("Seeing")
The Galactic ISM and Molecular Clouds

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

Carl* gave me this big title,
so...here's my piece of **"perspective"**...

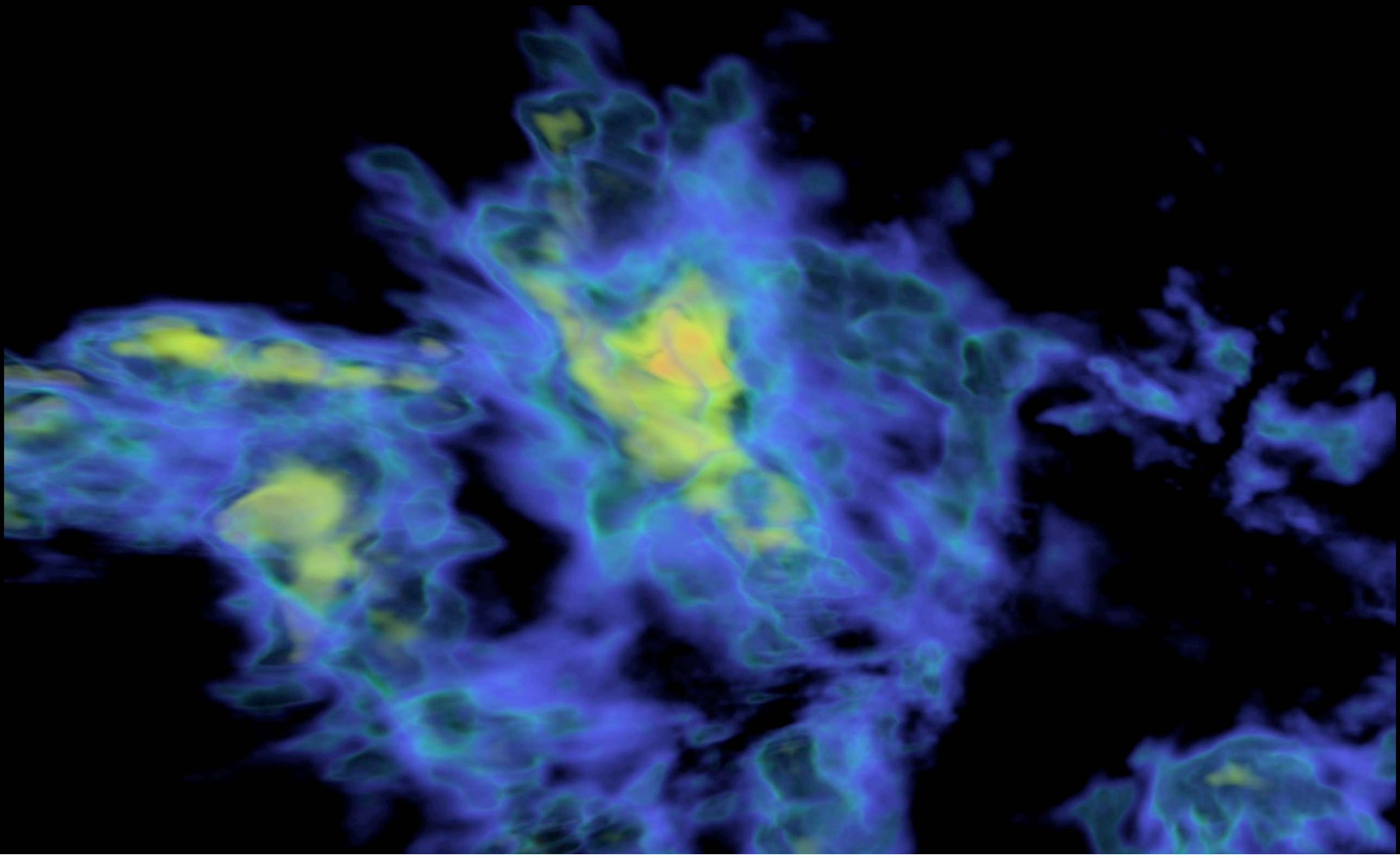
What's a **dendrogram**, and how does it help us understand **molecular clouds in the ISM** of our Galaxy and others?

Why is data **"seeing"** important in this field?

What does the future of image-intensive study of the ISM "look like"?
(**WWT** demo)

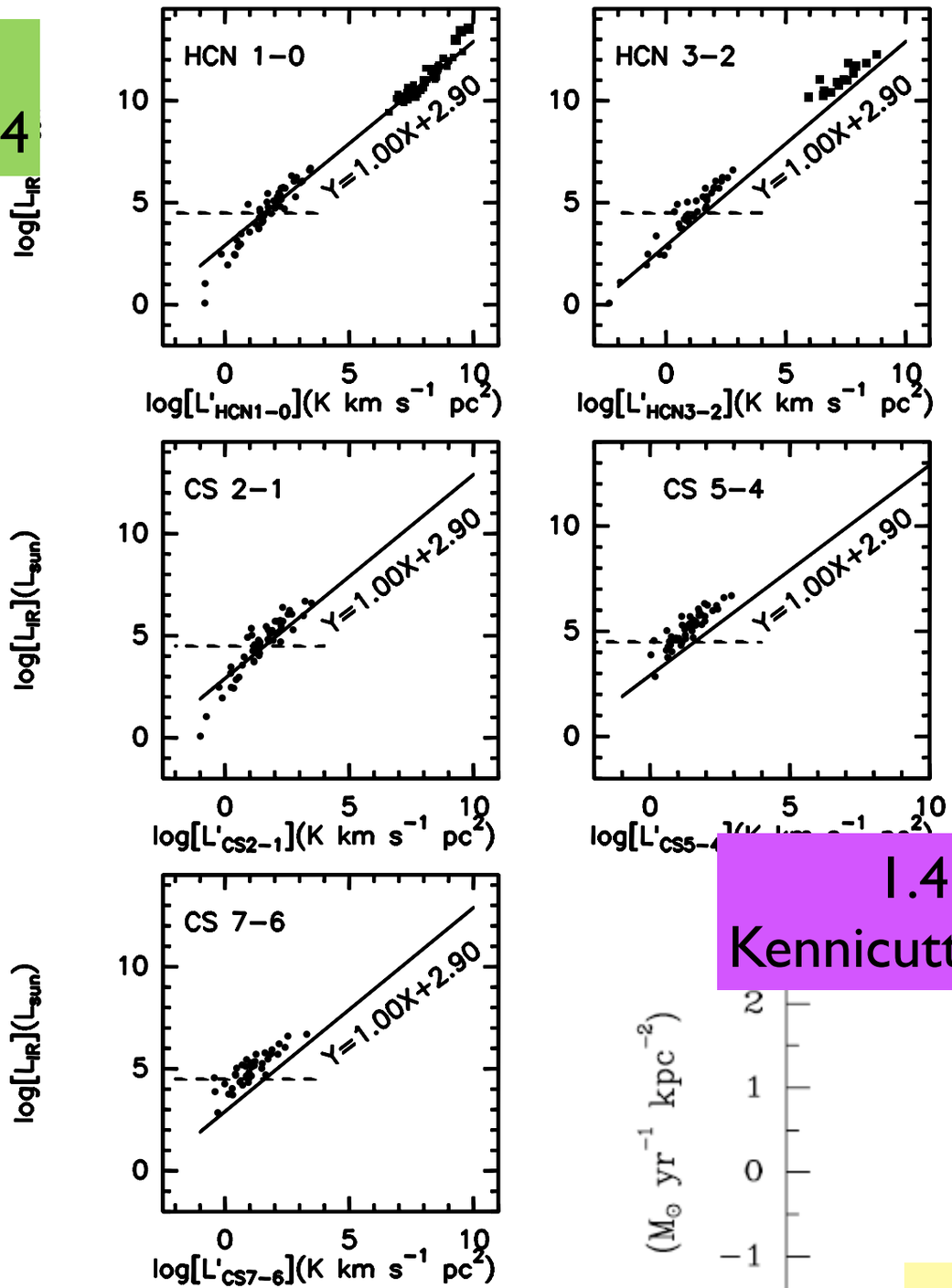
*MANY thanks to the RAL & Berkeley Astronomy!

“A Molecular Cloud in the Interstellar Medium”



Kennicutt-Schmidt Relations (including Milky Way Clouds)

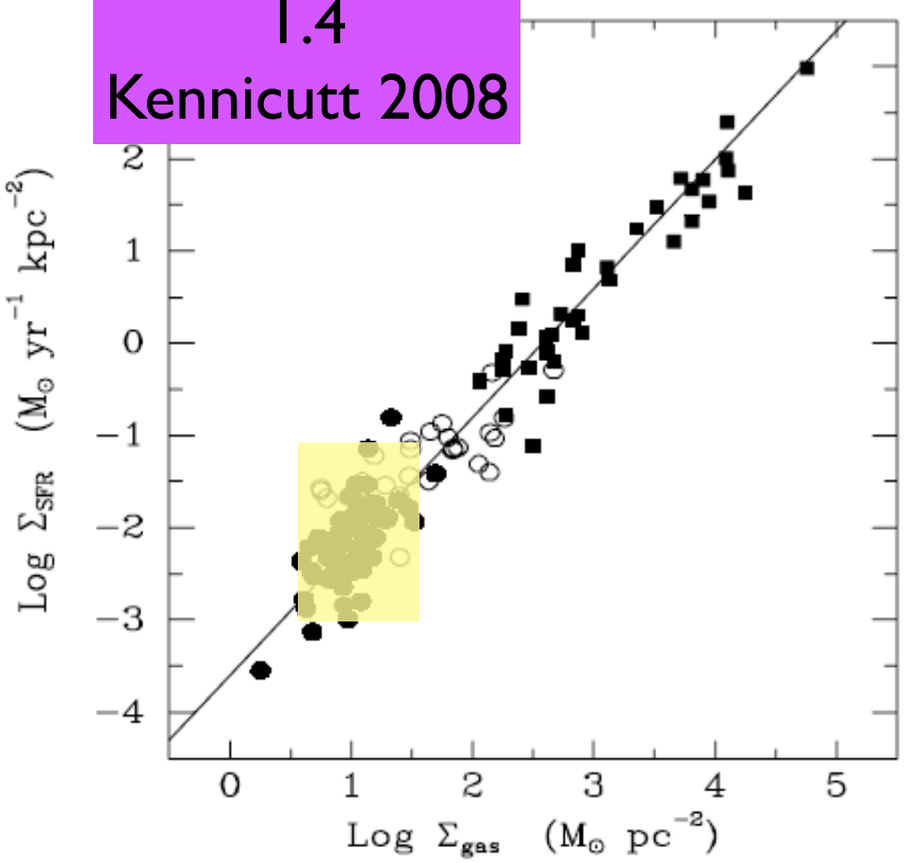
1.0
Gao & Solomon 2004



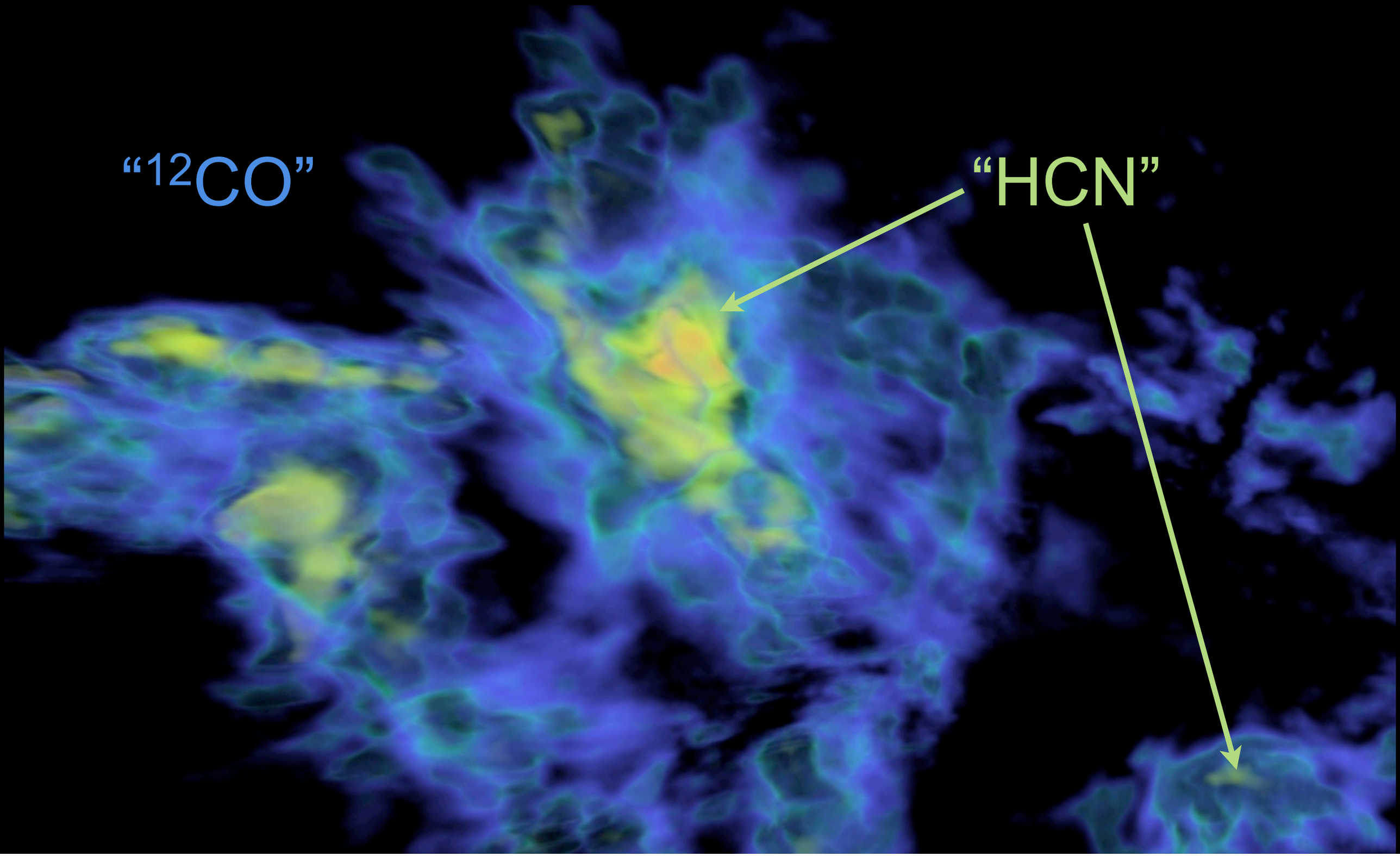
0.79±0.09
Bussmann et al. 2008

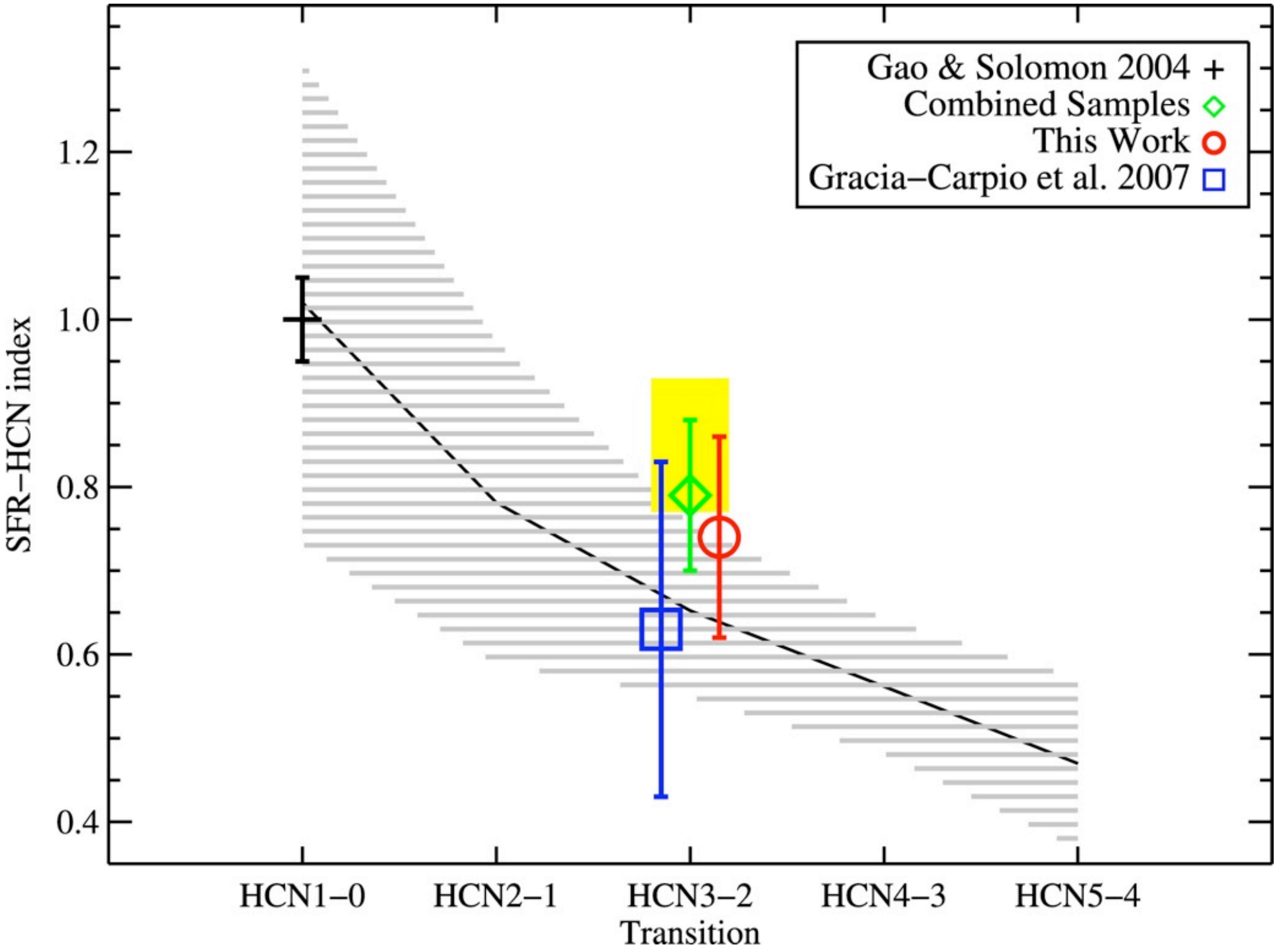
Wu et al. 2008

1.4
Kennicutt 2008



"A Molecular Cloud in the Interstellar Medium"





Bussmann et al. 2008; cf. Narayanan et al. 2008; Krumholz & Thompson 2007

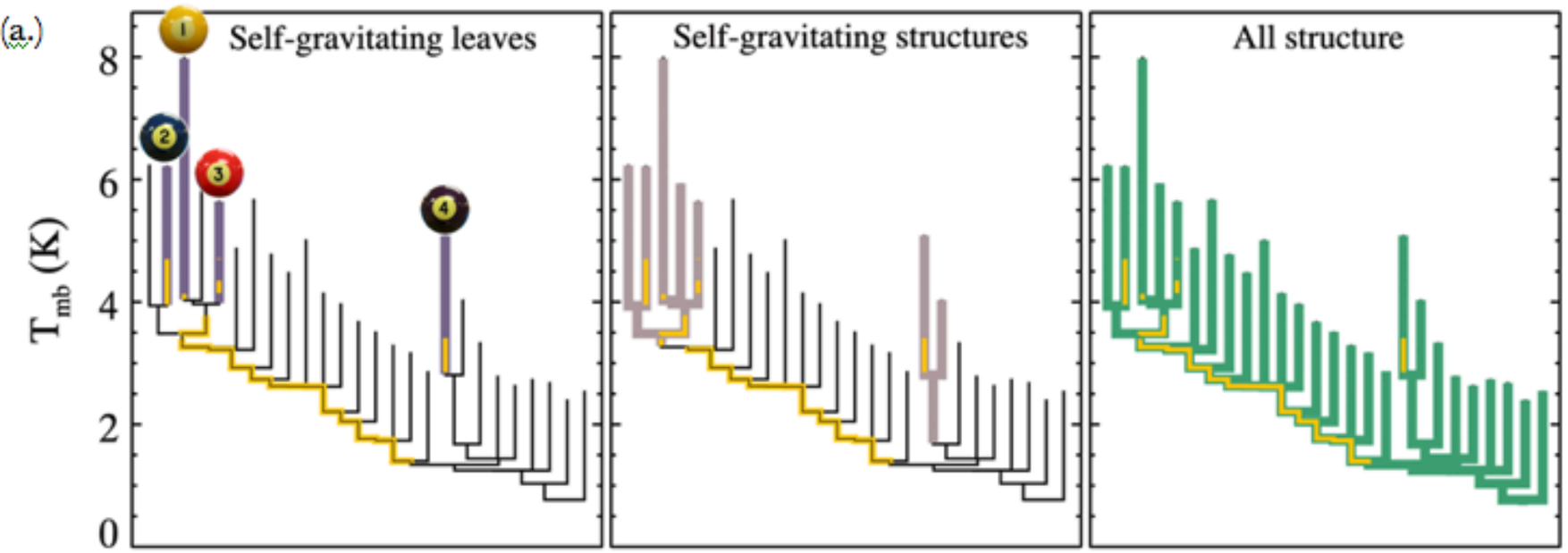
Krumholz & McKee's 2005 "K-S" Theory Assumes

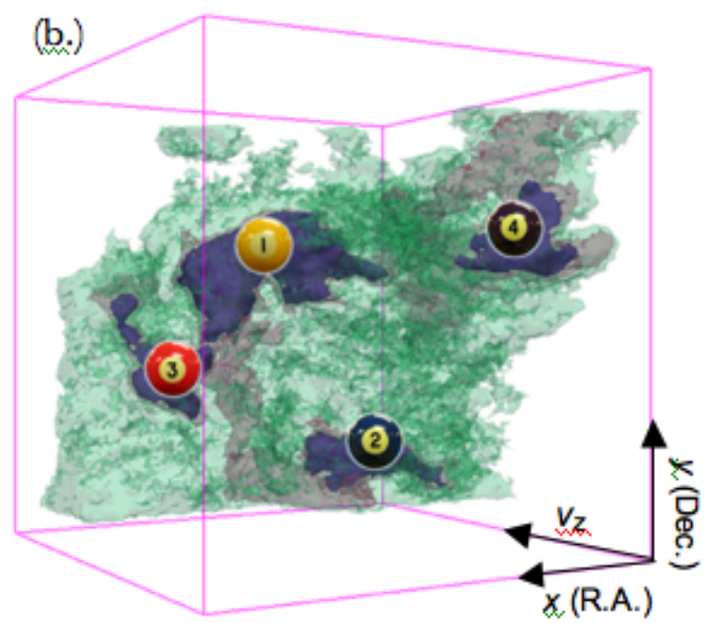
1. Star formation occurs in virialized molecular clouds that are supersonically turbulent; (Larson 1981)

2. the density distribution within these clouds is log-normal, as expected for supersonic isothermal turbulence; (Goodman et al. 2008) and

3. stars form in any subregion of a cloud that is so overdense that its gravitational potential energy exceeds the energy in turbulent motions (and now we can find those, see Rosolowsky et al. 2008; Goodman et al. 2008)

Value of Dendrograms



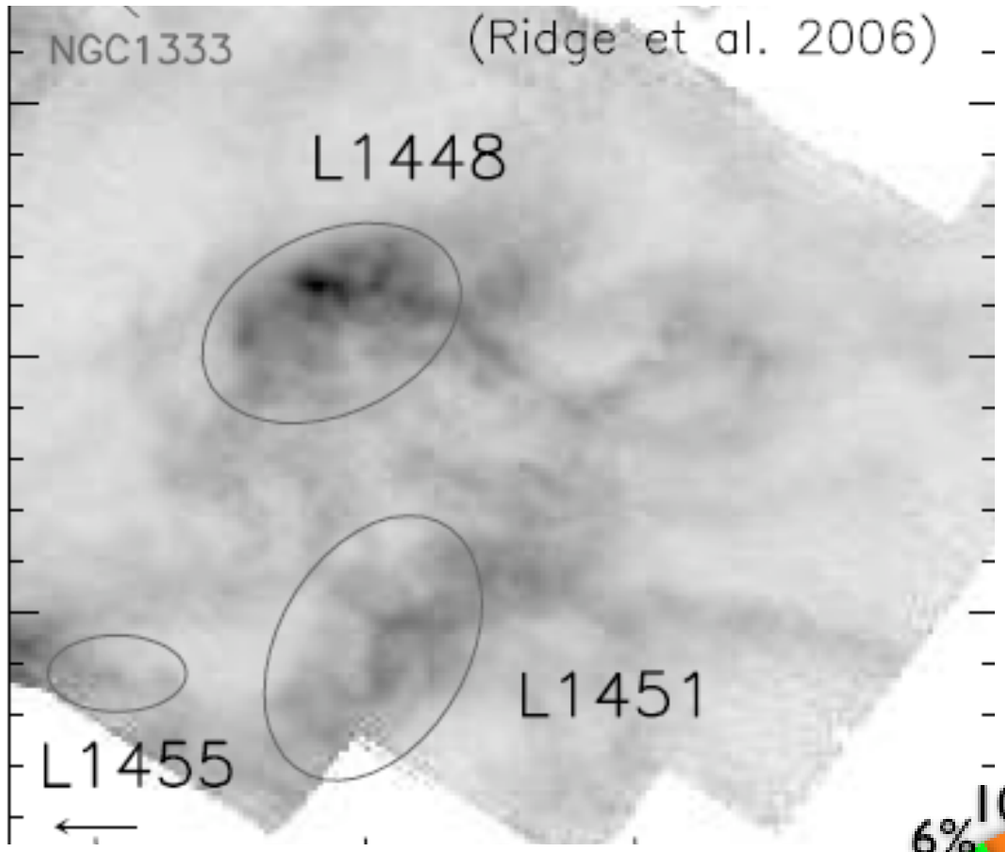


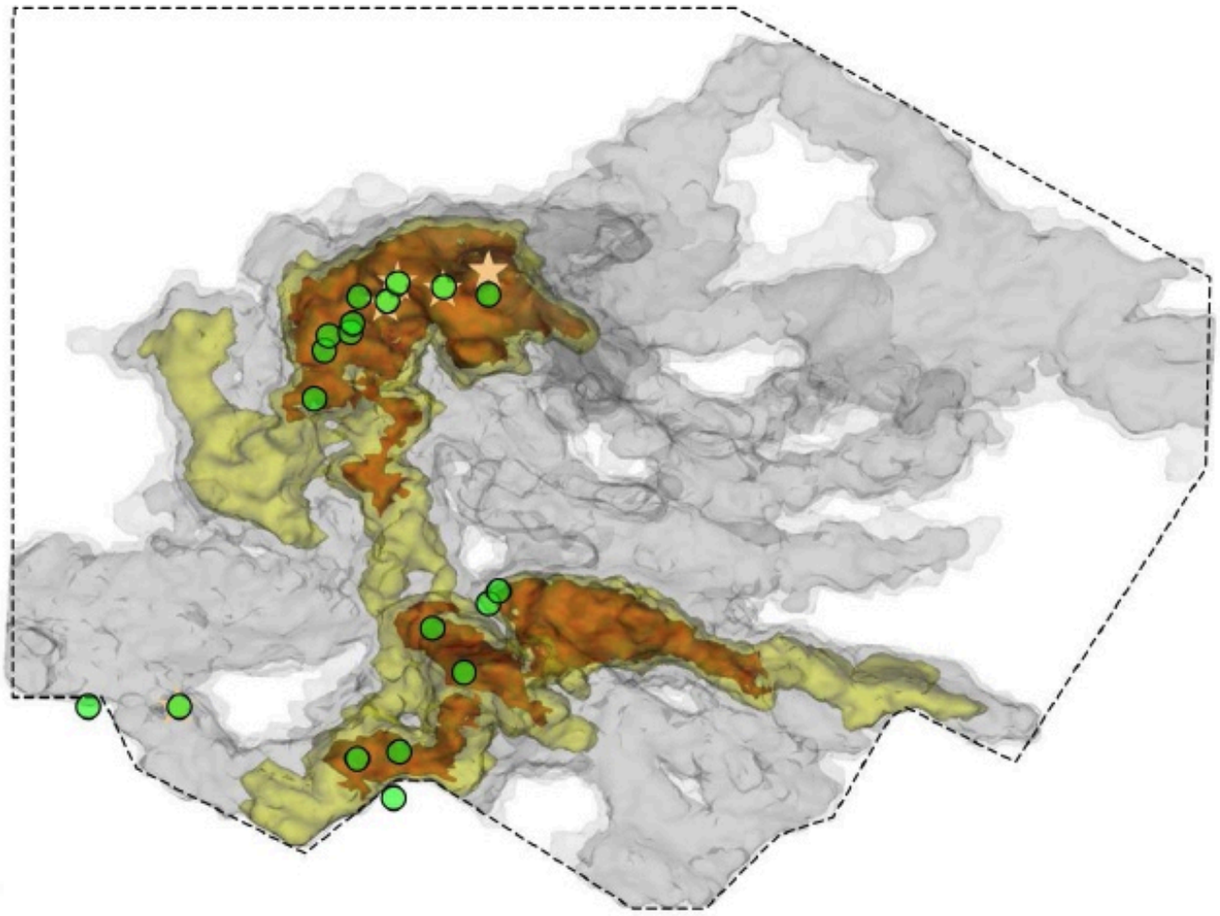
Yellow highlighting= "self-gravitating"

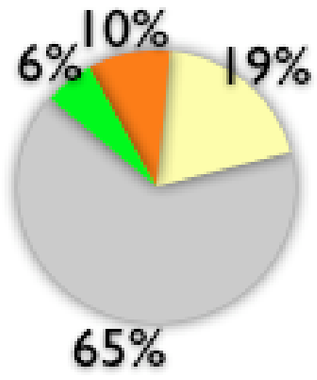
"Self-gravitating" here just means $\alpha_{\rm vir}\,(=5\mathrm{s}_v^2 R/GM_{\rm lum}) < 2$
(à la Bertoldi & McKee 1992)

Rosolowsky et al. 2008 (ApJ);
Goodman et al. 2009 (Nature, in press)

Dendrogram Decomposition of L1448: Finding the Truly "Star-Forming" Bits

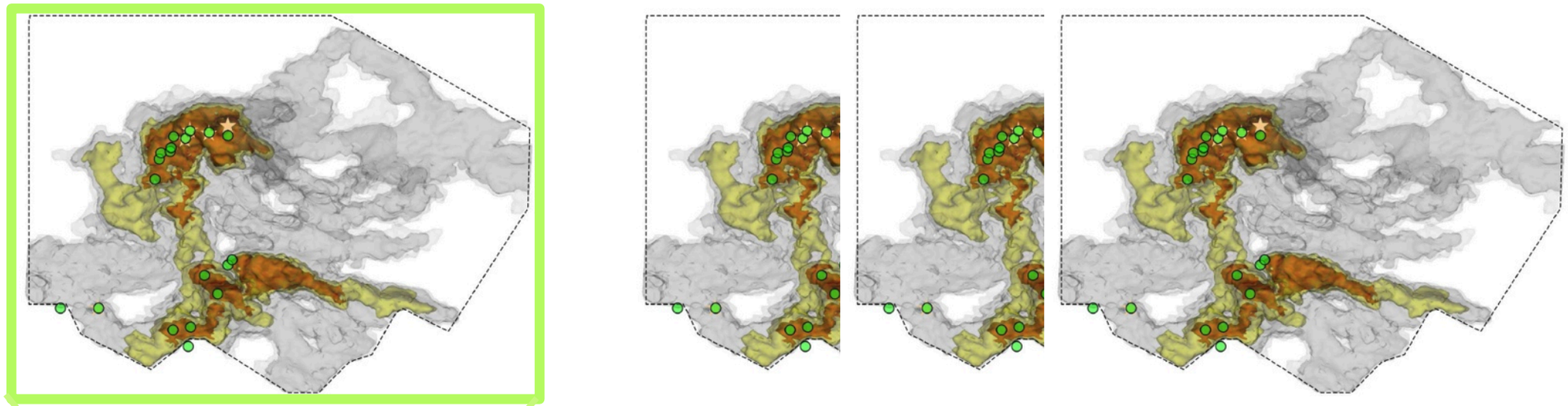




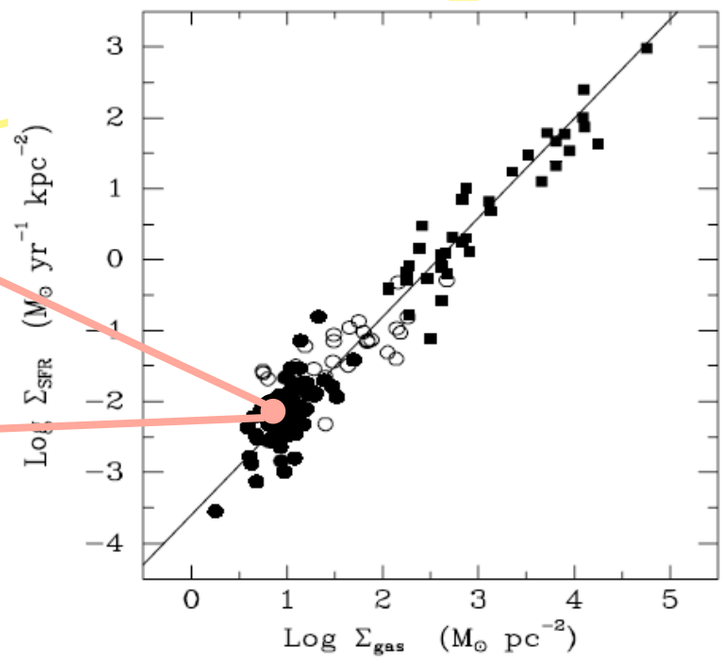


molecular cloud
self-gravitating cloud
filamentary network
dense core environments
dense cores
embedded YSOs

J. Kauffmann et al. 2008



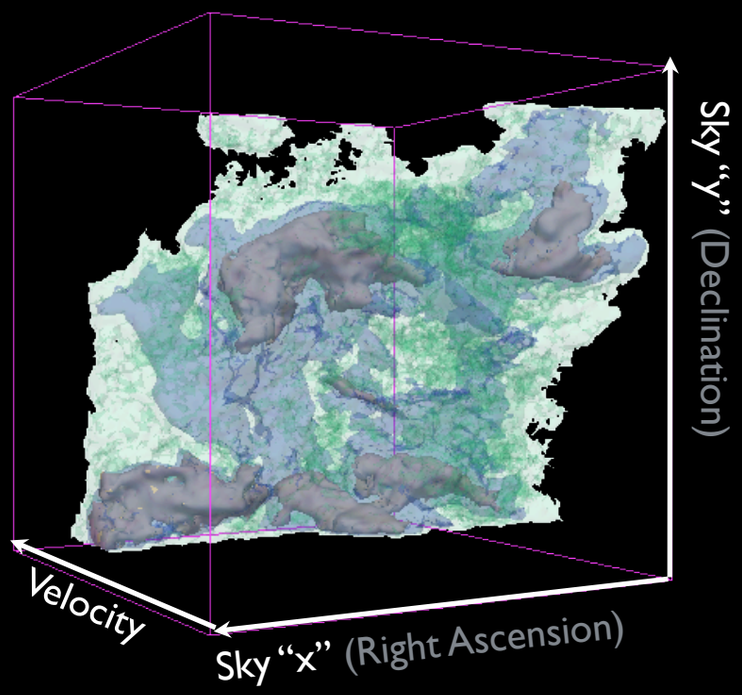
What we (think) we can do with that...



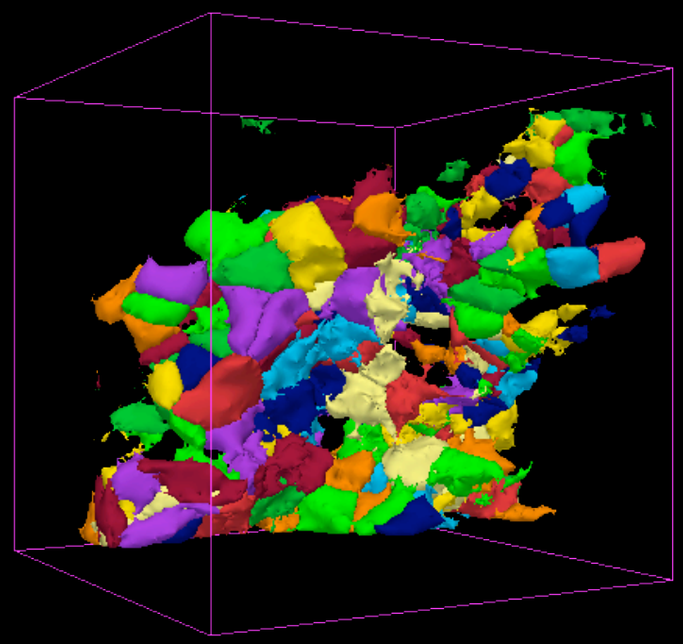
We=Goodman & Rosolowsky (w/Narayanan, Cox, C. Lada, Alves, Shetty, Wu)

"Seeing" L1448

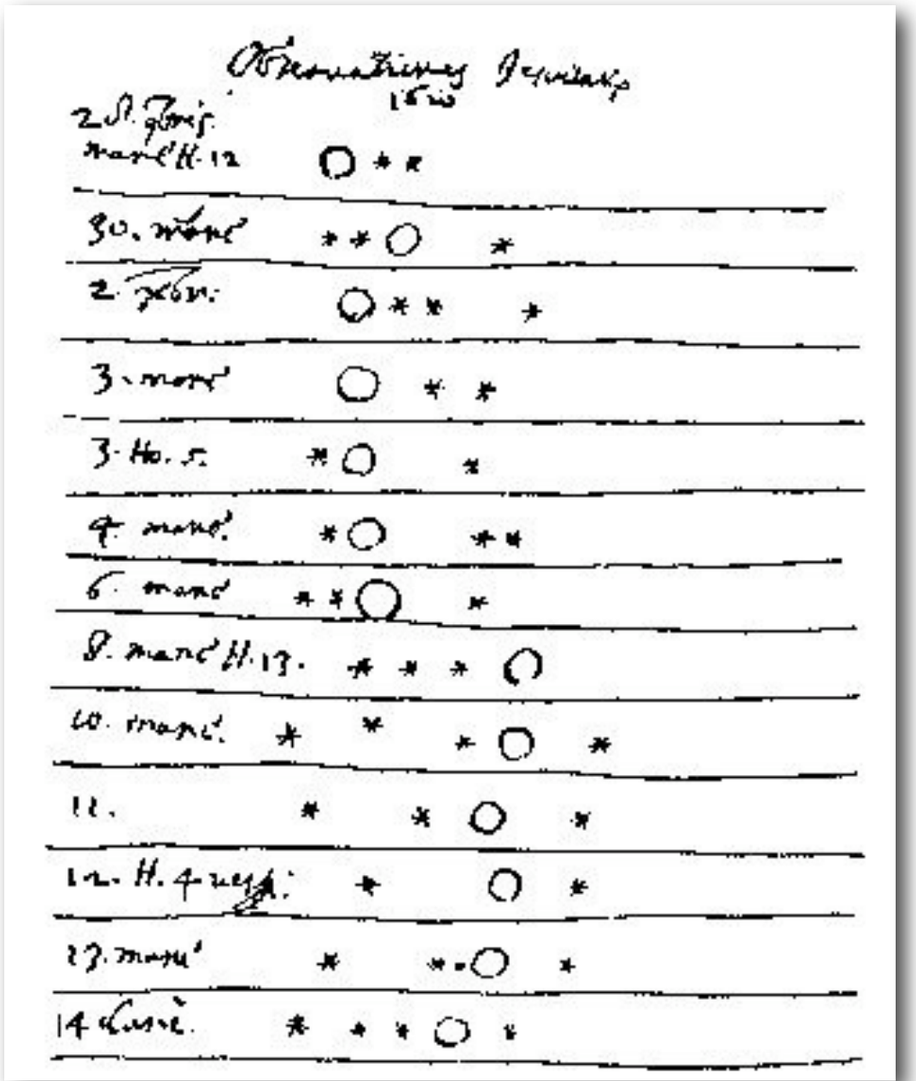
(Dendro)Surfaces

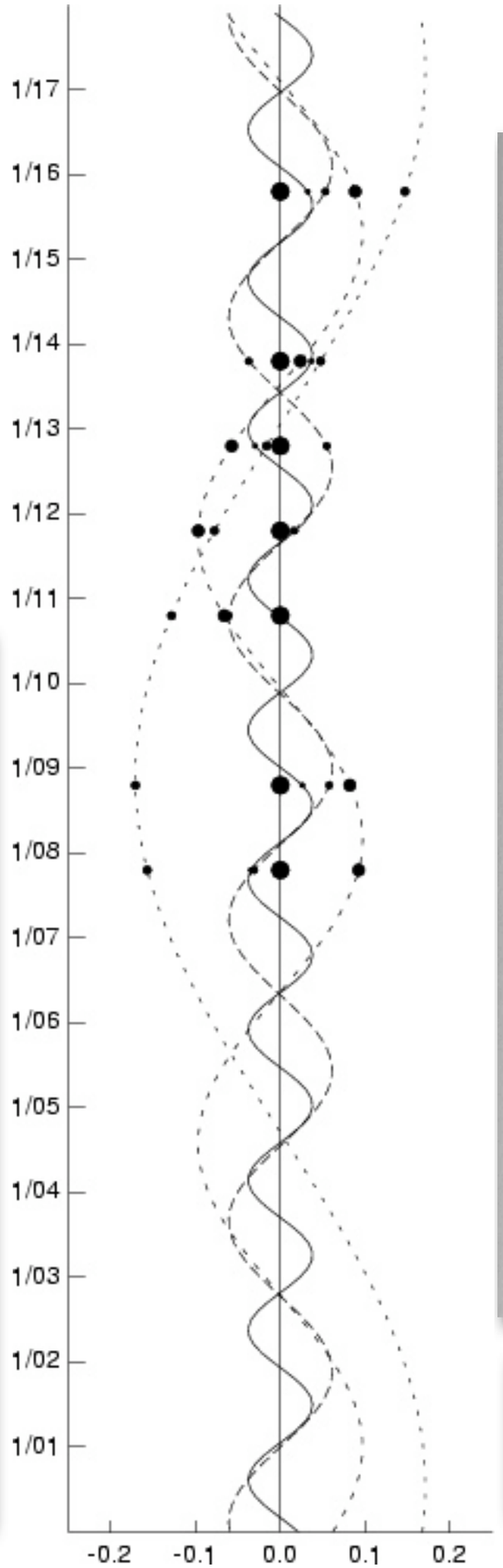


"CLUMPFIND"



Galileo
1610





On the third, at the seventh hour, the stars were arranged in this sequence. The eastern one was 1 minute, 30 seconds from Jupiter; the closest western one 2 minutes; and the other western one was

East * ○ * * West

10 minutes removed from this one. They were absolutely on the same straight line and of equal magnitude.

On the fourth, at the second hour, there were four stars around Jupiter, two to the east and two to the west, and arranged precisely

East * * ○ * * West

on a straight line, as in the adjoining figure. The easternmost was distant 3 minutes from the next one, while this one was 40 seconds from Jupiter; Jupiter was 4 minutes from the nearest western one, and this one 6 minutes from the westernmost one. Their magnitudes were nearly equal; the one closest to Jupiter appeared a little smaller than the rest. But at the seventh hour the eastern stars were only 30 seconds apart. Jupiter was 2 minutes from the nearer eastern

East ** ○ * * West

one, while he was 4 minutes from the next western one, and this one was 3 minutes from the westernmost one. They were all equal and extended on the same straight line along the ecliptic.

On the fifth, the sky was cloudy.

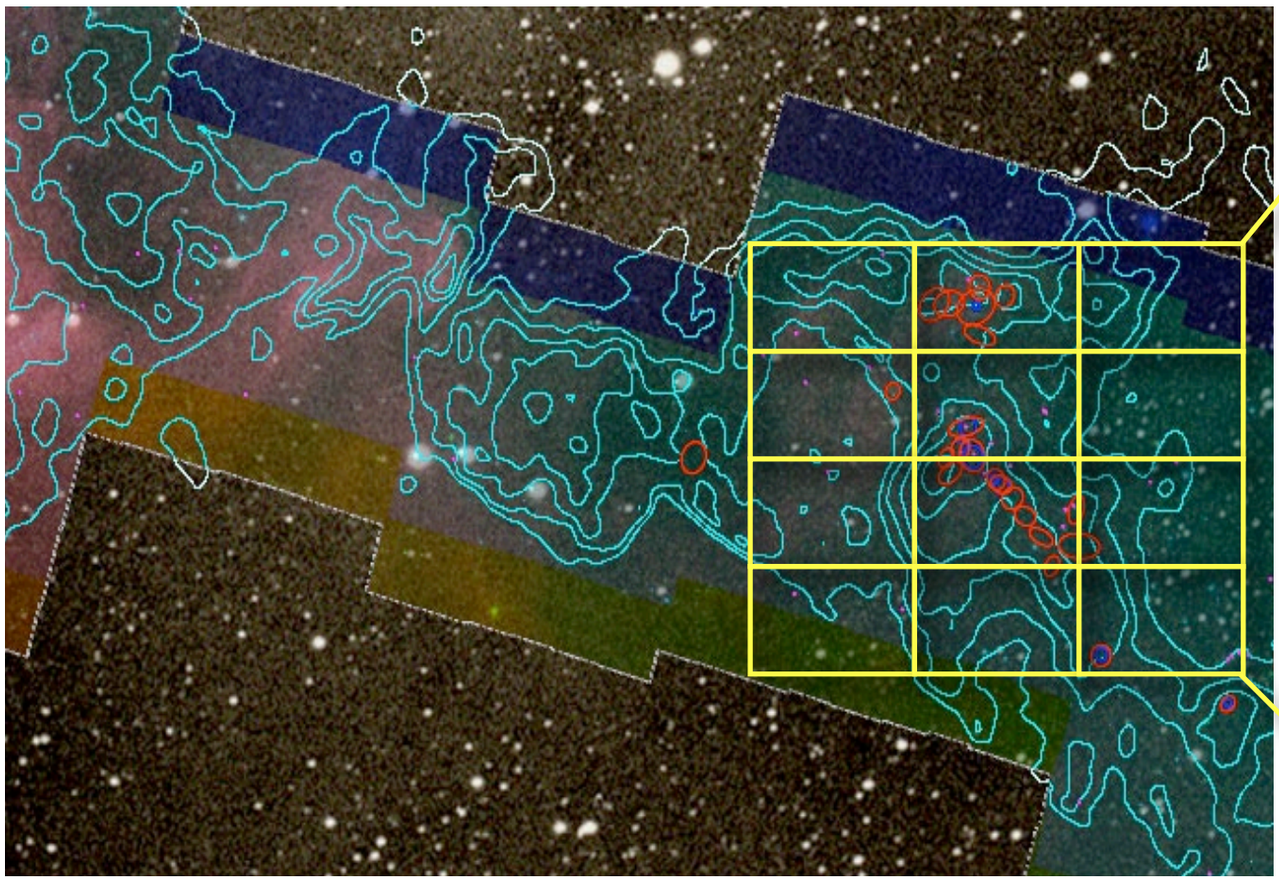
On the sixth, only two stars appeared flanking Jupiter, as is seen

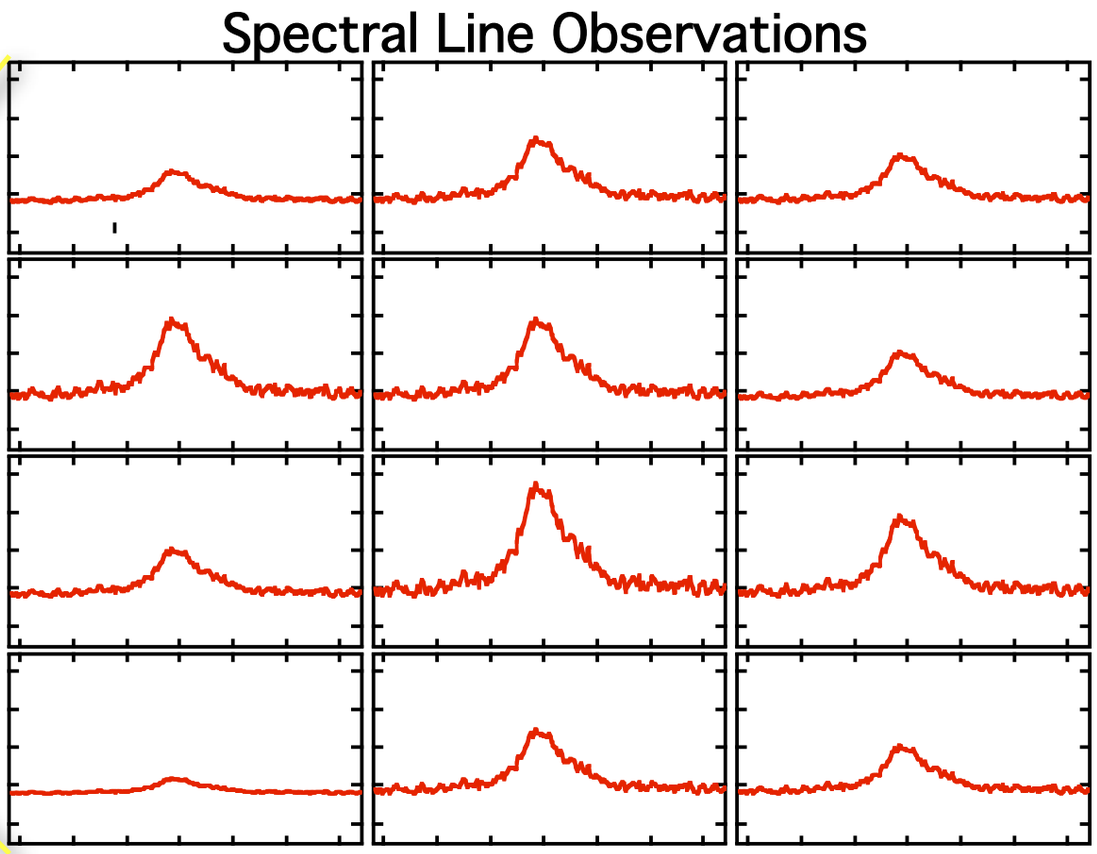
East * ○ * West

in the adjoining figure. The eastern one was 2 minutes and the western one 3 minutes from Jupiter. They were on the same straight line with Jupiter and equal in magnitude.

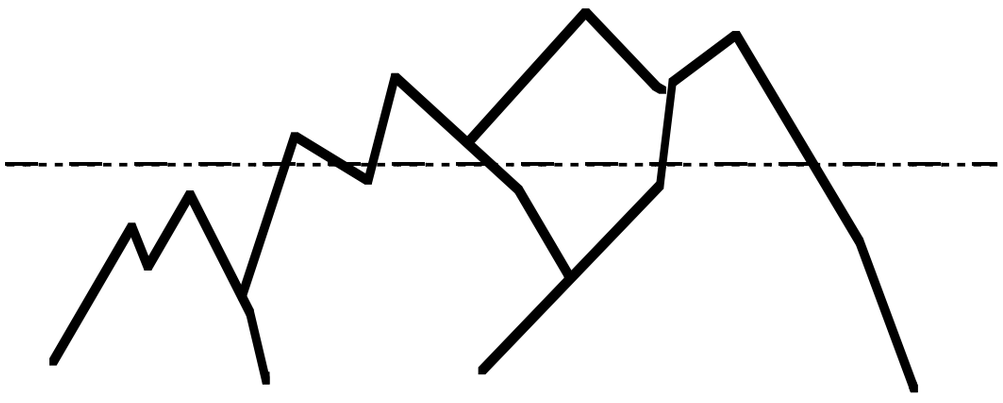
On the seventh, two stars stood near Jupiter, both to the east, arranged in this manner.

Velocity as a "Fourth" Dimension





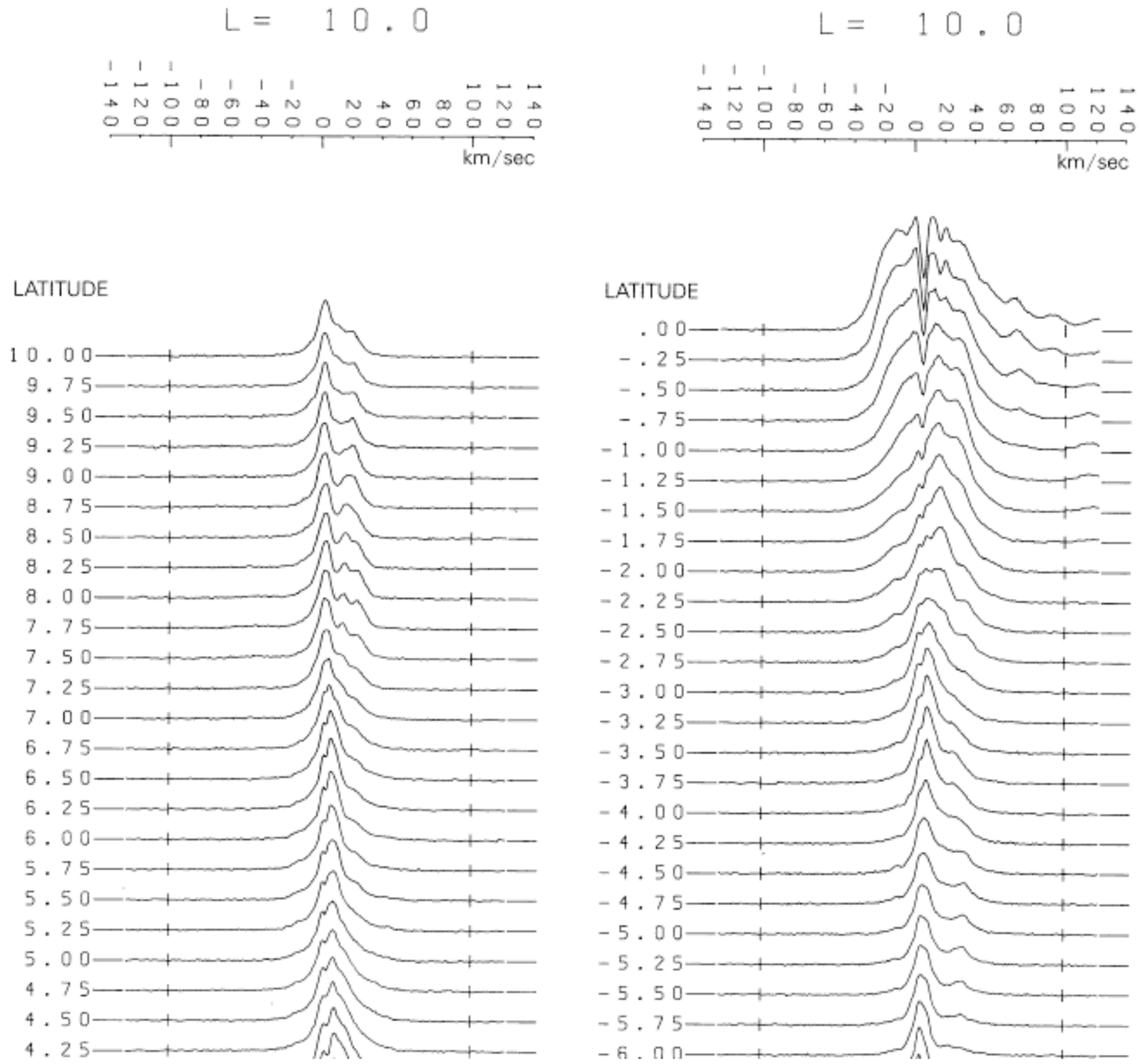
Loss of
1 dimension



Mountain Range

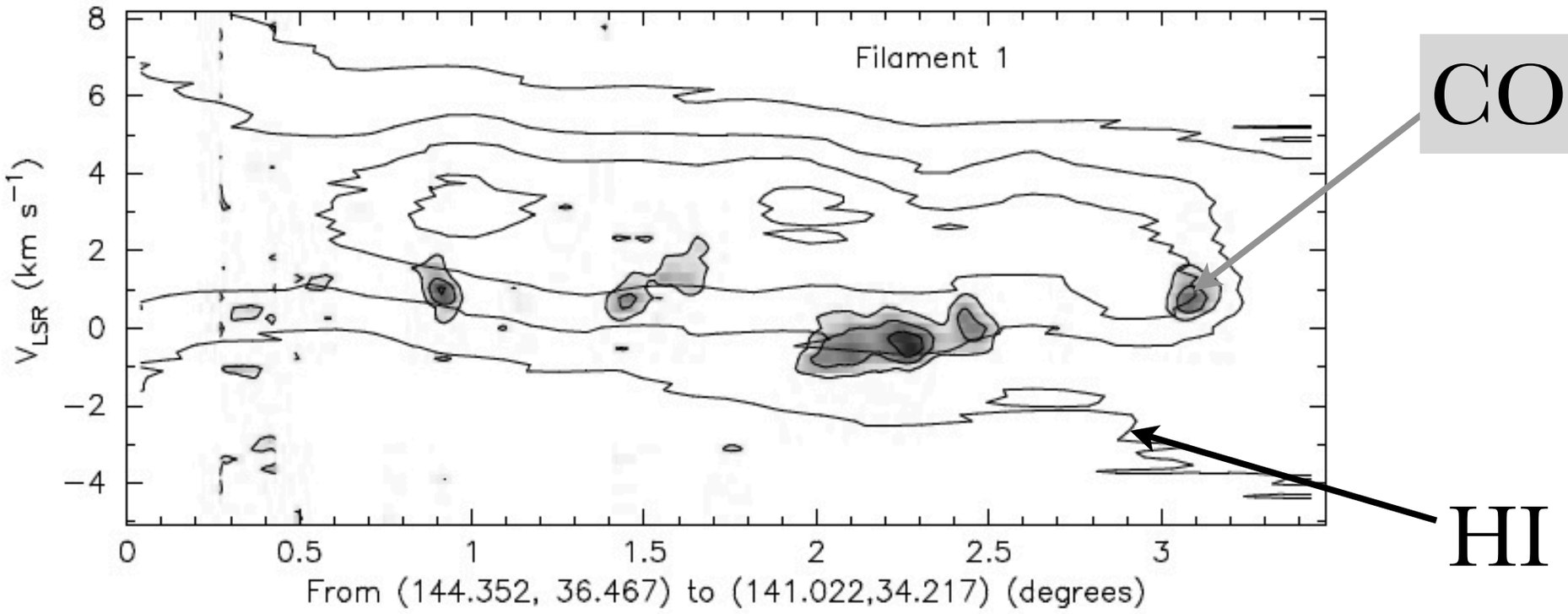
No loss of
information

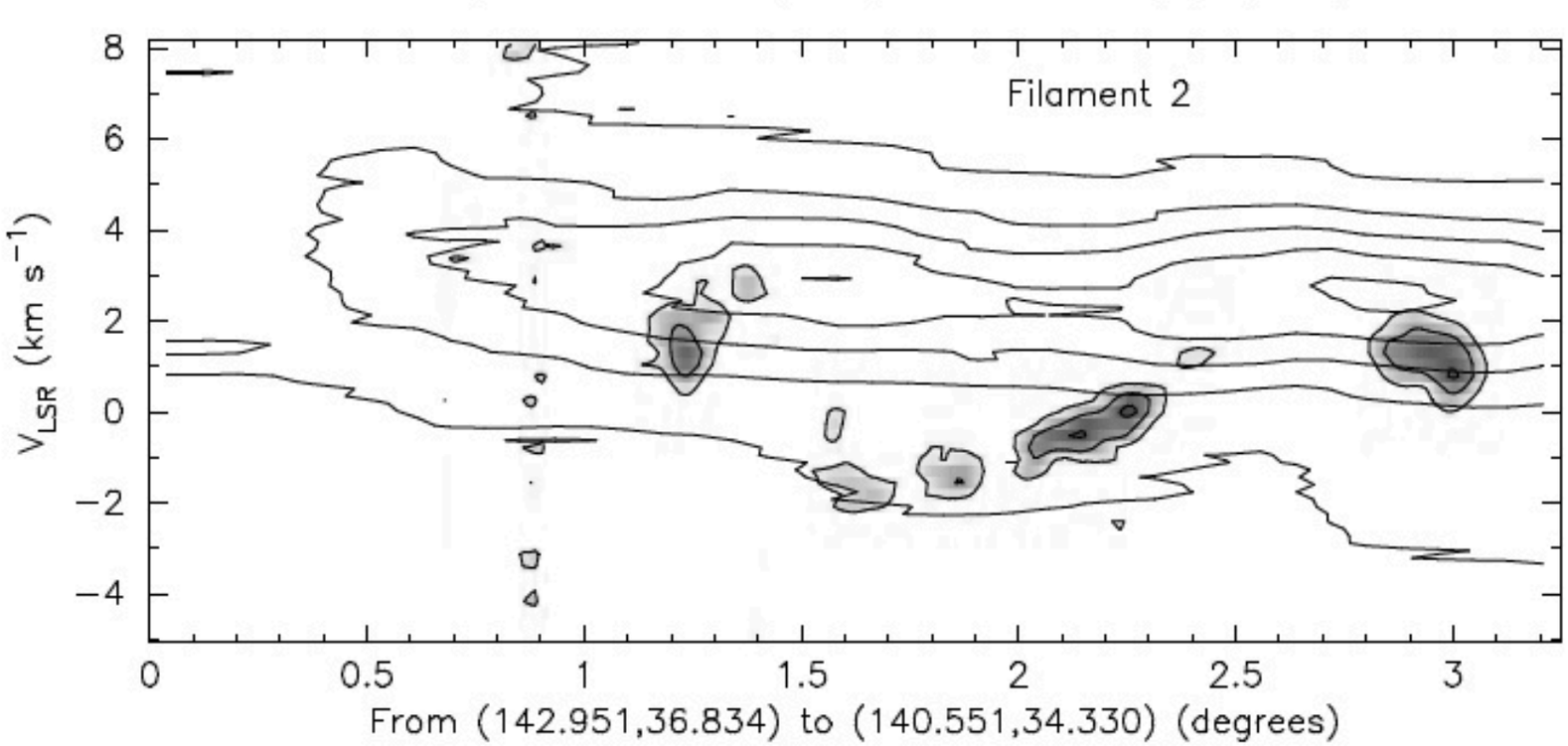
Hundreds of spectra, displayed together... I(v)(x,y)



Weaver & Williams 1973

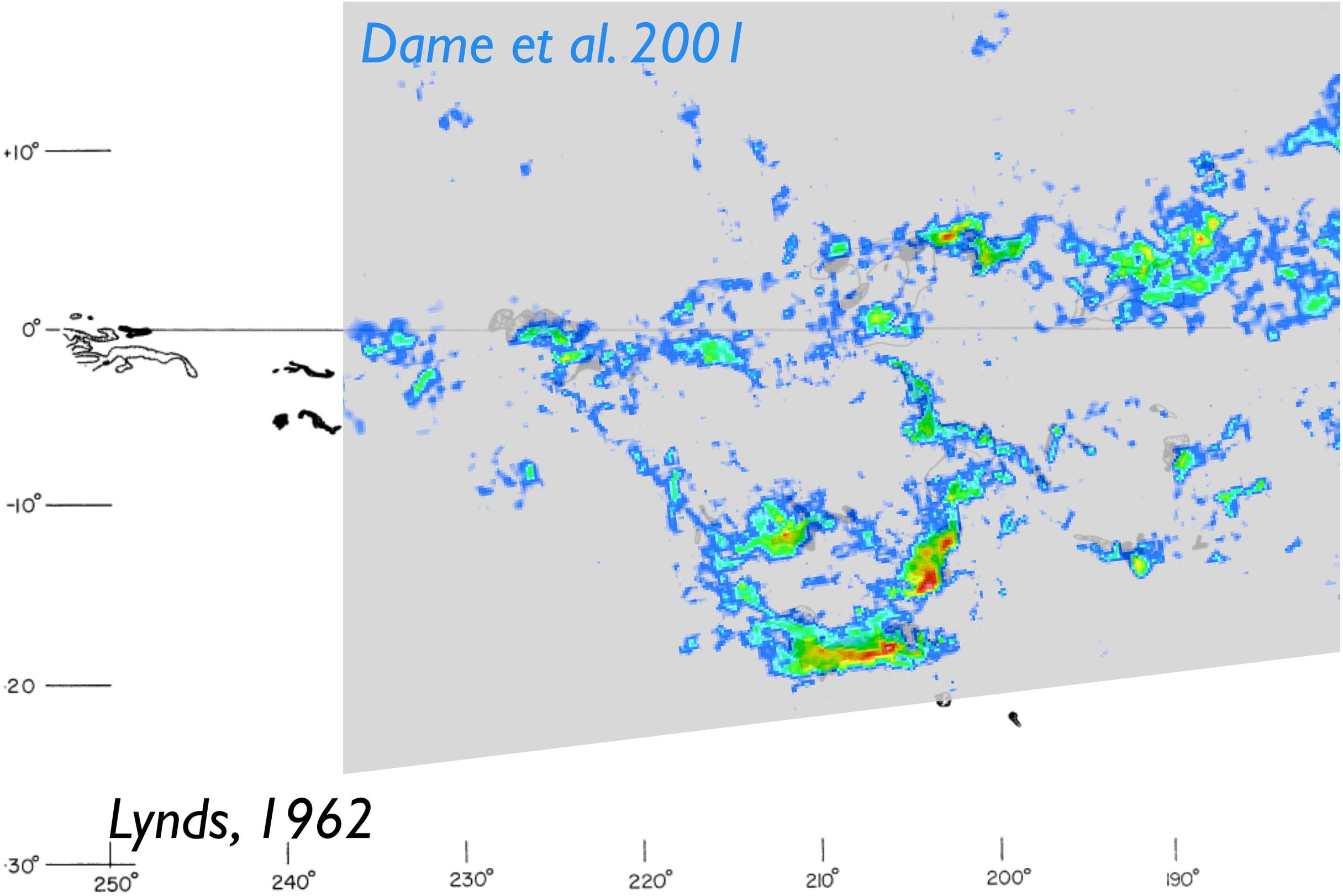
The Dreaded Position-Velocity Diagram?





Pound & Goodman 1997
(with thanks to Leo for the p-v!)

Dame et al. 2001



Lynds, 1962

COMPLETE Perseus

mm peak (Enoch et al. 2006)

sub-mm peak (Hatchell et al. 2005, Kirk et al. 2006)

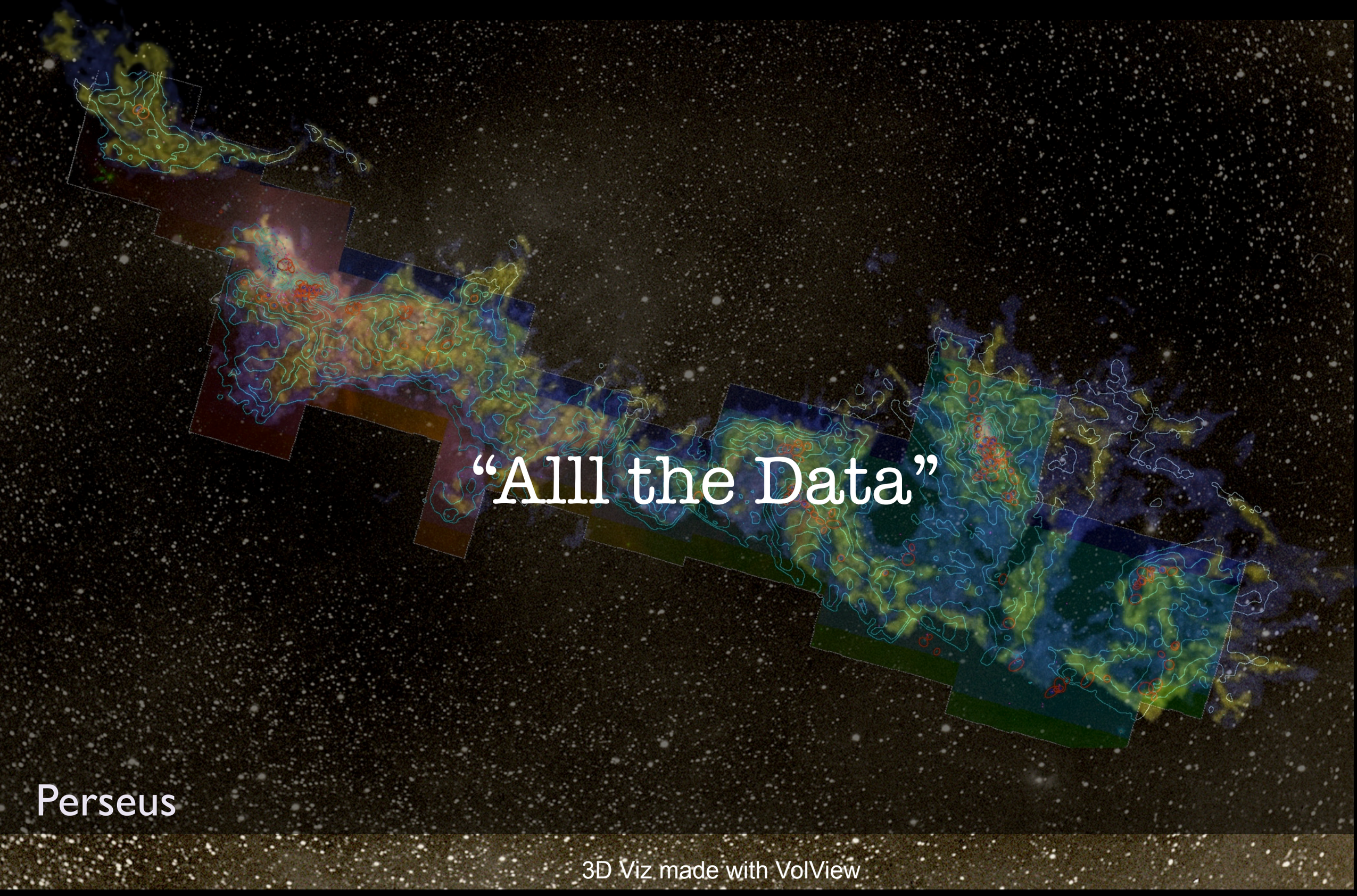
^{13}CO (Ridge et al. 2006)

mid-IR IRAC composite from c2d data (Foster, Laakso, Ridge, et al. in prep.)

Optical image (Barnard 1927)

“Channel Maps”

“Alll the Data”



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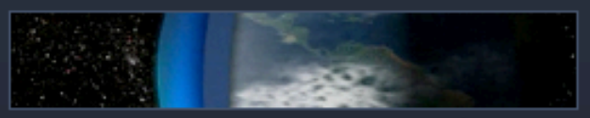

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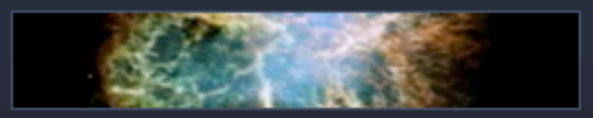

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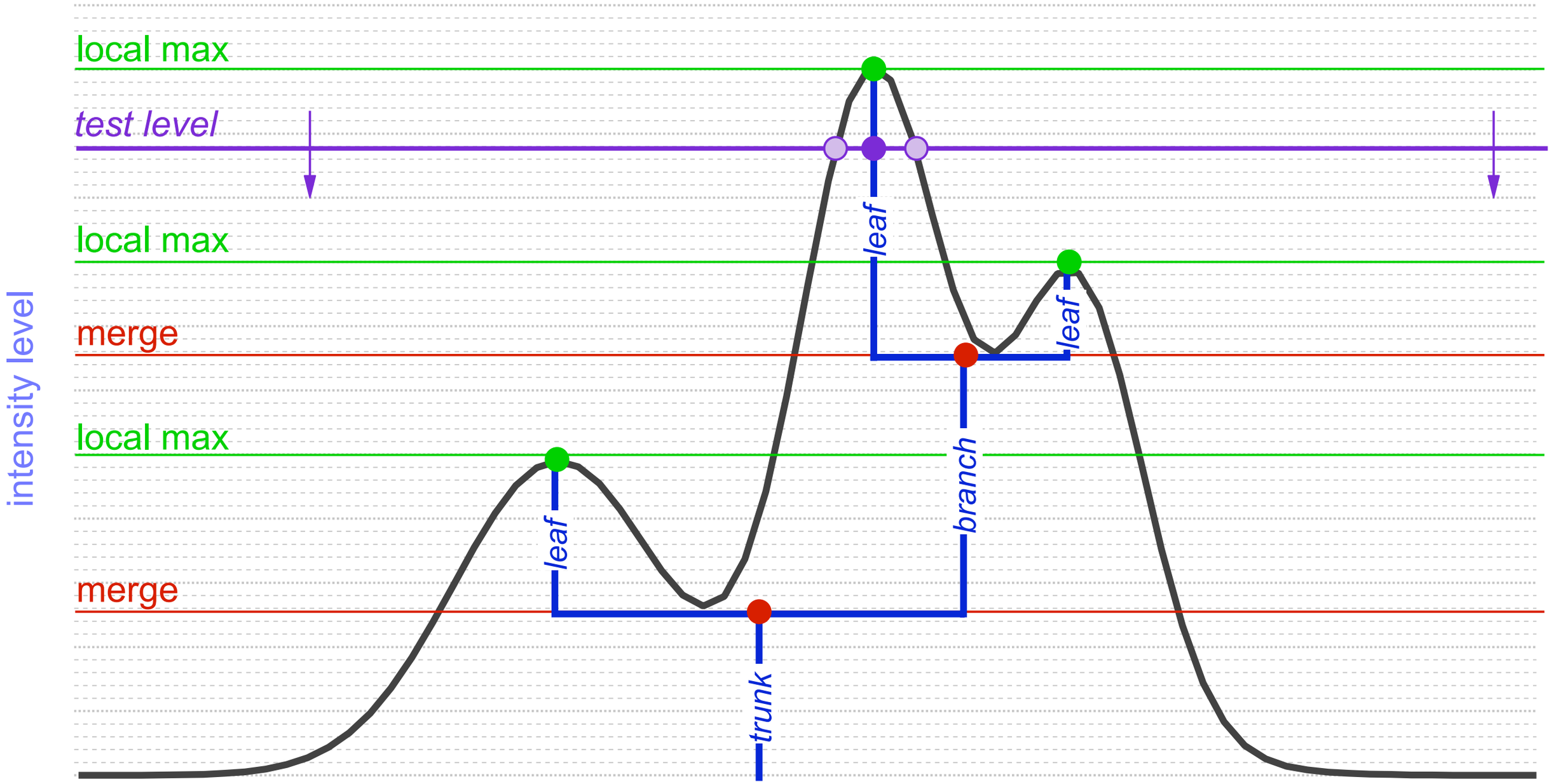
Dendrograms



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

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

Either Algorithm is an Example of Tasting in Observational-Space

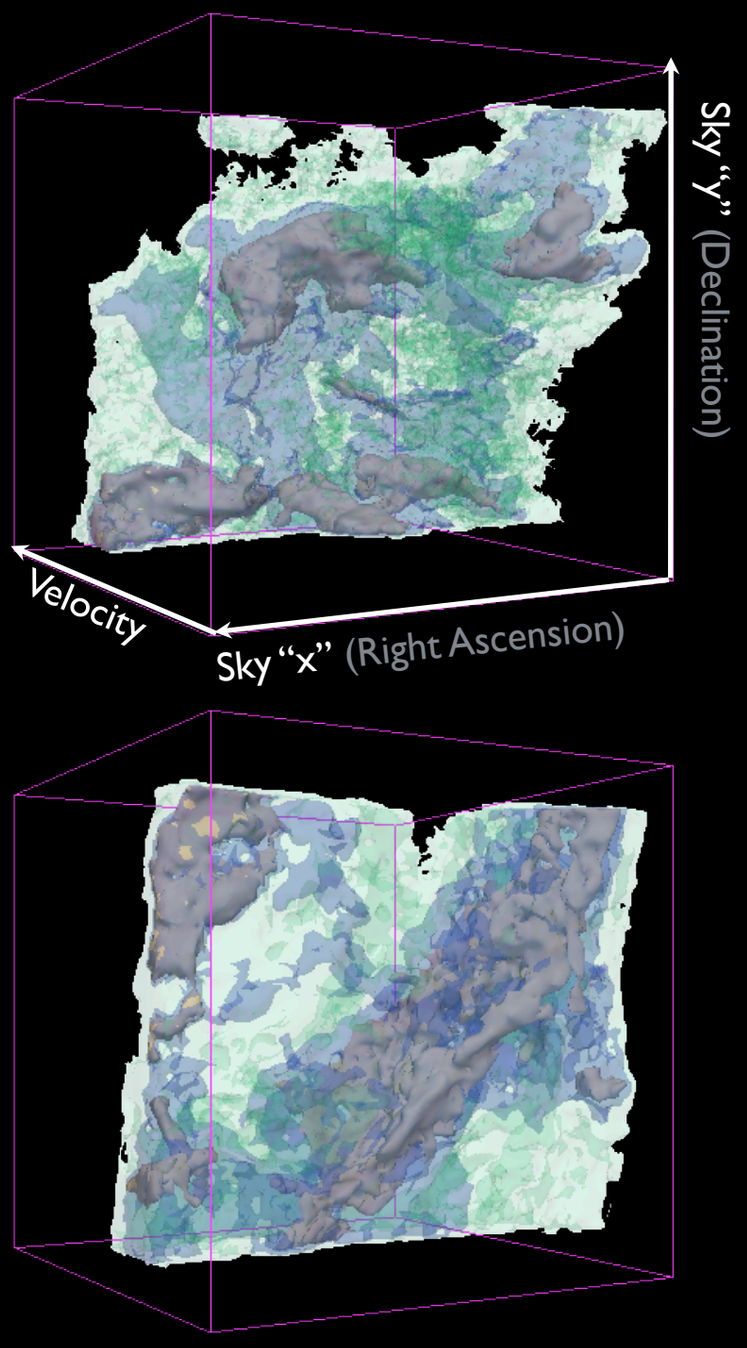
(Dendro)Surfaces

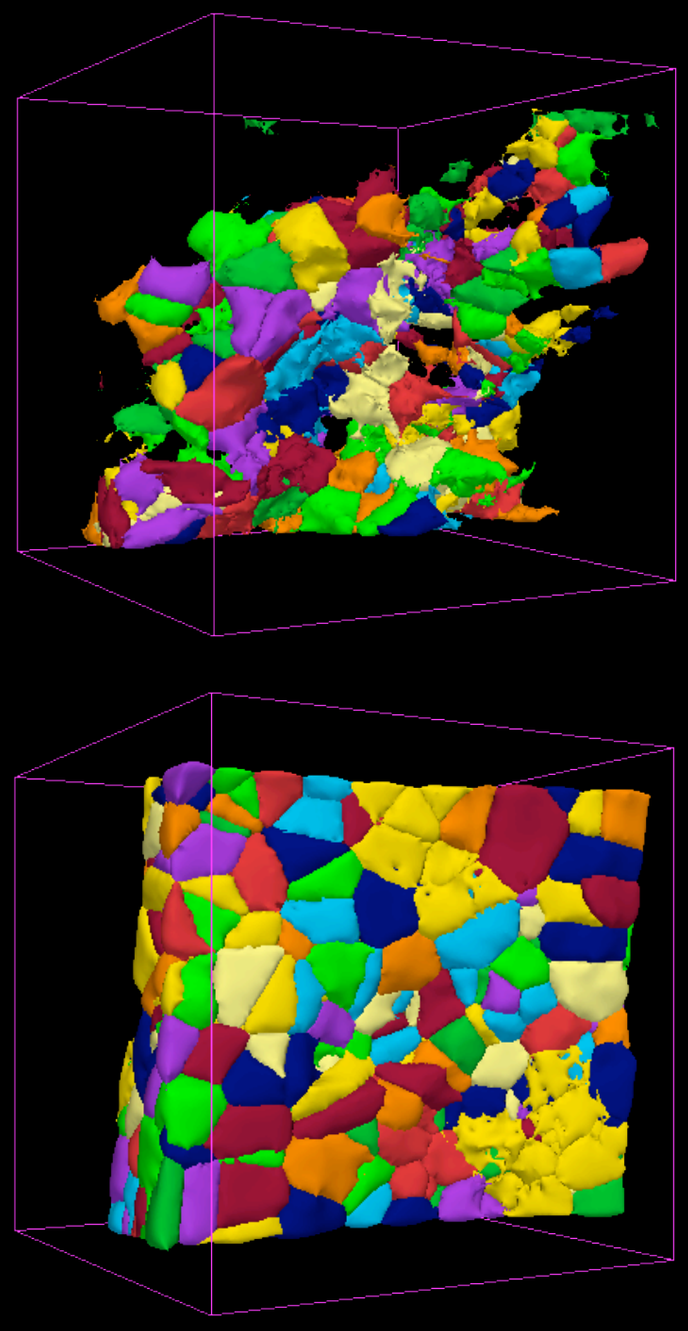
"CLUMPFIND"

Observed Reality

Taste Tests

"Observed" Simulations

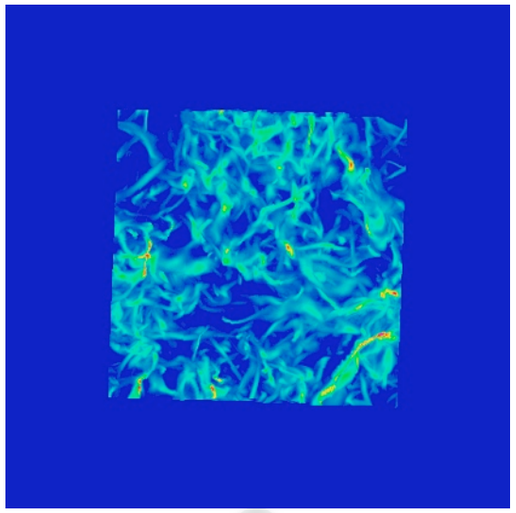




work of Rosolowsky, Pineda, Kauffmann, Borkin,Padoan, Halle & Goodman;
figure from Goodman & Rosolowsky NSF "Star Formation Taste Tests" Proposal, Fall 2006

The Taste-Testing Process

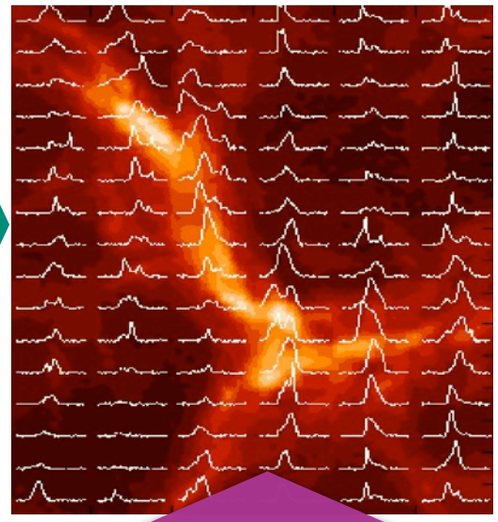
Simulation



Radiative Transfer (+Chemistry) Code(s)

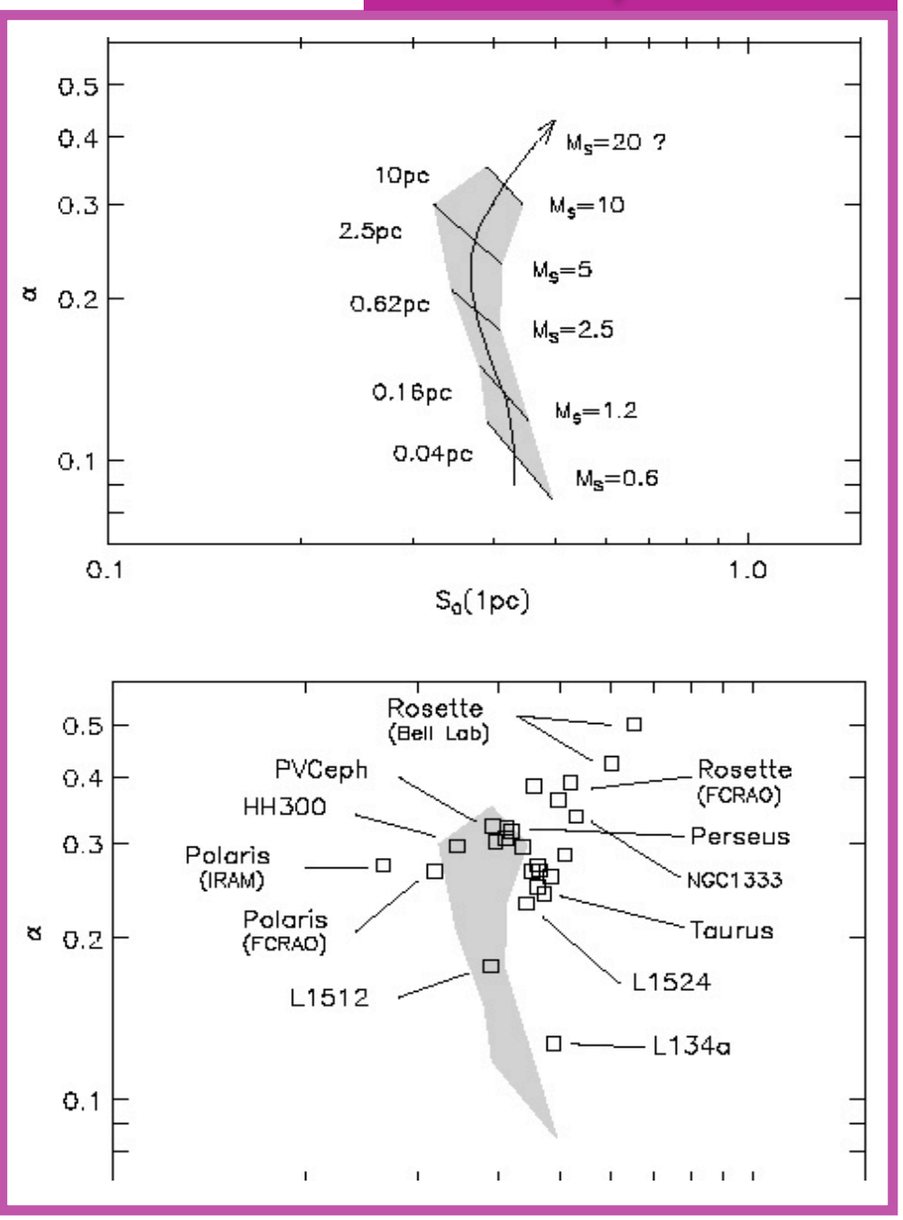
Synthetic Observing System

Synthetic Data



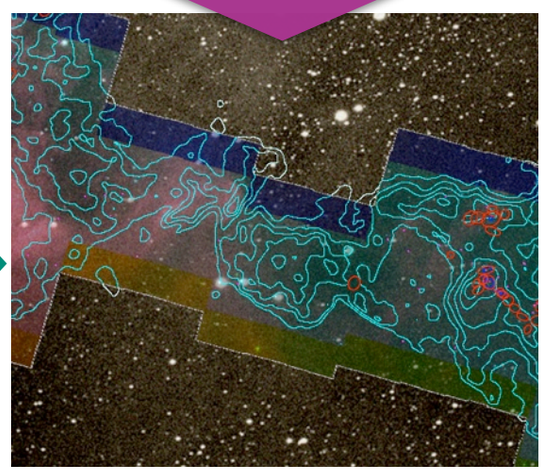
Taste Tests

SCF: A Sample Taste Test



Enabled Indirectly

Observing System



Nature

Observed Data