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

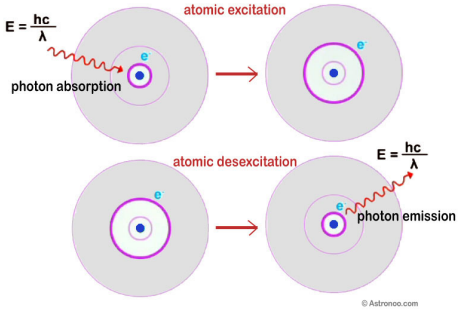
Image of an HII region, the Trifid Nebula.

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

Observing HII Regions

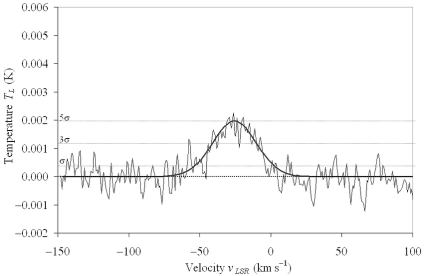
Observing HII Regions

Radio Recombination Lines



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

Radio Recombination Lines



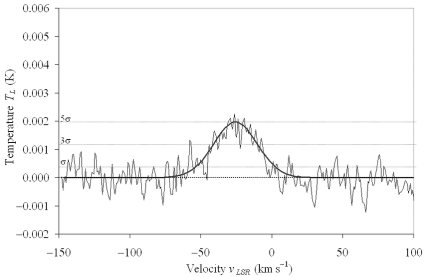
Typical radio recombination line spectrum. 1051 erg less: the Galactic H II region OA 184 - Scientific Figure on ResearchGate. Available from:

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]

Radio Imaging

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



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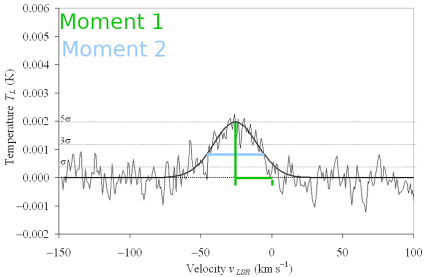

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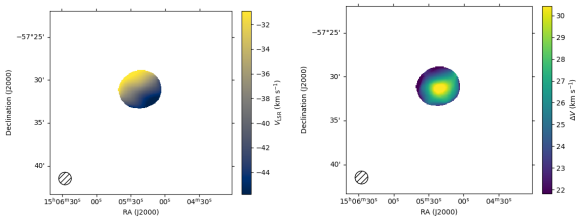
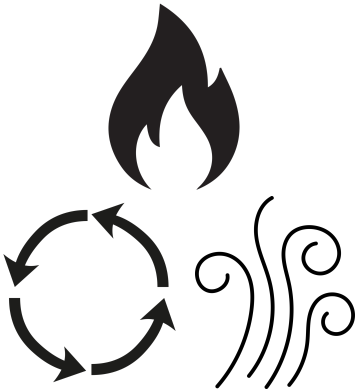


First and second moment maps of an HII region.

Emission Line-Broadening

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

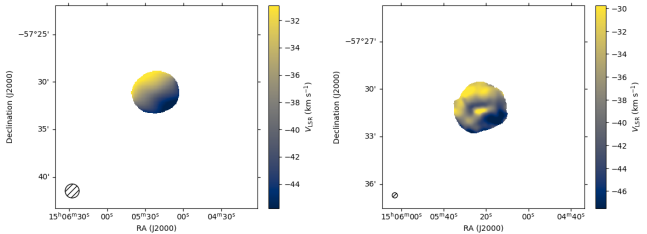


Fire image source here
Cycle image source here

Wind image source here

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 appear different based on the beam width.

Turbulence

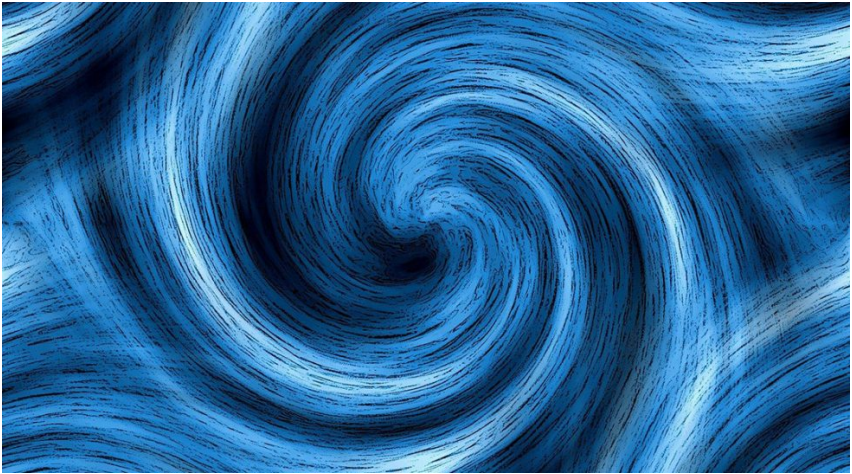
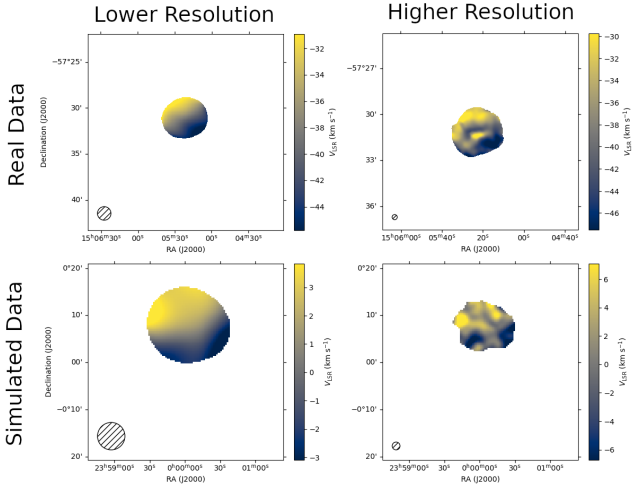


Image attribution

Project Goals

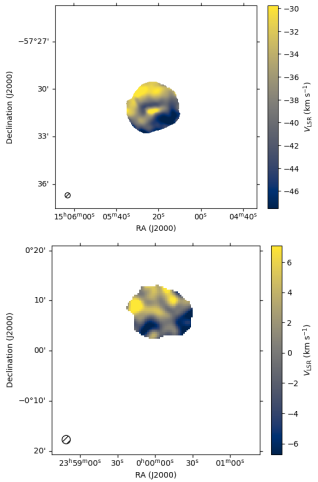
- Simulate turbulence in HII regions
- Compare to reality qualitatively
- Characterize HII regions by their observables

Results

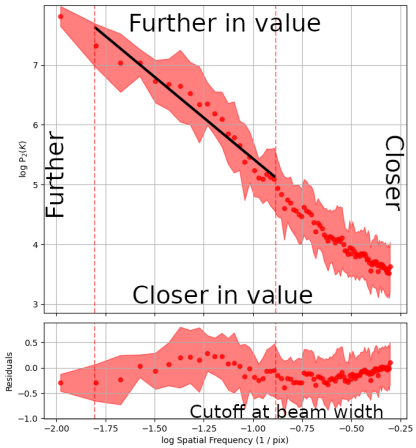

Lower Resolution
Higher Resolution
Real Data
Simulated Data
Declination (J2000)
RA (J2000)
V_{LSR} (km s^{-1})

Results

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

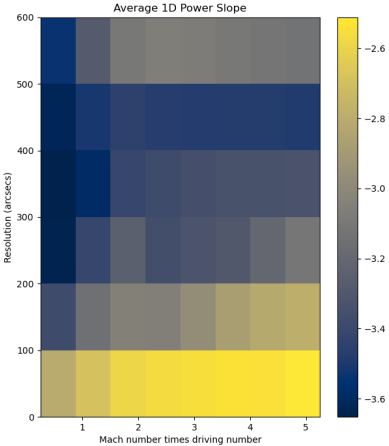


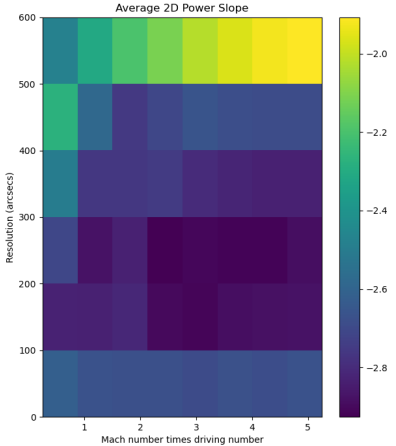
Correlation



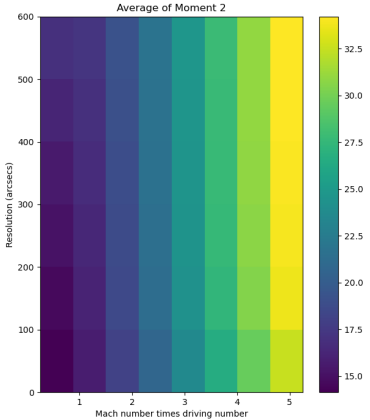
- We can quanitify how related a pixel is to nearby pixels
- The more extreme the slope, the less related to far pixels it is

Correlation





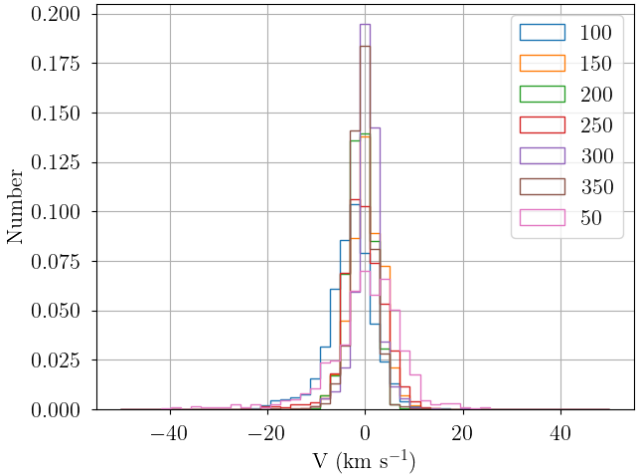
At Last, a Sanity Check



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.