PROBA2 Guest Investigator Program

STUDYING THE KINEMATICS OF EUV WAVES

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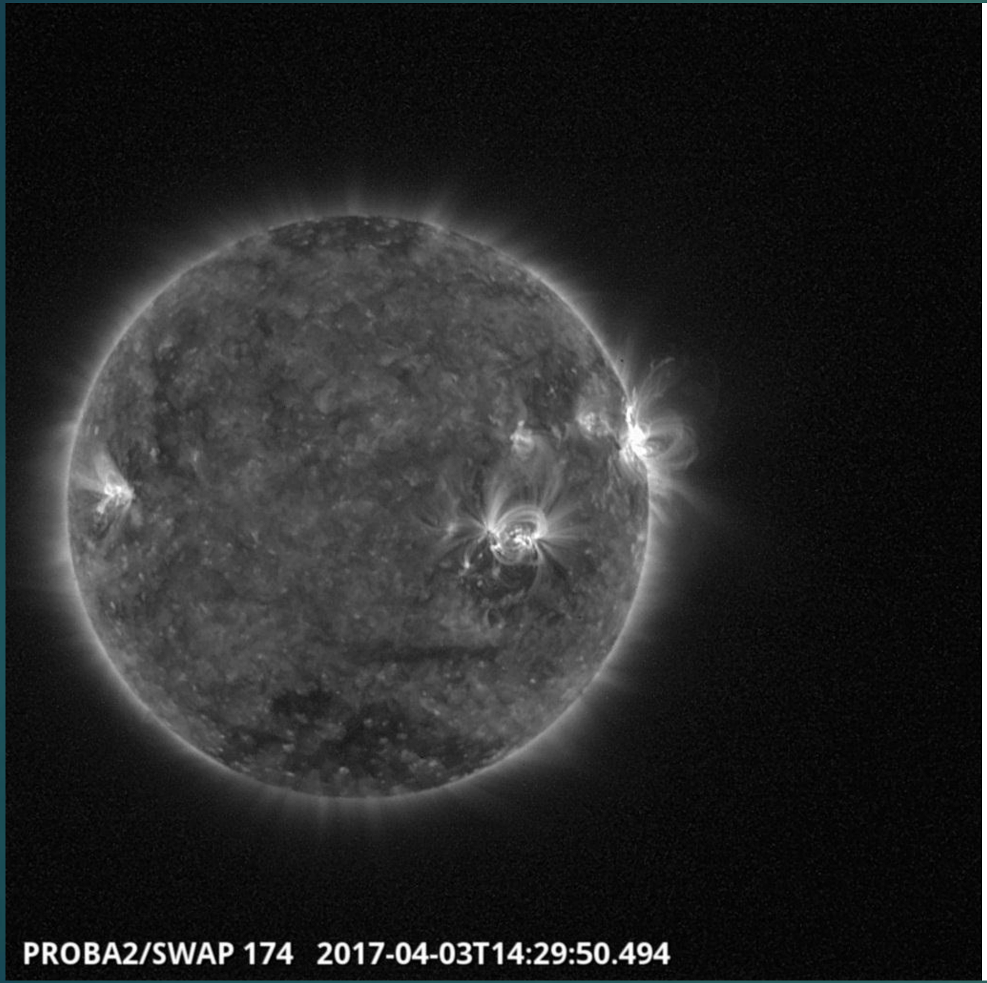
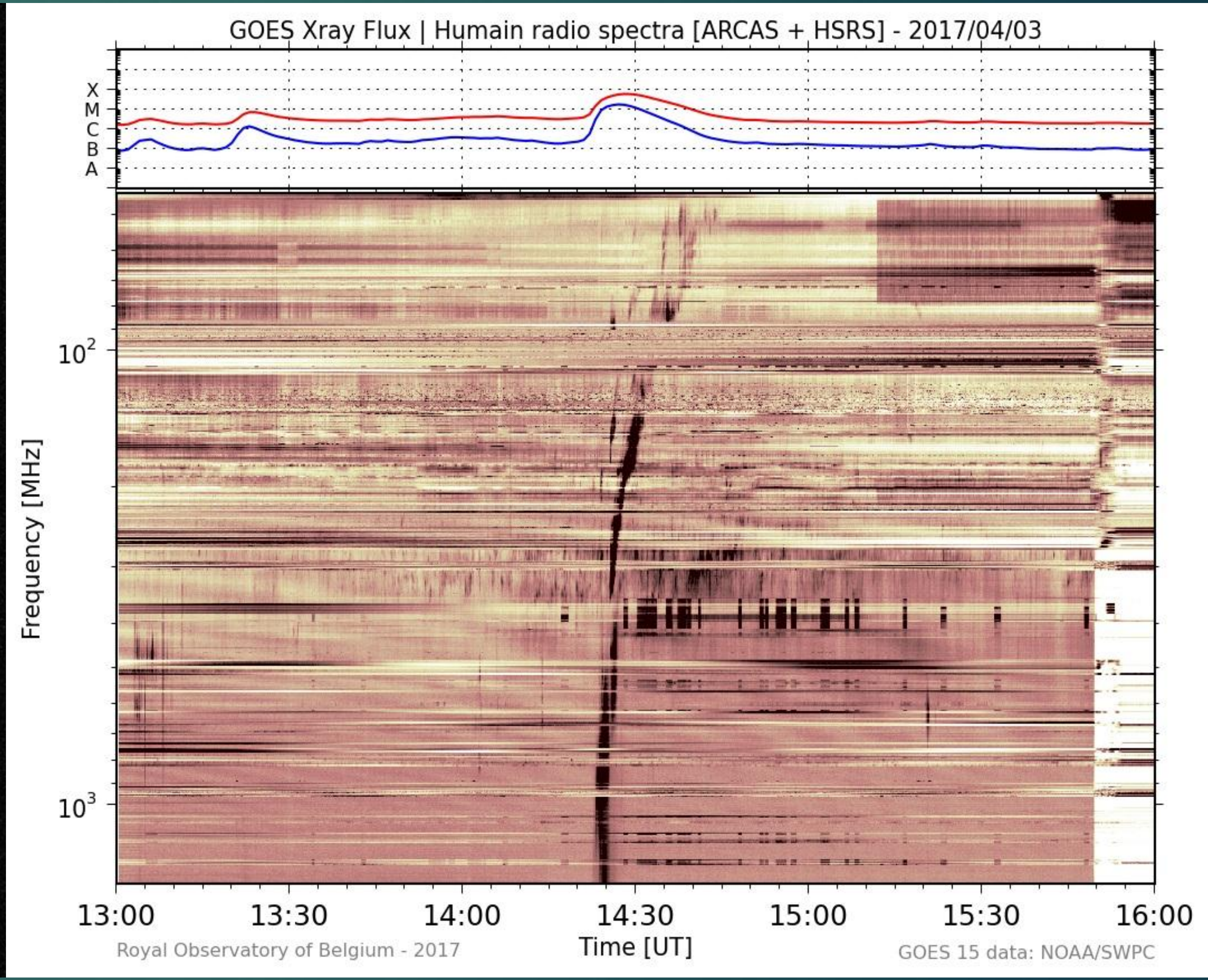
Introduction

- A unique opportunity of observing and modeling a CME event from the low to the outer corona

- Interesting CME event on 03-04-2017
- Take advantage of the large field of view of PROBA2/SWAP
- SWAP off-pointed in the direction of propagation
- Special coordinated campaign by Jean-Claude Vial (HOP 334)
- SWAP bridged the gap between EUV imagers and coronagraphs
- Radio data, a type II burst

Introduction





Introduction

- Goals

  - Study the fast-mode MHD waves propagation and their connection with EUV waves and type II bursts

- Methodology

  - Numerically propagate a fast MHD wave

  - Compare with observations

    (EUV(SWAP, SDO/AIA), White Light, Radio (Humain)

Theory - Model

- EUV ('EIT') waves

  wavelike disturbances (front) of enhanced EUV emission that propagate away from an eruptive active region across the solar disk

- Presumed coronal counterparts of Moreton waves (Ha images)
- Wide range of speeds
- A number of different models

Theory - Model

- Ushida model (1968,1970,1973), Wang formalism (2000)
- In the short-wavelength WKB approximation, a hydromagnetic wave may be regarded as being propagated along rays that are refracted by the nonuniform coronal medium
- When dissipation and damping effects are neglected the propagation of a fast-mode wave is given by the equations

$$r'(t) = \kappa_r v_f, \quad (2a)$$

$$\theta'(t) = \kappa_\theta v_f / r, \quad (2b)$$

$$\phi'(t) = \kappa_\phi v_f / (r \sin\theta), \quad (2c)$$

$$k_r'(t)/k = -\partial v_f/\partial r + (\kappa_\theta^2 + \kappa_\phi^2) v_f / r, \quad (2d)$$

$$k_\theta'(t)/k = -(1/r)\partial v_f/\partial\theta - (\kappa_r \kappa_\theta - \kappa_\phi^2 \cot\theta) v_f / r, \quad (2e)$$

$$k_\phi'(t)/k = -(1/r\sin\theta)\partial v_f/\partial\phi - \kappa_\phi(\kappa_r + \kappa_\theta \cot\theta) v_f / r. \quad (2f)$$

Theory - Model

- Coronal data from Predictive Science 3D MHD model
- Temperature and Alfven speed values
- Not take into account the B orientation
- $u_f = ({u_A}^2 + {c_s}^2)^{\frac{1}{2}}$

- Code written in Python
- Equations solved numerically using python libraries
- Parallelization of our code, to be able to handle large numbers of wave-vectors

- Validation of our model by reproducing the results of Wang and performing a number of tests

Studying Events

- New coronal data

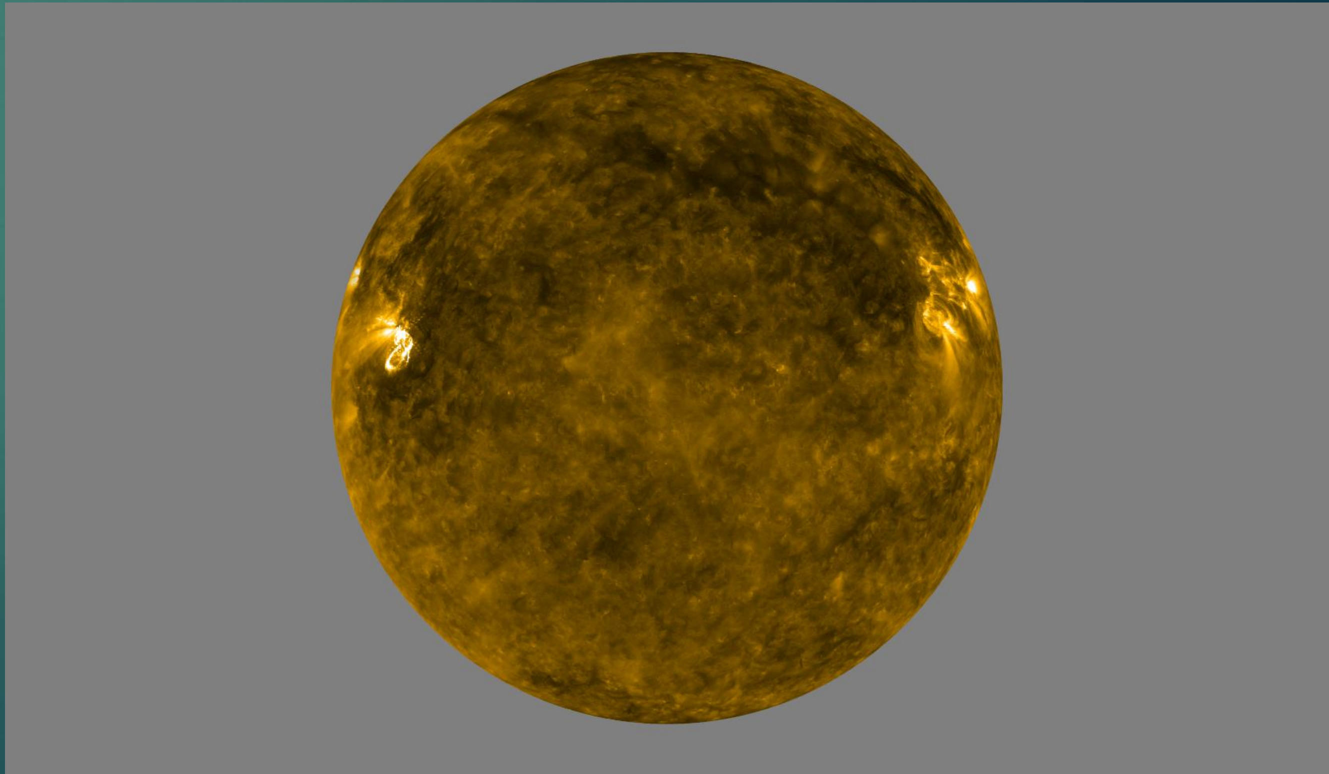
- Identification of the coordinates of the initial point by EUV images
- A uniform distribution of initial wave vectors in all directions
- Interpolate in time the calculated raypaths (same time step)

Studying Events

- Visualization

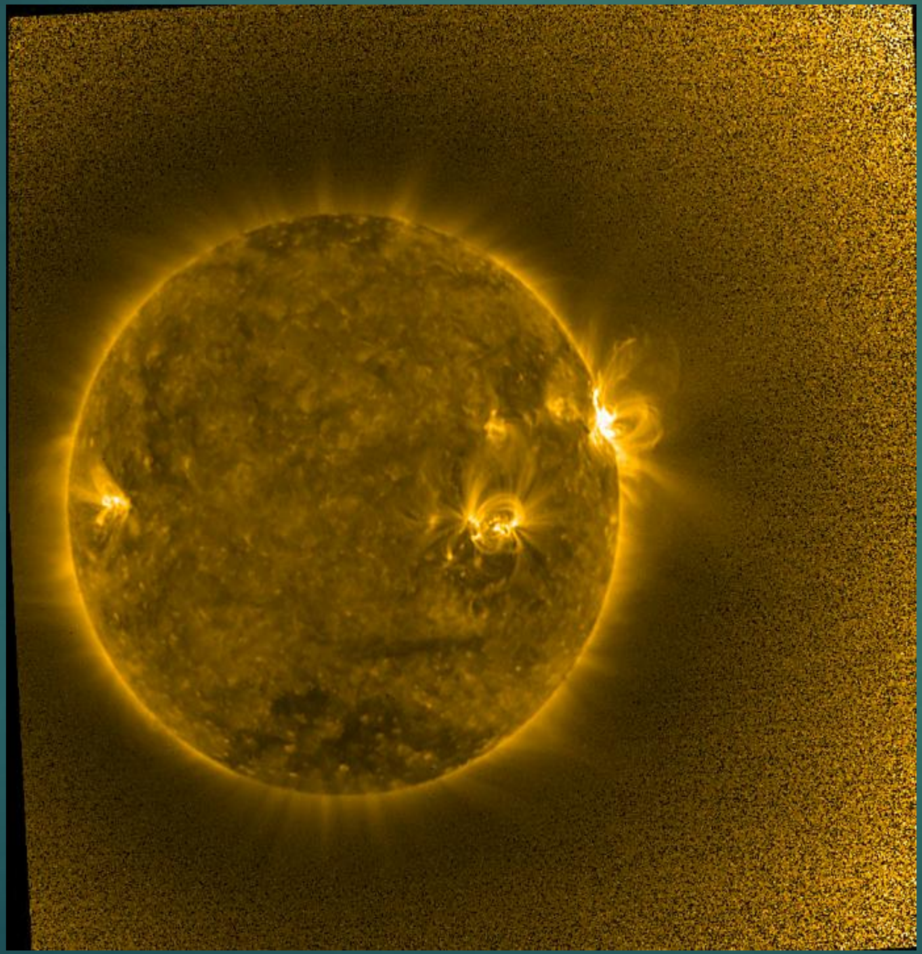
- Build of the 3D scene using Mayavi and tvtk (vtk + traits) libraries
- Creation of the wave-front using Delaunay 3D triangulation
- 3D representation of the Sun surface
- Wrap as texture to the surface EUV images
- Alignment and images correction

- Creation of interactive 3D animation
- Movies for each event



Studying Events

- April 3 2017



Studying Events

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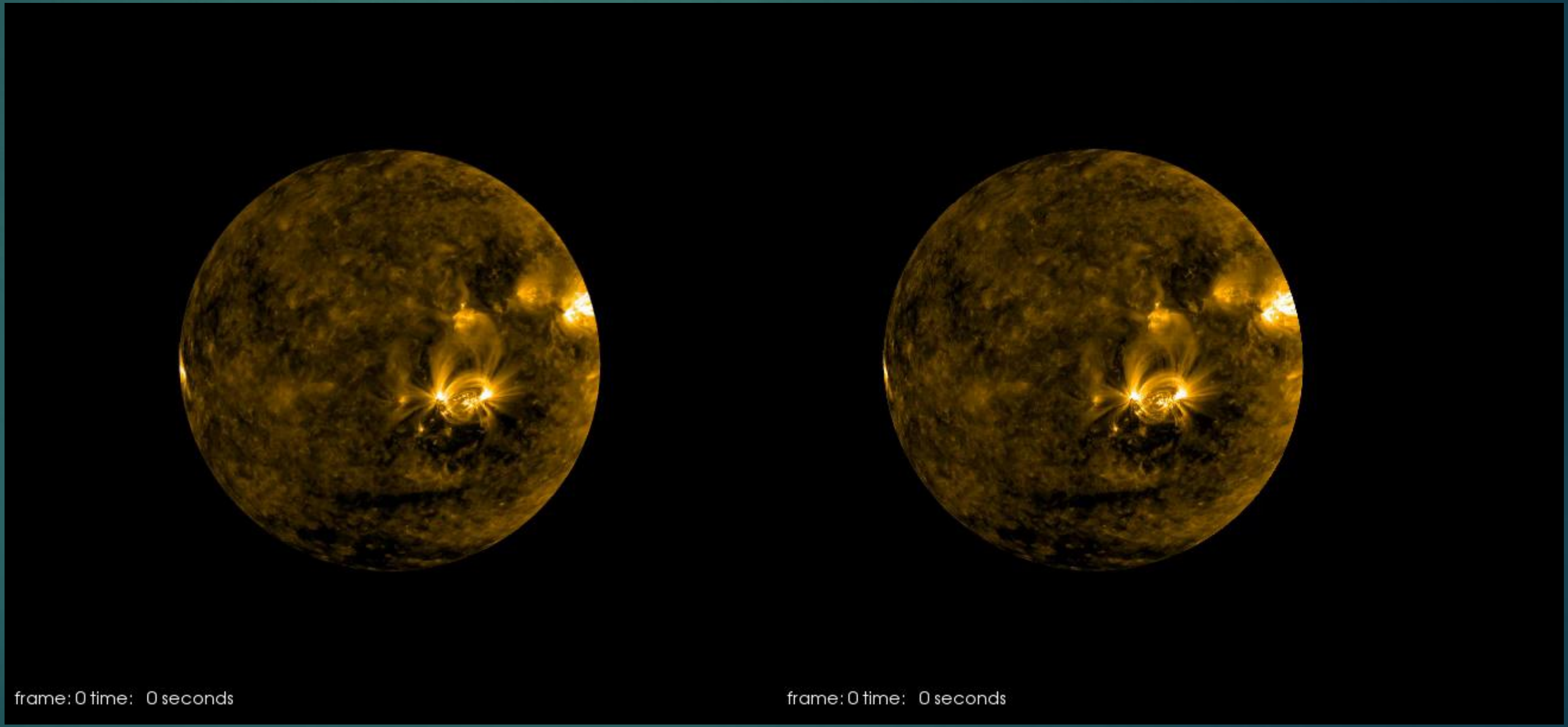

Studying Events

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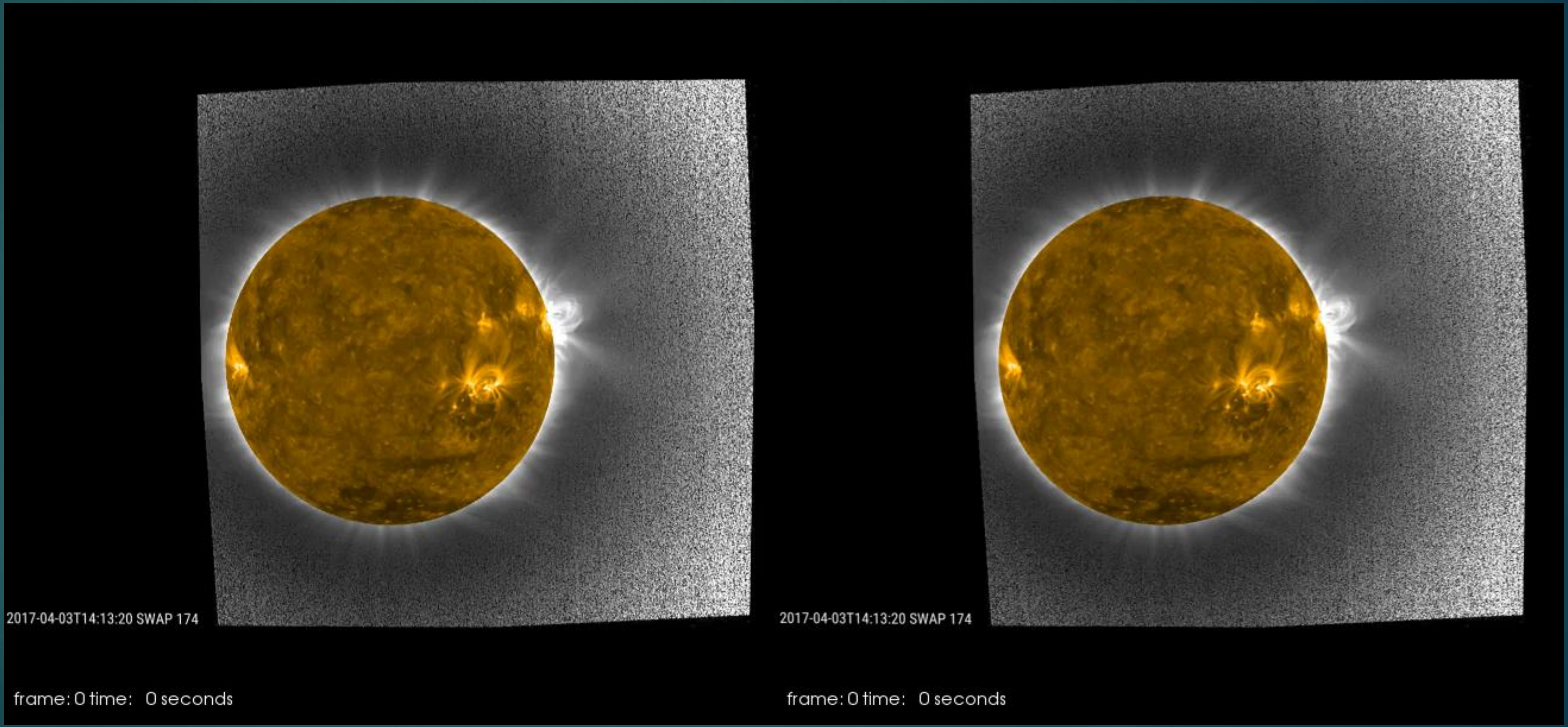
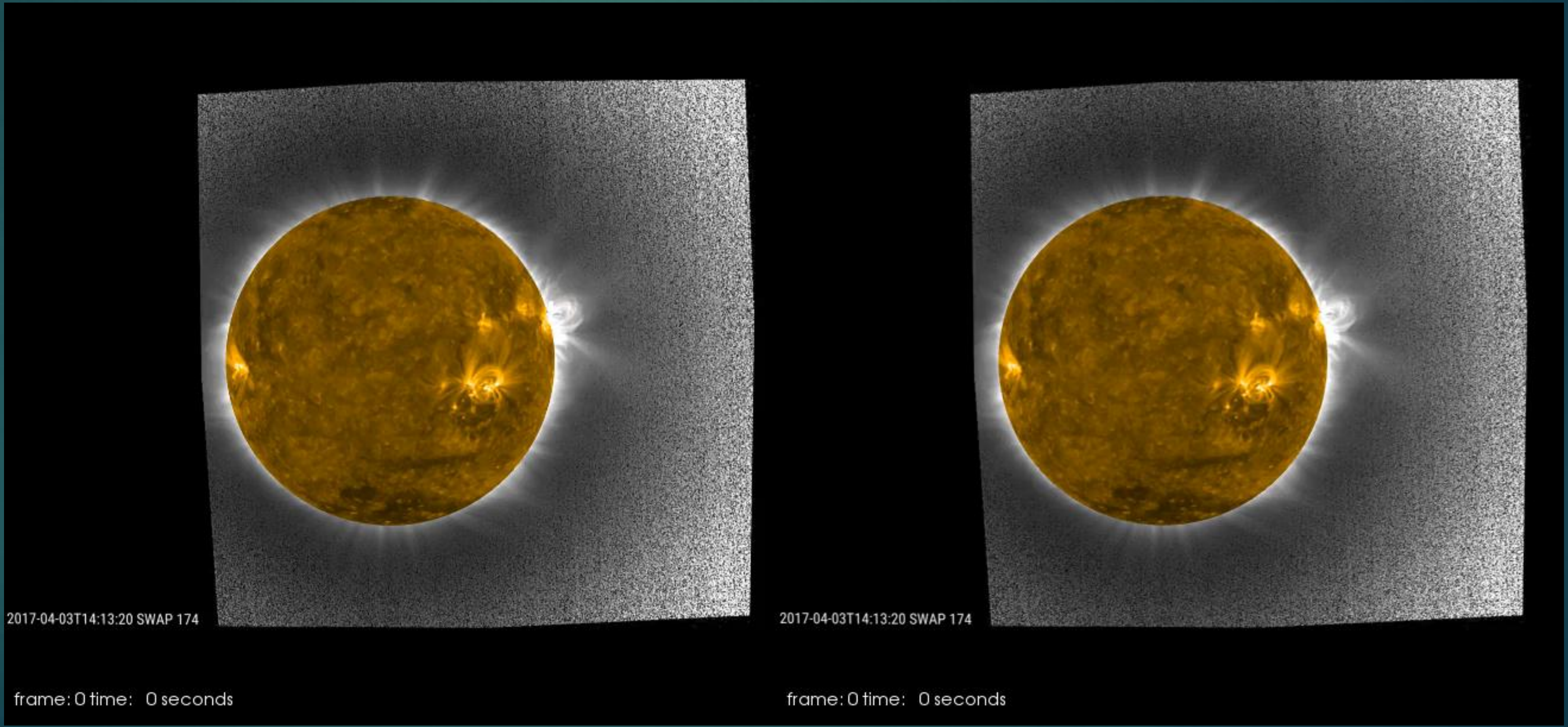


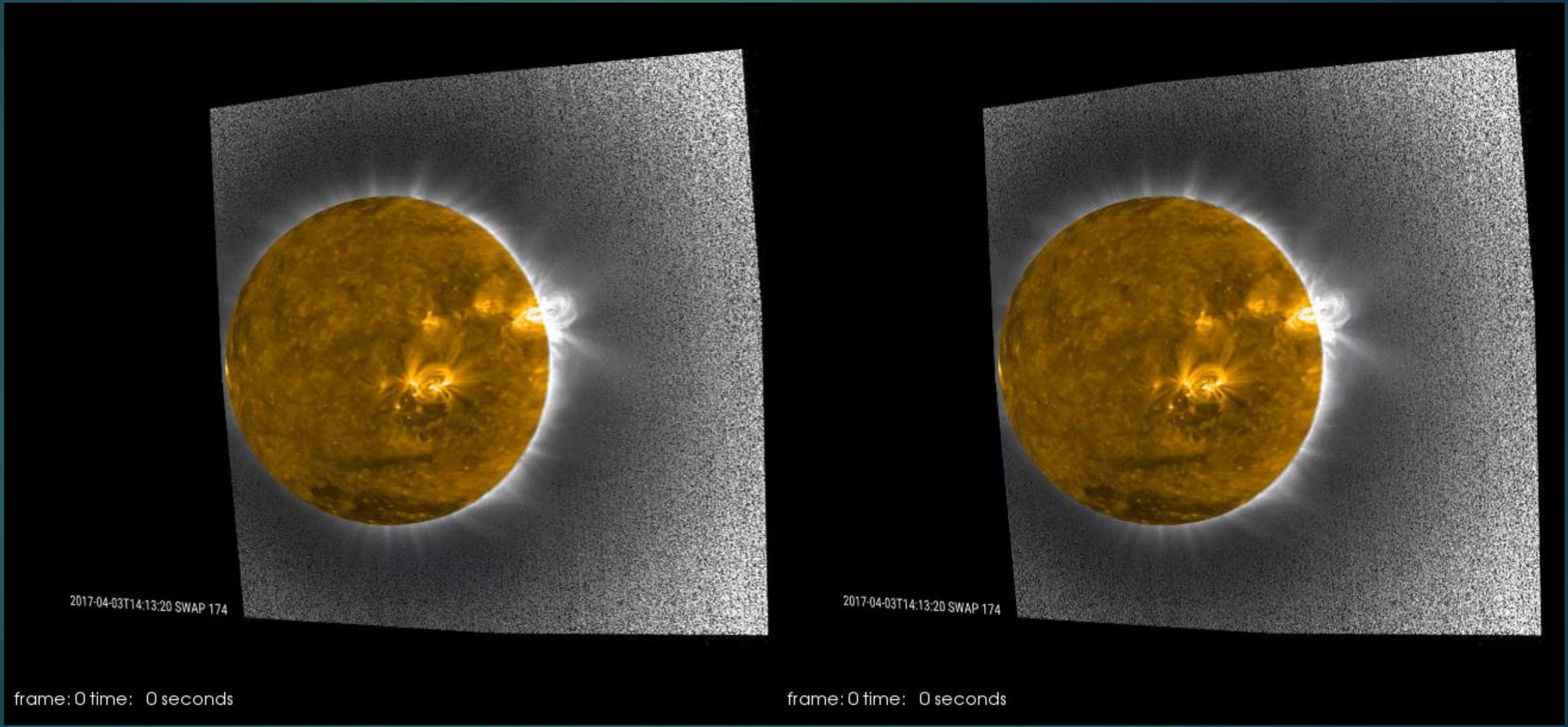
Studying Events

- April 3 2017



Studying Events

- April 3 2017

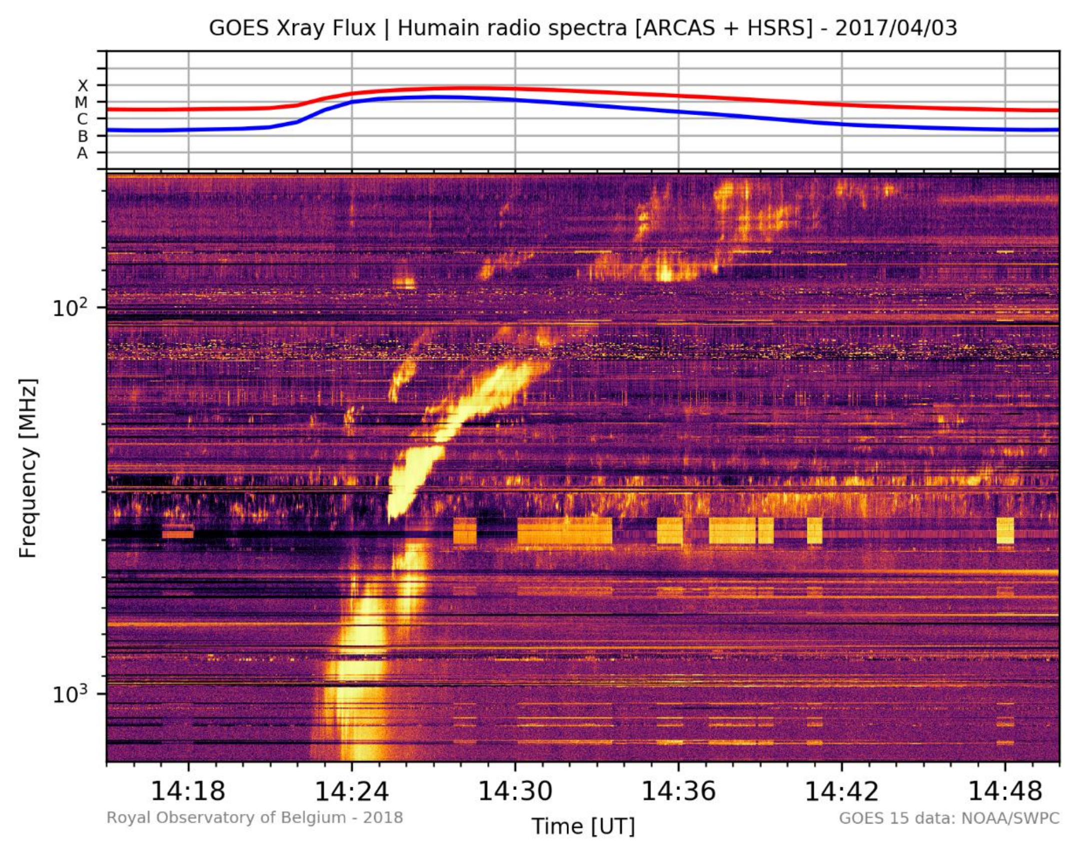


Studying Events

- September 12 2017

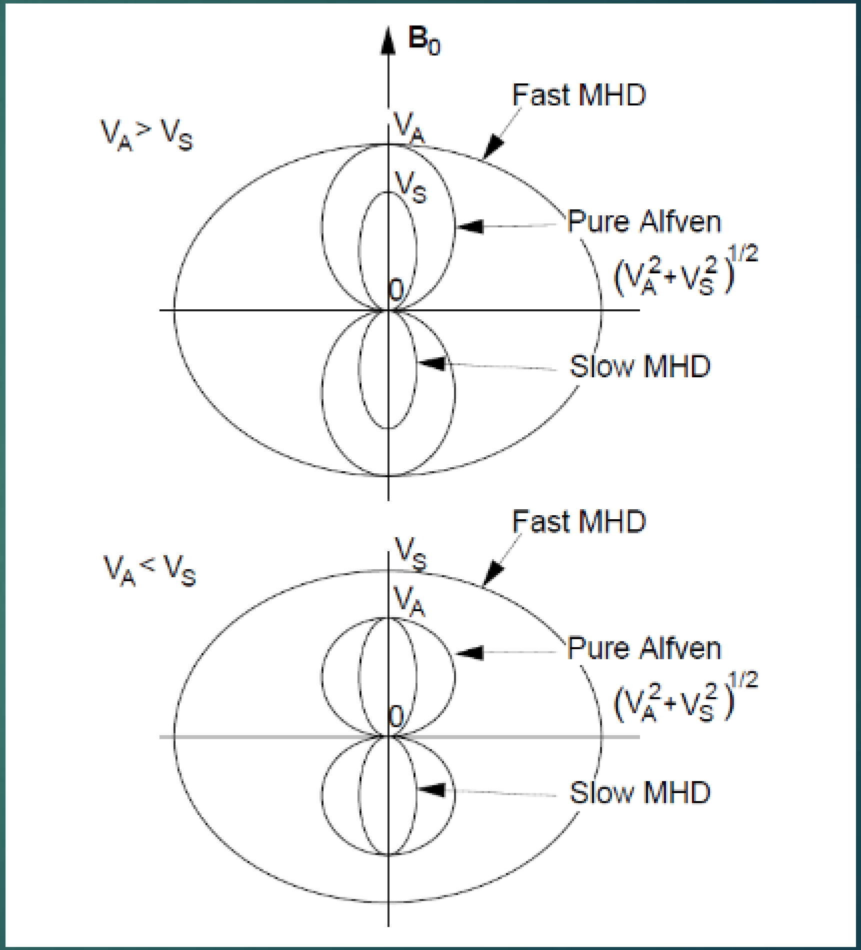
Future Plans

- Second visit: end of July – September 2018
  - Quantitatively comparison with observations
  - Test the effect of perturbation in the initial point positions
  - Repeat the process for the 2 new coronal models (Predictive Science)
  - Stack SWAP images for better visualization of coronal structures
  - Use the kinematics of the modeled wave to constrain the source of type II
  - Prepare publication



Thank you

$$\left(\frac{\omega}{k}\right)^2 - \frac{V_a^2 + c_s^2 \pm \sqrt{(V_a^2 + c_s^2)^2 \quad 4V_a^2 c_s^2 \cos^2\theta}}{2}$$



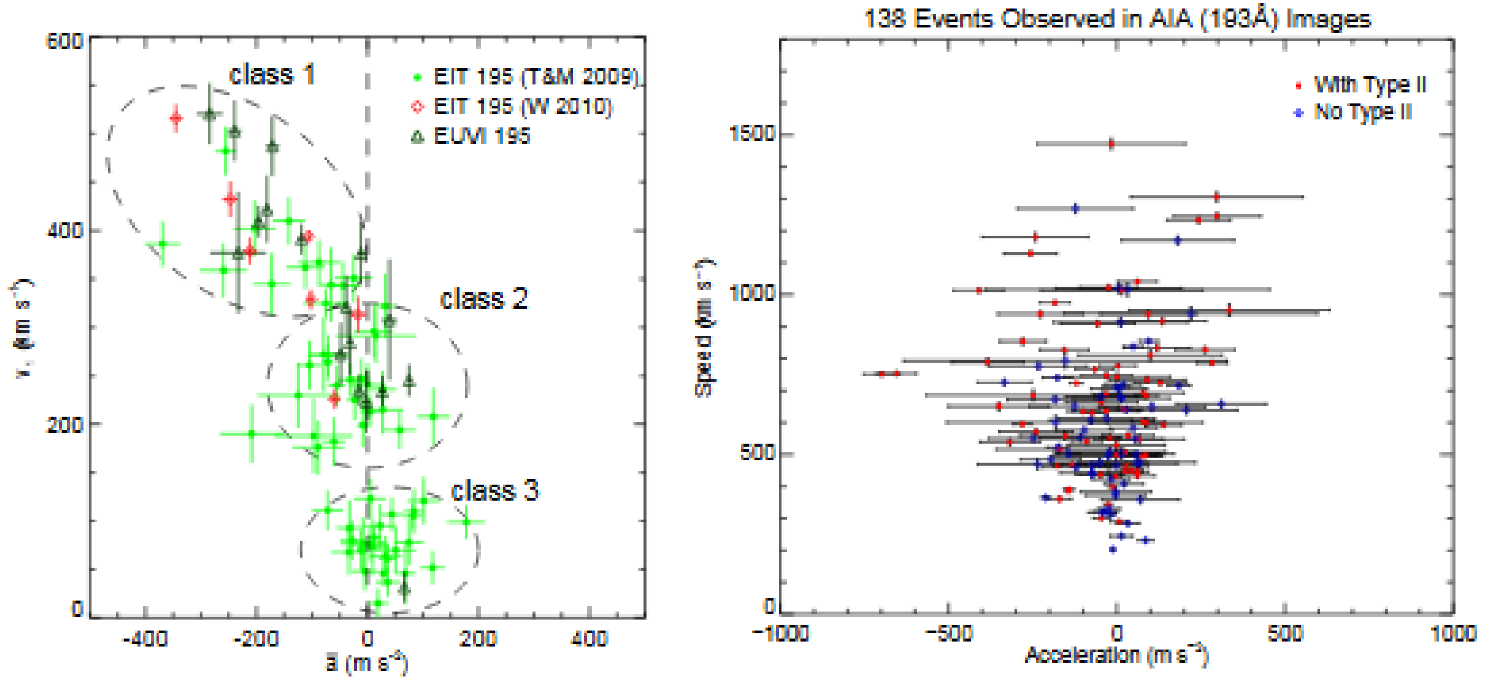
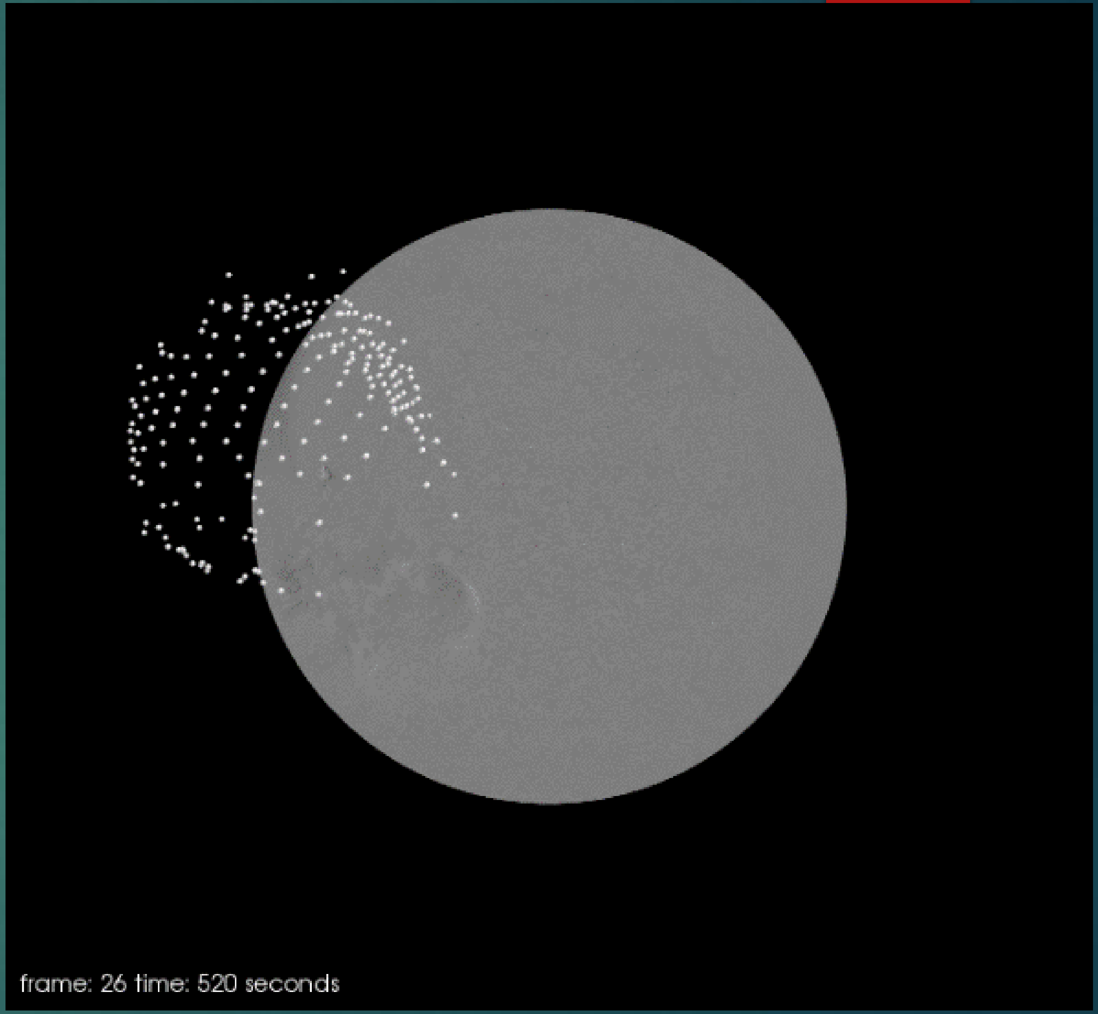


Figure 4. Distributions of EIT wave speeds *vs.* accelerations obtained from EIT and EUVI showing three distinct classes (left; from Warmuth and Mann, 2011) and from AIA appearing more continuously but with some similar trends (right; from Nitta *et al.*, 2013).


frame: 15 time: 300 seconds


frame: 26 time: 520 seconds