Trunks, branches and leaves: understanding the early stages of star formation by applying tree diagrams to molecular line data.

John Alexander Pena Lopez

From Gas to Stars: The Links between Massive Star and Star Cluster Formation

Yorkshire Museum, York UK - 18/9/19

SFM STARFORMMAPPER

AstroJLo

Setting the scene…

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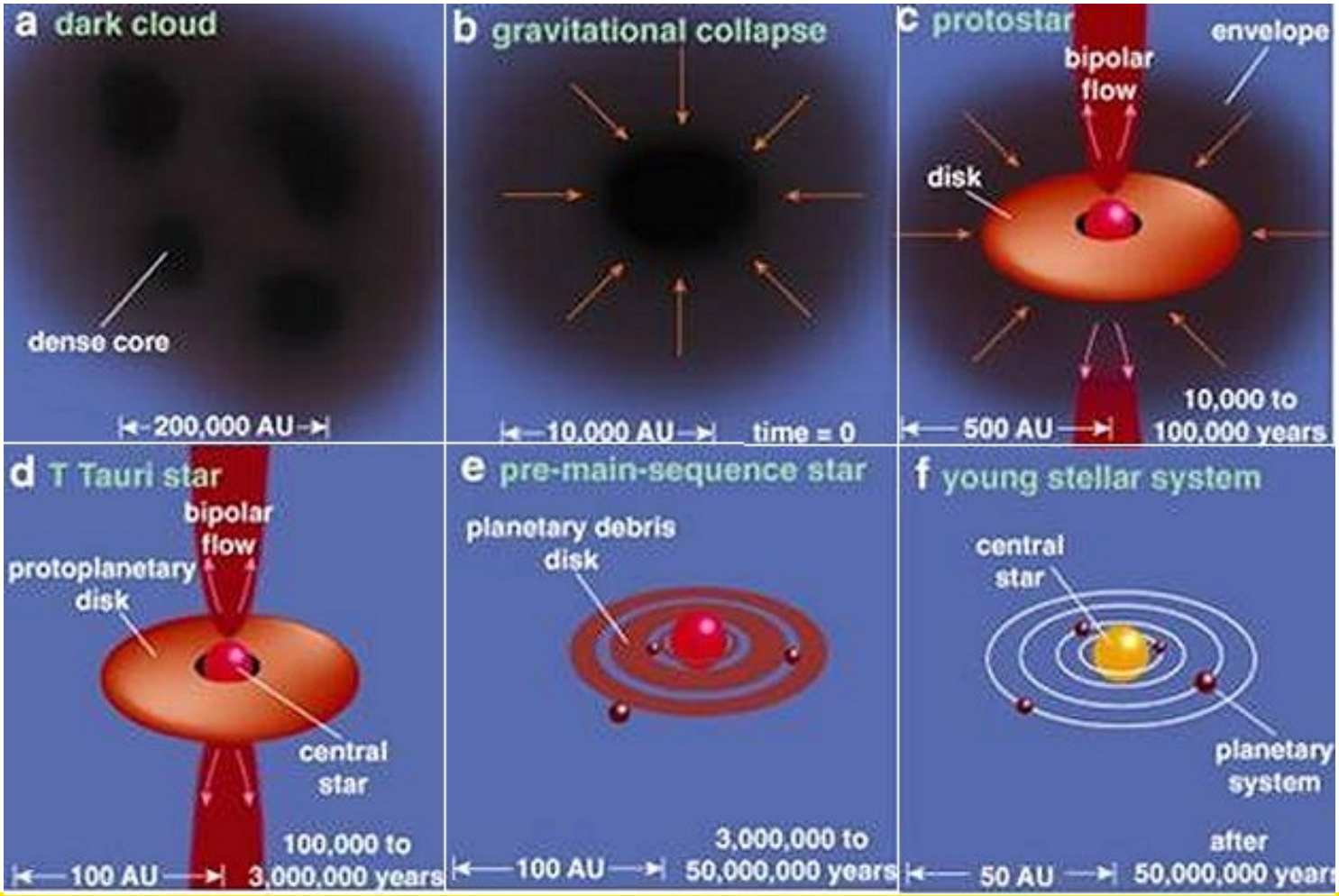
Star formation, briefly:

- A lot of gaps exist in our knowledge!
- High- vs. low-mass star formation.



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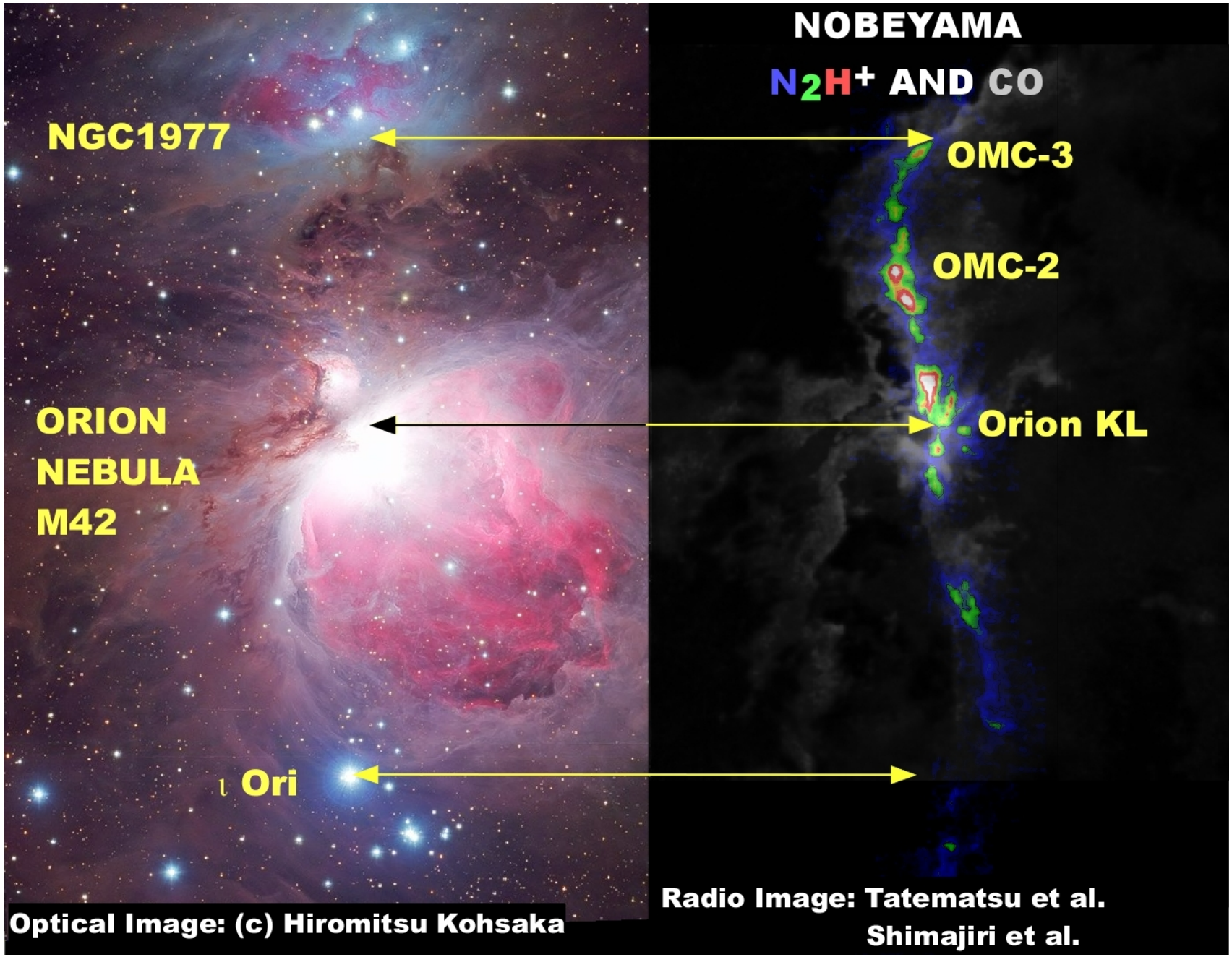
NOBEYAMA
N_2H^+ AND CO
NGC1977
OMC-3
OMC-2
ORION
NEBULA
M42
Orion KL
ι Ori
Optical Image: (c) Hiromitsu Kohsaka
Radio Image: Tatematsu et al.
Shimajiri et al.

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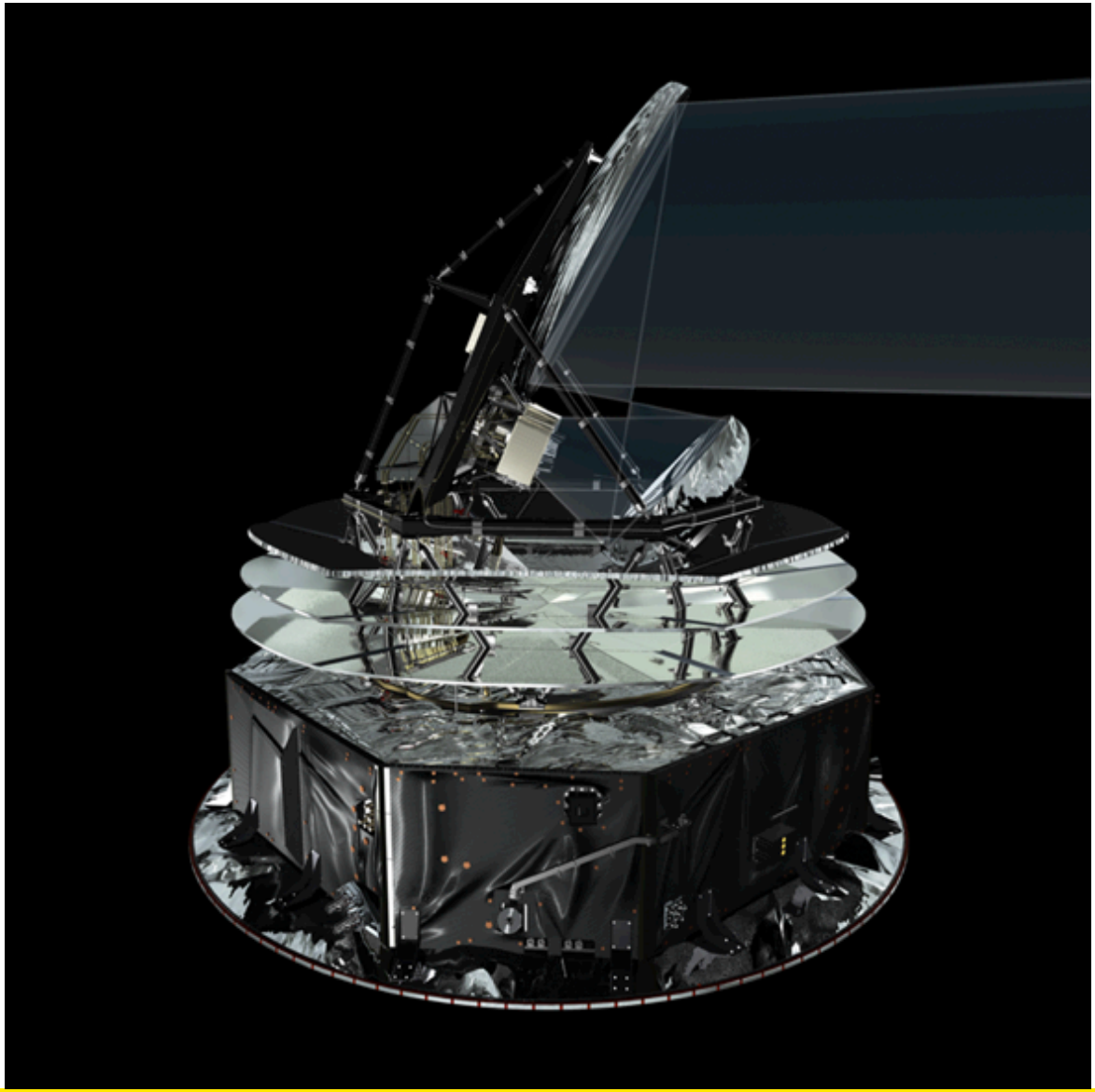
The *Planck* satellite and telescope:



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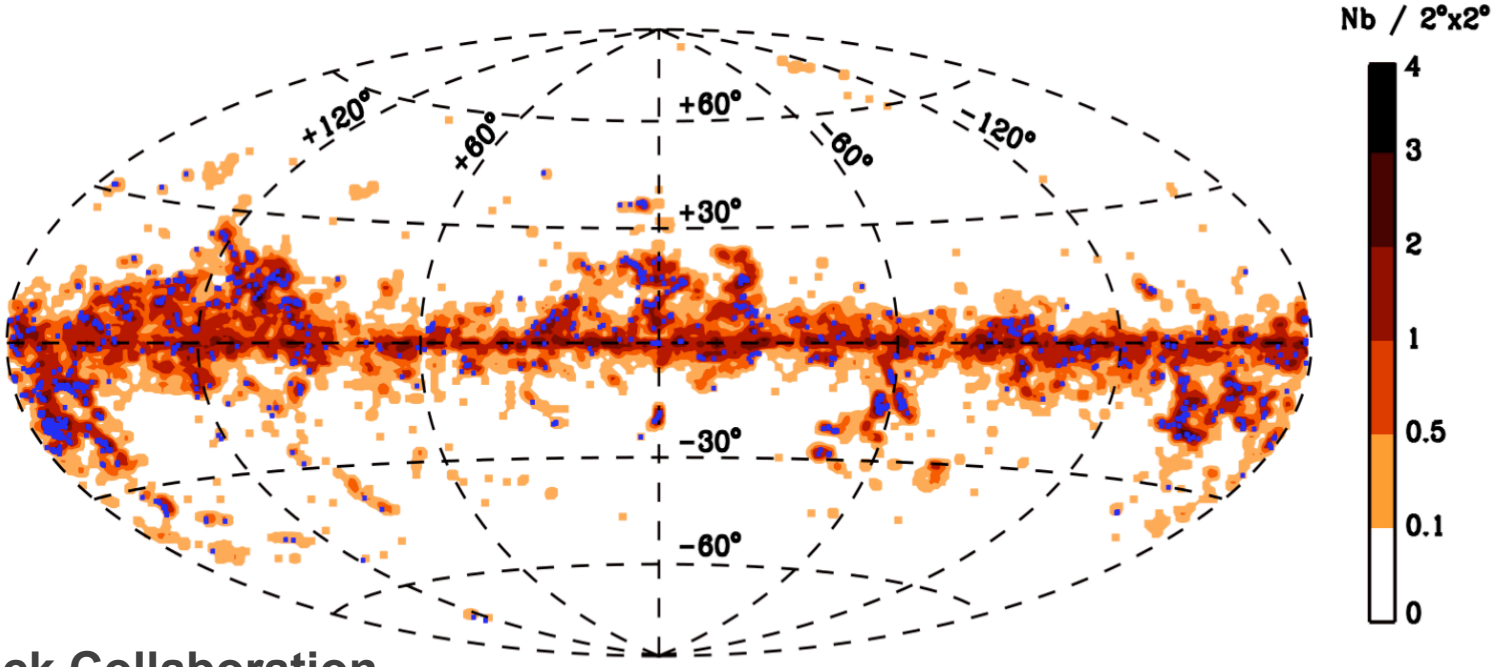
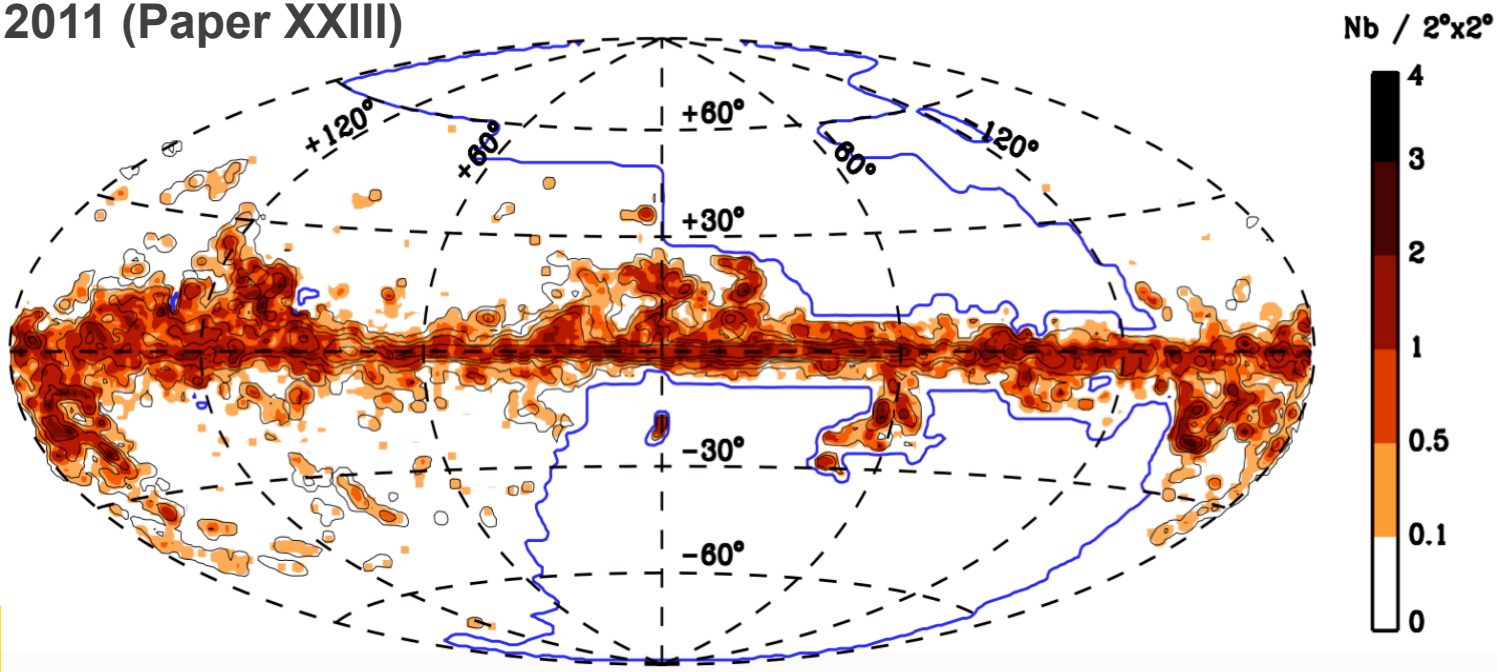
Planck Collaboration et al. 2011 (Paper XXIII)



Cold Clump Density Map



CO contours on Cold Clump Density Map

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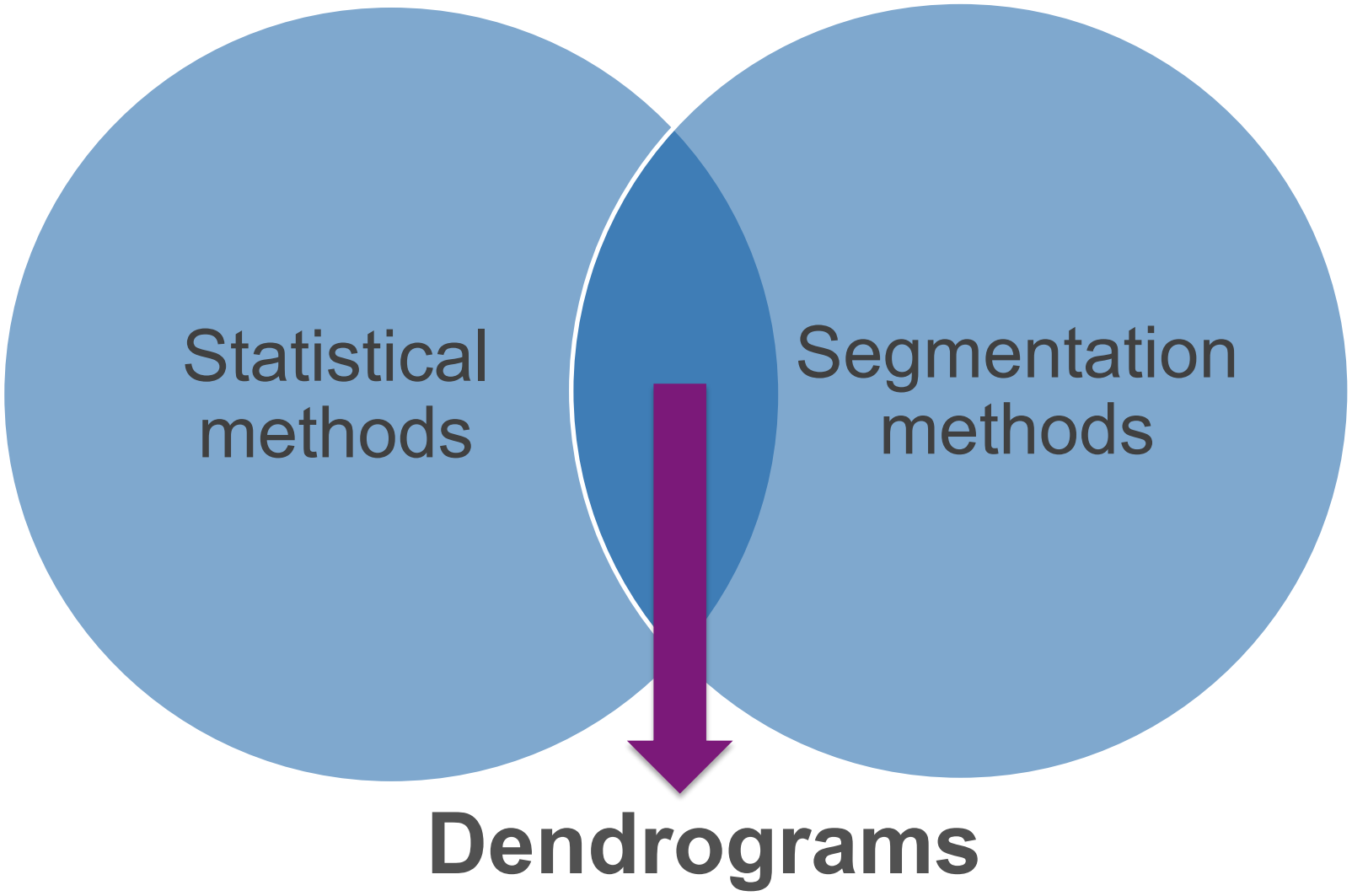
What telescope and data am I working with?

- 674 sources.
- Beam size: 56” @ 115 GHz.
- Observations of ^{12}CO, ^{13}CO and $C^{18}O$ (all J = 1-0).
- Velocity resolution: 0.16-0.17 km/s
- **Only dealing with ^{12}CO in this talk.**

Purple Mountain Observatory (PMO): Qinghai Station (China)

How do we analyse molecular clouds?



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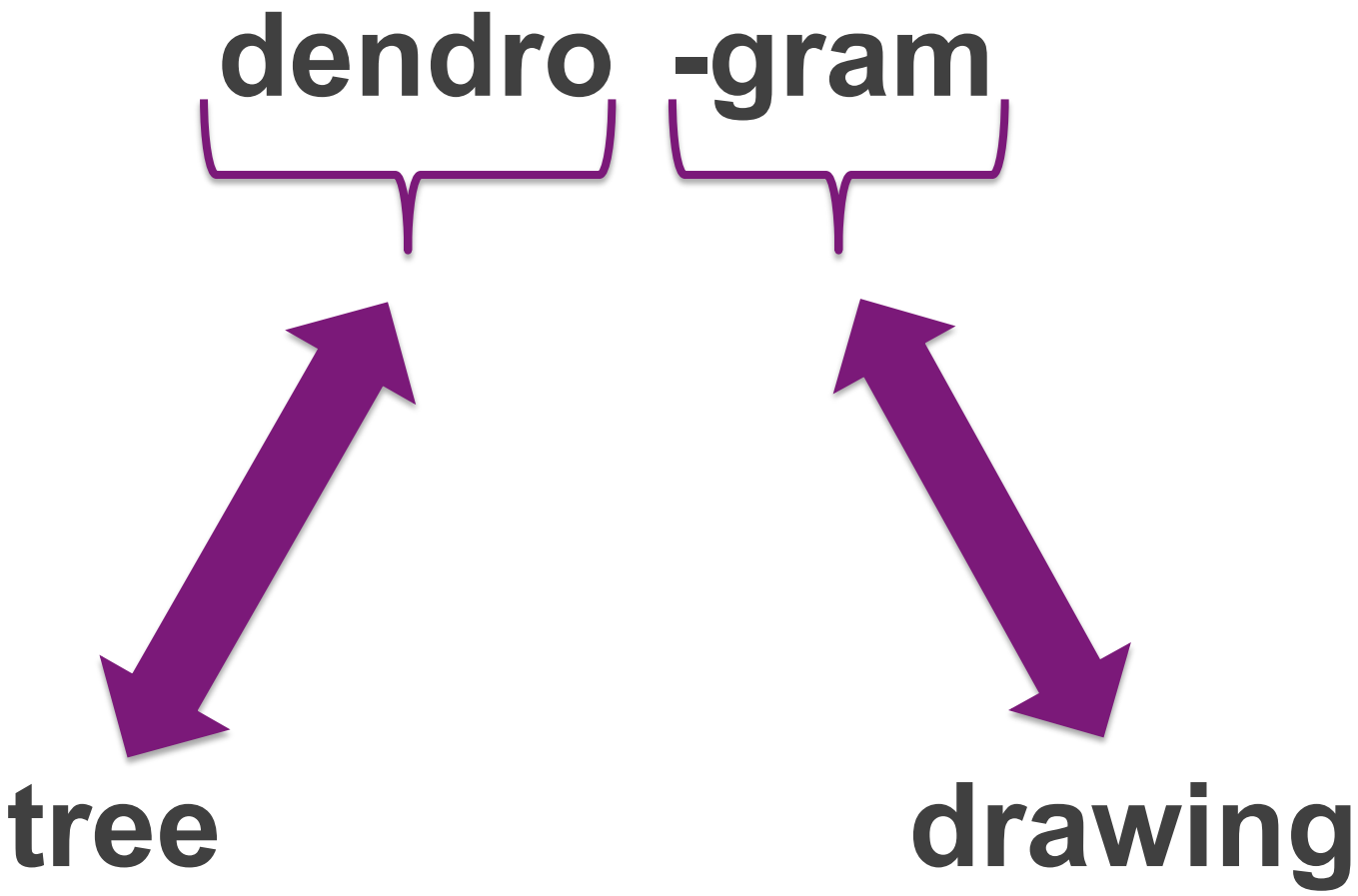

Dendrogram = tree diagram

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Tree diagrams?

Source: https://www.fast-growing-trees.com/products/SawtoothOak

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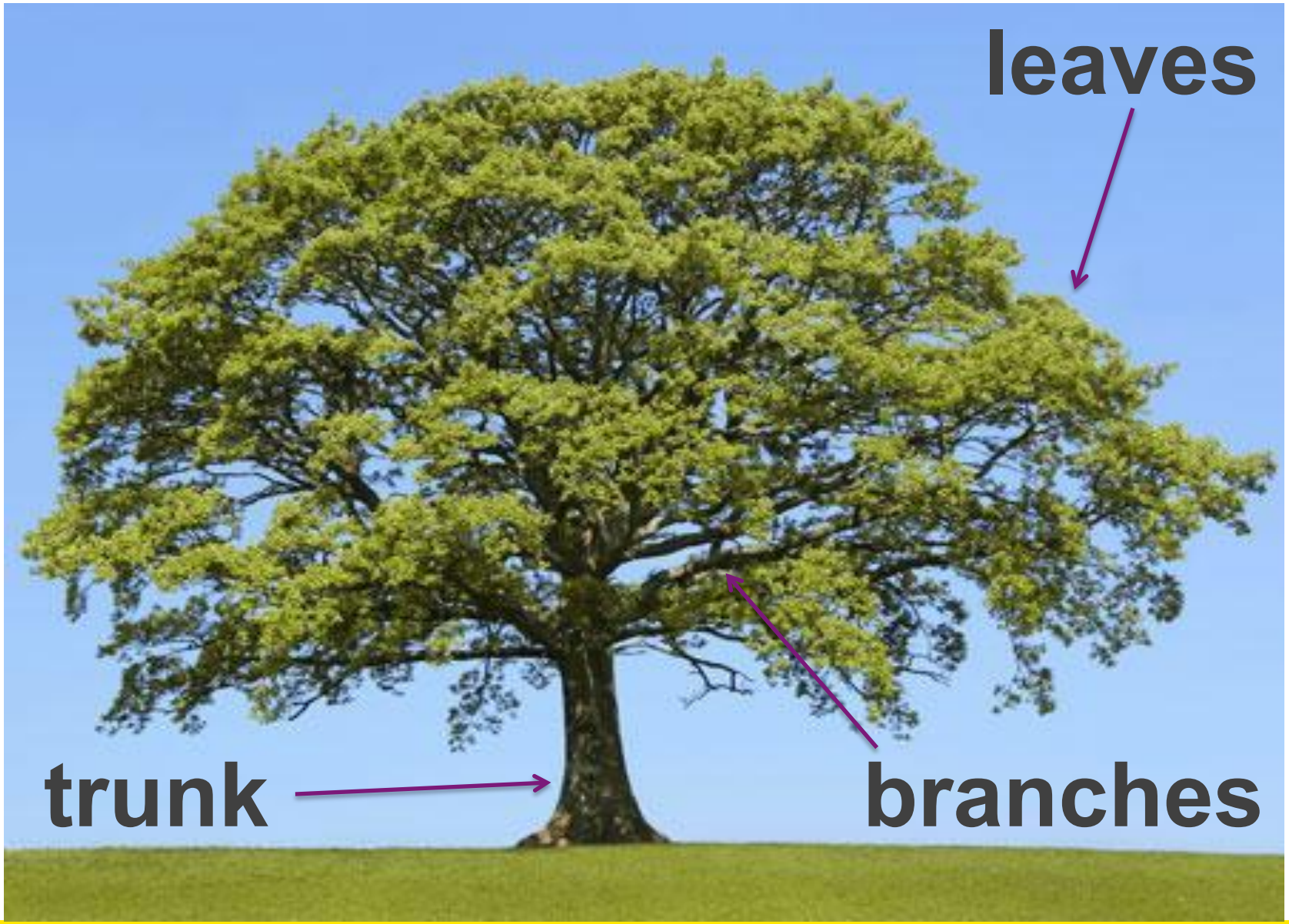

Source: https://www.fast-growing-trees.com/products/SawtoothOak

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STRUCTURAL ANALYSIS OF MOLECULAR CLOUDS: DENDROGRAMS

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Received 2007 November 15; accepted 2008 February 11

dendrograms.readthedocs.io/en/stable/#

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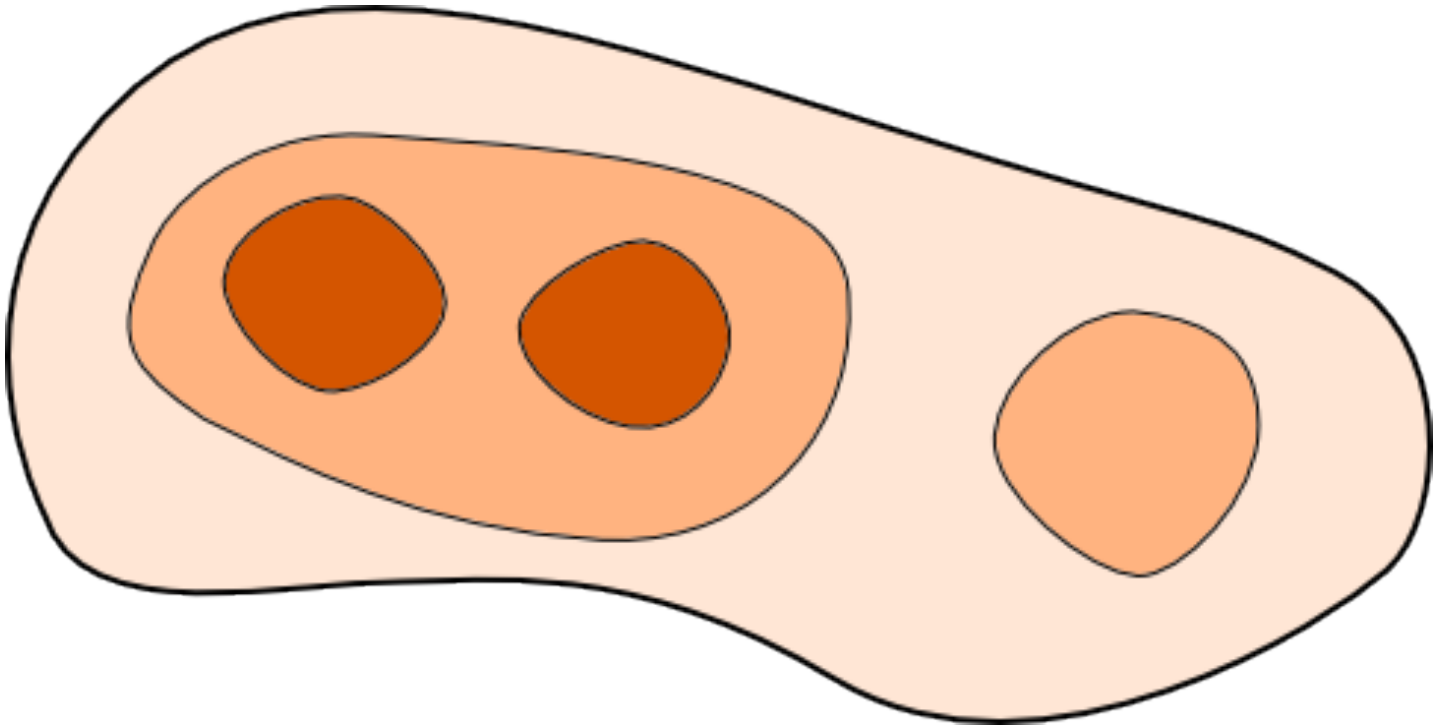
What do dendrograms look like?



Source:
https://dendrograms.readthedocs.io/en/stable/

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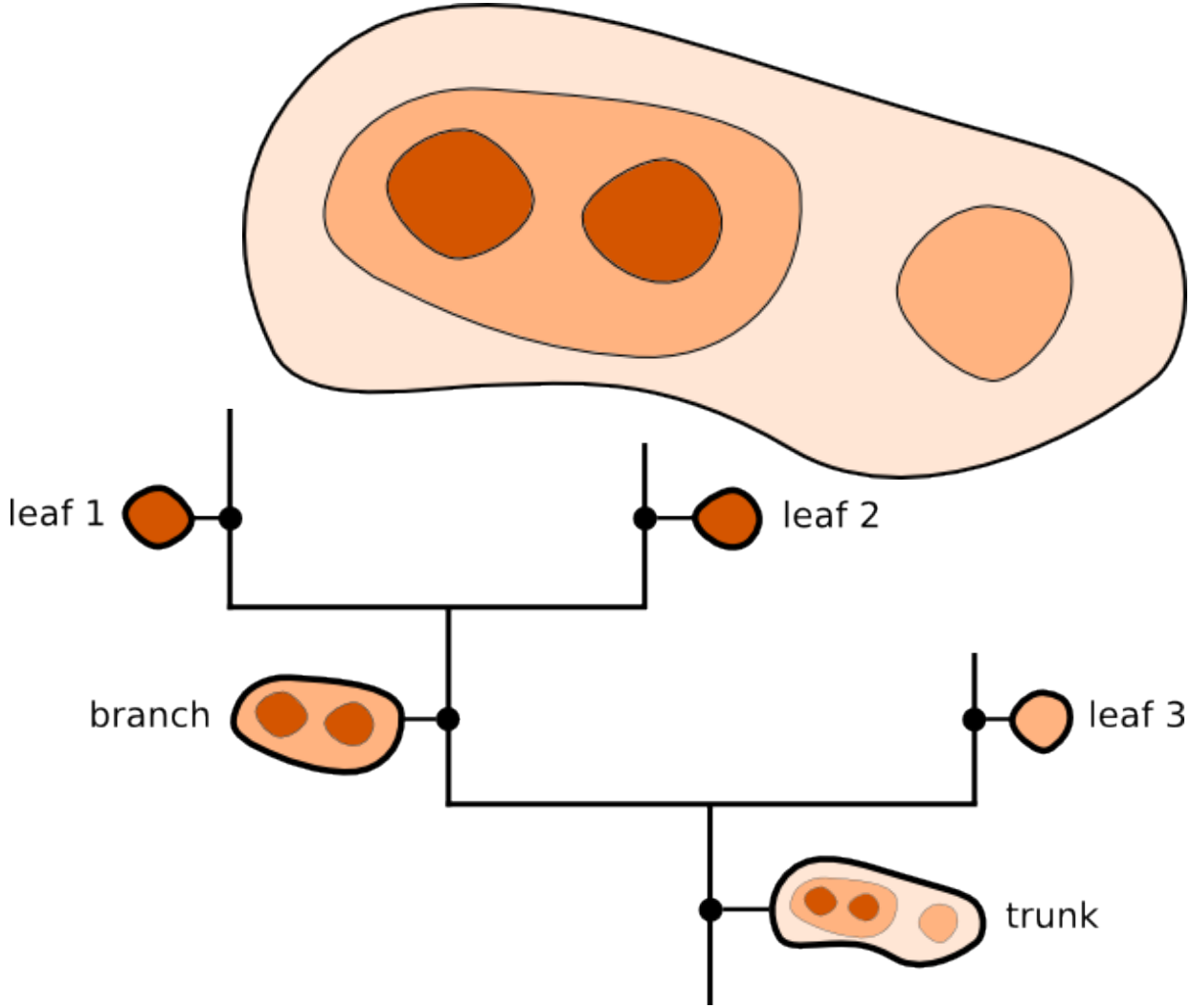
What are dendrograms?



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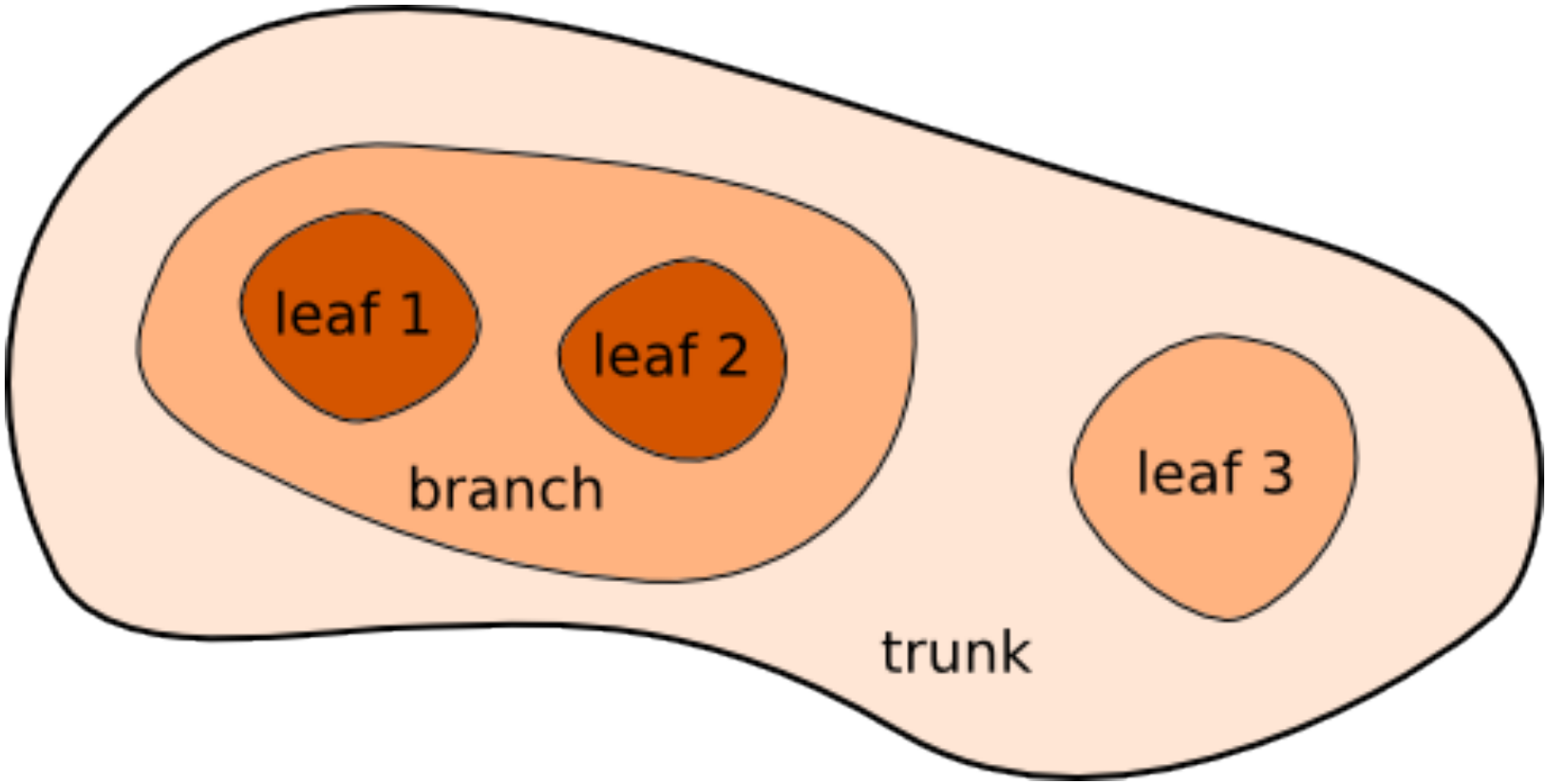
What are dendrograms?



Source:
https://dendrograms.readthedocs.io/en/stable/

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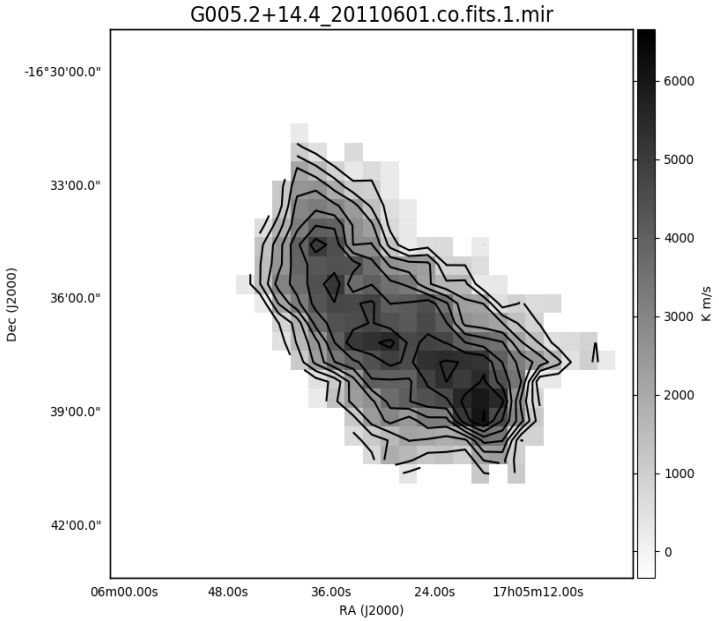
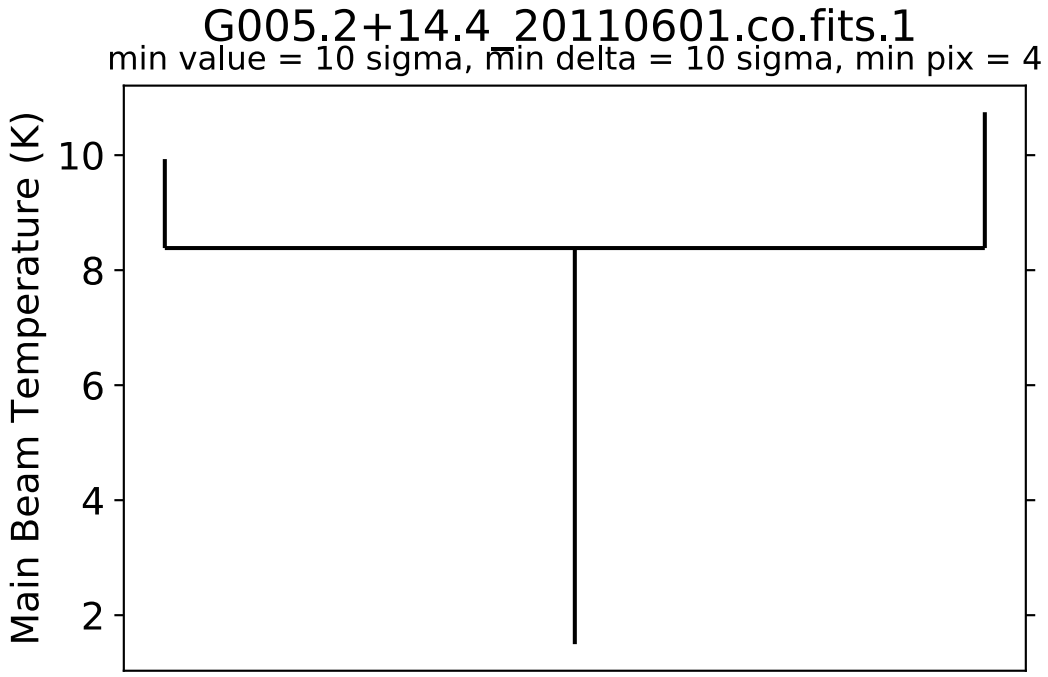
Applying the dendrogram algorithm to my dataset.

- Only 3 parameters needed to run the code:
- The algorithm was applied to the data cubes.





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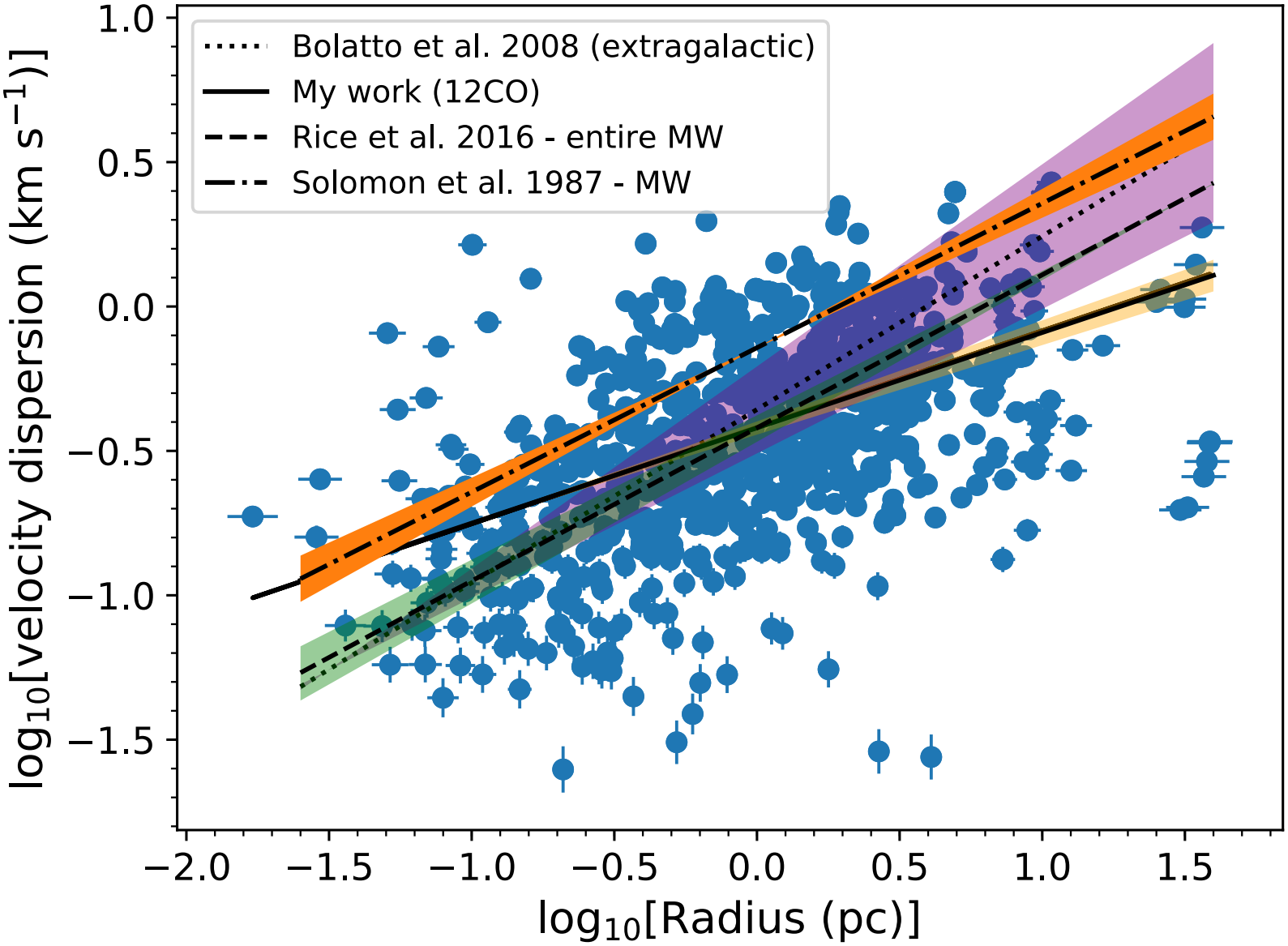
Results.

Larson's 1st law (σ_v vs. R)



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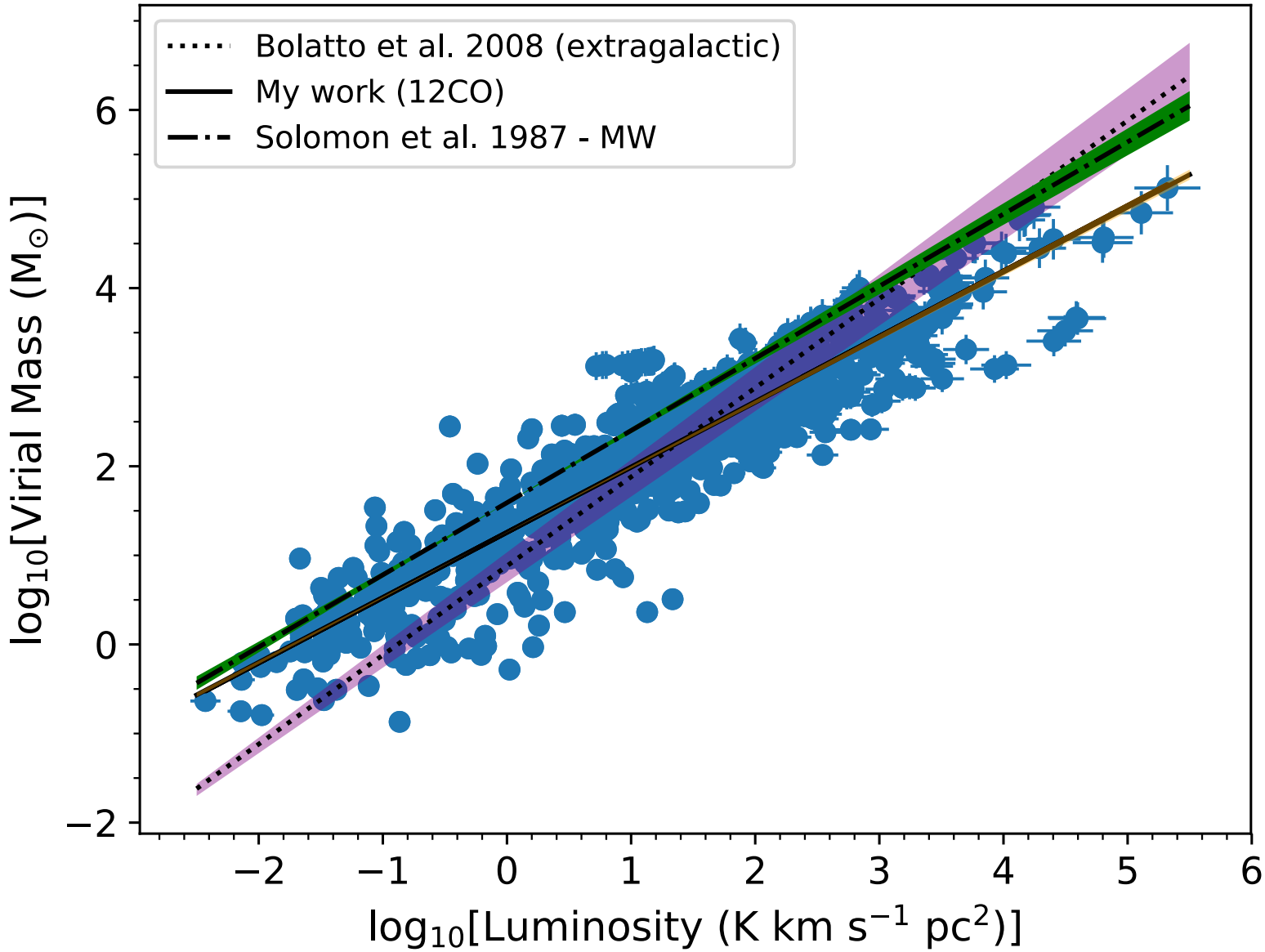
Larson's 2nd law (M_{virial} vs. L_{CO})



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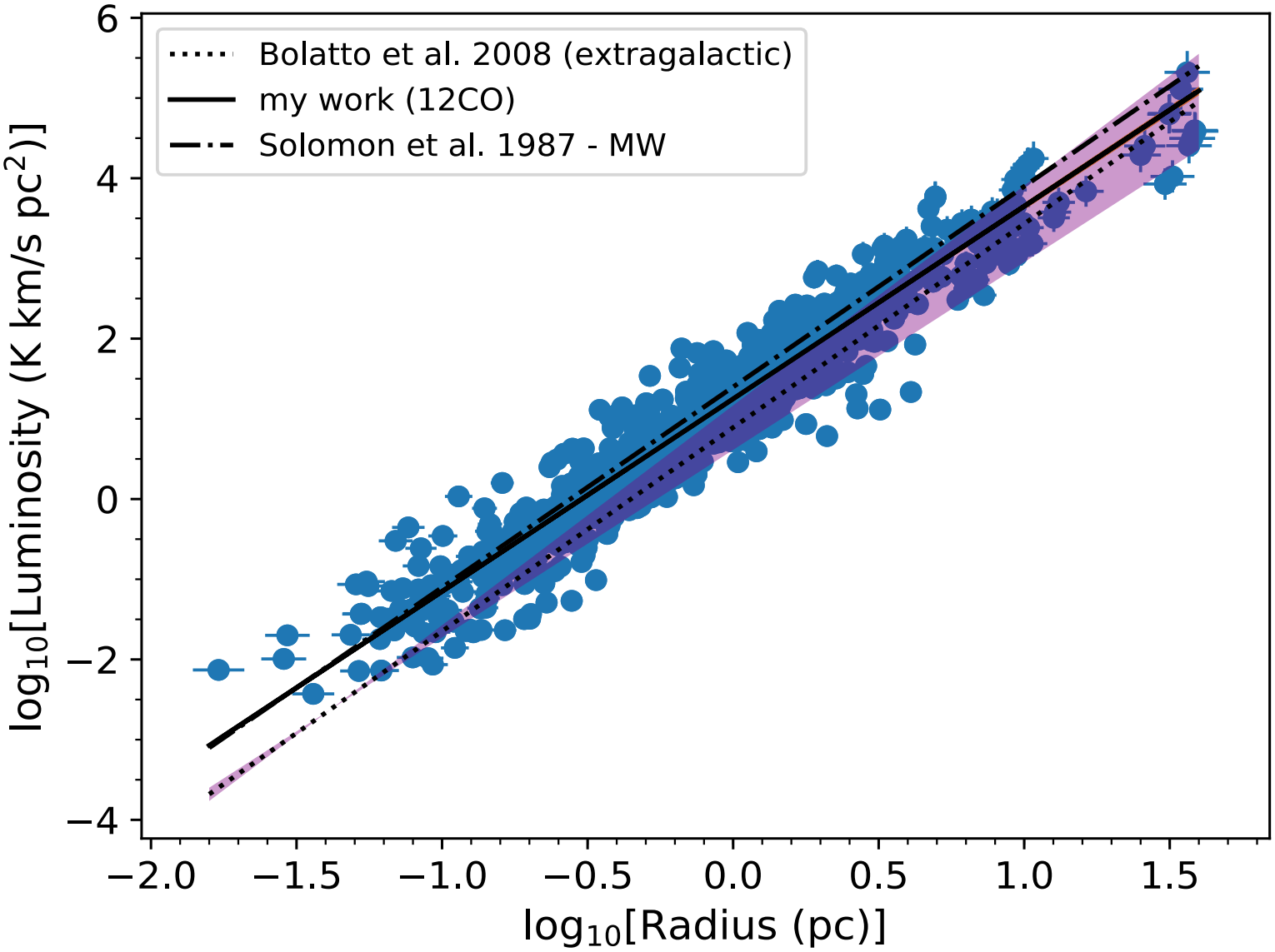
Larson's 3rd law (L_{CO} vs. R)



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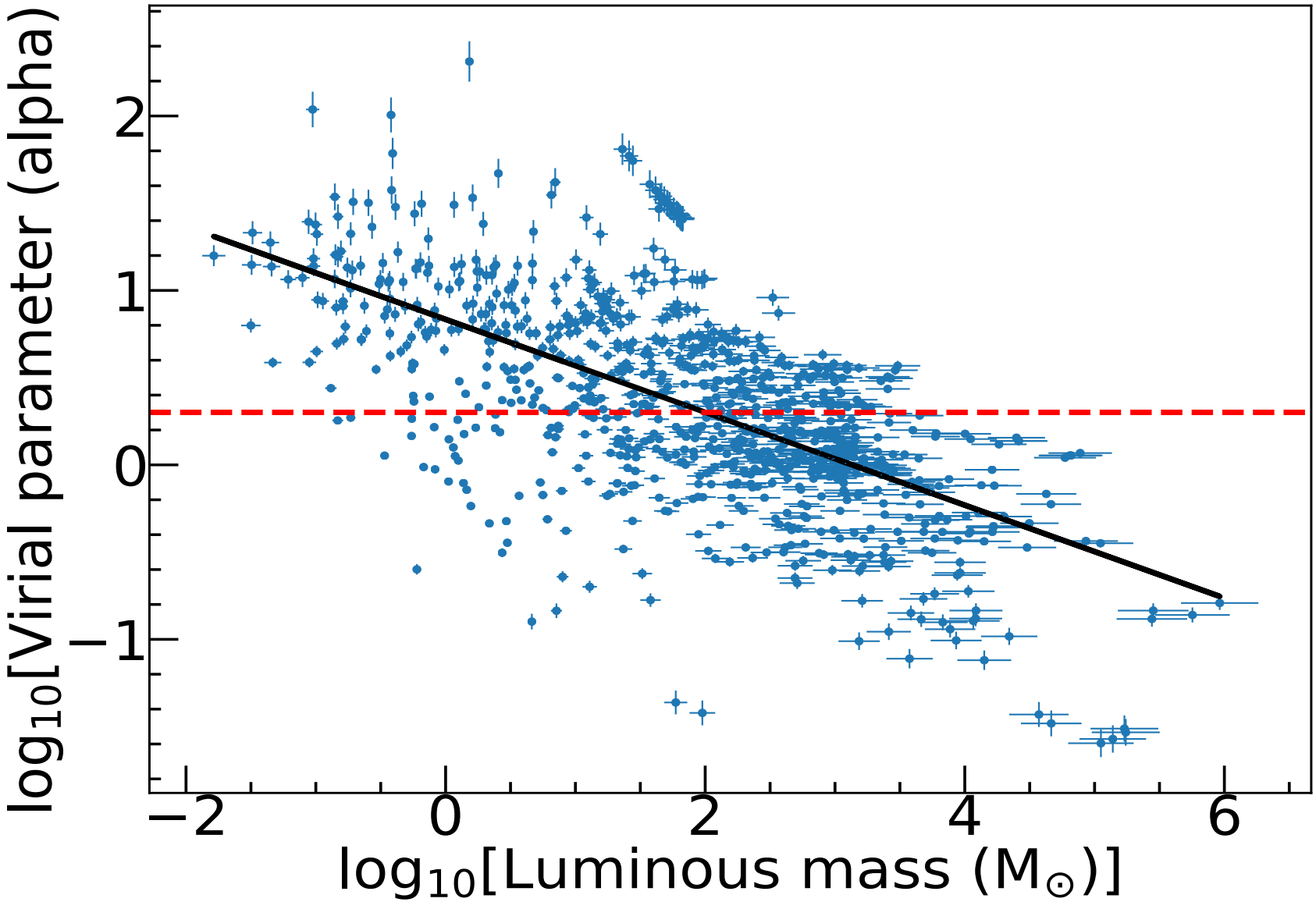
Virial parameter (alpha) vs. luminous mass ($M_\odot$)



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Summary:

- 12CO molecular line data cubes, that were following up *Planck* early cold cores were successfully decomposed using a dendrogram algorithm.
- Our results reproduce all 3 of Larson's laws and are similar to results found elsewhere in our galaxy and in resolved extragalactic clouds, but they have a wide spread; and **these results must be <u>cautiously</u> interpreted!**
- Virial parameter suggests nearly 50/50 split of gravitationally bound vs. unbound objects.
- We are dealing with a unique dataset that needs to be scrutinized further.