SynCOM: A Synthetic Corona Outflow Model for the PUNCH community

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Motivation and Goal

- Validating and comparing the different algorithms for measuring coronal flow velocities
- Assessing the impact of different types of noise in the algorithm accuracy
- Determining the measurements errors (uncertainties)
- Extrapolating the altitude range of previously operated missions
- Goals of the PUNCH mission:
  - ✦ Produce images extending to ~ 180 $R_\odot$ to better understand how the mass and energy of the Sun's corona become the solar wind that fills the solar system

Model

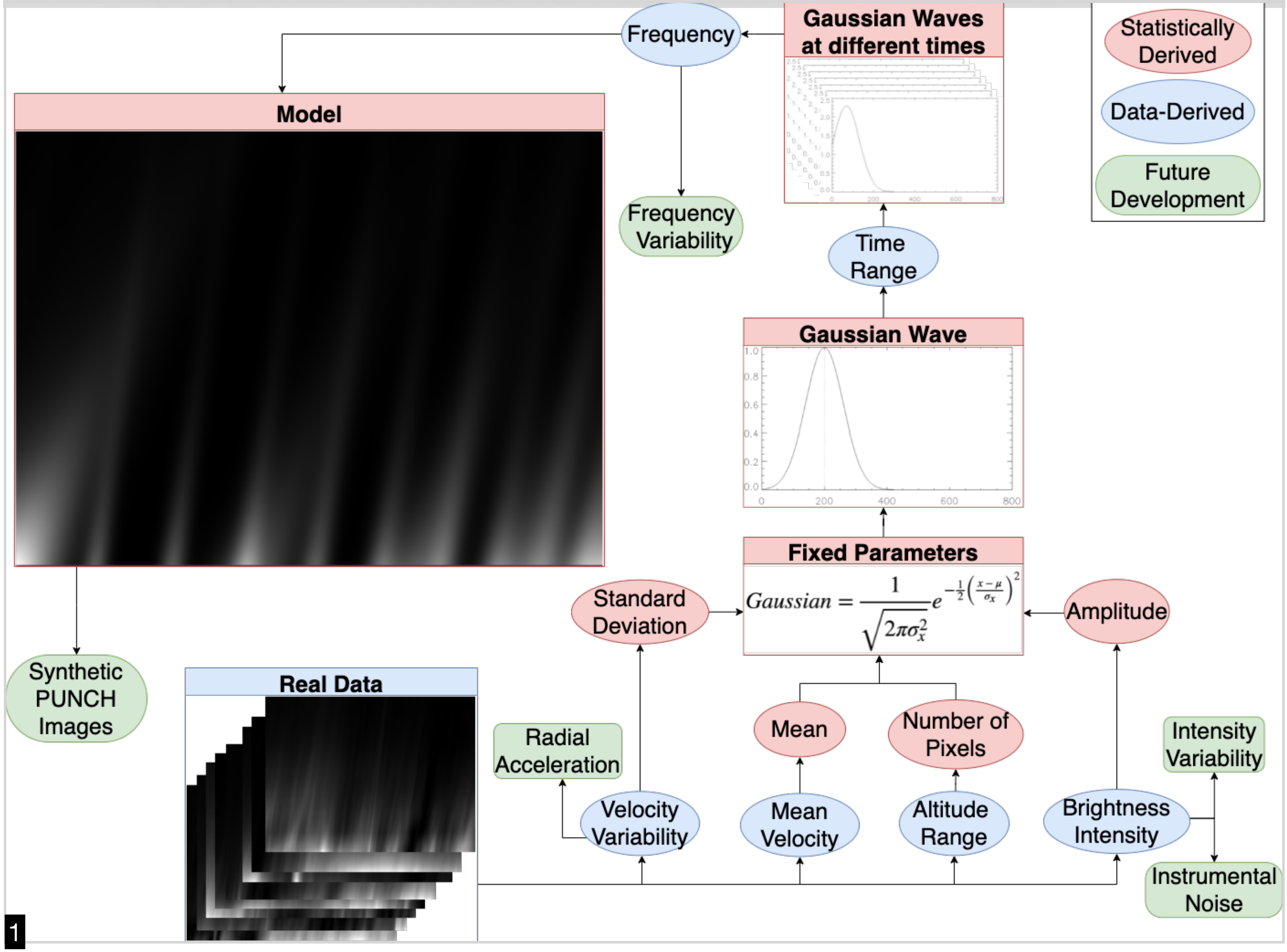

Fig 1. Flowchart of process to create a synthetic corona outflow. In blue, fixed parameters used in our model come from previous observations, such as STEREO-A / COR 2. In red, each parameter controls one aspect of the Gaussian wave, in particular its central position, width and height. In green, features still in development for our model. Our model can easily be extrapolated to altitude ranges of future mission like PUNCH.

Data - STEREO-A / COR 2

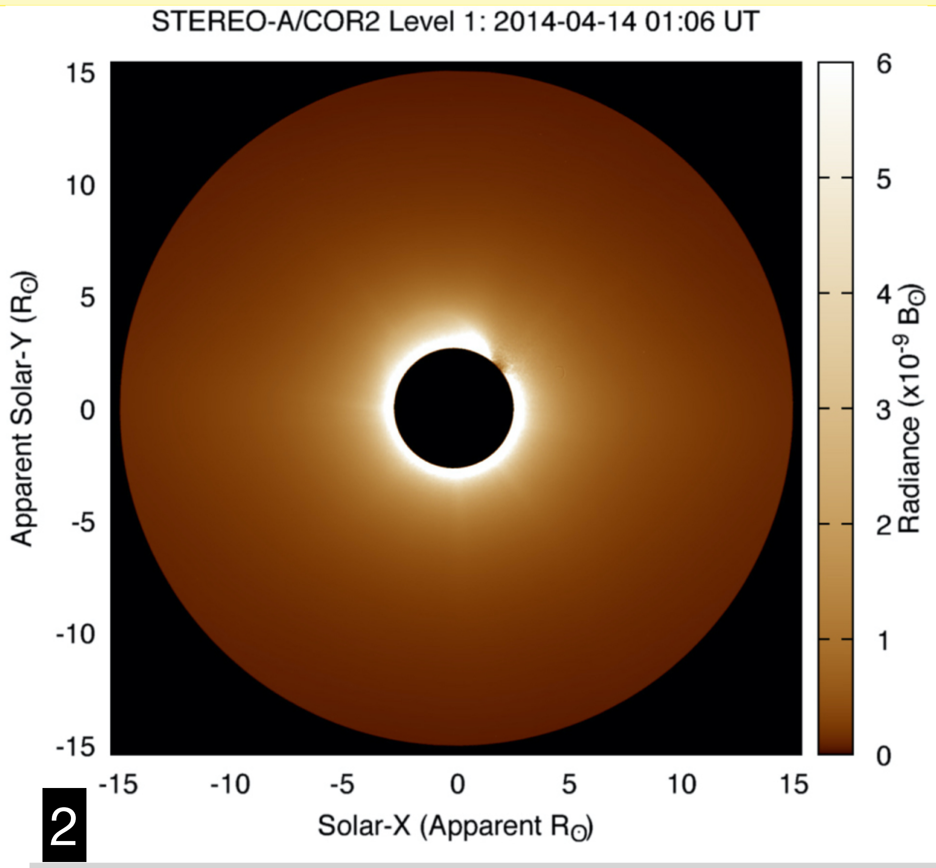

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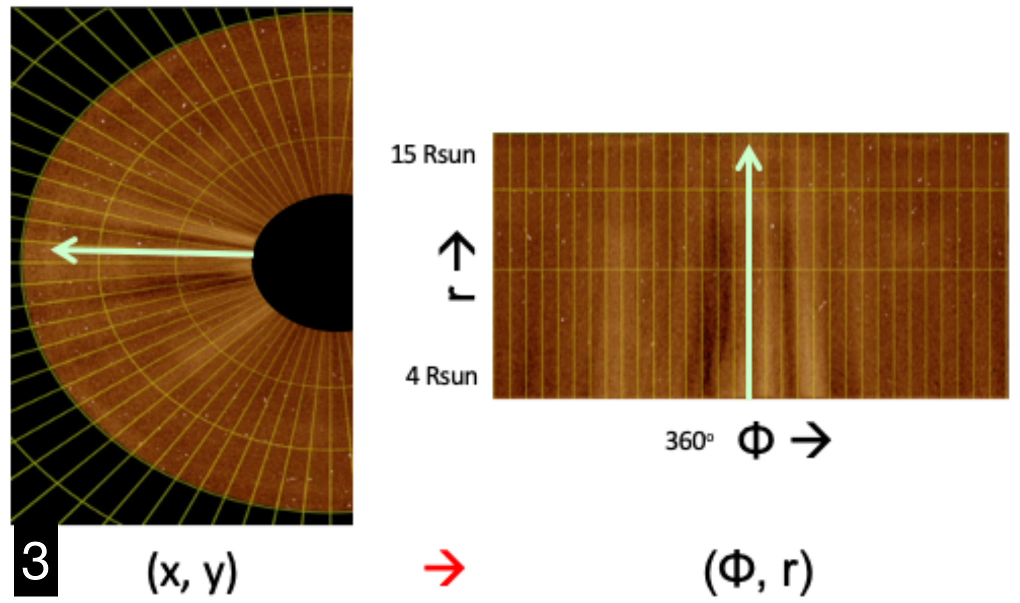
Fig 2. Raw unpolarized long-exposure coronagraph image extracted from SECCHI instrument. Each image was taking every 5 minutes. (Source: [**1**])



3

Fig 3. Coordinate transformation from Cartesian (x, y) to polar (ϕ, r). (Source: [**2**])

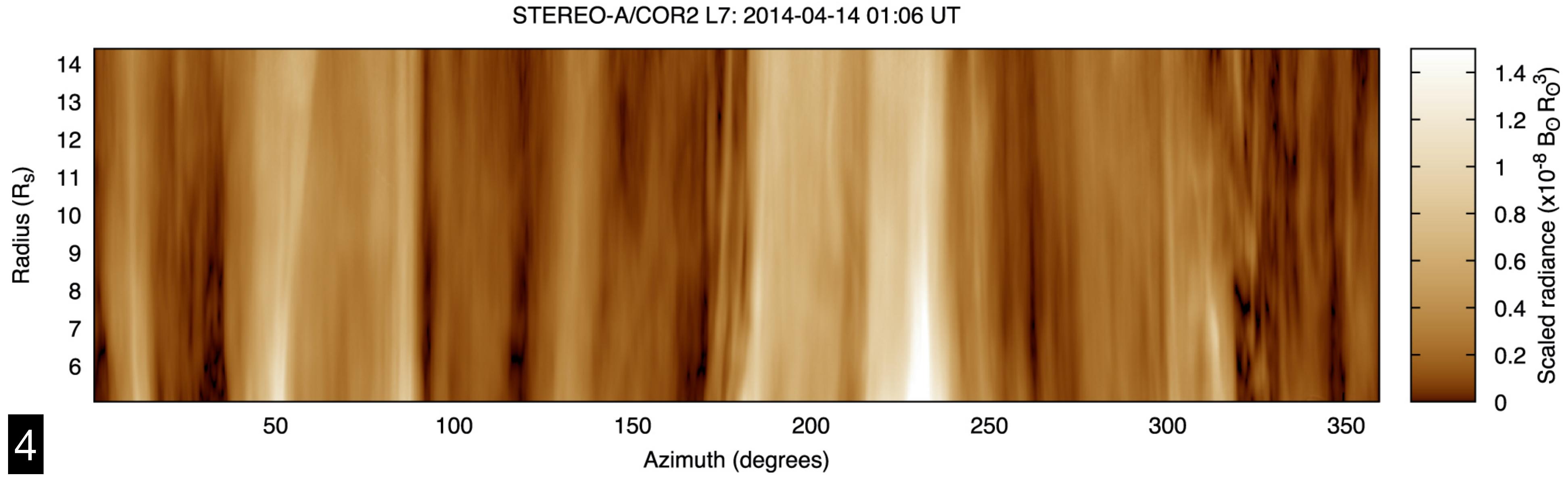


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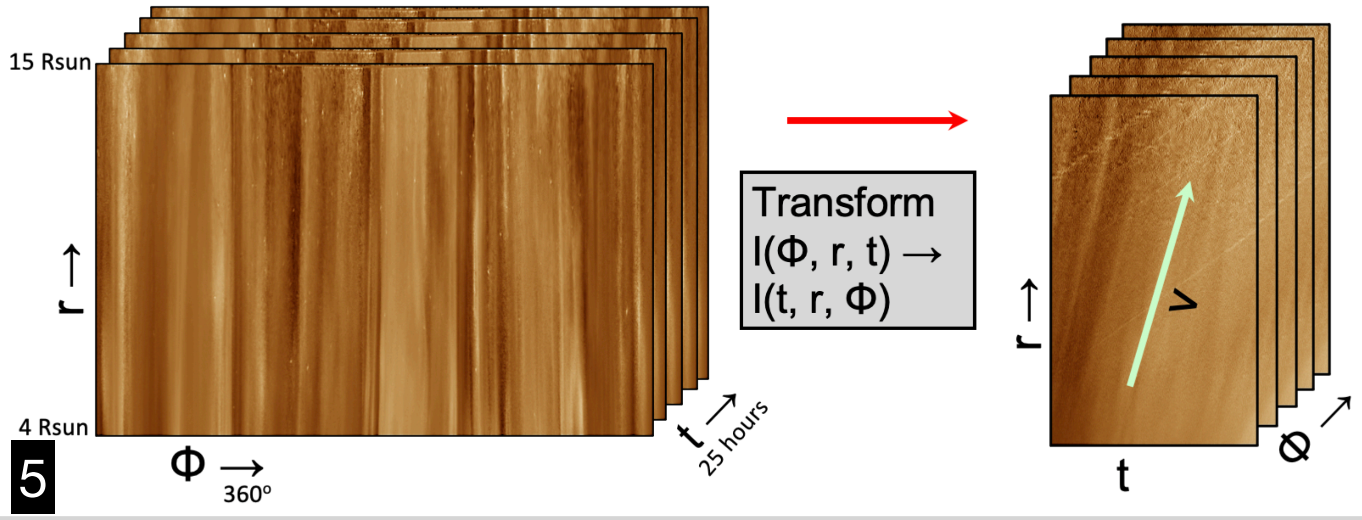
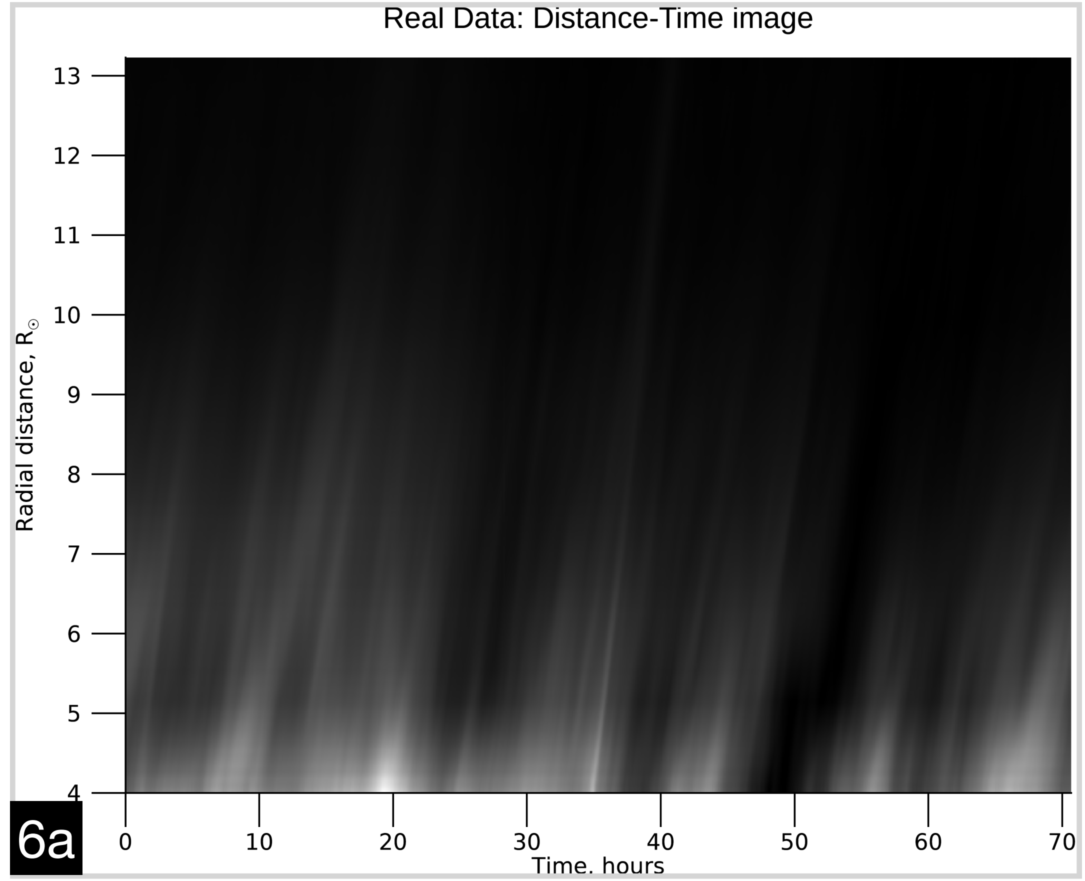
Fig 4. Flow-friendly corona image, is one of the final stages of the image preparation done by Craig DeForest. These had their ad hoc background removed, blur reduced, coordinate resampled and represents a true feature-excess brightness. (Source: [**1**])



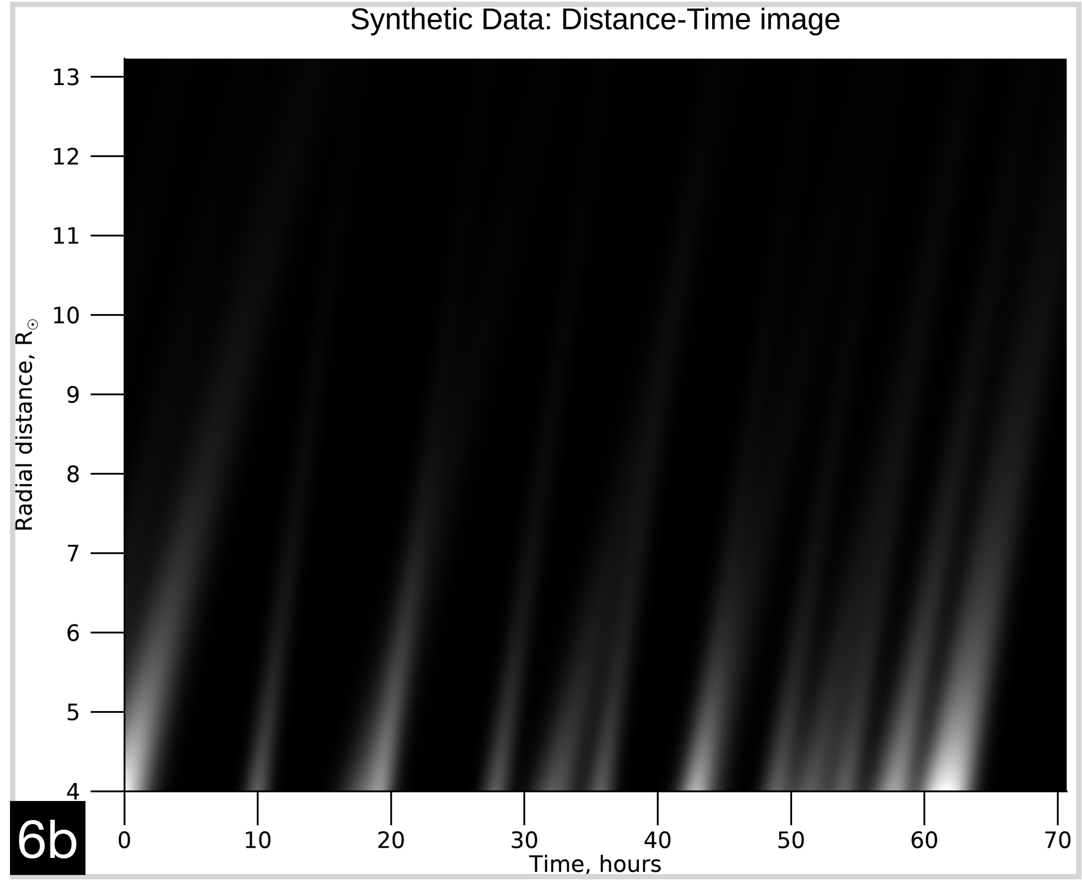
5

Fig 5. The collection of images at different times allows us to transform the image coordinates from spatial-spatial (ϕ, r) to spatial-temporal (t, r). (Source: [**2**])

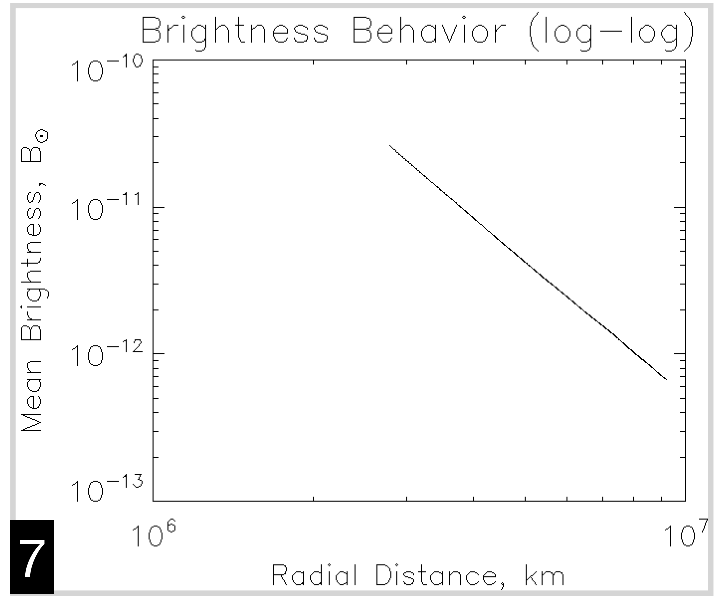
Parameters



6a



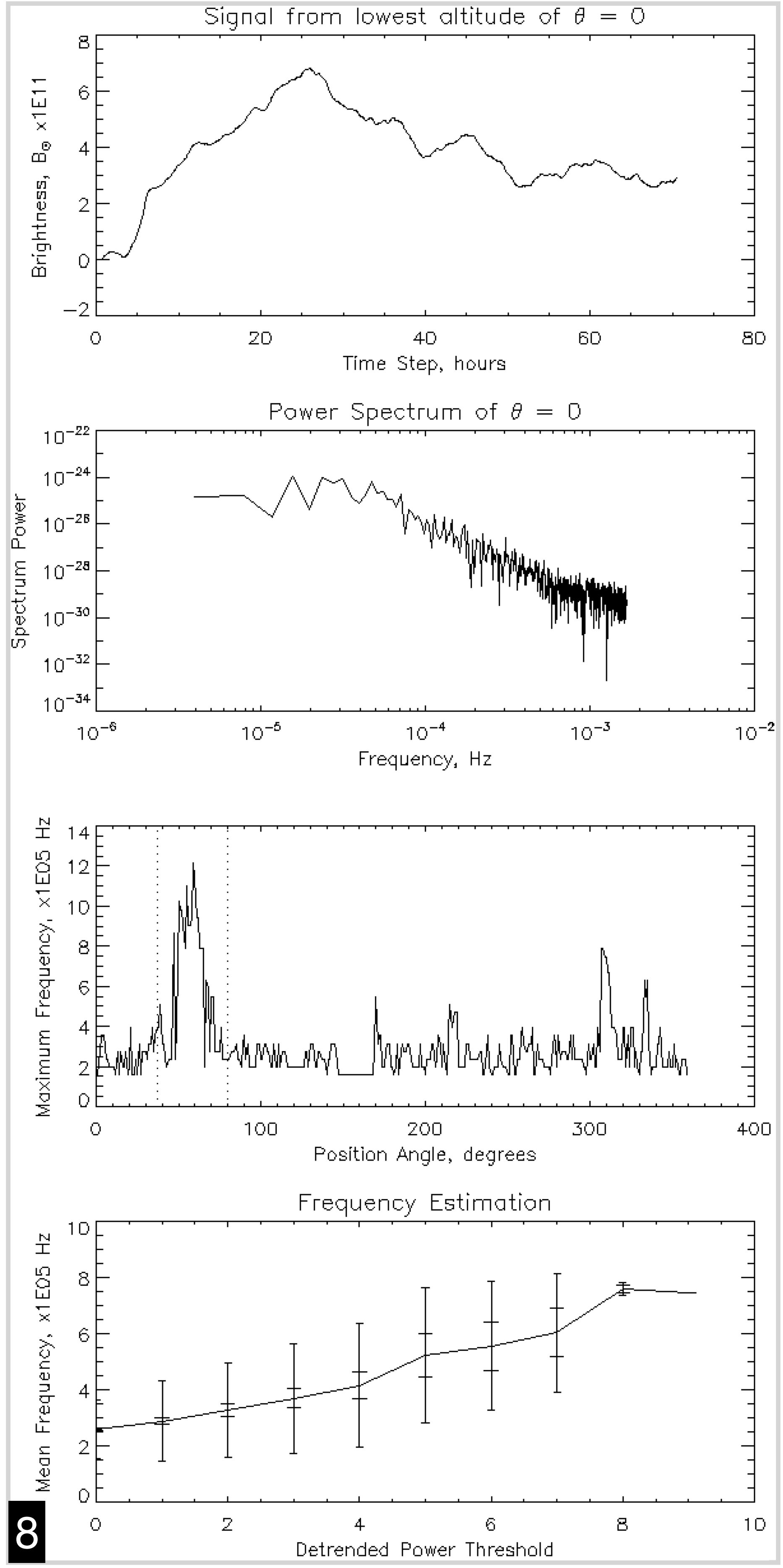
6b



7

Fig 6. Distance-time arrays. **6a** represents the real data, and **6b** represents the synthetic data. The synthetic data can mimic the radial behavior, but does not have random noise. A future effort includes an adjustable noise level generated by a random seed.

Fig 7. Power-law behavior of the brightness. A simple linear fit of the mean brightness by the cube of the distance indicates the decay.



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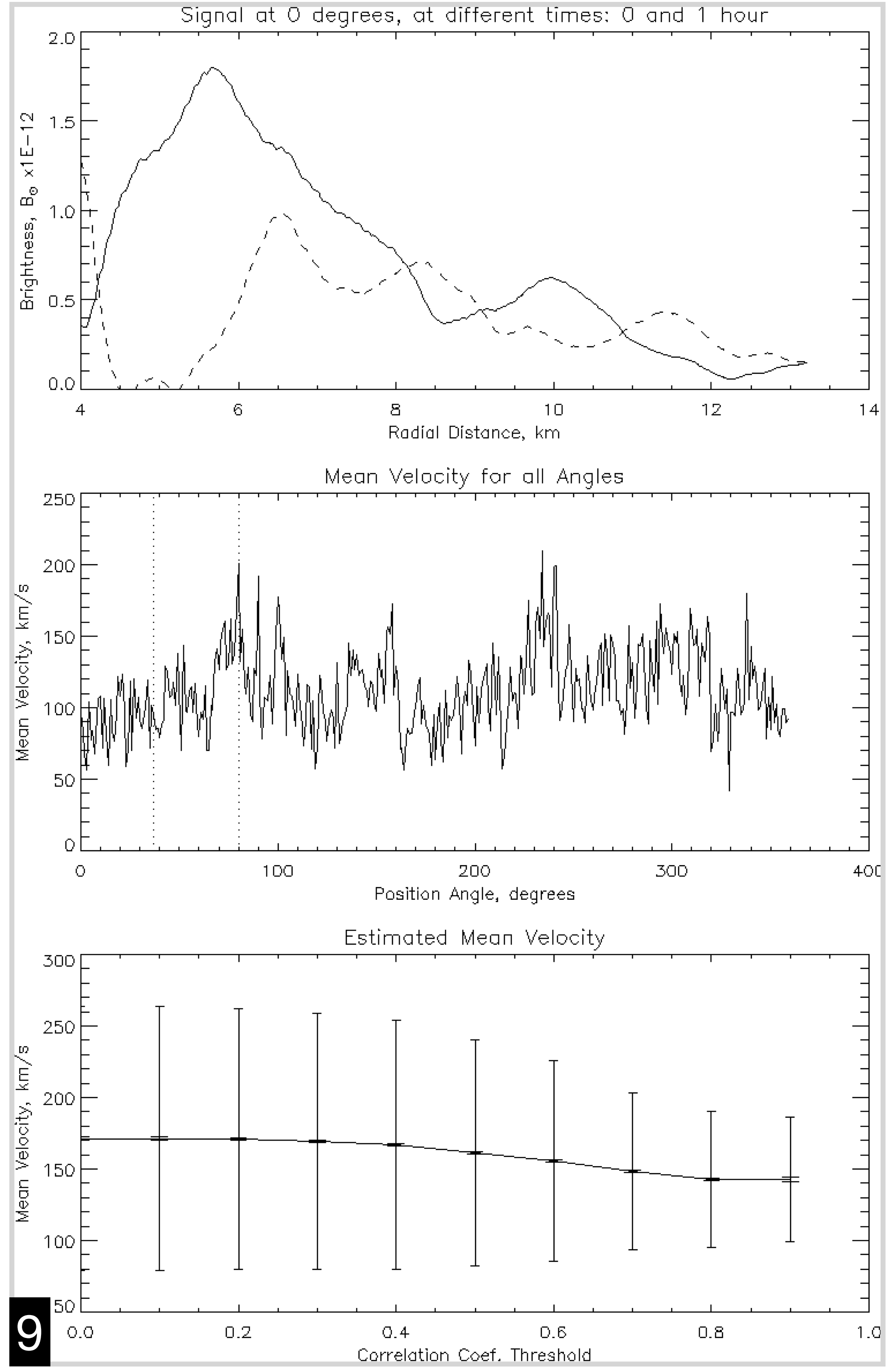

9

Fig 8. Frequency exploration. The estimated frequency was taken by accounting the maximum frequency for each position angle. This frequency can gauge the amount of features a certain position-time array exhibits.

Fig 9. Velocity exploration. The estimated velocity was obtained using a cross-correlation technique. This velocity could be assessed by any other flow tracking algorithm.

Table 1. Model parameters values. Our synthetic model presented here was produced by using the power-law decay, and the frequency and velocity exploration.

Parameter	Value	Unit
Velocity	173.2	km/s
Velocity Variability	58.4	km/s
Period	4.2	hours
Radial Behavior	-3.0	-

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Flow Tracking Challenge

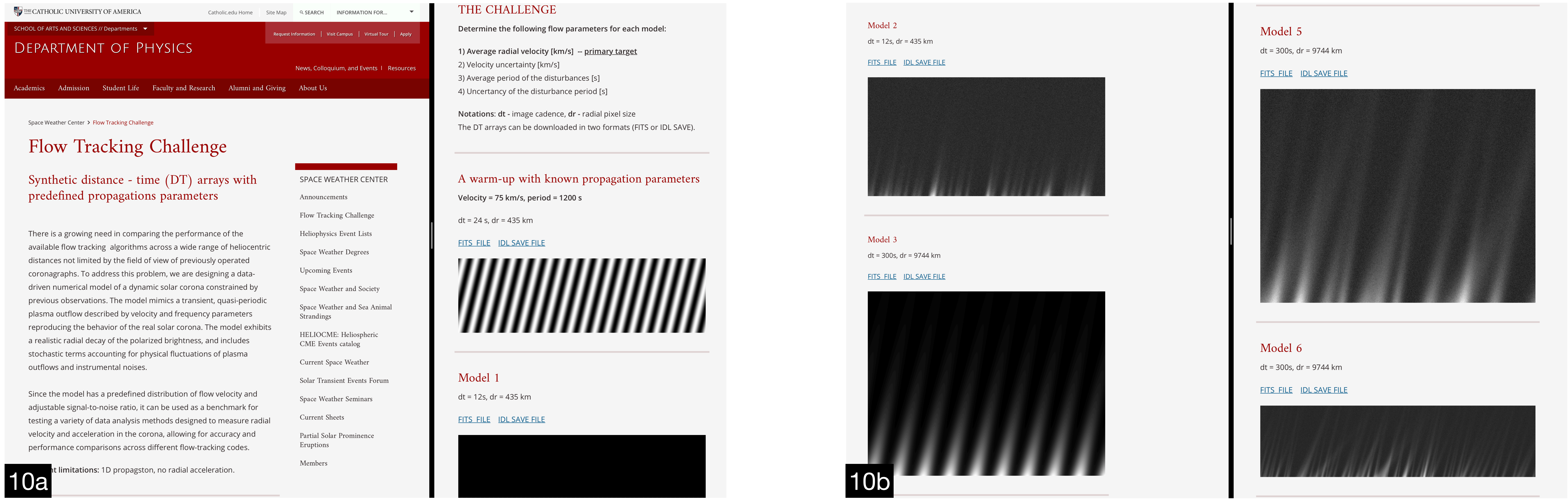

Fig 10. Website of the Flow Tracking Challenge, and QR code for the page. **10a** represents the challenge description and an example model for testing, and **10b** a collection of model with noise and velocity and frequency variabilities. All models have their sampling time and distance available. The mini-challenge was launched in June. We are inviting all flow trackers and enthusiasts to test their algorithms using our synthetic images. The results will help us to improve our model and to validate the efficiency of the different algorithms.

https://physics.catholic.edu/faculty-and-research/space-weather-lab/flow-tracking-challenge.html

Future Plans

- Implement additional features: noises, variability in frequency and brightness
- Include radial acceleration: velocity increasing with altitude
- Integrate realistically a 2D Gaussian wave for spatial-spatial images
- Create a time series of synthetic PUNCH images

References

[1] DeForest et al., “The Highly Structured Outer Solar Corona”, Astrophysical Journal, Vol. 862, 2018.
[2] Thompson et al., “Tracking Flows and Disturbances in Coronagraph Data”, AGU, 2018.