Characterizing Molecular Cloud Populations Using Dendrograms

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Image Credit: Florian Breuer

A Brief History of Trees

Structure Trees

cprops

Dendrograms

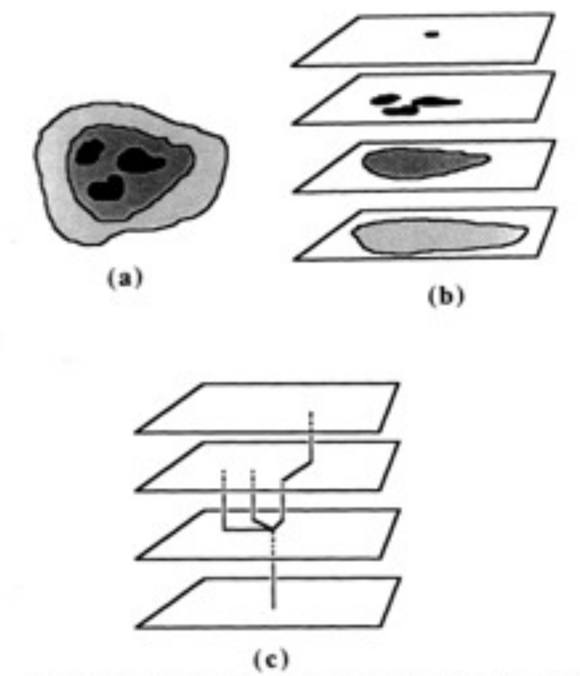

Fig. 1.—Schematic for structure tree construction. (a) Original system. (b) Result of thresholding to partition the image into "clouds." (c) Structure tree connecting "cloud" centers of masses according to overlap or lineage.

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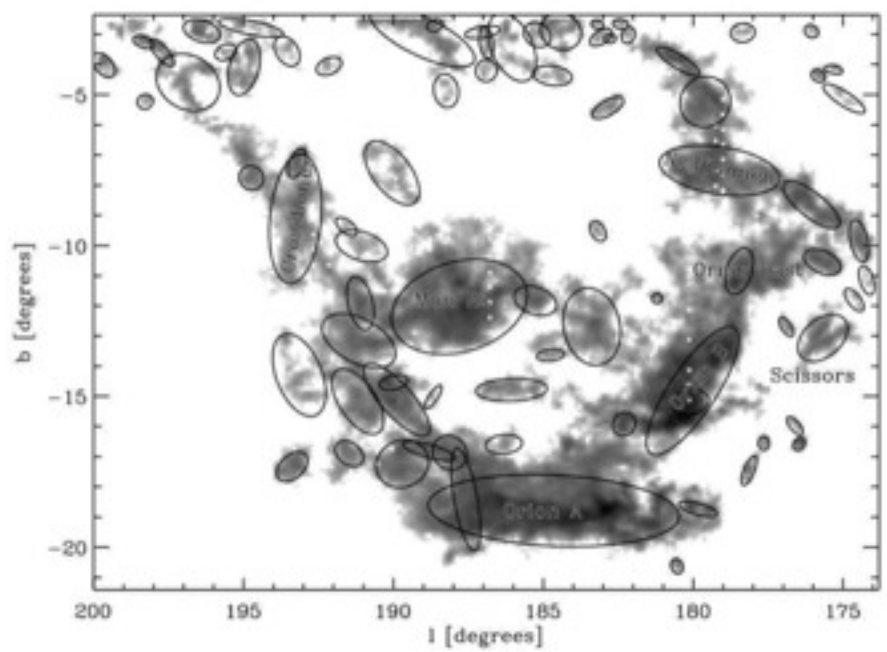

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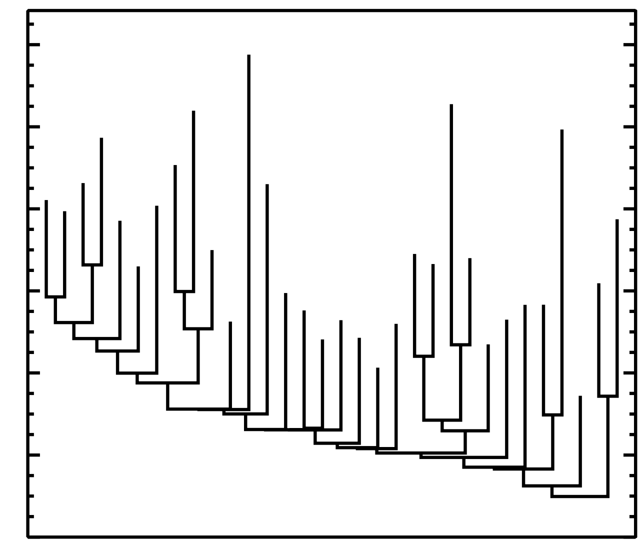
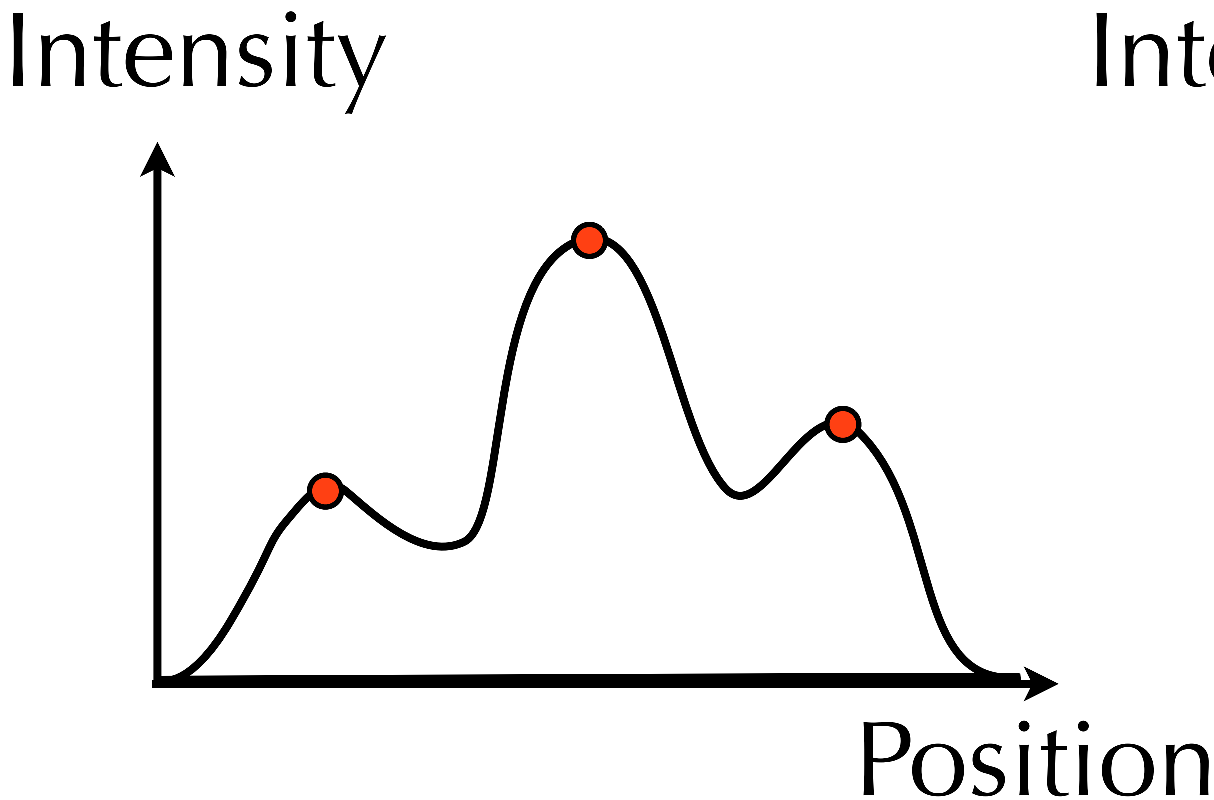


Houlahan & Scalo (1992)

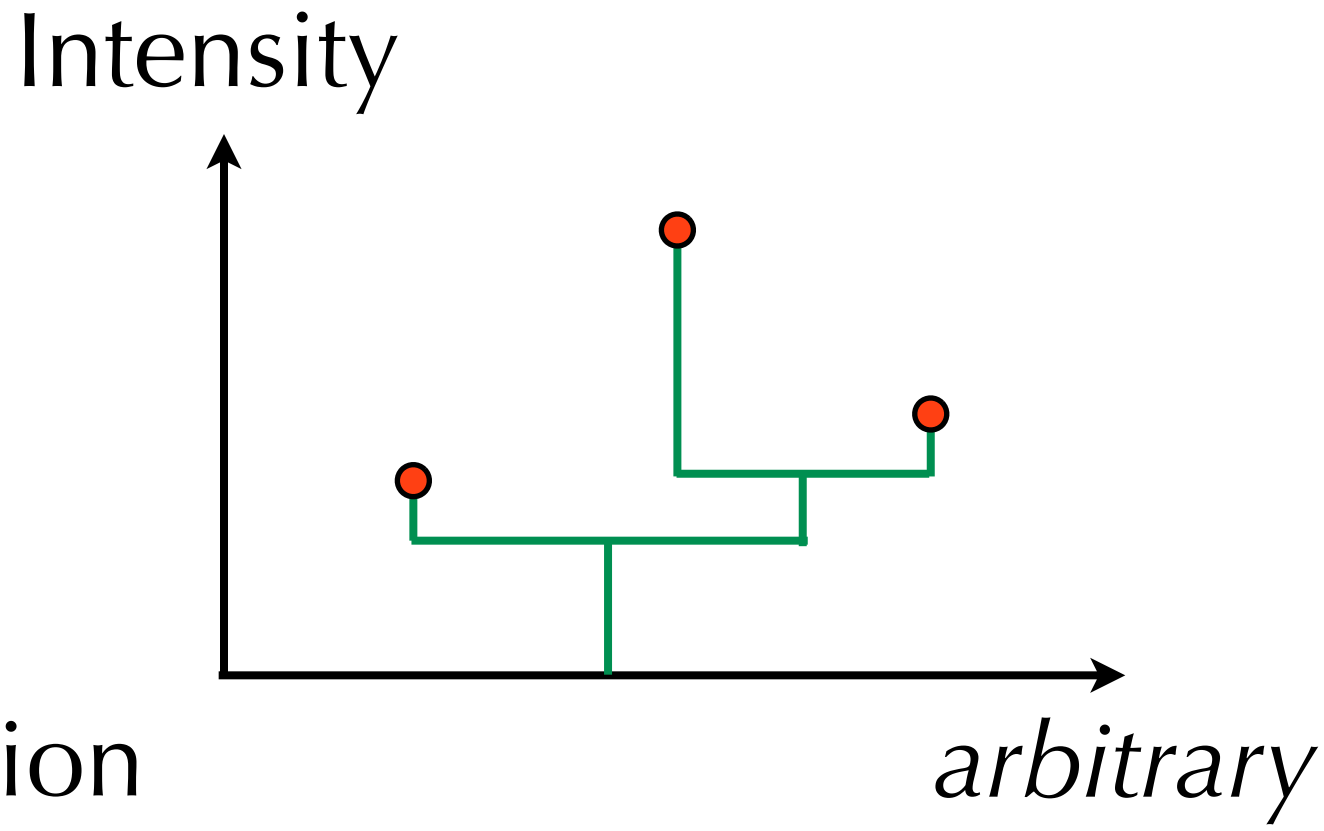
Rosolowsky & Leroy (2006)

Rosolowsky+ (2008)
Goodman+ (2009)

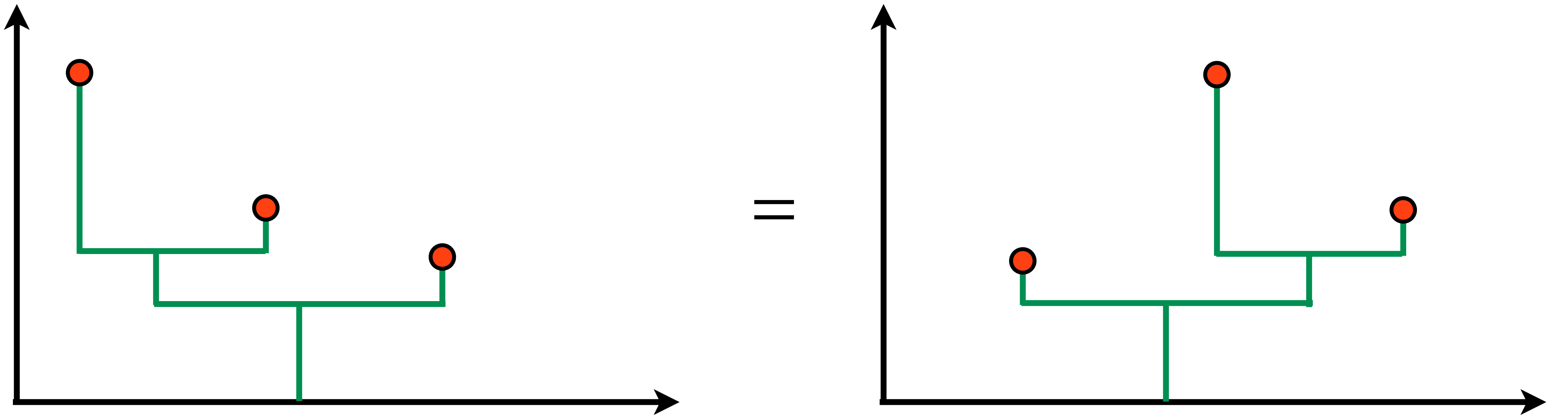
4) Iterate until zero intensity is reached



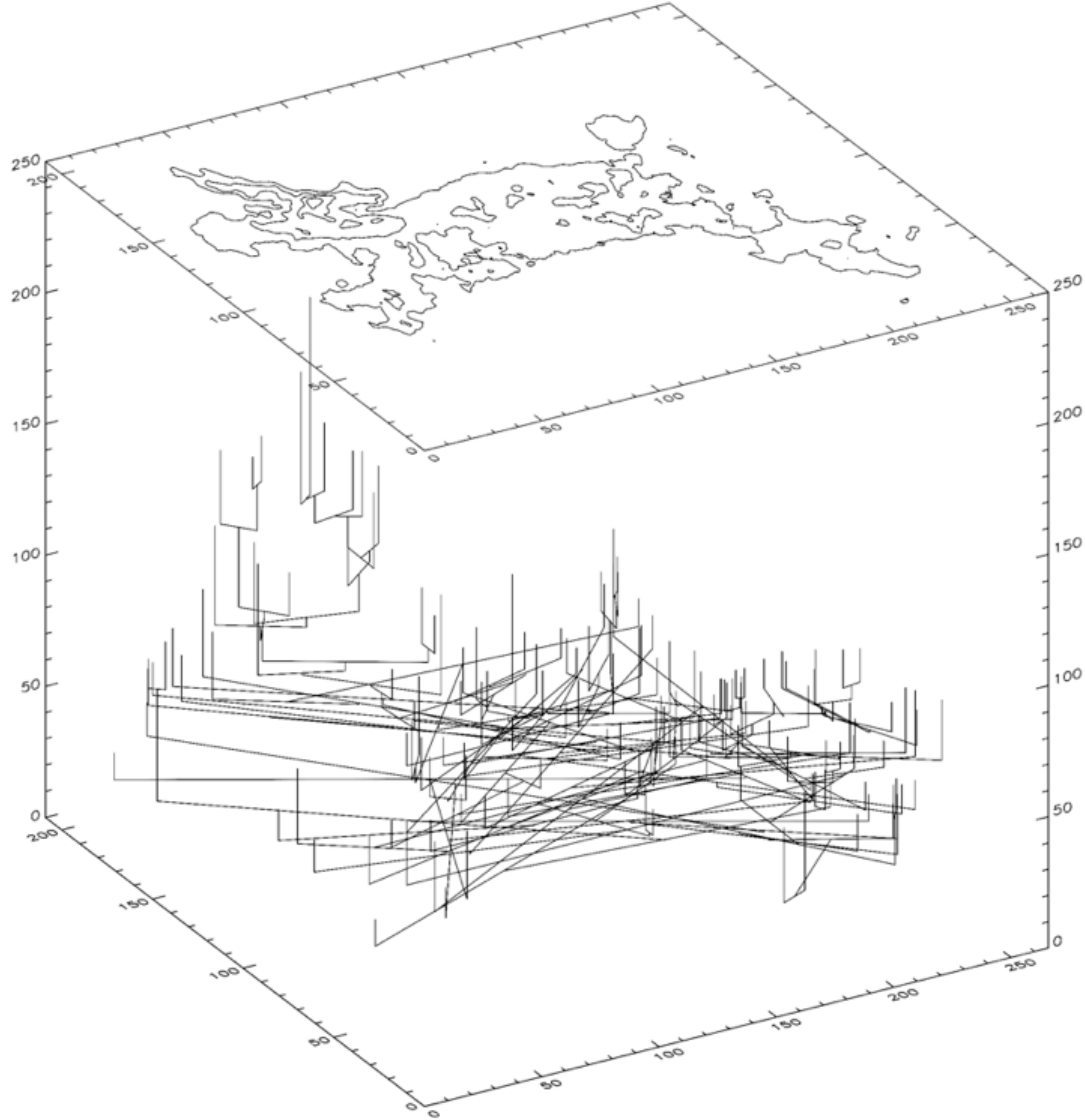
Emission Profile



Dendrogram



Ordering (Left-Right) is usually unimportant


250
200
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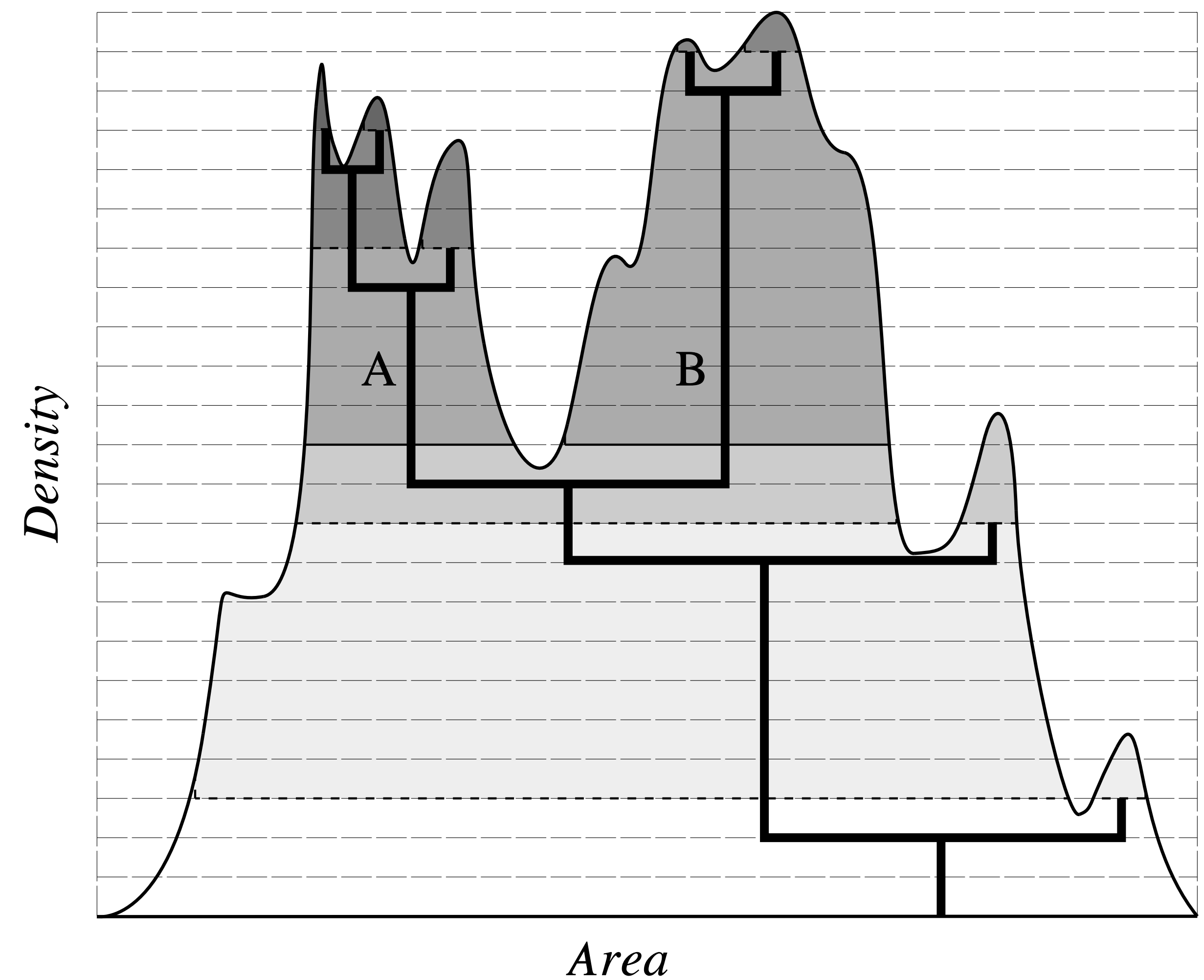
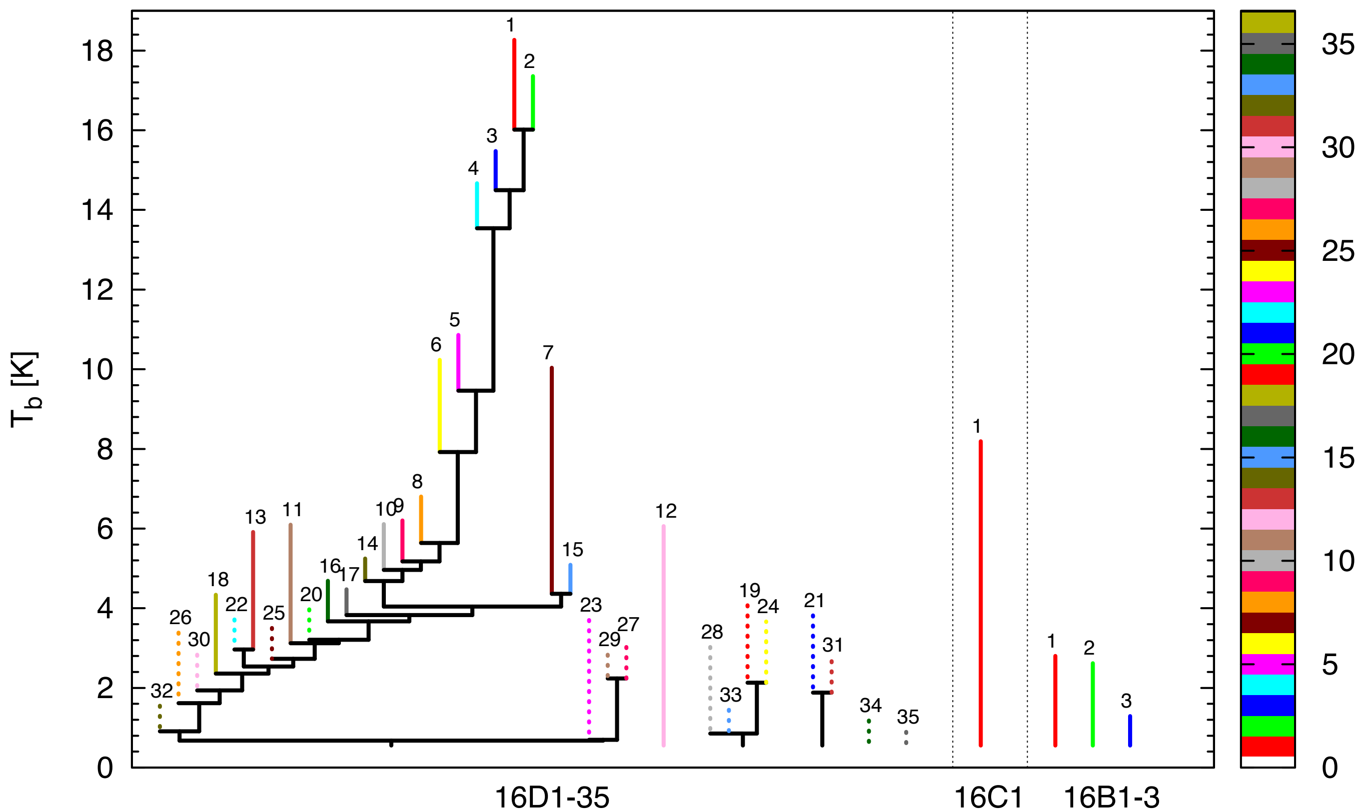
200
250

Dendrograms are not *intrinsically* a drop-in replacement for Clumpfind, cprops, or other segementation algorithms

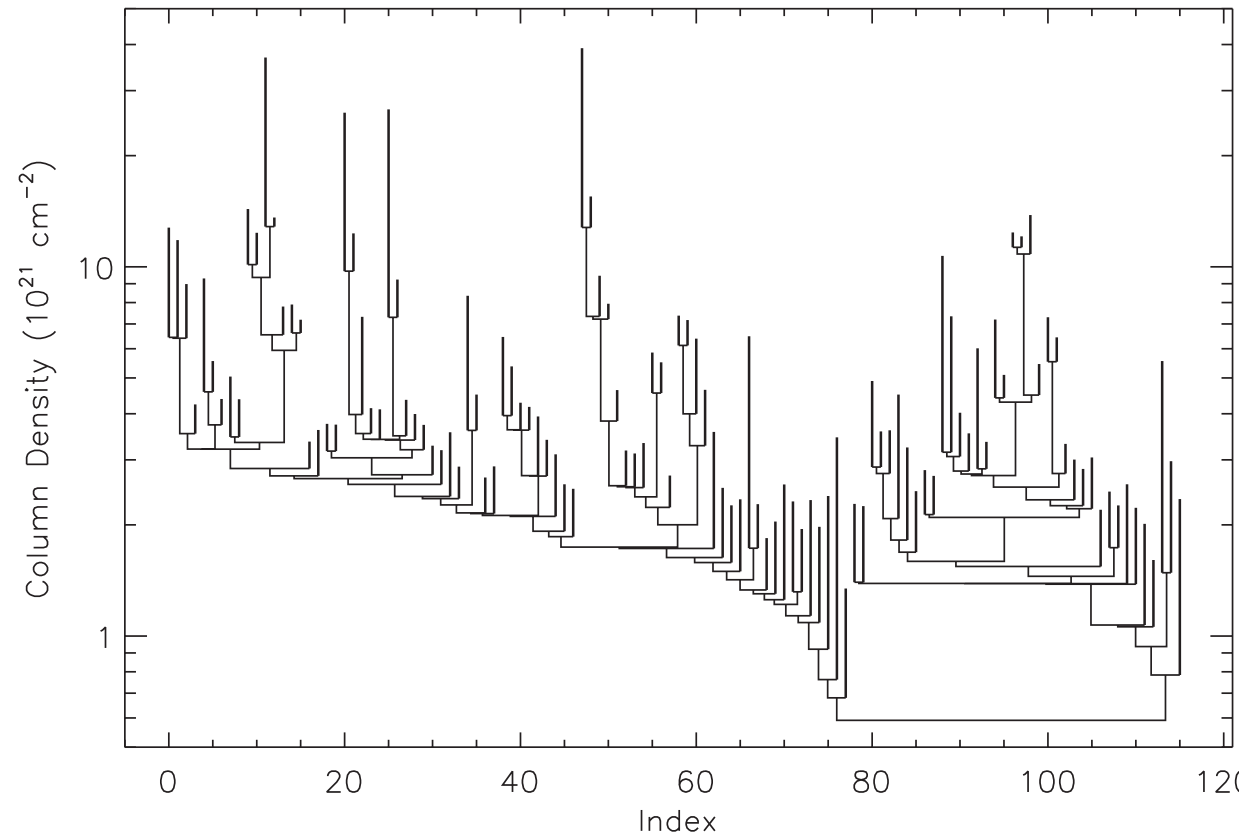


SExtractor Manual

But dendrograms can be leveraged as a data description supporting segmentation.



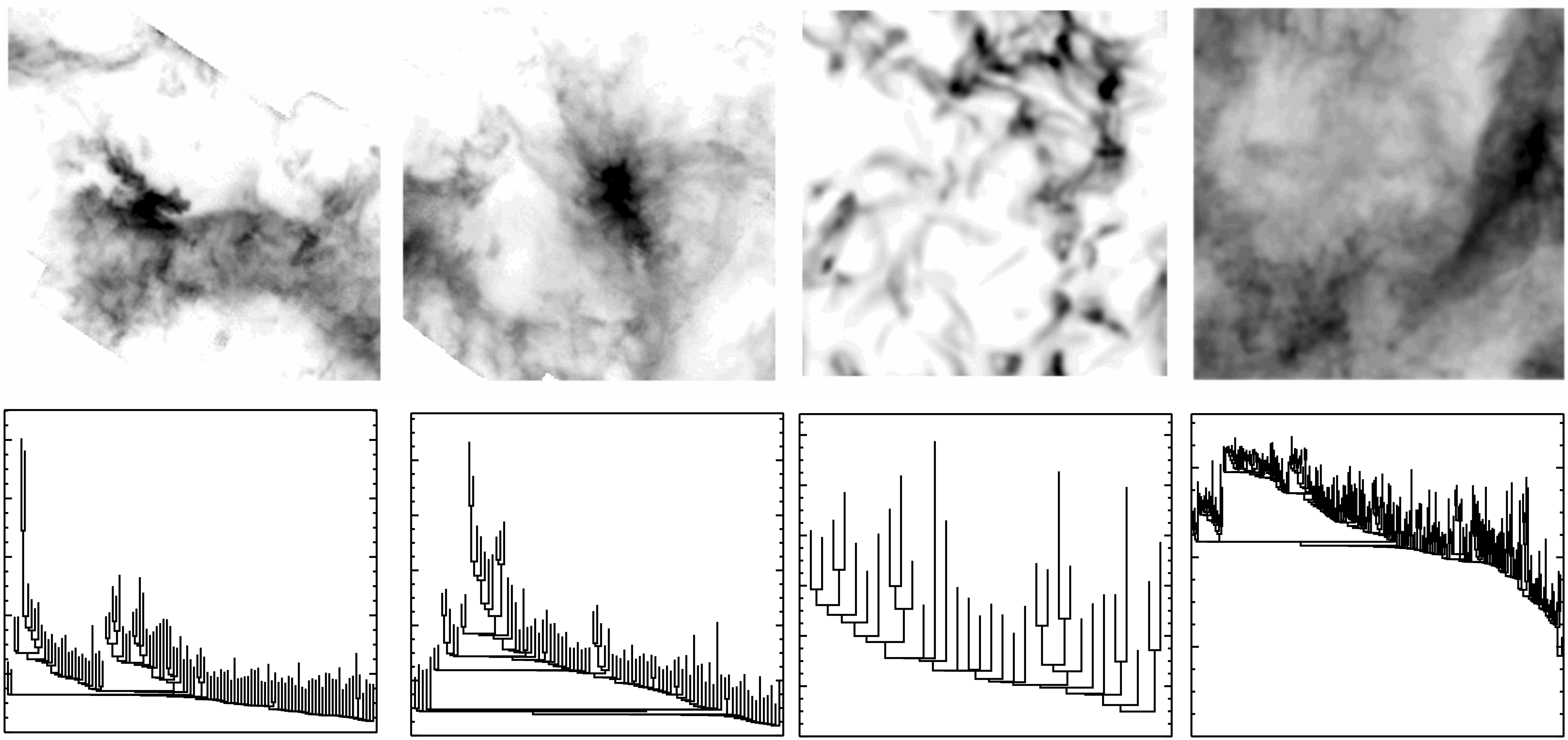
DENDROFIND
Wünsch+(2012)
= cprops with eclump option



CSAR
Kirk et al. (2013)

Graph Statistics on Dendrograms

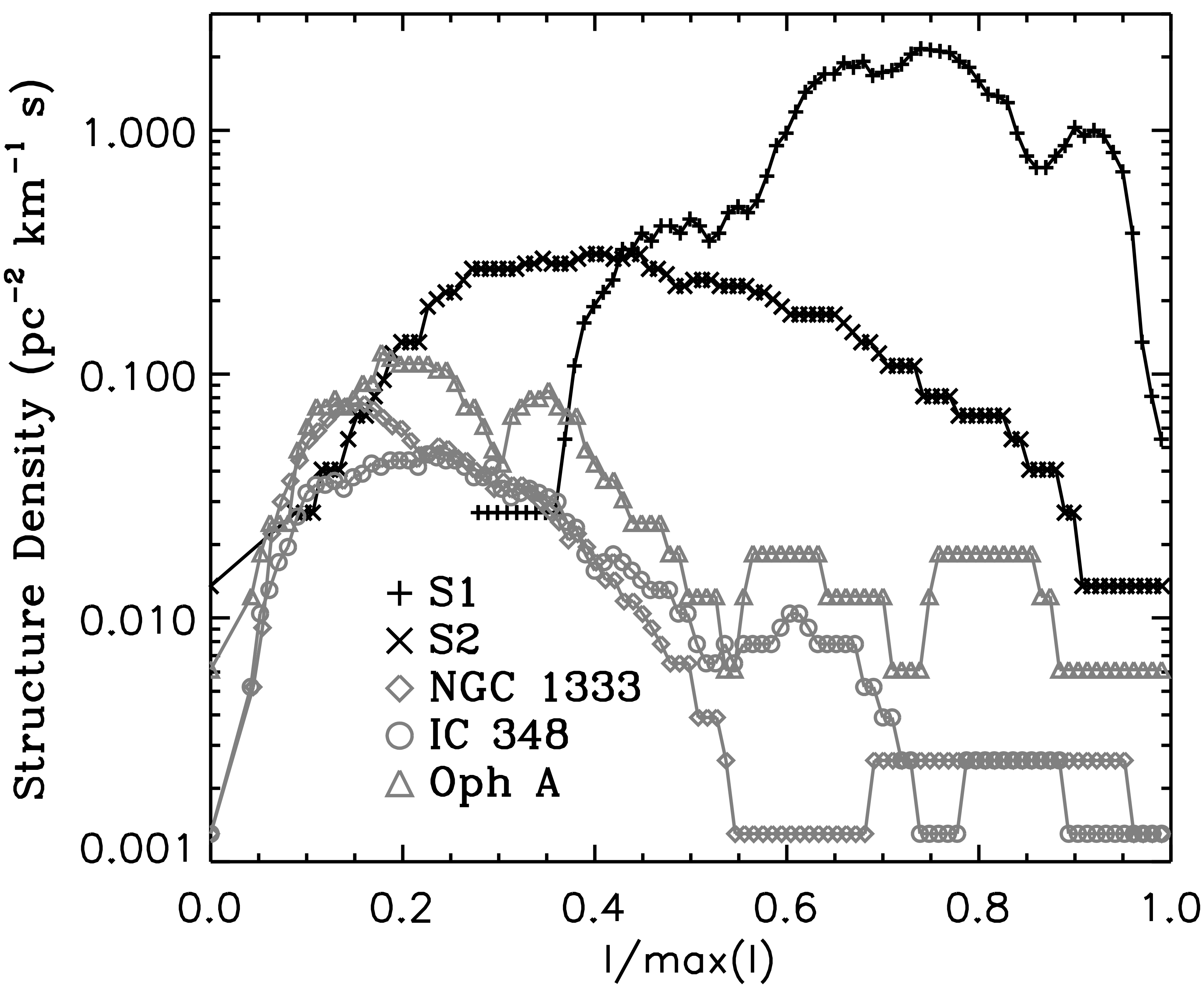
IC 348 | NGC 1333 | Offner+ (S2) | Padoan+ (S1)



Common noise levels adopted across PPV data

Rosolowsky+ (2012) Proc. IEEE

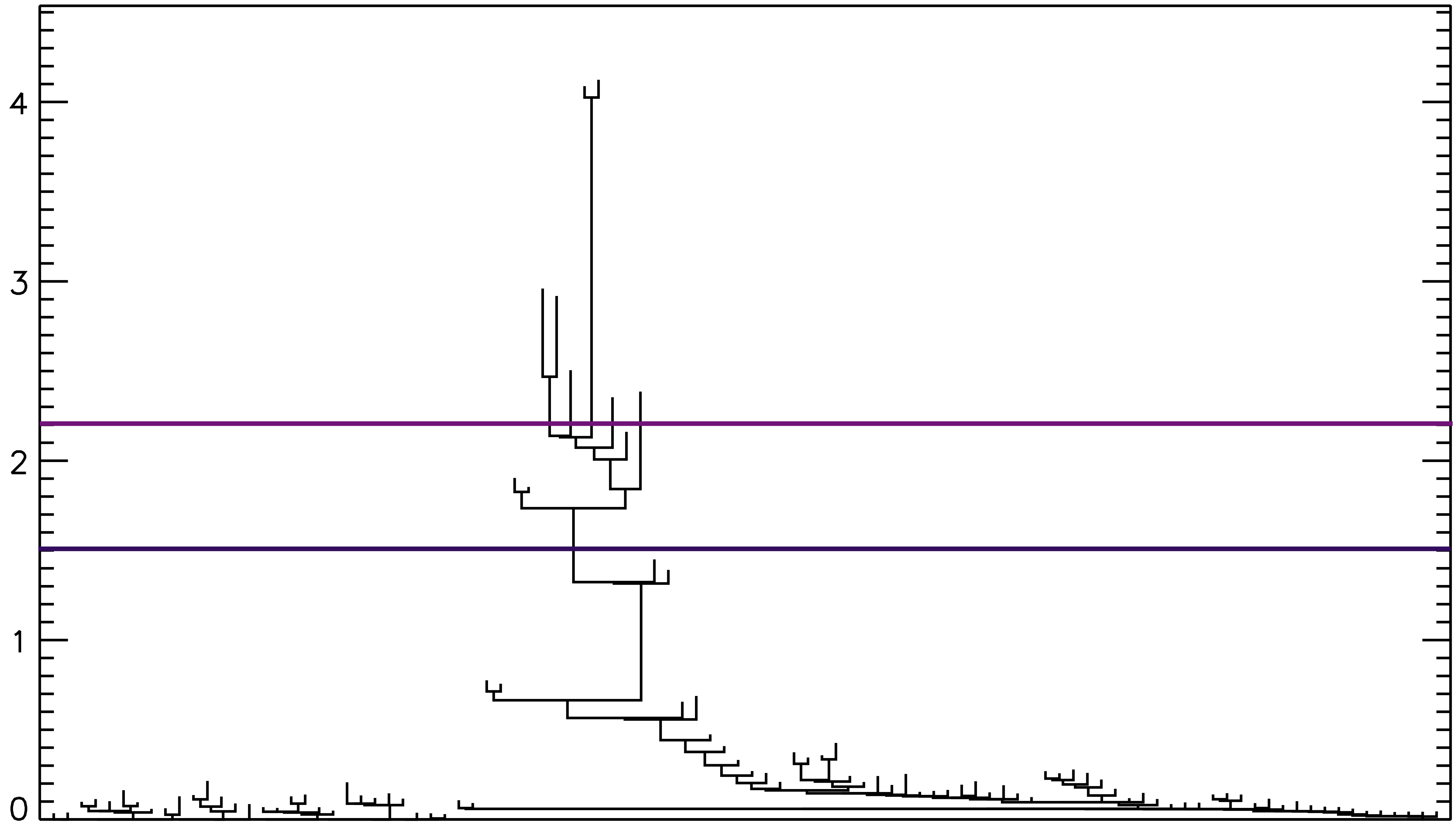
Genus vs. Intensity curve



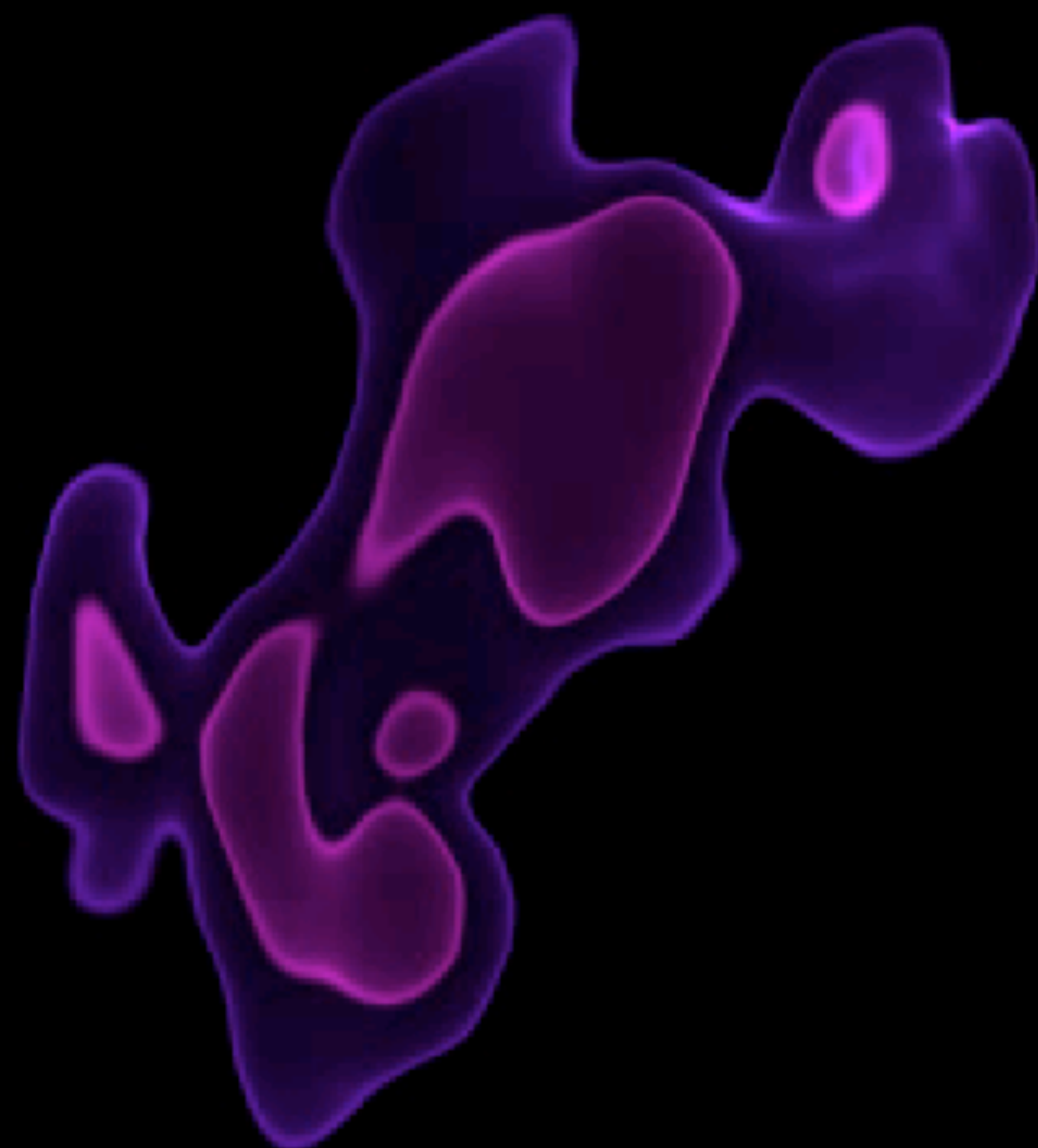
Dendrogram provide a flexible representation of all the salient features in the data.

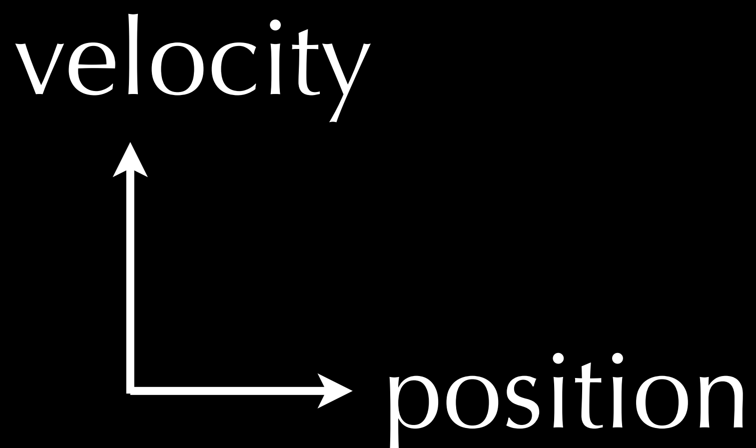
Can we make a better catalog of molecular gas in the Milky Way **using a method that can be applied to extragalactic clouds too?**

NGC 253 in CO

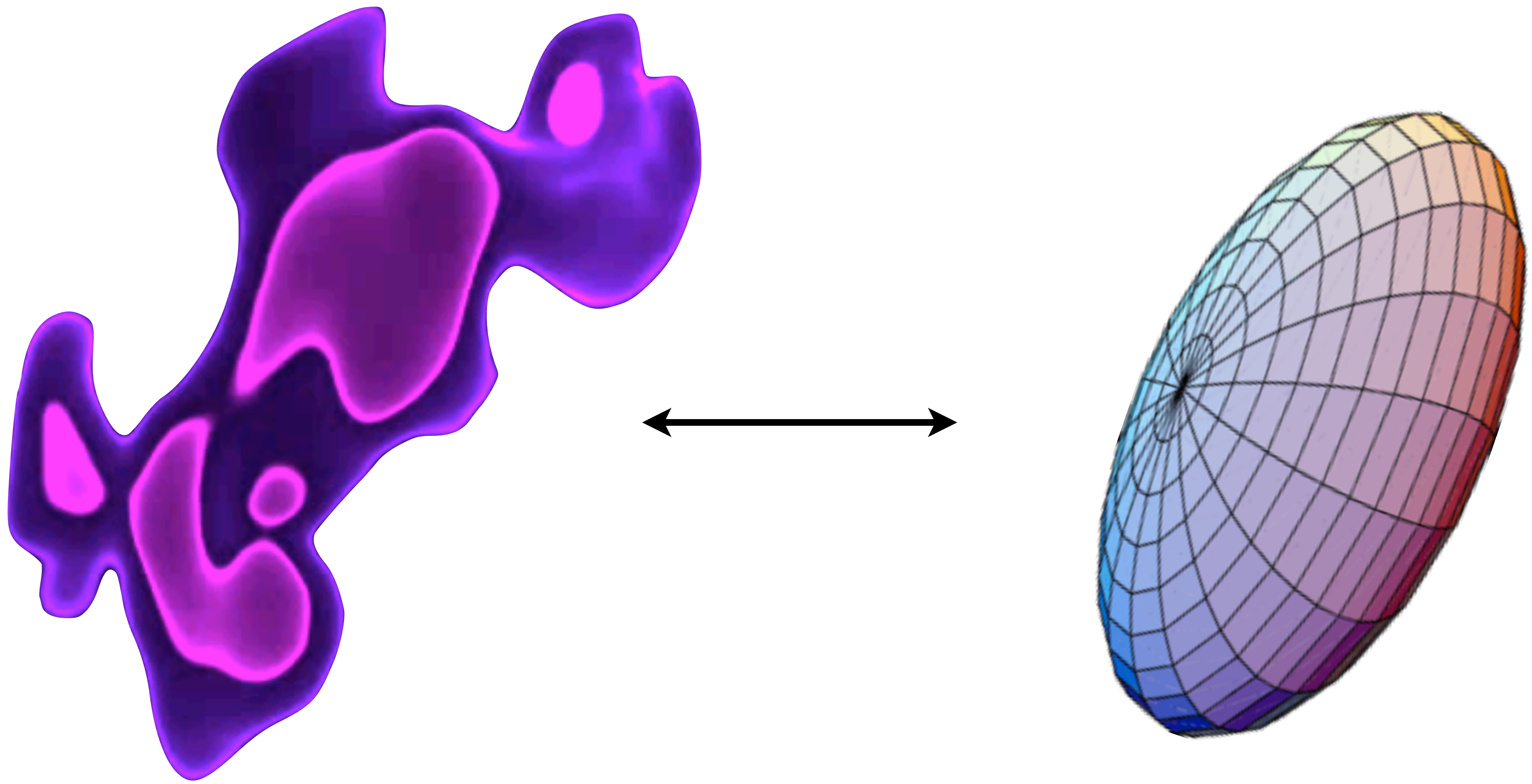


Every point on a dendrogram is an isosurface.





Levels at 1.5 and 2.2 Jy/beam



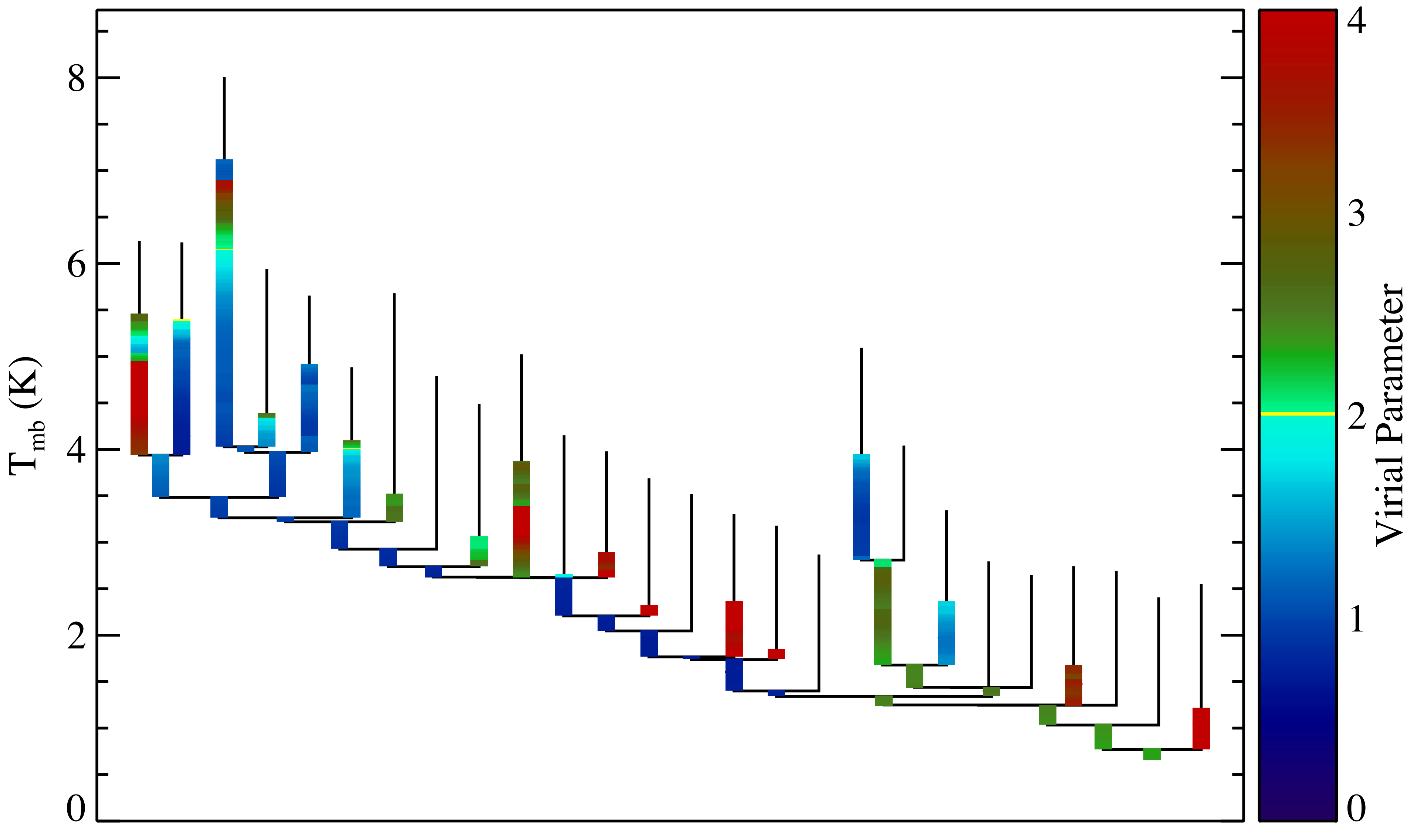
The moments over these contours give us properties.

$$L_{\mathrm{CO}} = \delta A \sum_{i \in \mathcal{C}} I_i \qquad \sigma_v^2 = \sum_{i \in \mathcal{C}} (v_i - \bar{v})^2$$

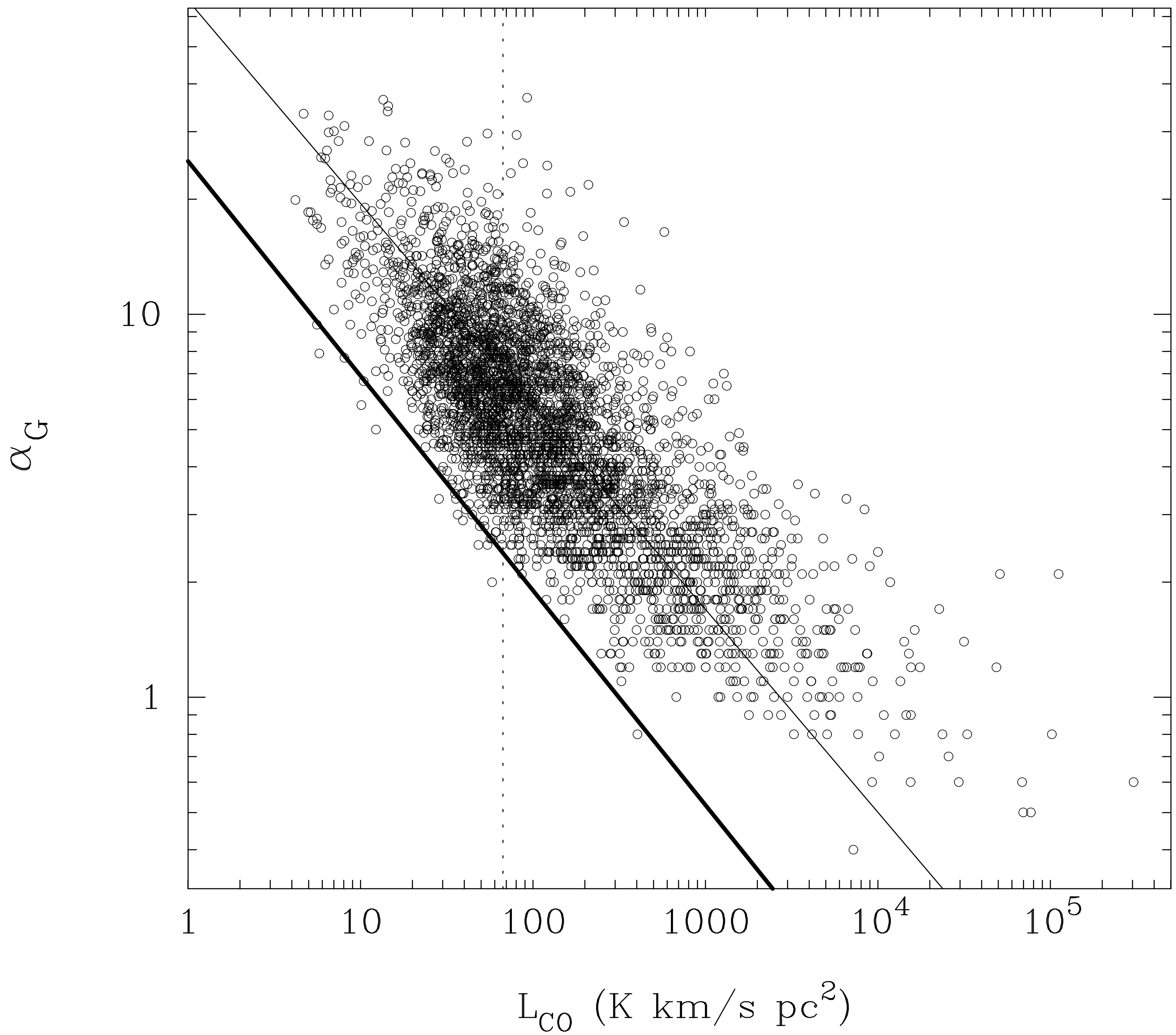
Estimating Energetics:

$$\alpha_{\rm VIR} = \frac{2U_{kin}}{U_{grav}} = \frac{5\sigma_v^2 R}{GM}$$ B=0; uniform density profile

$$M = \alpha_{\rm CO} L_{\rm CO}$$ assume an X factor

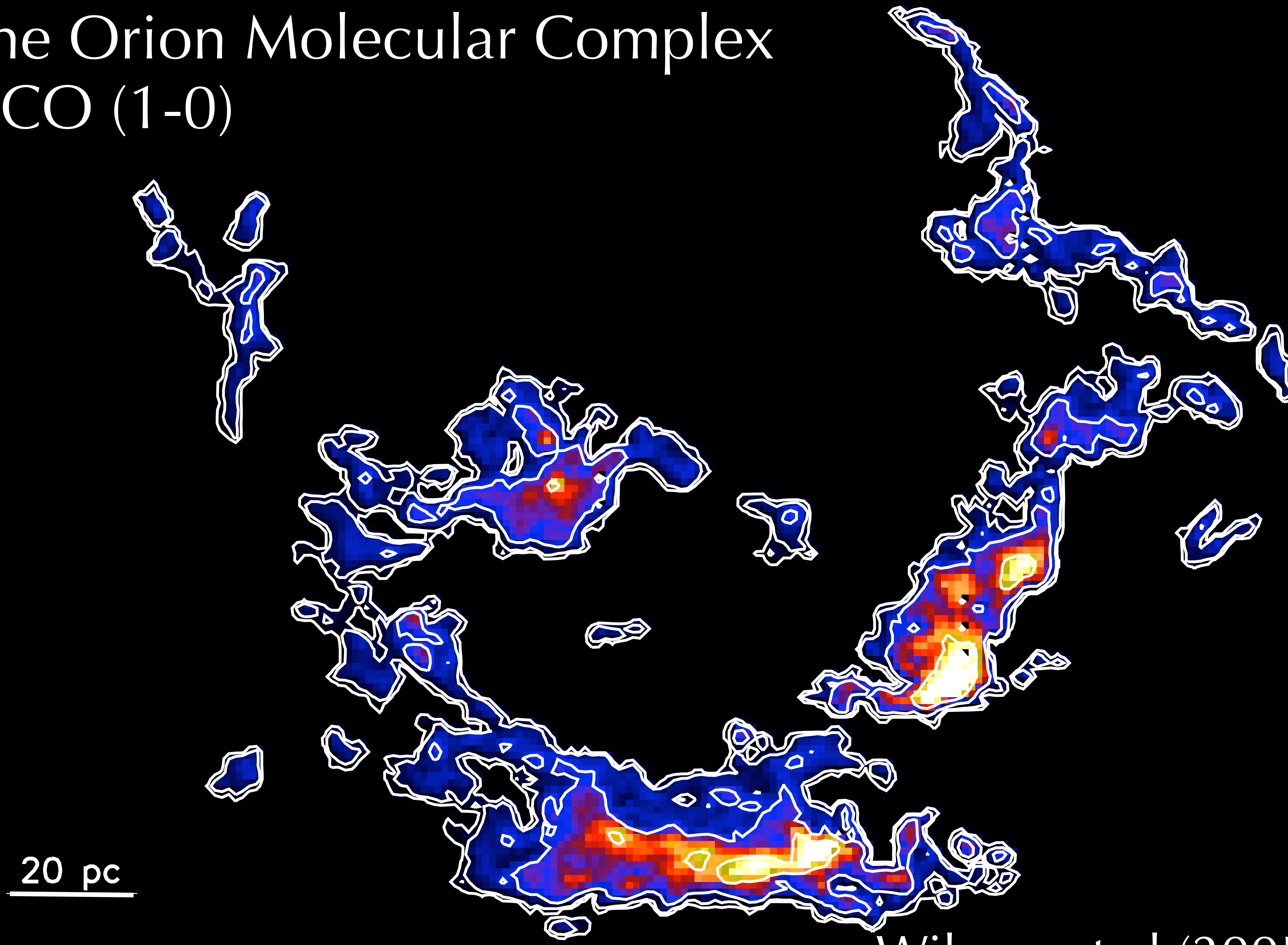


Regions from simple connectivity Outer Galaxy Survey in ^{12}CO (1-0)

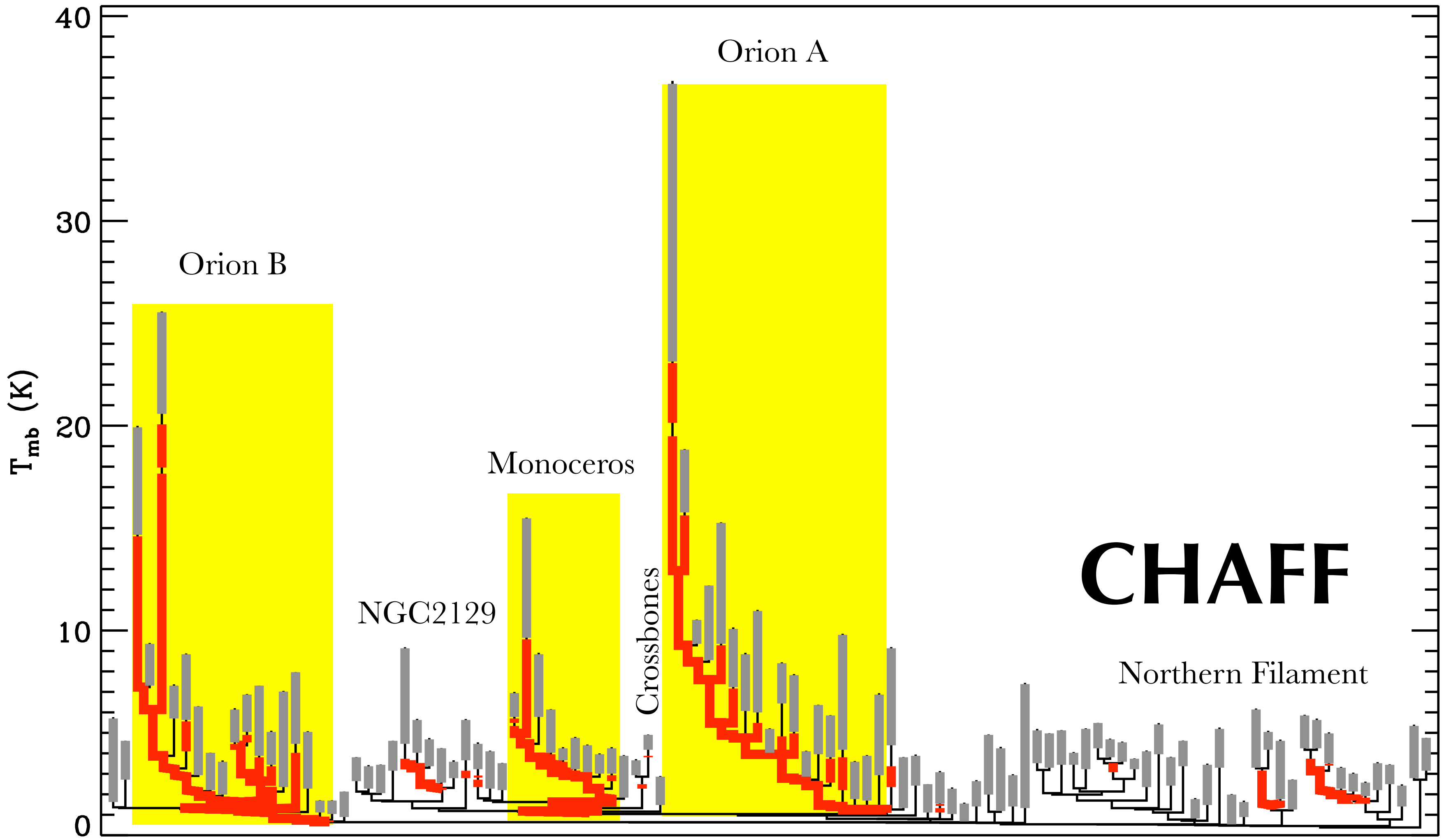


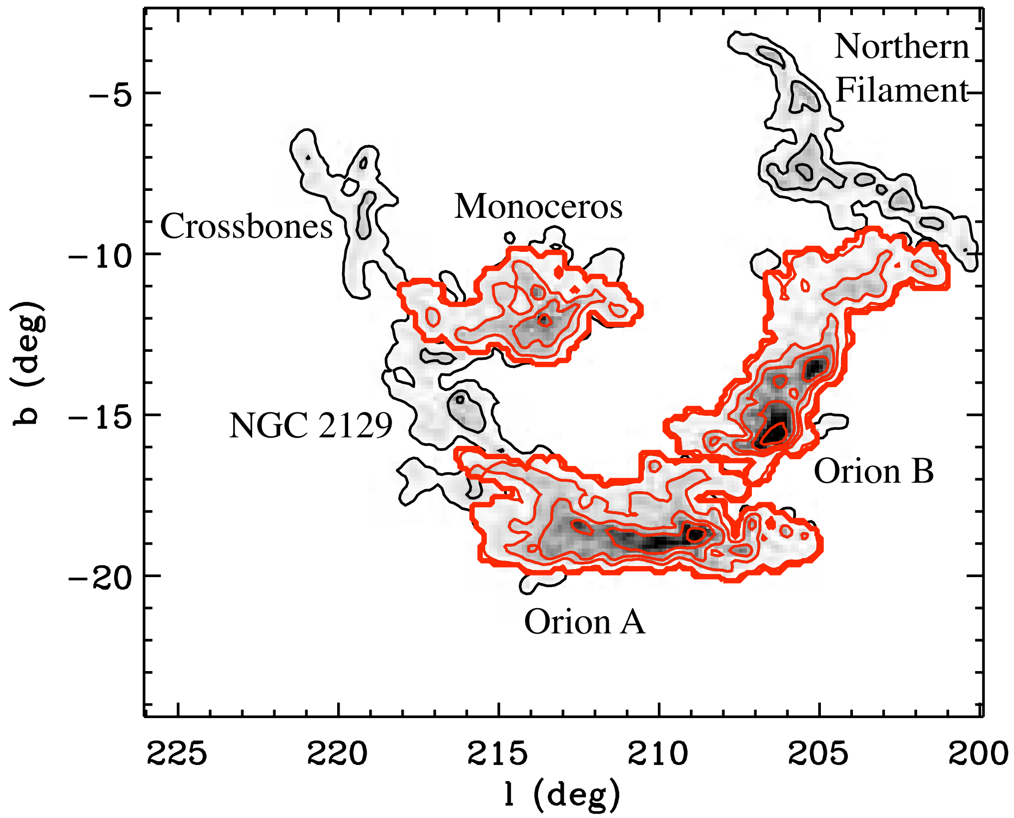
Heyer+ (2001)

The Orion Molecular Complex
^{12}CO (1-0)



Wilson, et al.(2005)



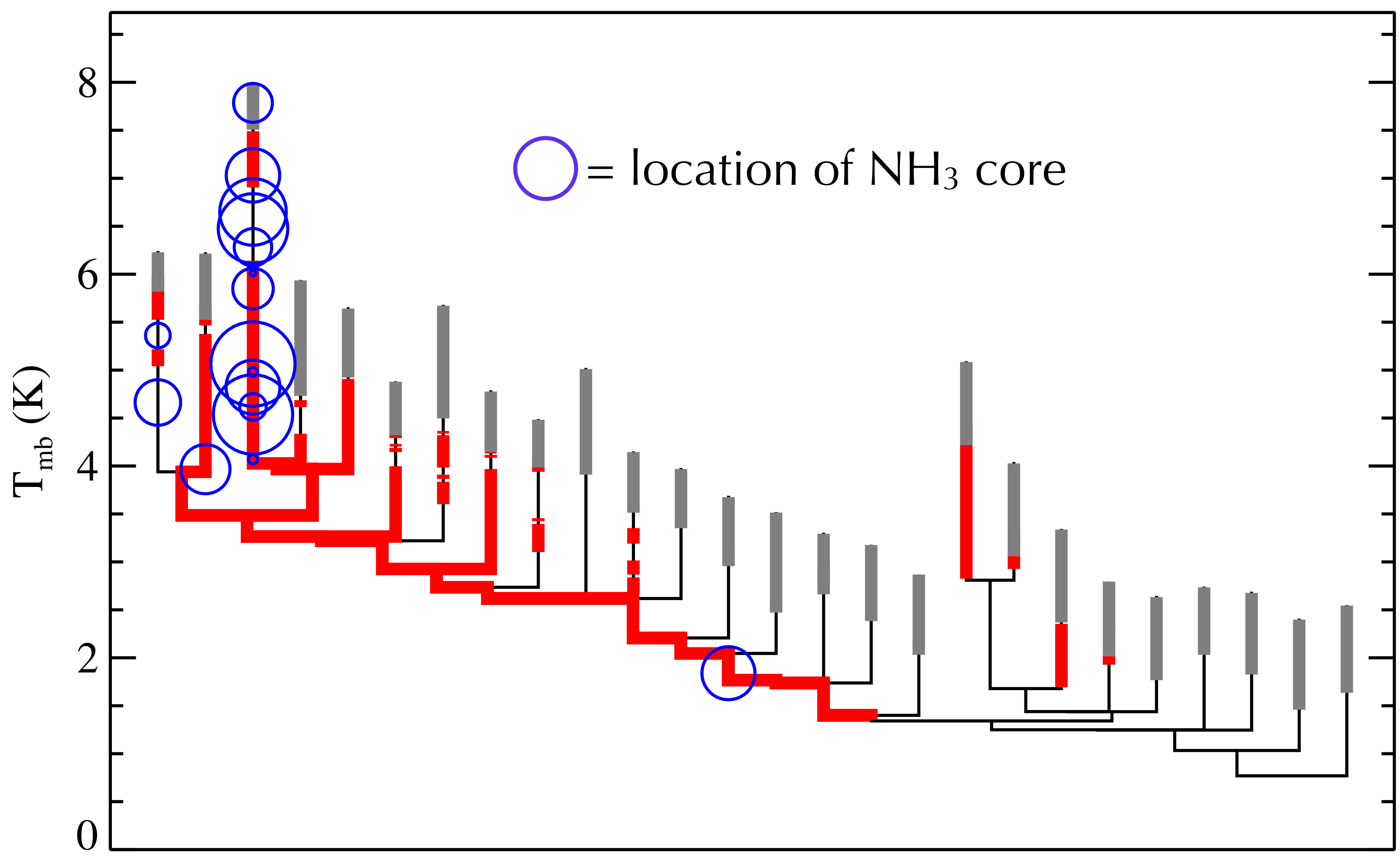


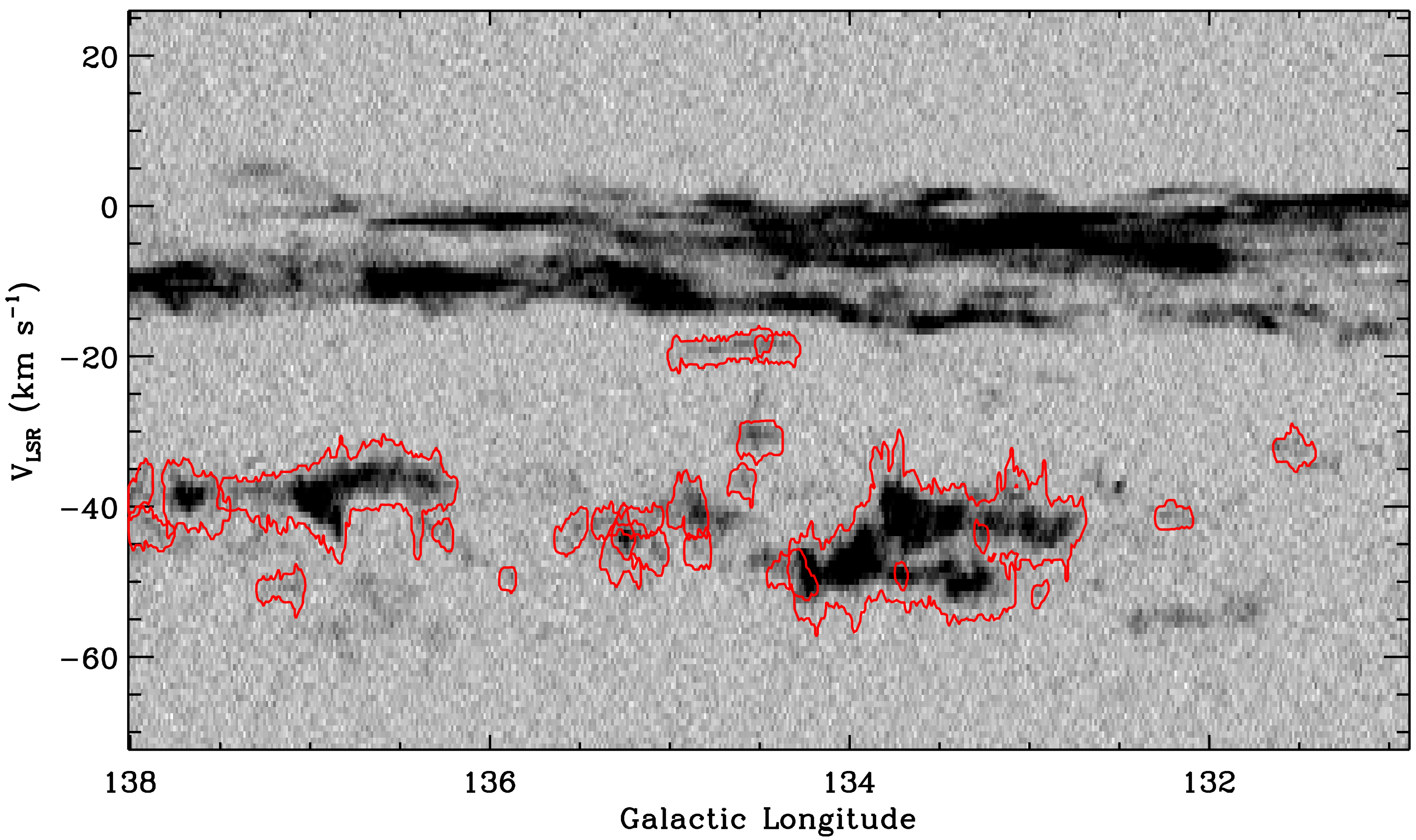
Identifying GMCs in blended data using self-gravitation

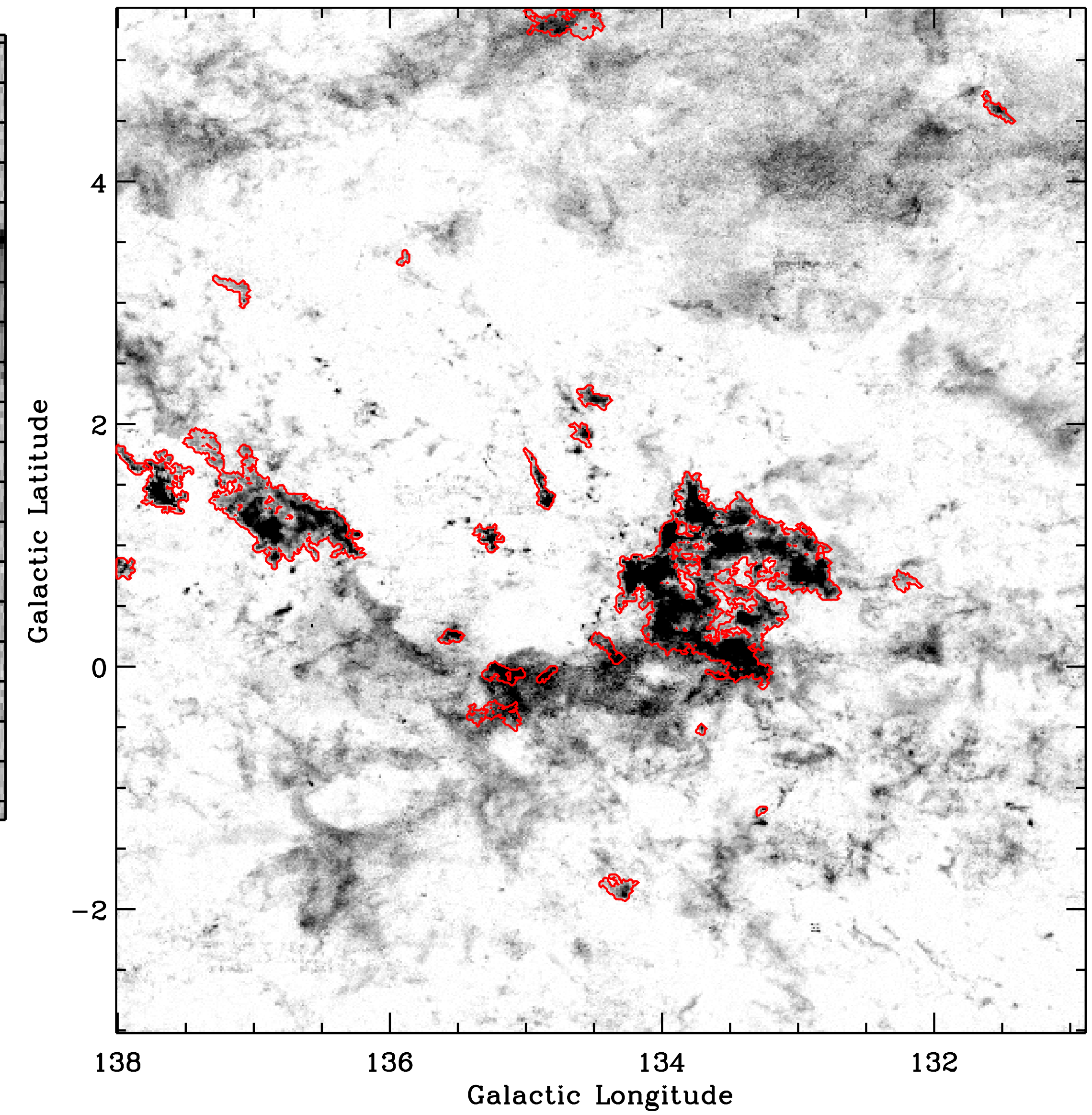
Use extrapolation to 0 K to establish properties.

Rosolowsky et al. (2008)

Dense gas is found where there is gravity



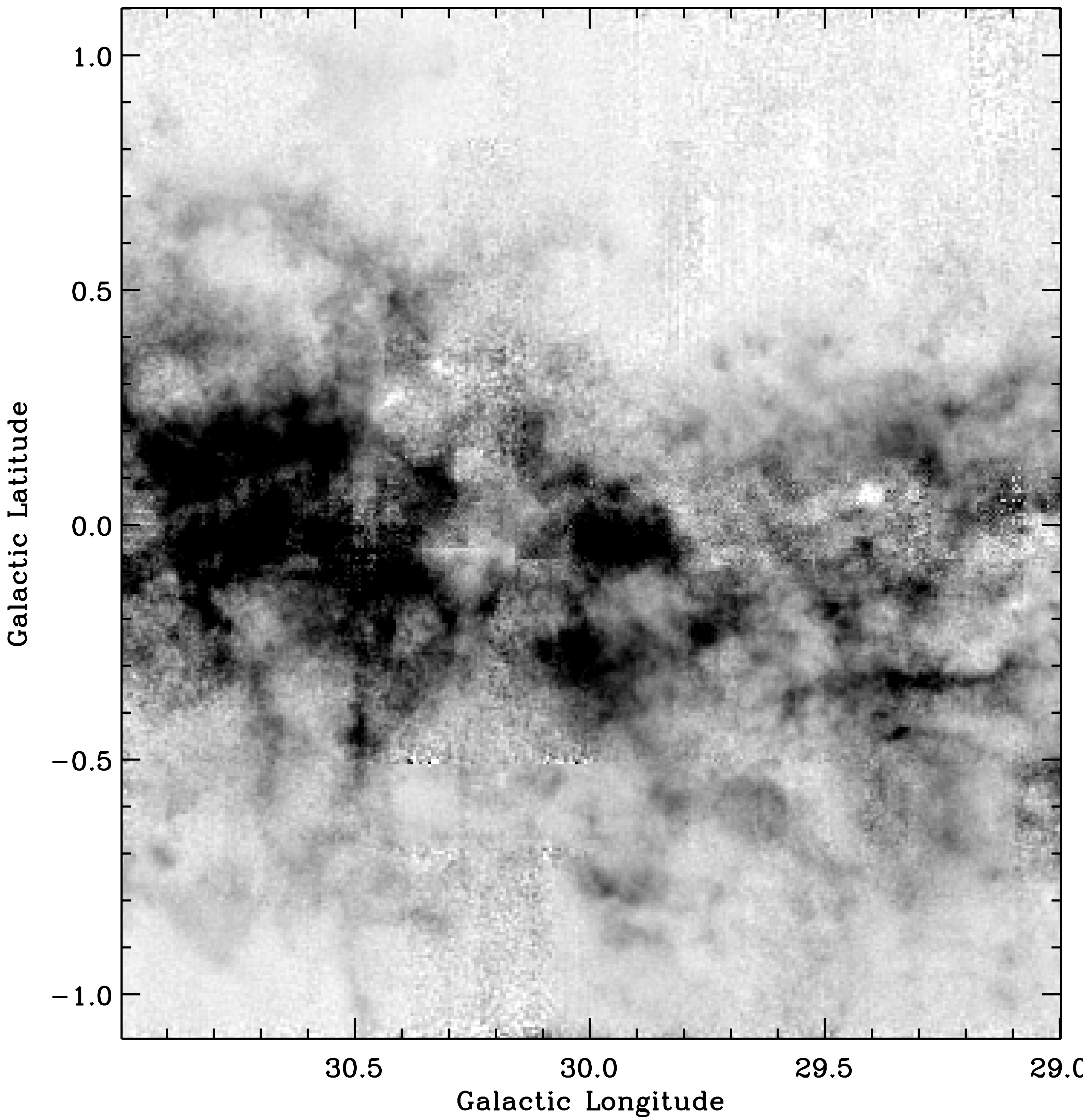




Bound structures in the OGS

Kinematic distances to non-local regions.

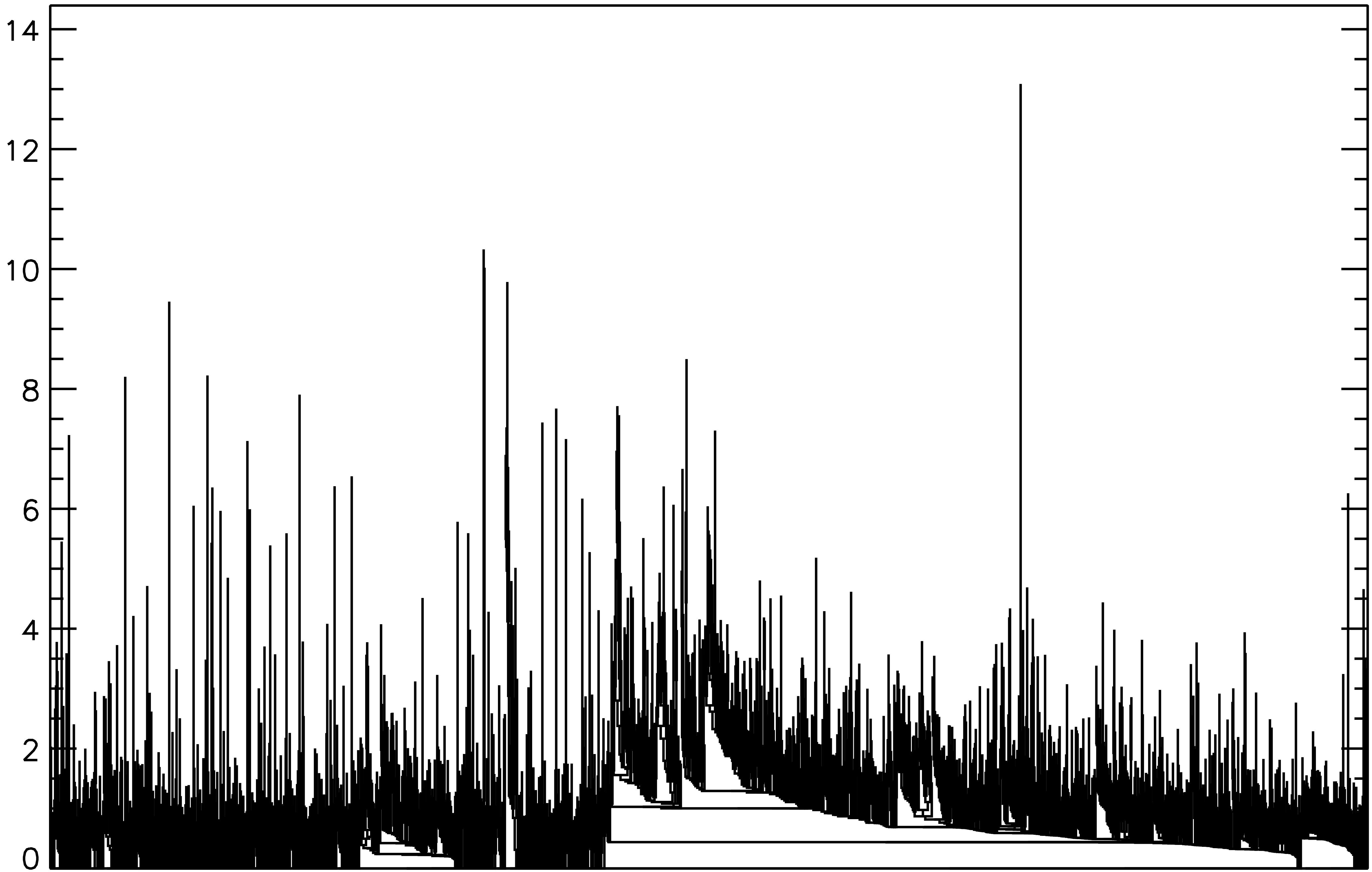
BU-FCRAO Galactic Ring Survey



^{13}CO (1-0)

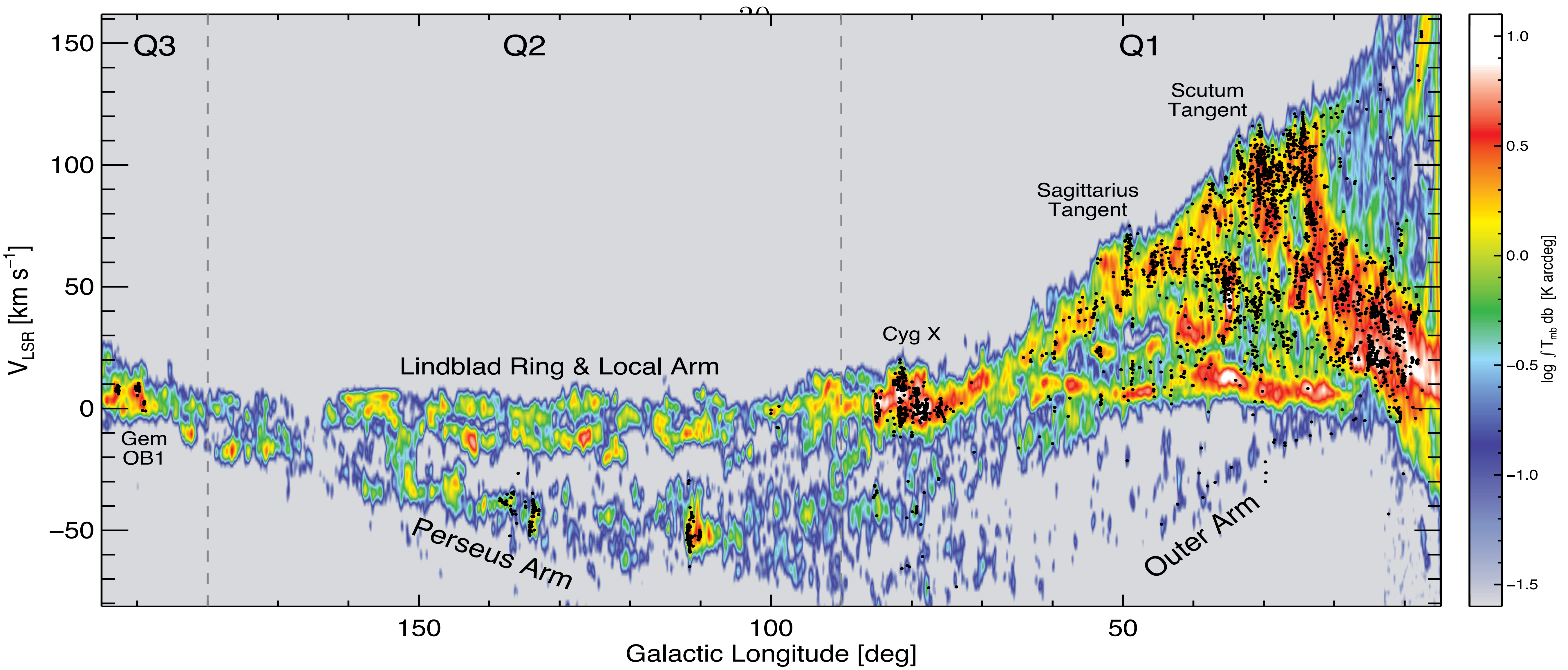
45″ Resolution
vs.
8.4′ for CfA Telescope

Jackson+ (2006)



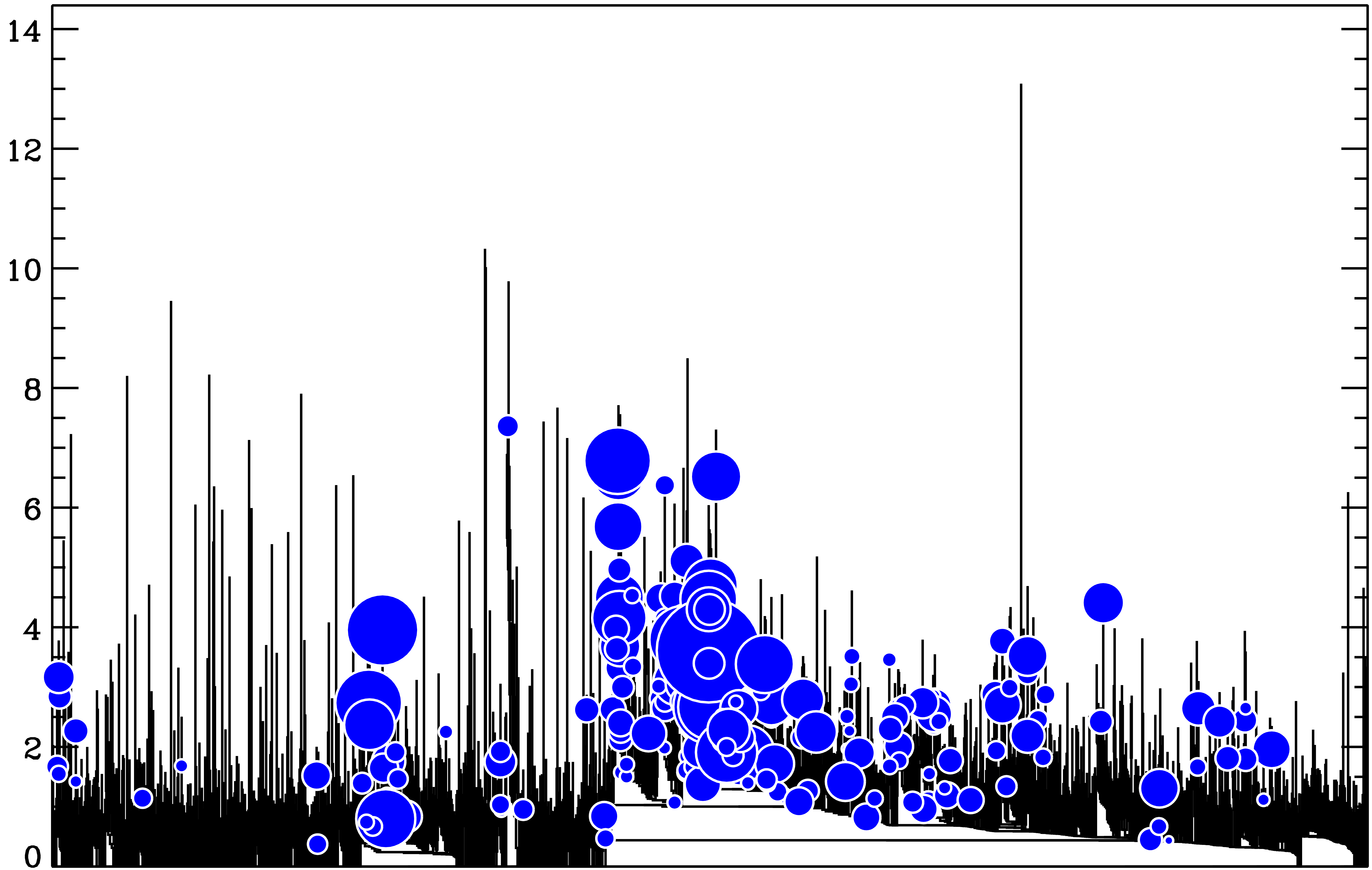
14
12
10
8
6
4
2
0

Dense gas spectroscopy of high column sources



3126 HCO^+ (3-2) or $N2H^+$ (3-2) detections

Shirley+BGPS (submitted)



14
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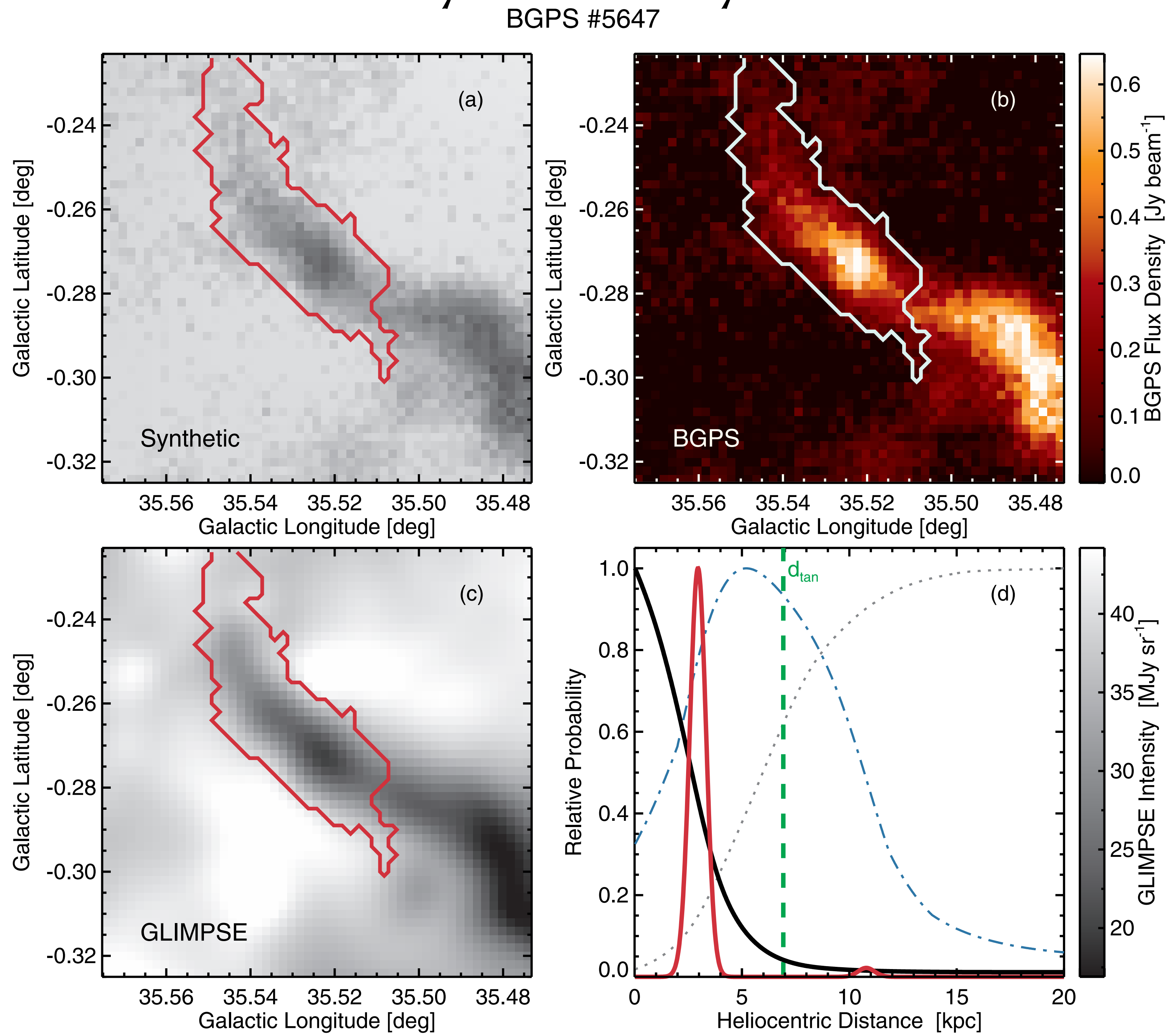
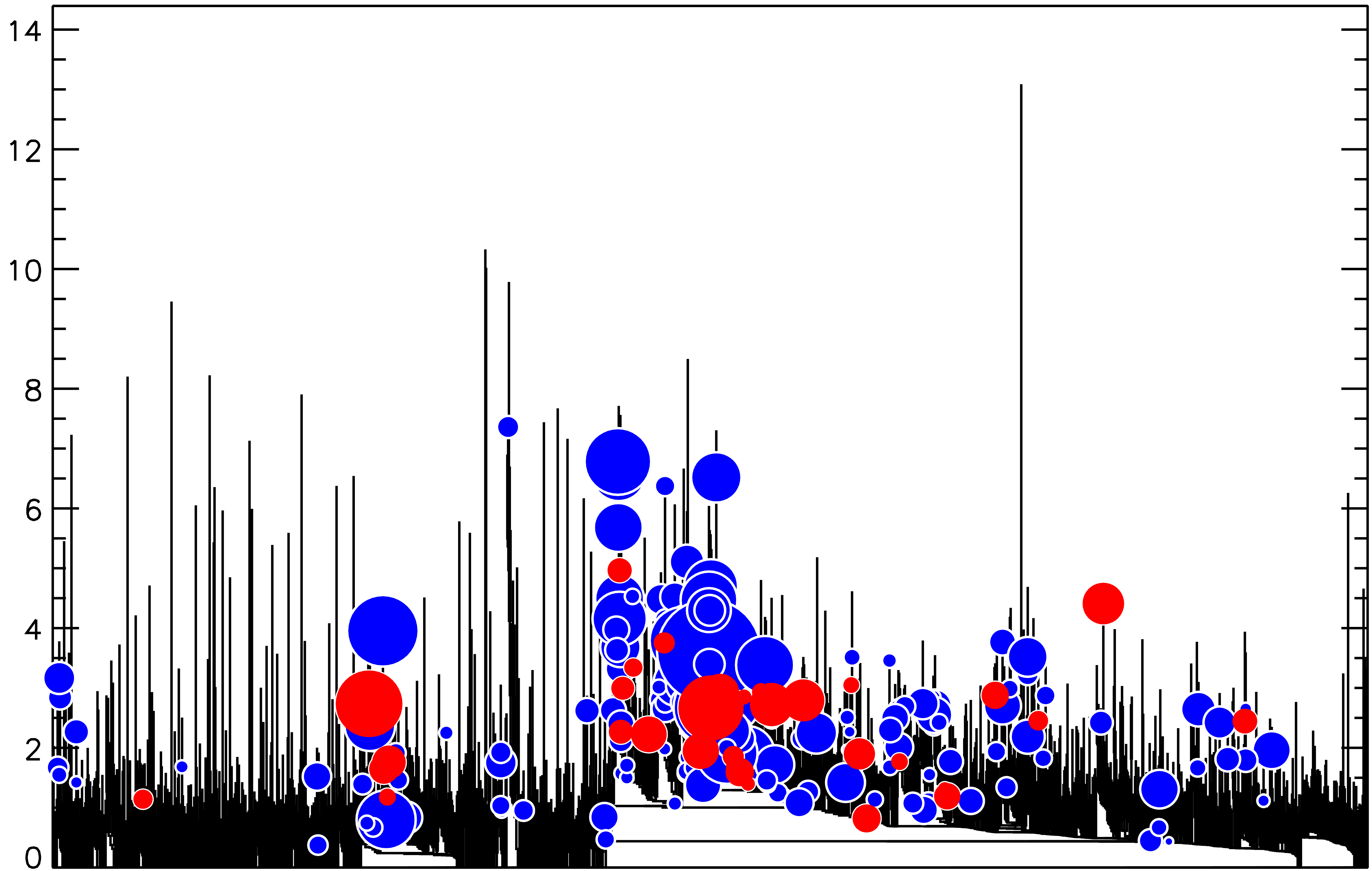
2
0

Distance Probability Density Functions (DPDFs)



Bonus finding: 10% of IRDCs at far distance.

Ellsworth-Bowers+BGPS (2013)



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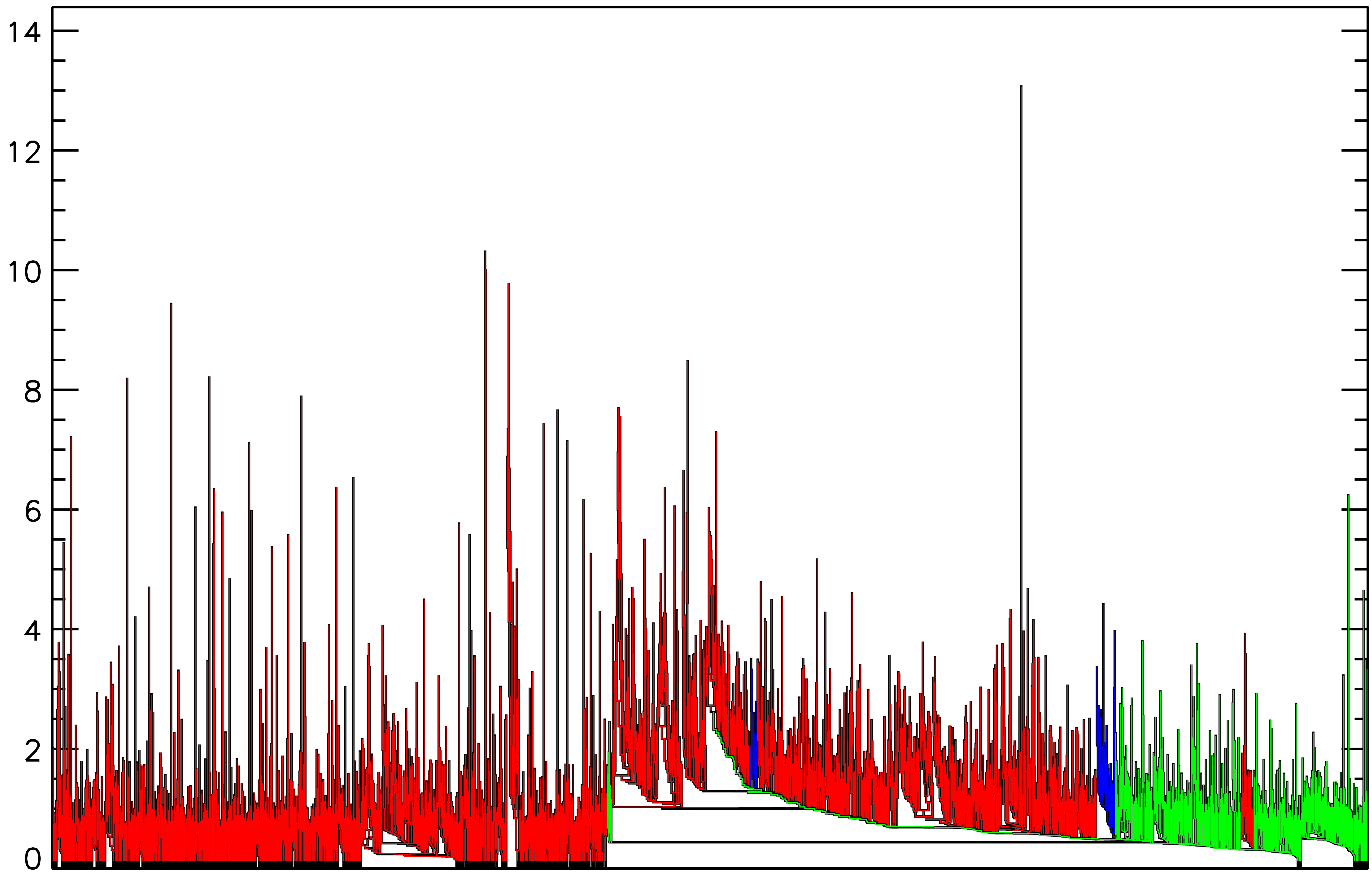
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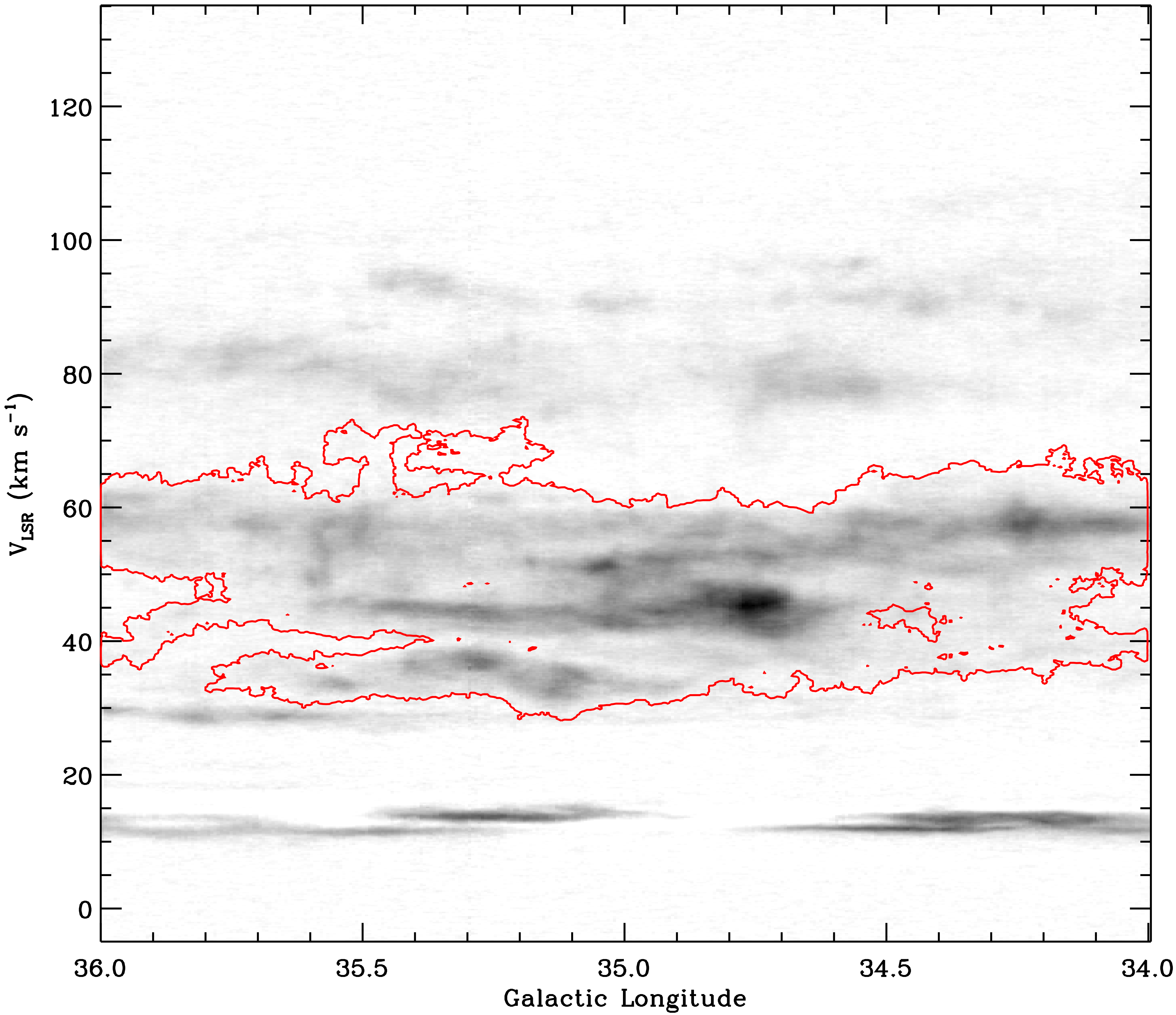
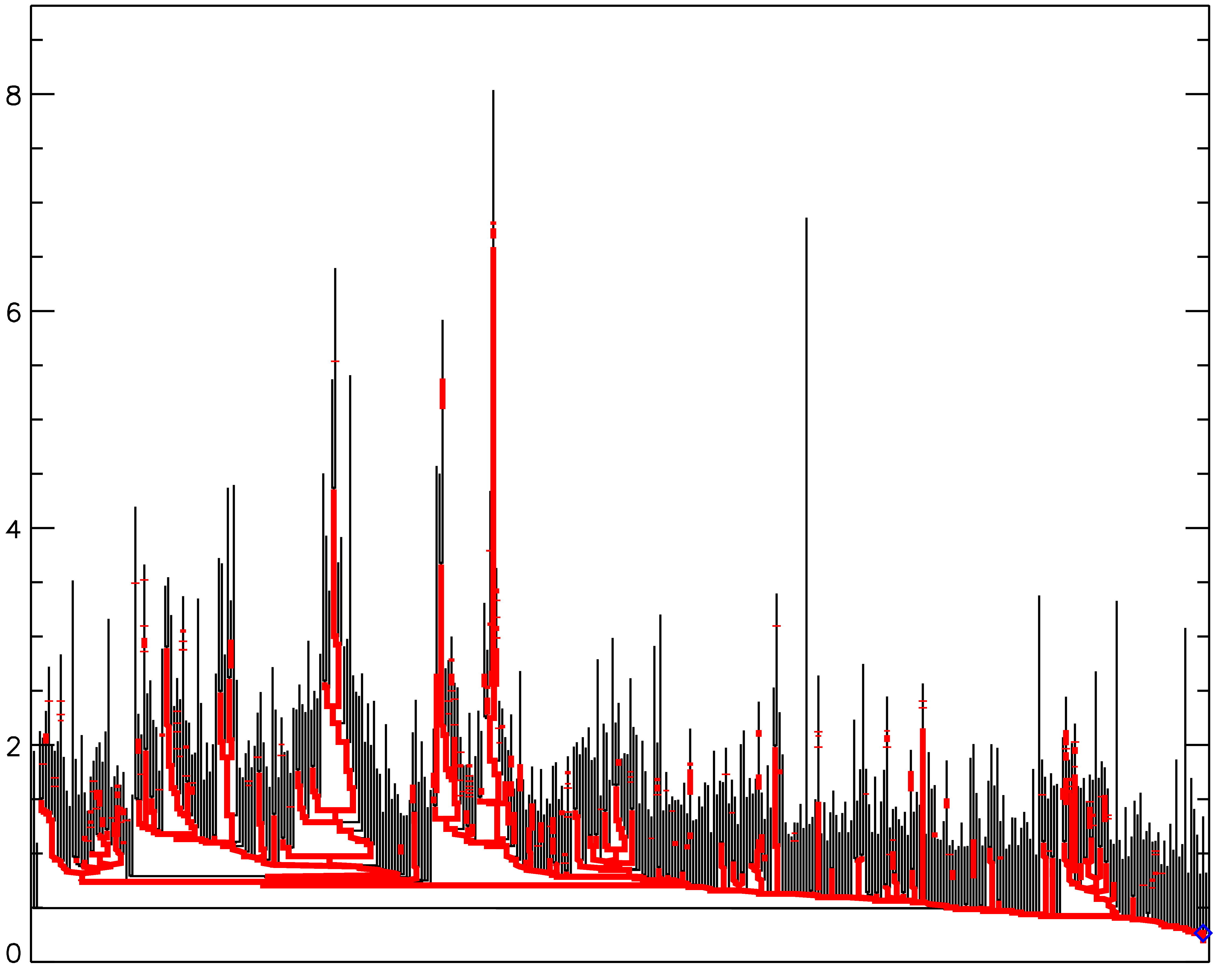
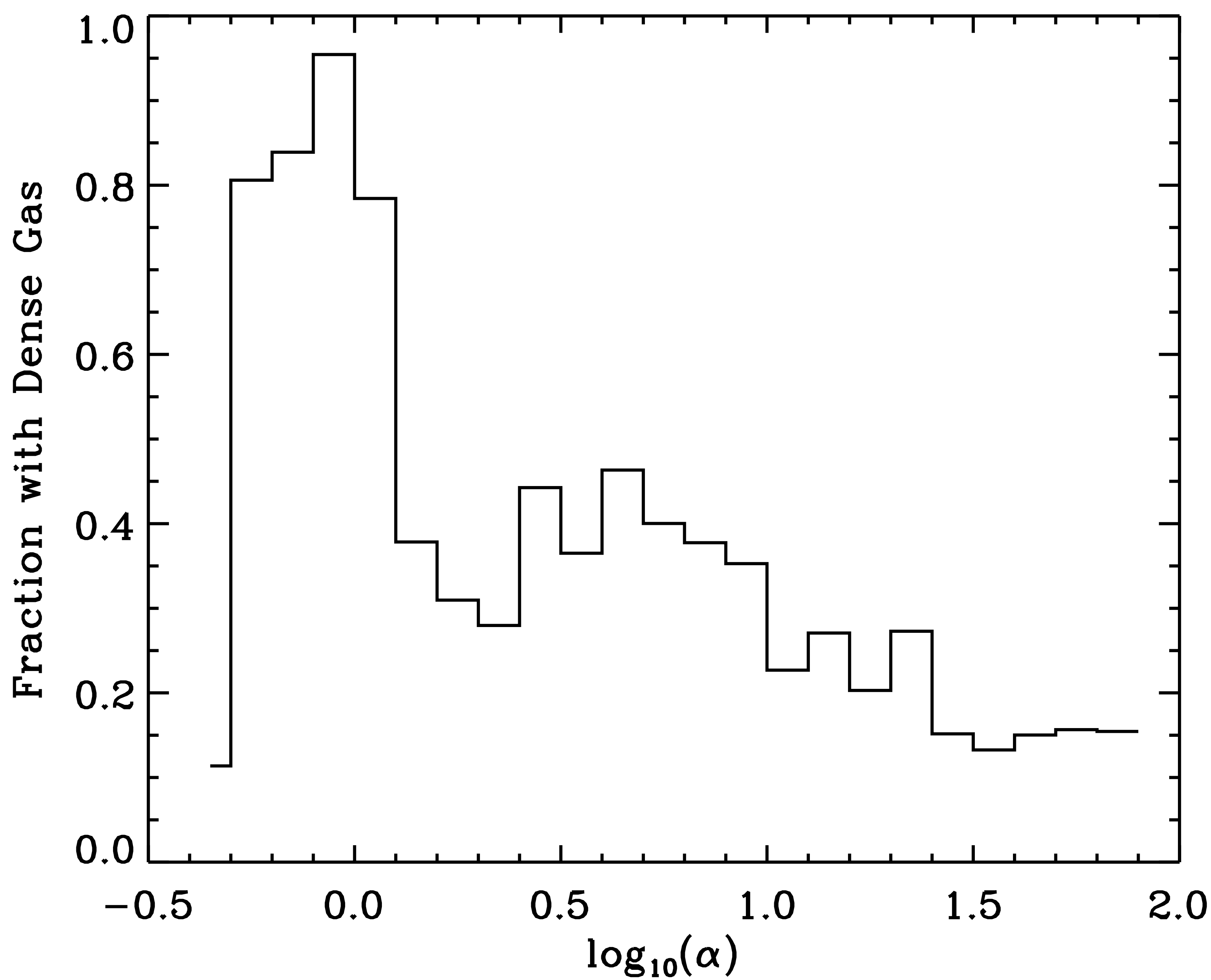


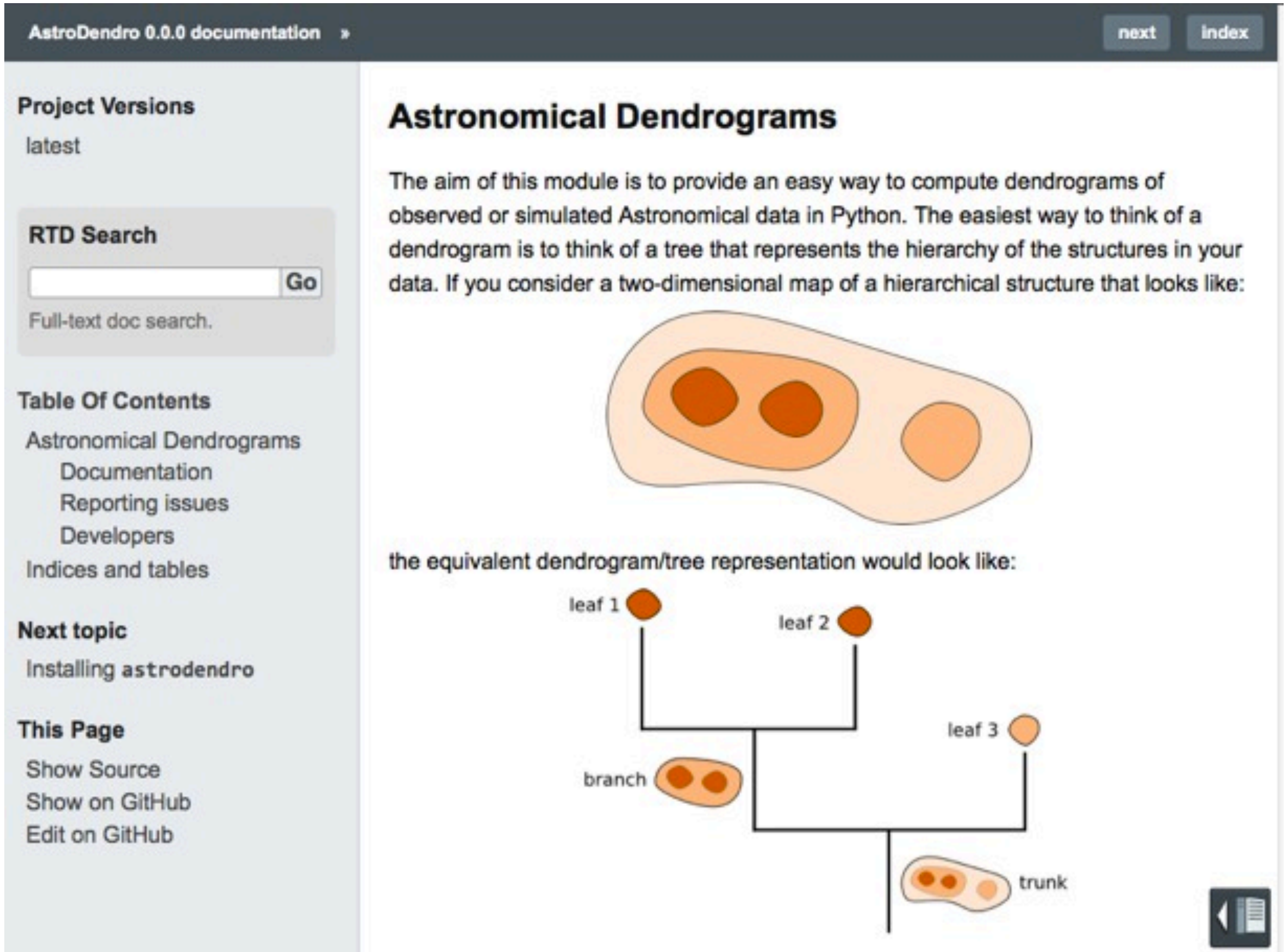
120
100
80
60
40
20
0
V_{LSR} (km s^{-1})
36.0
35.5
35.0
34.5
34.0
Galactic Longitude



8
6
4
2
0

Low virial parameter predicts for dense gas.





dendrograms.org

A Fast Python Implementation

by
Tom Robitaille
Chris Beaumont
Braden MacDonald

Tom Robitaille is happy to help you try out **`astrodendro`** this week

Dendrograms:

1) offer new statistical representations of the molecular ISM.
2) provide a channel for a physically-motivated decomposition of blended emission.
3) offer agile navigation of complicated emission structure.