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

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

Yorkshire Museum, York UK - 18/9/19
Setting the scene...
Star formation, briefly:

• A lot of gaps exist in our knowledge!
• High- vs. low-mass star formation.
Motivation:
The *Planck* satellite and telescope:
Planck Collaboration et al. 2011 (Paper XXIII)

Cold Clump Density Map

CO contours on Cold Clump Density Map
What telescope and data am I working with?

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

Purple Mountain Observatory (PMO): Qinghai Station (China)
How do we analyse molecular clouds?

- Statistical methods
- Segmentation methods

Dendrograms
Motivation:

Dendrogram = tree diagram
Tree diagrams?

Source: [https://www.fast-growing-trees.com/products/SawtoothOak](https://www.fast-growing-trees.com/products/SawtoothOak)
Motivation:

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

leaves

trunk

branches
STRUCTURAL ANALYSIS OF MOLECULAR CLOUDS: DENDROGRAMS

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dendrograms.readthedocs.io/en/stable/
What do dendrograms look like?

What are dendrograms?

What are dendrograms?

Applying the dendrogram algorithm to my dataset.

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

G005.2+14.4_20110601.co.fits.1
min value = 10 sigma, min delta = 10 sigma, min pix = 4
Results.
Larson's 2nd law ($M_{\text{virial}}$ vs. $L_{\text{CO}}$)

- Bolatto et al. 2008 (extragalactic)
- My work (12CO)
- Solomon et al. 1987 - MW
Larson's 3rd law ($L_{CO}$ vs. $R$)

- Bolatto et al. 2008 (extragalactic)
- my work (12CO)
- Solomon et al. 1987 - MW
Motivation:

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

\[
\log_{10}[\text{Virial parameter (alpha)}] \quad \log_{10}[\text{Luminous mass (} M_\odot \text{)]}
\]
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 cautiously 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.