocity Gradient method to solve for the CO level populations. Here, we focus on how the observed intensity traces the underlying column densities, as well as the X-factor.

Maps of N_{H2}, W_{CO}, and the X Factor
• Maps on right show N_{H2}, W_{CO}, and the X factor (N_{H2}/W_{CO}) from a model with Z₂ = 0.2.
• Contours correspond to vertical lines in the PDFs.
• At low densities (solid contours), W_{CO} traces N_{H2} relatively well, which is also evident on the PDF.
• However, at high densities, W_{CO} does not trace N_{H2} in any straightforward way.
• The X factor shows large variation within the cloud.
• The highest values of X occur in low density regions.
• In high density regions, the X factor is near the 'constant' value determined from observations of Galactic GMCs (3x10¹⁸ cm⁻² K⁻¹ km⁻¹ s).

X Factor Distributions
• Probability distribution functions (PDFs) of the X factor densities, N_{H2}, are well described as log-normal.
• N_{H2} PDFs depend on intrinsic cloud properties. Only high density clouds show log-normal PDFs.
• The W_{CO} integrated CO intensity PDF starkly differs from the N_{H2} PDF.

Zeeman effect spectral line synthesis

T. Linnarsson, P. Paulsen, S. Jonell, A. Sordin
Department of Physics, University of Gothenburg

Introduction
The Zeeman effect is a fundamental property of atoms and molecules. It is the splitting of spectral lines of atoms and molecules into several components in the presence of an external magnetic field. This effect is used to measure the magnetic field strength in the interstellar medium.

Modeling
The Zeeman effect is modeled by solving the radiative transfer equations for the Zeeman-split spectral lines. This involves calculating the Zeeman splitting of the spectral lines and the resulting intensity profiles.

Results
The Zeeman effect is observed in the spectral lines of atoms and molecules. The Zeeman splitting of the spectral lines is observed as a splitting of the spectral lines into several components. The Zeeman splitting of the spectral lines is observed as a splitting of the spectral lines into several components.

Conclusions
The Zeeman effect is a powerful tool for measuring the magnetic field strength in the interstellar medium. It is used to measure the magnetic field strength in the interstellar medium.

Initial conditions for chemistry in prestellar cores

Where do we start?
Initial conditions for chemistry in prestellar cores are determined by the physical and chemical state of the gas and dust. The initial conditions are determined by the physical and chemical state of the gas and dust.

Where do we go?
The evolution of the chemical state of the gas and dust is determined by the physical and chemical processes that occur in the core. The evolution of the chemical state of the gas and dust is determined by the physical and chemical processes that occur in the core.

Initially hydrogen is not totally molecular
Initially hydrogen is not totally molecular. The initial conditions for chemistry in prestellar cores are determined by the physical and chemical state of the gas and dust.

Molecular column densities in DR21(OH)
Molecular column densities in DR21(OH) are determined by the physical and chemical state of the gas and dust. The molecular column densities in DR21(OH) are determined by the physical and chemical state of the gas and dust.

CO and NH₃ survey of ARCHEOPS cold cores

Enria Vorobykh, Gabor Mamon, L. Viktor Tantal, Santha Zarewicz, Mikha Juvav, Martin Kiefer, Zoltan Muzsi

Abstract
Density and velocity distribution of 13 molecular cold cores have been derived from multi-wavelength CO observations with the ARCHEOPS survey. The cores are located in the ARCHEOPS field. The cores are located in the ARCHEOPS field. The cores are located in the ARCHEOPS field.

CO survey of 13 cores
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Velocity & density gradient in Arcturus 88-05-29
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Molecular column densities
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Emission Signatures from a Young Embedded Object: 3D Line Transfer Studies and Pseudo Observation toward ALMA

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Calculations
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Intensity Map
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Collapsing Cores are not Spherically Symmetric

Roman J. Smith, Simon Glover, Ian Bonnell, Paul O. Clark, Raf Klessen

Abstract
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Contribution of stars to the nebular He II emission line

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RMHD simulation of Proto-stellar Collapse

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The Effect of Dust-Gas Energetics on Clustered Star Formation

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The ubiquity of lognormal column density distributions

Abstract
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YSO Jets – MHD 2D Simulations and Synthetic Observations

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Adaptable Radiative Transfer Innovations for Submillimeter Telescopes

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Core mass estimates in simulated observations

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Radiative Transfer Simulations of Infrared Dark Clouds

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X-RAY EMISSION AND DYNAMICS OF MASSIVE YSO WINDS

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Star formation triggered by runaway O/B stars

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Three-dimensional molecular line

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A Synthetic 21-cm Galactic Plane Survey of an SPH Galaxy

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Tracing Magnetic Field Structure in Molecular Clouds with BLAST-pol

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Prestellar Core Population Revealed

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The Green Bank Telescope HII Region Discovery Survey

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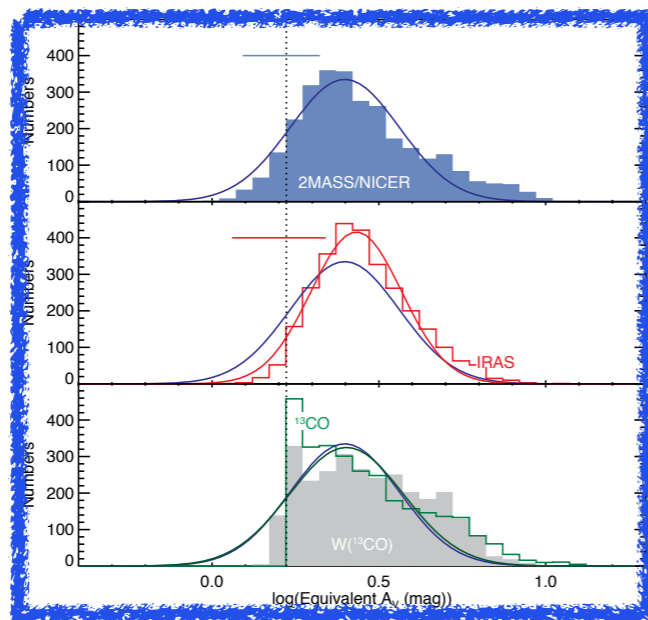
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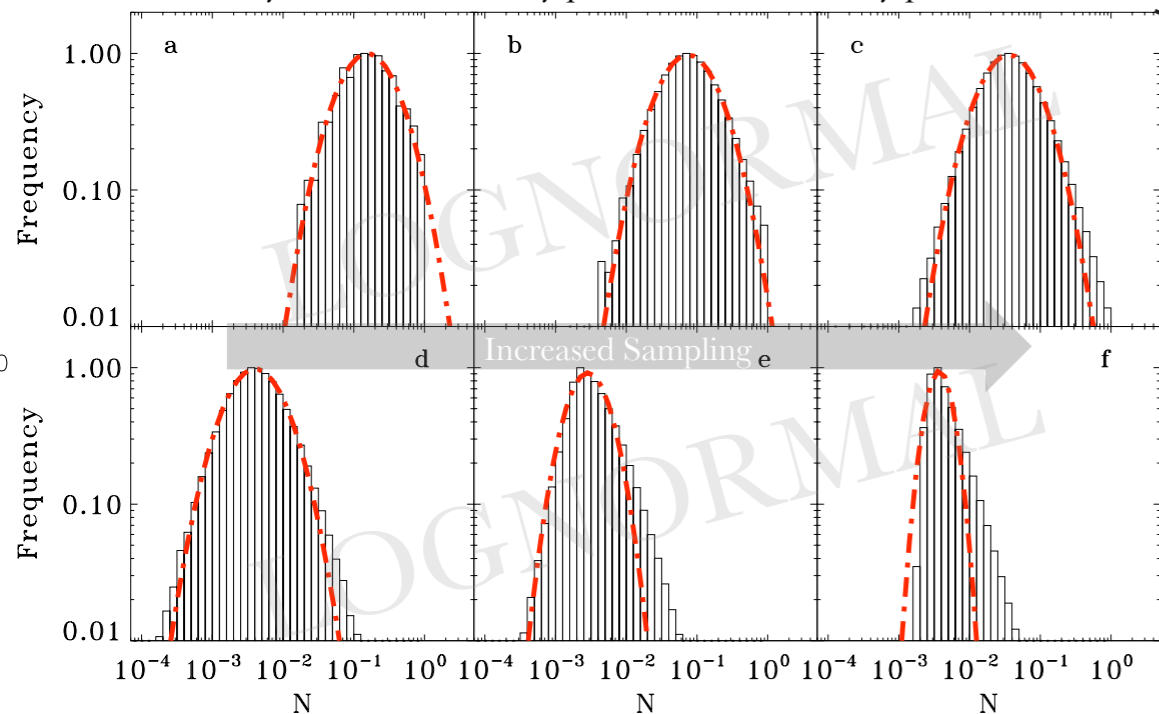
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Diner Beware?

“lognormals” from many non-turbulent “recipes”
(Andrea Urban’s Poster)



Analytic smooth density profile with *no* density perturbations.



The ubiquity of lognormal column density distributions¹

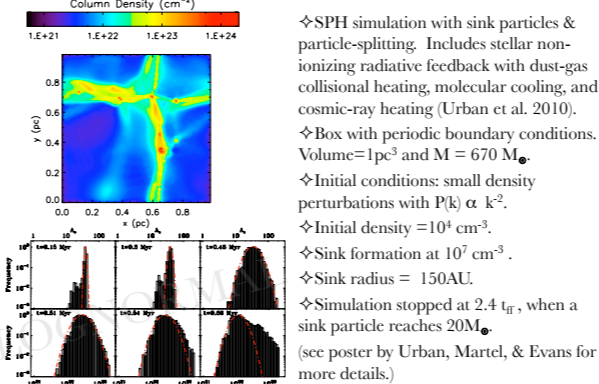
A. Urban², K. Tassis², D. A. Christie³, J. L. Pineda²,
T. Ch. Mouschovias³, H. W. Yorke², H. Martel⁴

¹ Based on the paper Tassis, K. et al. 2010 ² Jet Propulsion Laboratory, California Institute of Technology, ³ University of Illinois at Urbana-Champaign, ⁴ Université Laval

Molecular clouds have long been assumed to be supersonically turbulent due to their large line-widths. Simulations of turbulent molecular clouds routinely produce lognormal column density distributions. This feature has also been seen in molecular clouds. We investigate the nature of column density distributions for non-turbulent dominated simulations and simple analytic model clouds. *We question the uniqueness of supersonic turbulence as the origin of observed lognormal column density distributions in molecular clouds.*

The three cases we investigate are:
(1) a molecular cloud core evolving under the influence of self-gravity with thermal energetics,
(2) a magnetically supported molecular cloud with subsonic turbulence evolving due to ambipolar diffusion, and
(3) an analytic Bonnor-Ebert-type sphere.

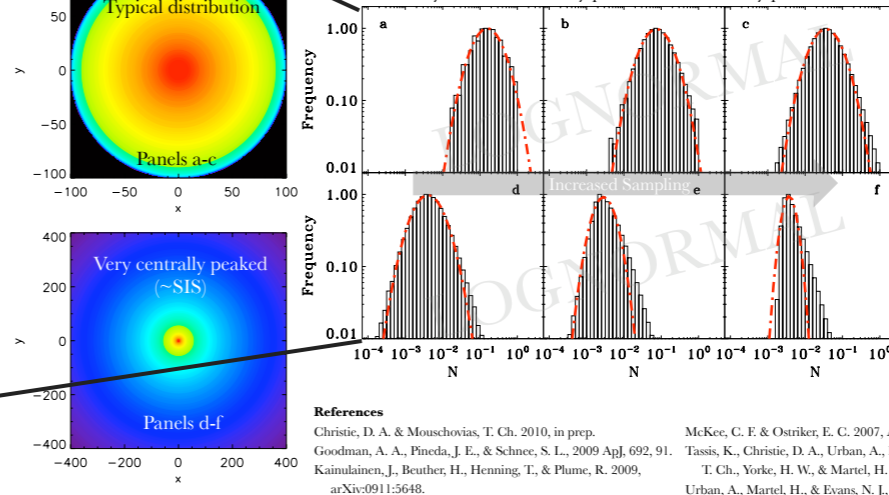
(1) Let gravity dominate...



(3) What if we consider a completely analytic model cloud?

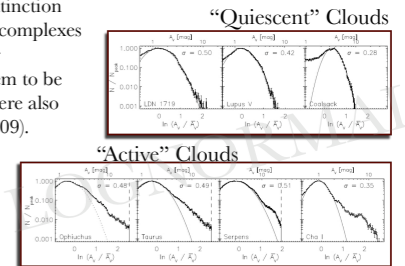
Let’s try a Bonner-Ebert sphere.

Spherical, isothermal cloud with Bonner-Ebert-like profile, i.e., flat inner region and power-law profile in outer regions. Analytic smooth density profile with *no* density perturbations.

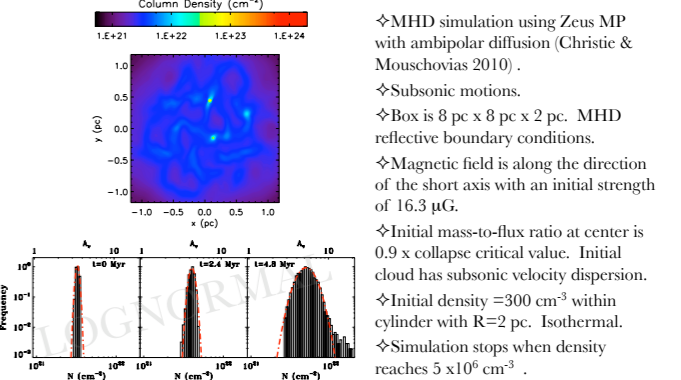


Observational Motivation

Recently Kainulainen et al. 2009 (see figures) used near infrared extinction maps of 23 molecular cloud complexes to study their column density distributions. They found them to be lognormal. Similar results were also found by Goodman et al. (2009). Theoretical justifications for lognormal distributions center around the idea of supersonic turbulence (McKee & Ostriker 2007).



(2) What about magnetic fields?



Conclusions

All three of the cases presented are radically different from each other in many respects, yet they all produce a lognormal column density distribution, as well as a power law tail at late times. Therefore, observed lognormal column density distributions are not evidence of supersonic turbulence-dominated clouds, but rather a general feature of cloud models. **We find that lognormal column density distributions are NOT unique to simulations dominated by supersonic turbulence.** These degeneracy hinder our ability to confidently distinguish between cloud models.

References
Christie, D. A. & Mouschovias, T. Ch. 2010, in prep.
Goodman, A. A., Pineda, J. E., & Schnee, S. L., 2009 ApJ, 692, 91.
Kainulainen, J., Beuther, H., Henning, T., & Plume, R. 2009, arXiv:0911.5648.
McKee, C. F. & Ostriker, E. C. 2007, ARAA, 45, 565.
Tassis, K., Christie, D. A., Urban, A., Pineda, J. L., Mouschovias, T. Ch., Yorke, H. W., & Martel, H. 2010, MNRAS submitted.
Urban, A., Martel, H., & Evans, N. J., 2010, ApJ, 710, 1343.

For more information, contact urban@jpl.nasa.gov or ktassis@jpl.nasa.gov

Column Density in Perseus, Measured 3 Ways

