Solar photospheric plasma and magnetic field dynamics: modelling of the temporal evolution of flow motions.

Jose Iván Campos Rozo[1, 2]

Dominik Utz[1]

Astrid Veronig[1]

Santiago Vargas Domínguez[2]

1. IGAM/Institute of Physics, Karl-Franzens University of Graz, Austria
2. Observatorio Astronómico Nacional, Universidad Nacional de Colombia, Colombia

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Outline:

- Motivation
- A little Introduction
- Used Observational Data
- Proper Motions and Dynamics
- Summary

Note: All the procedures have been written using Python and SunPy (an open source library for solar physics data analysis)

Motivation

- Studies of the formation of active regions are of great importance for a better understanding of the origin of solar magnetic fields.
- In this particular presentation, we are mainly interested in the study of horizontal and vertical motions in active region AR 11190. (Date: April 11, 2011).

Note: All the procedures have been written using Python and SunPy (an open source library for solar physics data analysis)

sunpy powered

python™

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Evolution and dynamic properties of photospheric plasma during formation of solar active regions

- Photospheric granulation is the most evident feature that describes the solar convection.
- Photospheric granulation is dominated by the expansion, emergence and fragmentation of convective cells (e.g. Schrijver & Zwaan 2000, Palacios et al., 2012).
- Three different sizes have been proposed within the granulation: granulation (~1000 km; Bushby and Favier, 2014), mesogranulation (4 – 12 Mm; November et al., 1981), and supergranulation (> 20 Mm; Rieutord and Rincon, 2010).
- It is known that exploding granules can occur with certain preferences within divergent flows inside mesogranular regions (Title et al., 1989).

Local Correlation Tracking

- The LCT method was applied for the first time by November and Simon (1988)
- LCT techniques are used to calculate flow fields at many different spatial and temporal scales.
- The algorithm is based on a basic but powerful idea of "maximizing and finding the best local congruence between two images”.

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Observational Data

- Telescope - Solar Dynamics Observatory (SDO).
- Instrument - Helioseismic and Magnetic Imager (HMI).
- Data - Continuum and Line of Sight Magnetic Field.
- Tracking photospheric plasma motions on April 11, 2011 during the whole day (00:00:00 - 23:59:15)
- Resolution ≈ 0.5 arcsec/pix, Cadence = 45 sec
- FWHM = 12.5'', $t_{average}$ = 2 h (160 frames)

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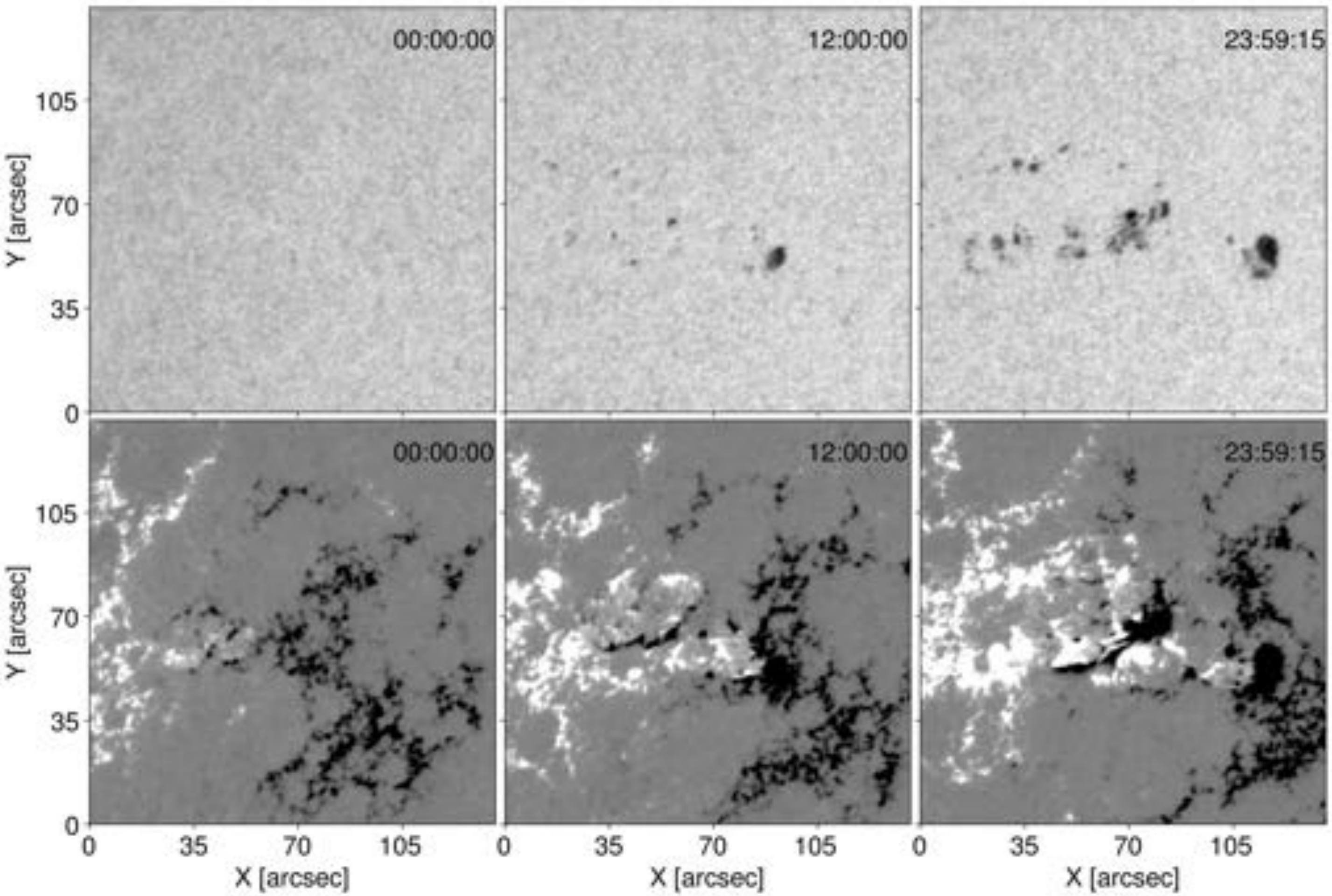
Improving the data for best results



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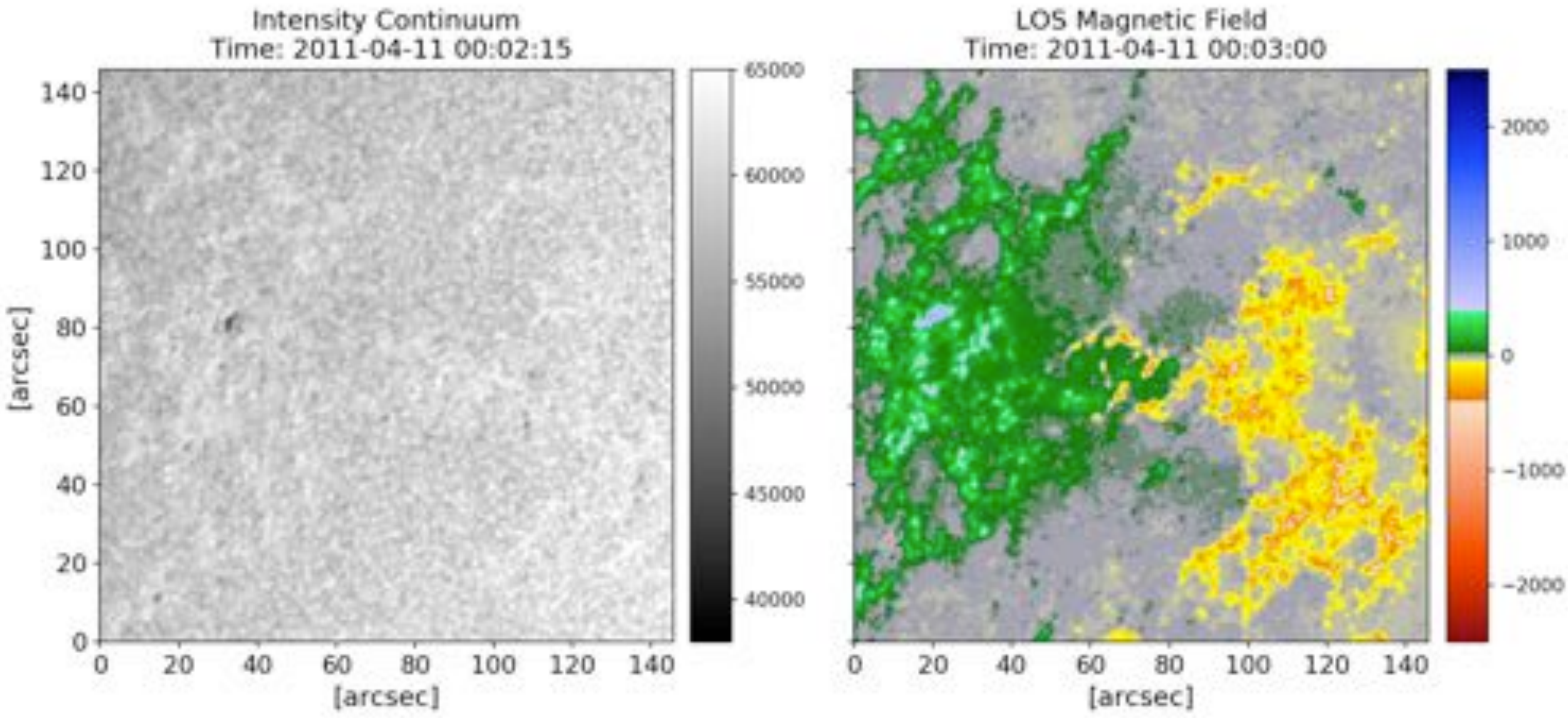
Observational Data



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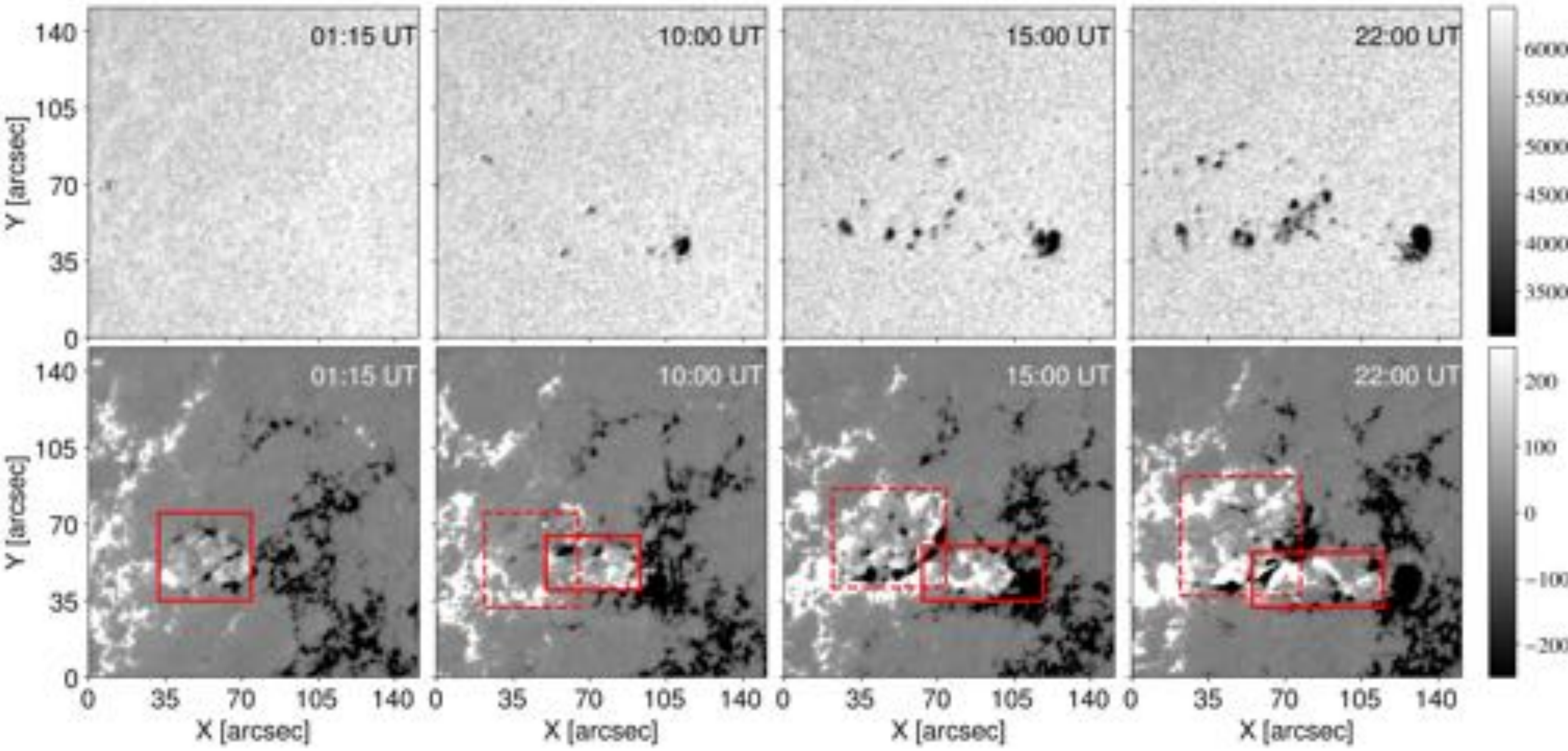

Jose Iván Campos Rozo. PhD. Student
IGAM/Institute of Physics, Karl-Franzens
University of Graz

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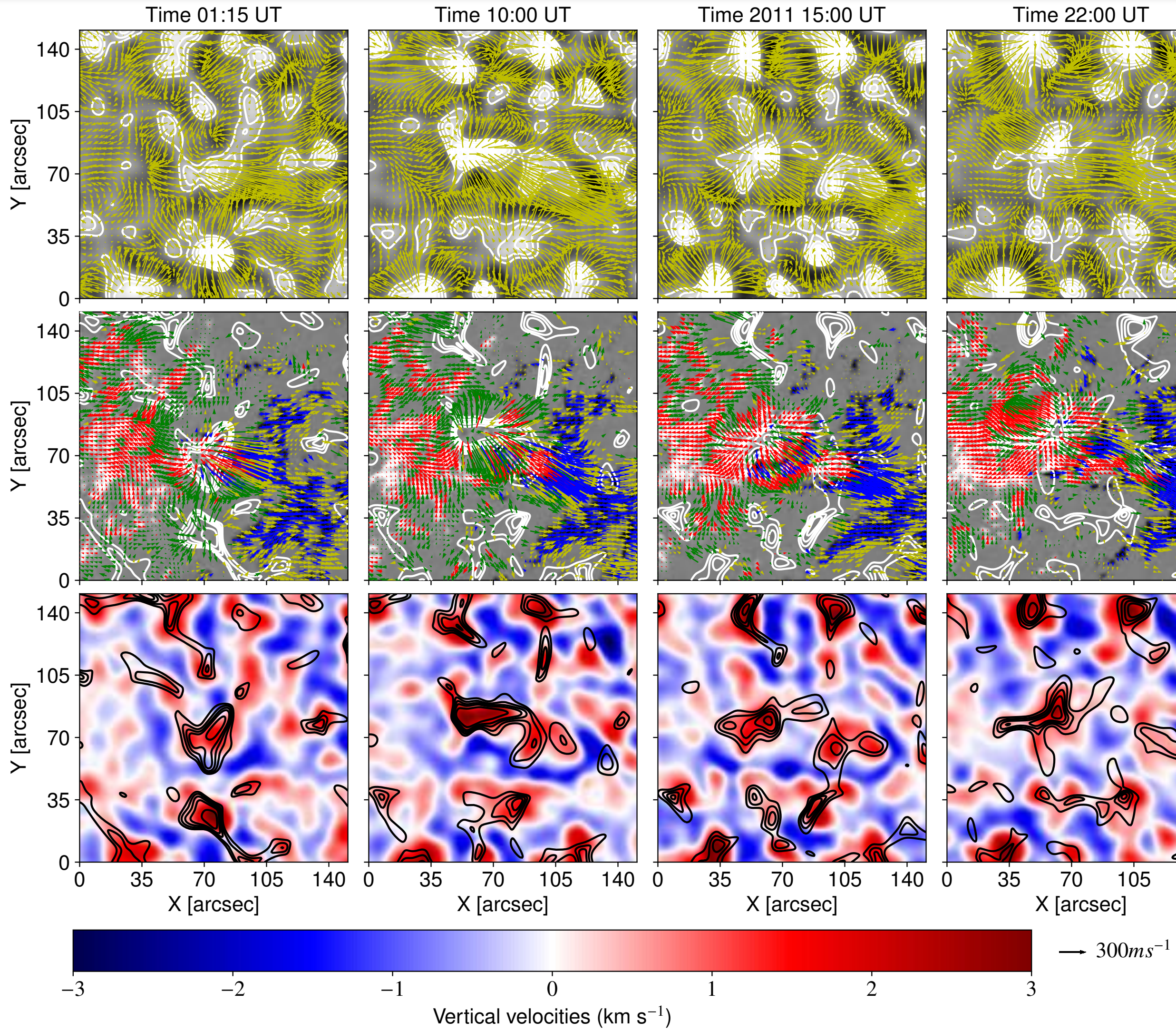
Flow maps show the evolution of the emergence in four different stages. The color code of the color bar is for the last panel and it is given in km/s.



Jose Iván Campos Rozo. PhD. Student
IGAM/Institute of Physics, Karl-Franzens
University of Graz

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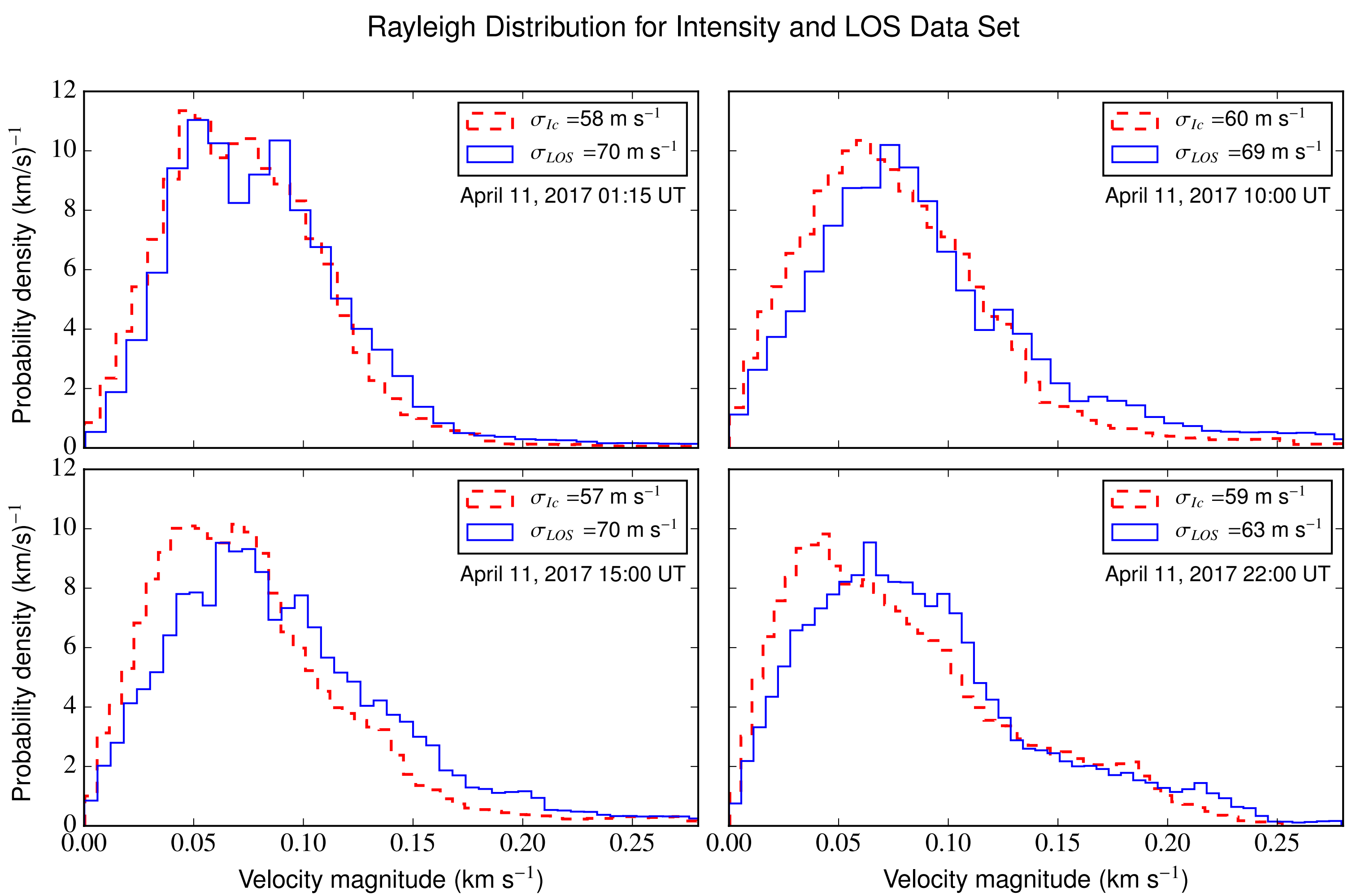
Distribution of velocities. The red line shows the distribution for the plasma motions, whereas the blue line show the distribution of magnetic elements movements.



Jose Iván Campos Rozo. PhD. Student
IGAM/Institute of Physics, Karl-Franzens University of Graz

Due to the nature of the flow fields, the best suitable statistical distribution that describes the proper motions is a Rayleigh distribution. However, the strong and fast changes require the addition of a second component.

Addition of two Rayleigh functions:

$$f(v,\sigma_{R_1}) + f(v,\sigma_{R_2}) = A_1 \cdot \frac{v}{\sigma_{R_1}^2} \exp\left(\frac{-v^2}{2\sigma_{R_1}^2}\right) + B_1 \cdot \frac{v}{\sigma_{R_2}^2} \exp\left(\frac{-v^2}{2\sigma_{R_2}^2}\right),$$

$$f(v,\sigma_{R_1}) + f(v,\mu_G,\sigma_G) = A_2 \cdot \frac{v}{\sigma_{R_1}^2} \exp\left(\frac{-v^2}{2\sigma_{R_1}^2}\right) + \frac{B_2}{\sqrt{2\pi}\sigma_G} \exp\left(\frac{-(v-\mu_G)^2}{2\sigma_G^2}\right);$$

or the addition of one Rayleigh function plus one Gaussian function.

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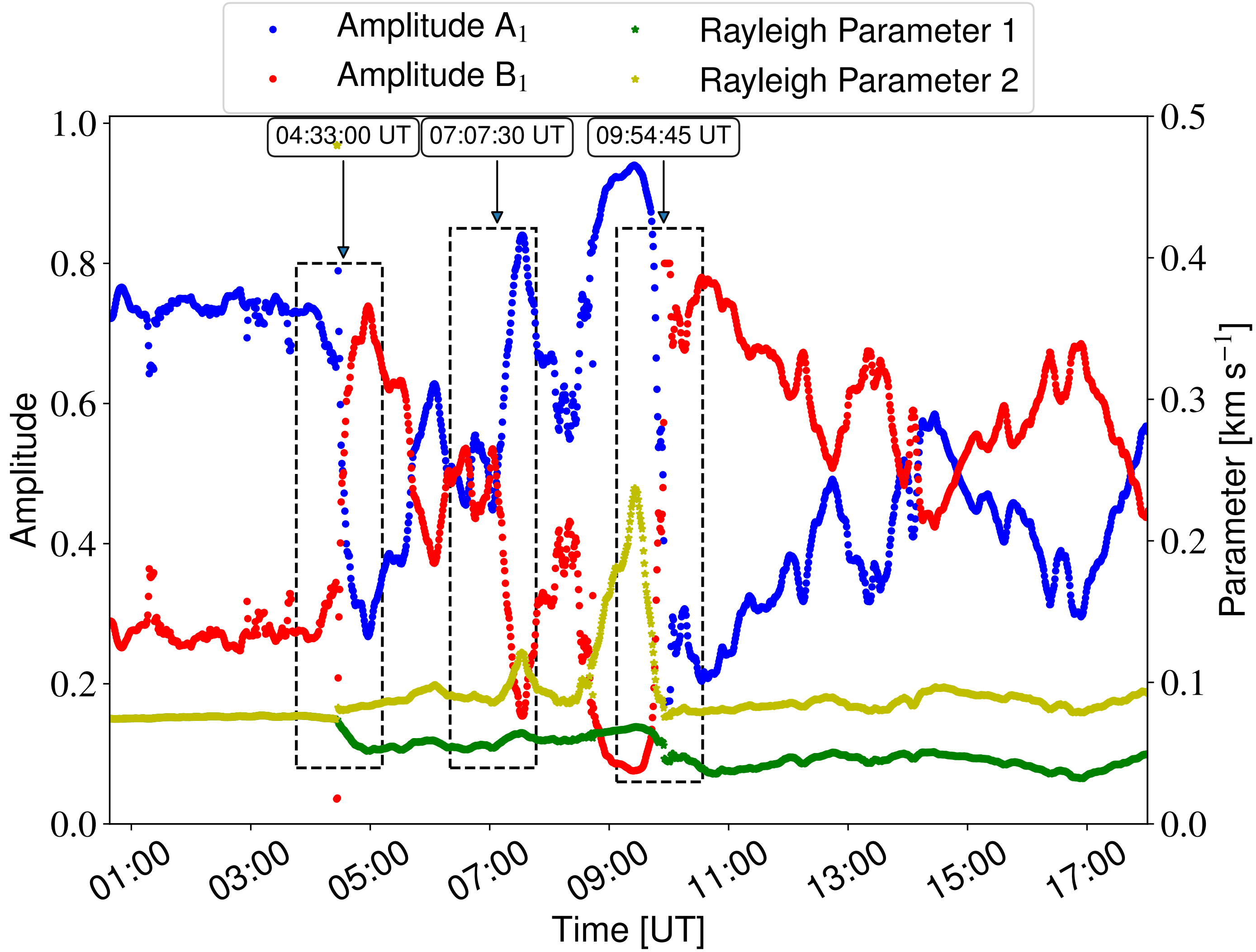

Temporal evolution of the parameters associated to the mixture of two Rayleigh distributions calculated from LOS magnetograms velocity fields.

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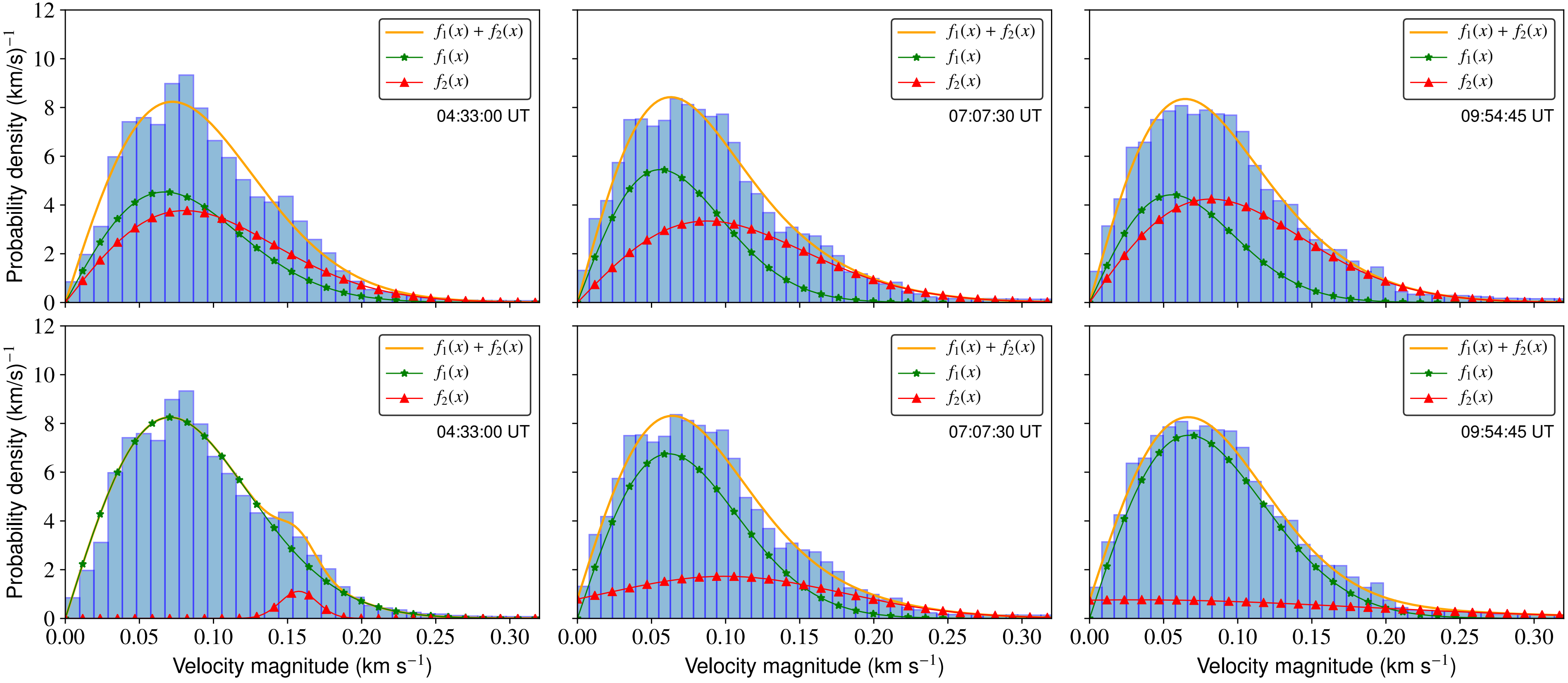
Testcases for the proposed combination of two component distributions for LOS magnetic field data



JOSE IVÁN CAMPOS ROZO. PHD. STUDENT
IGAM/INSTITUTE OF PHYSICS, KARL-FRANZENS UNIVERSITY OF GRAZ

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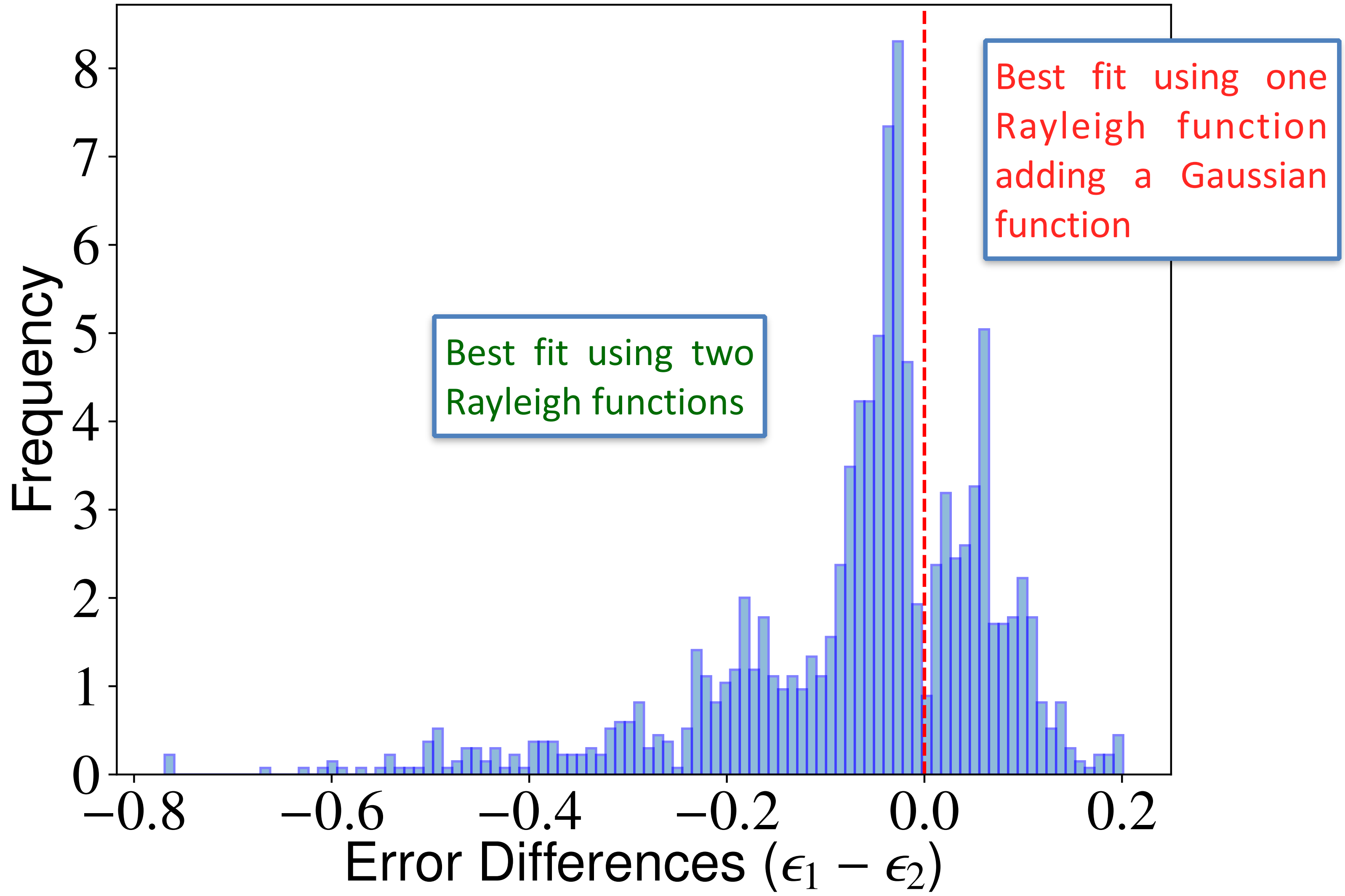

Jose Iván Campos Rozo. PhD. Student
IGAM/Institute of Physics, Karl-Franzens University of Graz

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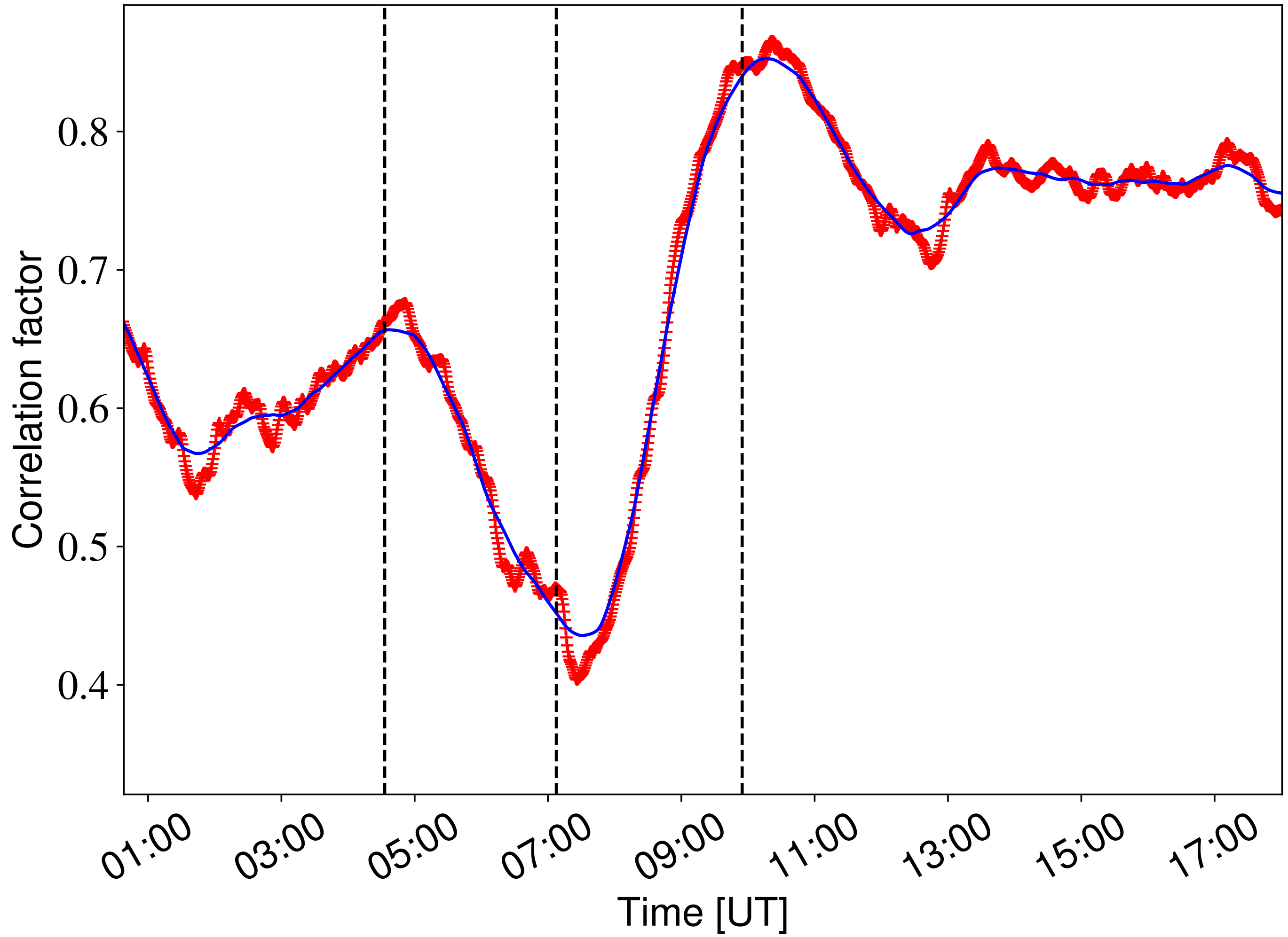

Pearson correlation coefficients for the vertical velocities in the center of the FOV (ROI). Window size = 90” x 65”

Summary

The main finding of our study is that the flow in evolving active regions can be modelled as a background flow field which follows a Rayleigh distribution and remains stable, while the newly emerging flux forms a secondary distribution. The "stability" of the Rayleigh distributions seems to be affected by the new fast and strong emergences. The mixture of two Rayleigh distributions seems to fit better when the new elements in the FOV follow random paths, whereas the gaussian distribution may be associated to radial horizontal flow fields, or the separation between positive and negative magnetic elements.

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Questions?

Maybe, I have more questions than you

Jose Iván Campos Rozo. PhD. Student
IGAM/Institute of Physics, Karl-Franzens University of Graz