Billowing Hydrogen

Simulating Turbulence in HII Regions

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HII Regions

- What is an HII Region?
- Physical Traits
  - Powered by hot stars
  - Can range from AU to parsecs
  - A type of nebulae

Image of an HII region, the Trifid Nebula.

Nebula image: M20 — Trifid Nebula HII Region in Sagittarius 6° from Kaus Australis (Epsilon of the teapot) taken by R Jay GaBany

Emissions

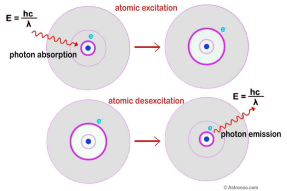
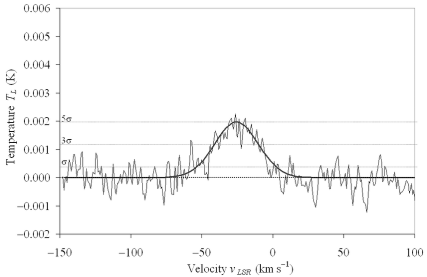


Image 2: Process in which radio recombination lines are created.

Radio recombination lines: https://astronoo.com/images/lumiere/absorption-et-emission.jpg

- A way we observe HII regions
- Why use radio?
- Radio recombination lines (RRLs)

Emissions



Typical radio recombination line spectrum. 1051 erg less: the Galactic H II region OA 184 - Scientific Figure on ResearchGate. Available from:

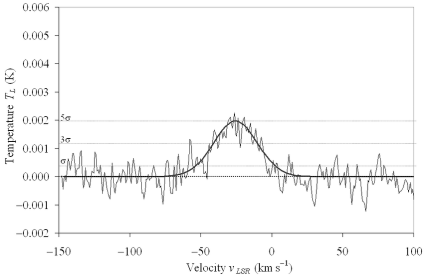
https://www.researchgate.net/figure/Radio-recombination-line-emission-from-OA-184-This-is-a-composite-spectrum-of-seven_fig1_44090151

[accessed 17 Nov 2025]

- A way we observe HII regions
- Why use radio?
- Radio recombination lines (RRLs)

Radio Imaging

- Multiple frequencies
- Doppler shift
- Velocity compared to Local Standard of Rest (VLSR)
- Velocity line width



Radio recombination line to discuss how velocity is mapped.

Radio Imaging

- Multiple frequencies
- Doppler shift
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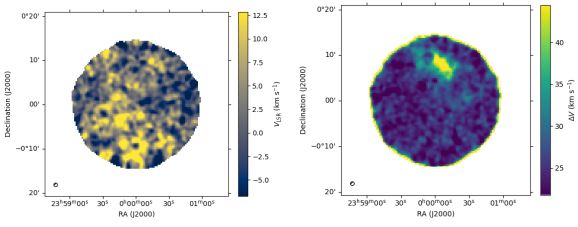
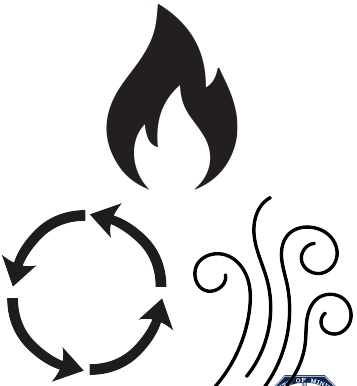


First and second moment maps of an HII region.

Emission Line-Broadening

- Thermal motion
- Bulk motion
  - Outflow
  - Expansion
  - Rotation
- Turbulence



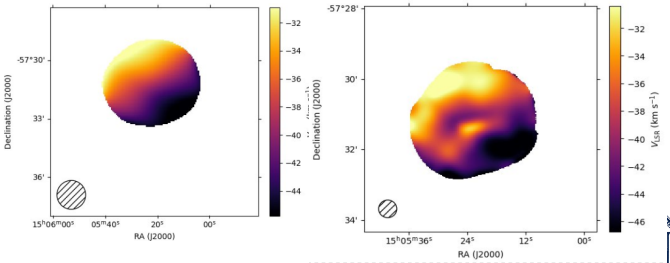
Fire: https://www.vecteezy.com/png/19787026- fire- icon- on- transparent- background

Cycle: https://www.vecteezy.com/png/18723264- roundabout- directional- arrow- on- transparent- background

Wind: https://www.vecteezy.com/png/22183351- hand- drawn- design- on- transparent- background

Motivations

- Previous work had shown what looked like rotation
- Later observations show a more complex story
- Can turbulence explain this behavior?



Showing the how the same object can act differently based on the beam width.

Turbulence

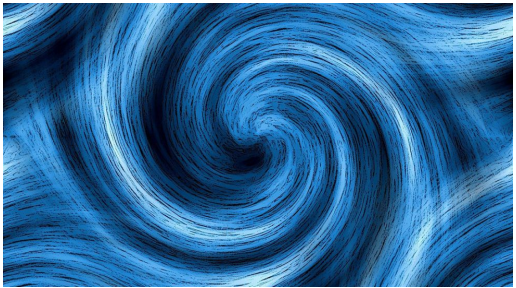


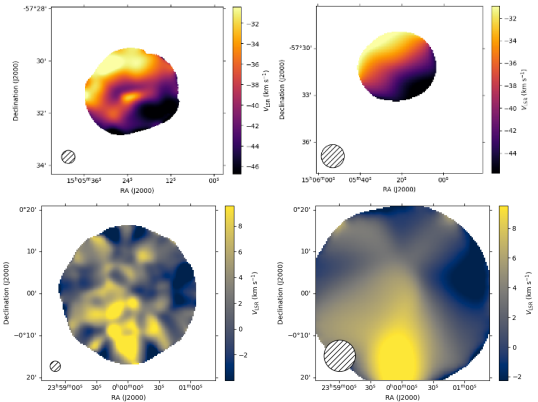
Image attribution: https://www.advancedsciencenews.com/wp-content/uploads/2023/07/swirl-g52ac5d4ac_1280.jpg

- Hard to model
- Not well understood
- But can be predicted to a degree!

Project Goals

- Simulate turbulence in HII regions
- Test different turbulence parameters
- Compare to reality

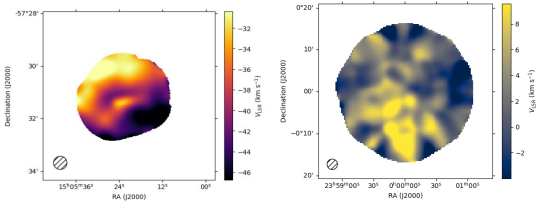
Results



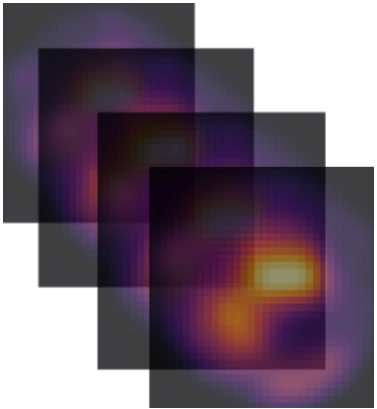
Comparing the effects of a higher resolution on the first moment map.

Results

- Similarity to reality
  - Turbulence looking like angular momentum
  - Similar velocity scales



Future Work

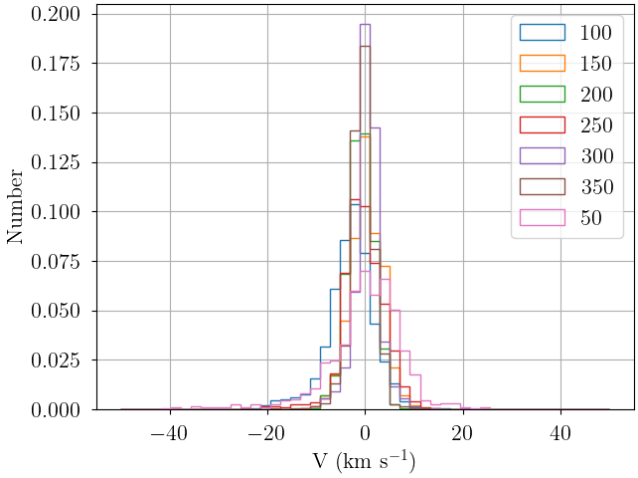


- Comparing with more radio data
- Develop new analyses

Pipeline

- Generate and truncate turbustat data
  - Creates cubes to represent density and velocity in 3d space
- Calculate emission measure for each physical "voxel" of HII region
- Calculate RRL strength for each pixel
  - Gaussian treating velocity cube as line centers
  - Add free-free emission afterwards

Resolution Dependance



Demonstrating that the resolution dependance is negligible past 300 pixels.