

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

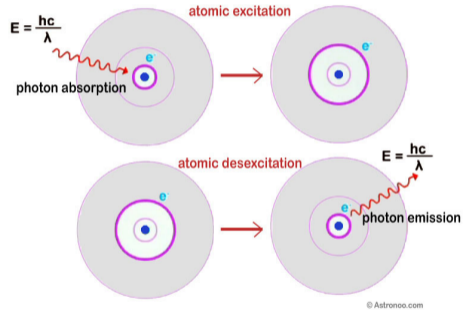
Observing HII Regions



Observing HII Regions

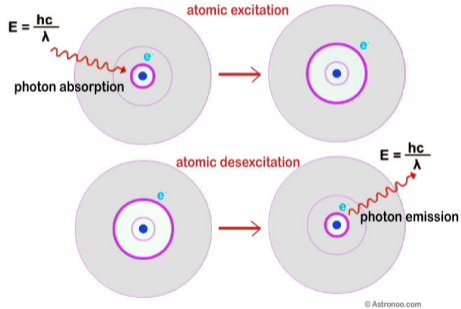


Radio Recombination Lines



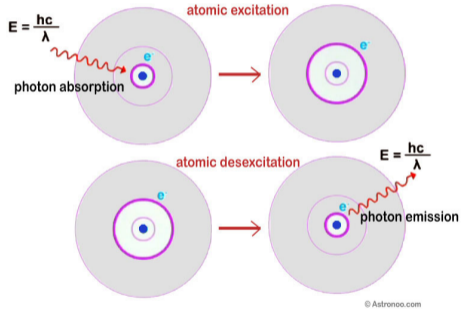
Radio recombination lines: <https://astronoo.com/images/lumiere/absorption-et-emission.jpg>

Radio Recombination Lines



- ▶ From $n=3-2$: 656 nm / 457 THz (Red)
- ▶ From $n=101-100$: ~ 5 cm / 6.5 GHz (Radio)

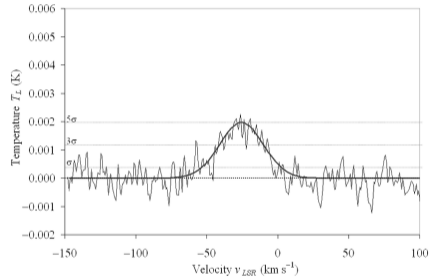
Radio Recombination Lines



- ▶ Not too bright
- ▶ Doesn't get reabsorbed

Radio Imaging

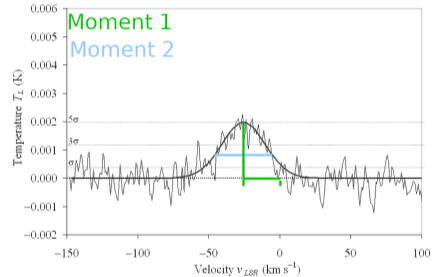
- ▶ Multiple frequencies
- ▶ Doppler shift
- ▶ Velocity compared to Local Standard of Rest (VLSR)
- ▶ Velocity line width (ΔV)



Typical radio recombination line spectrum. The Galactic H II region OA 184. Available [here](#).

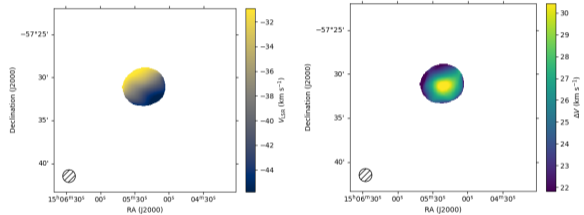
Radio Imaging

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Radio Imaging

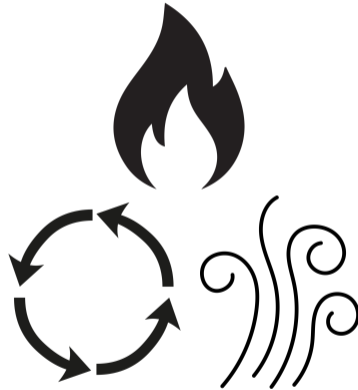
- ▶ Multiple frequencies
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First and second moment maps of the HII region RCW87.

Emission Line-Broadening

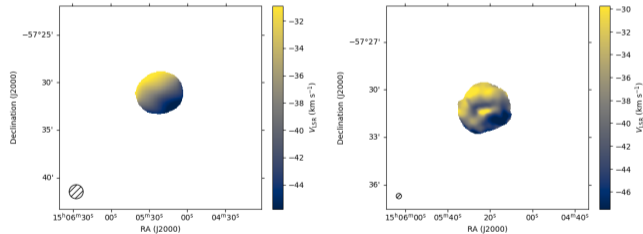
- ▶ Thermal motion
- ▶ Bulk motion
 - ▶ Outflow
 - ▶ Expansion
 - ▶ Rotation
- ▶ Turbulence



Fire source image [here](#), cycle image source [here](#), and wind image source [here](#)

Motivations

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



Showing the how the same object can appear different based on the beam width.

Turbulence

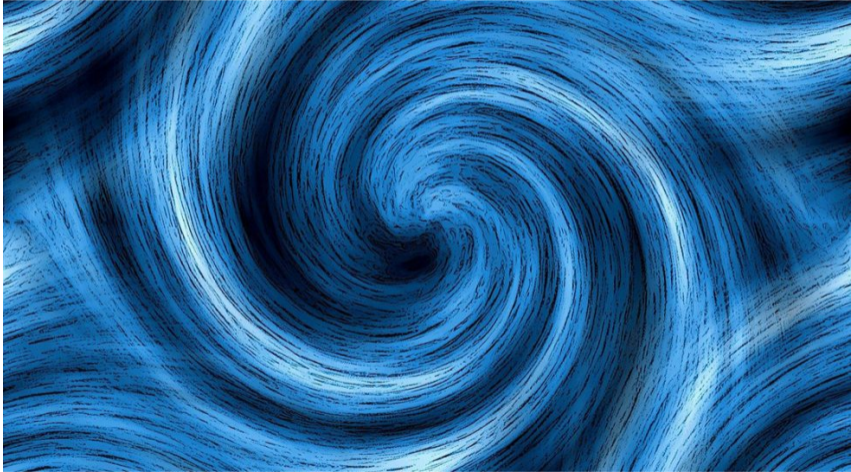
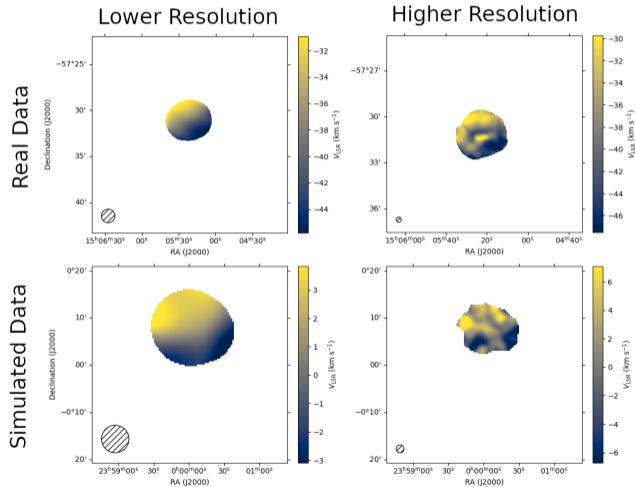


Image attribution

Project Goals

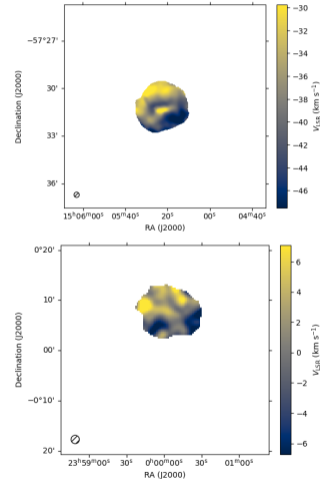
- ▶ Simulate turbulence in HII regions
- ▶ Compare to reality qualitatively
- ▶ Characterize HII regions by their observables

Results

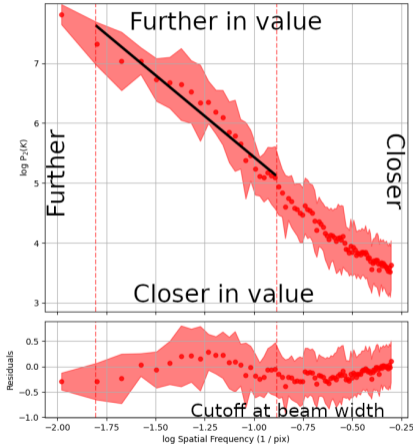


Results

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

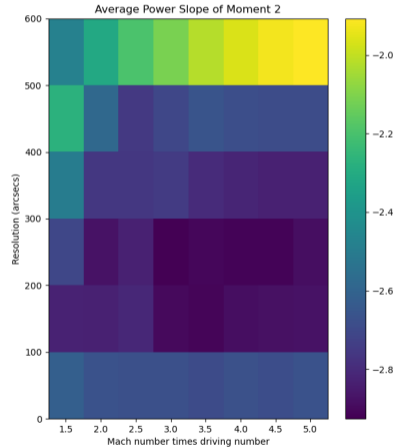
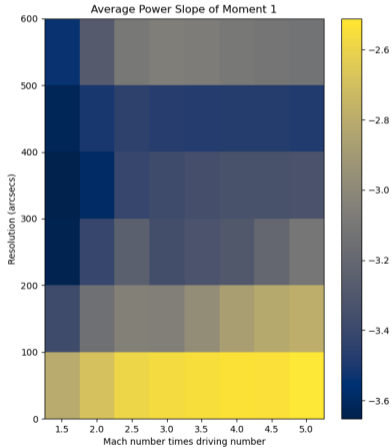


Correlation

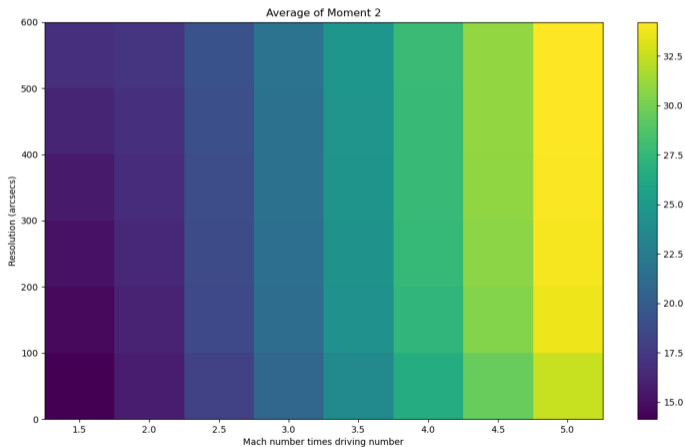


- ▶ We can quantify how related a pixel is to nearby pixels
- ▶ The more extreme the slope, the less related to far pixels it is

Correlation



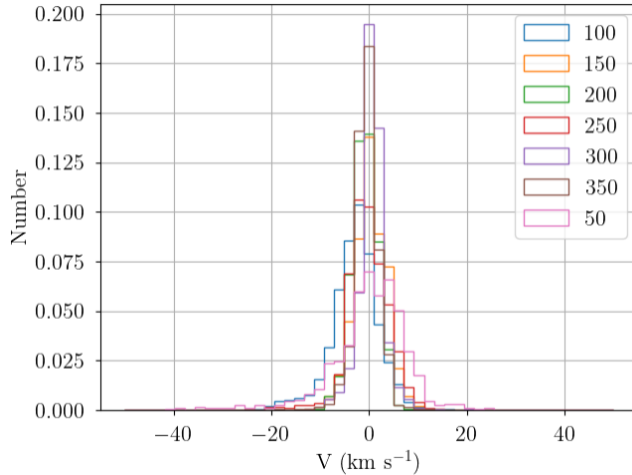
At Last, a Sanity Check



Pipeline

- ▶ Generate and truncate turbostat 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 Dependence



Demonstrating that the resolution dependence is negligible past 300 pixels.