A Pathway to Earth-like Worlds:

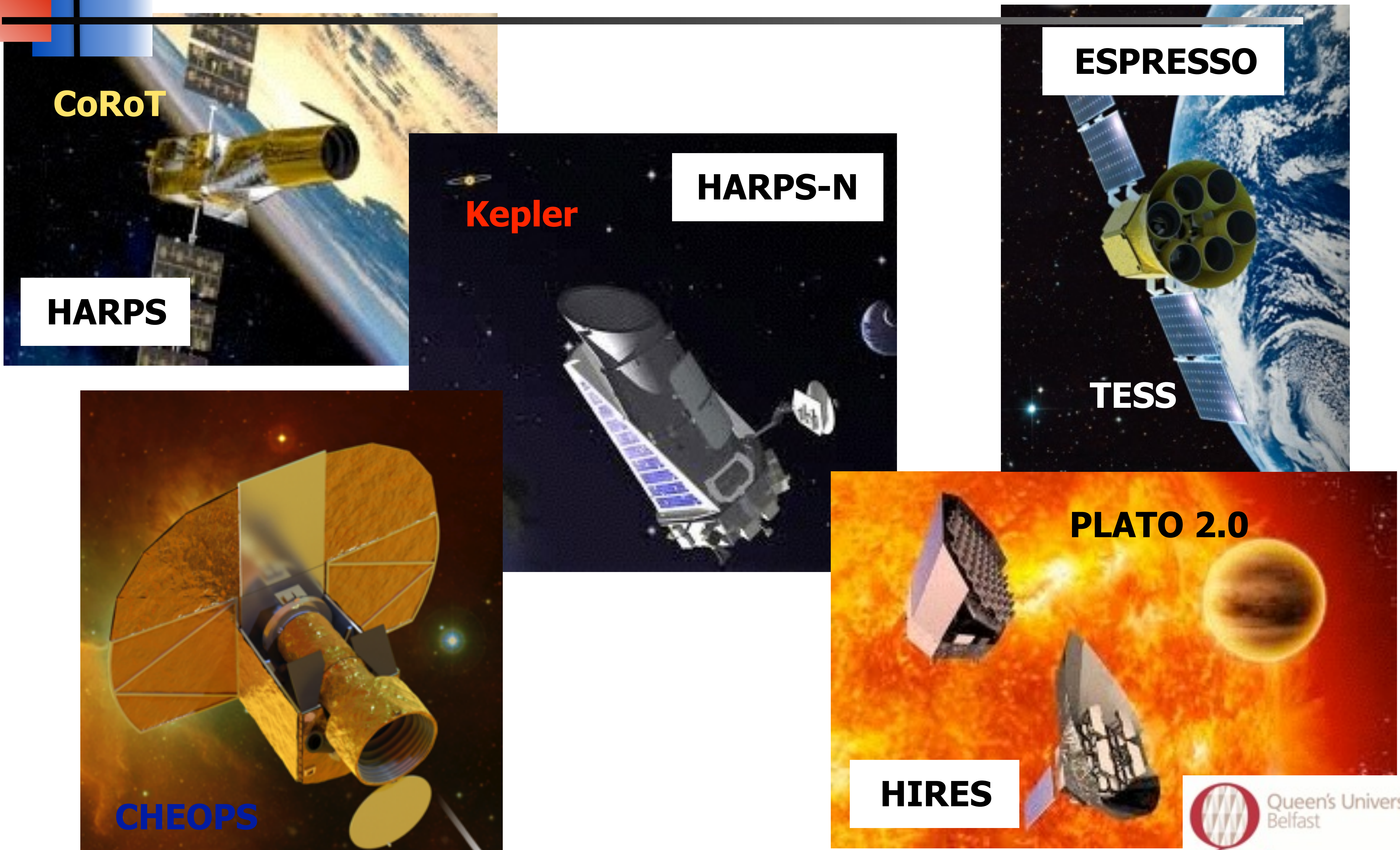
Overcoming Astrophysical Noise due to Convection

Dr. Heather Cegla

Dr. Chris Watson, Dr. Sergiy Shelyag, Prof. Mihalis Mathioudakis

Queen's University Belfast

A Pathway to Earth-like Worlds:



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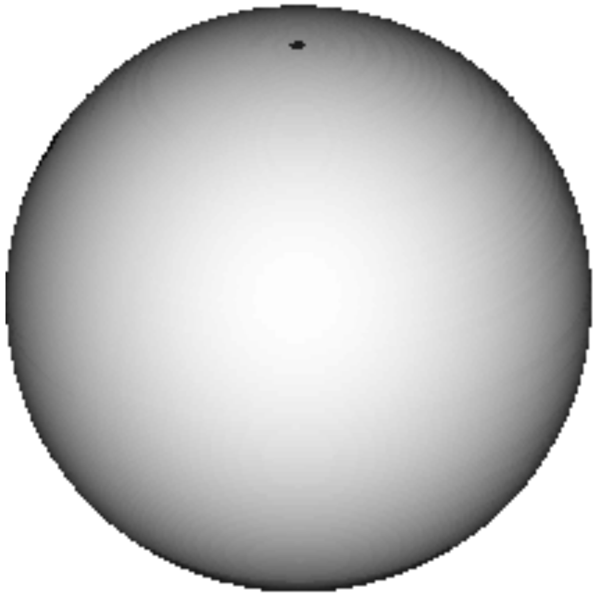
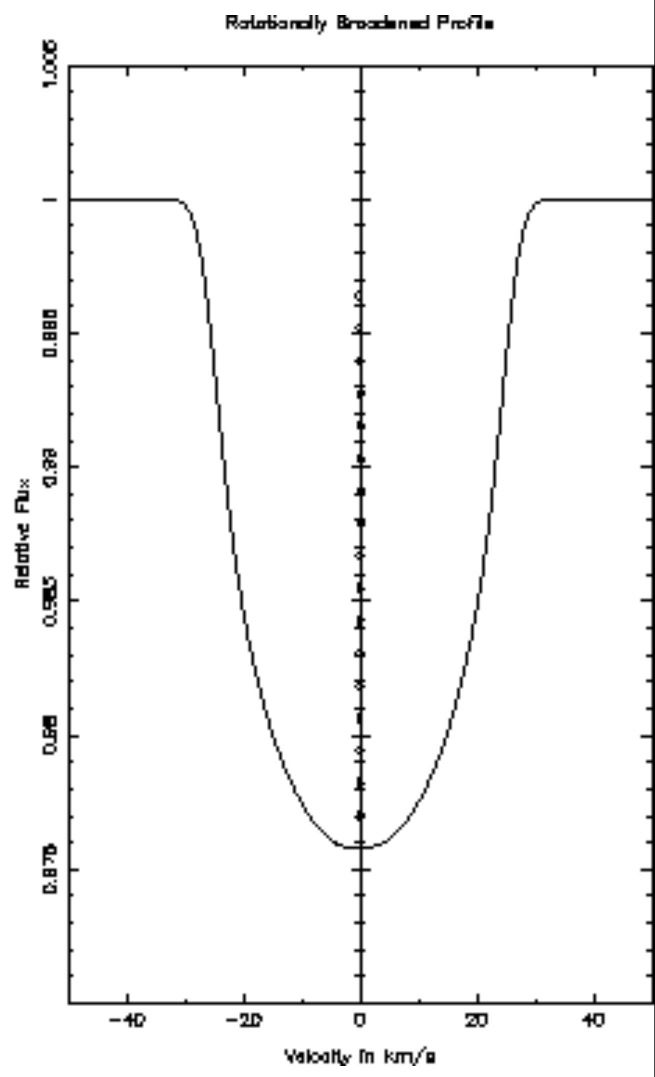
Astrophysical Noise

Astrophysical Noise

- Star spots, Plages





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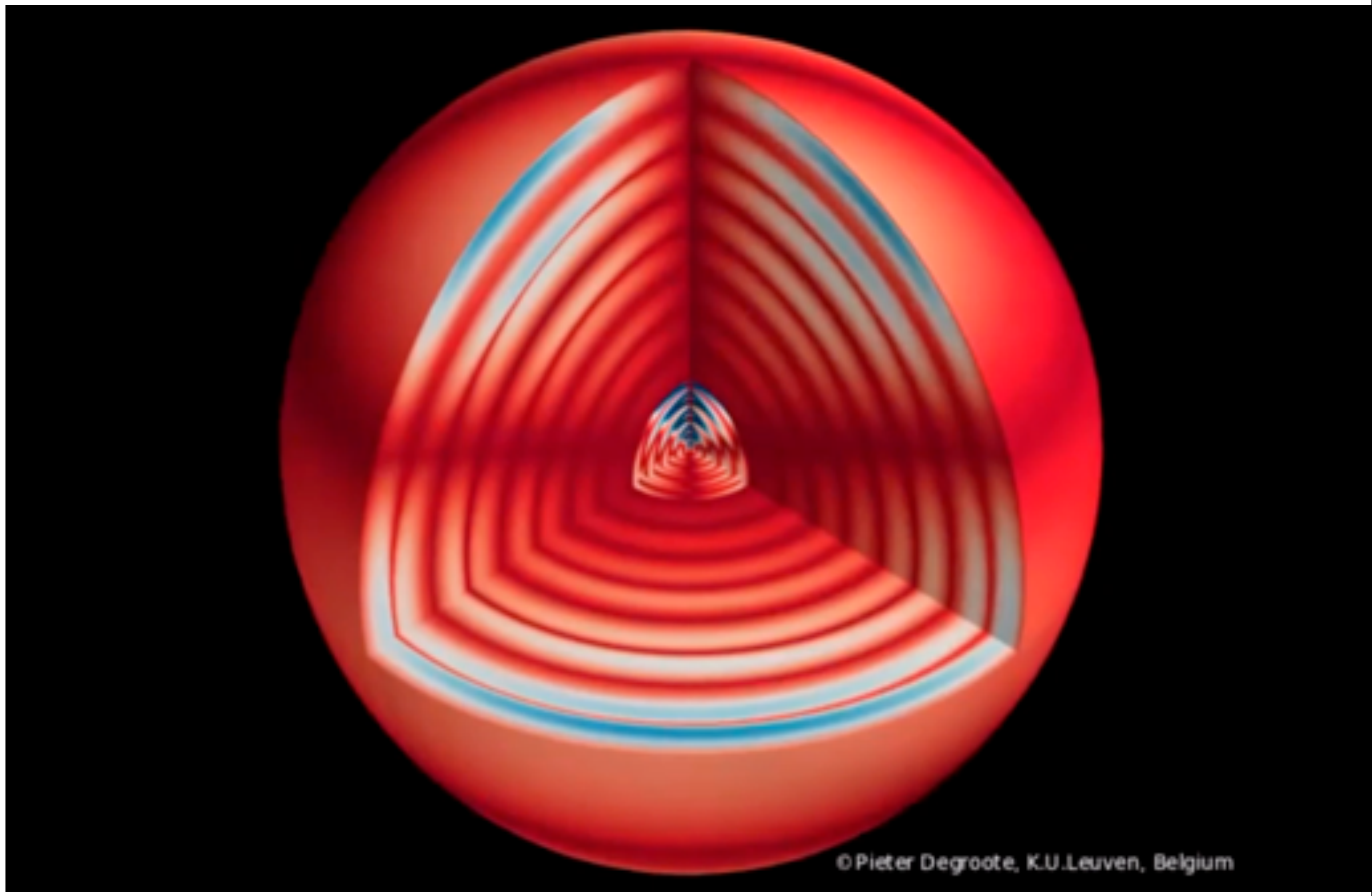
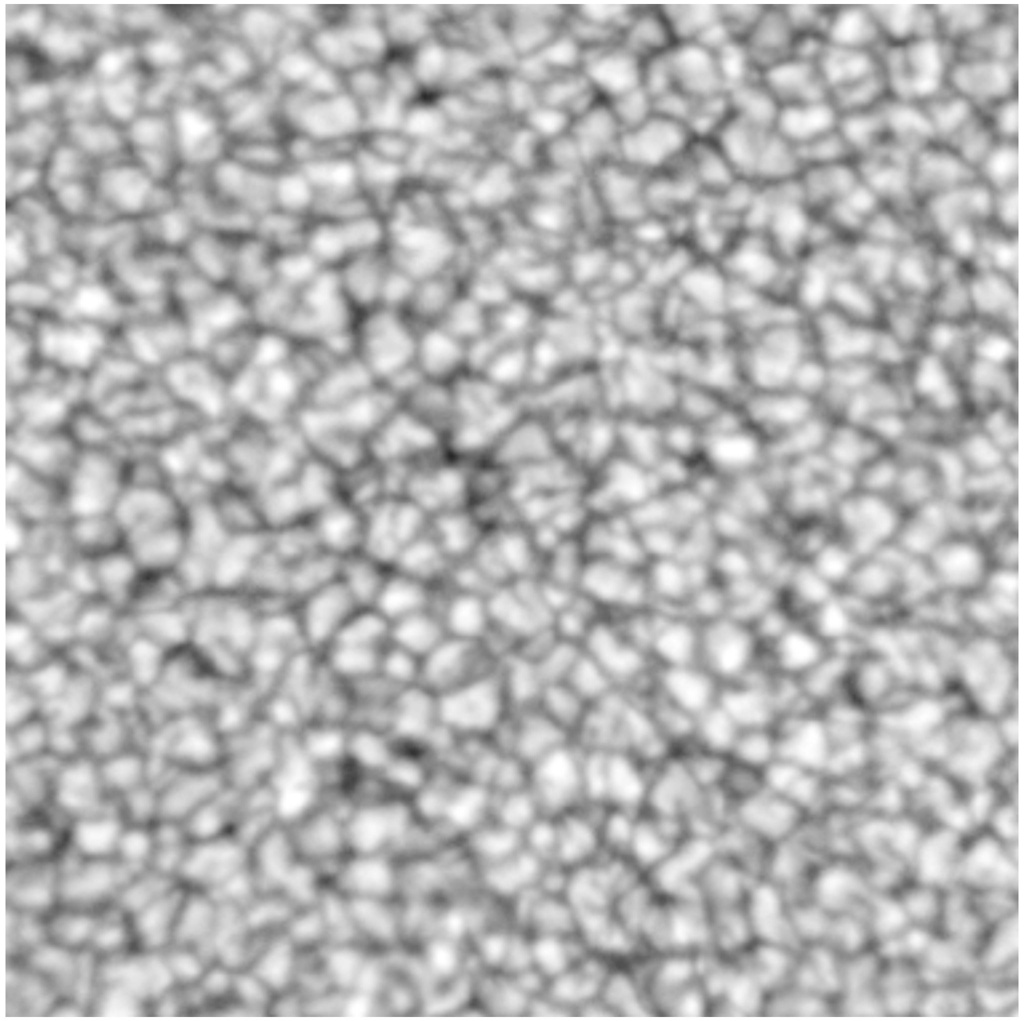
Astrophysical Noise

- Star spots, Plages
- Stellar Oscillations



Astrophysical Noise

- Star spots, Plages
- Stellar Oscillations
- Granulation



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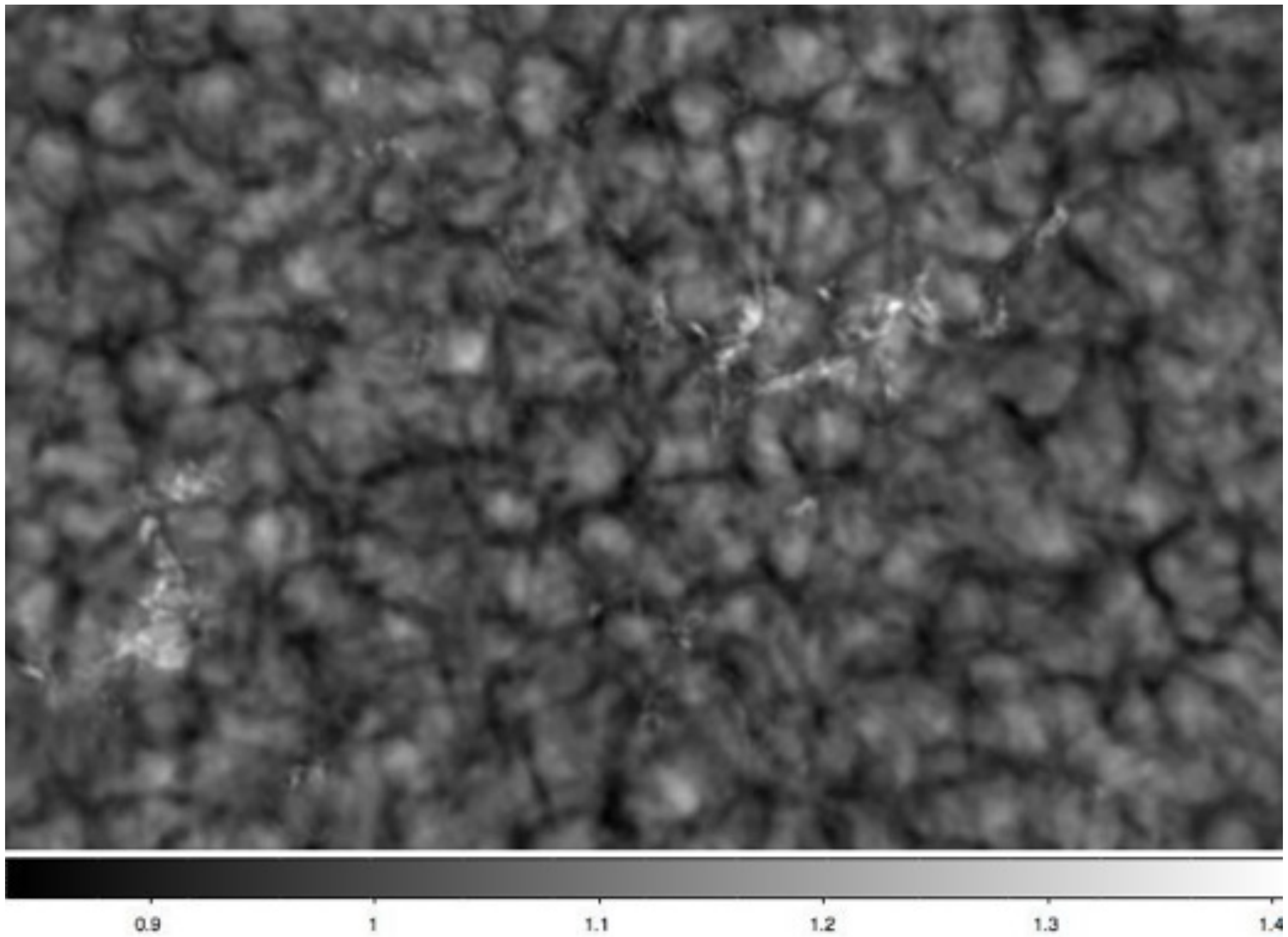
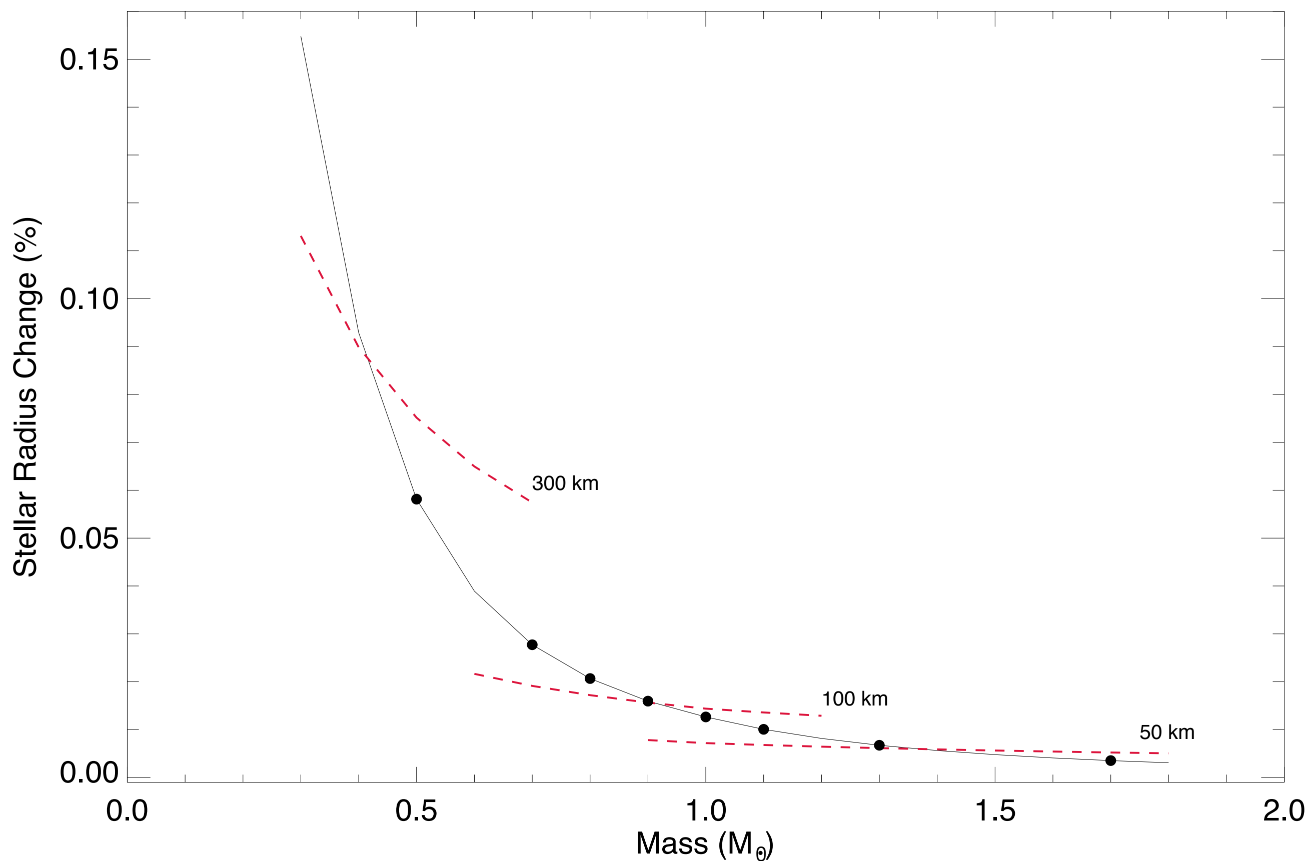
Astrophysical Noise

- Star spots, Plages
- Stellar Oscillations
- Granulation



Astrophysical Noise

- Star spots, Plages
- Stellar Oscillations
- Granulation
- Variable Gravitational Redshift



Mon. Not. R. Astron. Soc. **421,** L54–L58 (2012)
doi:10.1111/j.1745-3933.2011.01205.x

Stellar jitter from variable gravitational redshift: implications for radial velocity confirmation of habitable exoplanets

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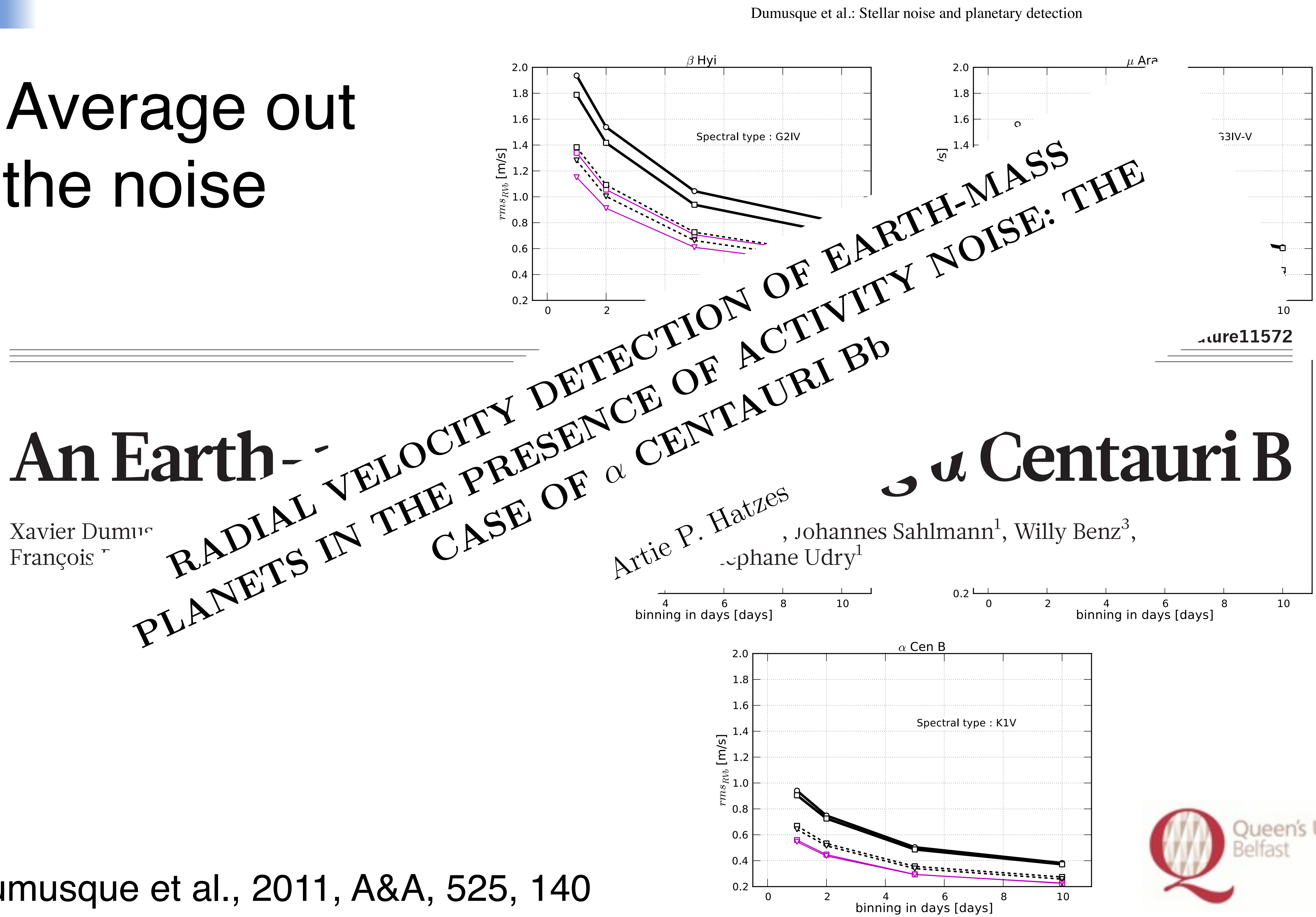
Astrophysical Noise

- Star spots, Plages
- Stellar Oscillations
- Granulation
- Variable Gravitational Redshift

Current Removal Method

- Average out the noise



Dumusque et al., 2011, A&A, 525, 140

Our Removal Method

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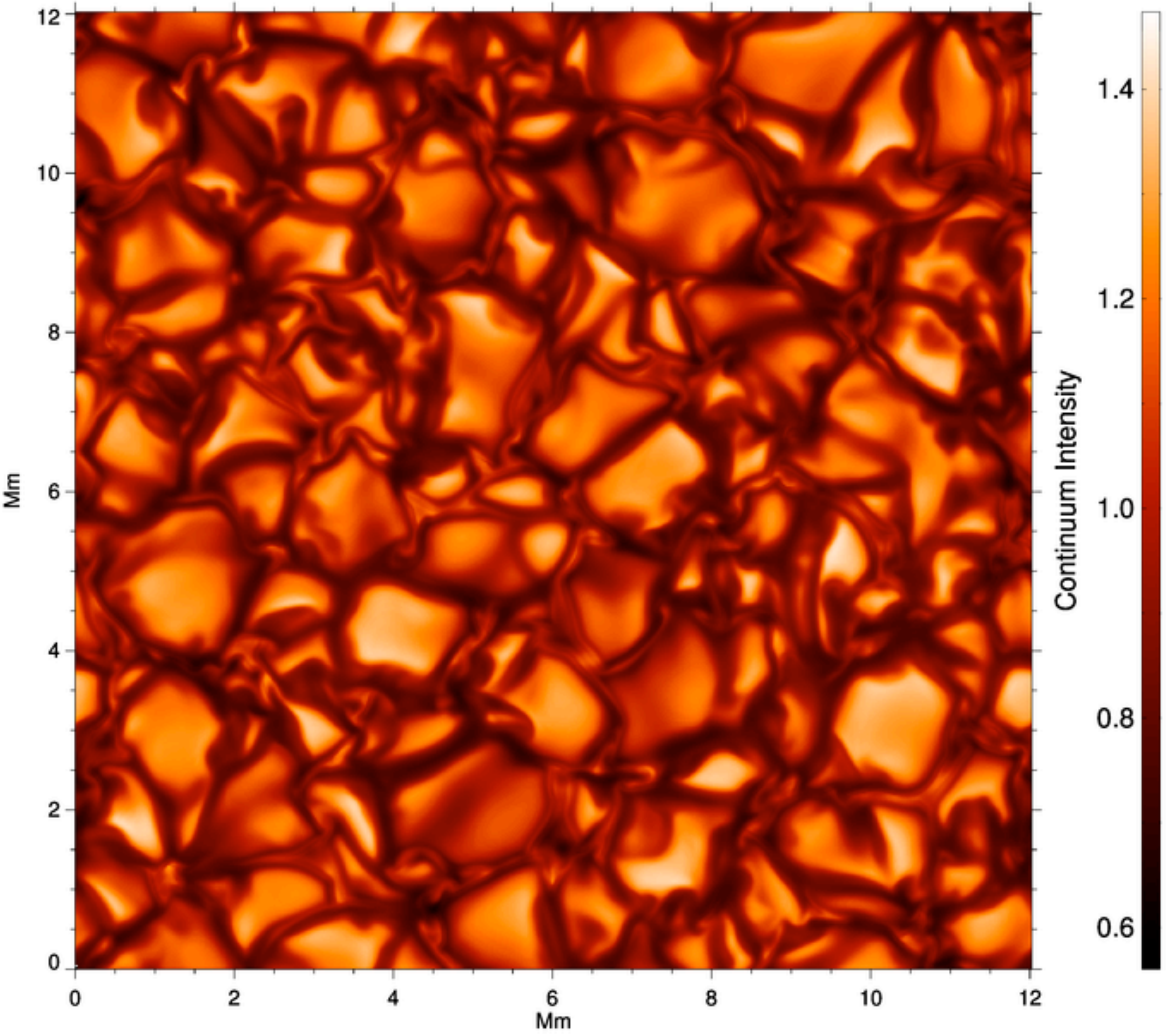
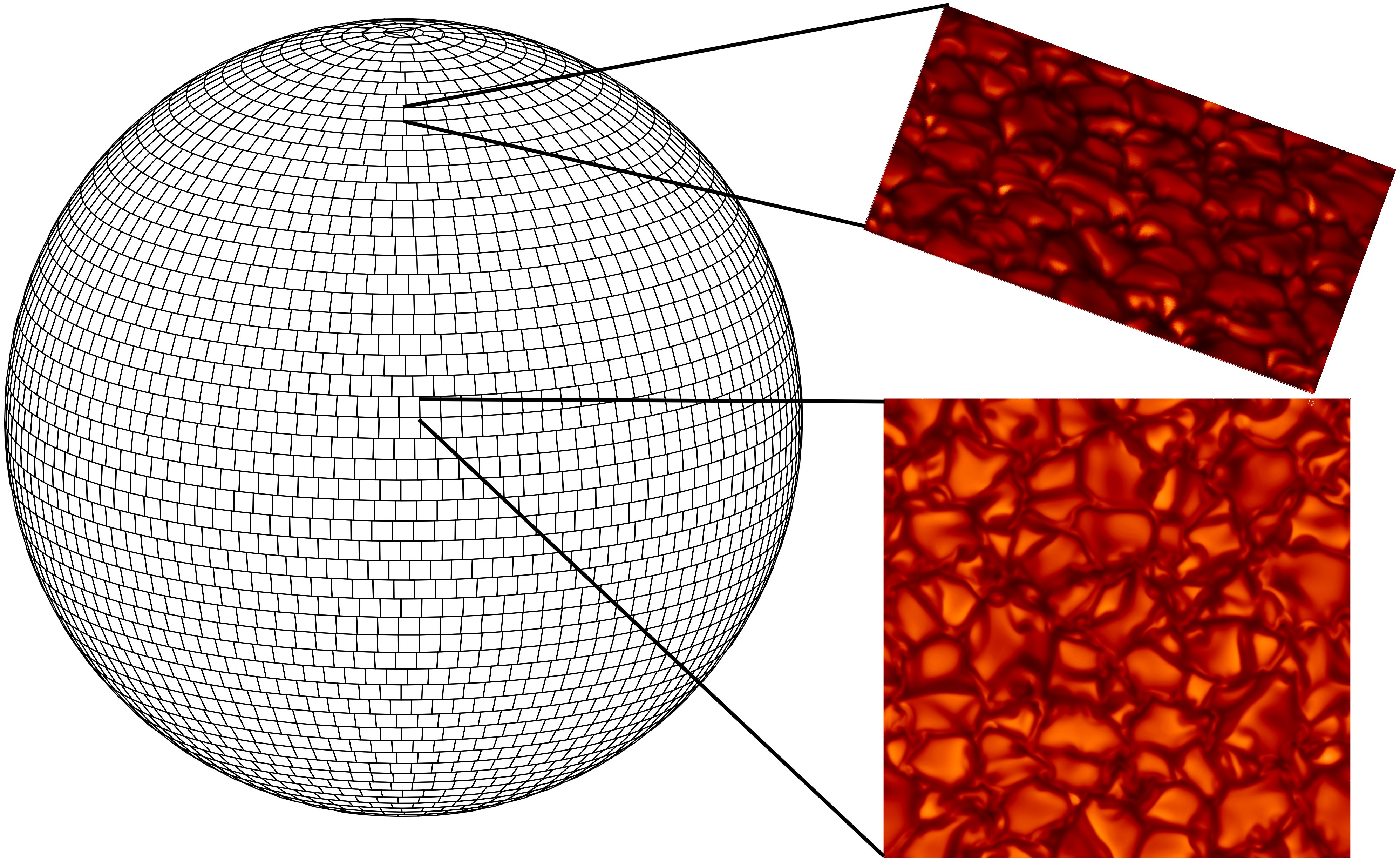


12
10
8
6
4
2
0
Mm
0
2
4
6
8
10
12
Mm
1.4
1.2
1.0
0.8
0.6
Continuum Intensity

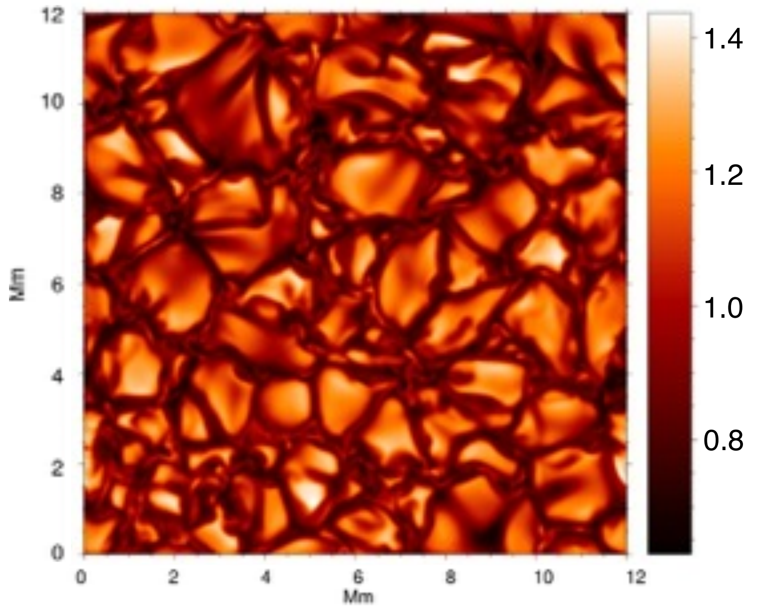
Our Removal Method



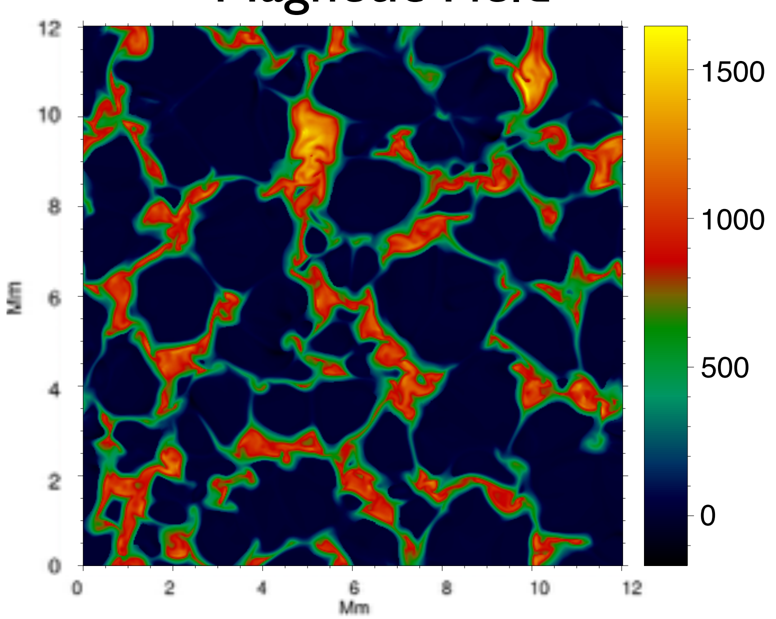
Parameterisation

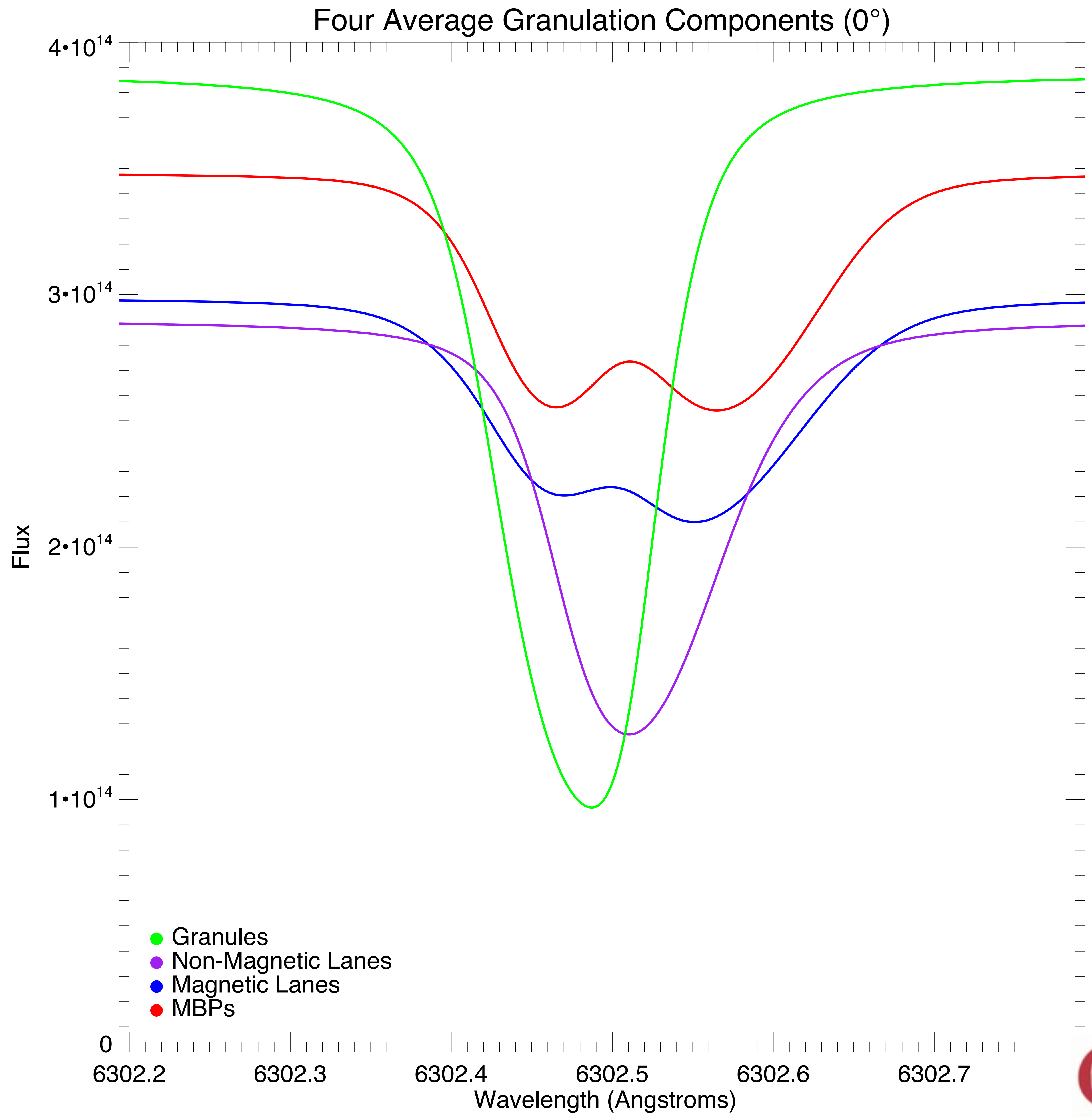
- Separate based on:
  - Continuum Intensity
  - Magnetic Field
- Four Components
  - Granules
  - Non-Magnetic Intergranular Lanes
  - Magnetic Intergranular Lanes
  - MBPs

Continuum Intensity



Magnetic Field





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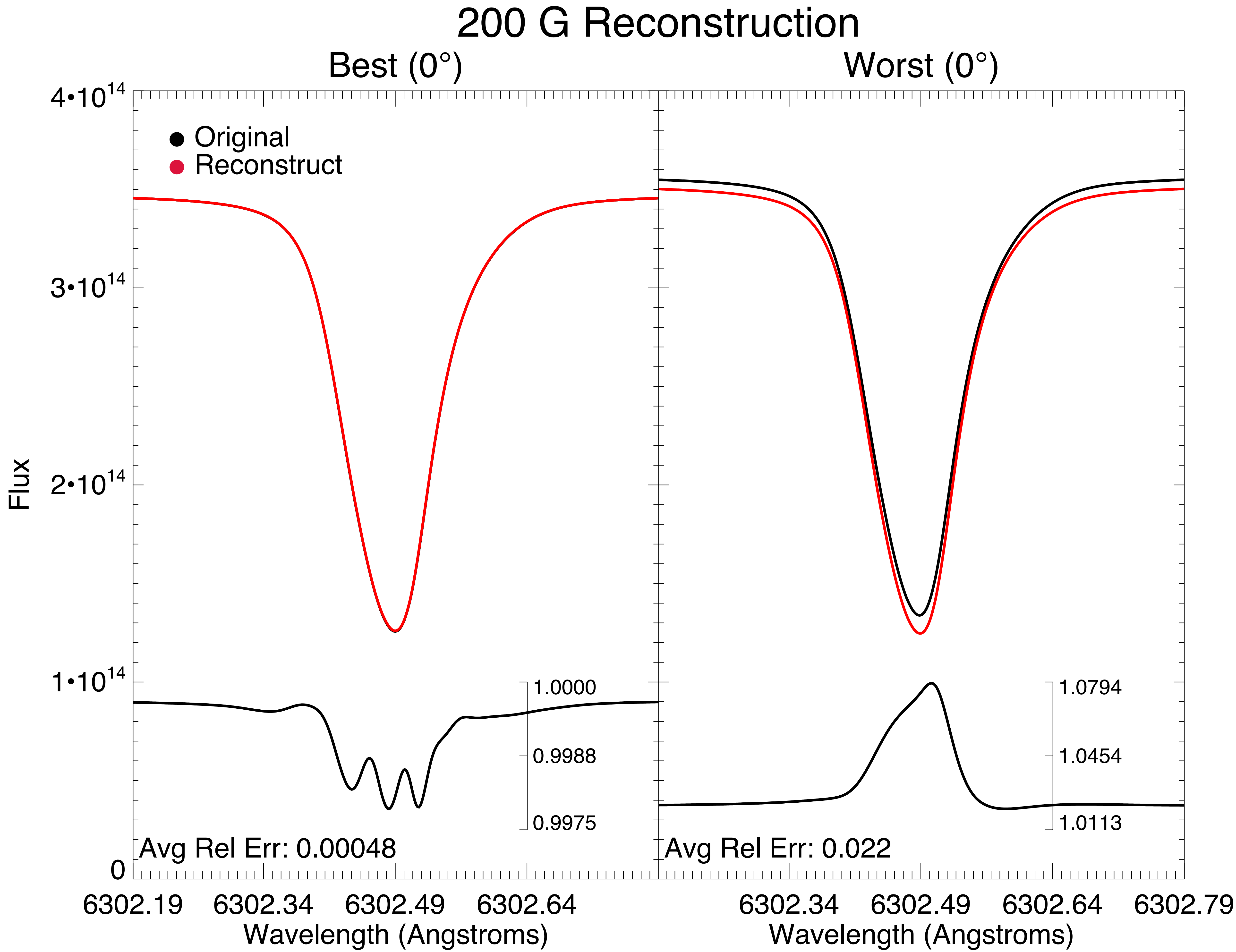
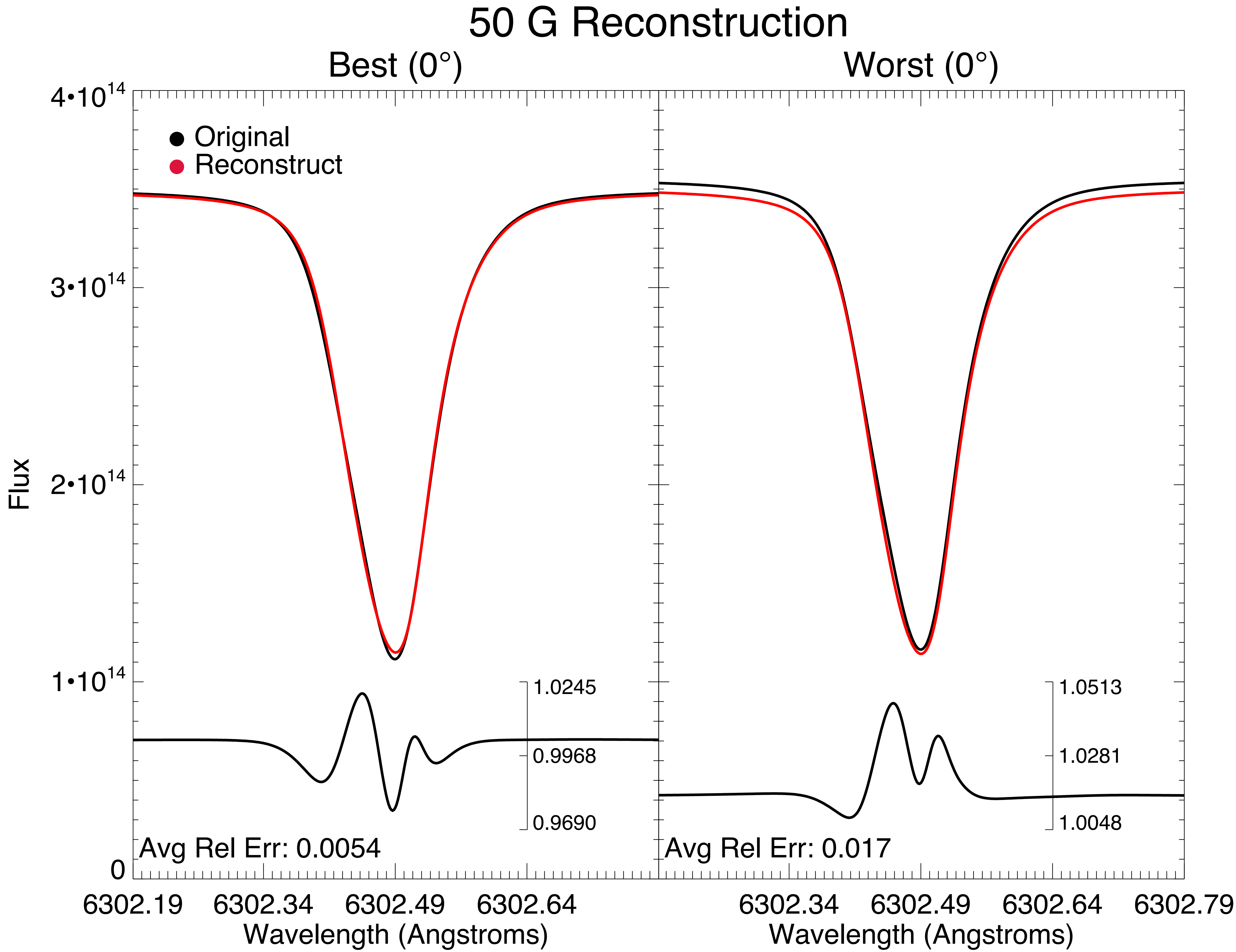

200 G Reconstruction
Best (0°)
Worst (0°)
Original
Reconstruct
Flux
4•10^14
3•10^14
2•10^14
1•10^14
0
1.0000
0.9988
0.9975
1.0794
1.0454
1.0113
Avg Rel Err: 0.00048
Avg Rel Err: 0.022
6302.19
6302.34
6302.49
6302.64
6302.79
Wavelength (Angstroms)
Wavelength (Angstroms)



50 G Reconstruction
Best (0°)
Worst (0°)
Original
Reconstruct
Flux
4•10^14
3•10^14
2•10^14
1•10^14
0
1.0245
0.9968
0.9690
1.0513
1.0281
1.0048
Avg Rel Err: 0.0054
Avg Rel Err: 0.017
6302.19
6302.34
6302.49
6302.64
6302.79
Wavelength (Angstroms)
Wavelength (Angstroms)

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doi:10.1088/0004-637X/763/2/95

STELLAR SURFACE MAGNETO-CONVECTION AS A SOURCE OF ASTROPHYSICAL NOISE. I. MULTI-COMPONENT PARAMETERIZATION OF ABSORPTION LINE PROFILES

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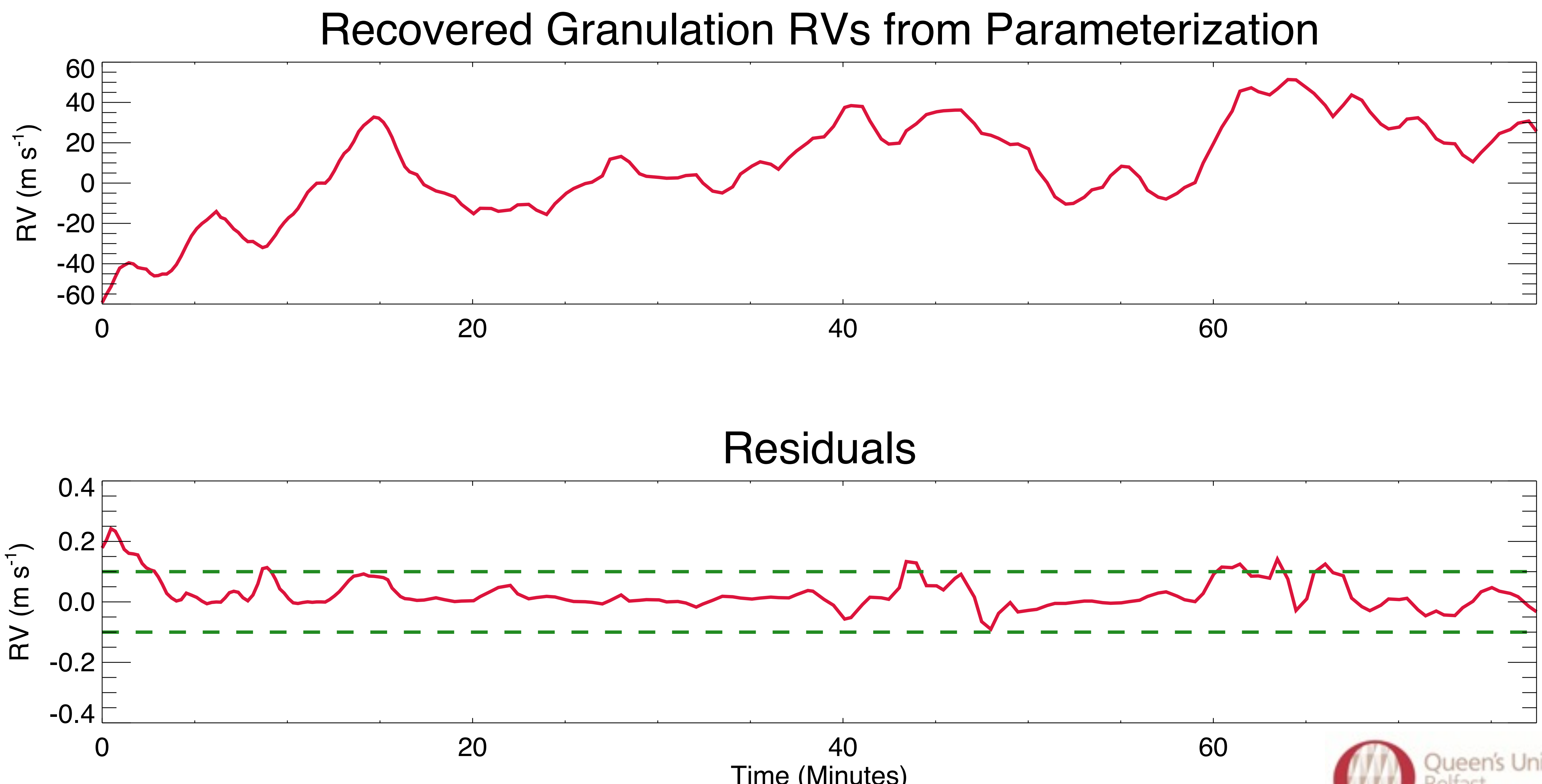

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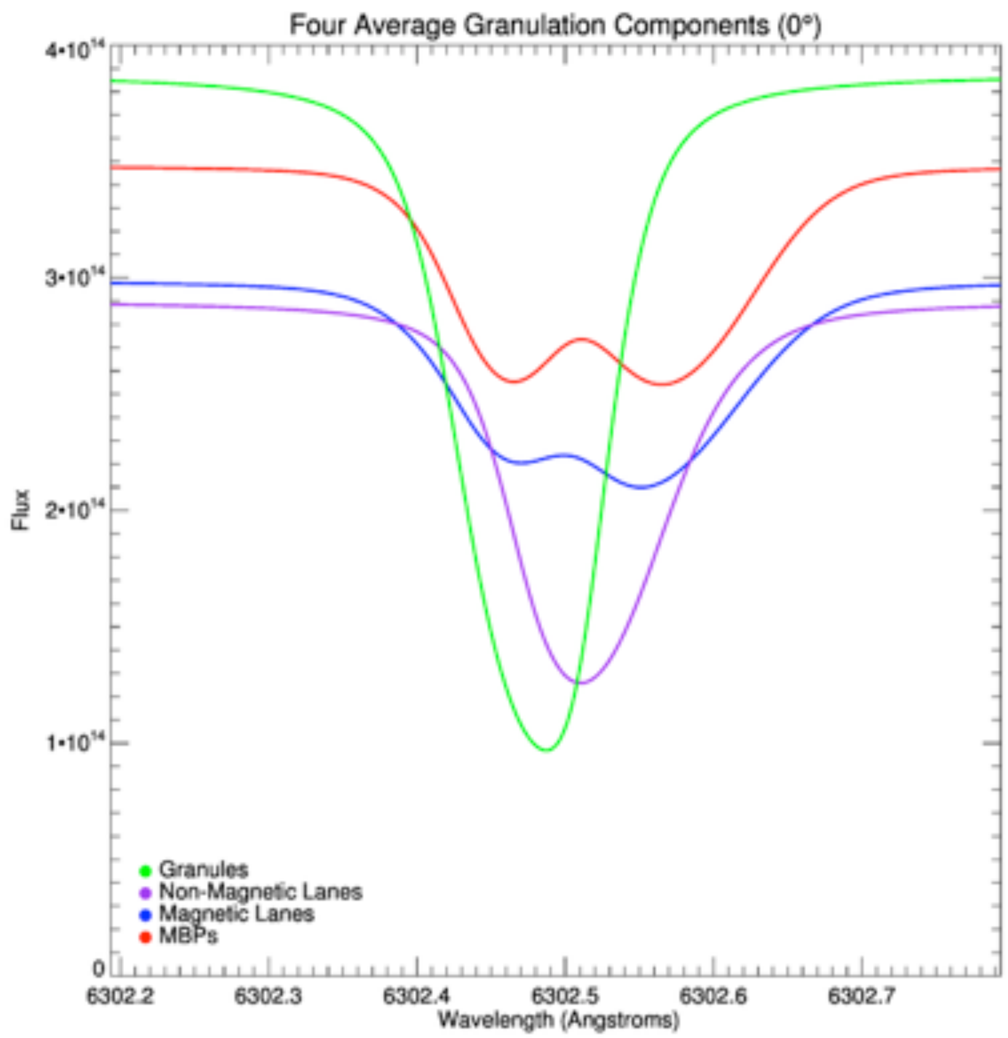

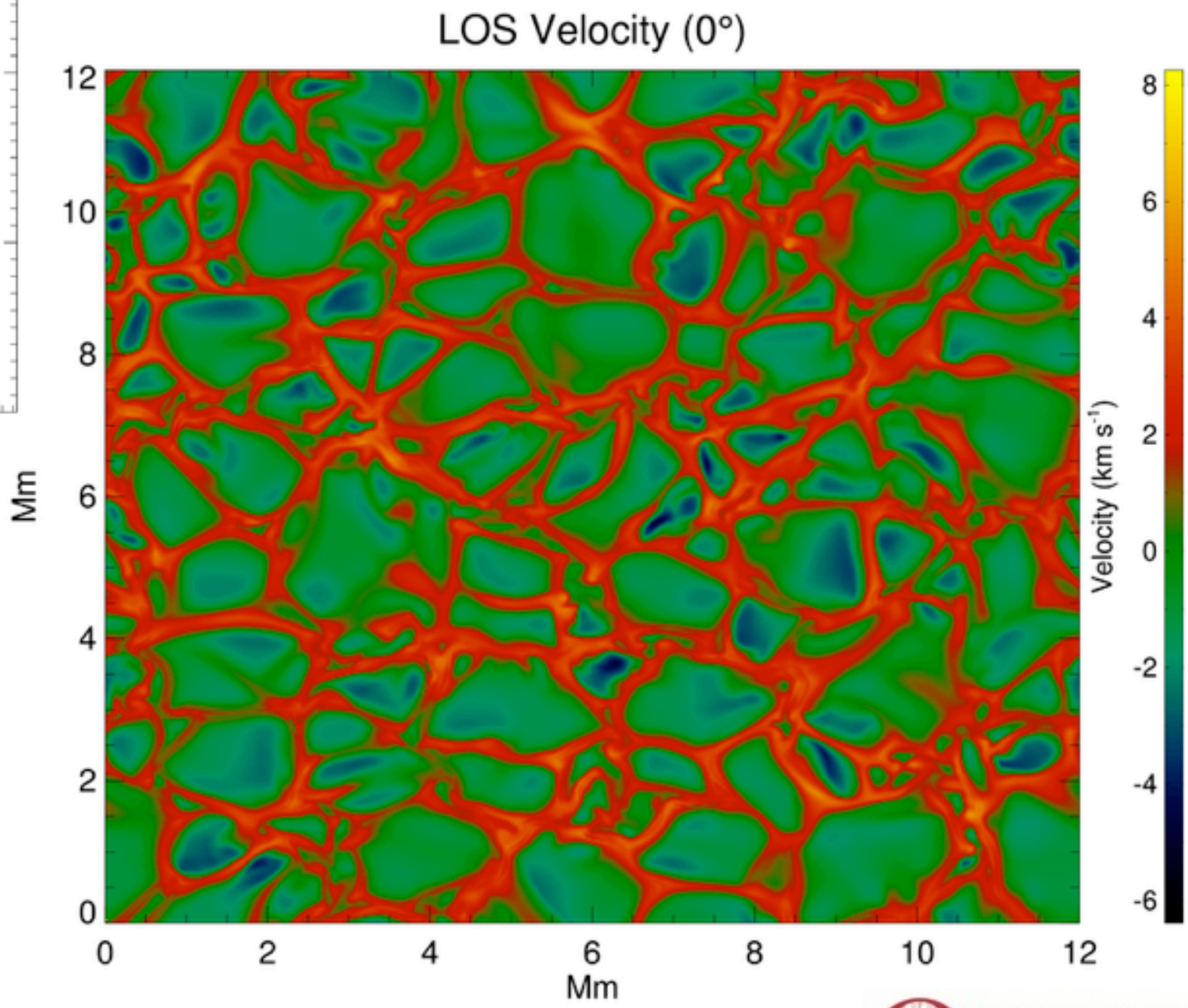

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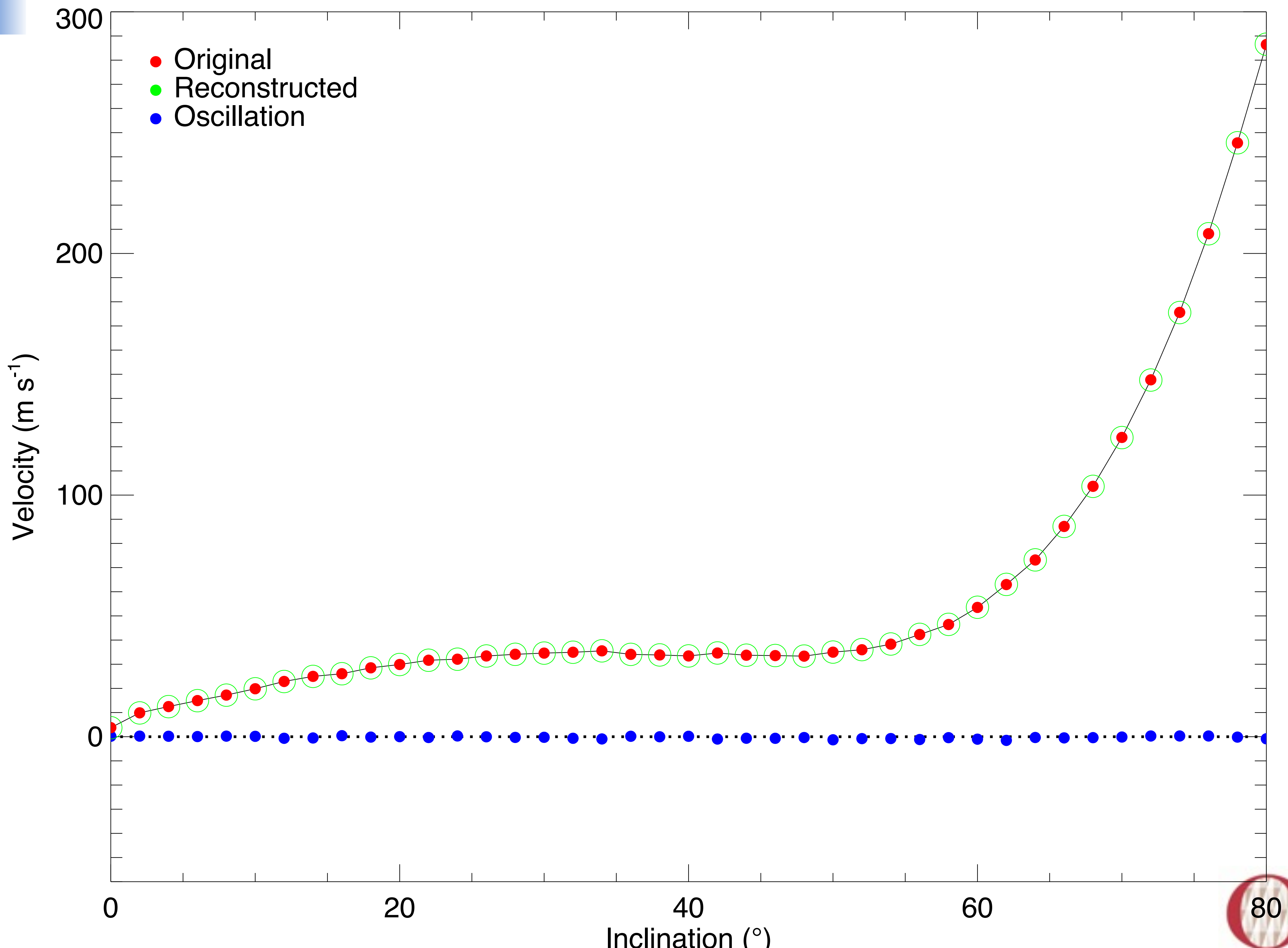
Velocities Across the Disc



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Generating **New** Profiles

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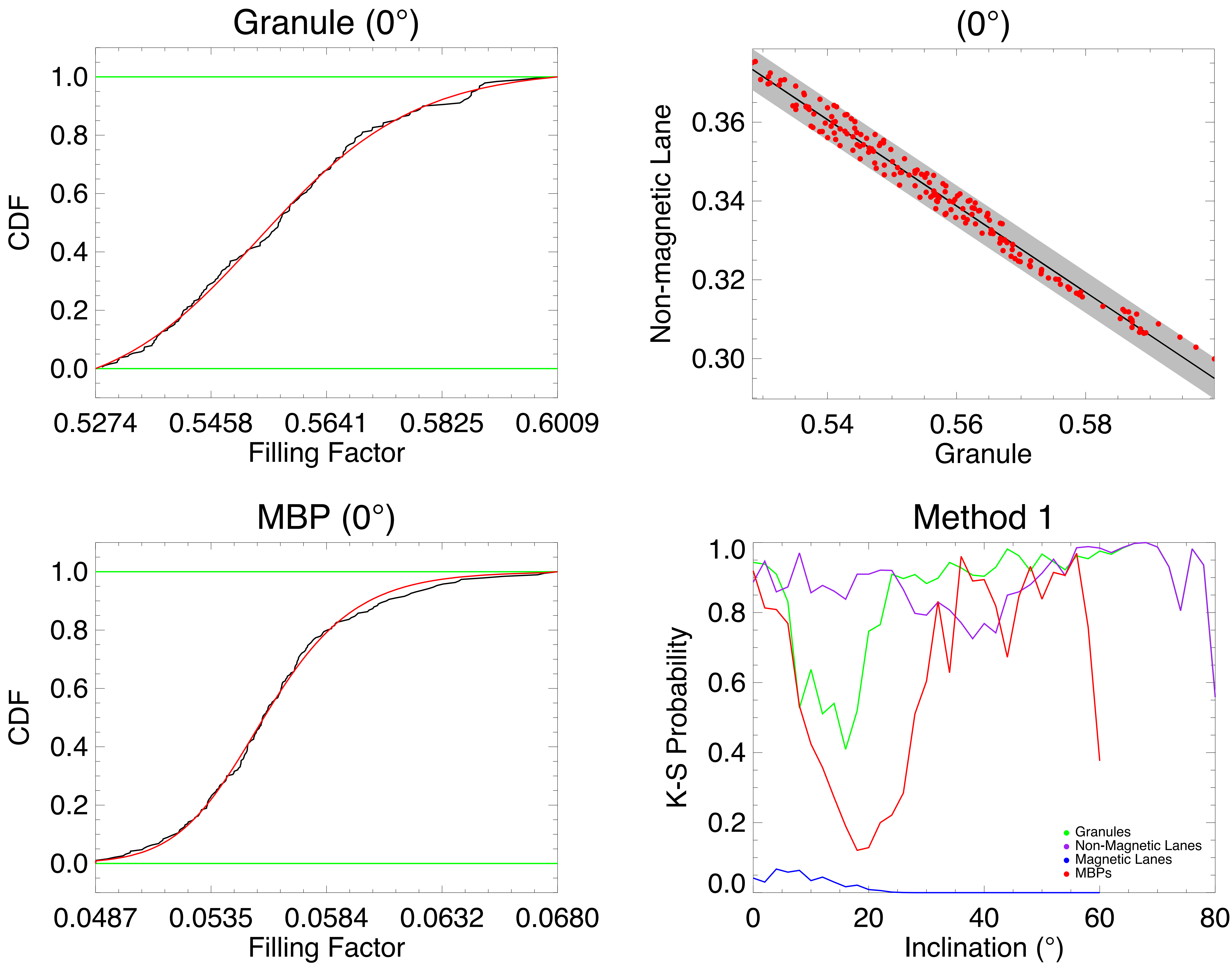
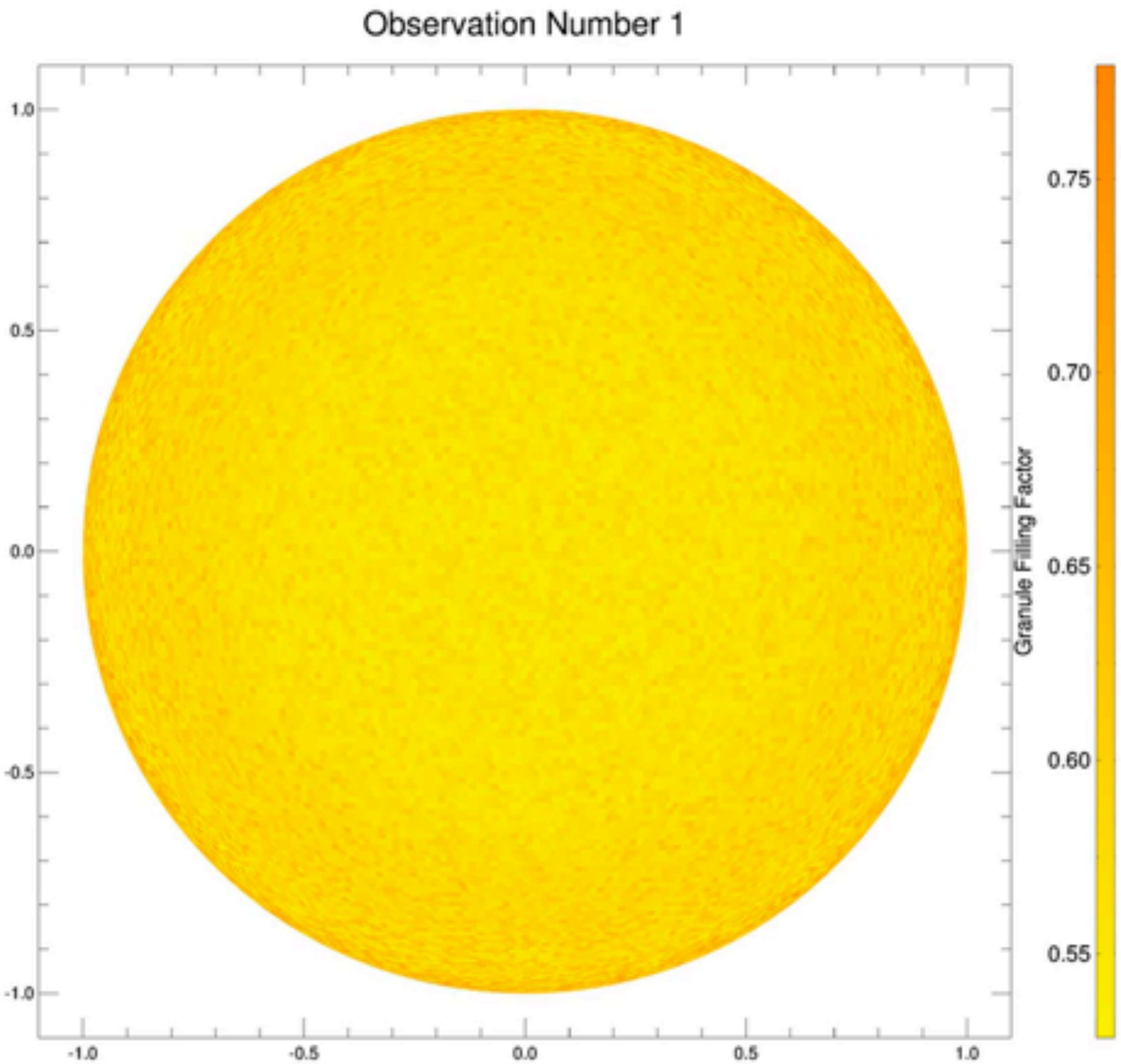
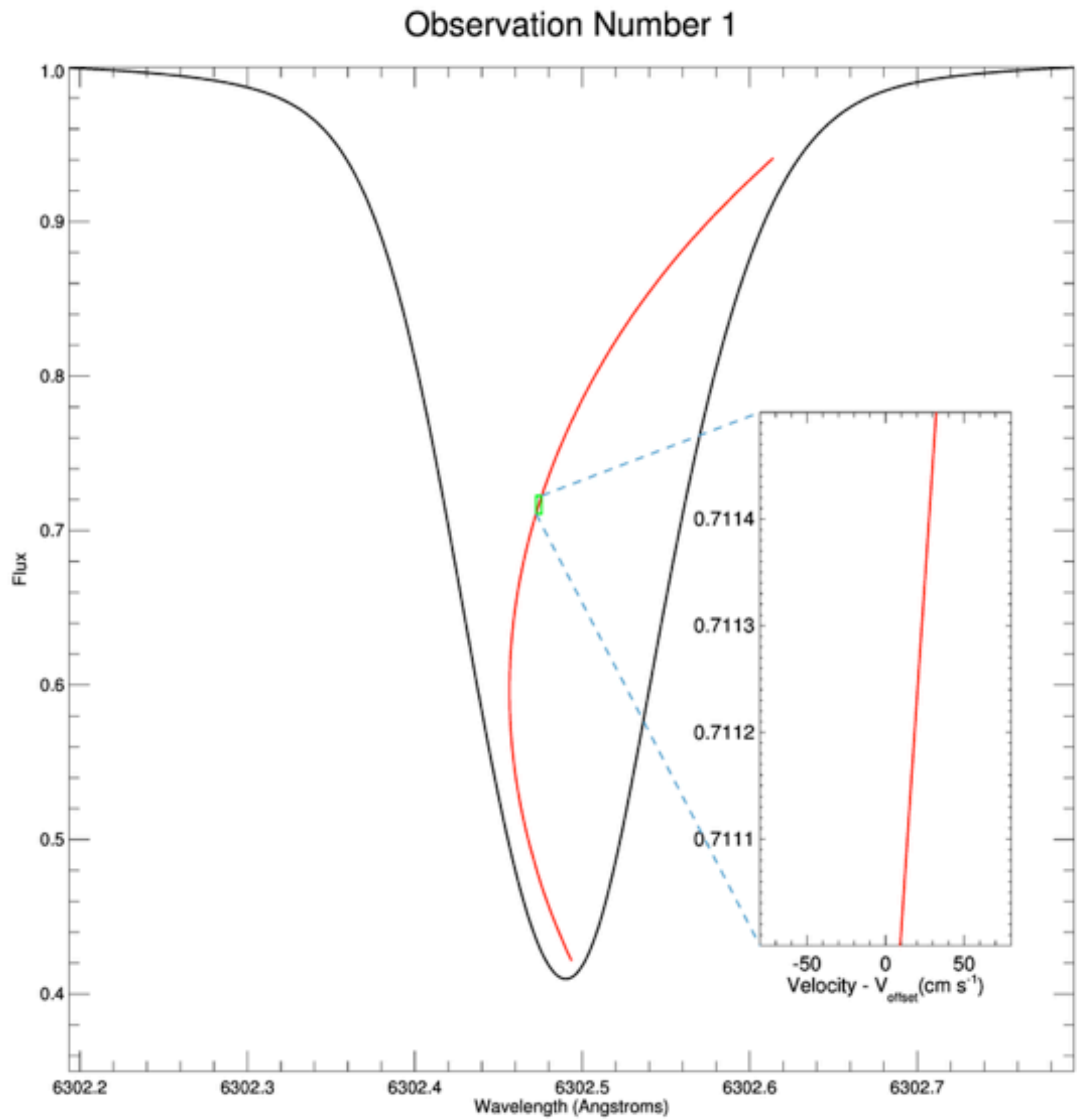

Granule (0°)
CDF
1.0
0.8
0.6
0.4
0.2
0.0
0.5274
0.5458
0.5641
0.5825
0.6009
Filling Factor
(0°)
Non-magnetic Lane
0.36
0.34
0.32
0.30
0.54
0.56
0.58
Granule
MBP (0°)
CDF
1.0
0.8
0.6
0.4
0.2
0.0
0.0487
0.0535
0.0584
0.0632
0.0680
Filling Factor
Method 1
K-S Probability
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
Inclination (°)
Granules
Non-Magnetic Lanes
Magnetic Lanes
MBPs





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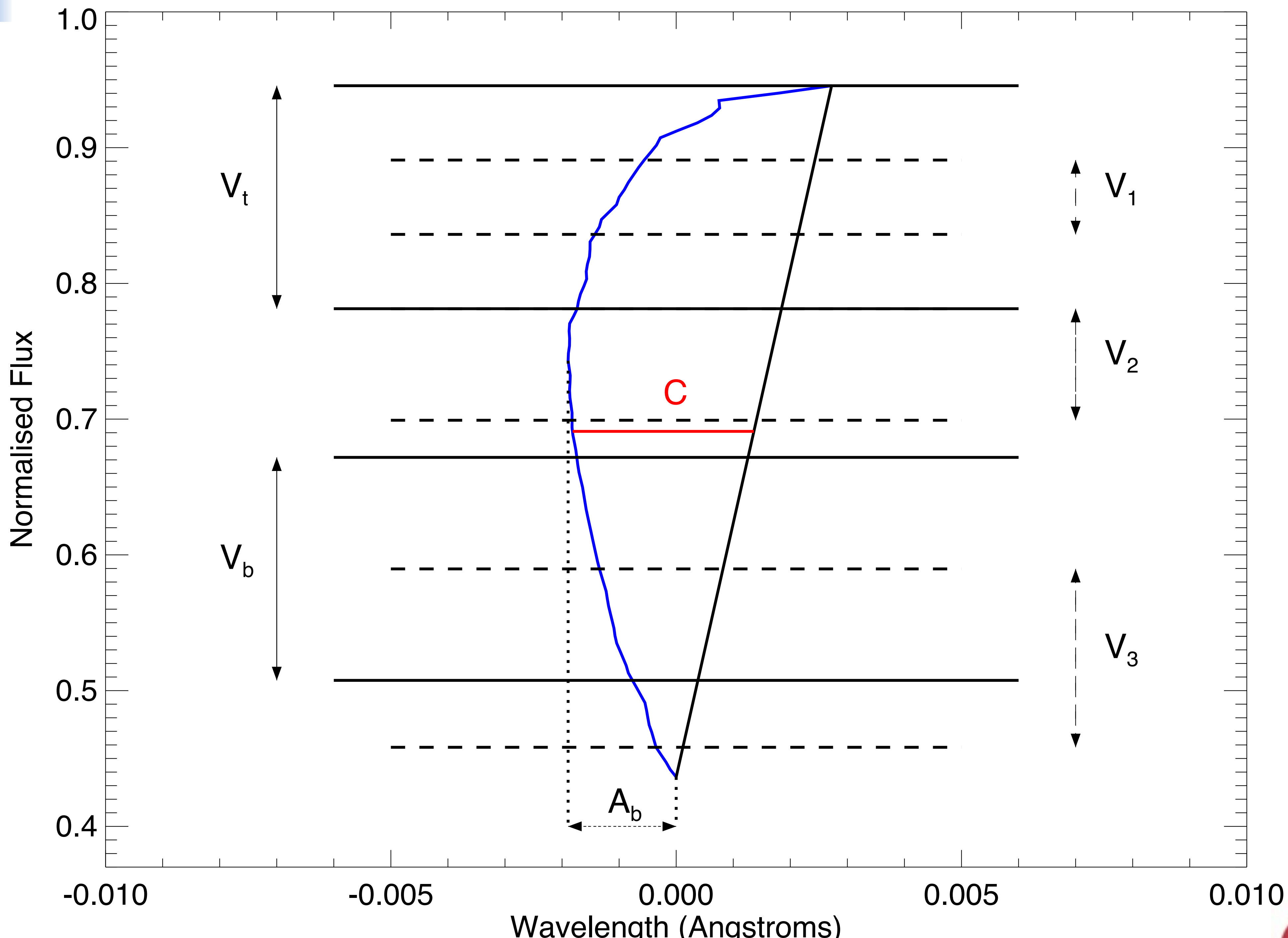
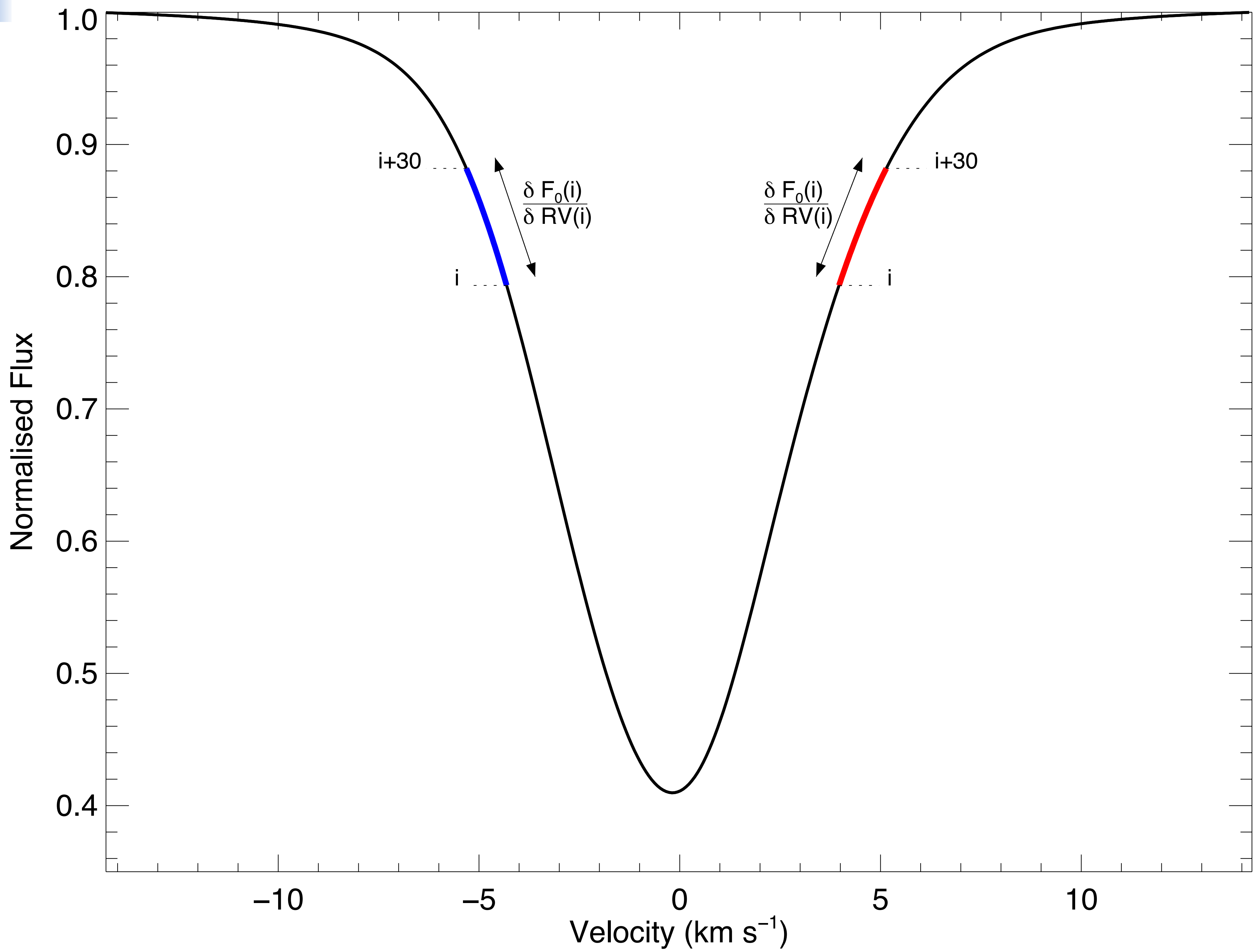
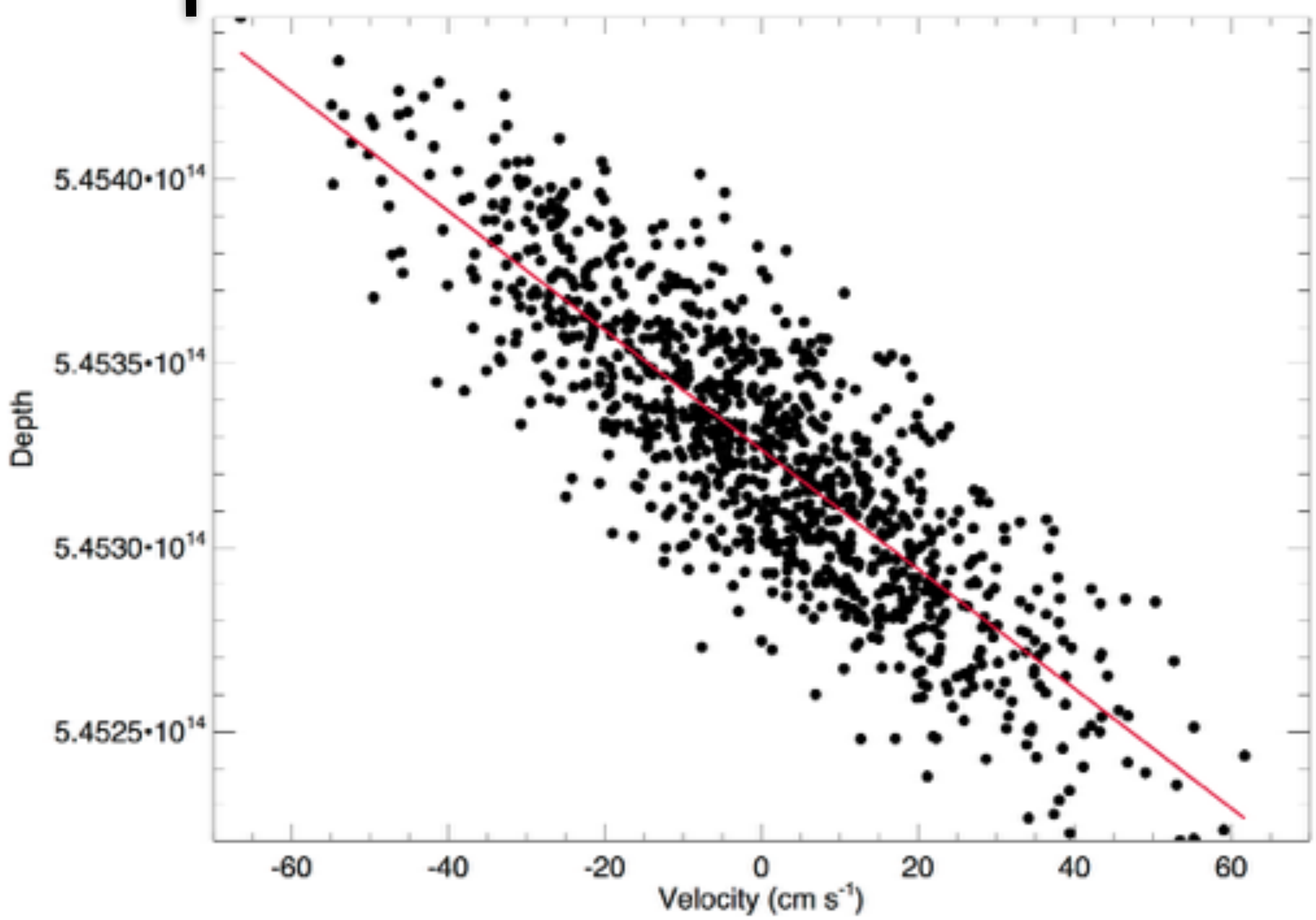
Analysing the Profiles

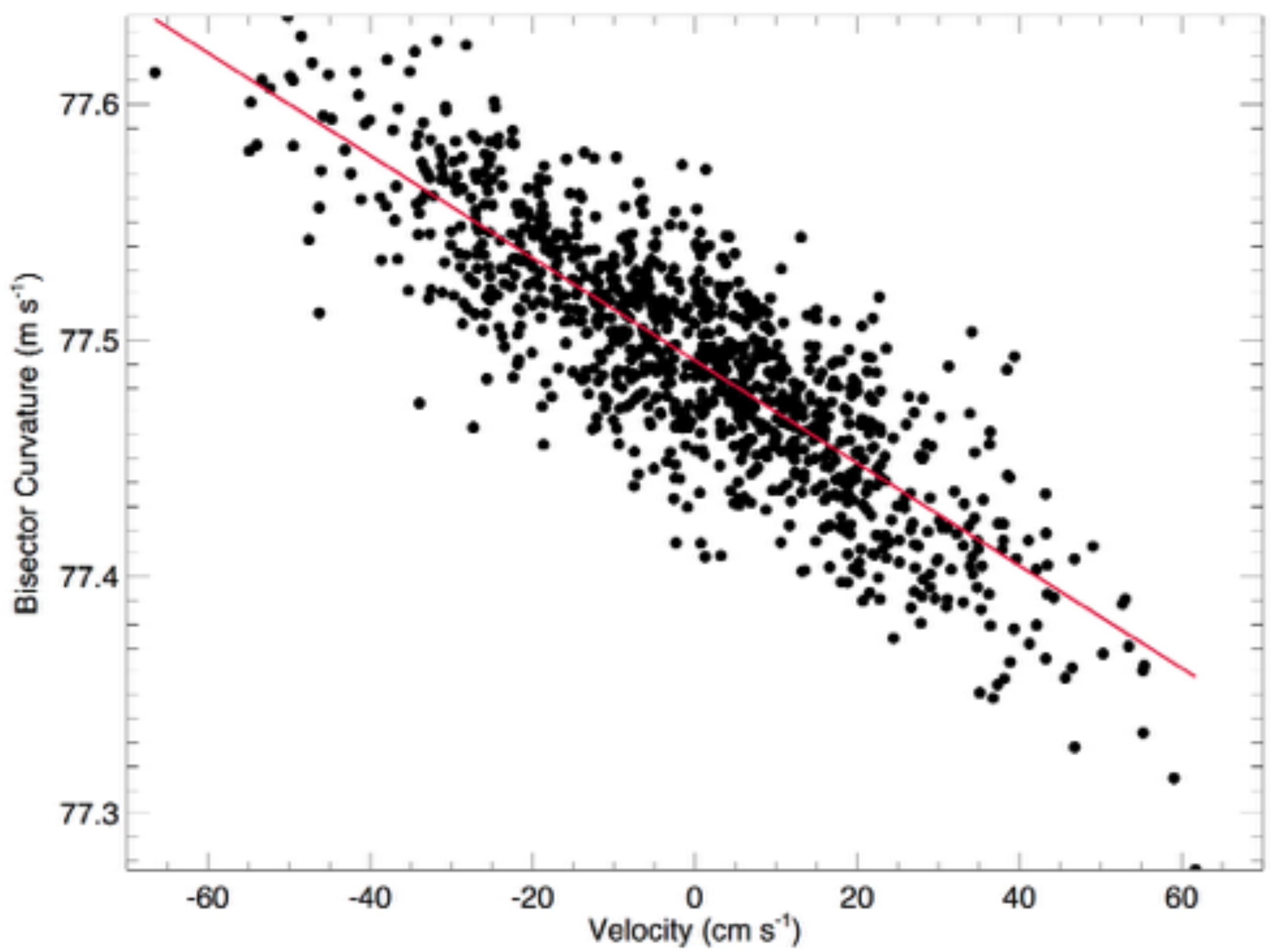


Analysing the Profiles



Initial Results





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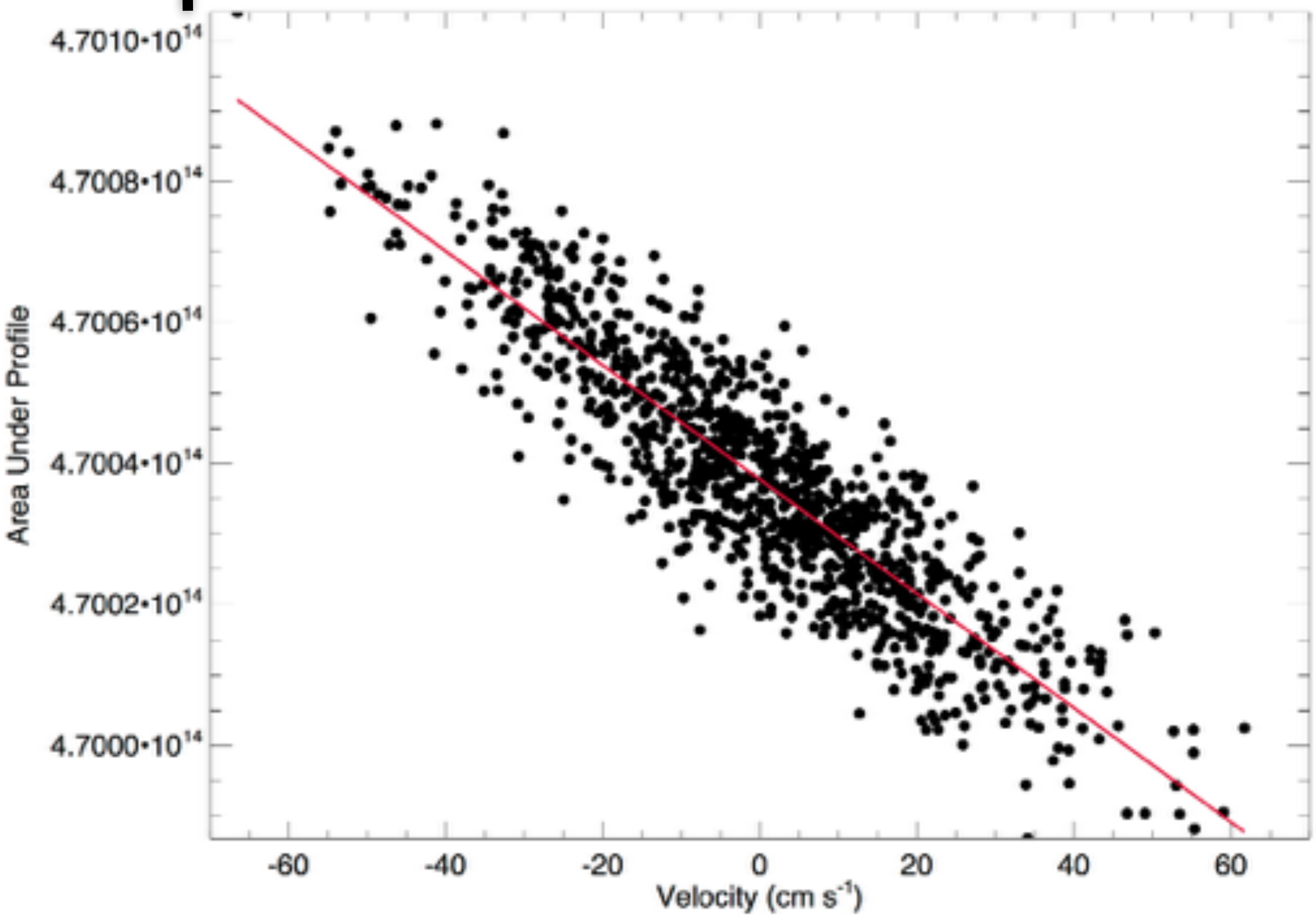
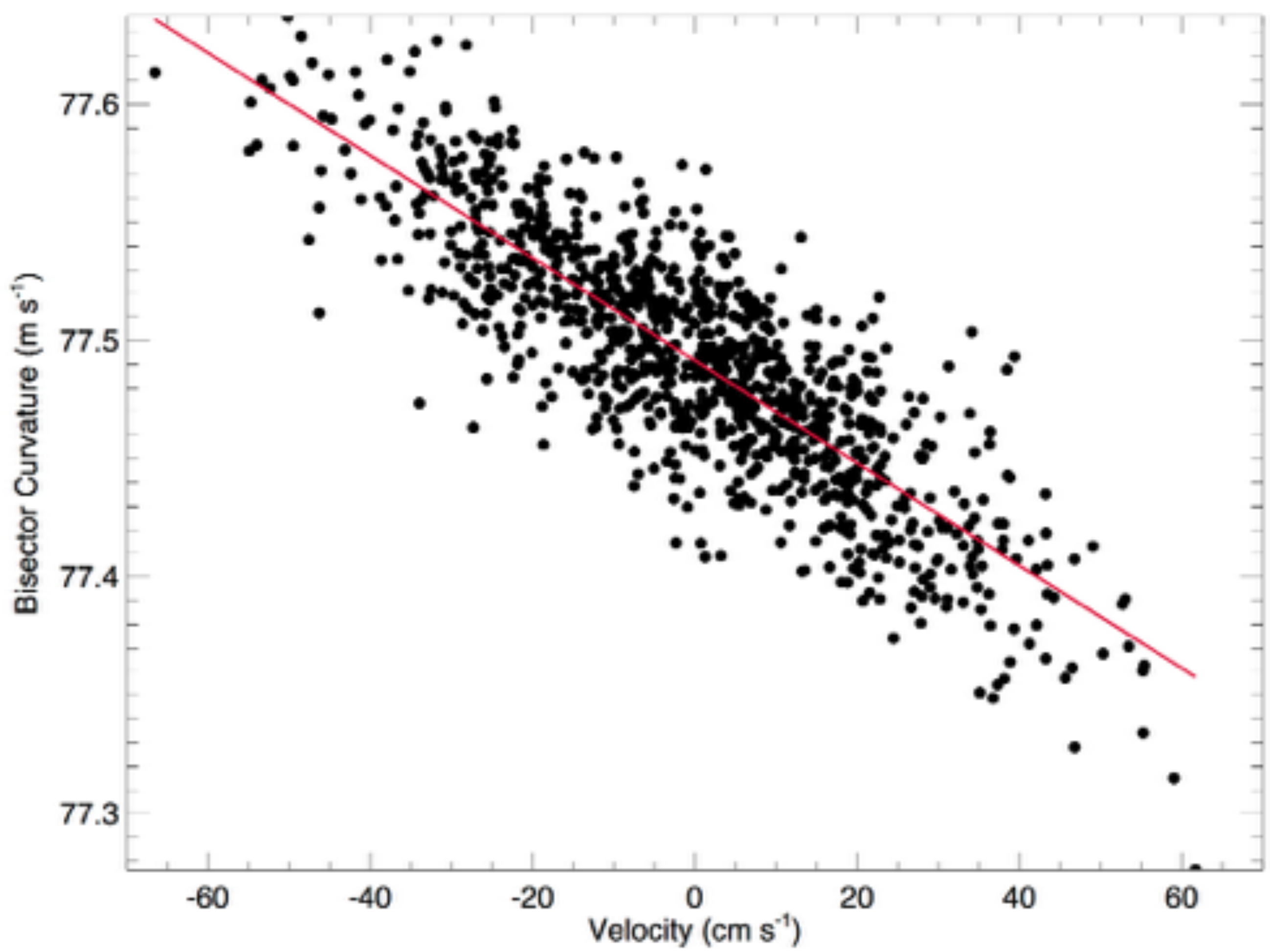
Initial Results





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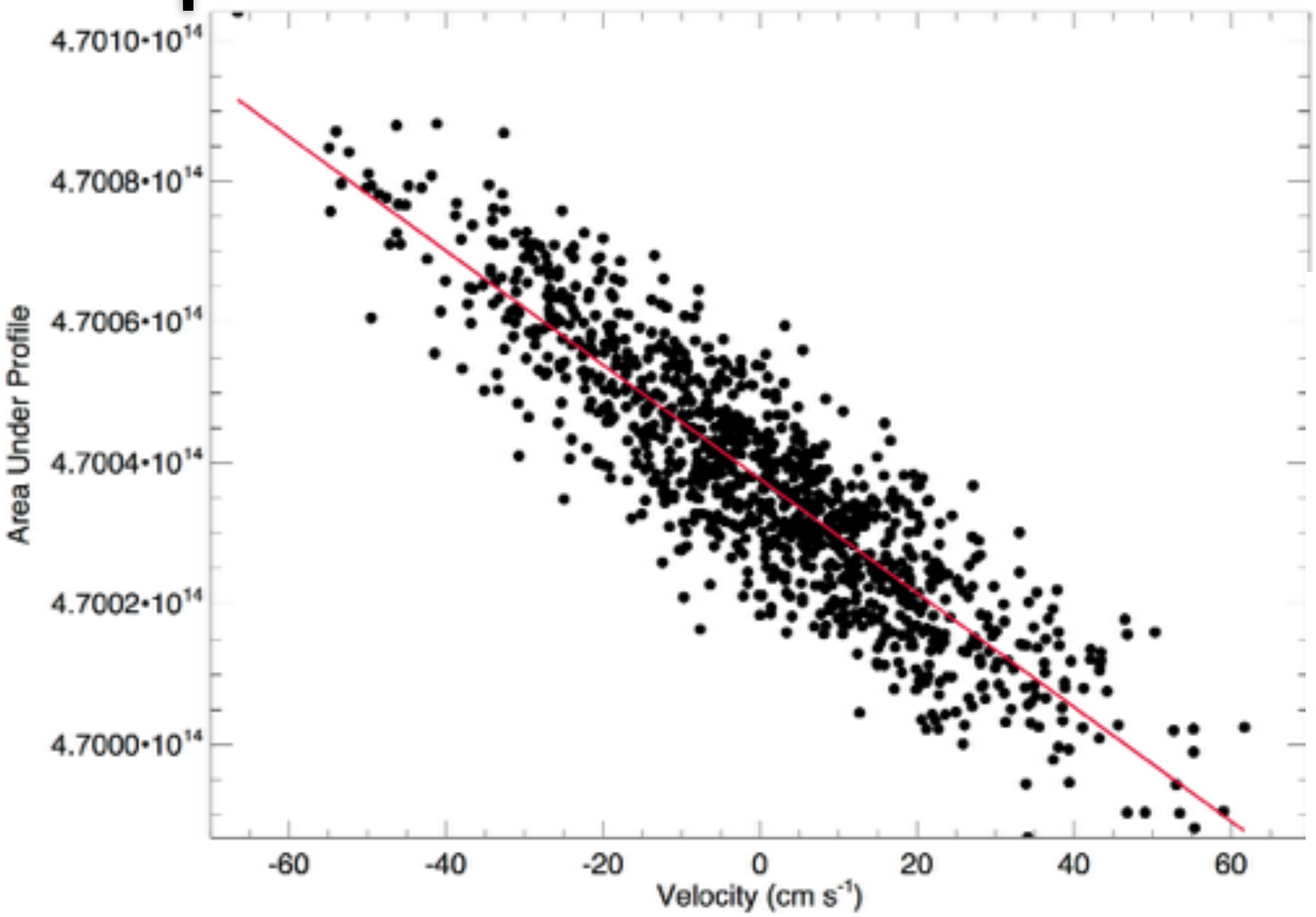
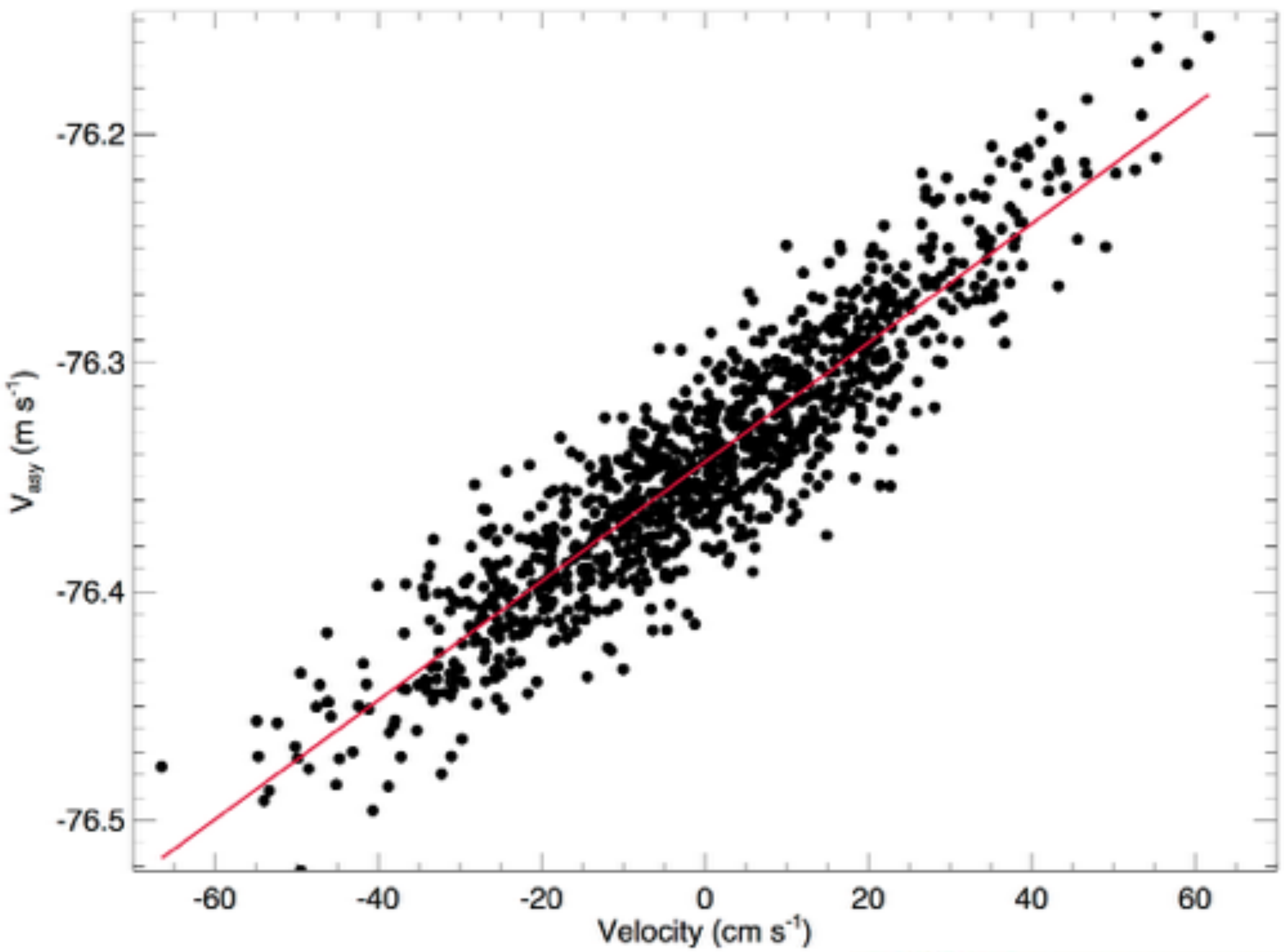
Initial Results





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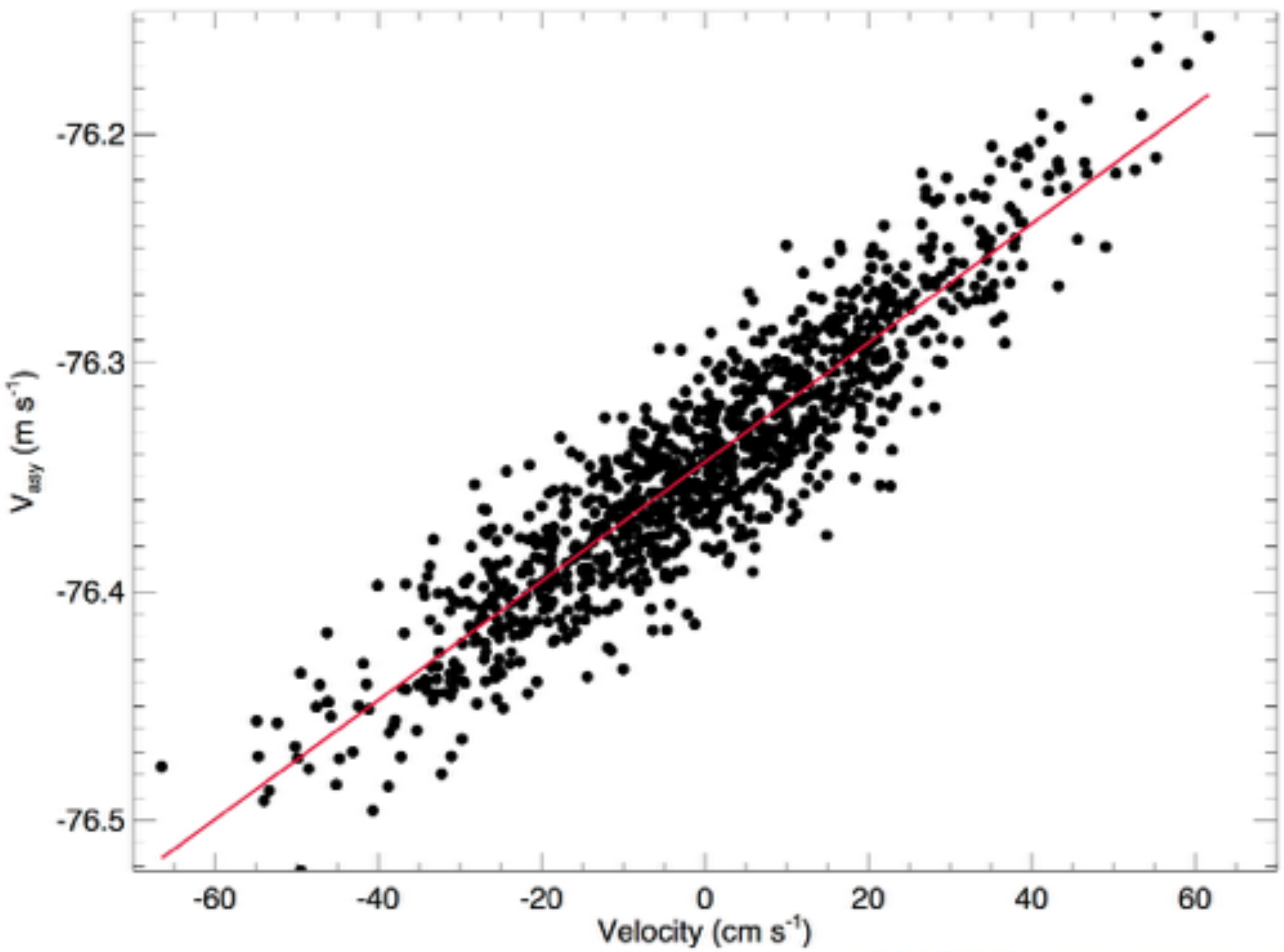
Initial Results

Diagnostic	V_σ (cm s^{-1})	Fractional Reduction (%)	Pearson's R
–	20.4	–	–
BIS	37.8	-85	-0.48
C	13.3	35	-0.84
V_b	15.5	24	0.80
A_b	16.2	21	-0.78
bi-Gauss	46.1	-126	-0.40
V_{asy}	9.0	56	0.91
FWHM	77.0	-277	0.26
Line Depth	13.0	36	-0.84
EW	17.4	15	-0.76
Brightness	10.5	49	-0.89



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Next Steps...

- Continue to make observations more realistic:
  - Instrumental profile, photon noise, finite exposures, additional noise sources, various magnetic fields, injecting planets
- Test observationally
  - Solar data, highest RV precision targets
- Expand to a suite of stellar lines with varying:
  - Formation heights, absorption strengths, excitation and ionisation potentials
- Expand to other spectral types