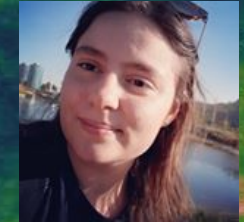




Emma Mannfors



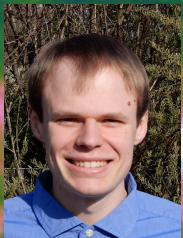
Mathilde Van Cuyck

Hands-on Project 11

Multi-scale and statistical analysis

Lana Ceraj, Mathilde Van Cuyck, Frederick Groth,
Emma Mannfors, Michalis Papachristou, Alvaro Segovia

supervised by Benoit Commerçon, Frederique Motte, Jean-François Robitaille

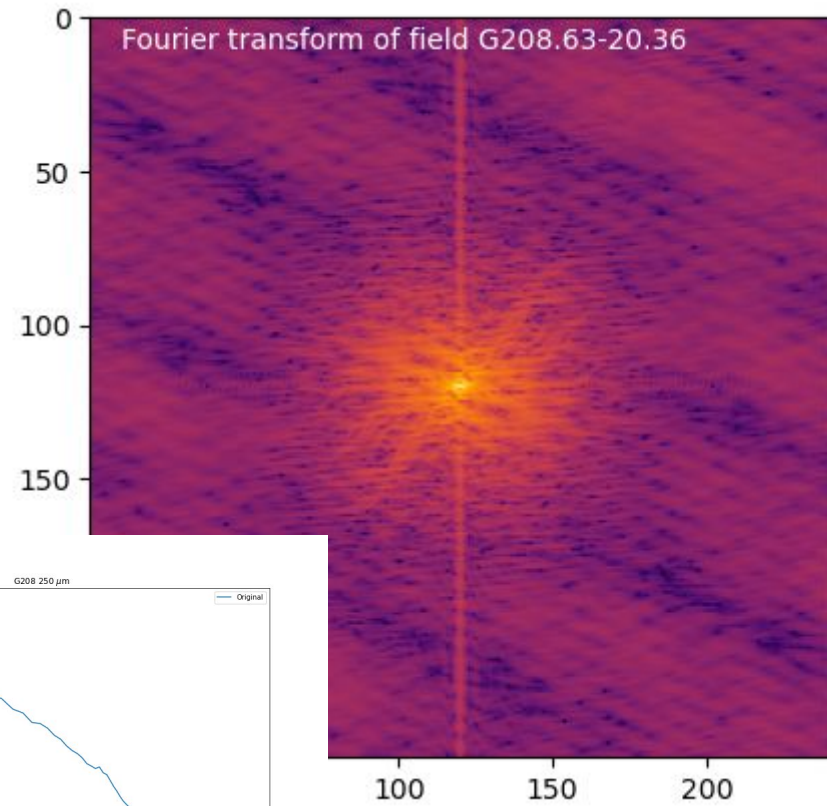
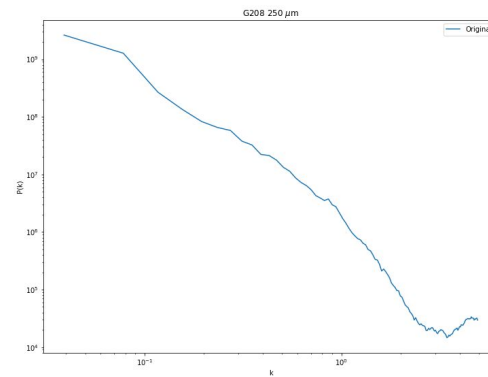
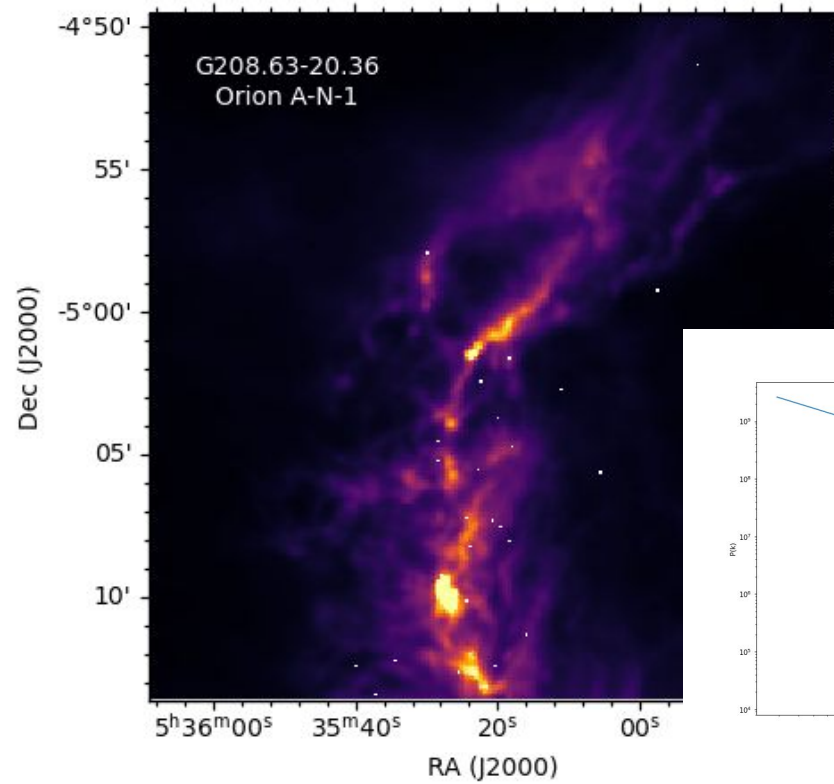


Frederick Groth



Alvaro Segovia Otero

Introduction: What are we doing? And why?



Programs for power-law analysis on astronomical data

- Jupyter Notebook tutorial on Google Colab
- Turbustat (Koch, Rosolowsky, et. al)
- Pywavan (J.-F. Robitaille)
- Astrodendro (MacDonald, Beaumont, et. al)
- + astropy, numpy, aplpy, matplotlib...

tutorial: https://colab.research.google.com/github/jfrob27/hands-on-ISM/blob/main/ISM_analysis.ipynb

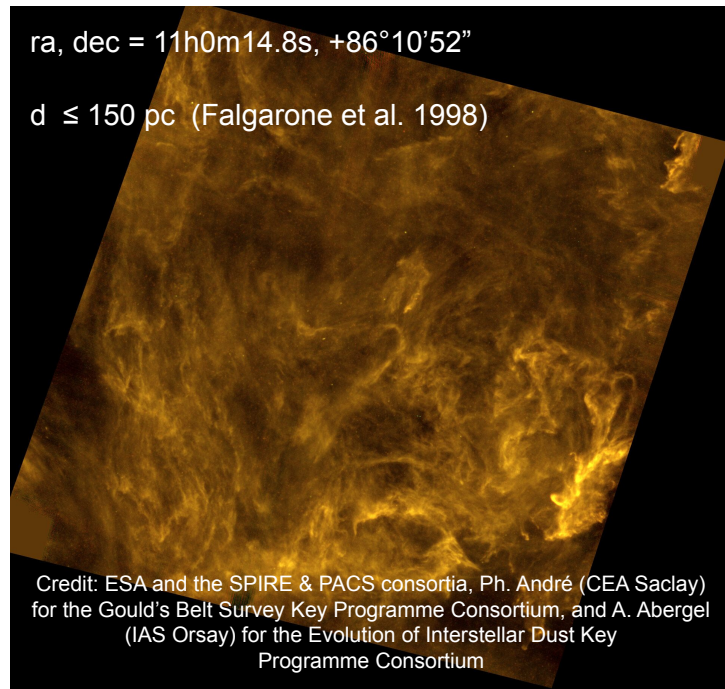
turbustat: <https://turbustat.readthedocs.io/en/latest/>

astrodendro: <https://github.com/dendrograms/astrodendro.git>

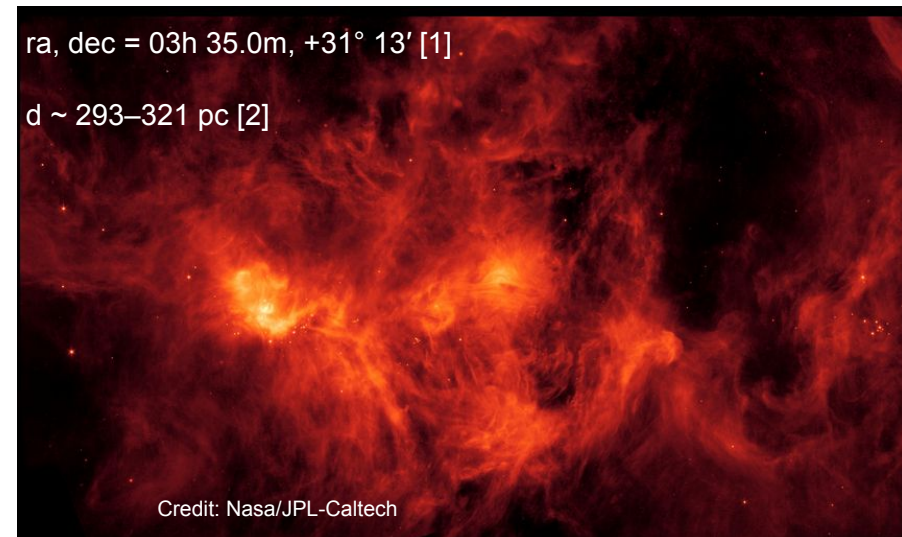
Pywavan: <https://github.com/jfrob27/pywavan.git>

Multi-scale and statistical analysis of the ISM

- Polaris Flare Complex Cloud



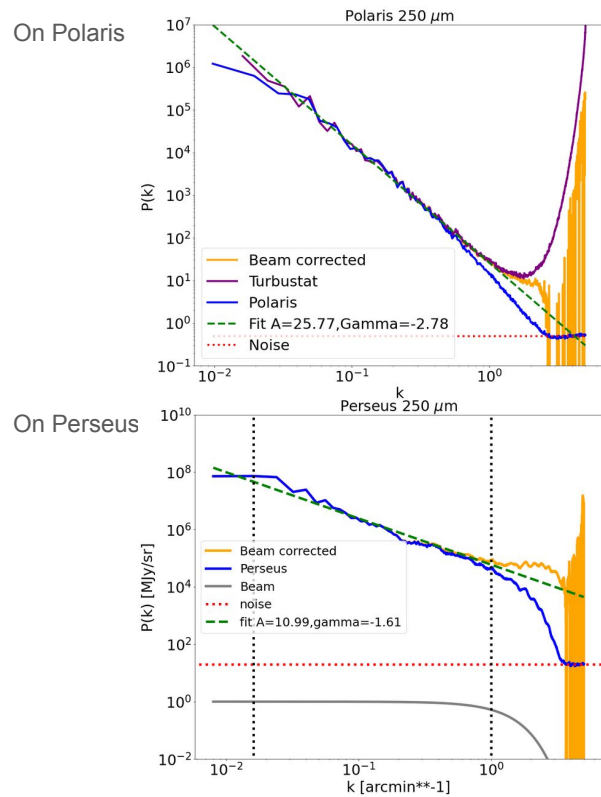
- Perseus Complex Cloud



- 1) "Perseus Cloud". SIMBAD.Retrieved 2014-03-14.
- 2) arXiv:1808.03499. Bibcode:2018ApJ...865...73O.

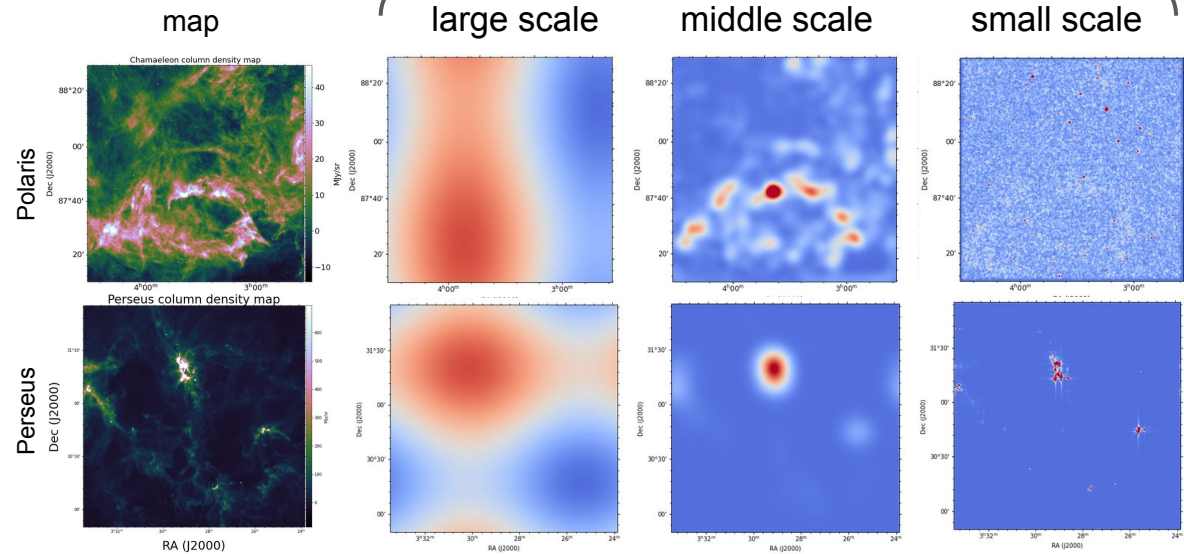
Fourier Power Spectrum & Wavelet Analysis

Power Spectrum



Wavelet Analysis

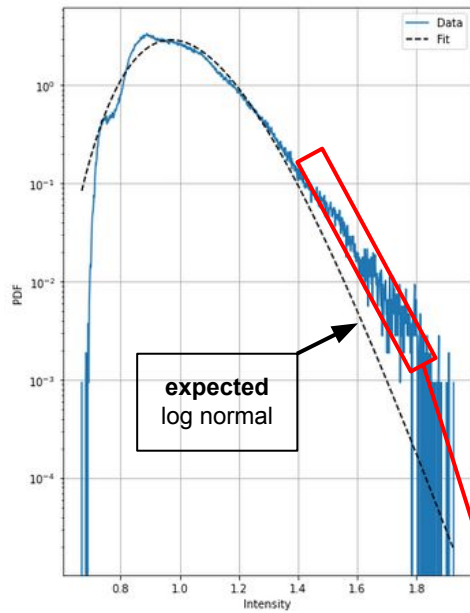
Wavelet decomposition



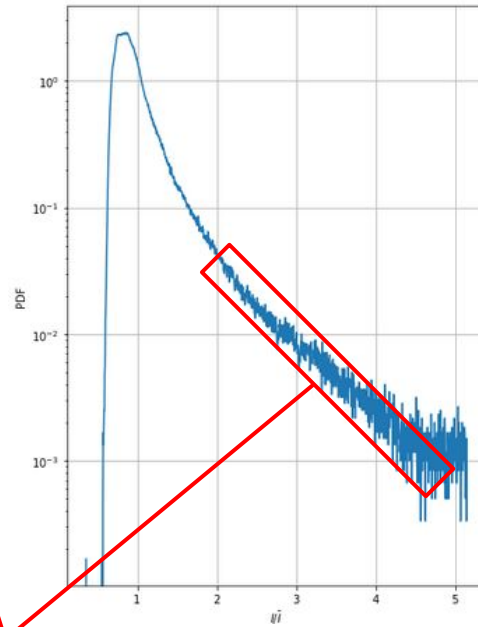
$P(k) \propto k^\gamma \rightarrow$ the **slope γ** is linked to gravity, turbulence and physical conditions in the cloud

Probability Density Function (PDF)

Polaris PDF



Perseus PDF

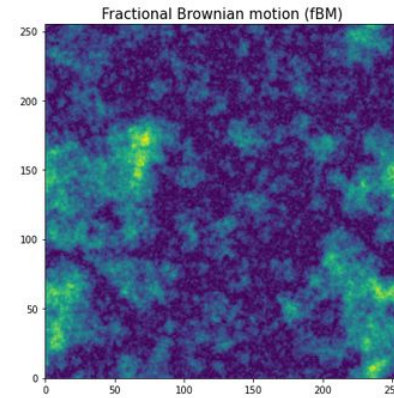


Extra power with respect to a log normal law expected for a gaussian field

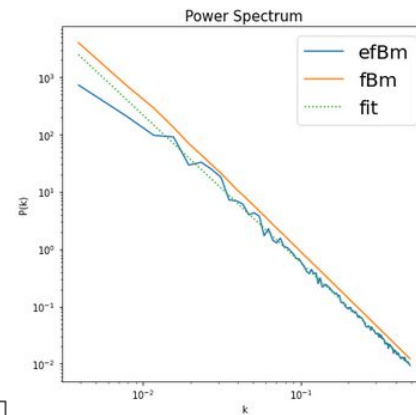
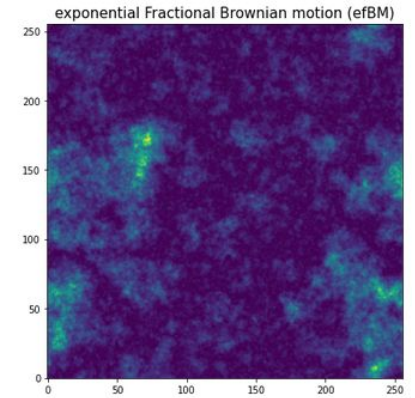
→ **Different analysis are needed** to understand the whole physics in the clouds

Beyond gaussianity with PDF

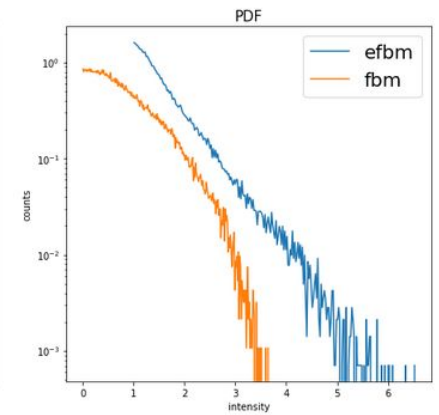
Gaussian simulation



non Gaussian simulation



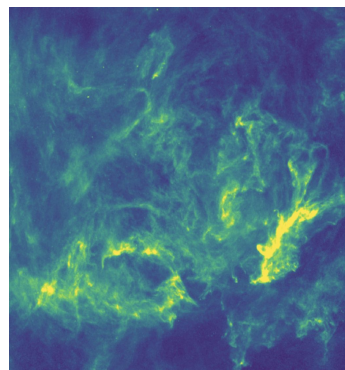
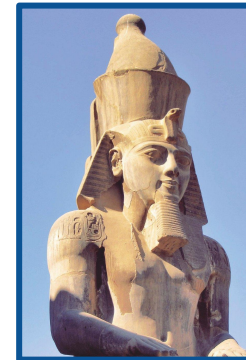
Same power spectrum...



...but different PDF

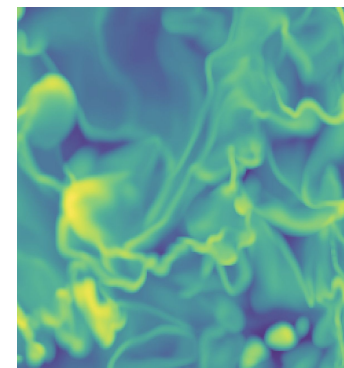
RAMSES & Osyris

- Open source by Romain Teyssier..in Fortran 90...
- N-body + mesh: dark matter, star particles and gas.
- Multiple features → interested on its turbulence prescription.
- Compare simulated turbulent box with star-forming regions:



Observation

Simulation



Ramses: <https://www.ics.uzh.ch/~teyssier/ramses/RAMSES.html> (Teyssier, 2002)

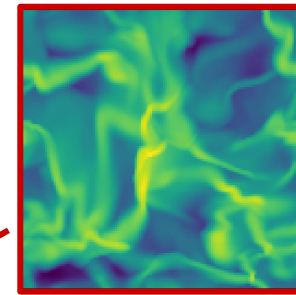
Osyris: <https://pypi.org/project/osyris/>

Evolution of box

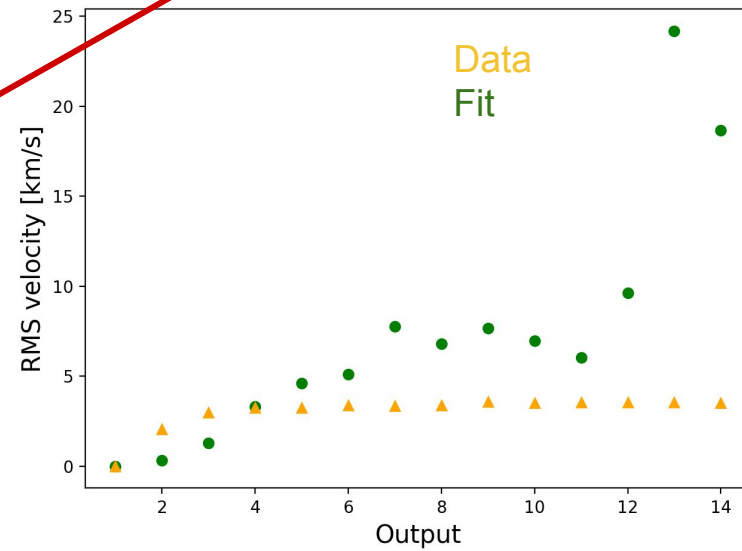
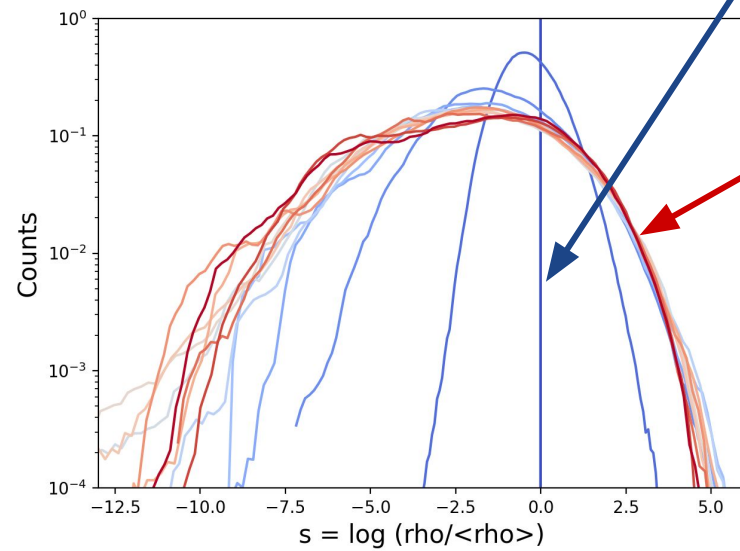
- 3D density PDFs.
- No self-gravity.



Output 1



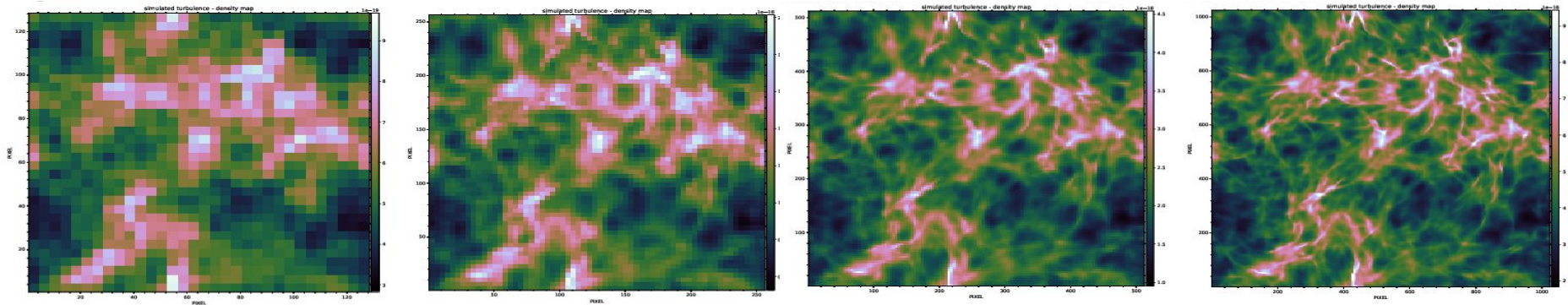
Output 14



Power Law Analysis on Ramses Data

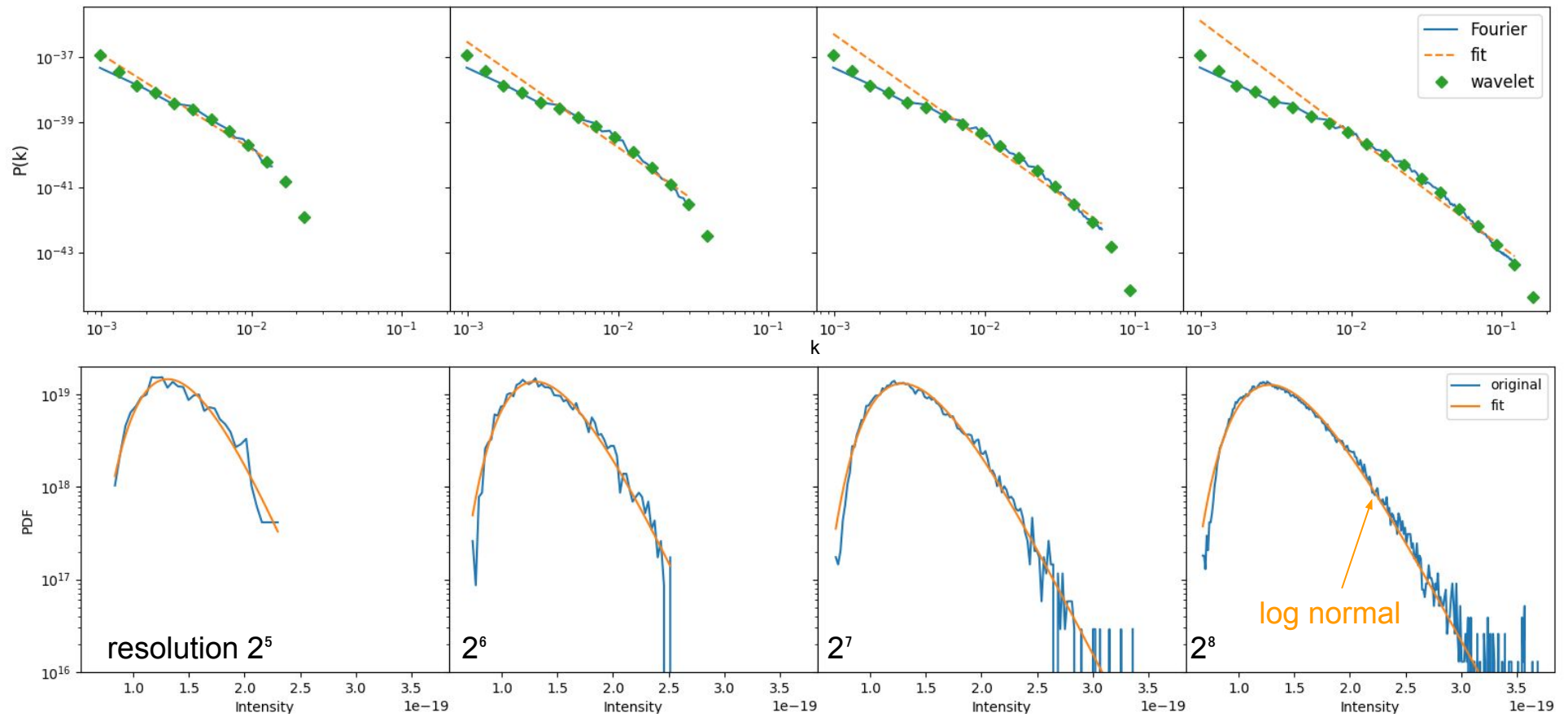
- projected along x-axis to obtain surface densities
- use the same tool as on Polaris

Projected surface density maps



resolution $2^5 = 32$ resolution $2^6 = 64$ resolution $2^7 = 128$ resolution $2^8 = 256$

PDF, Power Spectrum, Wavelet Decomposition



Conclusions

- Open source tools for multi-scale and statistical analysis
 - They are complementary:
 - Power spectra for gaussian fluctuations at different scales.
 - PDFs as a global average.
 - Wavelets to assess the non-gaussianity at different scales.
- Apply tools on observations (Polaris, Perseus) and simulations of turbulent gas for comparison
- Constrain physical aspects (turbulence, self-gravity,...)

LMC, N159 SF region
Credit: ESA/Hubble & NASA, CC BY 4.0