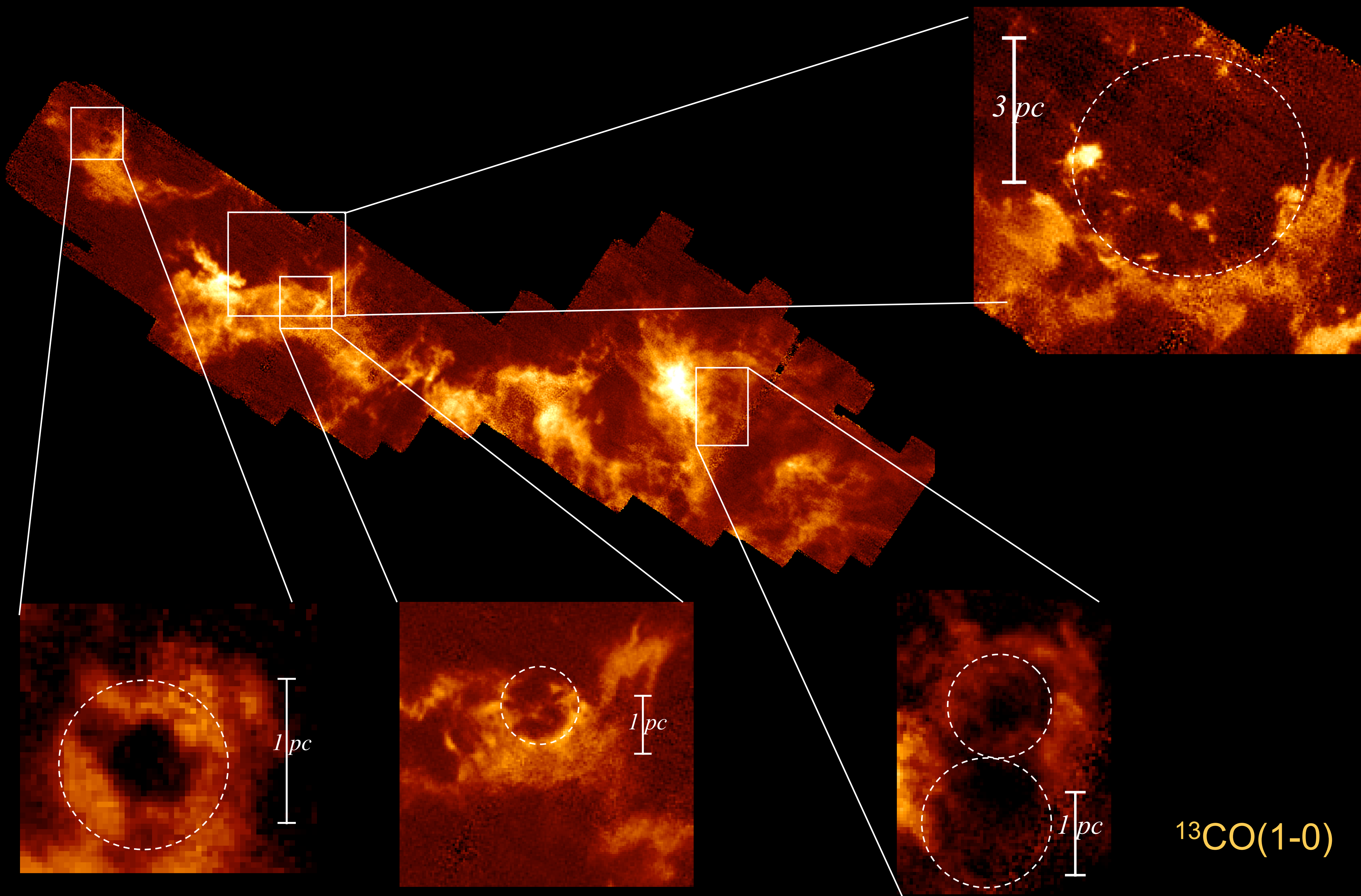
I believe Joao...



Arce, ALVES, Borkin & Goodman 2008

Ready to Eat?

What Early "Taste Tests" Say about Modern Simulations of Star Formation

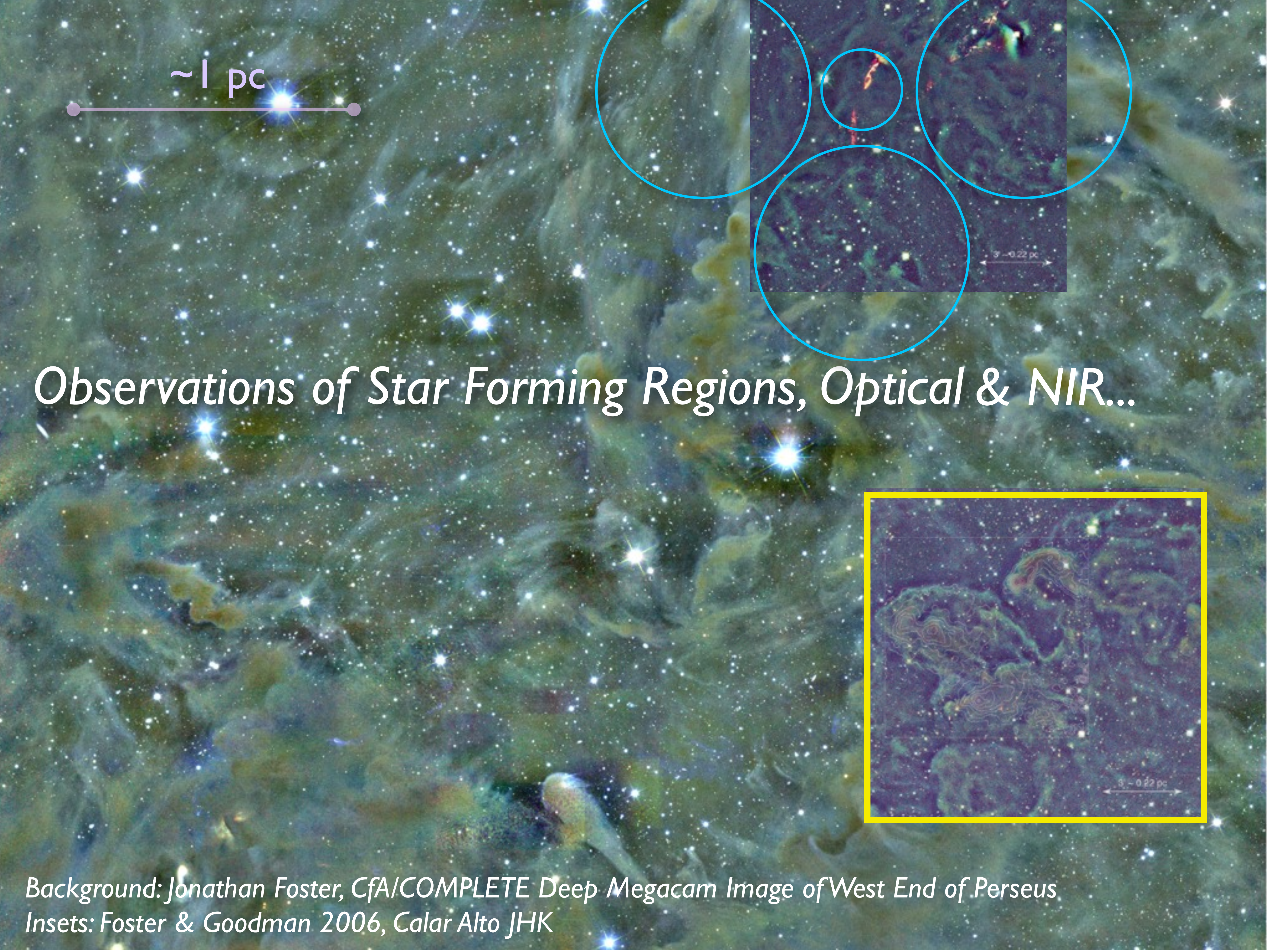
Featuring the work of collaborators:

João **Alves**, Héctor **Arce**, Michelle **Borkin**, Paola **Caselli**, Jonathan **Foster**, Mike **Halle**, Mark **Heyer**, Jens **Kauffmann**, Jaime **Pineda**, Erik **Rosolowsky**, Scott **Schnee**, Rahul **Shetty**

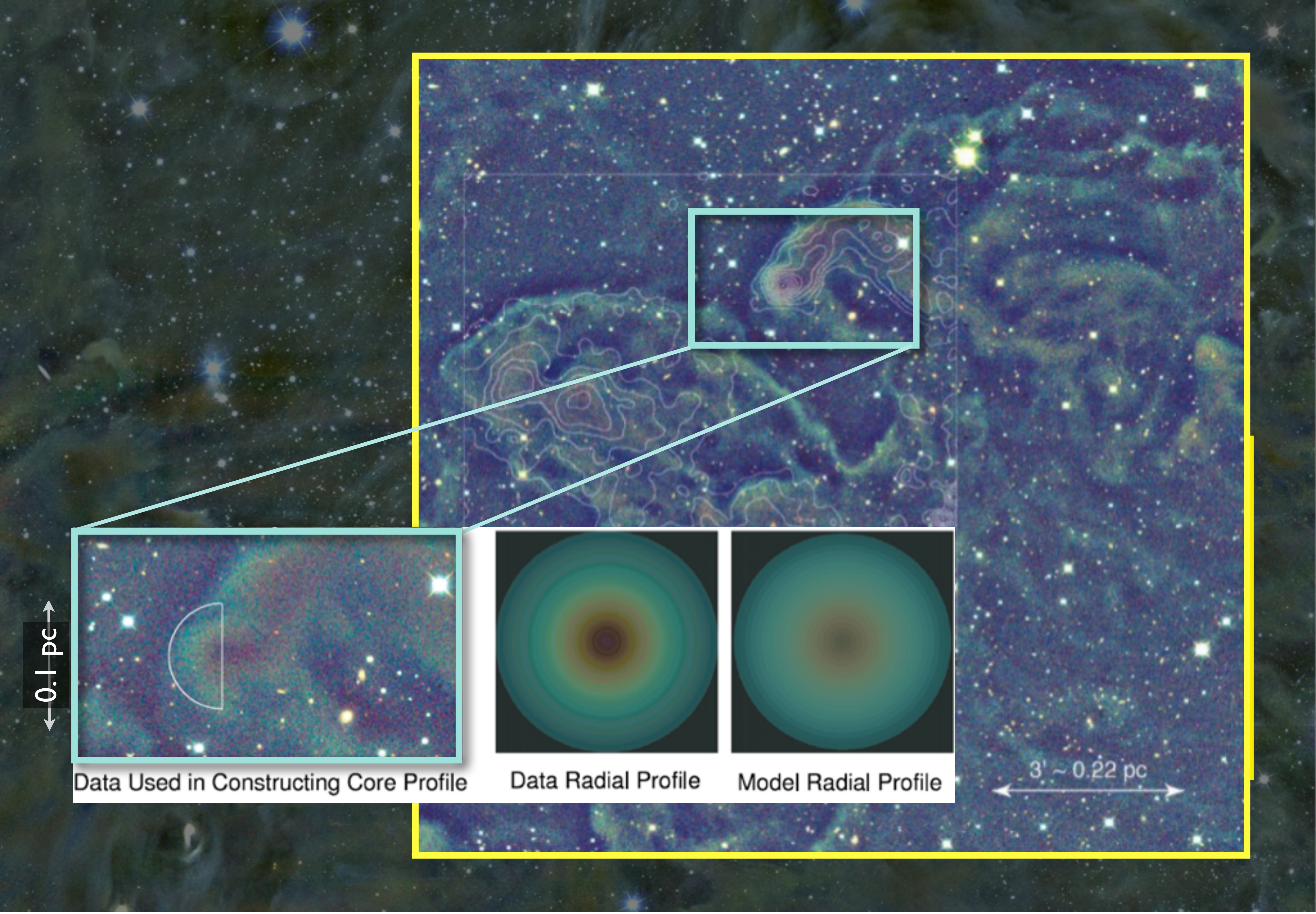
Alyssa A. Goodman
Harvard-Smithsonian Center for Astrophysics
Initiative in Innovative Computing at Harvard

& inspired by **EPoS I** particpants!!

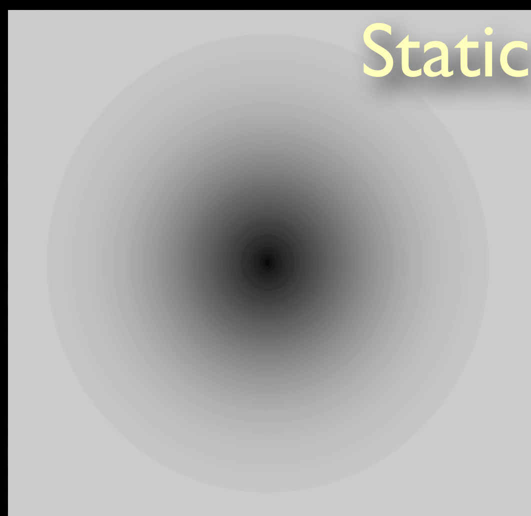
Image Credit: Jonathan Foster, CfA/COMPLETE Deep Megacam Image of West End of Perseus

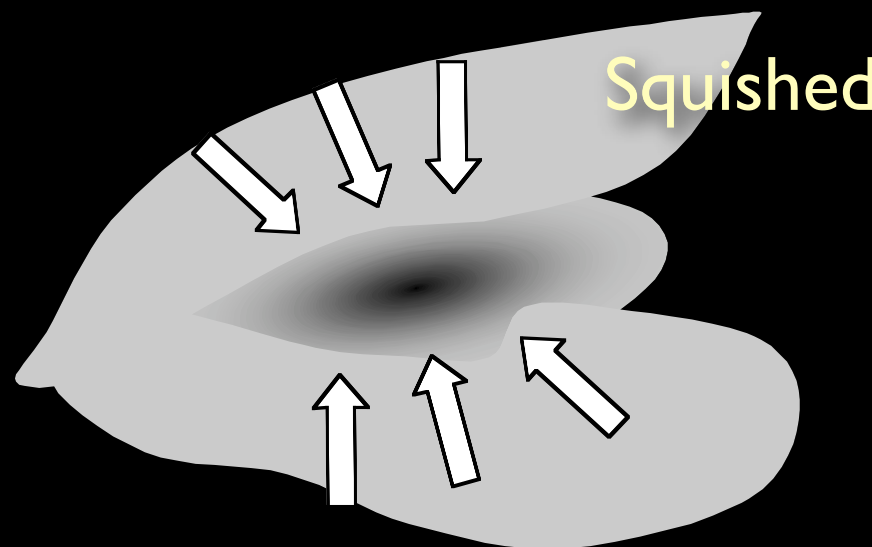

~1 pc
3' ~ 0.22 pc
Observations of Star Forming Regions, Optical & NIR...
3' ~ 0.22 pc
Background: Jonathan Foster, CfA/COMPLETE Deep Megacam Image of West End of Perseus
Insets: Foster & Goodman 2006, Calar Alto JHK

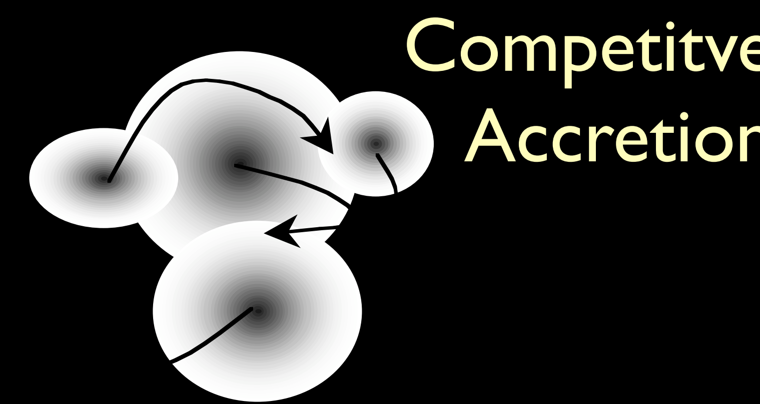
"Islands of Calm in a Turbulent Sea"

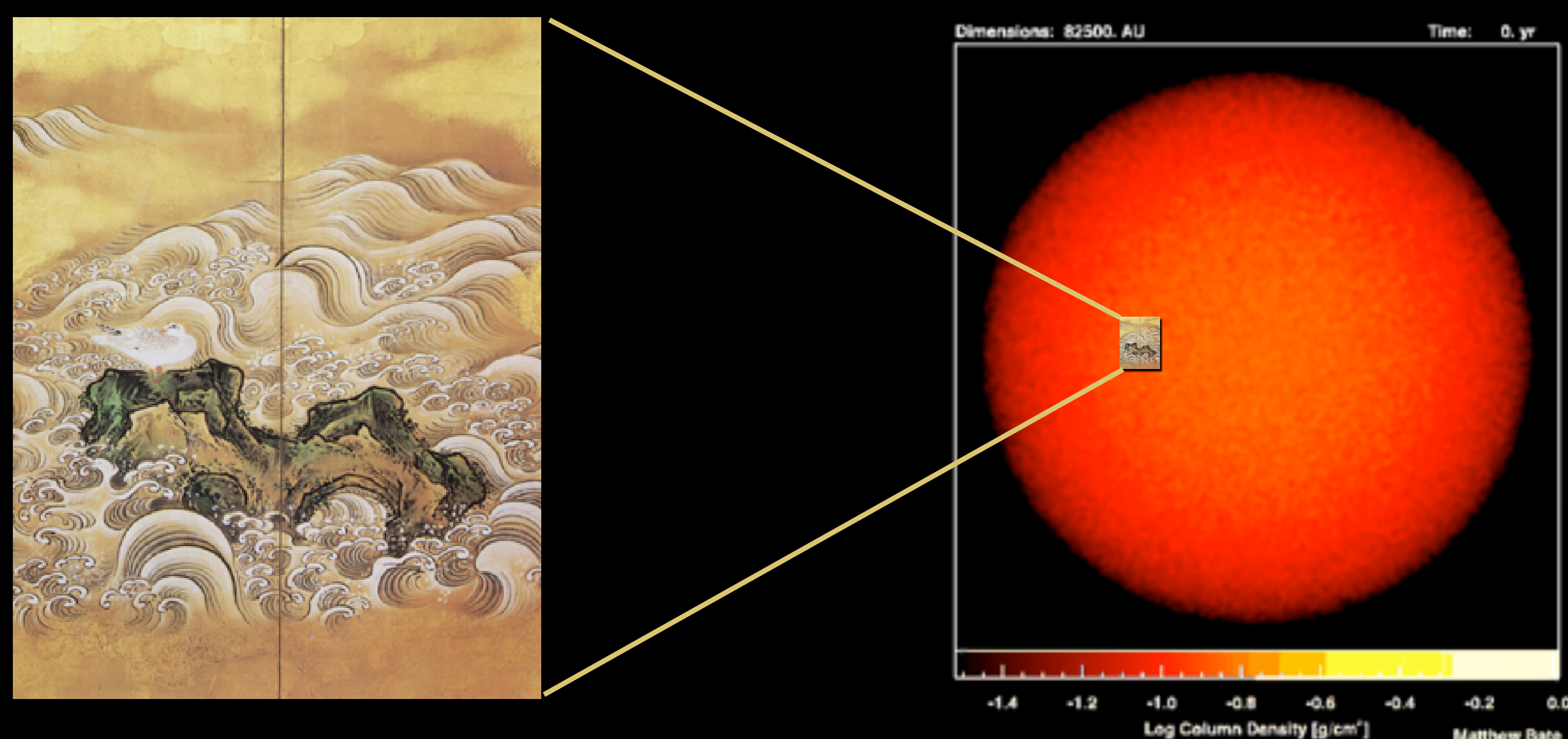


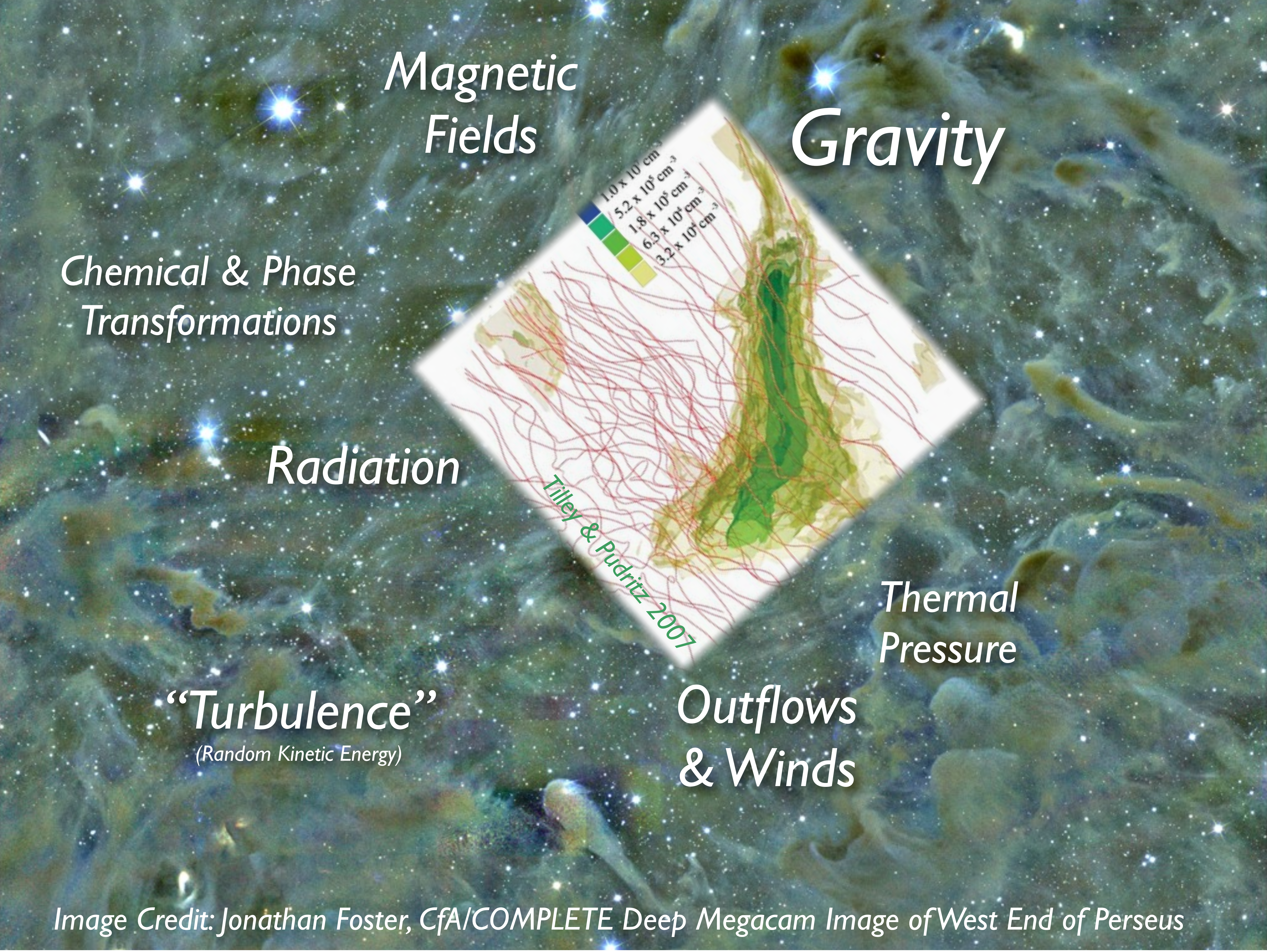
Can these all be "right"?



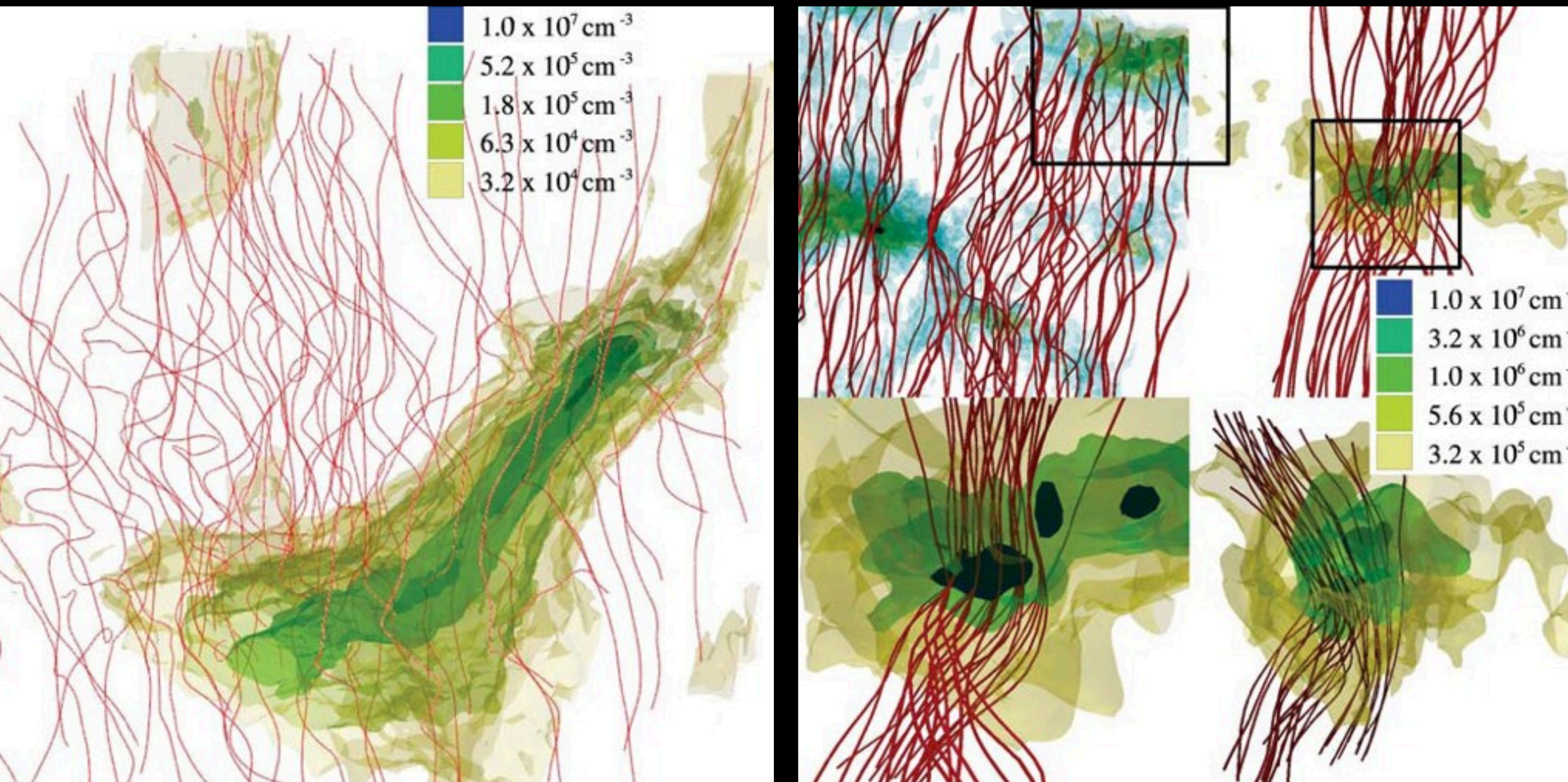







Magnetic Fields
Gravity
Chemical & Phase Transformations
Radiation
Thermal Pressure
"Turbulence"
(Random Kinetic Energy)
Outflows & Winds
$1.0 \times 10^7\ cm^{-3}$
$5.2 \times 10^5\ cm^{-3}$
$1.8 \times 10^5\ cm^{-3}$
$6.3 \times 10^4\ cm^{-3}$
$3.2 \times 10^4\ cm^{-3}$
Tilley & Pudritz 2007
Image Credit: Jonathan Foster, CfA/COMPLETE Deep Megacam Image of West End of Perseus

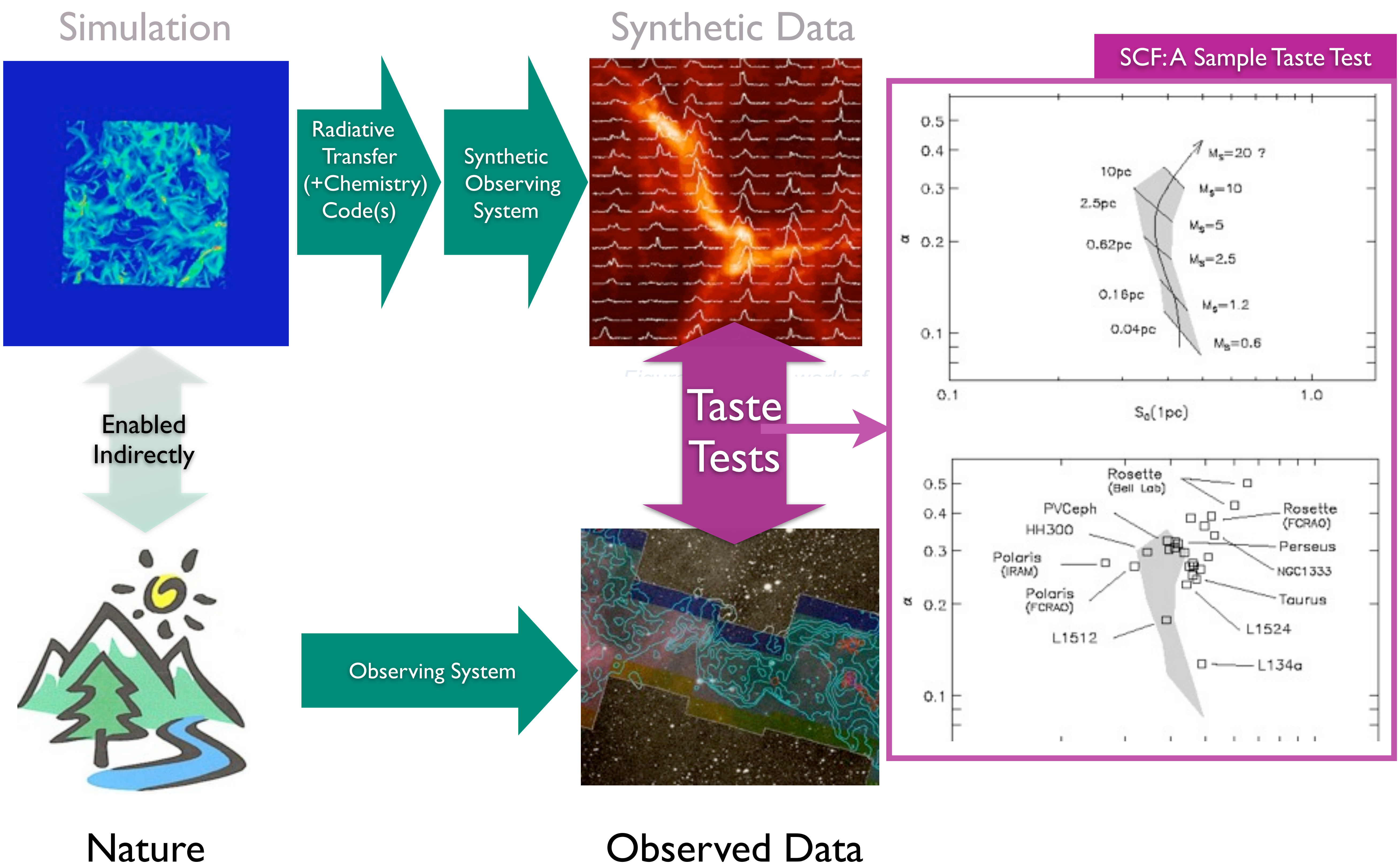
As we have seen this week...
Theorists' Kitchens now cooking *many*
Simulations sophisticated enough to "taste"...



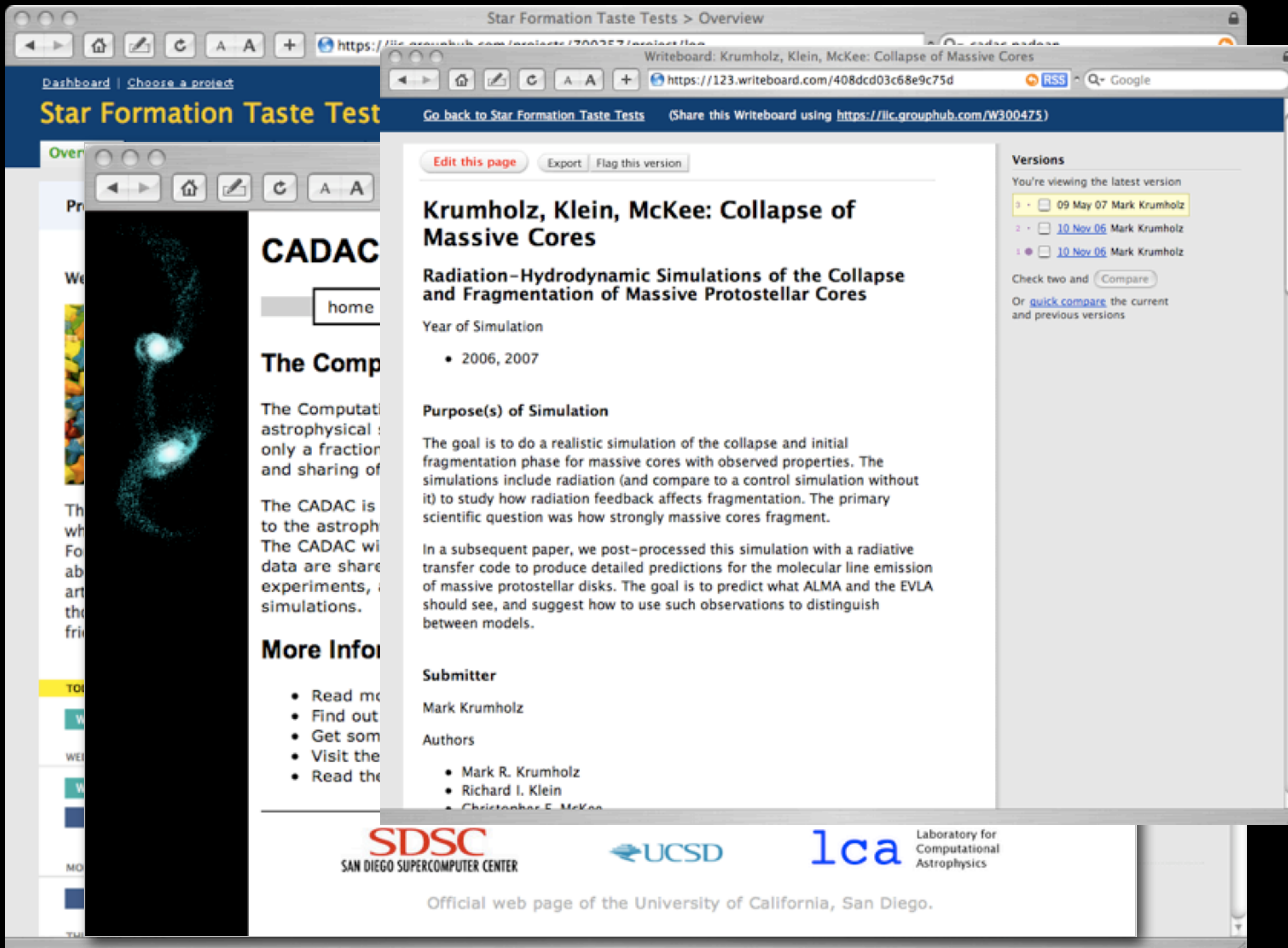
Tilley & Pudritz 2007;

see Padoan, P., Goodman, A., Draine, B., Juvela, M., Nordlund, A. and Rognvaldsson, O.E. 2001 for polarimetry "tastes"

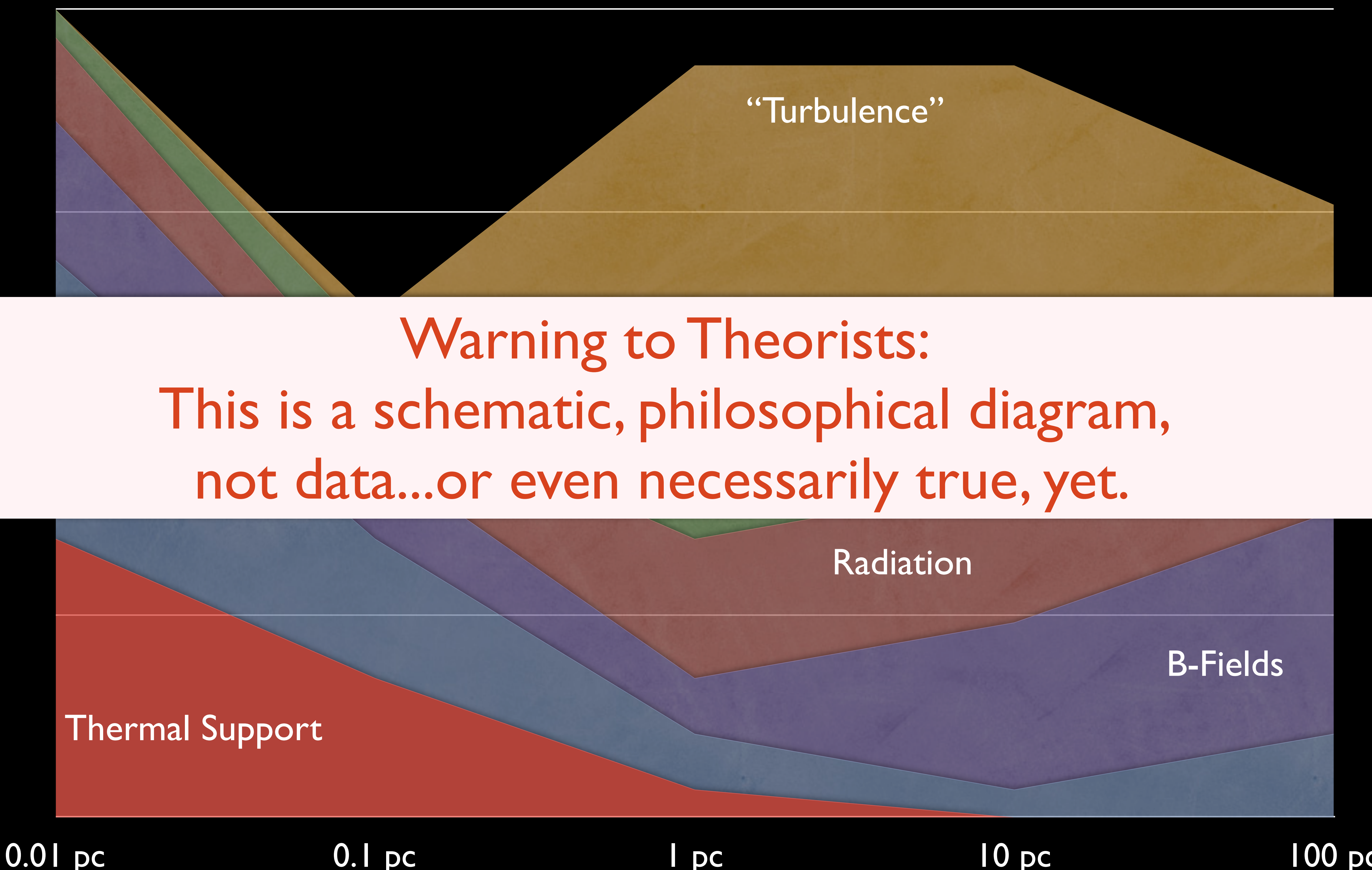
The Taste-Testing Process



Star Formation Taste Tests



What forces matter most on what scales?

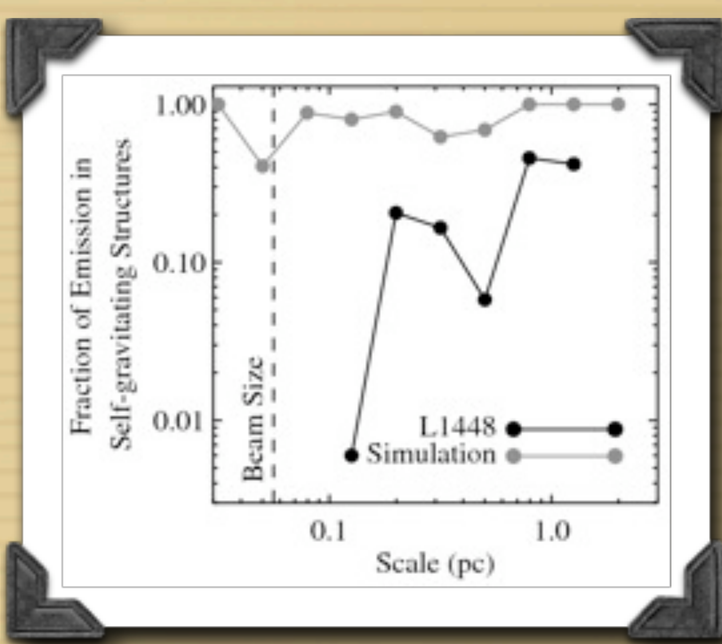


Warning to Theorists:
This is a schematic, philosophical diagram,
not data...or even necessarily true, yet.

Sample Taste Tests (of Simulations) I've Enjoyed...

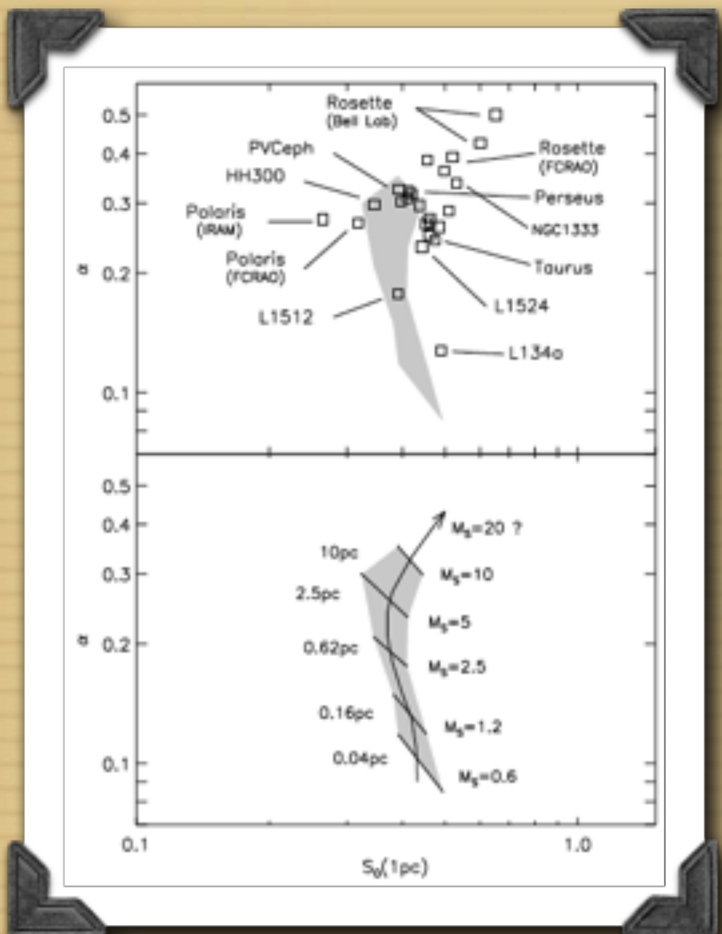
Dendrogram Analysis of Self-Gravity

Rosolowsky et al. 2008; Goodman et al. 2008; Kauffmann et al. 2008



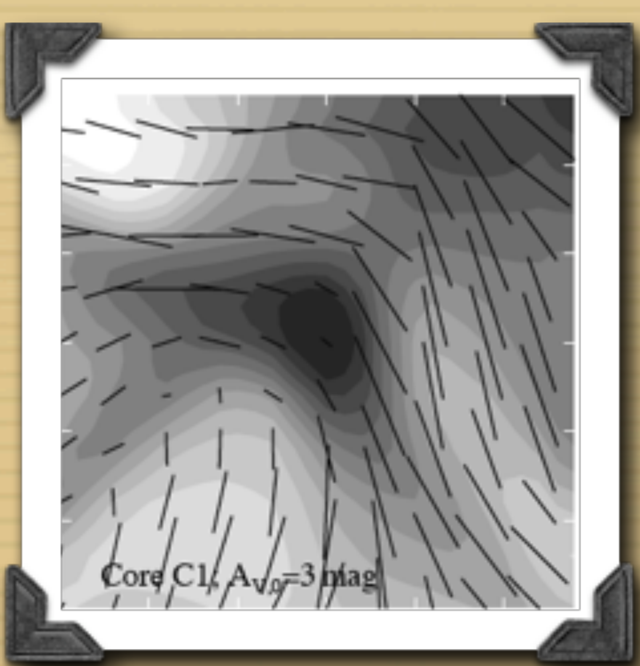
Spectral Correlation Function

Rosolowsky et al. 1999; Padoan et al. 2003



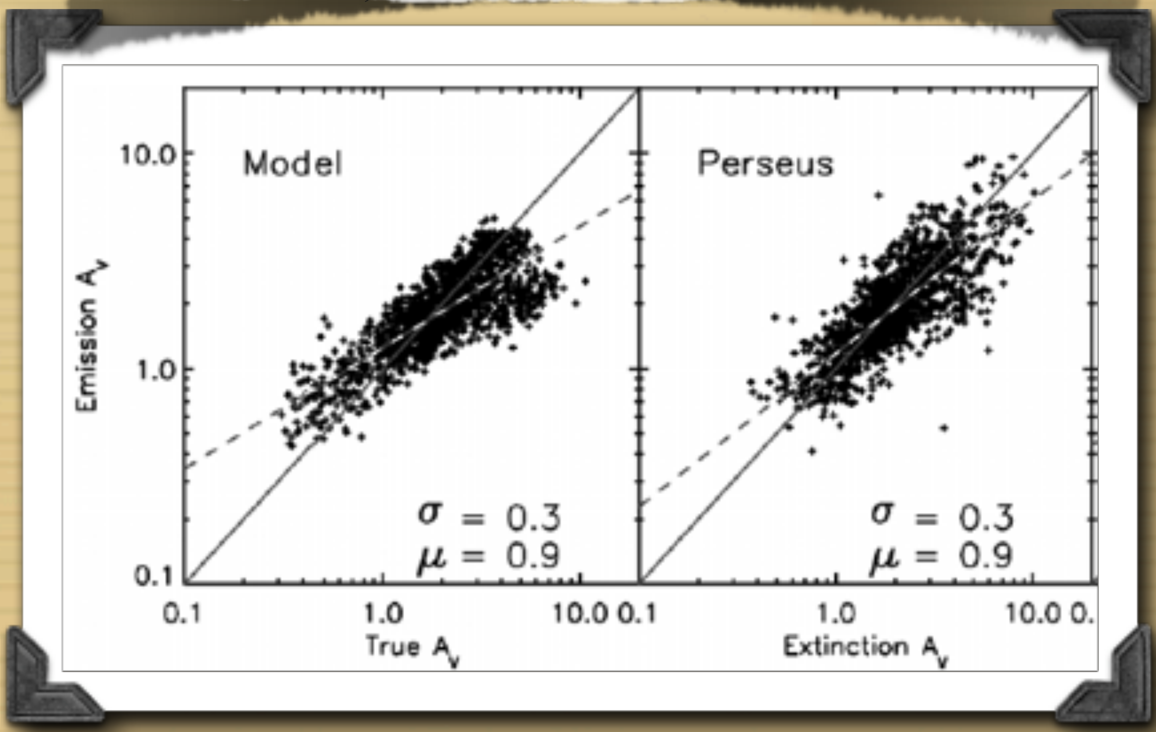
Polarization "Holes"

Padoan et al. 2001



"Column Temperature"

see Shetty et al. 2008



+ Several Recent "Taste Tests" (of Simulations) by Others...

SAO/NASA Astrophysics Data System (ADS)

Private Library Taste Tests (relevant to Taste Testing) for Alyssa Goodman (the link on the library name is a public link to this library)

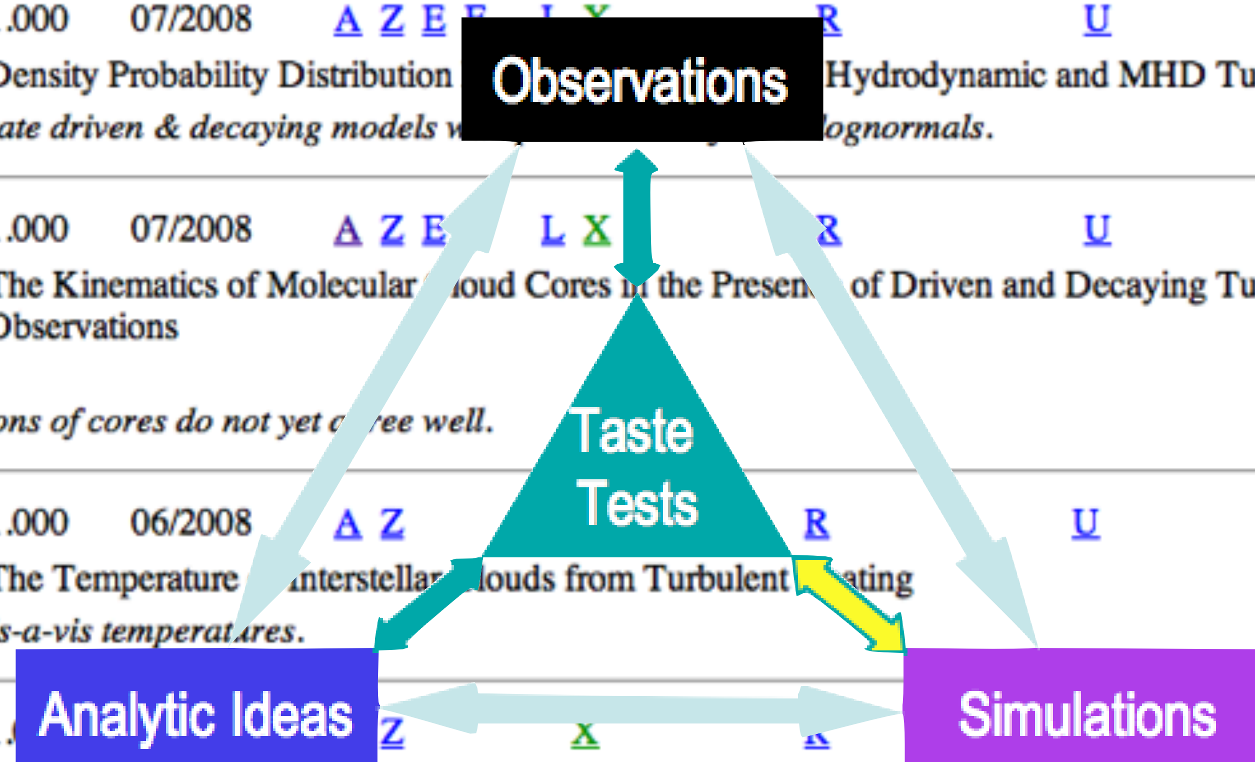
Go to bottom of page

Selected and retrieved **5** abstracts.

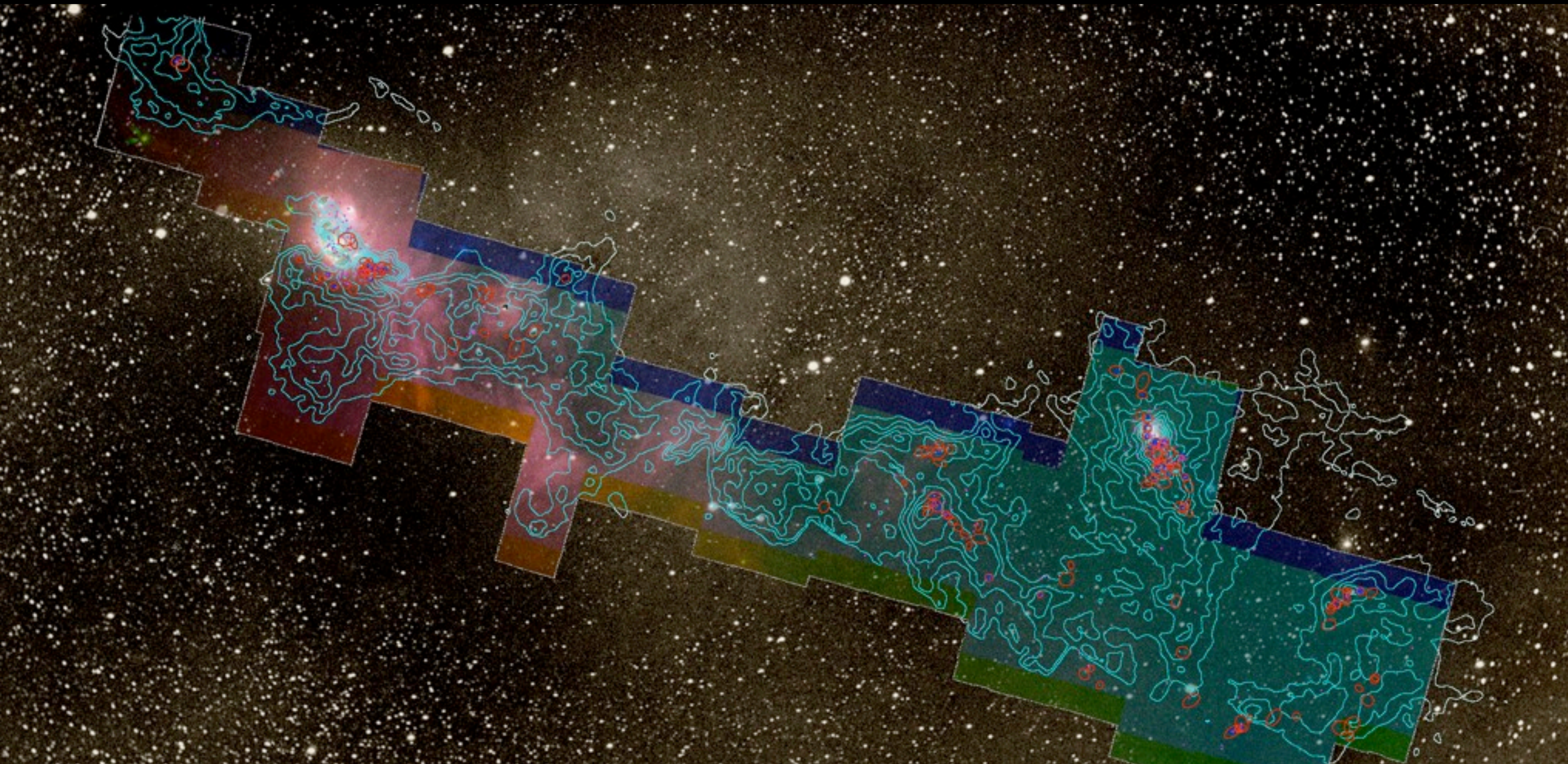
Sort options

# Bibcode / Authors	Score / Title	Date	List of Links / Access Control Help
1 2008ApJ...682L..97L / Lemaster, M. Nicole; Stone, James M.	1.000 / Density Probability Distribution ... Hydrodynamic and MHD Turbulence	07/2008	A Z E ... R U
2 2008AJ....136..404O / Offner, Stella S. R.; Krumholz, Mark R.; Klein, Richard I.; McKee, Christopher F.	1.000 / The Kinematics of Molecular ...oud Cores i... the Presen... of Driven and Decaying Turbulence: Comparisons with Observations	07/2008	A Z E L X R U
3 2008arXiv0806.4970P / Pan, Liubin; Padoan, Paolo	1.000 / The Temperature ...nterstellar ...louds from Turbulent ...ating	06/2008	A Z R U
4 2008arXiv0806.3854L / Lunttila, Tuomas; Padoan, Paolo; Juvela, Mika; Nordlund, Åke	1... / The Super-Alfv'enic Model of Molecular Clouds: Predictions for Zeeman Splitting Measurements		Z X R
5 2006ApJ...636L.101P / Padoan, Paolo; Juvela, Mika; Pelkonen, Veli-Matti	1.000 / High-Resolution Mapping of Interstellar Clouds by Near-Infrared Scattering	01/2006	A Z E F L X R C U

1. Private Note: *Shows that one cannot separate driven & decaying models w... lognormals.*
2. Private Note: *Shows simulations/observations of cores do not yet c...ree well.*
3. Private Note: *Makes testable predictions vis-a-vis temperat...res.*
4. Private Note: *Comparison to Crutcher et al. Zeeman Observations.*
5. Private Note: *Using Cloudshine to measure Column Density.*



COMPLETE = COordinated Molecular Probe Line Extinction Thermal Emission Survey of Star-Forming Regions



COMPLETE Collaborators, Summer 2008:

Alyssa A. Goodman (CfA/IIC)

João Alves (Calar Alto, Spain)

Héctor Arce (Yale)

Michelle Borkin (IIC)

Paola Caselli (Leeds, UK)

James DiFrancesco (HIA, Canada)

Jonathan Foster (CfA, PhD Student)

Katherine Guenthner (CfA/Leipzig)

Mark Heyer (UMASS/FCRAO)

Doug Johnstone (HIA, Canada)

Jens Kauffmann (CfA/IIC)

Helen Kirk (HIA, Canada)

Di Li (JPL)

Jaime Pineda (CfA, PhD Student)

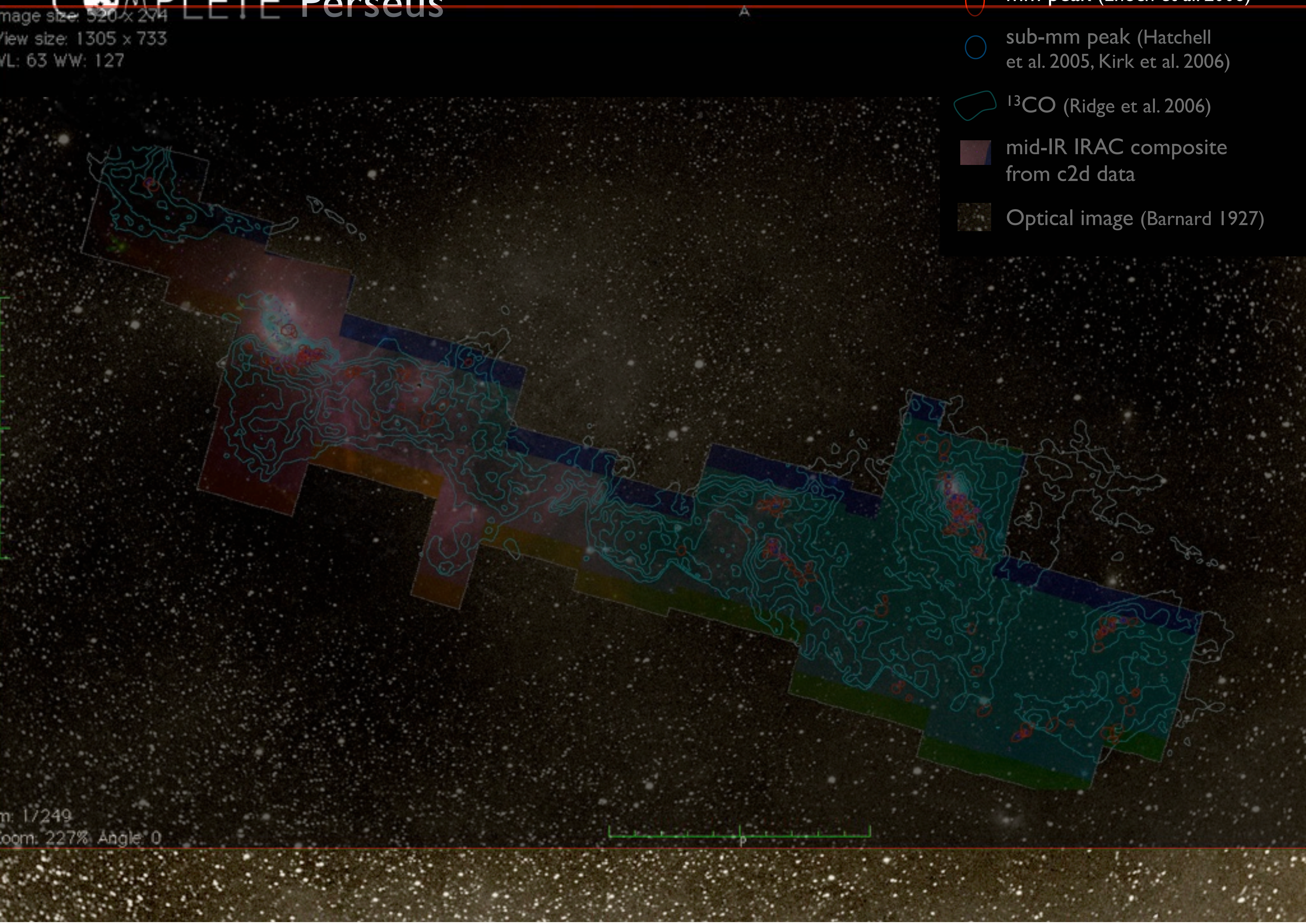
Erik Rosolowsky (UBC Okanagan)

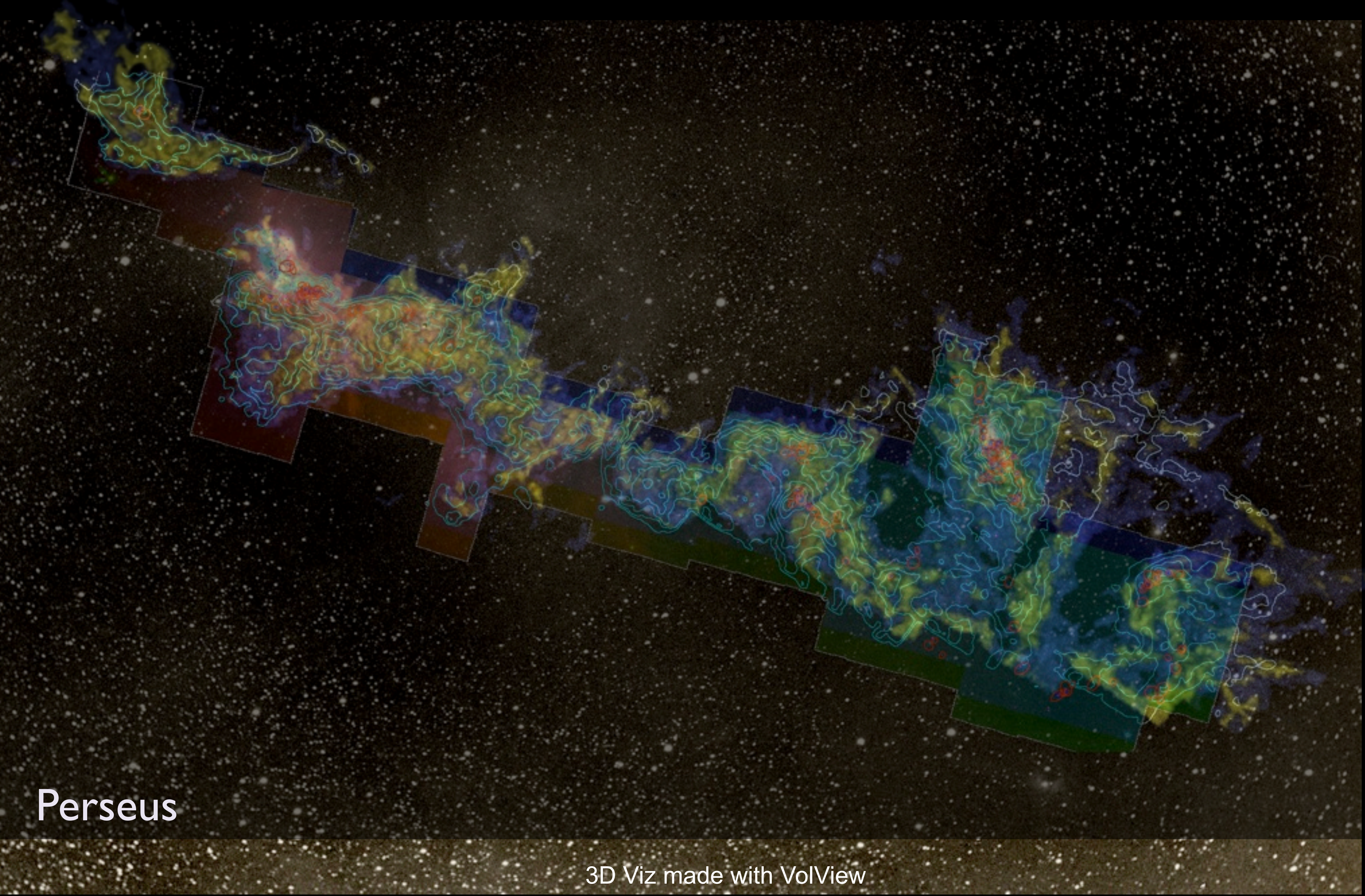
Rahul Shetty (CfA)

Scott Schnee (Caltech)

Mario Tafalla (OAN, Spain)

COMPLETE Perseus

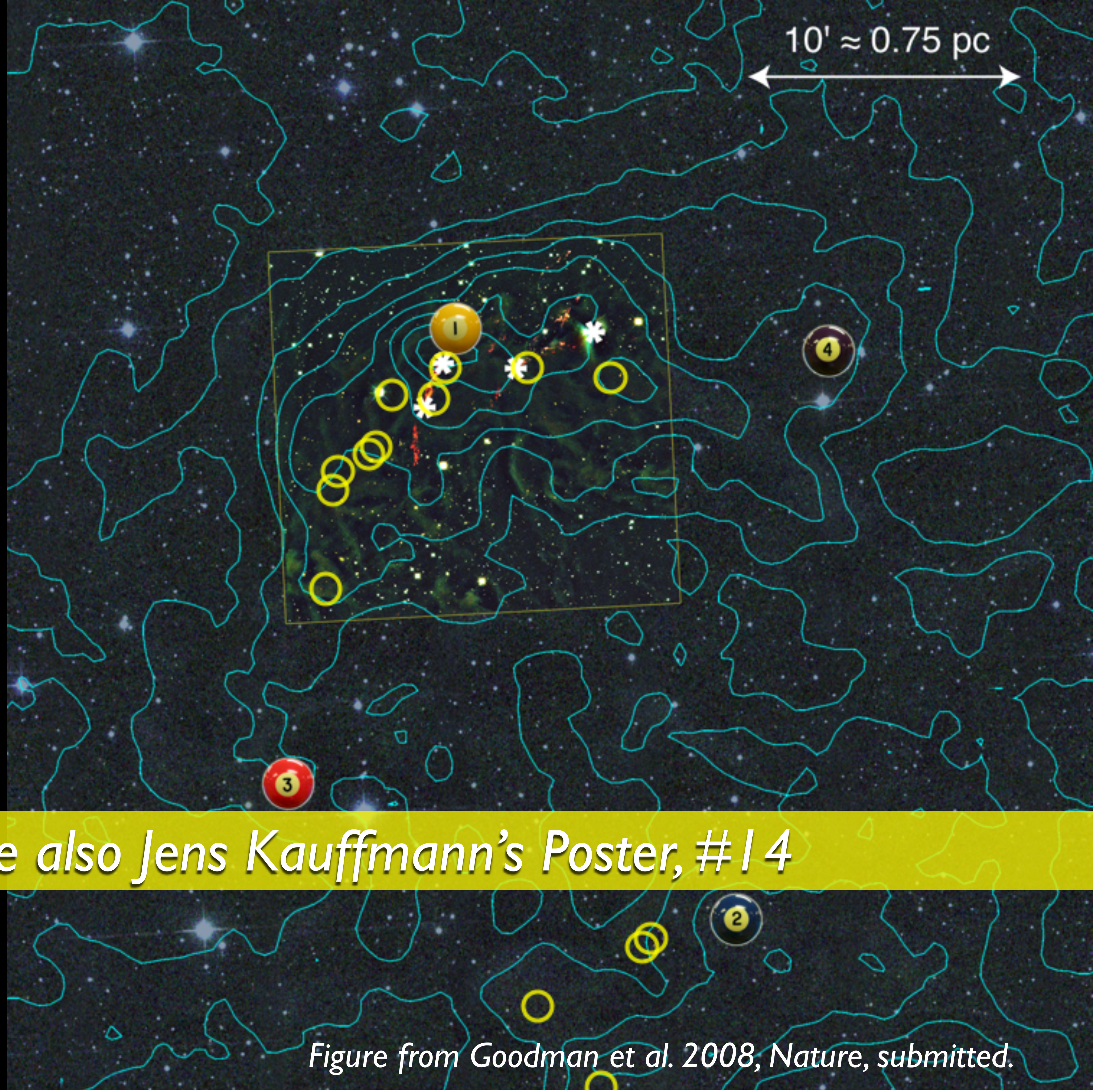



Perseus
3D Viz made with VolView

L1448 in *p-p-v* space

Volume Rendering/Movie created by Nick Holliman (U. Durham) & Michelle Borkin (Harvard/IIC).

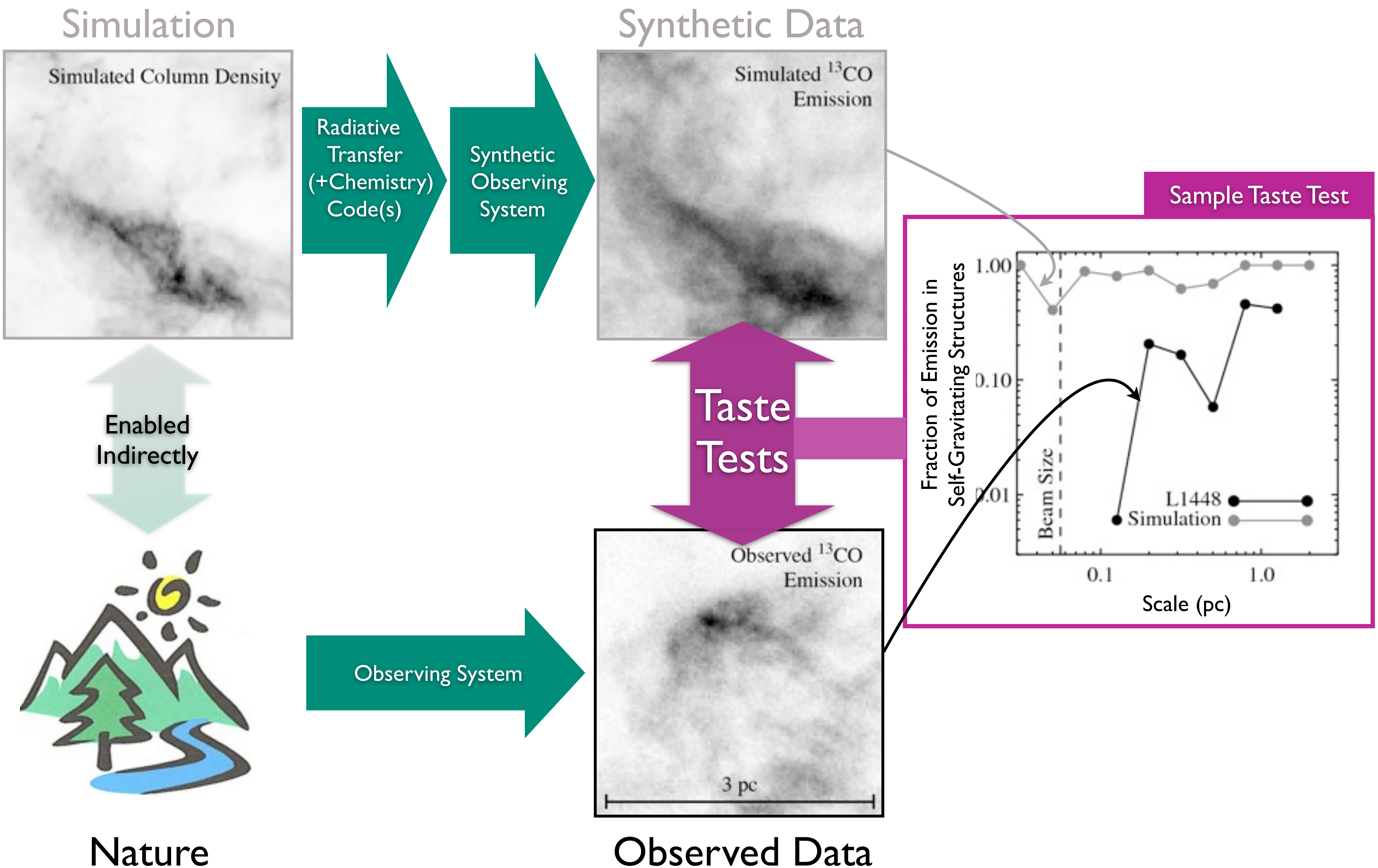
Tasting L1448 (The Role of Gravity)



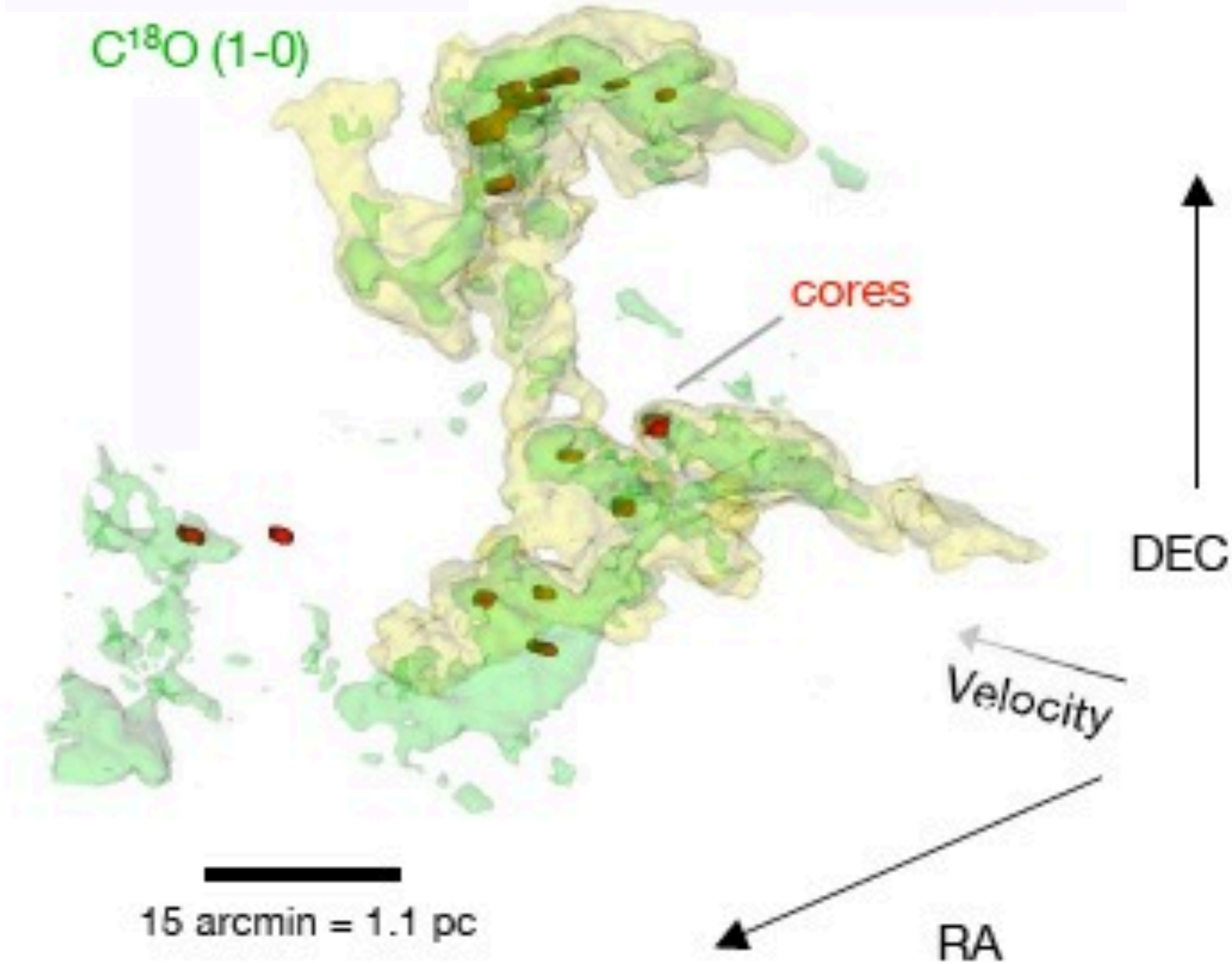
See also Jens Kauffmann's Poster, #14

Figure from Goodman et al. 2008, Nature, submitted.

The Taste-Testing Process

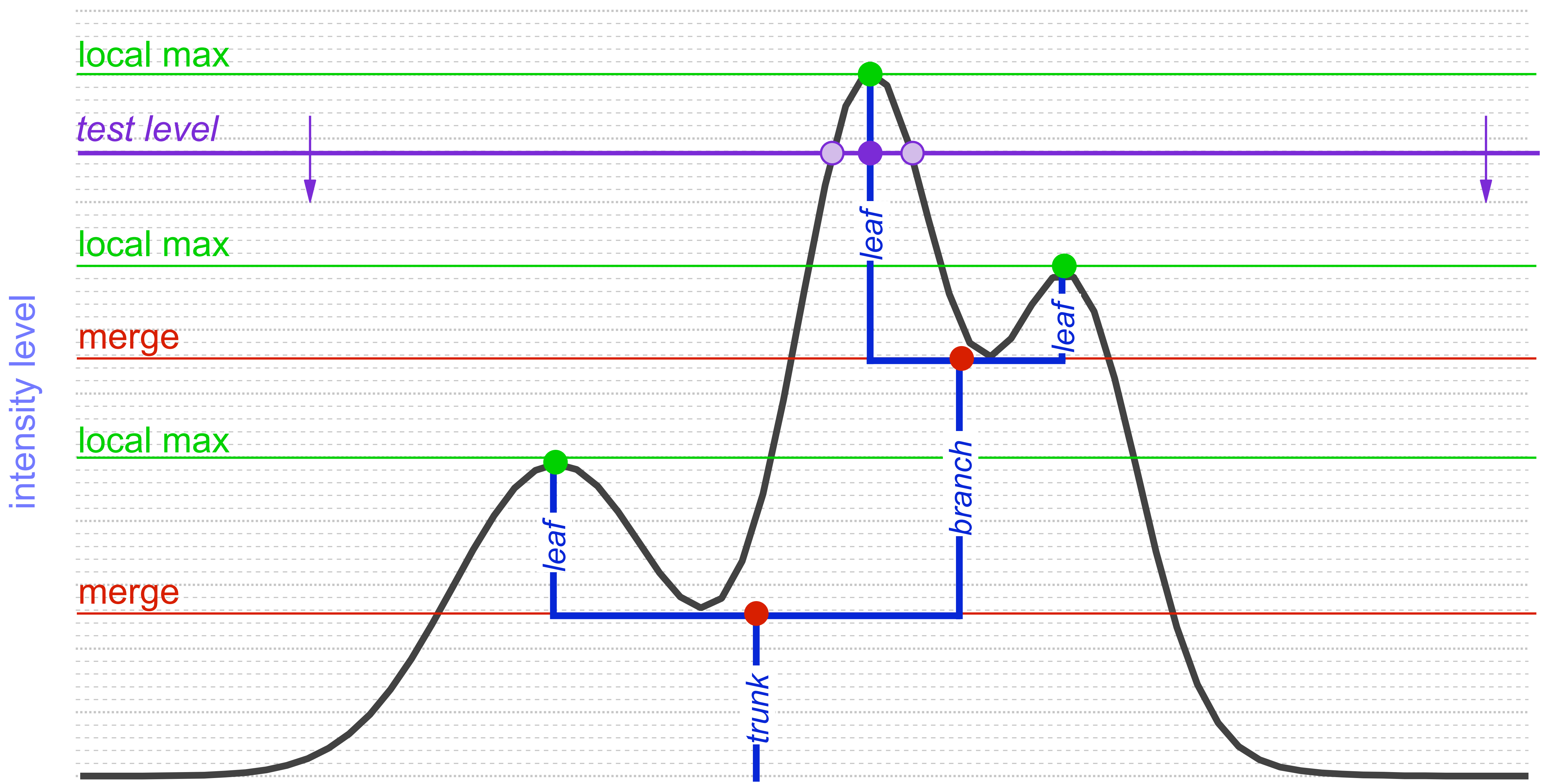


L1448 in *p-p-v* space



Static visualization created by Jens Kauffmann using 3D Slicer; See his poster, #14, for more on L1448.
Volume Rendering/Movie created by Nick Holliman (U. Durham) & Michelle Borkin (Harvard/IIC).

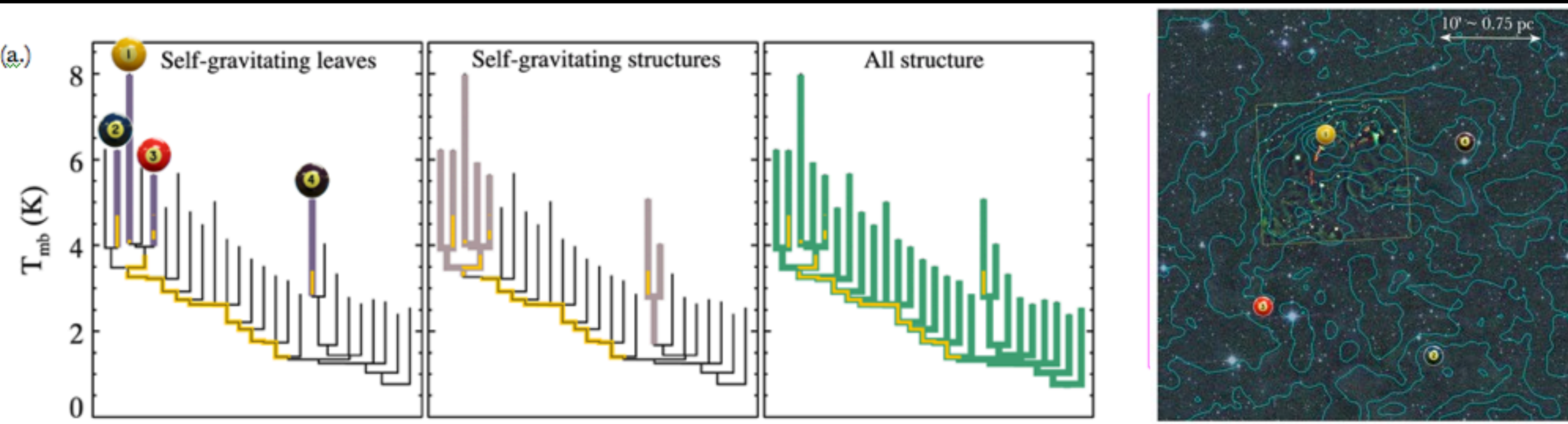
Dendrograms



1-D: points; 2-D closed curves (contours); 3-D surfaces enclosing volumes

see demo at http://aerial.client.fas.harvard.edu/~nessus/dendrostar/

Value of Dendrograms

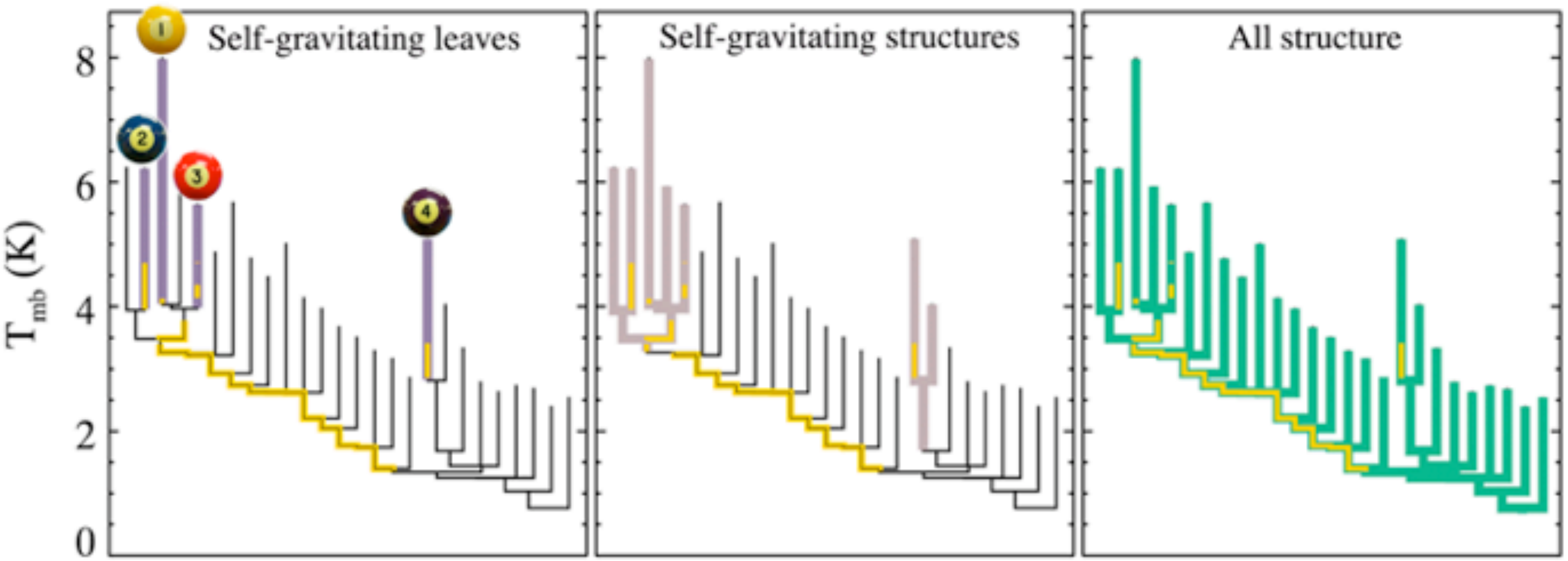


Yellow highlighting= “self-gravitating”

“Self-gravitating” here just means α_{vir} $(=5s_v^2 R/GM_{lum}) < 2$
(à la Bertoldi & McKee 1992)

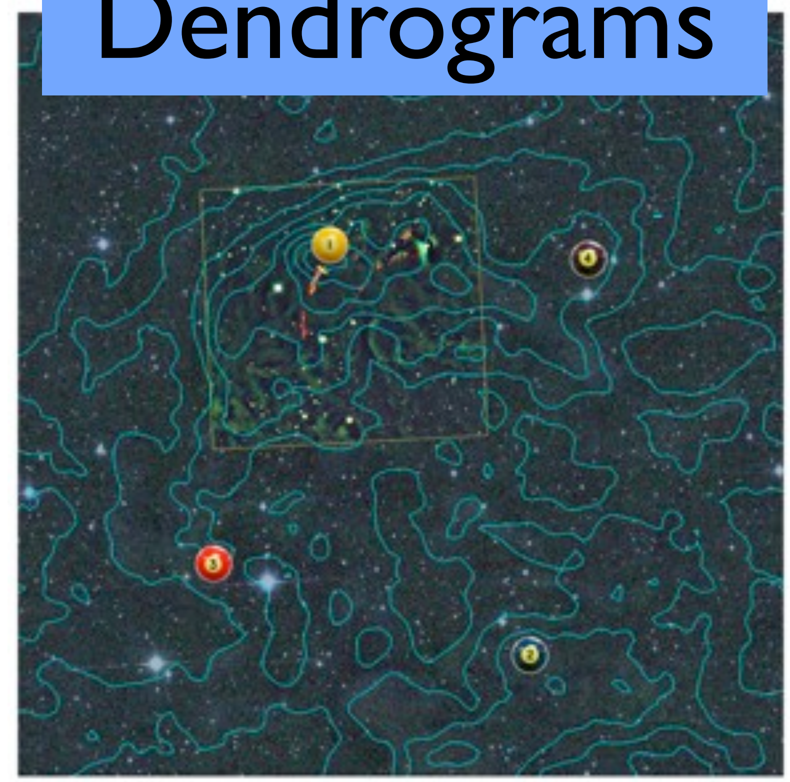
Rosolowsky et al. 2008 (ApJ);
Goodman et al. 2008 (Nature, submitted)

CLUMPFIND vs. Dendrograms: L1448

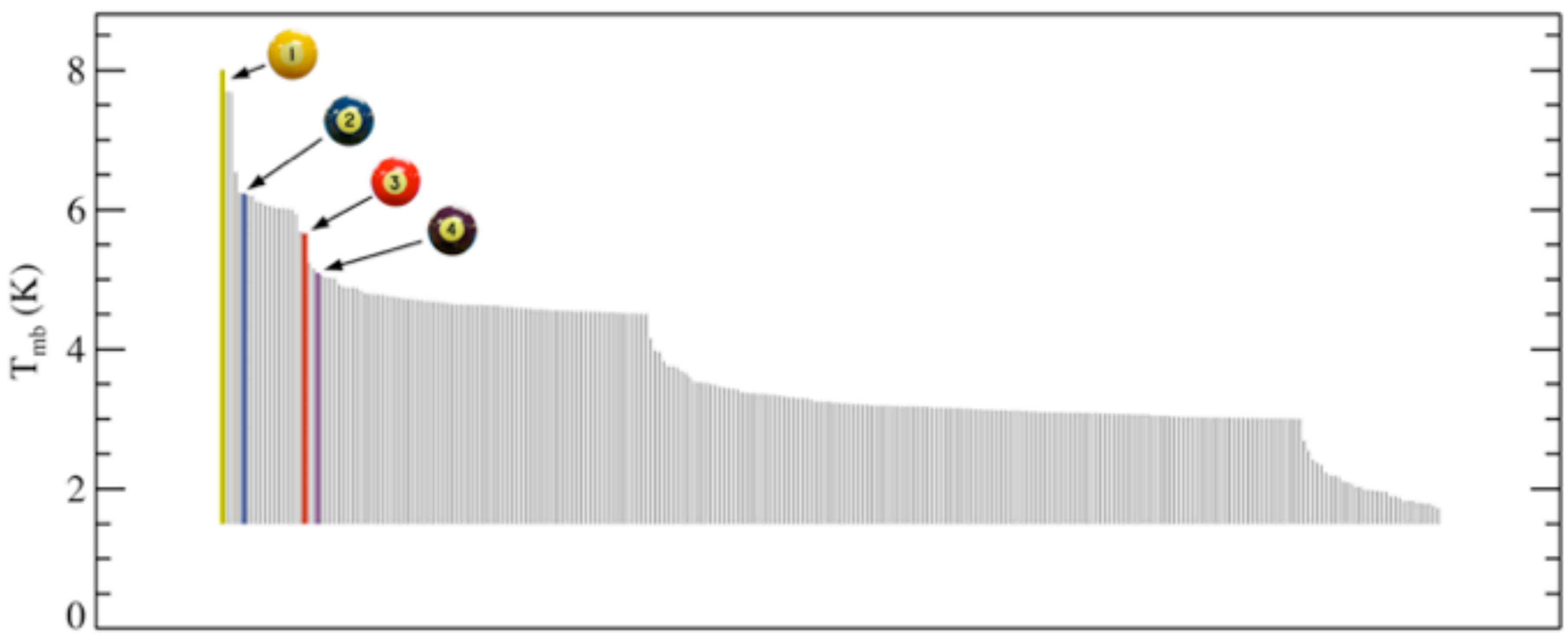


(Yellow = self-gravitating components)

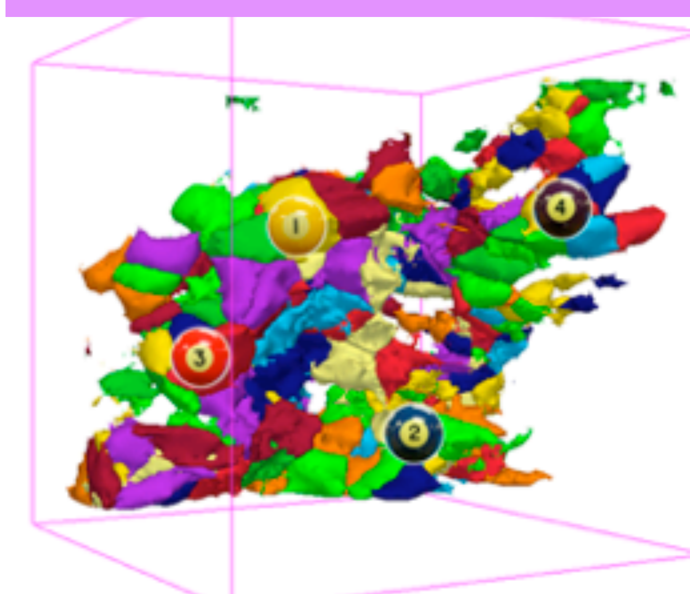
Dendrograms



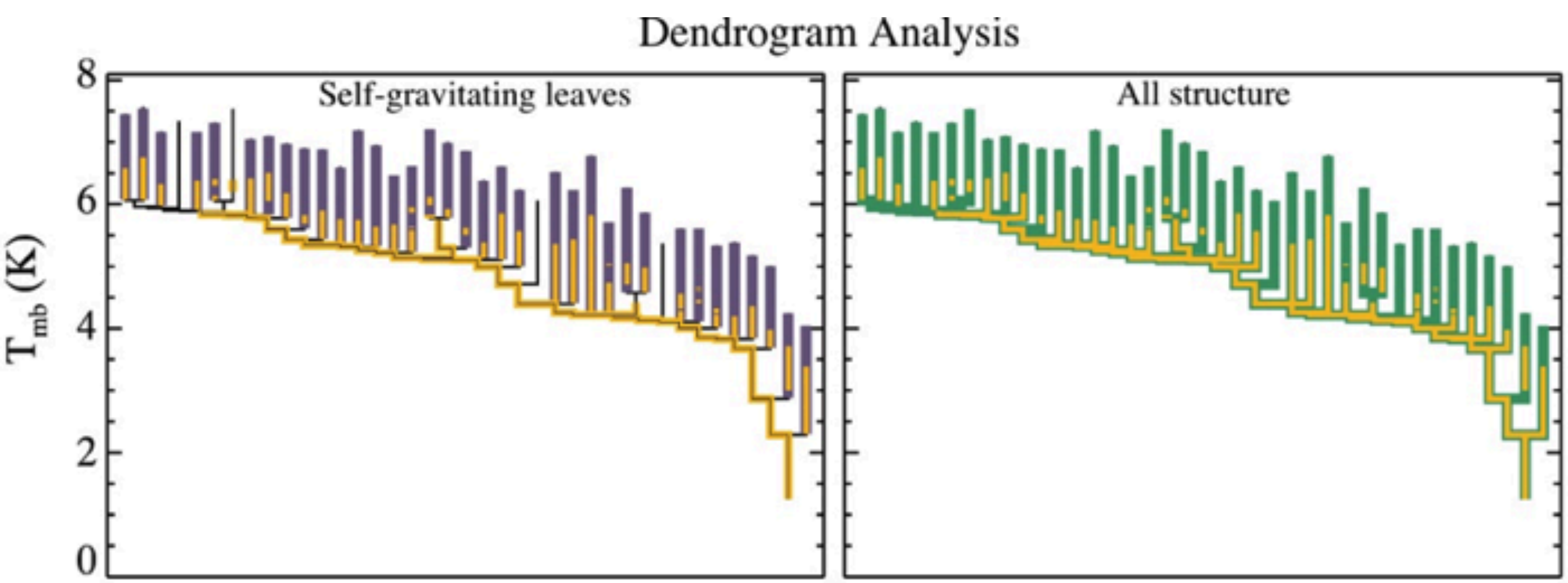
The online PDFs of these insets



“CLUMPFIND”

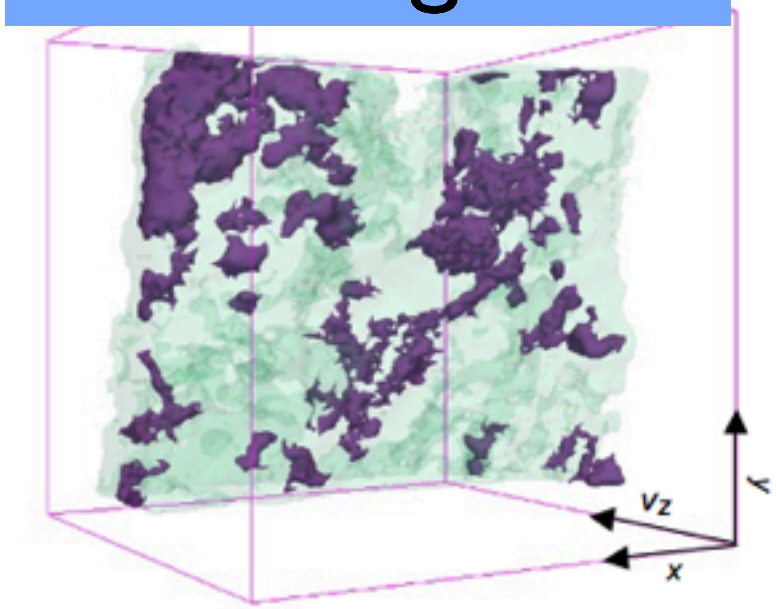


CLUMPFIND vs. Dendrograms: Synthetic Data

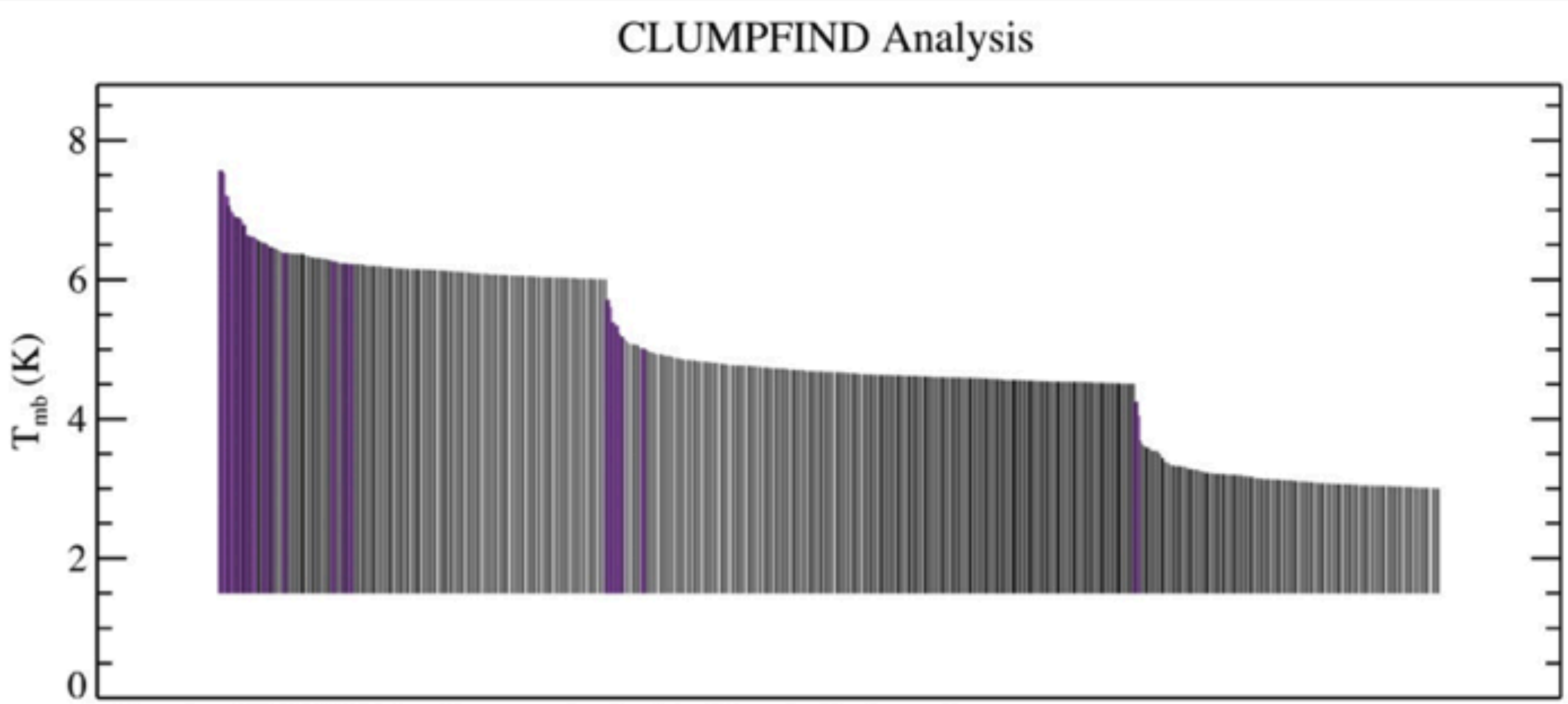


(Yellow = self-gravitating components)

Dendrograms

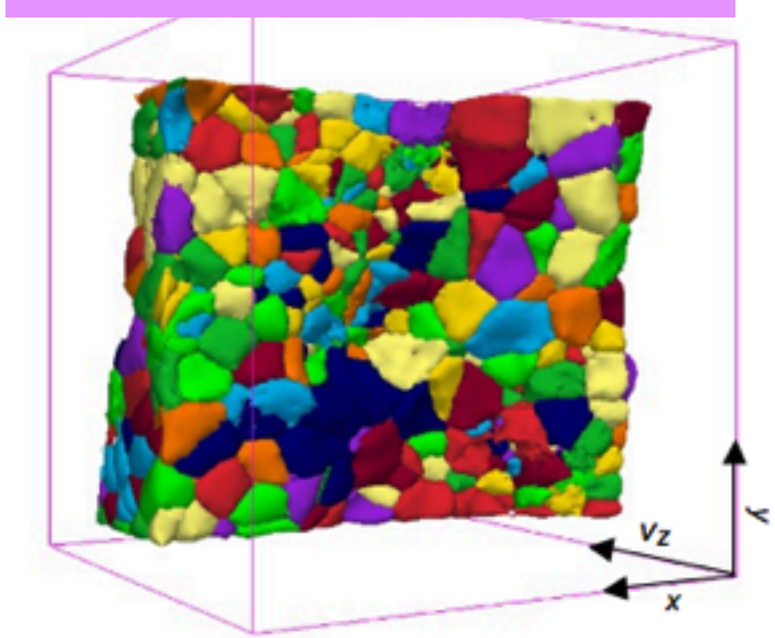


The online PDFs of these insets are interactive, offer additional surfaces, and can be rotated and manipulated by

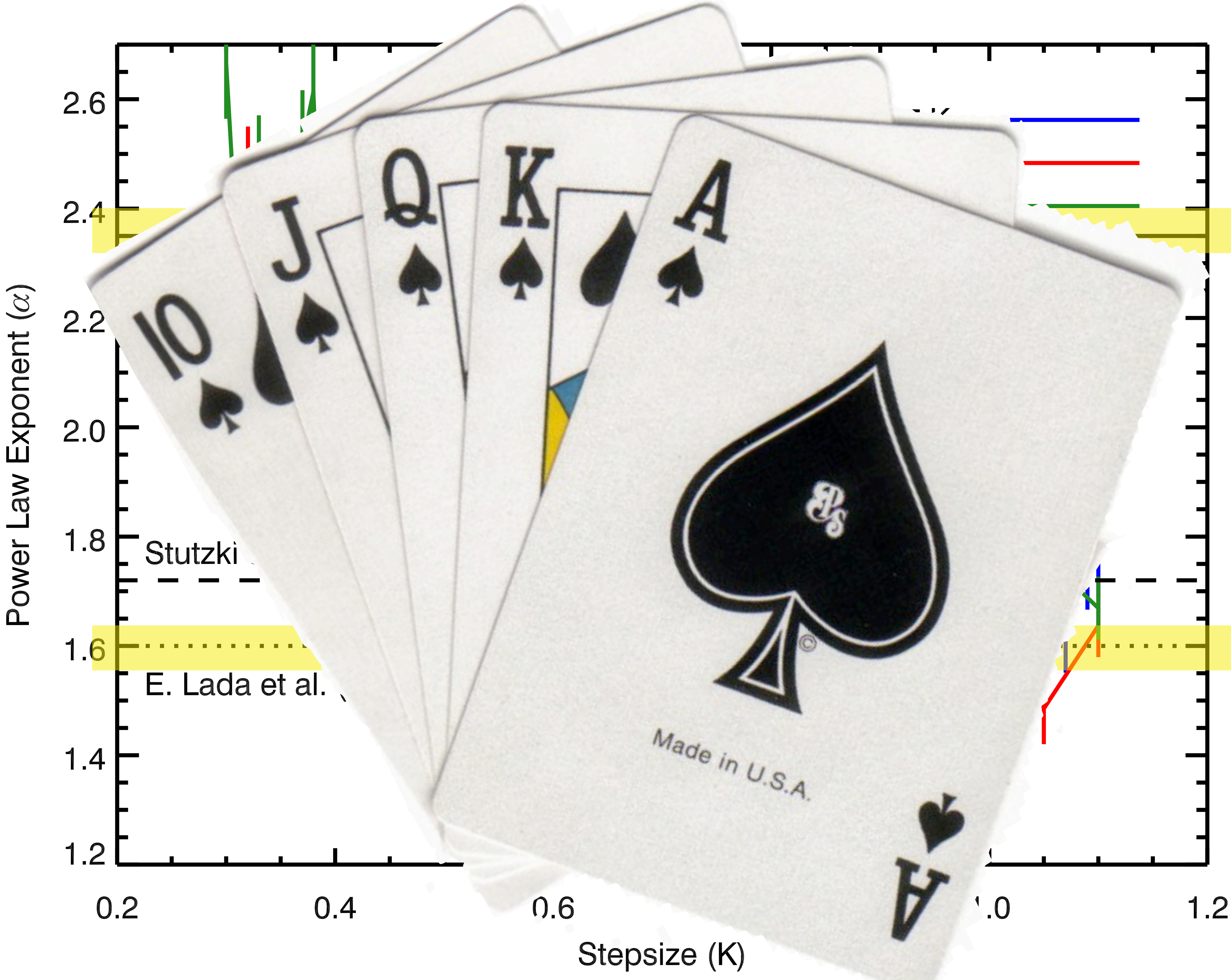


(Purple = CLUMPFIND regions associated with self-gravitating leaves)

"CLUMPFIND"



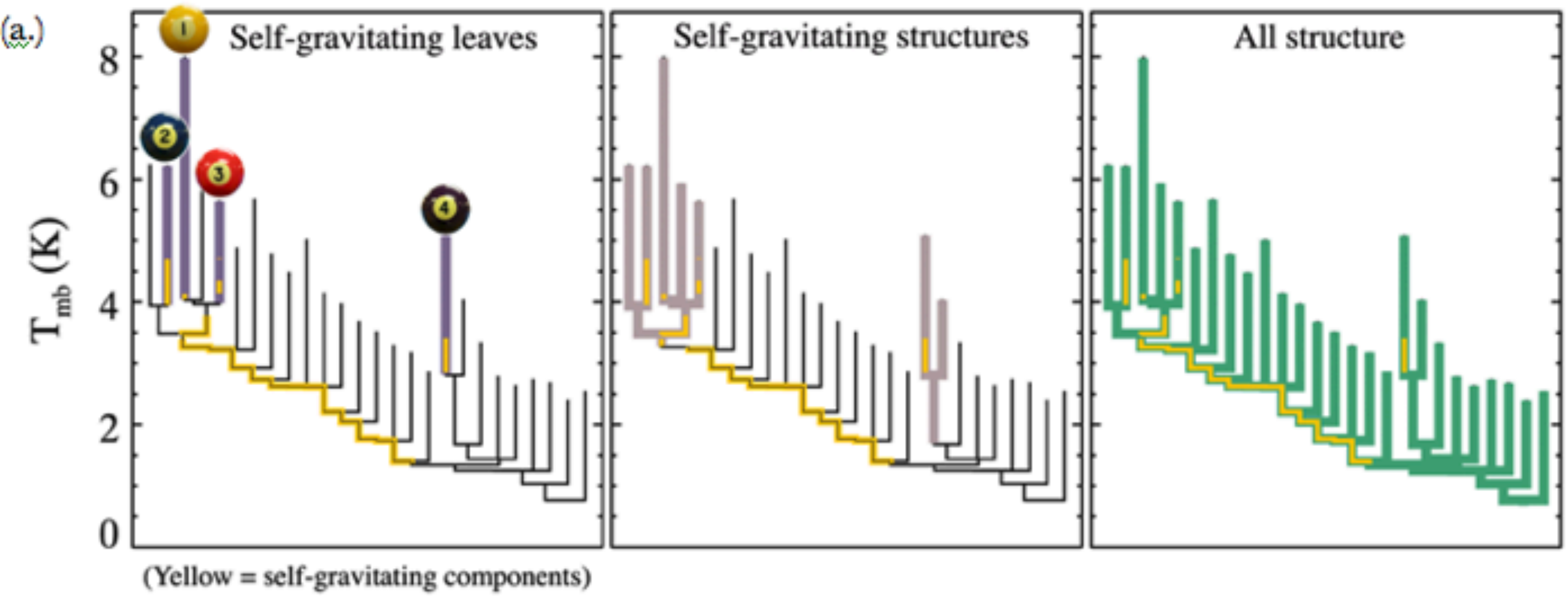
Pick an exponent, any exponent...

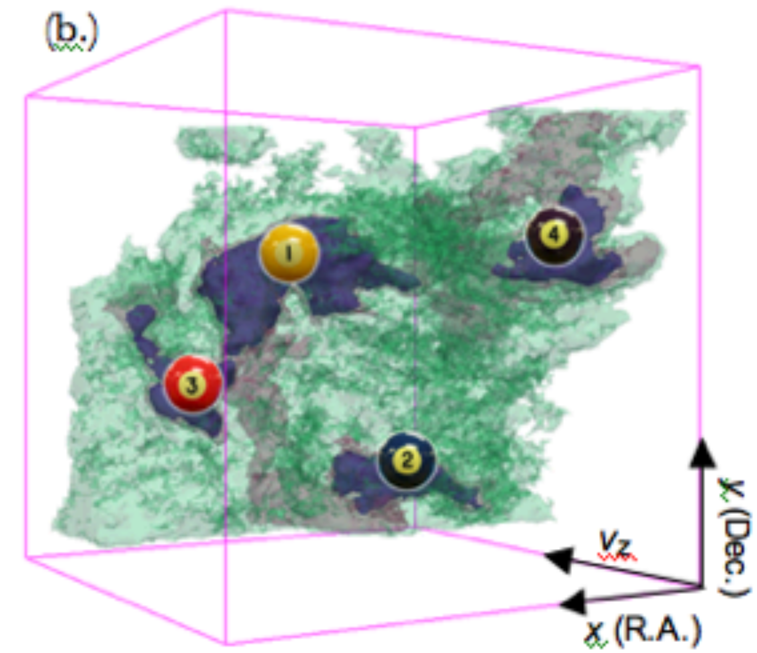


CLUMPFINDing in the Full Perseus ^{13}CO Map; Pineda et al. 2008

Value of Dendrograms

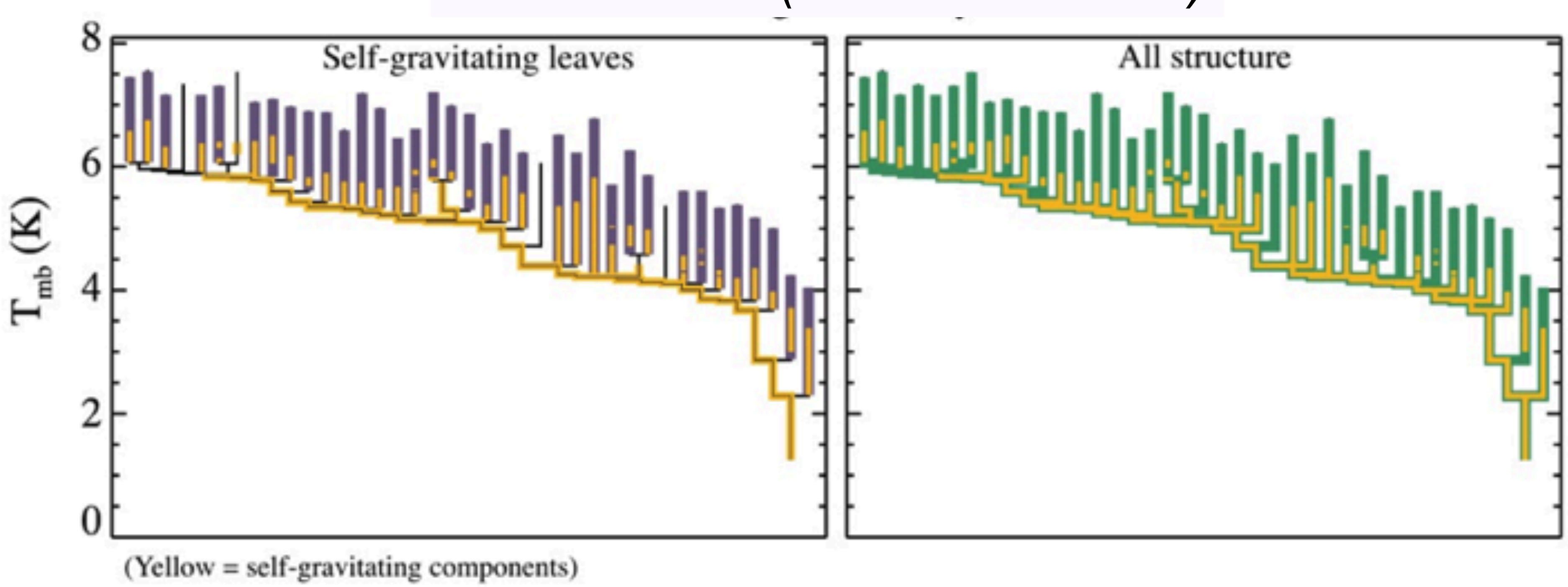
Observations (COMPLETE)

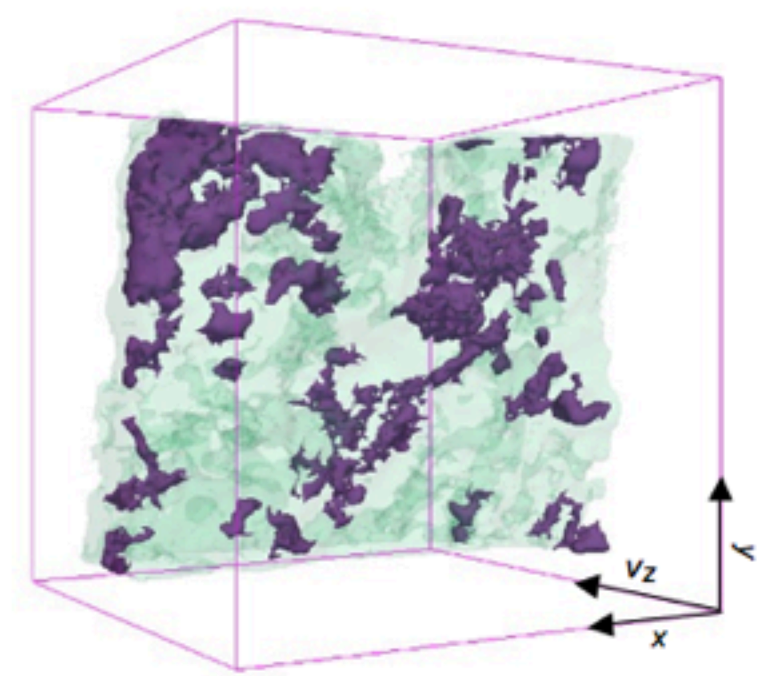




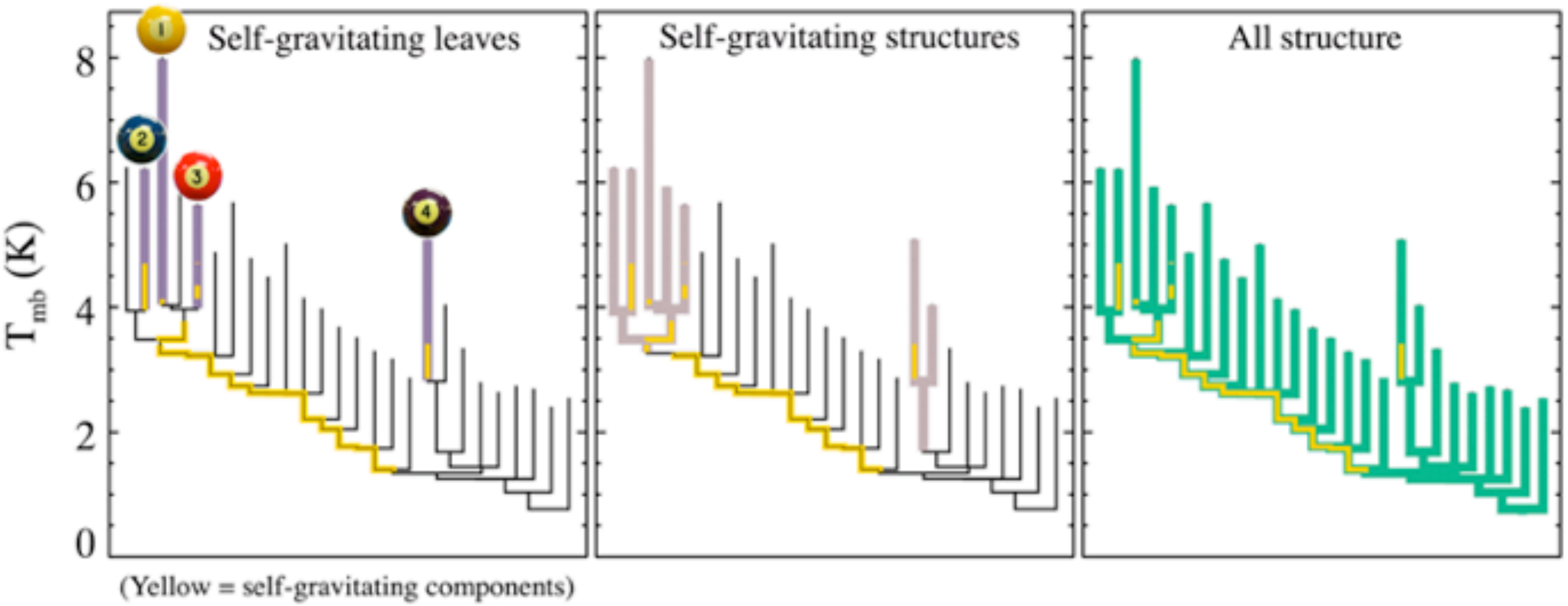
The online PDFs of these insets are interactive, and can be rotated and manipulated by the viewer.

Simulation (Padoan et al.)

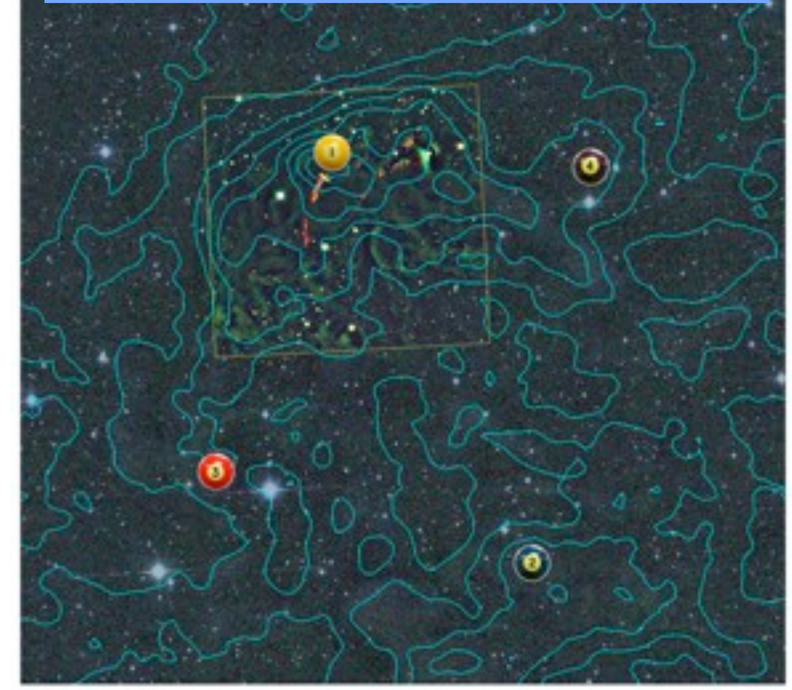




CLUMPFIND vs. Dendrograms: L1448

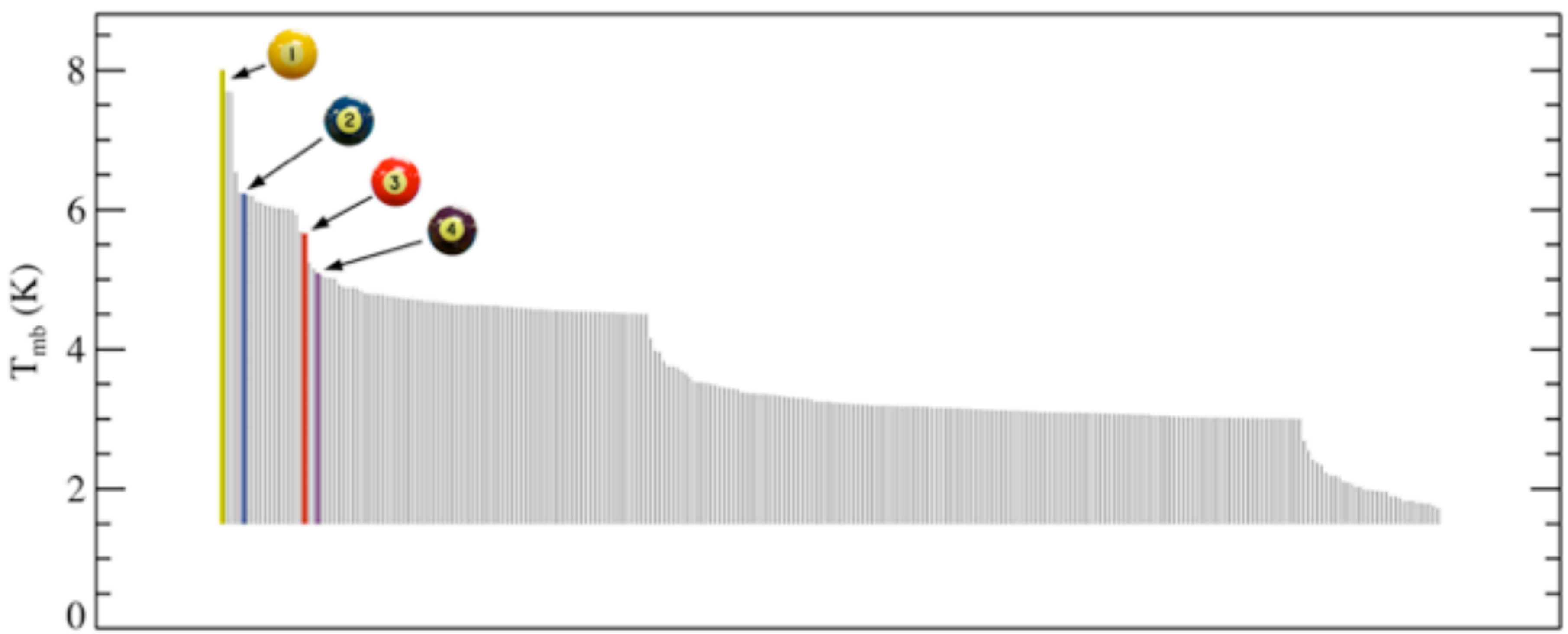


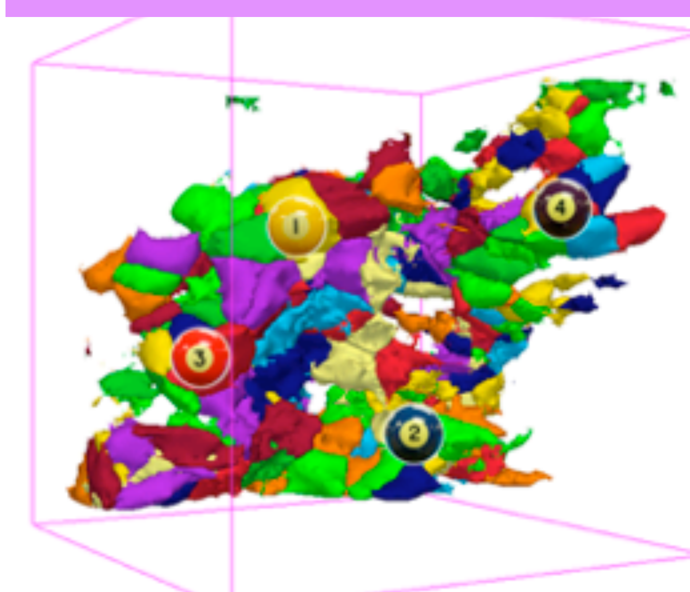
Dendrograms



The online PDFs of these insets

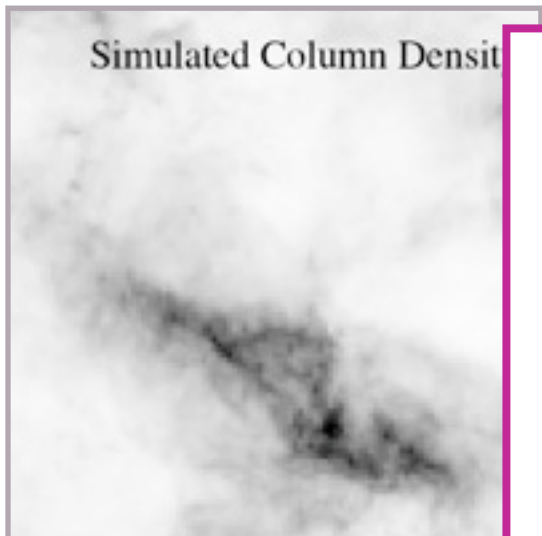
"CLUMPFIND"





Taste-Testing Gravity

Simulation

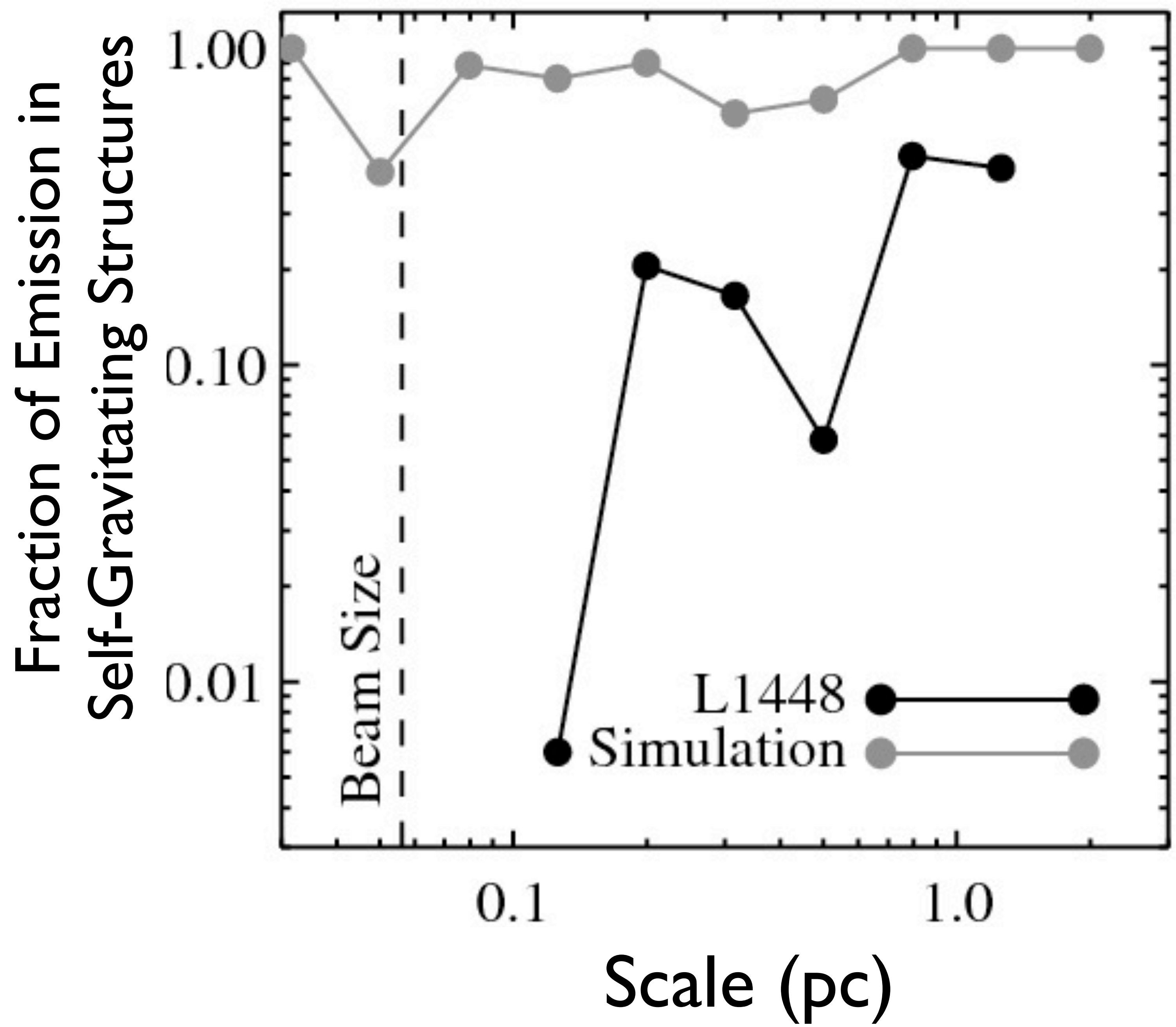


Enabled Indirectly

Nature

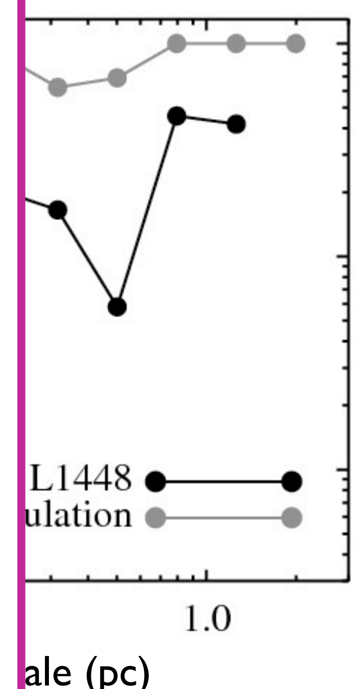
Synthe

Sample Taste Test



Observed Data

Sample Taste Test



A tasty challenge from Frank Shu...

Star Formation Taste Tests > All Messages

https://iic.grouphub.com/projects/700257/msg/all

Back to Dashboard | Switch to a different project

Star Formation Taste Tests CfA

Overview | Messages | To-Do | Milestones | Writeboards | Chat | Time | Files

All Messages

Expanded view | List view

THURSDAY, 19 JUNE 2008

Column Density Paper

A paper entitled: "The "True" Column Density Distribution in Star-Forming Molecular Clouds", by Goodman, Pineda & Schnee, is now available, on astro-ph, at http://adsabs.harvard.edu/cgi-bin/nph-data_query?bibcode=2008arXiv0806.3441G&db_key=PRE&link_type=ABSTRACT&high=485efe37dd27343. Here's a copy.

goodman_pineda_schnee08.pdf (PDF, 927K)

Posted by Rahul Shetty in Publications | Edit | Post the first comment

THURSDAY, 10 APRIL 2008

Frank Shu's "Test of the Test" Idea: Are Dendrogram Identified Cores really Self-Gravitating?

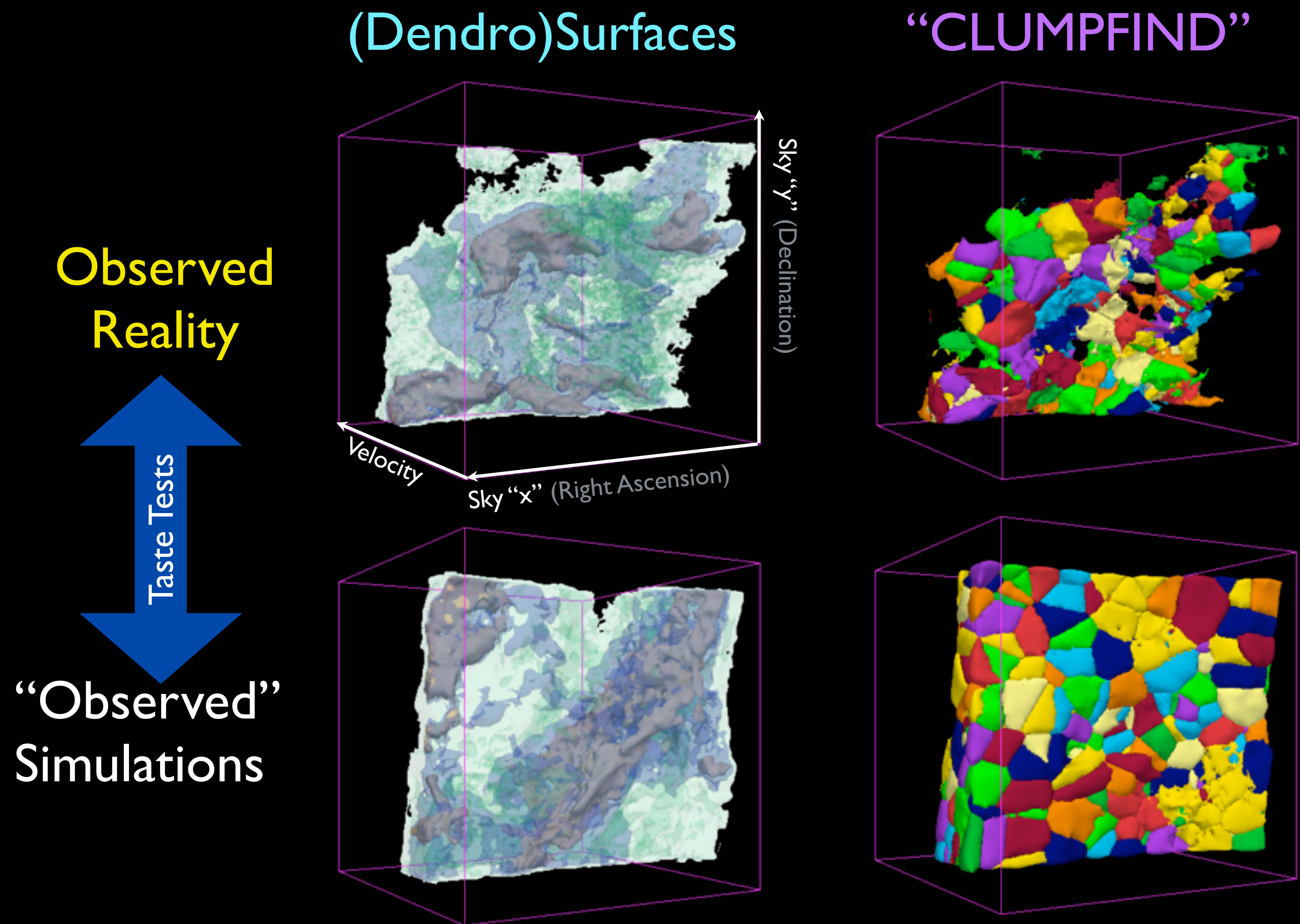
We have been investigating the use of Dendrograms (http://arxiv.org/abs/0802.2944) to identify self-gravitating regions in molecular clouds. As a test, Frank Shu has suggested that we apply this method to simulation cubes of molecular clouds. We can perform a dendrogram analysis on simulation cubes at early times, before the clumps have completely collapsed. We will then verify whether the dendrogram identified self-gravitating clumps do indeed collapse by inspecting the simulation cubes at later times. In order to carry out this test, we are requesting simulation data cubes of star forming clouds (where the calculation of self-gravity is included); we would certainly appreciate a wide variety of simulations for a thorough test of the dendrogram analysis. Please let us know if you are able to contribute your simulation data cubes for this test. We are also happy to collaborate if you'd like to go through this kind of analysis with us together.

Posted by Rahul Shetty in Collaboration Projects | Edit | Post the first comment

TUESDAY, 1 APRIL 2008

Cosmic Dust & Radiative Transfer
a workshop devoted to radiative transfer coding

Either Algorithm is an Example of Tasting in Observational-Space



work of Rosolowsky, Pineda, Kauffmann, Borkin, Padoan, Halle & Goodman;
figure from Goodman & Rosolowsky NSF "Star Formation Taste Tests" Proposal, Fall 2006

Clarifying the Shopping List(s)

Region Type
"Sparse"
"Dense"

Population
Pre-stellar cores
Cores with stars

Structure Identification Space
p-p (2D)
p-p-p (3D, theory only)
p-p-v (3D)

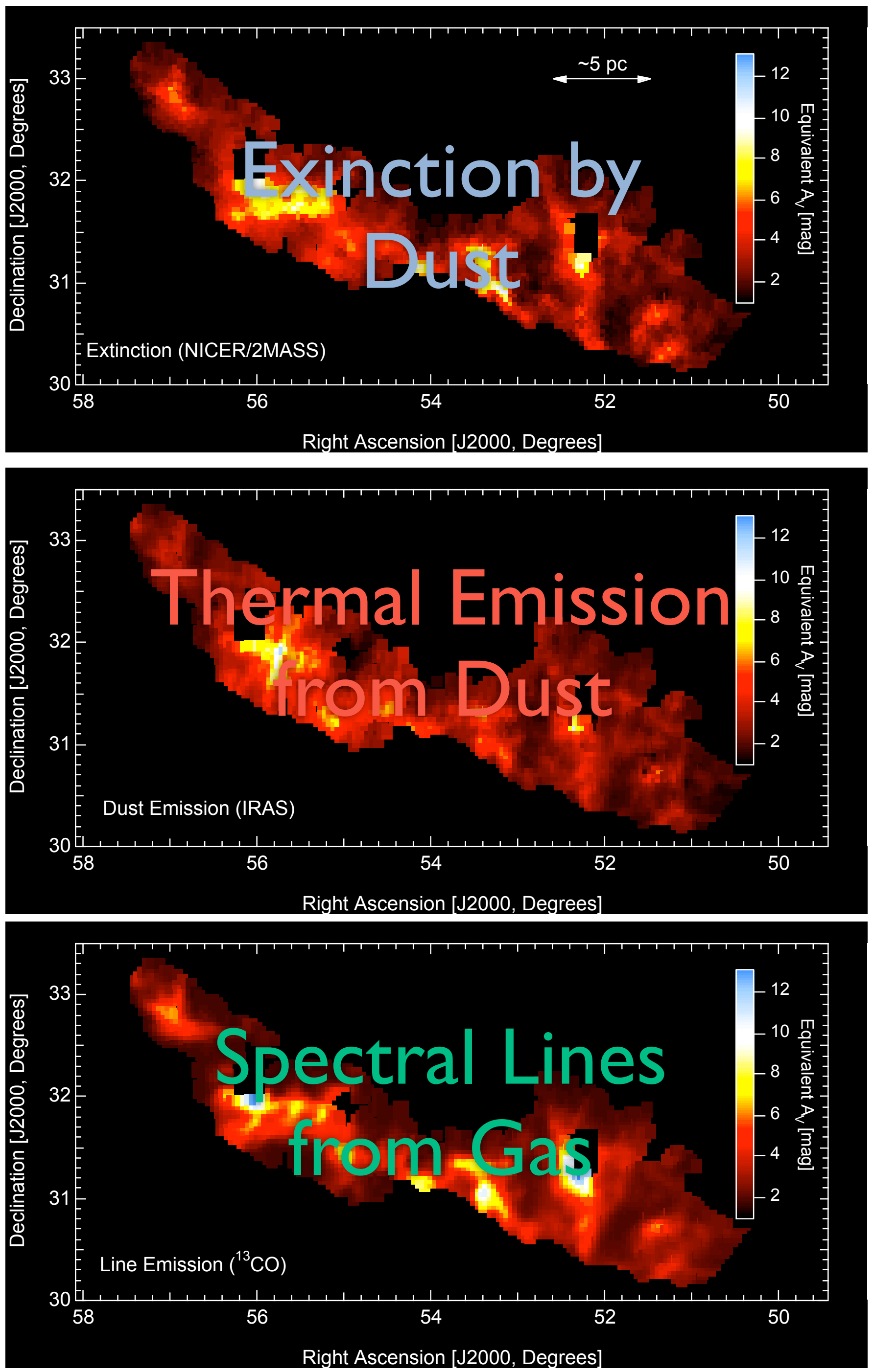
Chemistry
Nature (Observed)
"Synthetic, Faked"
"Synthetic, Modeled"

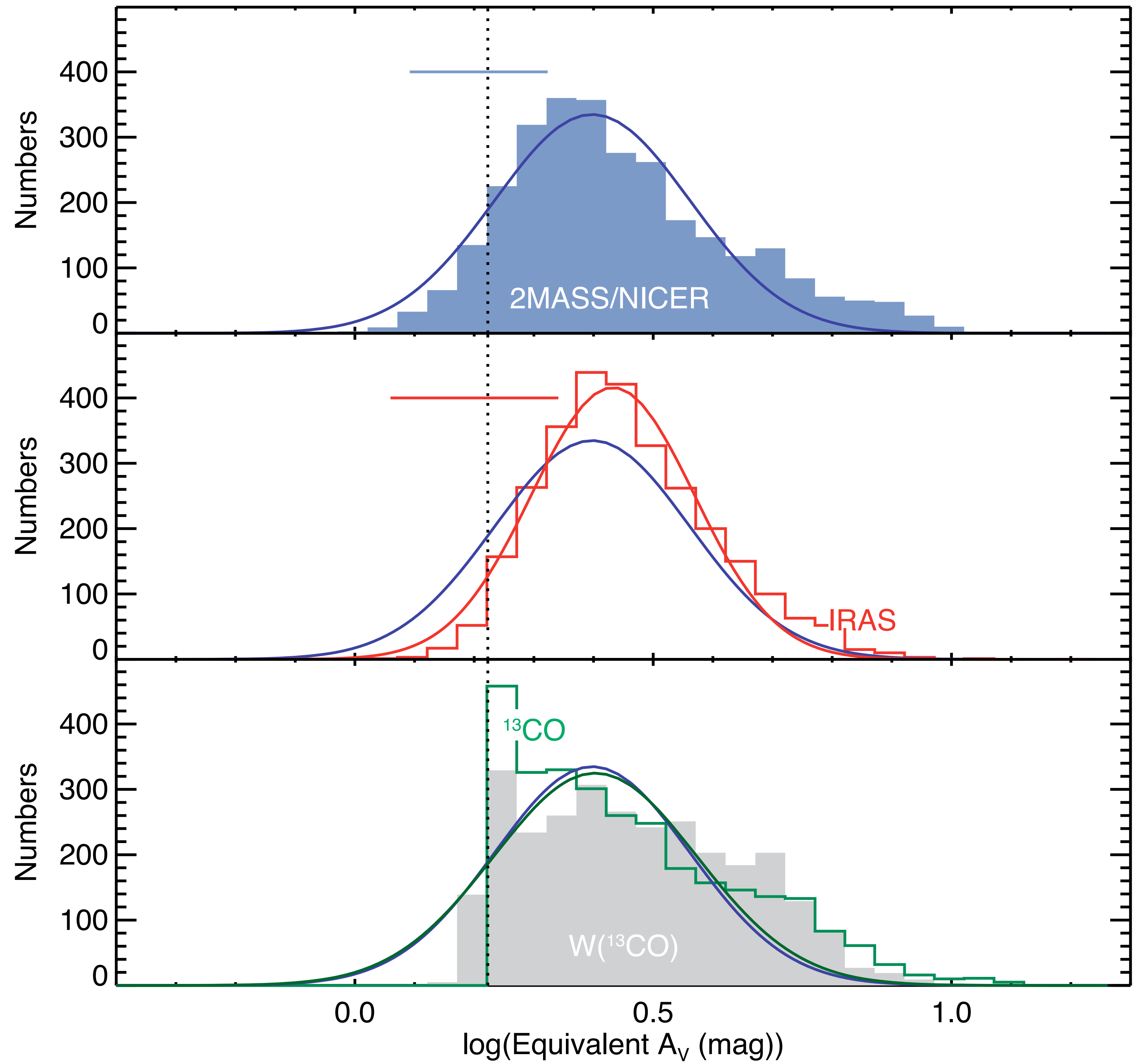
Nearly all combinations can be imagined, and tasted.

New *tasty treats for sale* by observers... (to start discussion)

- ☑ **Column density "PDFs"** and regional variations thereof (Goodman et al. 2008)
- ☑ **Polarimetry** from galactic to core scales (see Li et al. 2008)
- ☑ Large-scale **Surveys of Core Properties** (Pipe: Alves, Lada et al.; Perseus: Foster et al. 2008; Enoch et al. 2007; *several* others)
- ☑ Early **Radial Velocity Surveys** of **Stars** (e.g. Furesz et al. 2008)

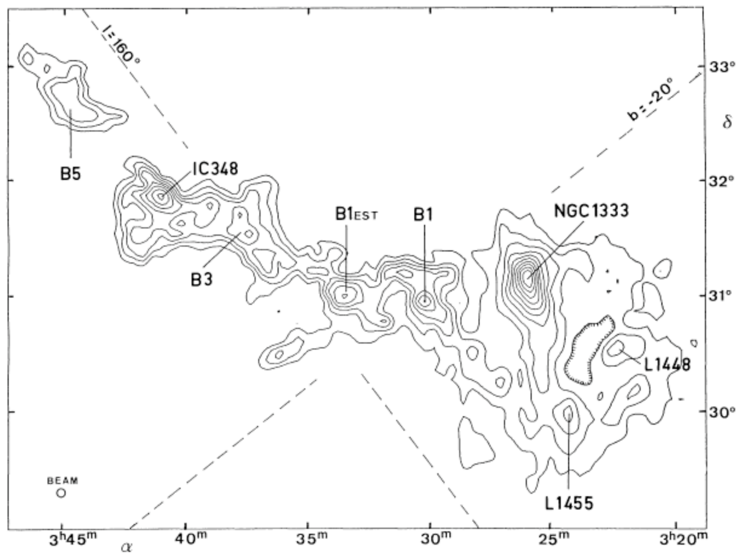
*Which measure of **Column Density** gives the **“Truest” Taste**?*

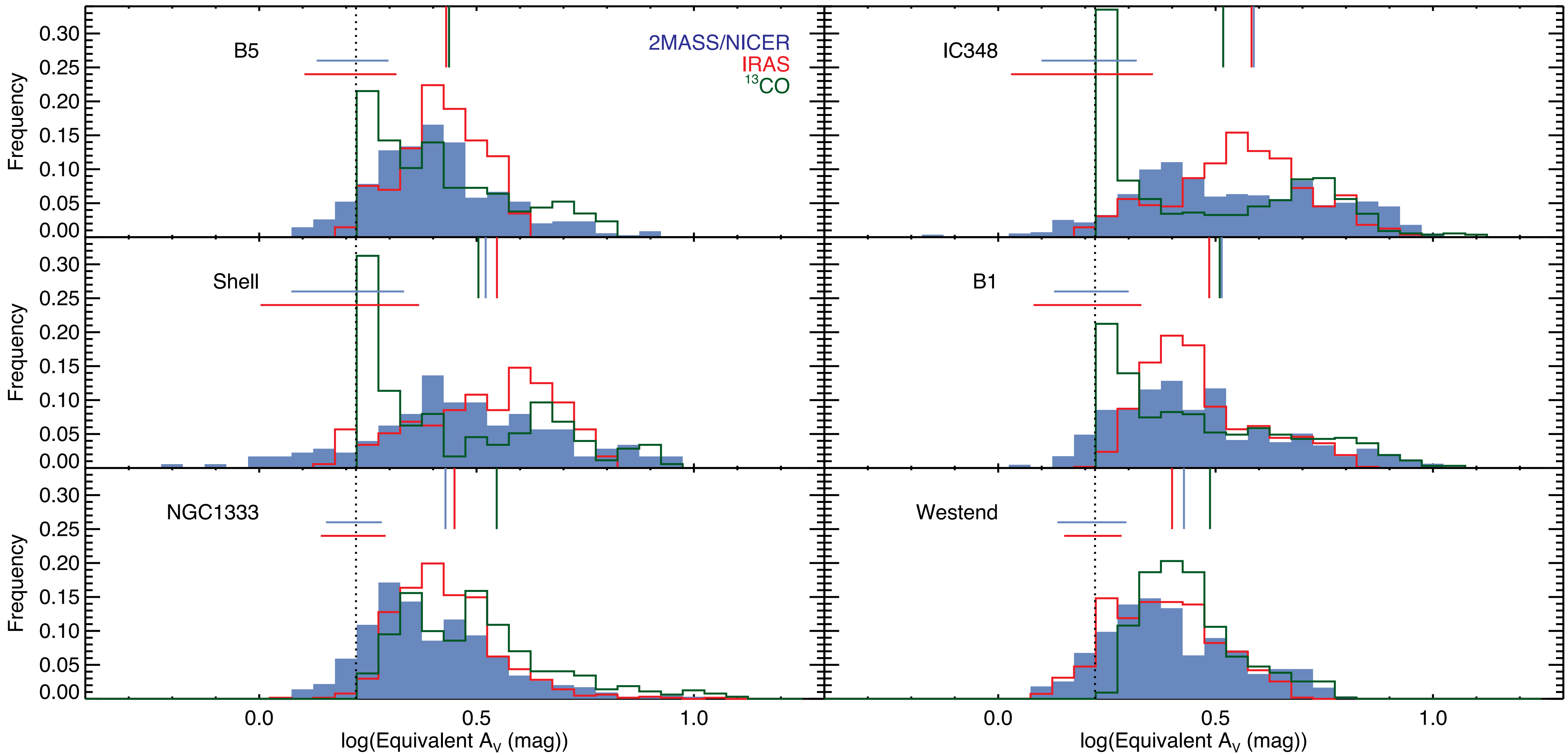




Goodman, Pineda & Schnee 2008

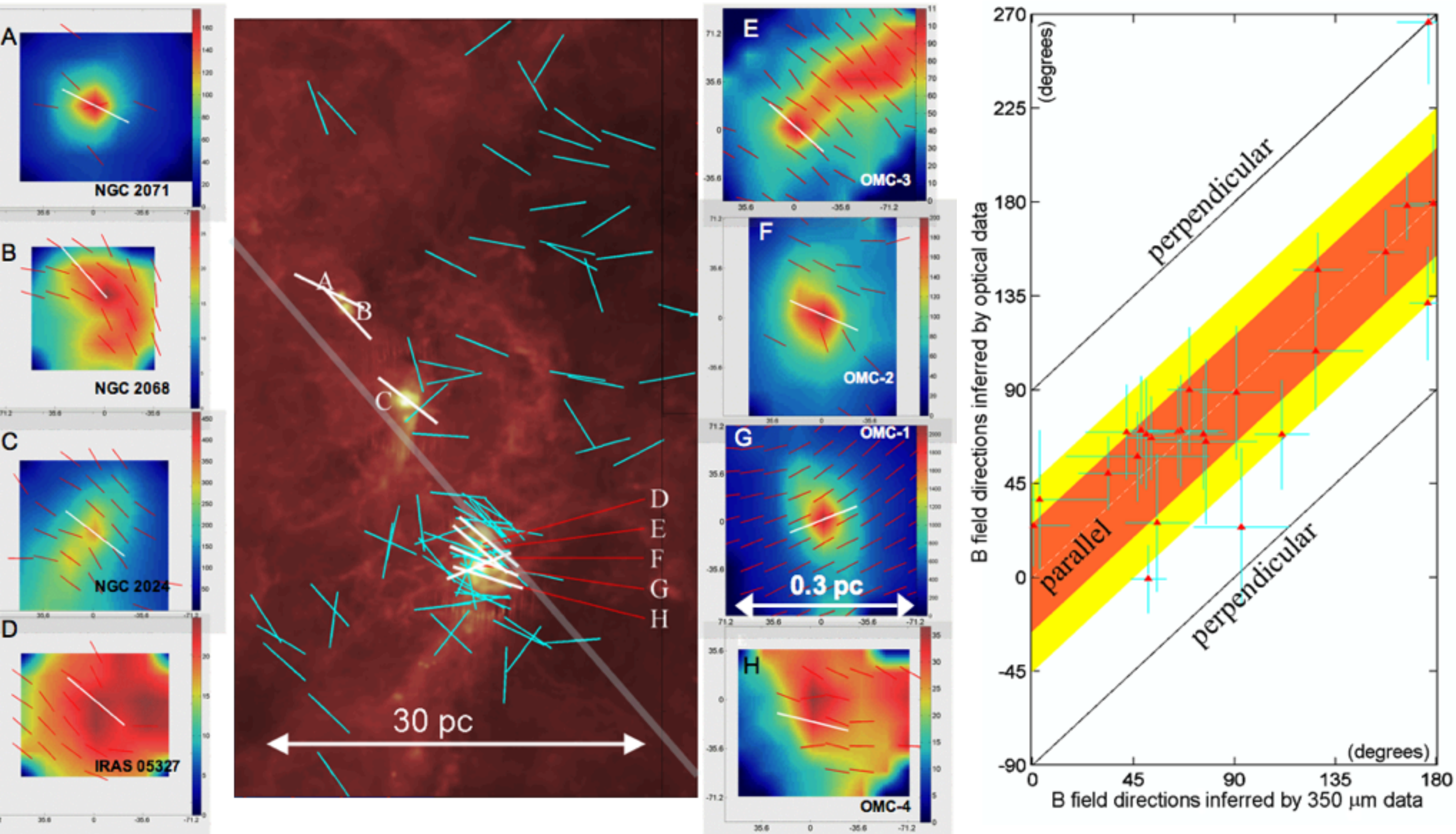
Regional Variations within Perseus





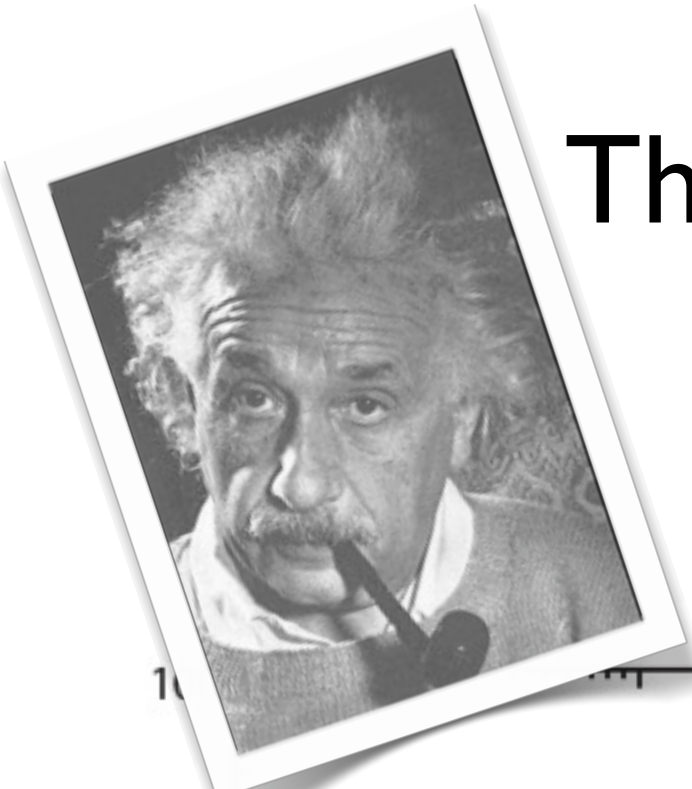
Goodman, Pineda & Schnee 2008; Pineda et al. 2008

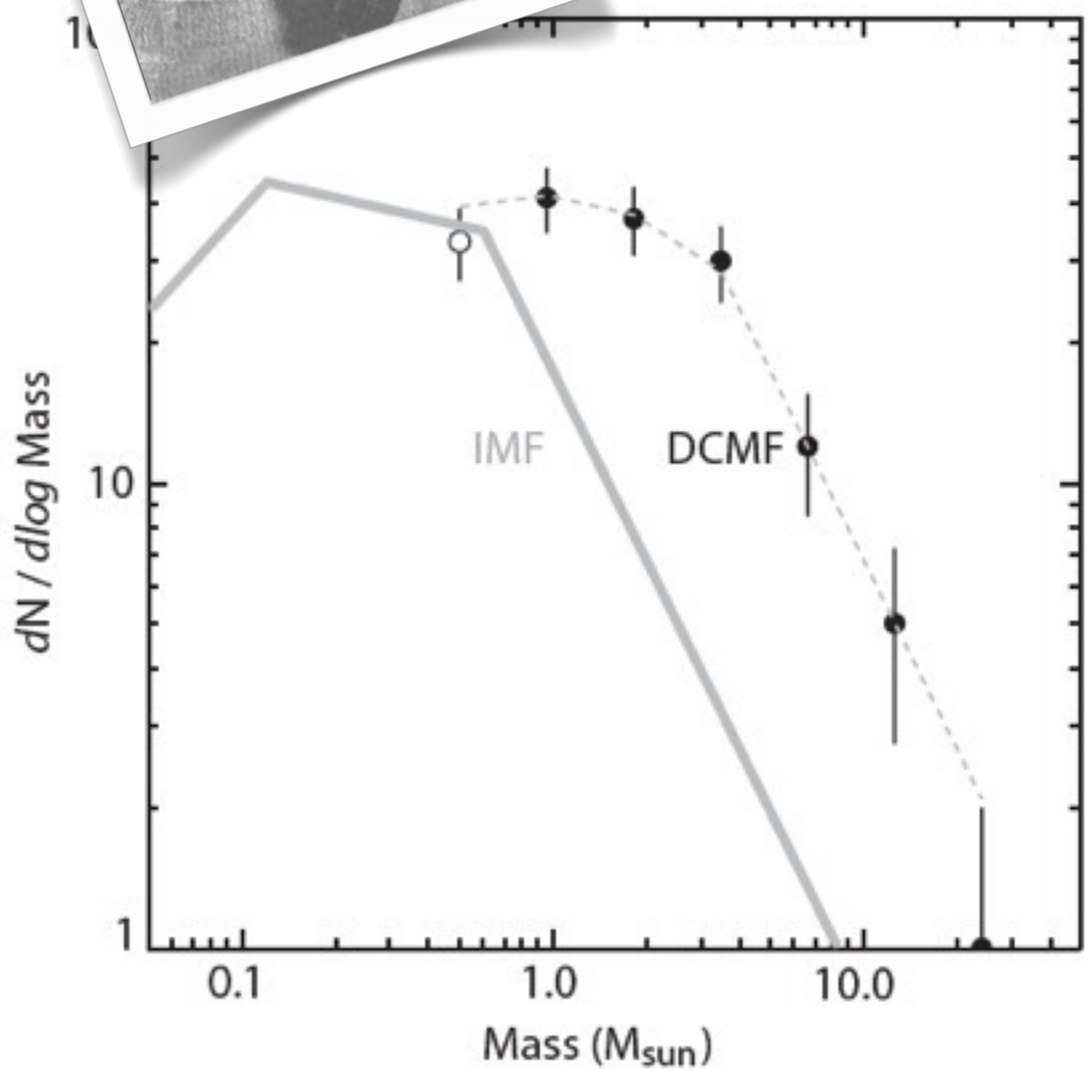
Galactic B-Field "Anchored" in Clouds?



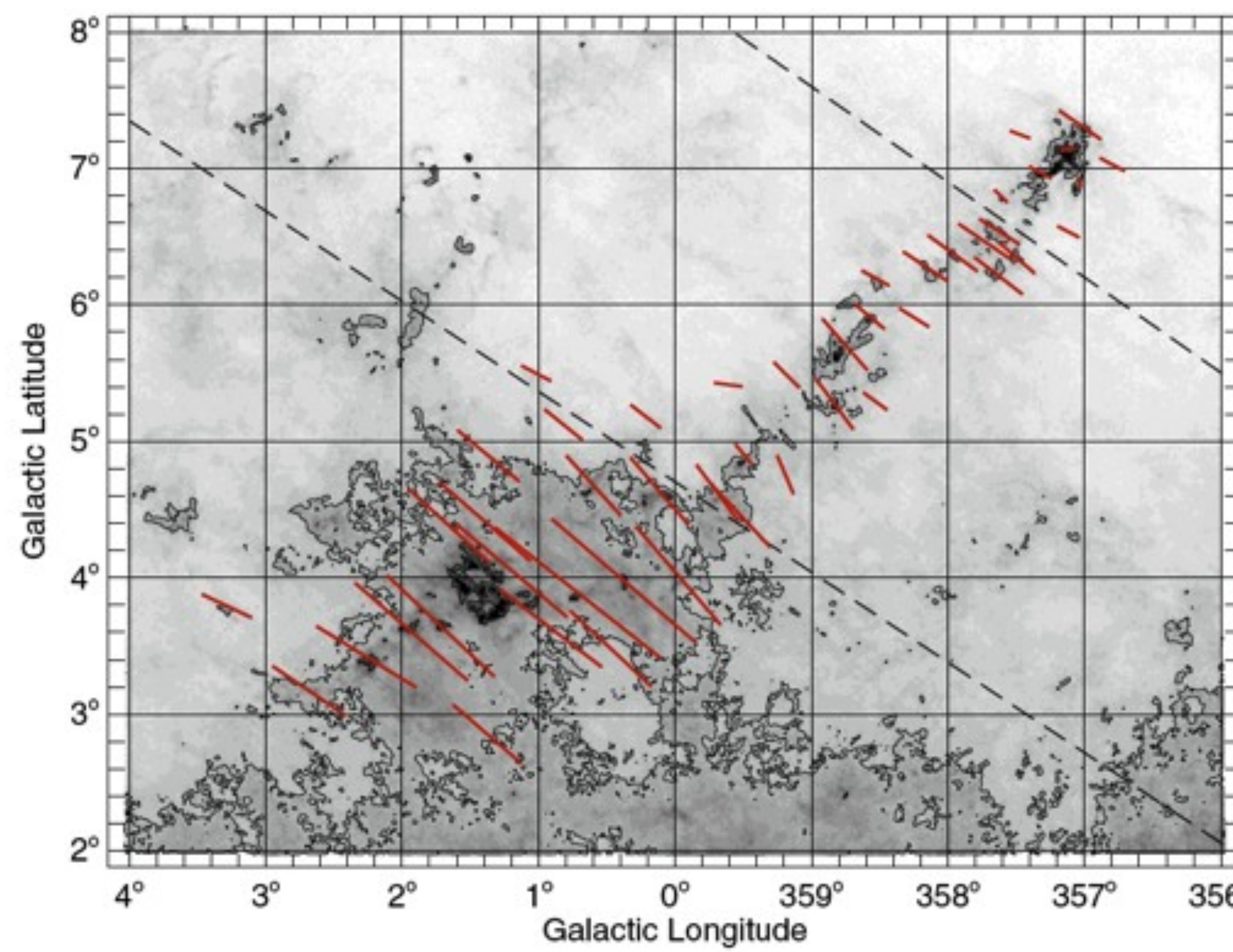
Hua-bai Li, Goodman, Hildebrand & Novak 2008 in prep.

The Lure of the Pipe... will too much smoking dull your taste buds?



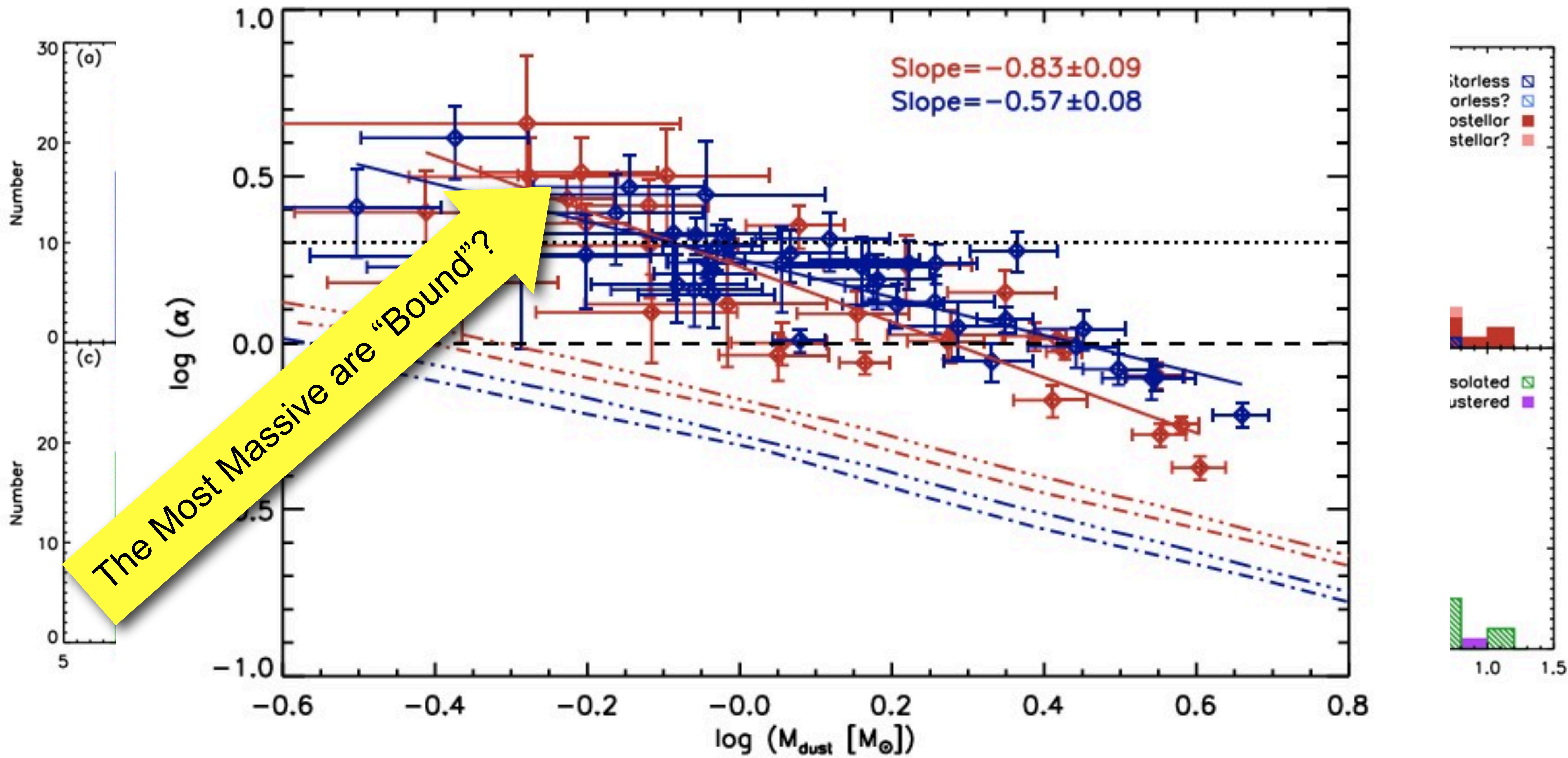


Mass Functions from
J. Alves, Lombardi & C. Lada 2007



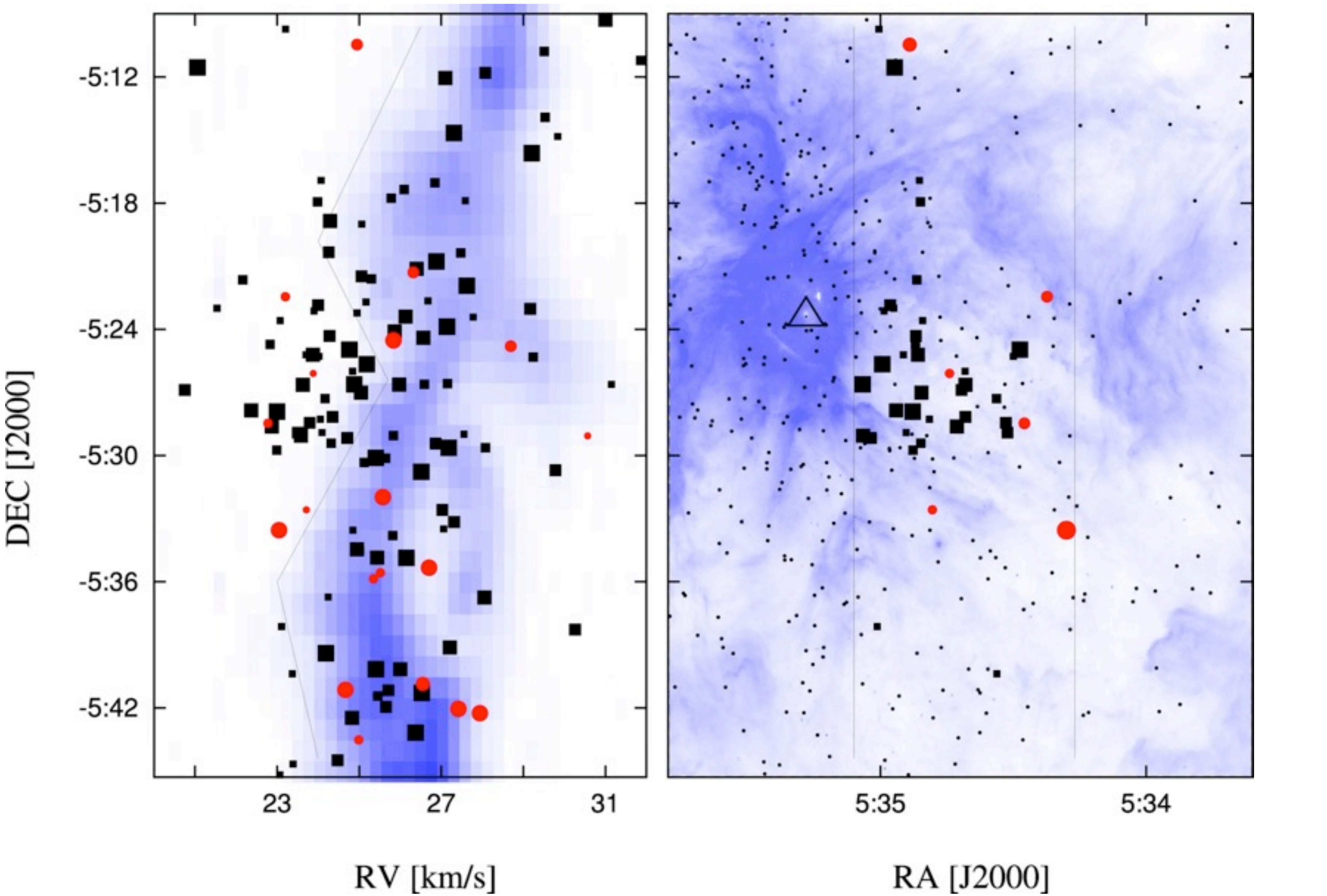
R-band Polarization from
F. Alves, Franco & Girart 2008

Exquisite new studies of dense core properties... +maps (not shown)



Foster et al. 2008; GBT NH3 study; Derived from Rosolwosky et al. 2008

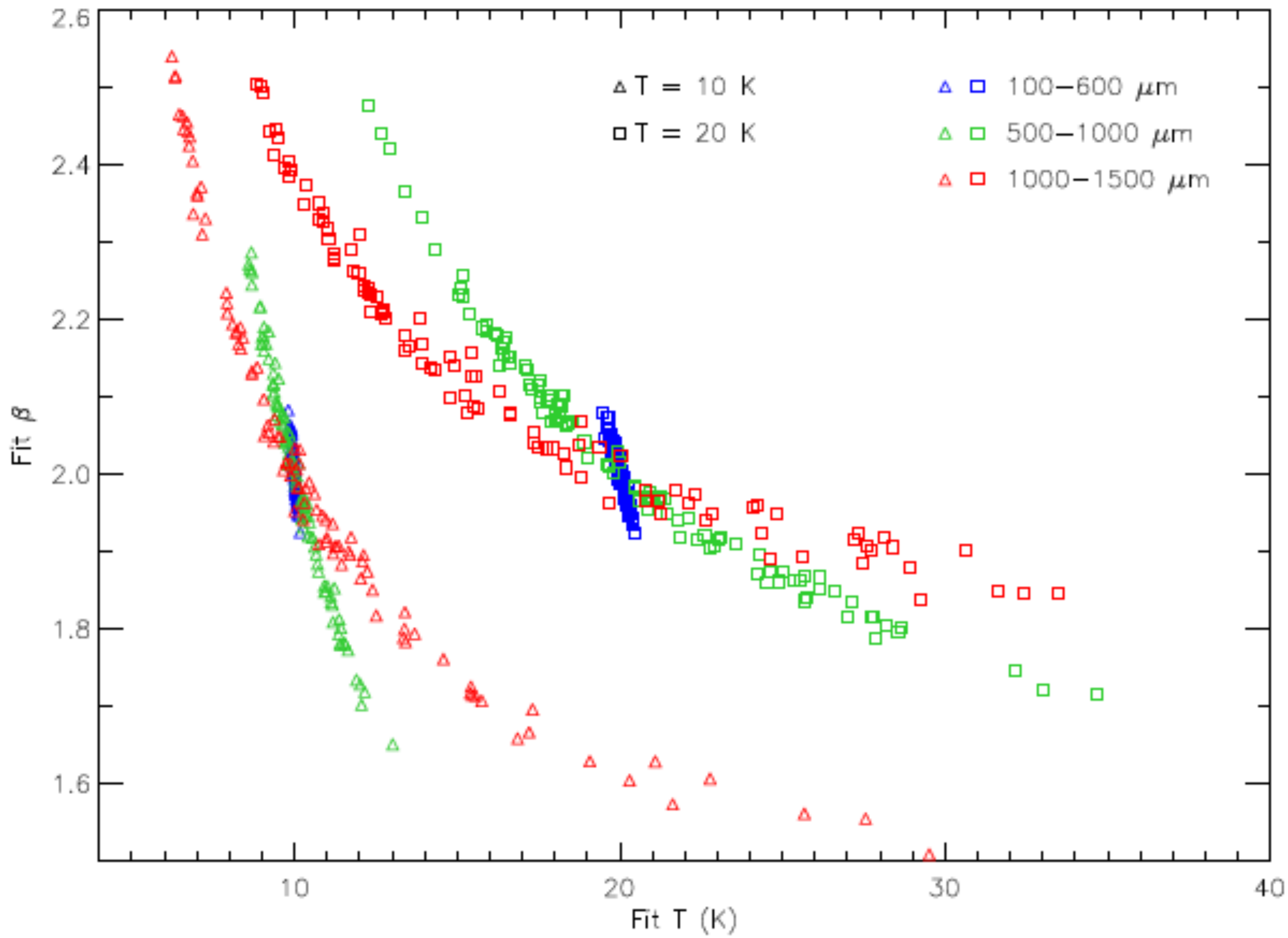
Radial Velocity Study of Orion (Furesz et al. 2008)



My notes for the focus group...

- (When) is the "clump mass spectrum" well-defined?
  How does 2D relate to 3D?
  Are other measures (e.g. dendrograms, wavelets) safer?
  - Further study of p-p-p to p-p-v (e.g. Ballesteros-Paredes et al., Rowan Smith et al., Ostriker et al.)
- Angular momentum (define metrics)
- B- Field structure (HARD to simulate polarization correctly.)
- Cloudshine (could be a big winner, very high-resolution)
- The future: analyses of time and temperature **variation**
- ...and I will, if you like, reveal deep dark secrets of observers (e.g. about chopping, interferometry, etc.)

Emissivity-T Correlations Can Be Fake



Shetty et al. 2008

Fig. 4.— Fit β and T to noisy fluxes from 10 K (triangles) and 20 K (squares) isothermal sources. Different wavelengths fluxes were considered in each fit: 100-600 μm (blue), 500-1000 μm (green), and 1000-1500 μm (red). Gaussian distributed noise is added to each flux, with $\sigma = 5\%$.

“CLUMPFINDing” Tasted

Rowan, Bonnell & Smith 2007

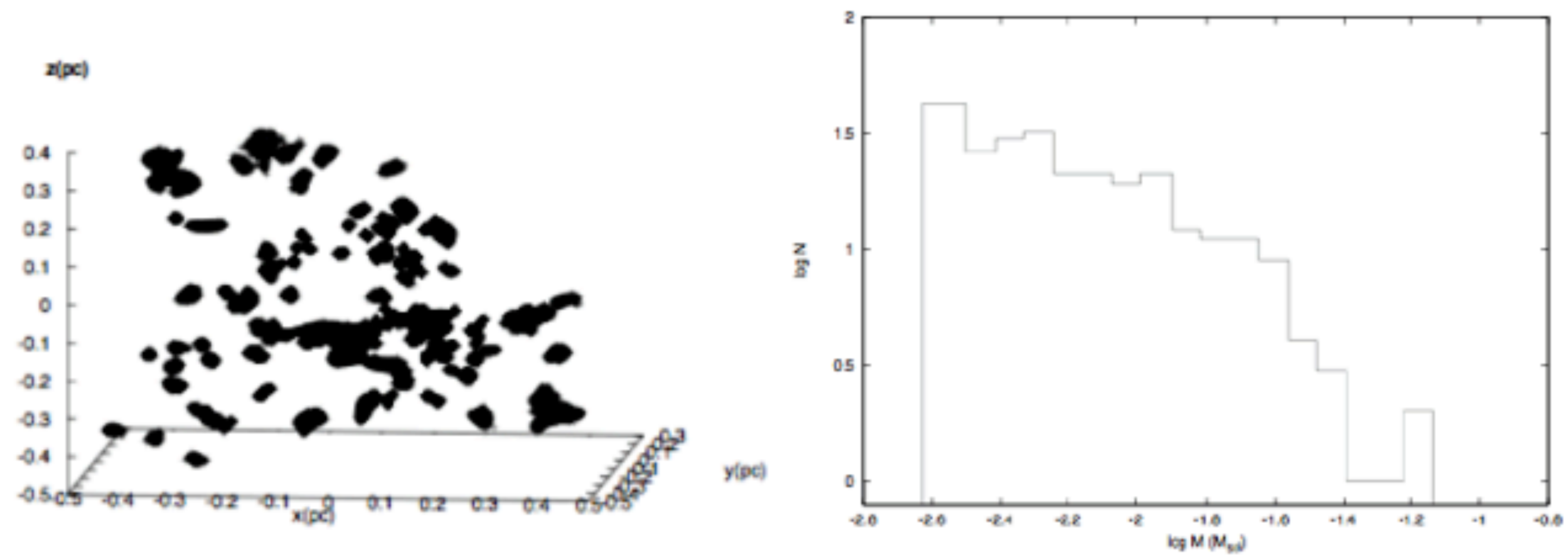


Figure 3: The positions of dense clumps found in the 3D clumpfind & the resulting Clump Mass Function.

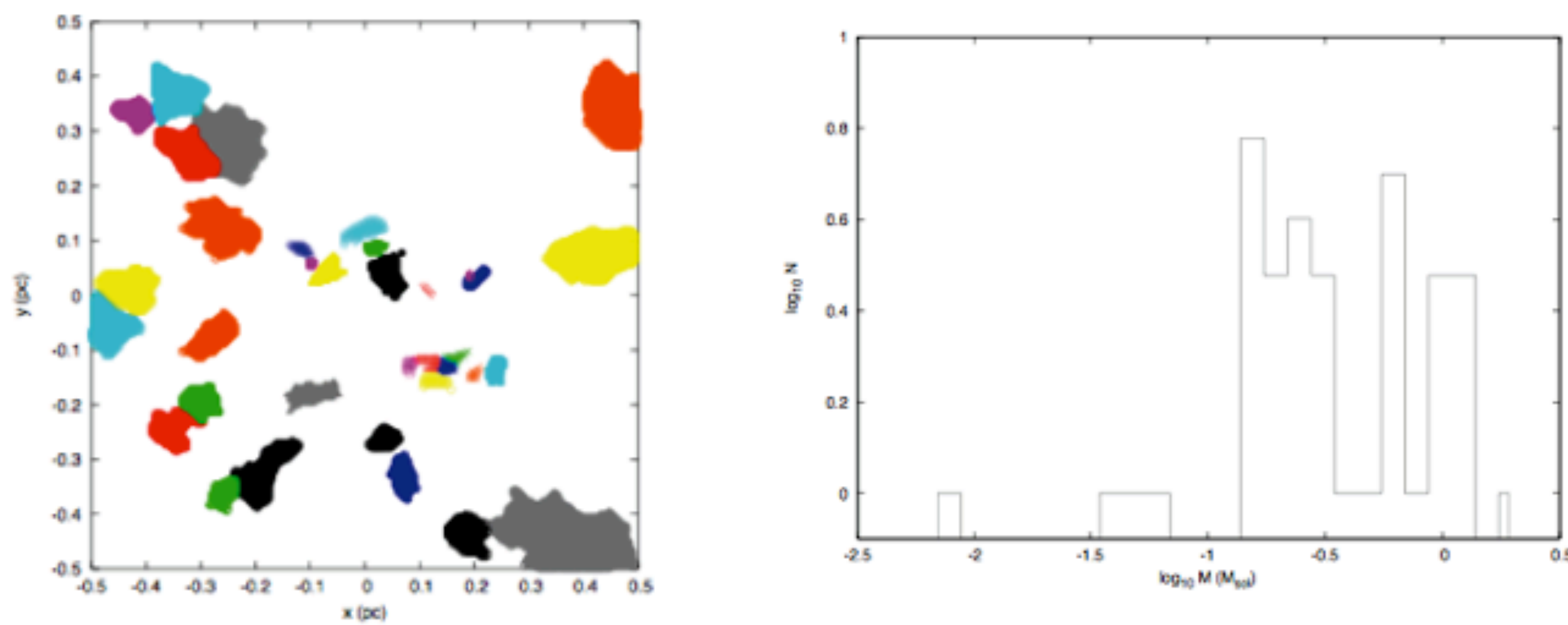


Figure 4: The position of clumps found in the 2D clumpfind (individual clumps are shown in different colours) & the resulting Clump Mass Function.

A Dark Secret of Observer's Kitchens:

WYSI(N)WYG

What you see is NOT what you get

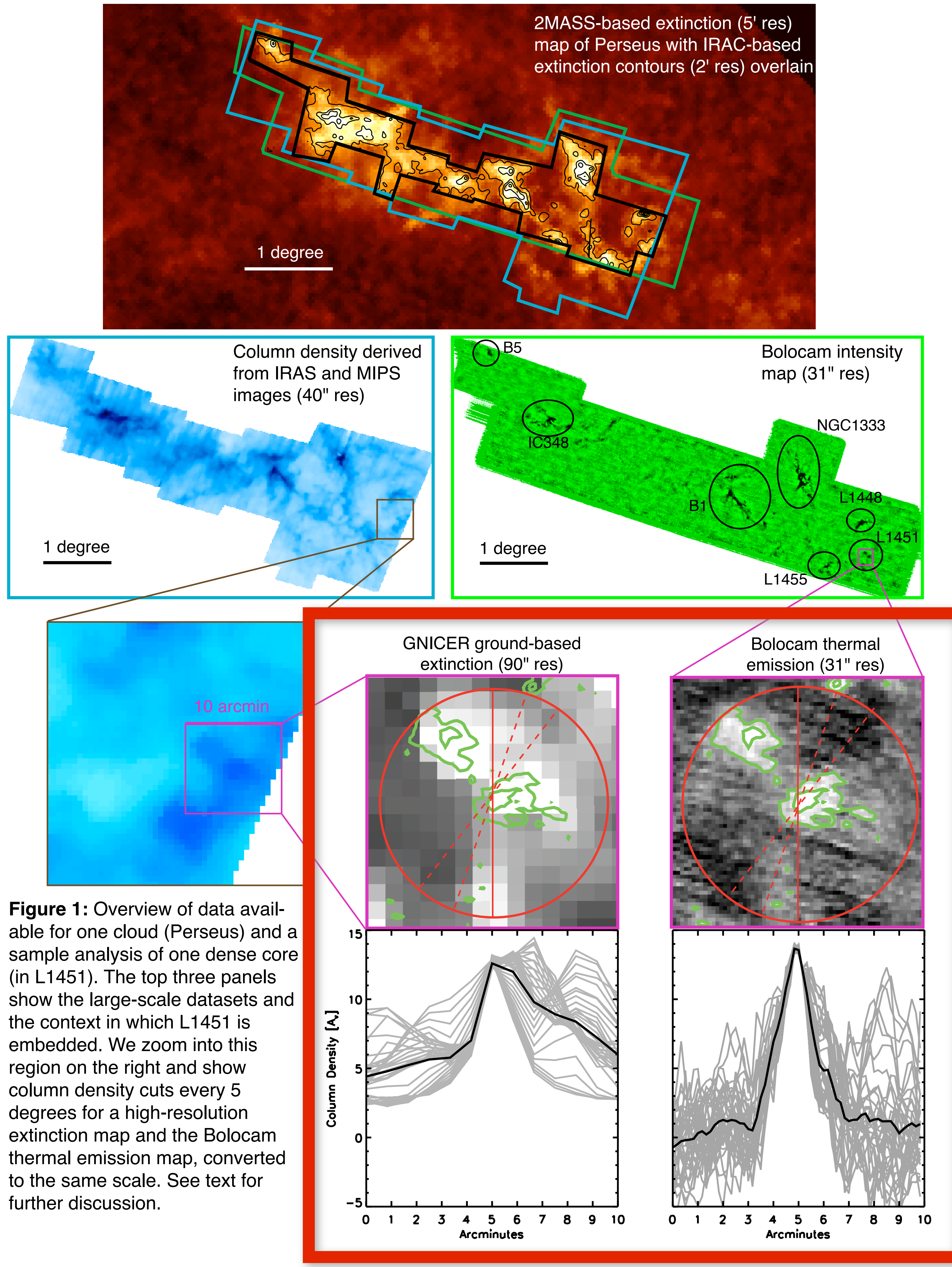
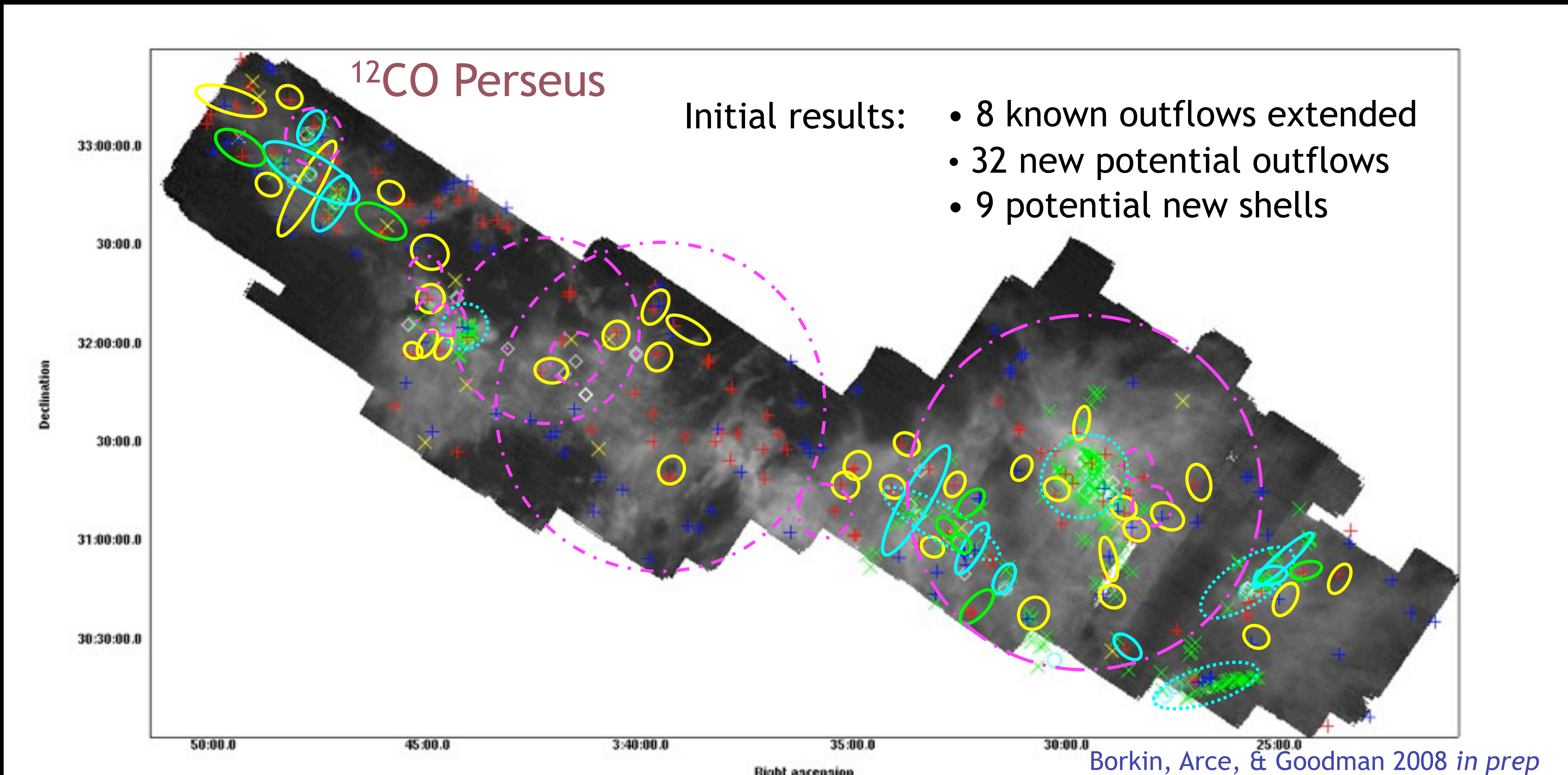


Figure 1: Overview of data available for one cloud (Perseus) and a sample analysis of one dense core (in L1451). The top three panels show the large-scale datasets and the context in which L1451 is embedded. We zoom into this region on the right and show column density cuts every 5 degrees for a high-resolution extinction map and the Bolocam thermal emission map, converted to the same scale. See text for further discussion.

A Challenge for the Next Round of Cooking

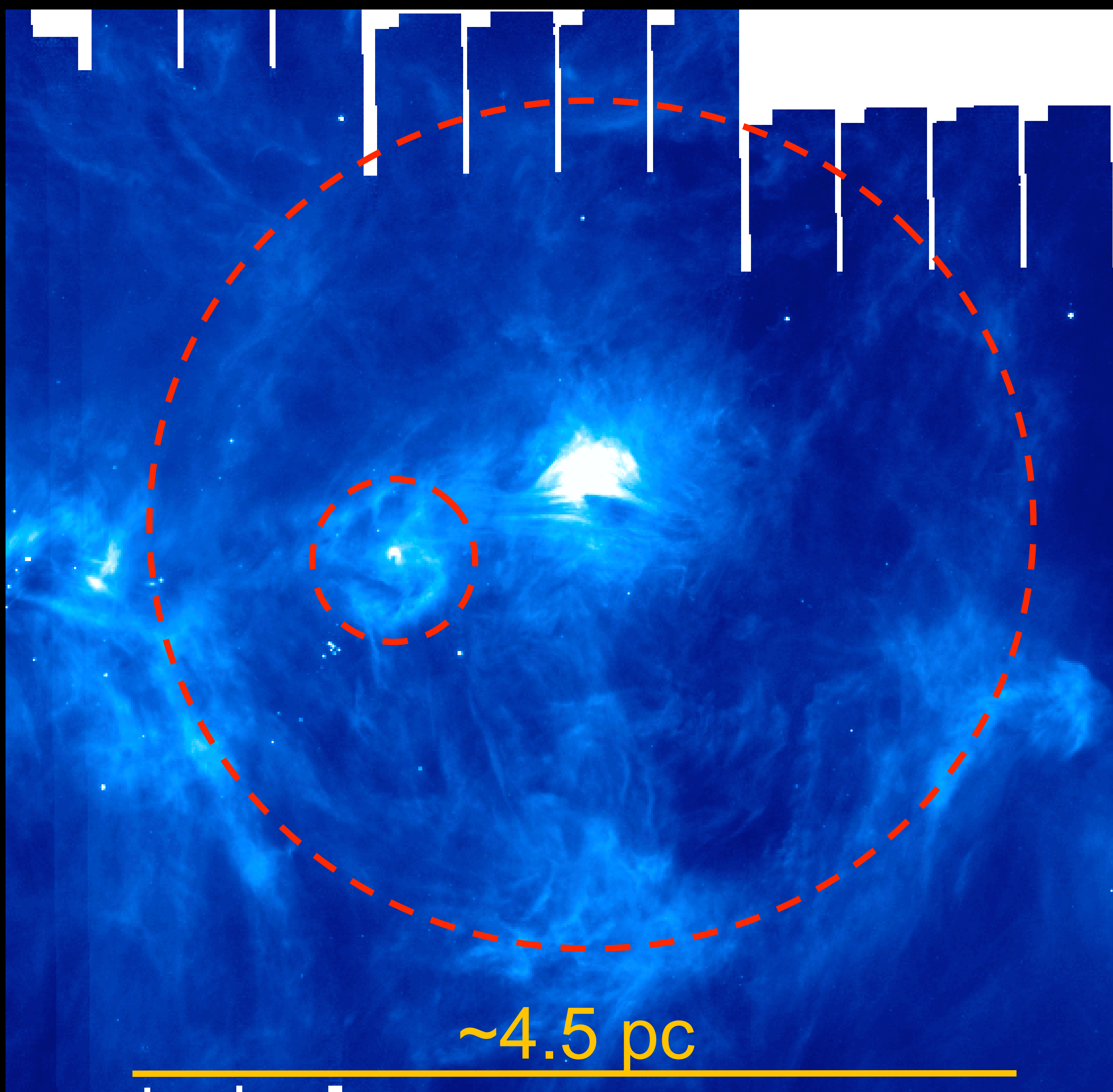
Perseus Outflows

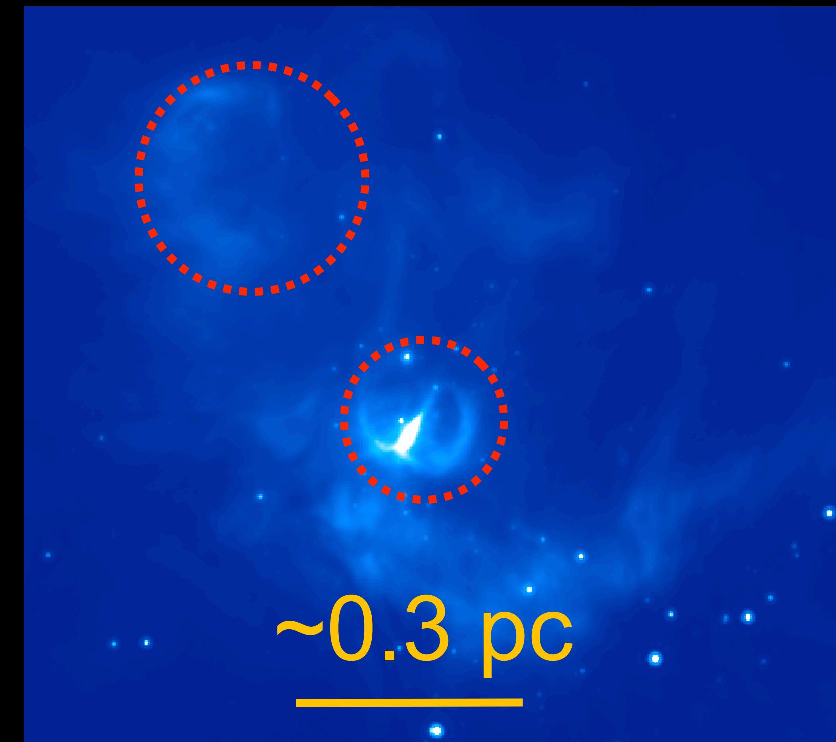


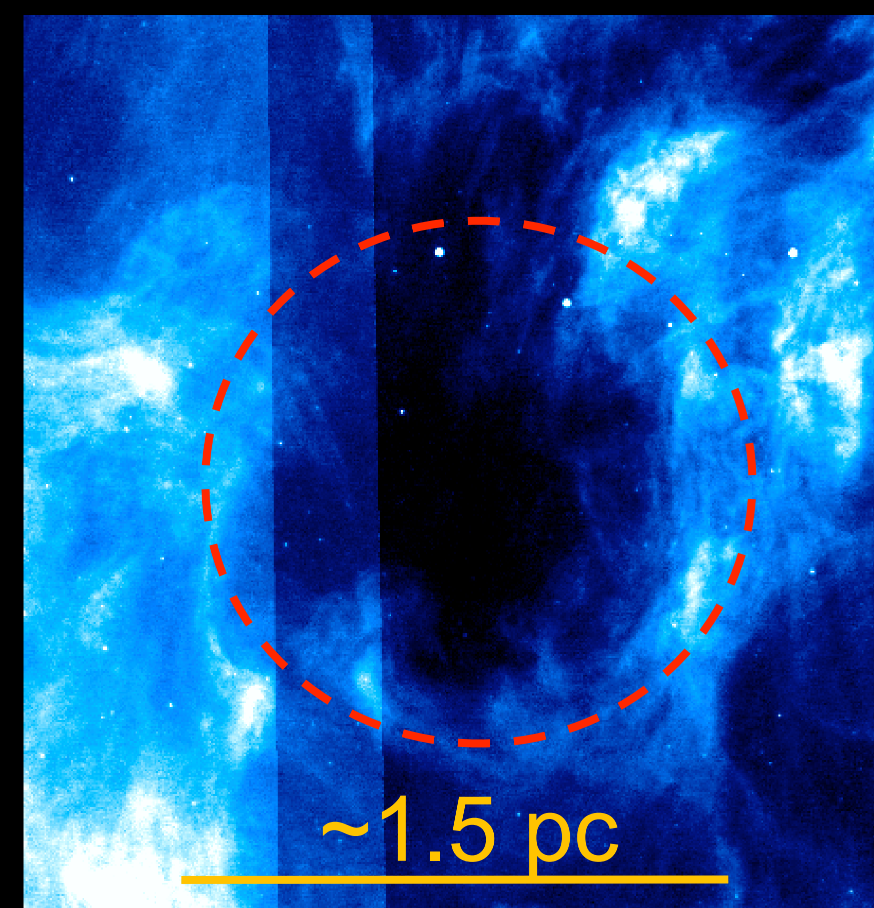
- Red Shifted points
- Blue Shifted points
- HH Objects
- New outflows
- Known outflows
- Many small known outflows
- Outflow extensions
- IRAS Sources
- Known Outflow Sources
- New shells

Spitzer (MIPS) View

c2d MIPS (24μm) maps of Perseus
Rebull et al. 2007







Preliminary Numbers say Shells are Much MORE Important than Outflows

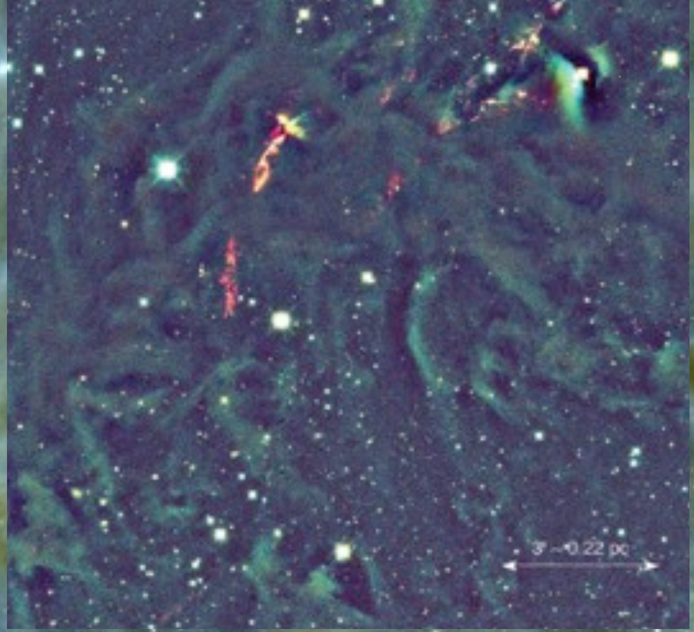
Table 2. Perseus Cloud Properties

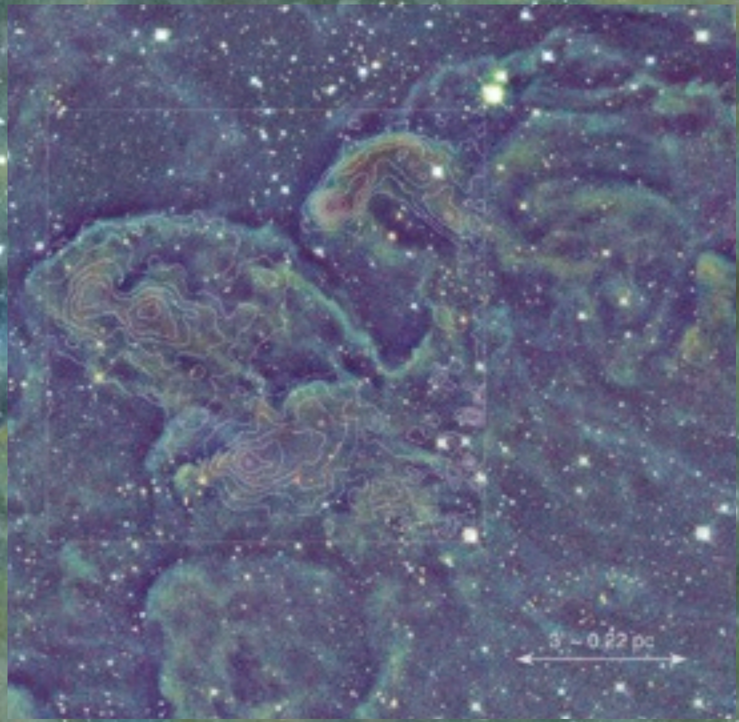
	Mass ($M_\odot$)	Momentum ($M_\odot$ km s^{-1})	Kinetic Energy (10^{42} ergs)
Perseus (Global)	11,050	...	...
All Shells	608	908.24	31,713.43
All Outflows	34.33	79.83	2,373.32
Outflows (New)	17.58	33.44	708.97
Outflows (Known)	14.99	42.24	1,535.98
Outflows (New Extensions)	1.76	4.15	128.37

Note. — Thus outflows comprise 0.31% of the total mass in Perseus, shells comprise 5.5% of the total mass in Perseus, and shells are injecting ~11 times the momentum and ~13 times the energy that outflows are injecting into the cloud.

Borkin, Arce, & Goodman 2008 *in prep*

Cloudshine:
(Problem for JWST)
Opportunity for Fine Dining...





Background: Jonathan Foster, CfA/COMPLETE Deep Megacam Image of West End of Perseus
Insets: Foster & Goodman 2006, Calar Alto JHK

“Cloudshine”=Scattered Ambient Starlight

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2006

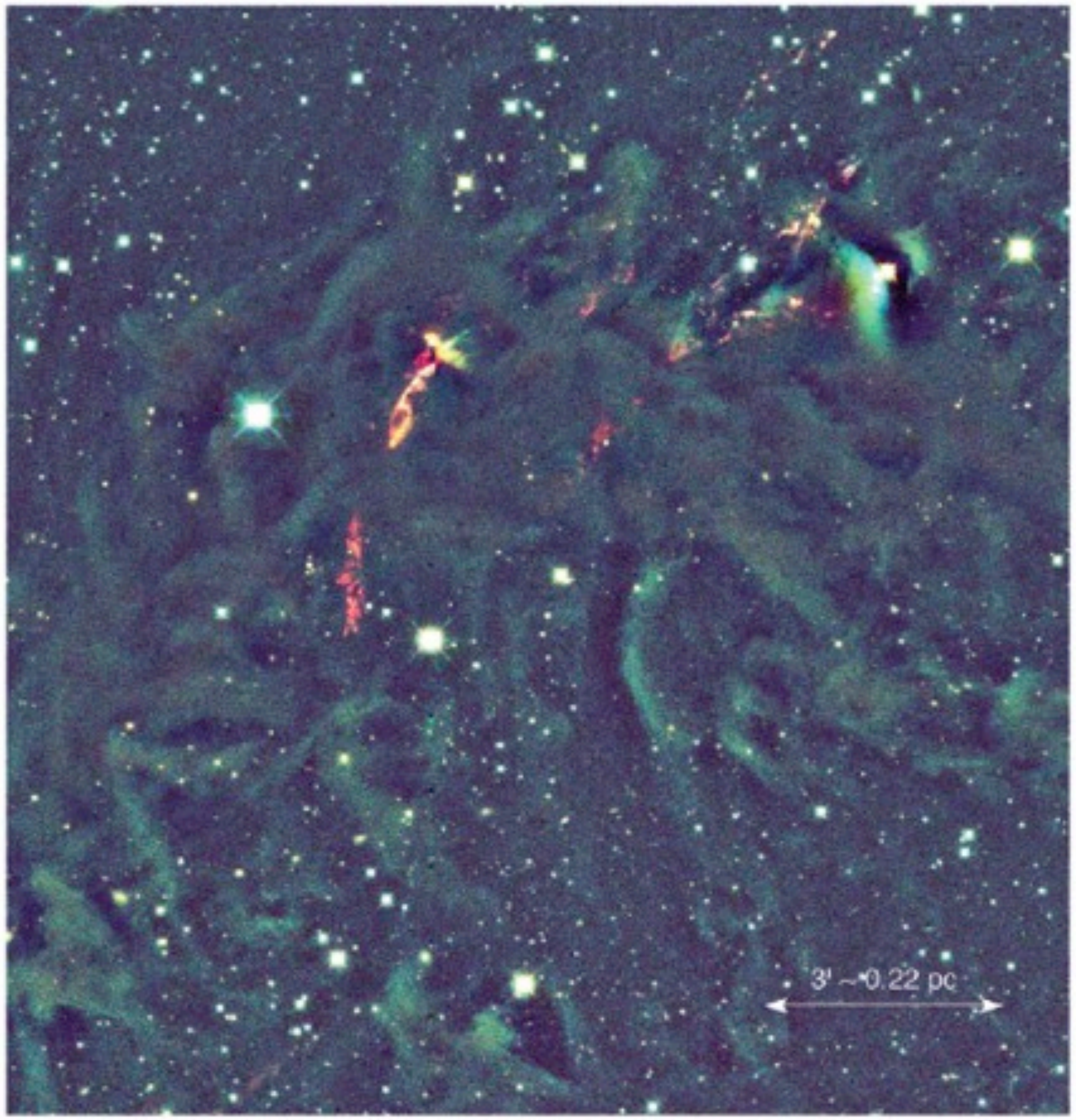


FIG. 1.—L1448 in false color. Component images have been weighted according to their flux in units of MJy sr^{-1}. J is blue, H is green, and K_s is red. Outflows from young stars glow red, while a small fan-shaped reflection nebula in the upper right is blue-green. Cloudshine, in contrast, is shown here as a muted glow with green edges. Dark features around extended bright objects (such as the reflection nebula) are the result of self-sky subtraction.

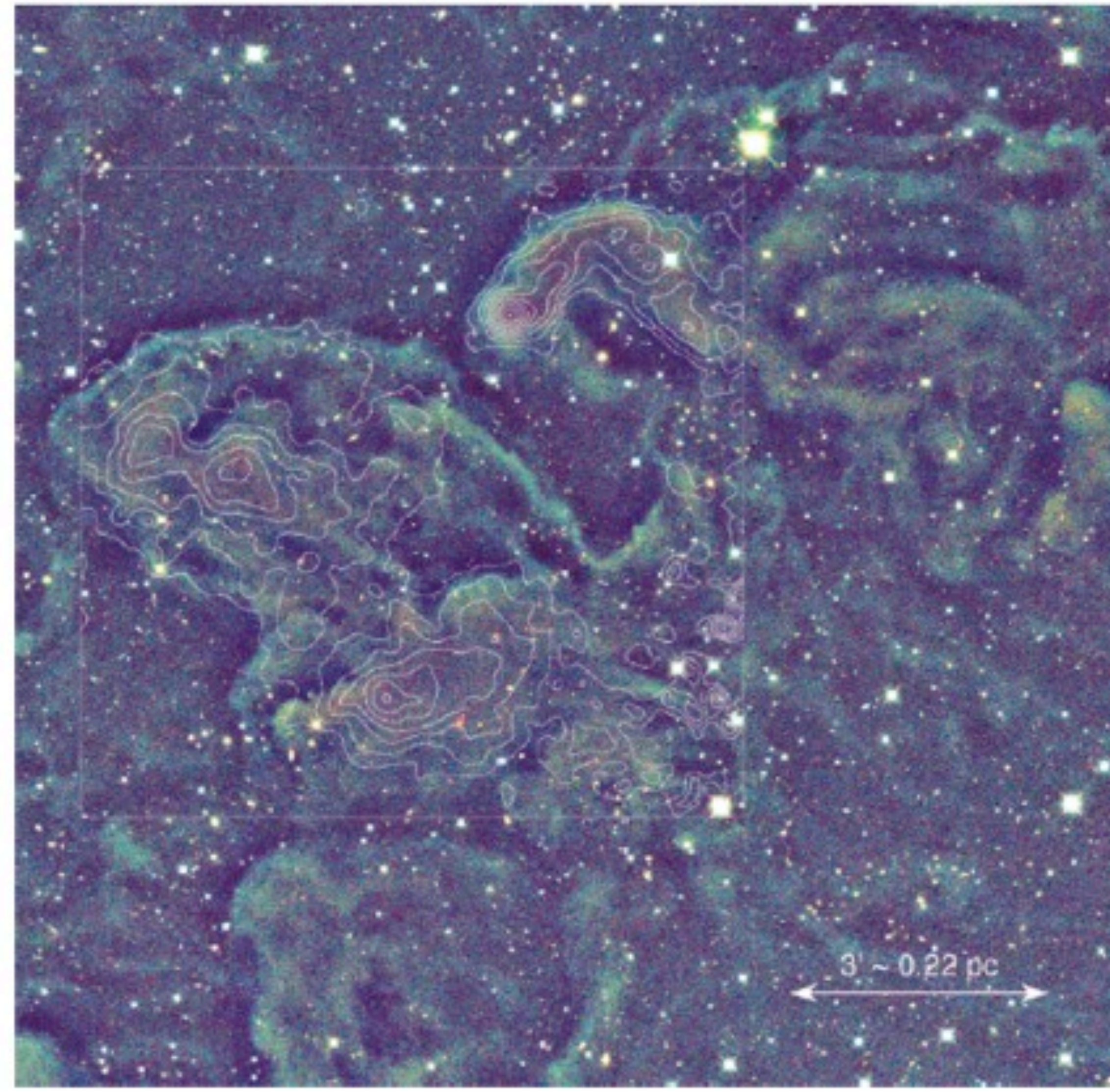
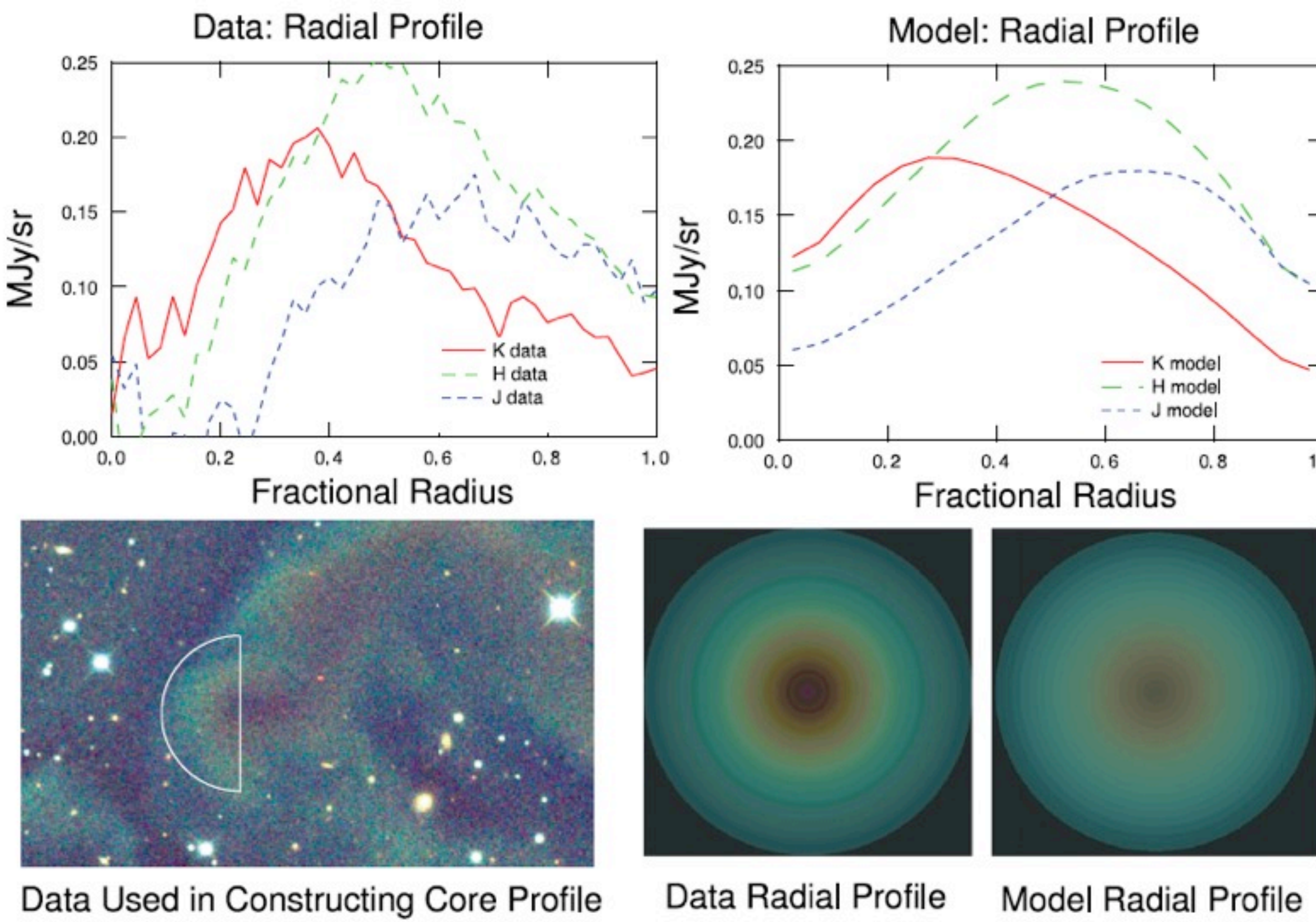


FIG. 2.—L1451 in false color. Again, each component image has been scaled to the same flux scale in units of MJy sr^{-1}; and J is blue, H is green, and K_s is red. A smaller map of 1.2 mm dust emission contours from COMPLETE (M. Tafalla 2006, in preparation) has been overlaid, showing that the color of cloudshine is a tracer of density. Redder regions have high dust continuum flux, and the edges of cloudshine match the edges of the dust emission. Dark edges around bright features (particularly noticeable along the northern edges) are the result of self-sky subtraction.

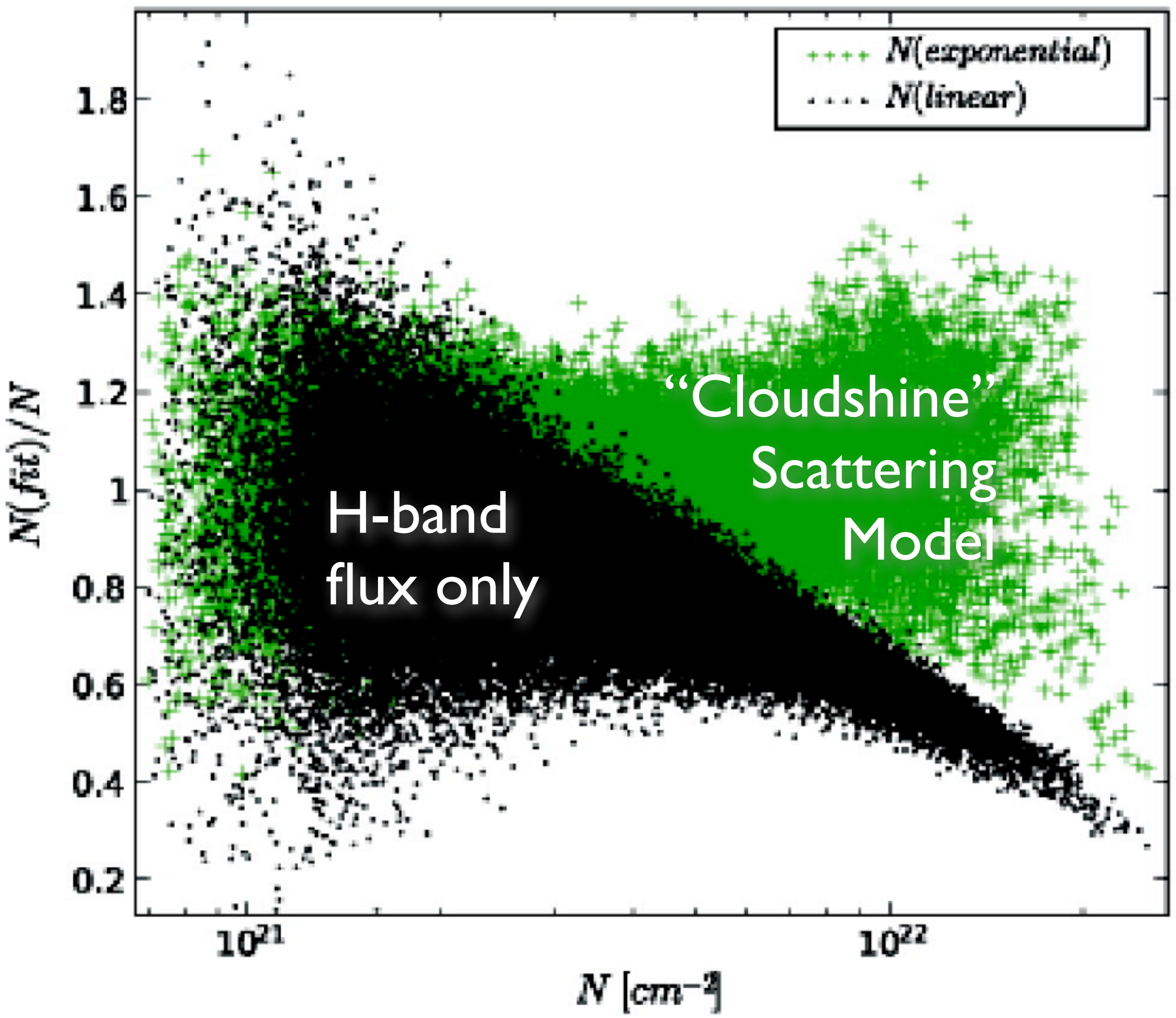
“Tasting” a Very Simple Recipe



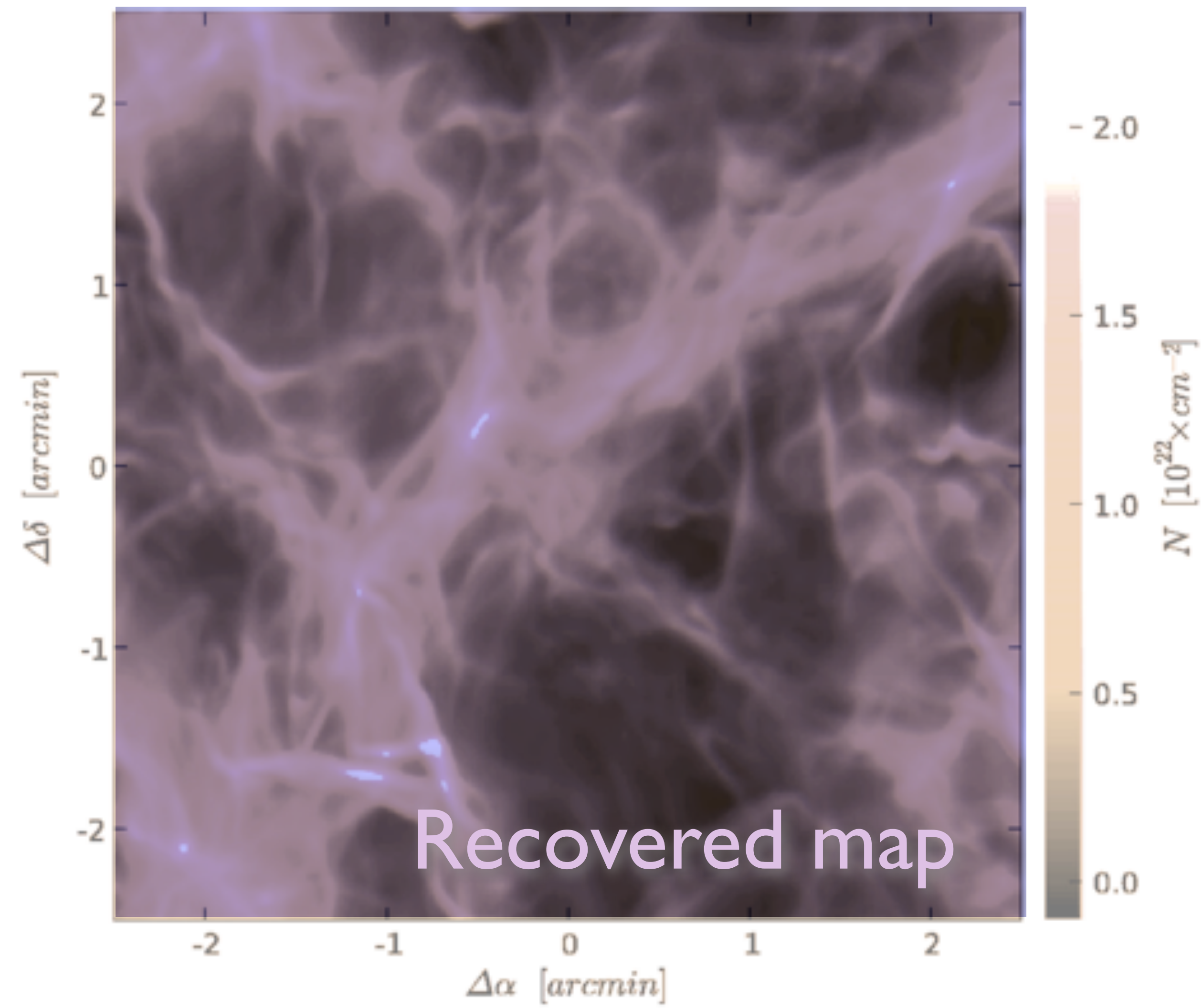
Foster & Goodman 2006

FIG. 3.—Model of cloudshine in one core as reflected interstellar radiation. The lower left panel shows the roughly circular feature we chose to model as a sphere. Due to the surrounding structure, only the left half of the circle was used to derive an angle-averaged radial profile. The comparison between this radial profile and our best-fit model (an r^{-2} density profile and a total optical depth of 120 mag of visual extinction) is shown in two ways: above as radial flux profiles in individual bands and in the lower right as a synthetic color-composite image that allows for an overall comparison. Although the fit is good, the central region of the core is darker than predicted by the model. Some of this may be due to self-sky subtraction in the image (which causes dark edges around bright features) and a nonspherical, nonisotropically illuminated core, and some may be due to a failure to adequately model the density structure at the center of the core.

Theorists doing the Tasting!

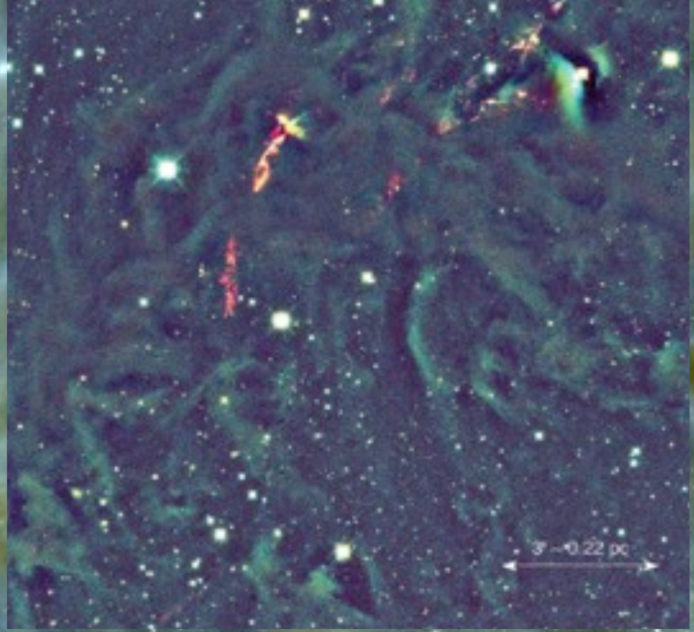


Simulation

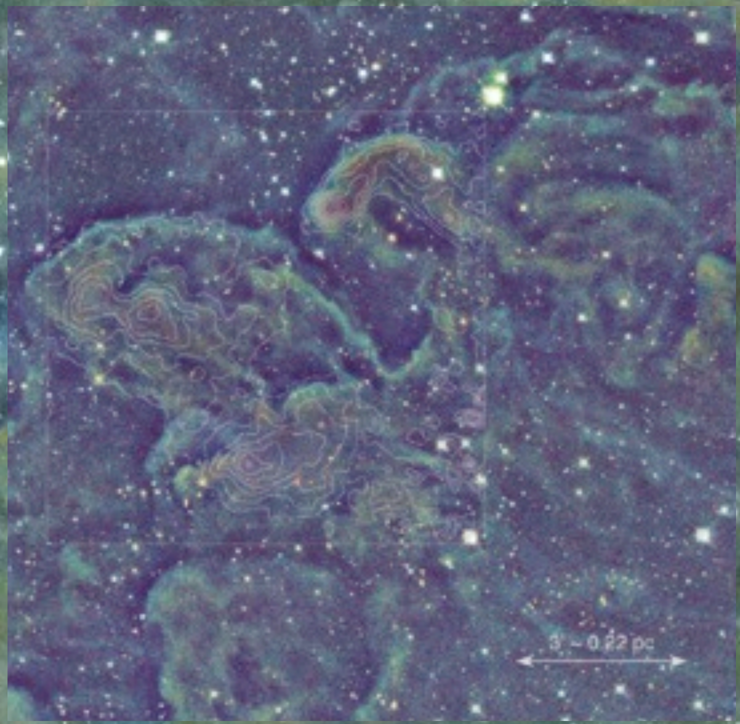


Tastes "right", with 20% scatter, at $1<A_V<10$, for NIR.

Padoan et al. 2006



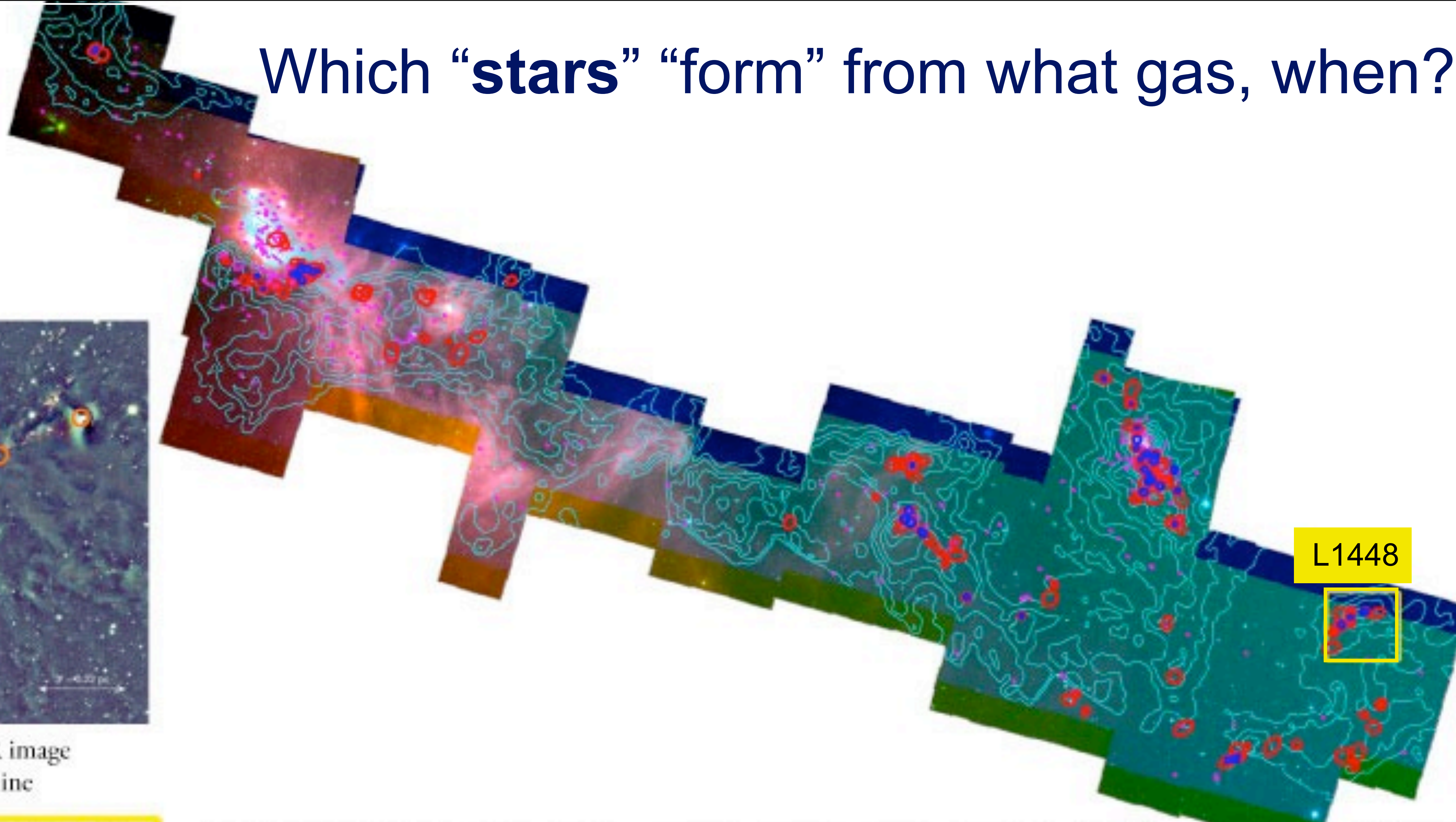
Cloudshine gives us a path to (much) higher-resolution column density maps

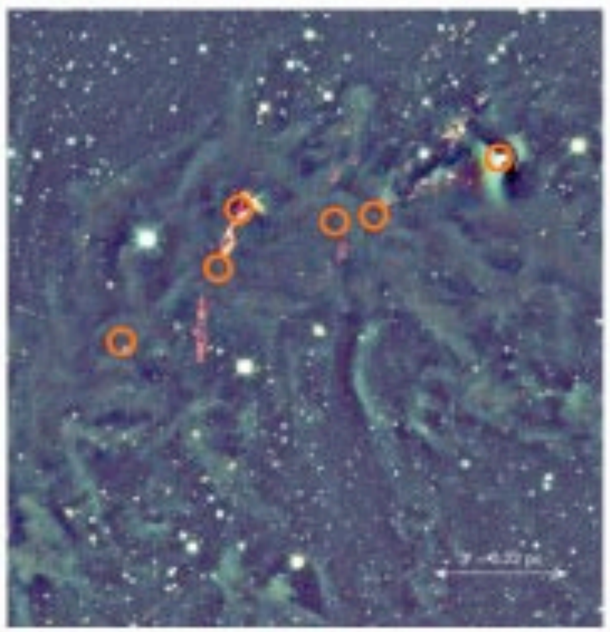


Background: Jonathan Foster, CfA/COMPLETE Deep Megacam Image of West End of Perseus
Insets: Foster & Goodman 2006, Calar Alto JHK

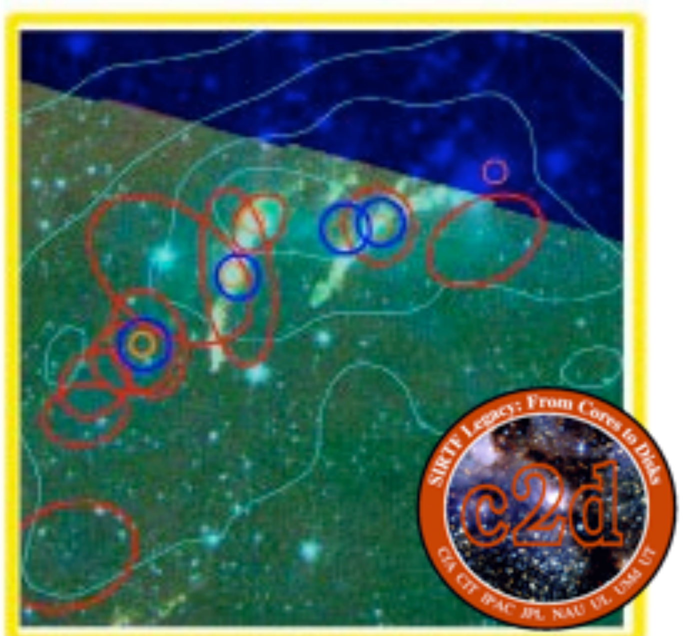
Which “**stars**” “form” from what gas, when?

Figure Credit: Jonathan Foster

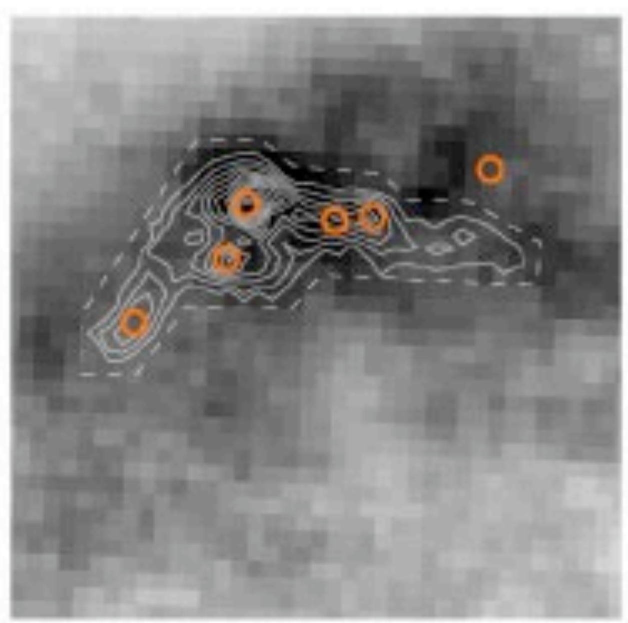




J,H,K Near-IR image of Cloudshine

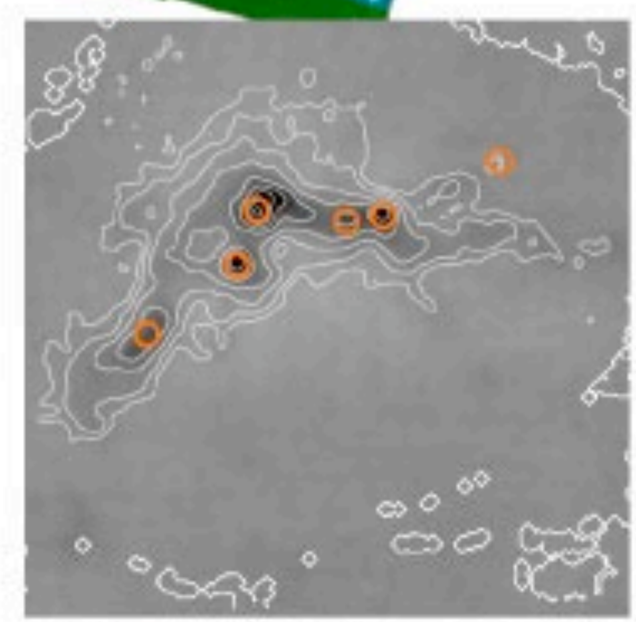


CO 850 micron and 1.1 mm clumps on a c2d IRAC 3-color image



MPL N_2H^+ on ^{13}CO integrated intensity

E Deep NIR Extinction on 2MASS Extinction



TE 1.2 mm (IRAM) on 850 micron (SCUBA) continuum

Topology of Stellar Distributions

e.g. Schmeja & Klessen 2006