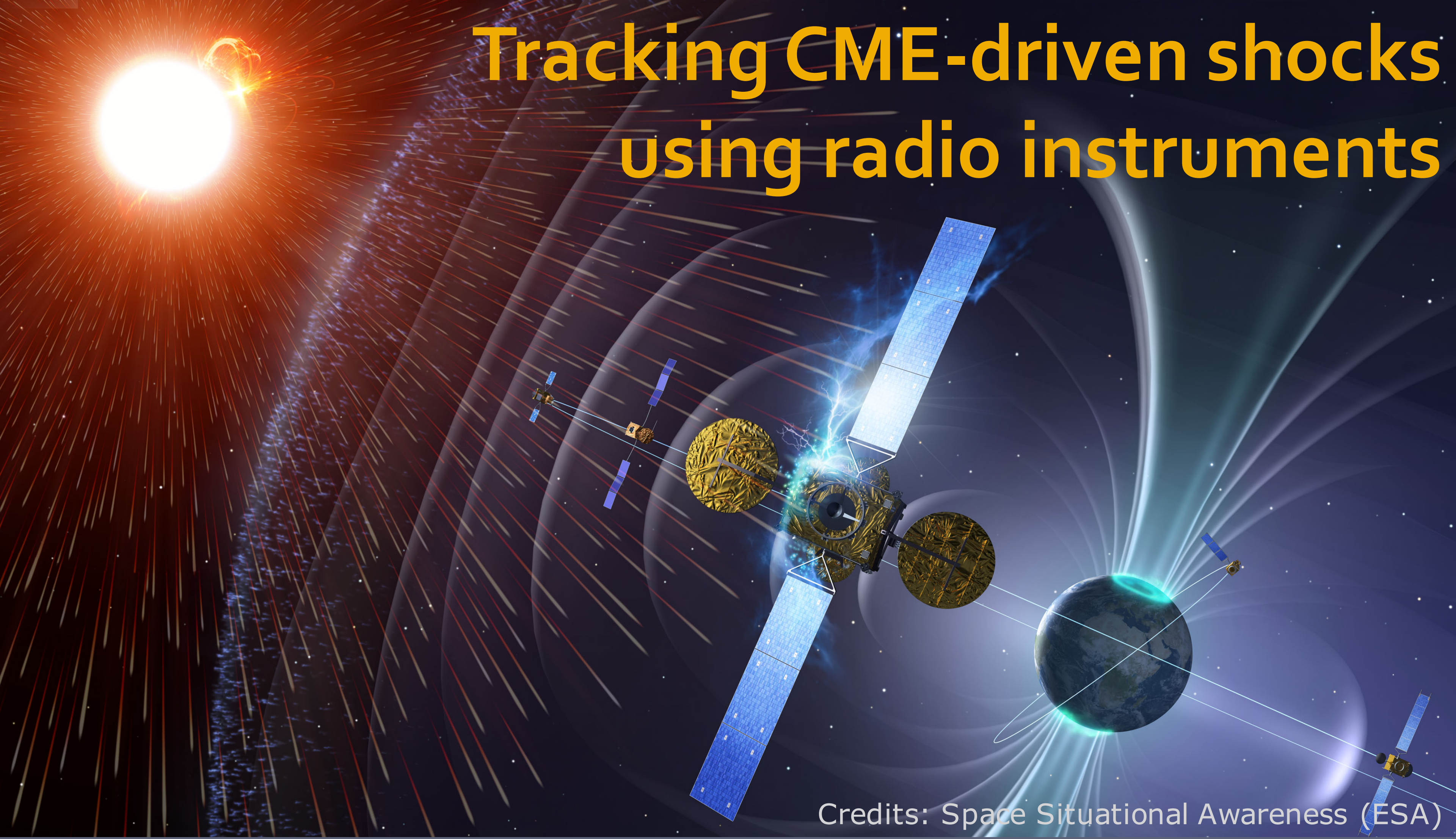
Tracking CME-driven shocks using radio instruments



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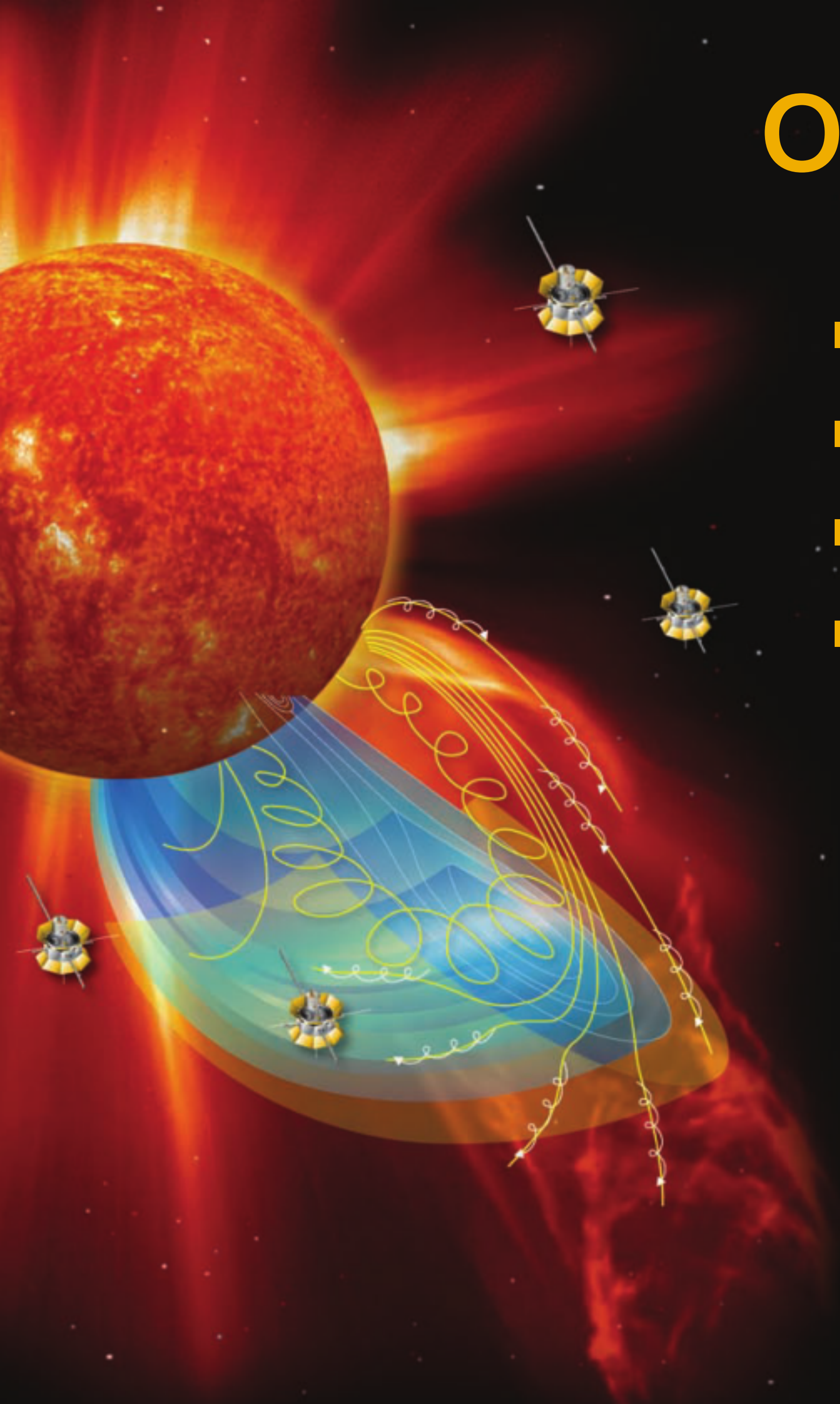
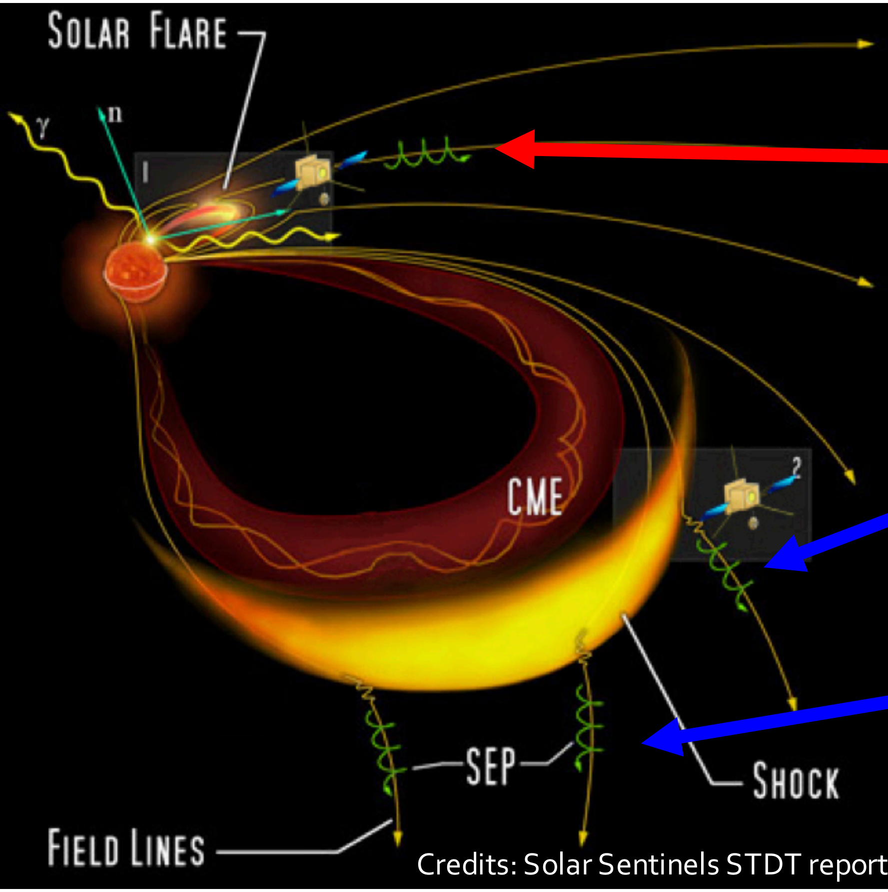
Outline

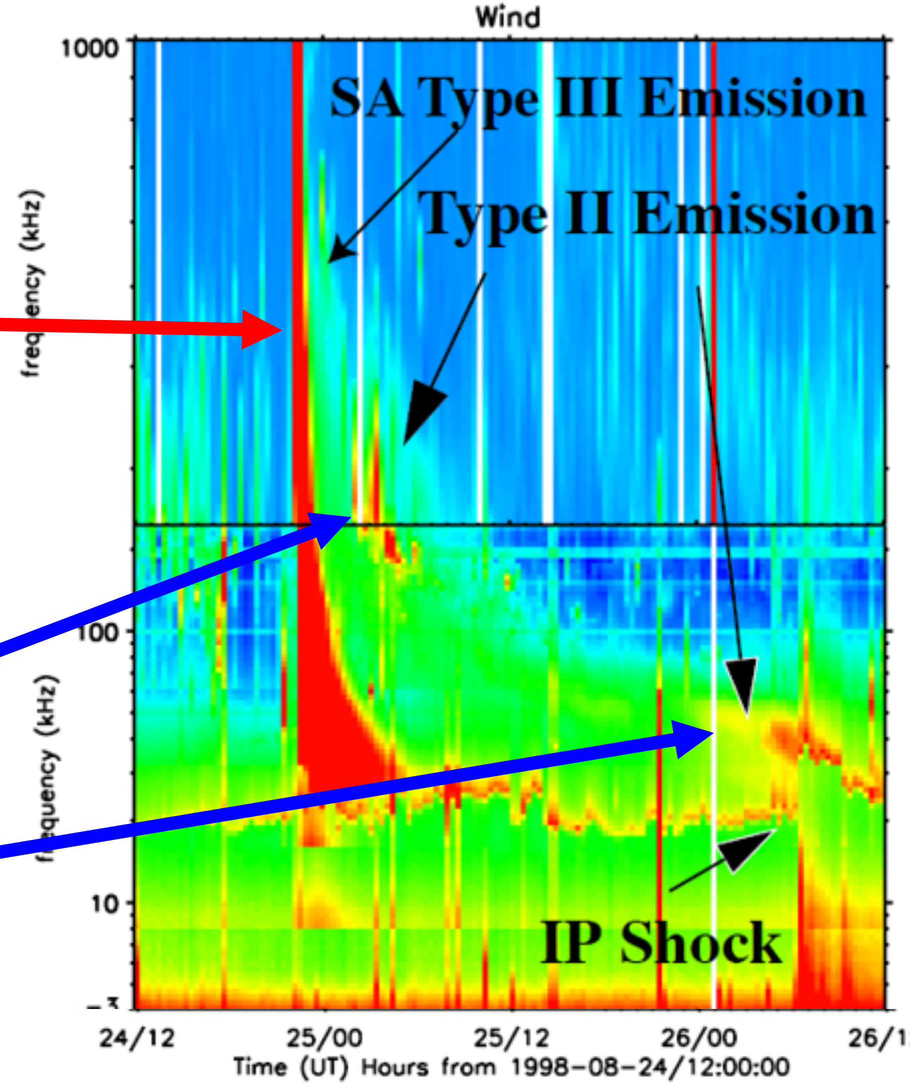
- Introduction
- Instrumentation
- The 2013 November 29 CME
- Proba2/SWAP observations



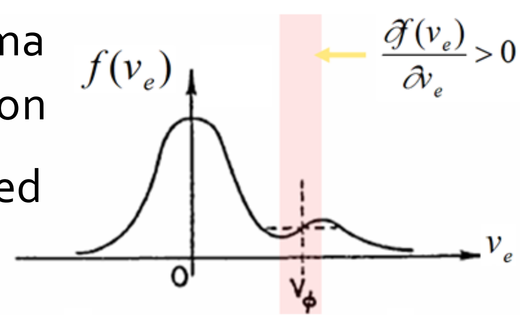
Introduction



Credits: Solar Sentinels STDT report



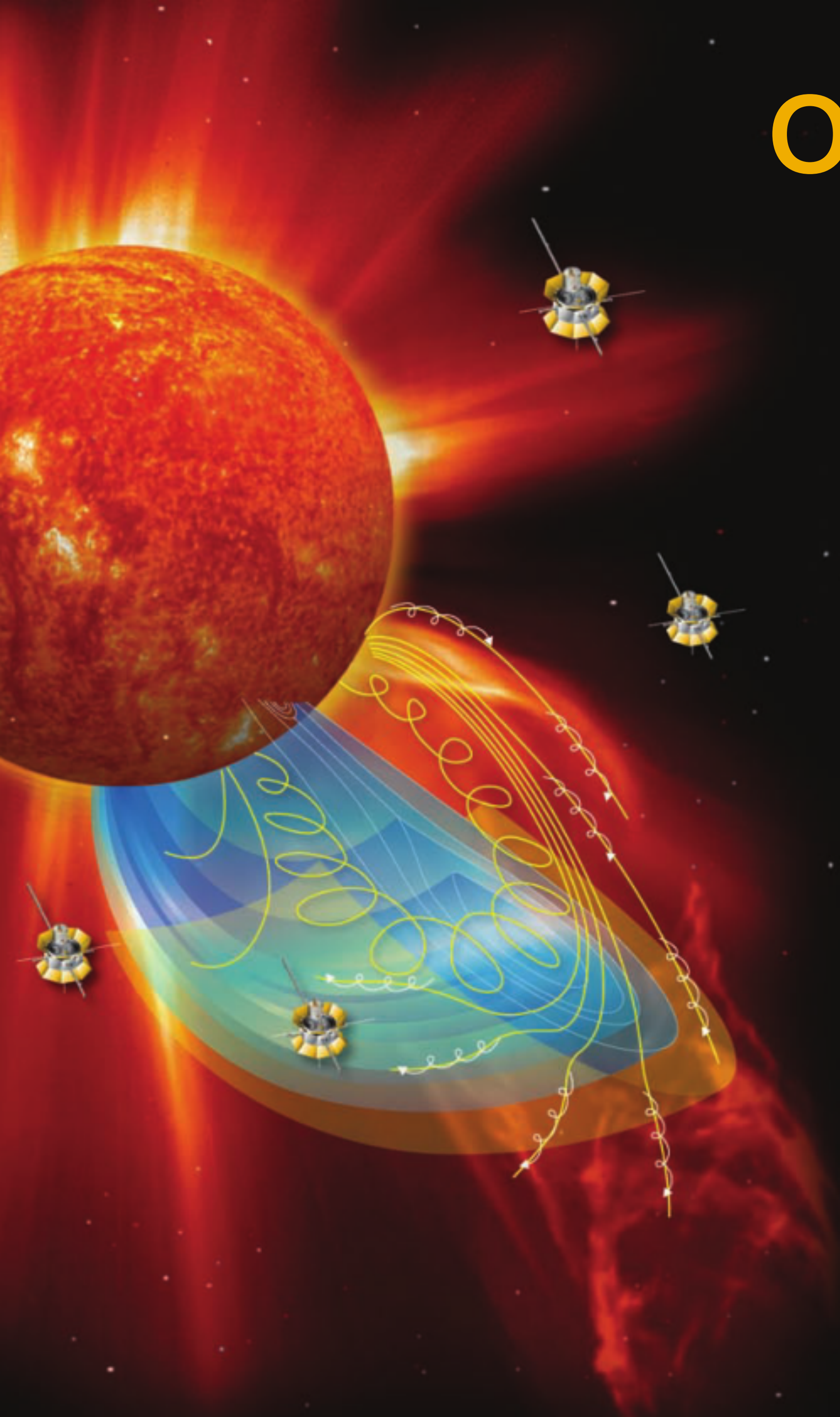
Suprathermal electrons → plasma oscillations (Langmuir waves) at the electron plasma frequency (f_{pe}) → partly converted into radio waves at f_{pe} and/or $2f_{pe}$



Wave mode conversion

$$L \longrightarrow T(f_{pe}) \pm S$$
$$L \longrightarrow L' \pm S$$
$$L + L' \longrightarrow T(2f_{pe})$$

Outline



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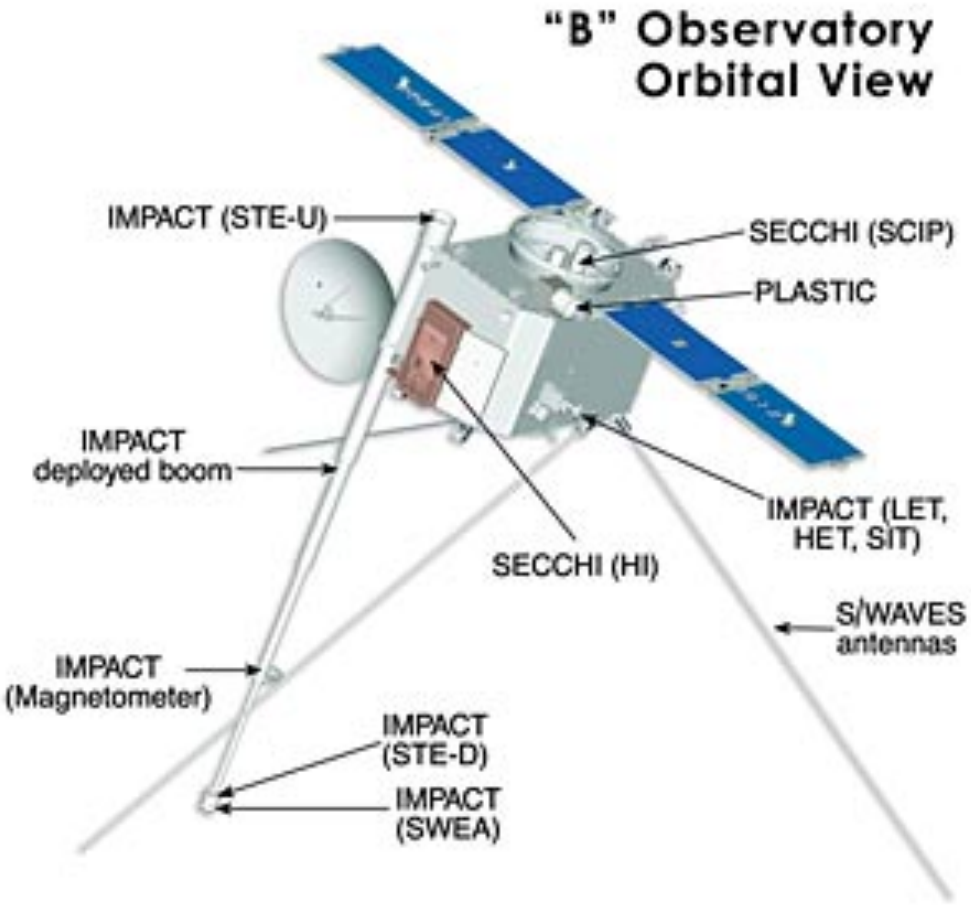
The STEREO spacecraft

- **STEREO** (Solar TErrestrial RElation Observatory) consists of two identical spacecraft launched October 26, 2006.
- The first three-axis stabilized solar mission.

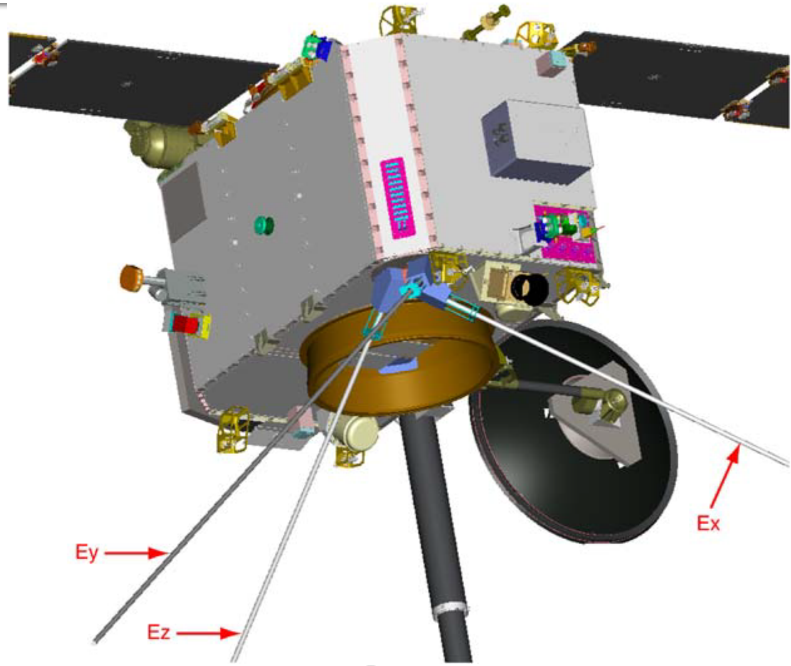
- **SECCHI** (Sun Earth Connection Coronal and Heliospheric Investigation): imaging capabilities
- **IMPACT** (In-situ Measurements of Particles and CME Transients)
- **PLASTIC** (PLAsma and SupraThermal Ion Composition)
- **S/Waves** (STEREO/Waves)

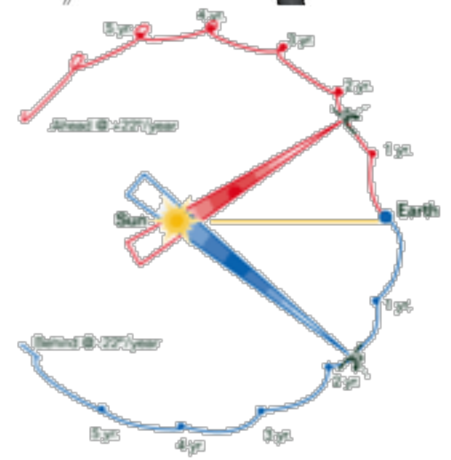


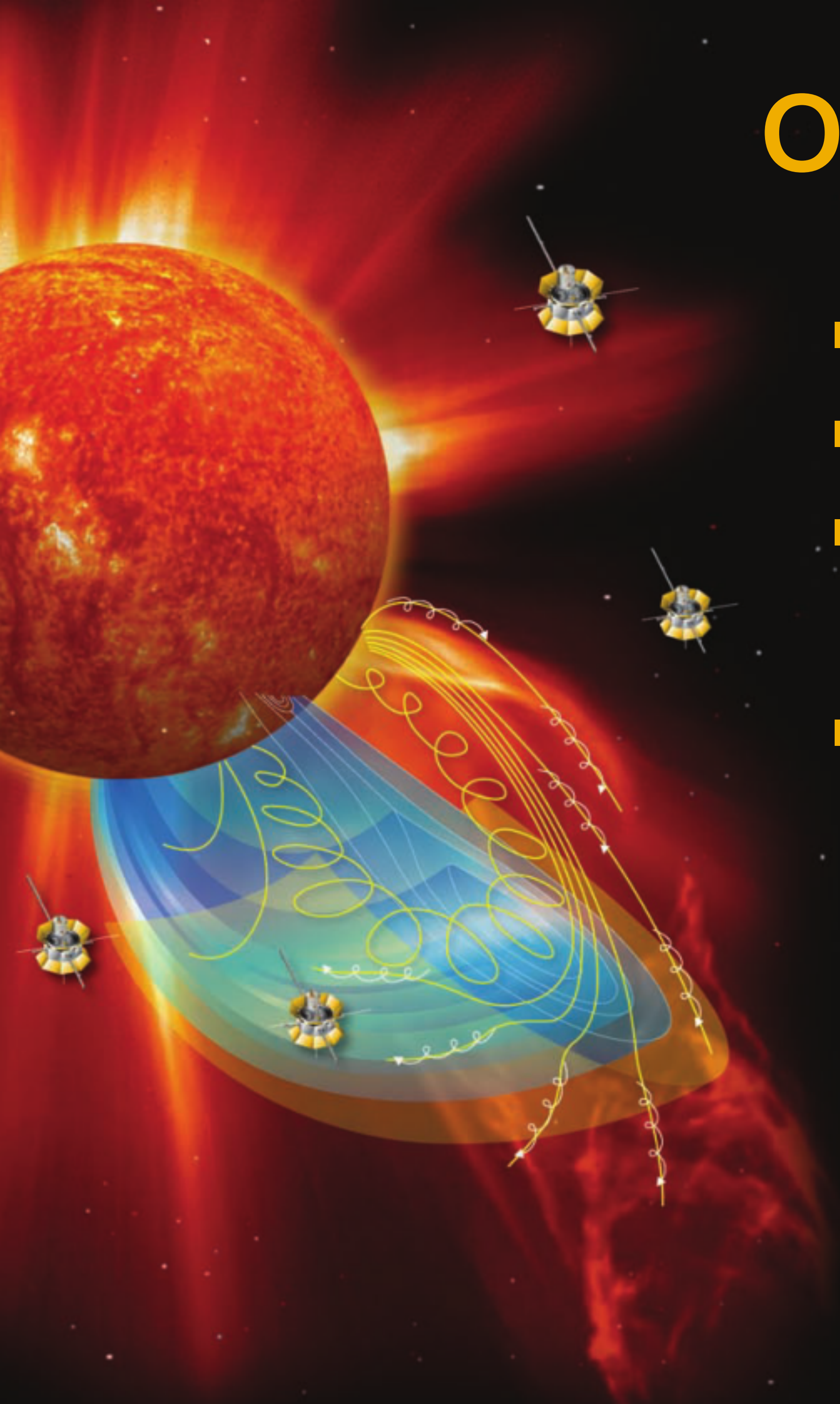
- The separation angle between the two STEREO increases by ~45° per year.

The STEREO/Waves instrument

- The S/Waves consists of:
  - LFR (Low Frequency Receiver): 2.5 – 160 kHz
  - HFR (High Frequency Receiver): 125 kHz – 16 MHz
  - FFR (Fixed Frequency Receiver): 30 or 32 MHz
  - TDS (Time Domain Sampler)
- Three monopole antennas with a physical length of 6 m each
- HFR is suitable for solar radio burst observations having direction-finding capabilities.
- The triangulation of radio sources → tracking solar energetic electrons responsible for solar radio bursts.







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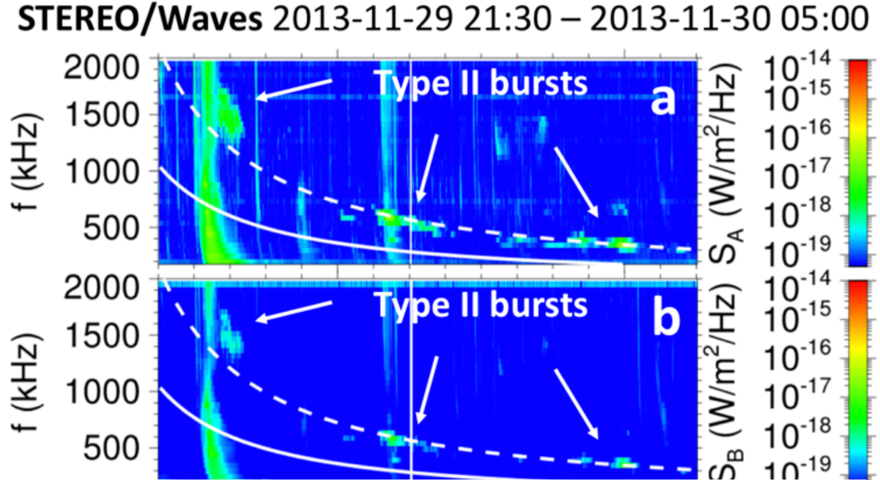
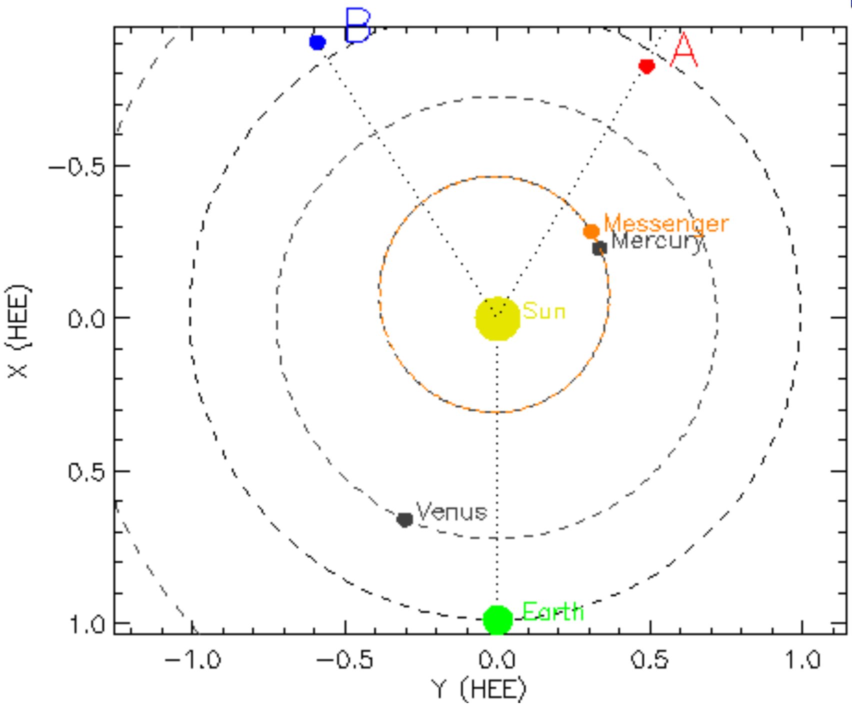
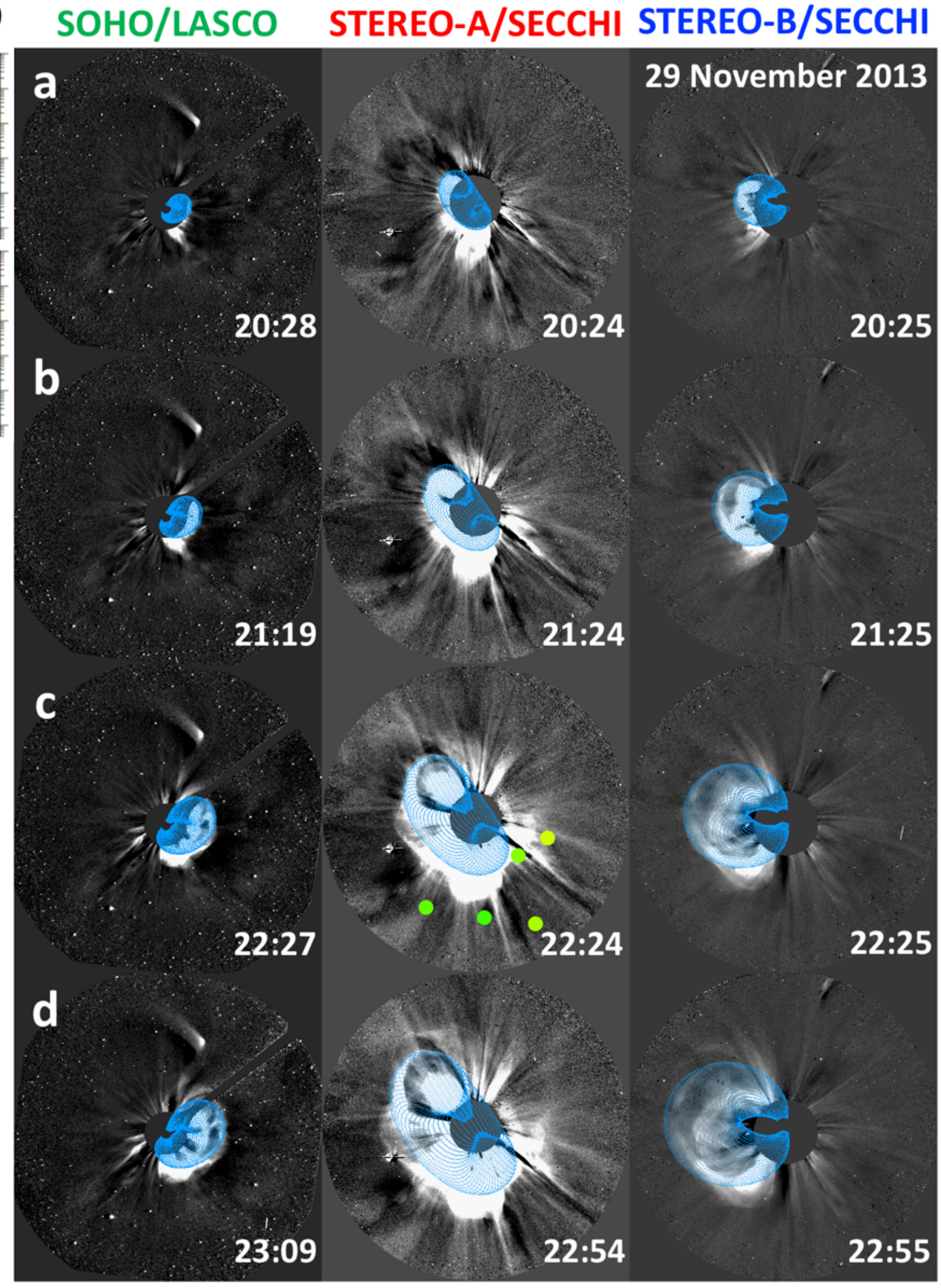


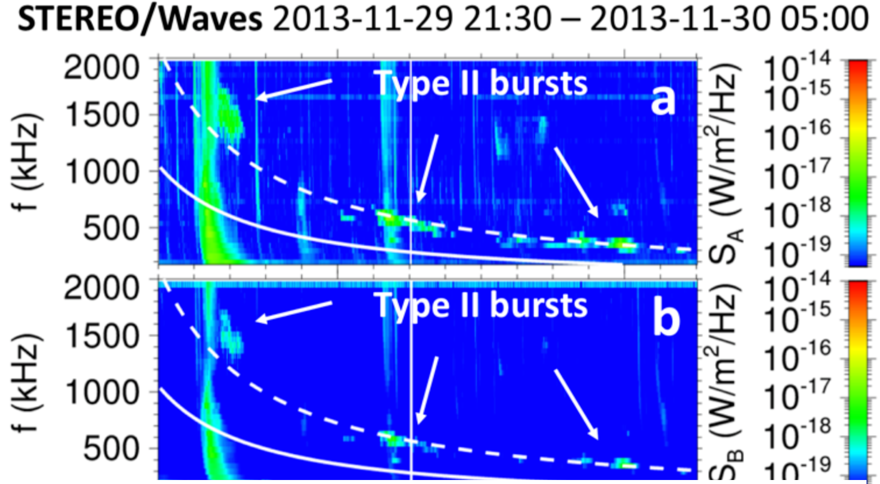


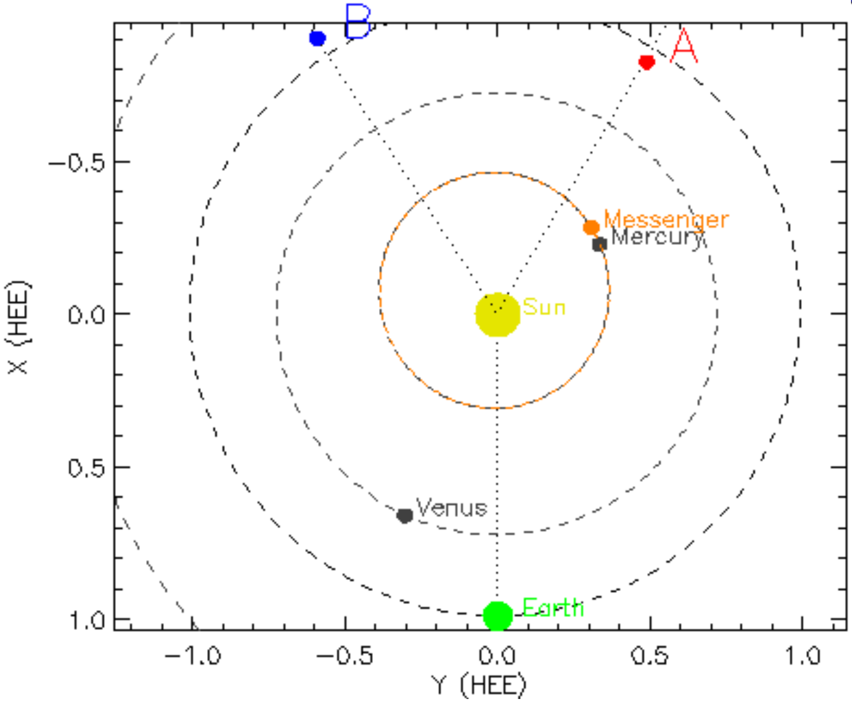


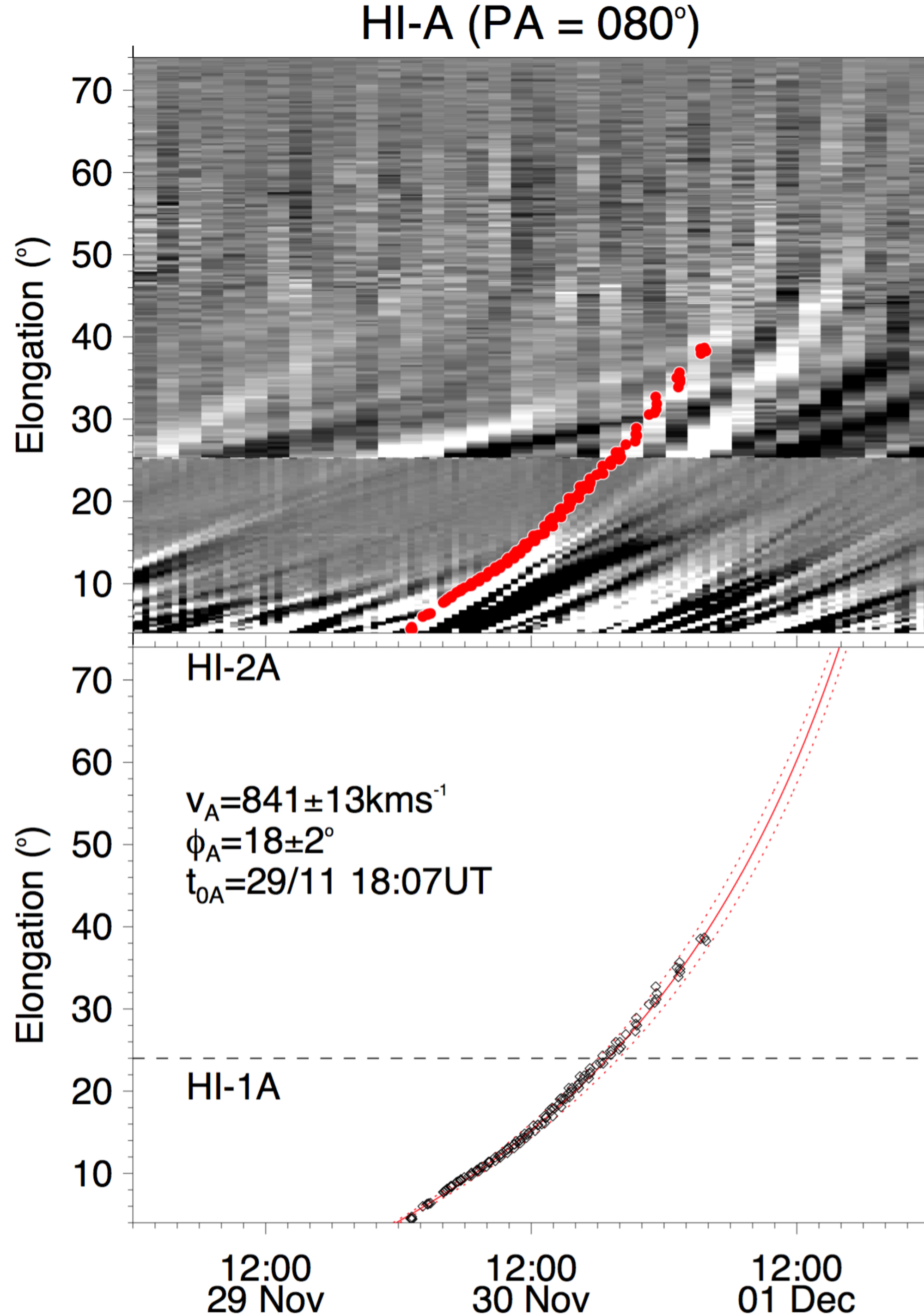
The Graduated Cylindrical Shell (GCS) model

v_{GCS} **= 761 ± 13 kms^{-1} (128°)**

Thernisien, Vourlidas, and Howard (2009)



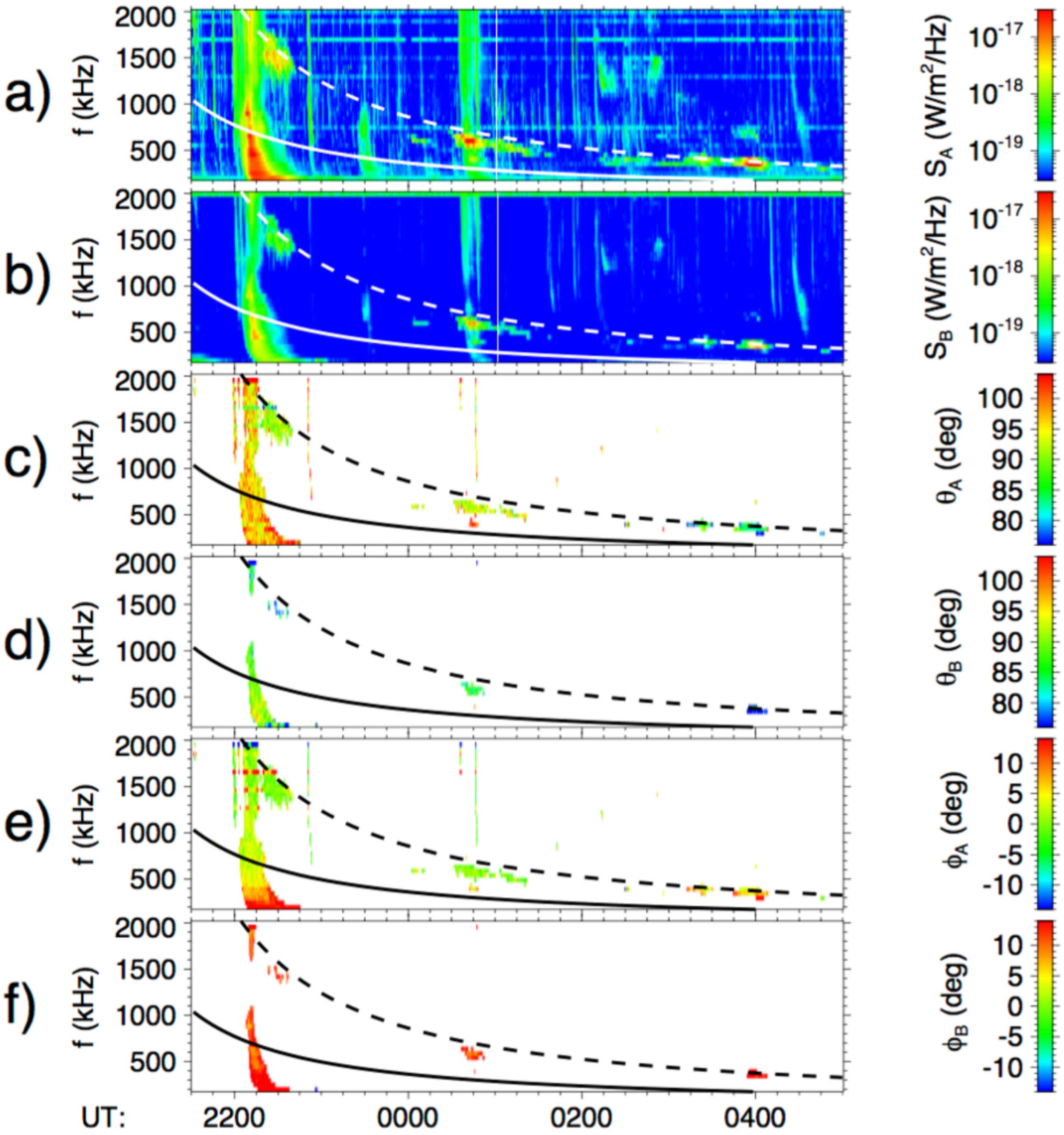




The Self Similar Expansion Fitting (SSEF)

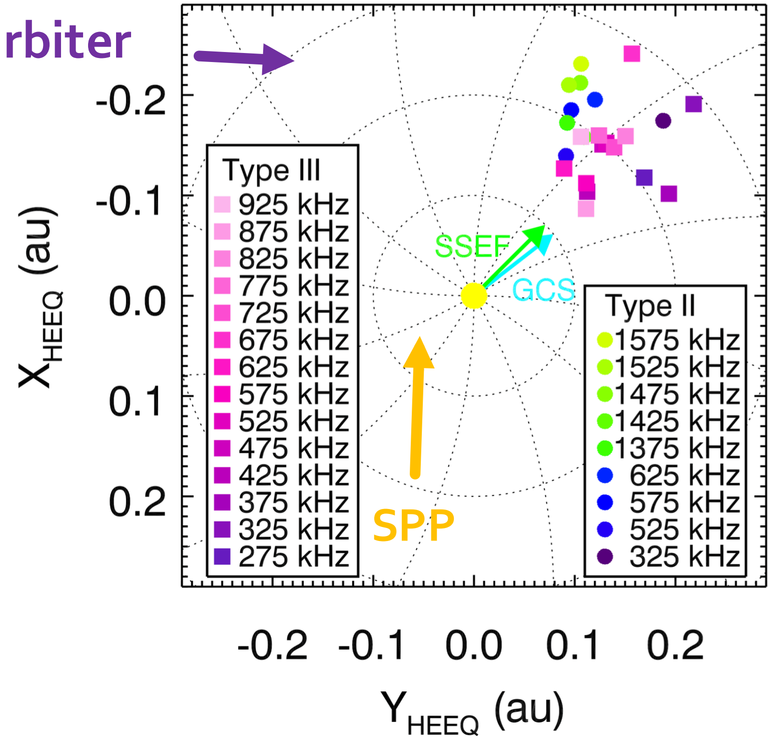
v_{SSEF} = 841 ± 13 kms^{-1} (135°)

Davies et al. (2012)

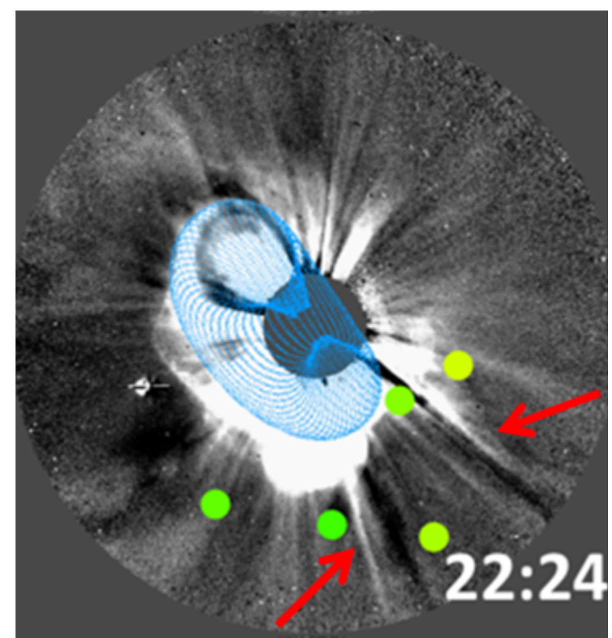


CME angular half-width λ_{GCS}= 59°

leading edge (f ~ r_{GCS}) and flanks (f ~ r_{GCS} cos λ_{GCS})

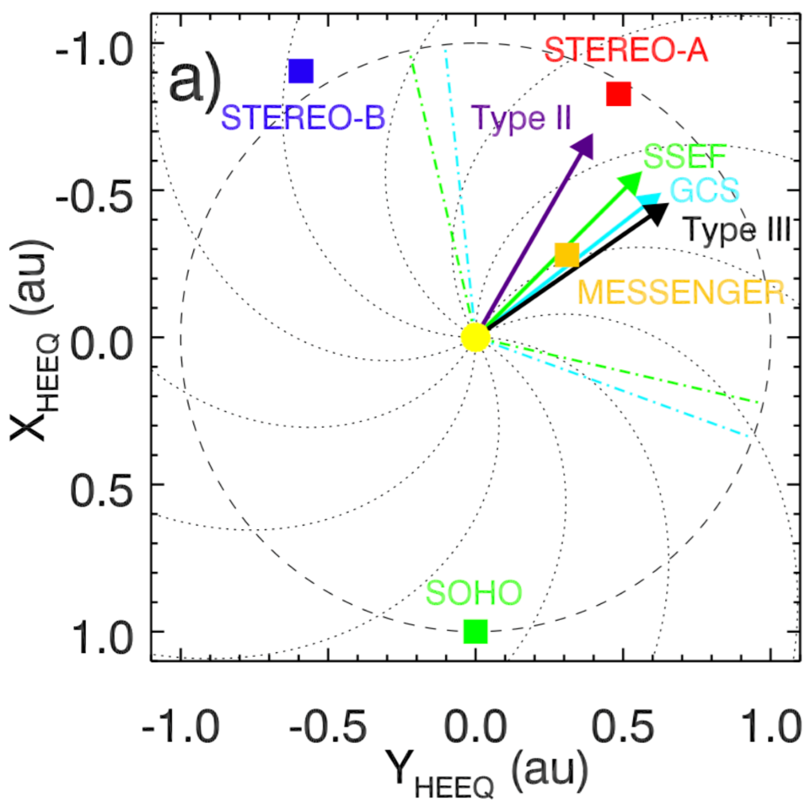


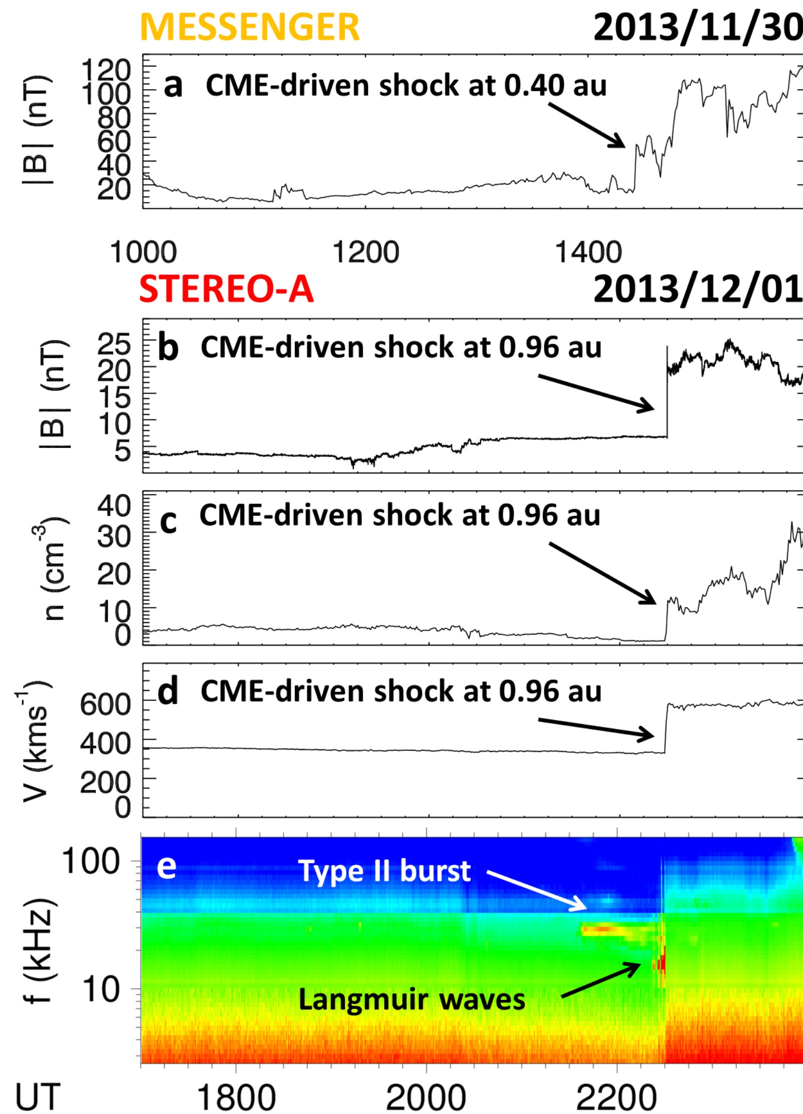
STEREO-A/SECCHI/COR2



The 2013 November 29 CME

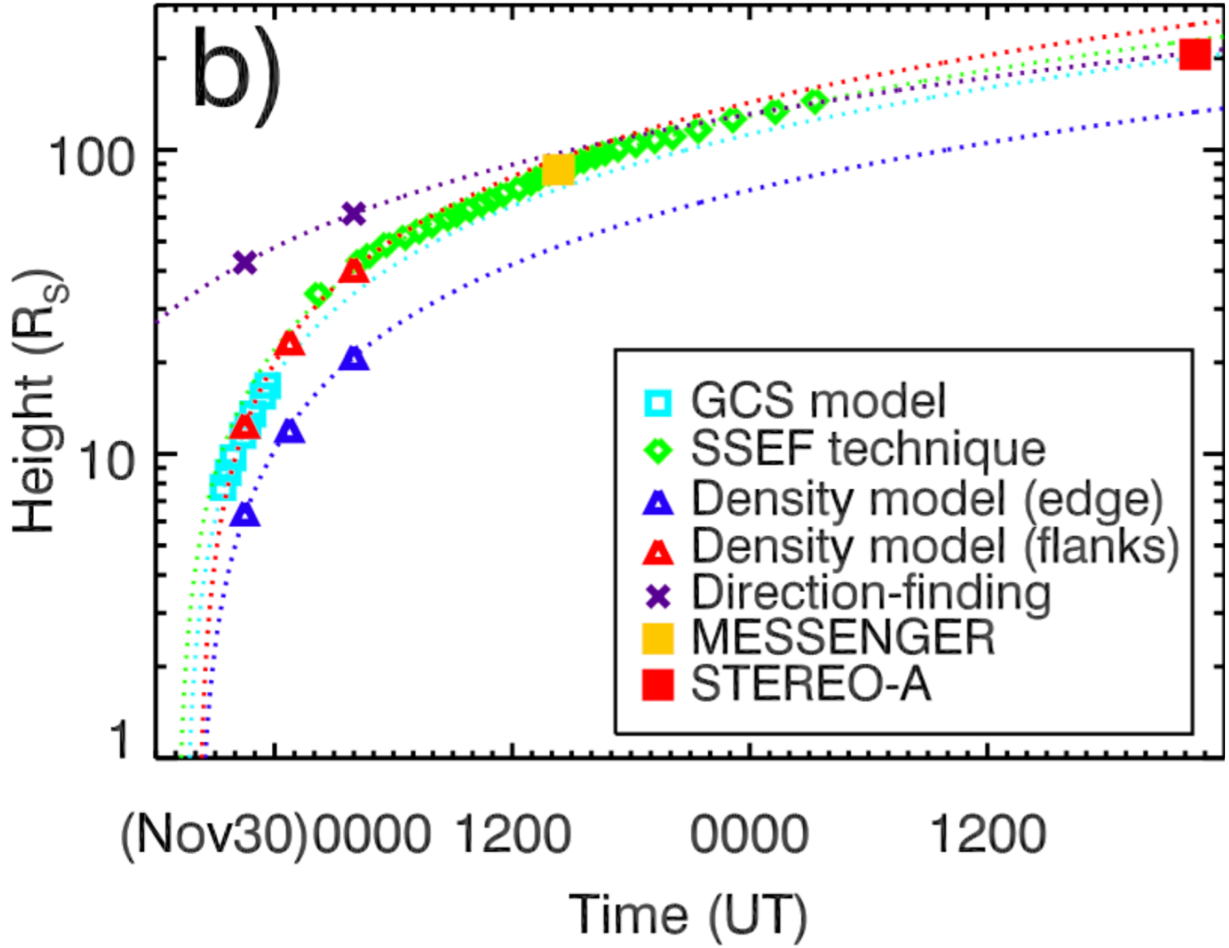
- IP shock observed by MESSENGER and STEREO-A
- Average azimuth of **type II and type III** bursts ~ the CME direction obtained by analysis of **white-light images**





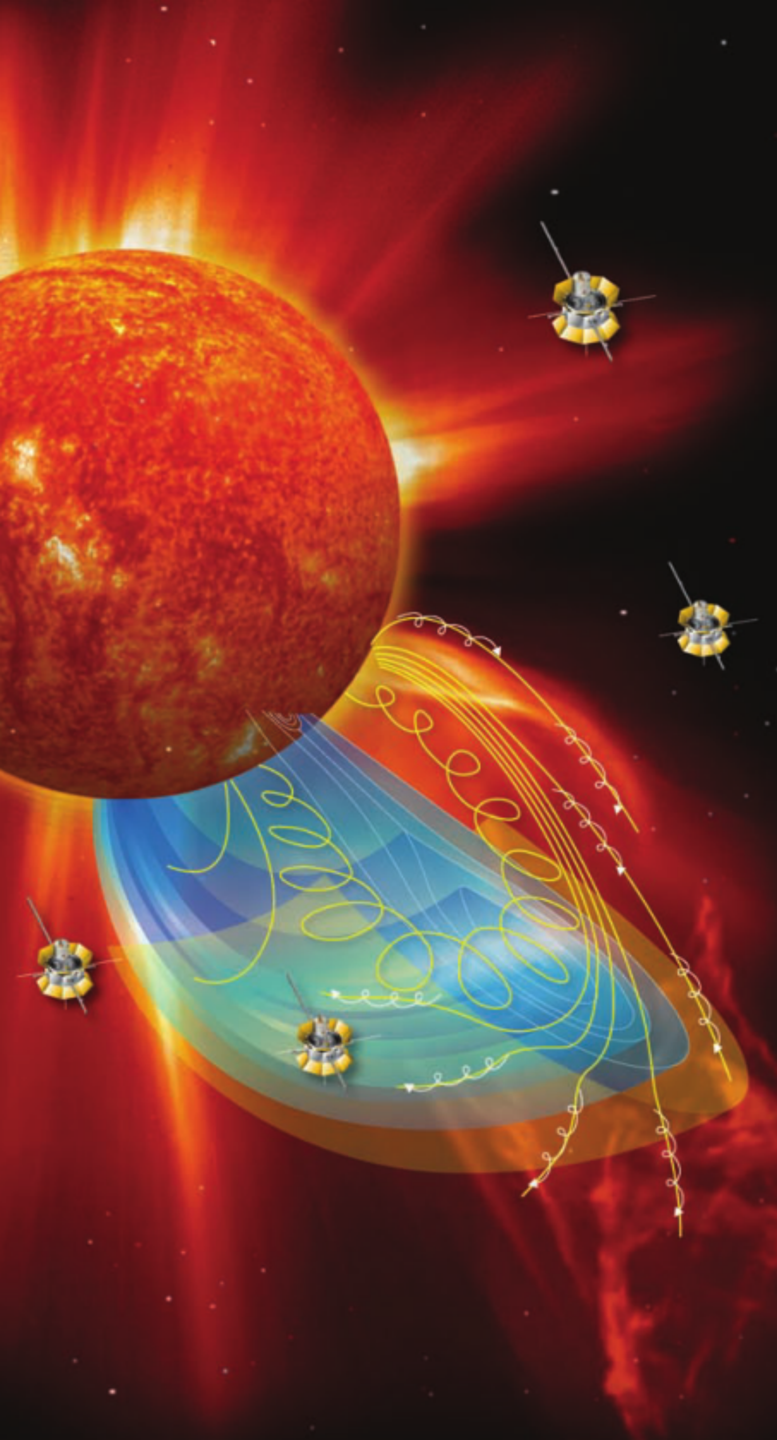
The 2013 November 29 CME

- Locations of **radio sources** using the **density model** correspond to **white-light** images of the CME
- **Triangulated radio sources** are located about **0.2 au farther** from the Sun than predicted by the density model
- IP **radio bursts** provide with reasonable **speed** (using the density model) and **direction** of the CME which can be used in a case of coronagraph failure.



Krupar et al., ApJL, 2016

Outline



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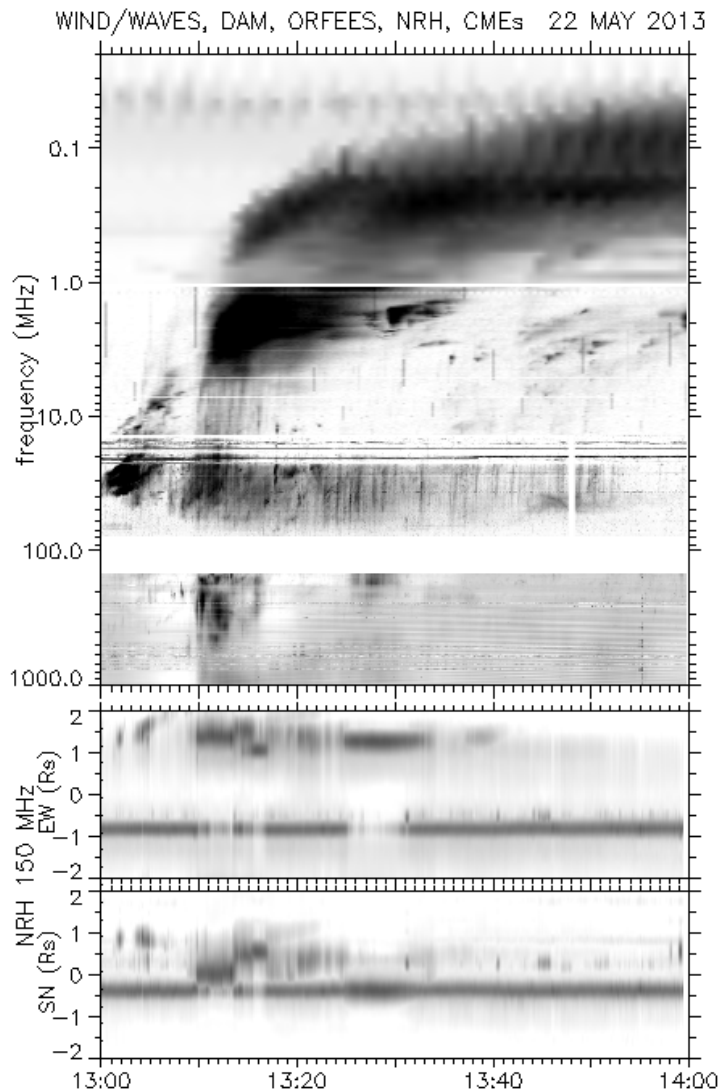
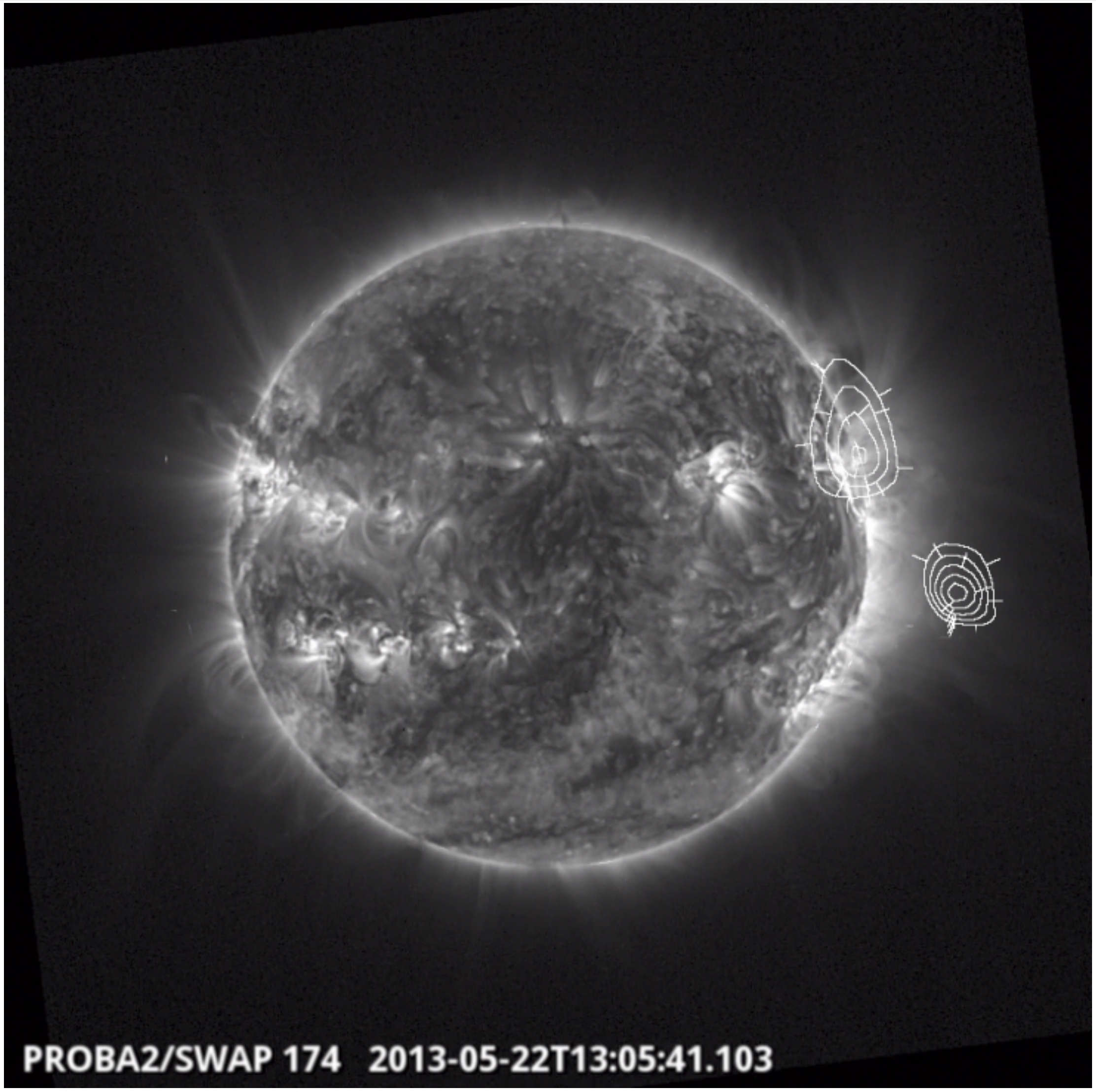
Proba2/SWAP observations





Conclusions

- A rare instance with **comprehensive in situ and remote sensing** observations of a CME combining **white-light, radio, and plasma measurements** from four different vantage points
- The **first** radio triangulation of an **interplanetary type II burst** detected by two **identical** radio receivers
- Triangulated **type II and type III bursts** in agreement with the **white-light CME reconstruction**
- The **radio** emission arises from the **flanks of the CME**
- The complementarity between **radio triangulation** and 3D reconstruction techniques for **space weather applications**
- **Proba2/SWAP** observations to be combined with ground-based high-frequency measurements


THANK YOU
FOR YOUR
ATTENTION