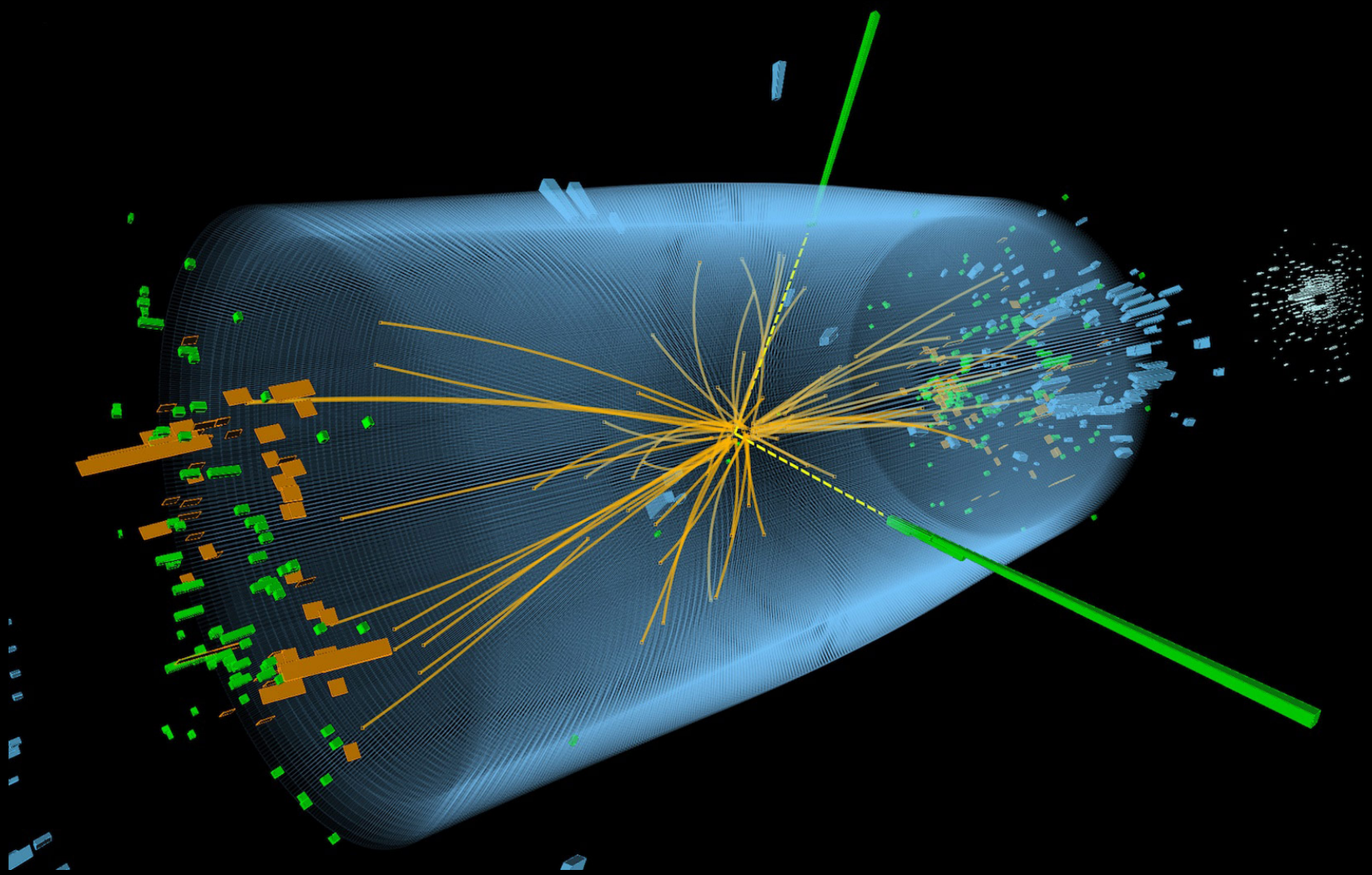
# Monitoring ultra un-energetic bosons with magnetic loop antennas

Thierry Dudok de Wit, Claude Cavoit, Vladimir Krasnoselskikh, Matthieu Kretzschmar, Aude-Lyse Millet

*LPC2E, CNRS/Univ. of Orléans, Orléans, France*



# Monitoring solar and interplanetary radio emissions with magnetic loop antennas

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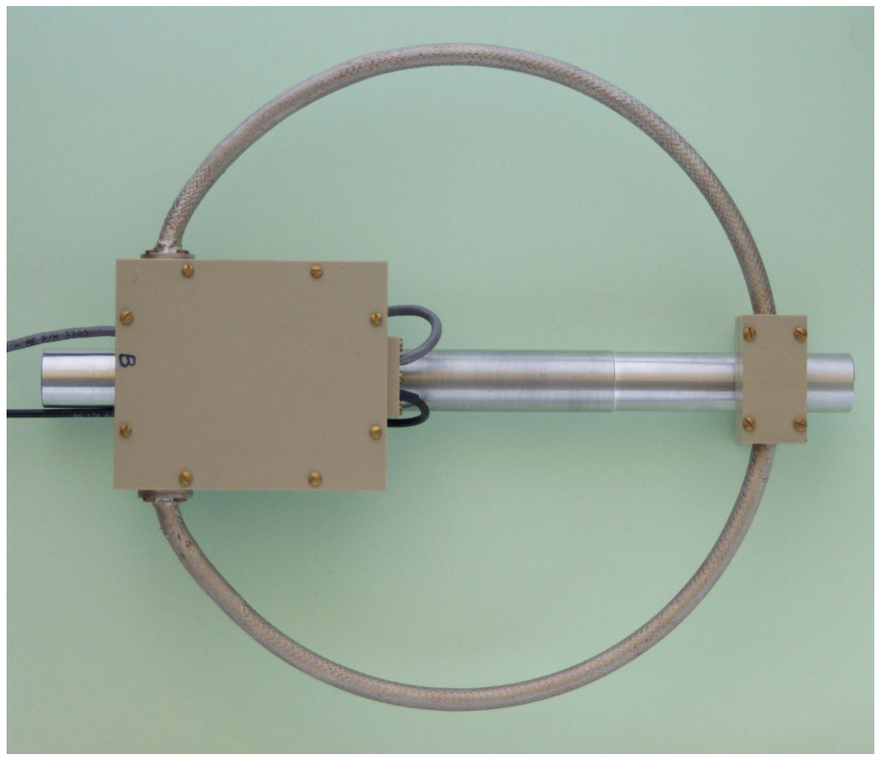
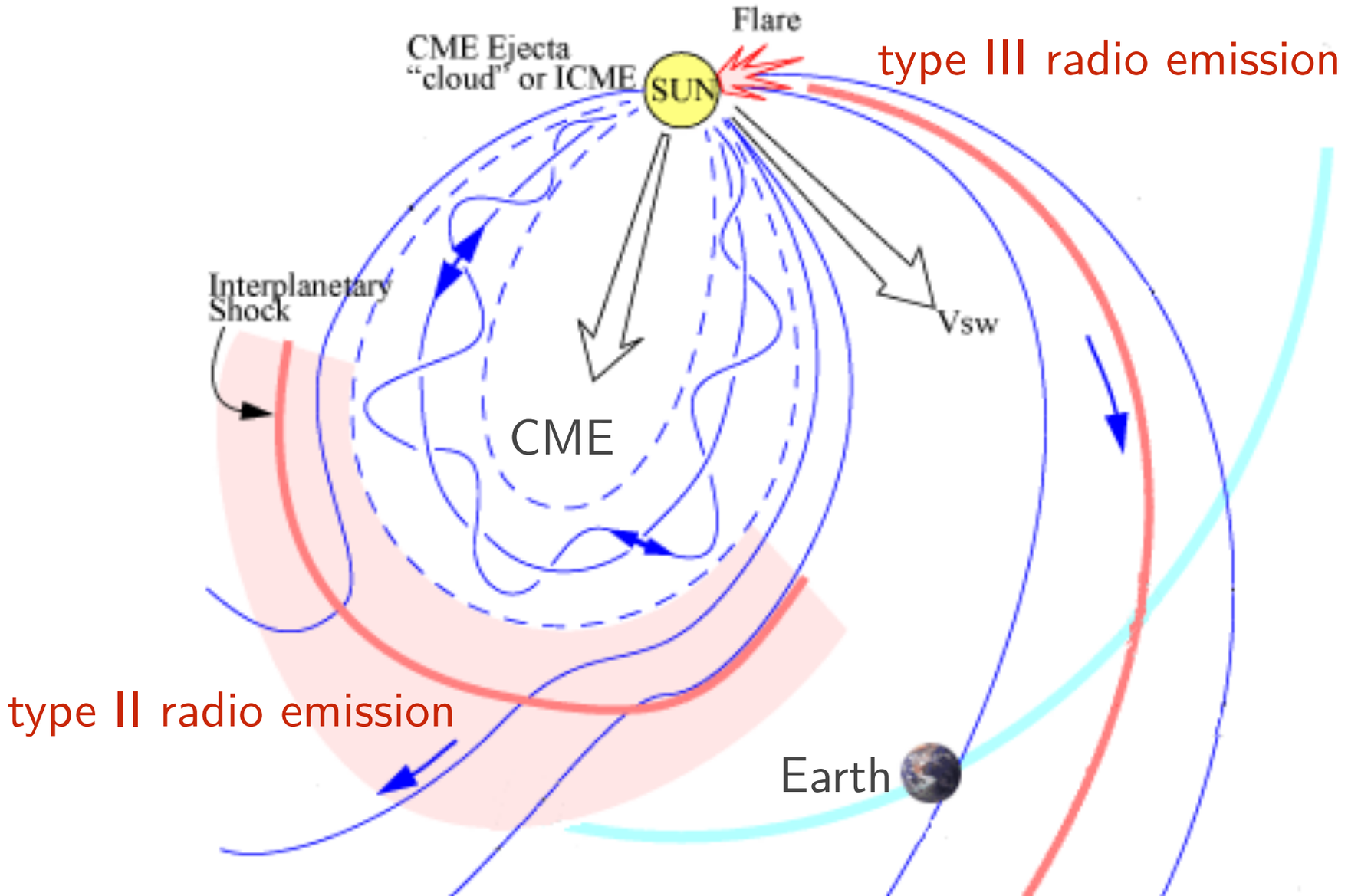
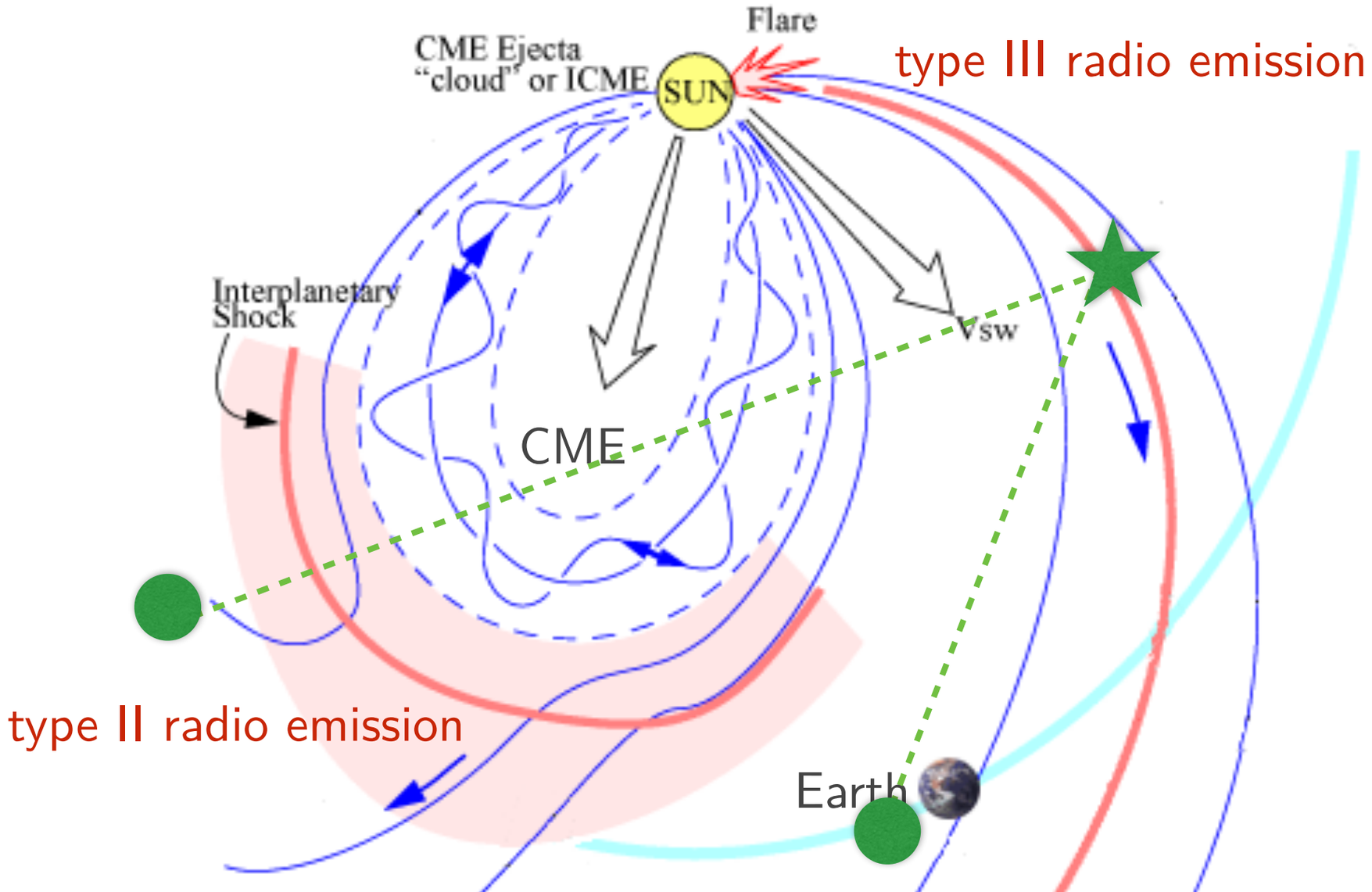


# Science case

- Solar radio bursts are **one of the very few precursors of geoeffective perturbations** (CMEs).
  [Reiner (2001), Gopalswamy (2006), Pick (2008), Lobzin (2010), Klein (2018), ...]

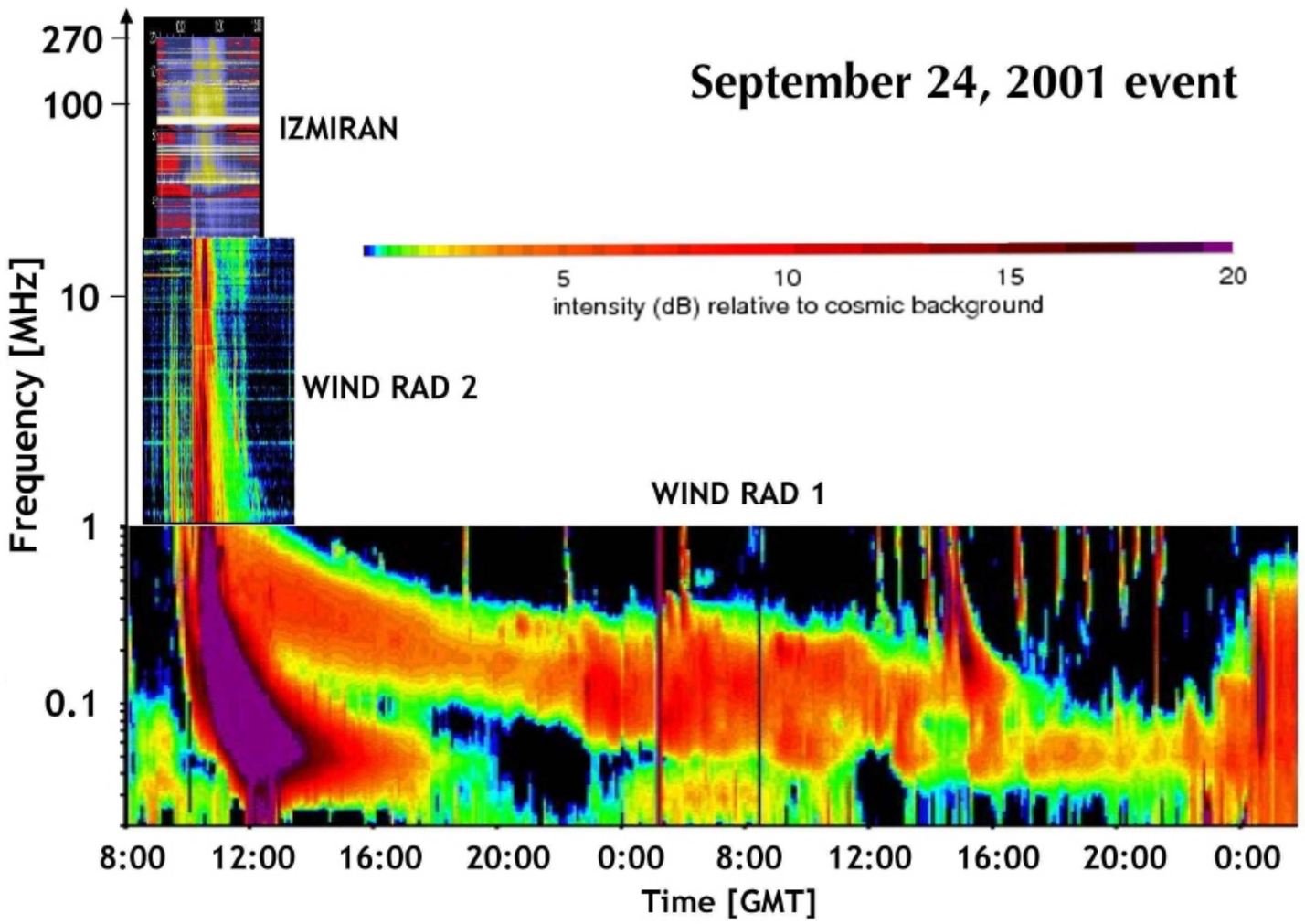


# Triangulation



# Science case

- Solar radio bursts have distinctive signatures (30 kHz - 30 MHz)



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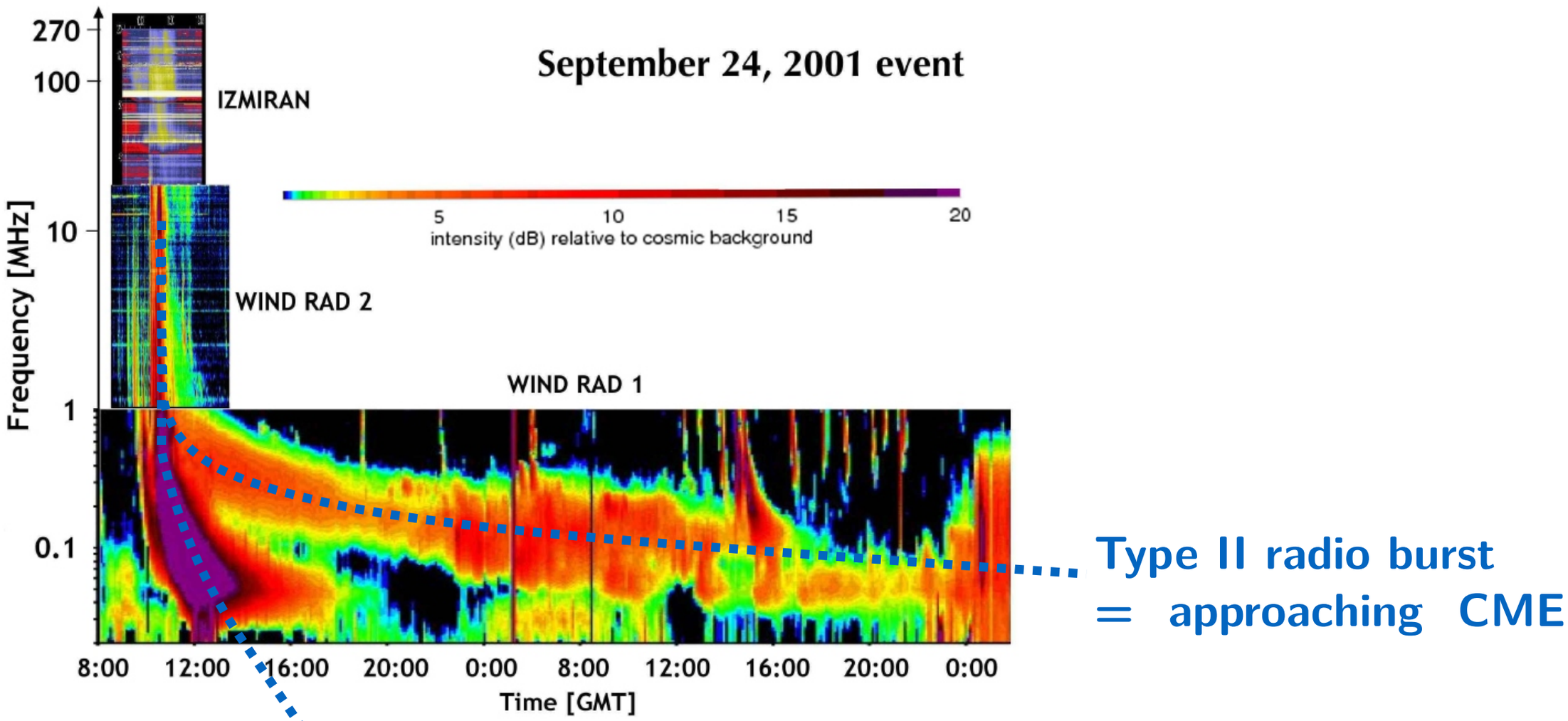
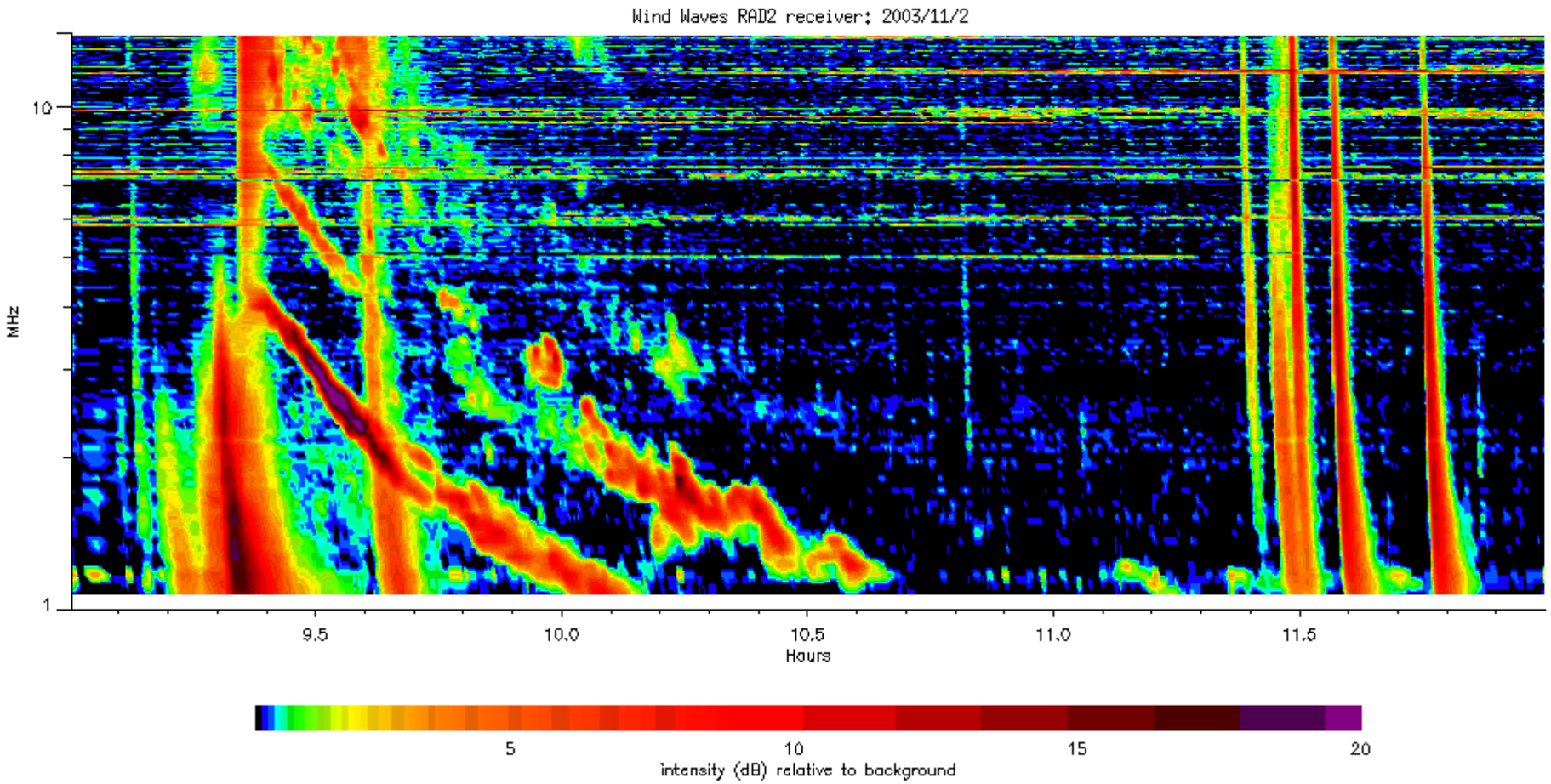


# Science case

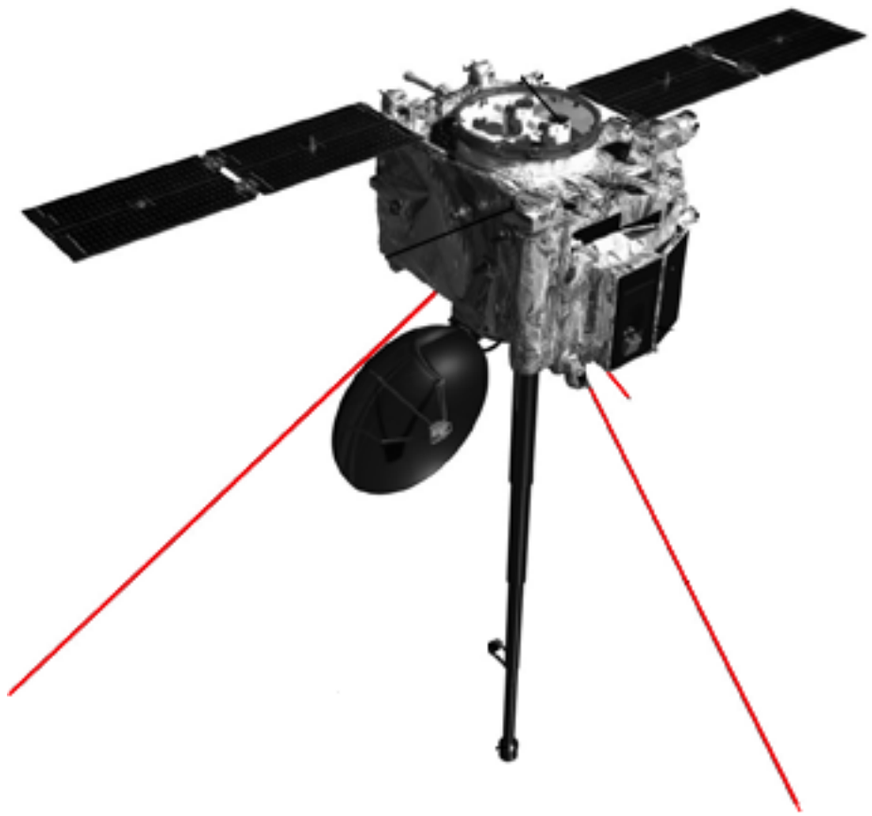
- Most events are more complex



# Measuring radio bursts

- Radio bursts are best measured from space
  - ionospheric cutoff below ~20 MHz
  - observations made by several missions (Ulysses, Wind, Stereo, Parker Solar Probe, soon Solar Orbiter, ...)

- They are usually measured by means of **electric** field antennas



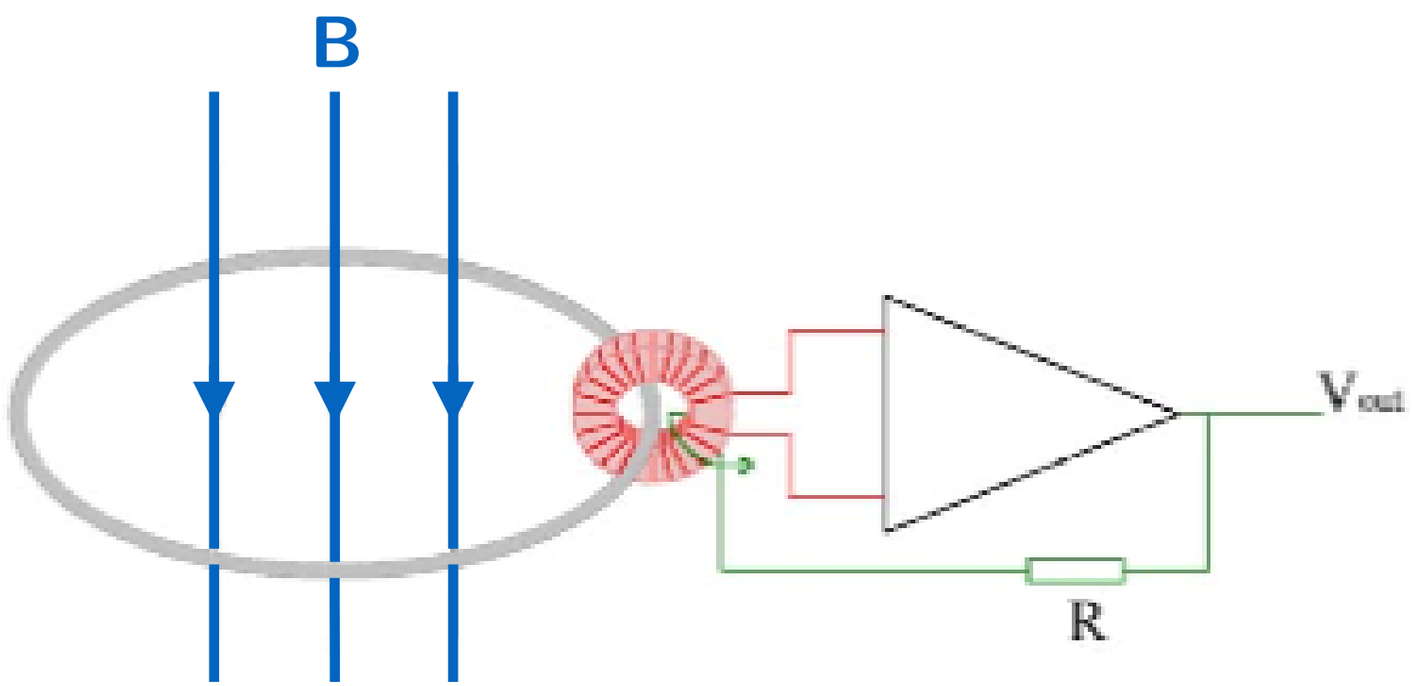
**Stereo**

# Measuring radio bursts

- **Magnetic** field antennas offer advantages over electric field antennas
  - Lighter and more compact : no need for spinning spacecraft or for long rigid E field antennas
  - Better dynamic range above cosmic noise background (f $>$ 10 MHz)

→ **use magnetic field measurements to monitor solar radio bursts**

# Measurement principle

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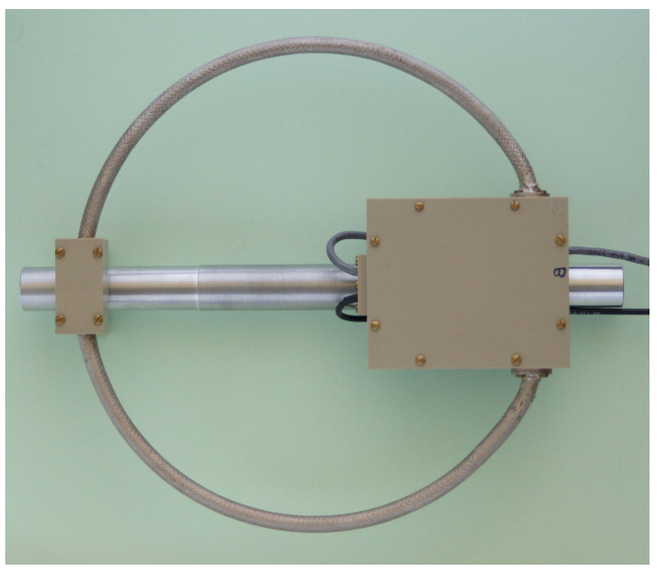
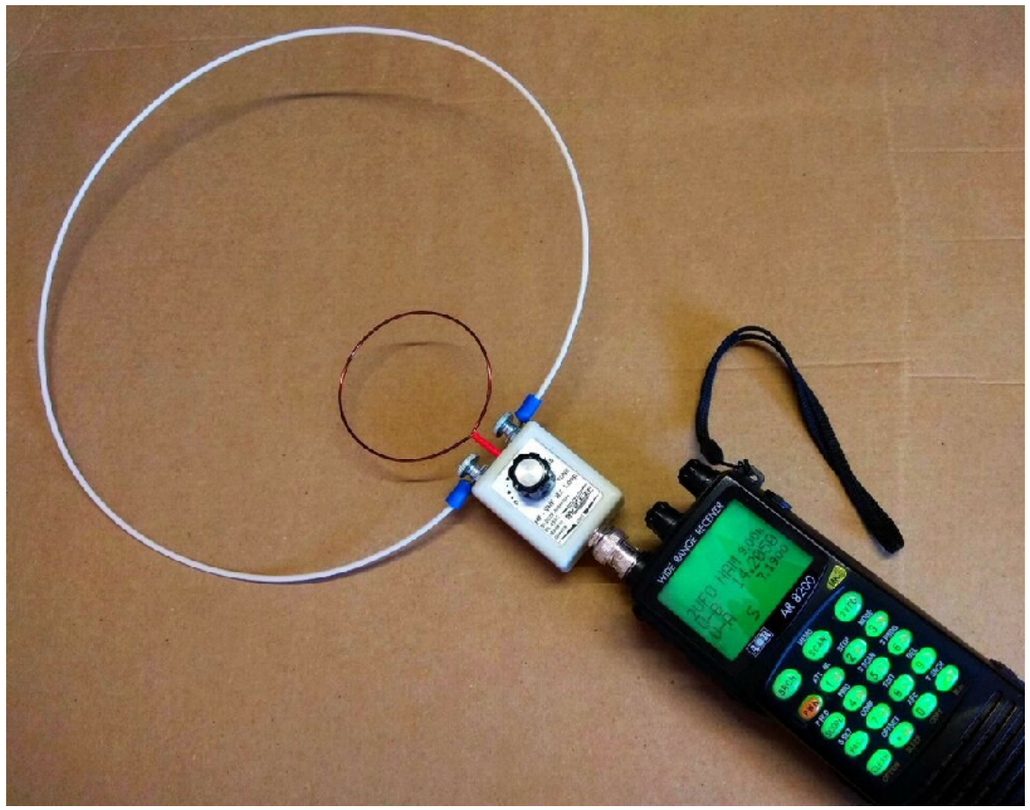


- Diameter: 20 cm diameter for monitoring solar radio bursts
- Bandwidth : 0.05–50 MHz
- Mass $<$ 300 g (one loop)
- Power $<$ 300 mW

# Heritage

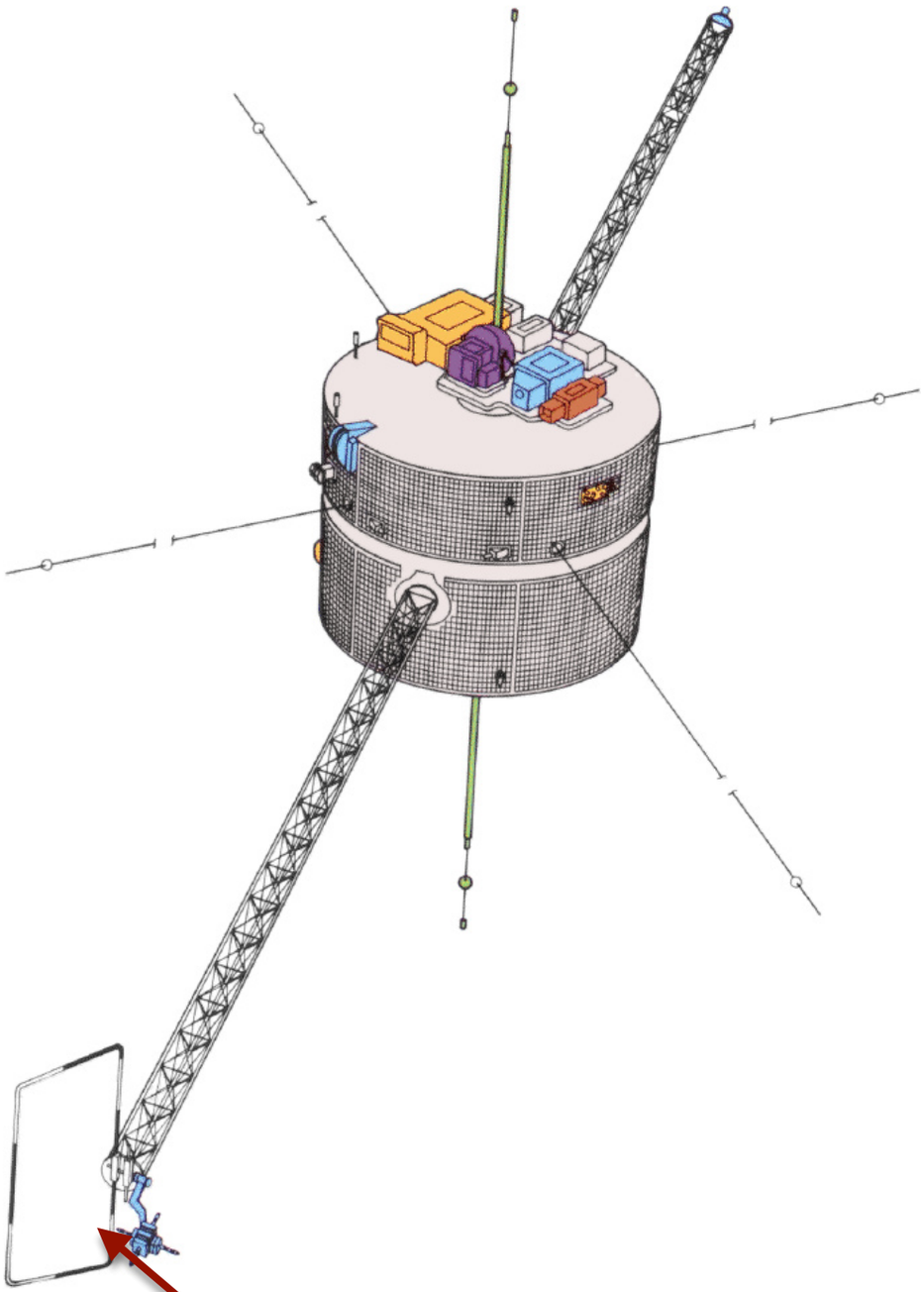
## loop antennas for HF/VHF radio amateurs



Loop antennas = magnetic component of a electromagnetic field
Standard antennas (e.g. dipole, Yagi, etc) = electric component.

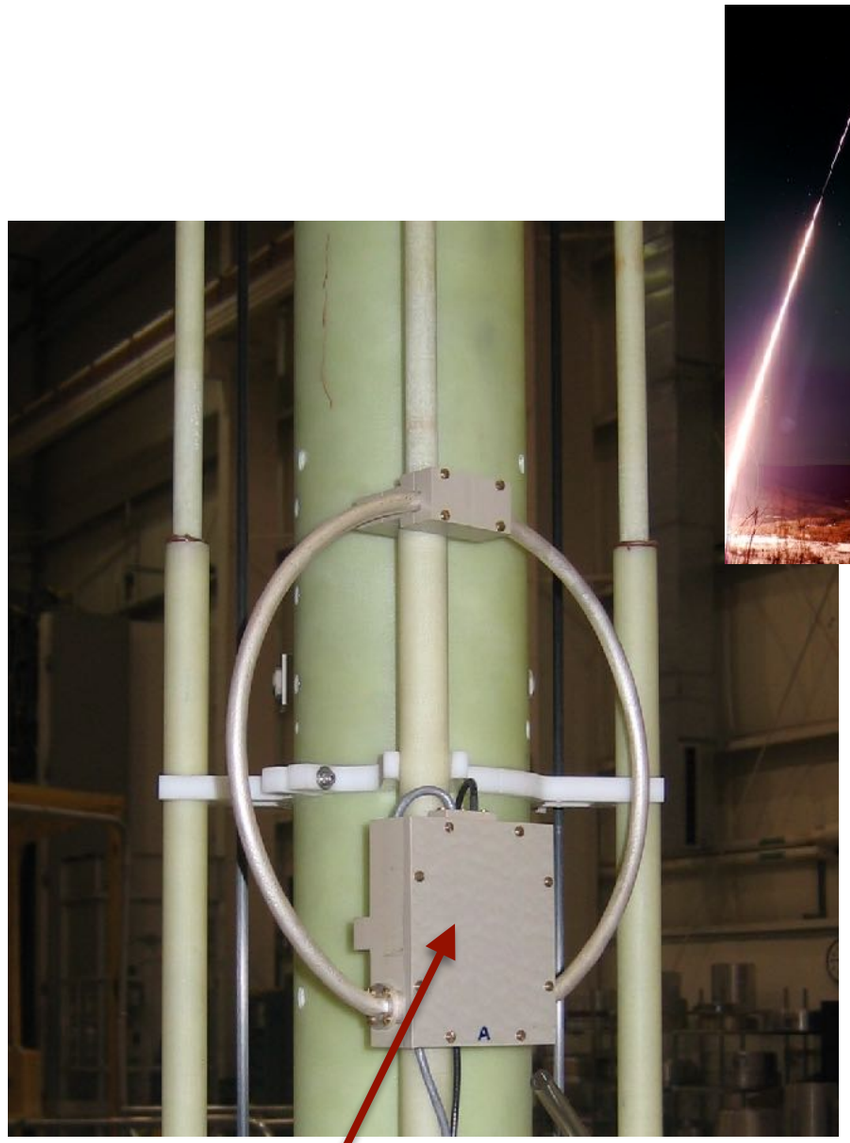
# Heritage

## Polar spacecraft (1996-2008)



Magnetic loop antenna (Univ. Iowa). Area 1 m²

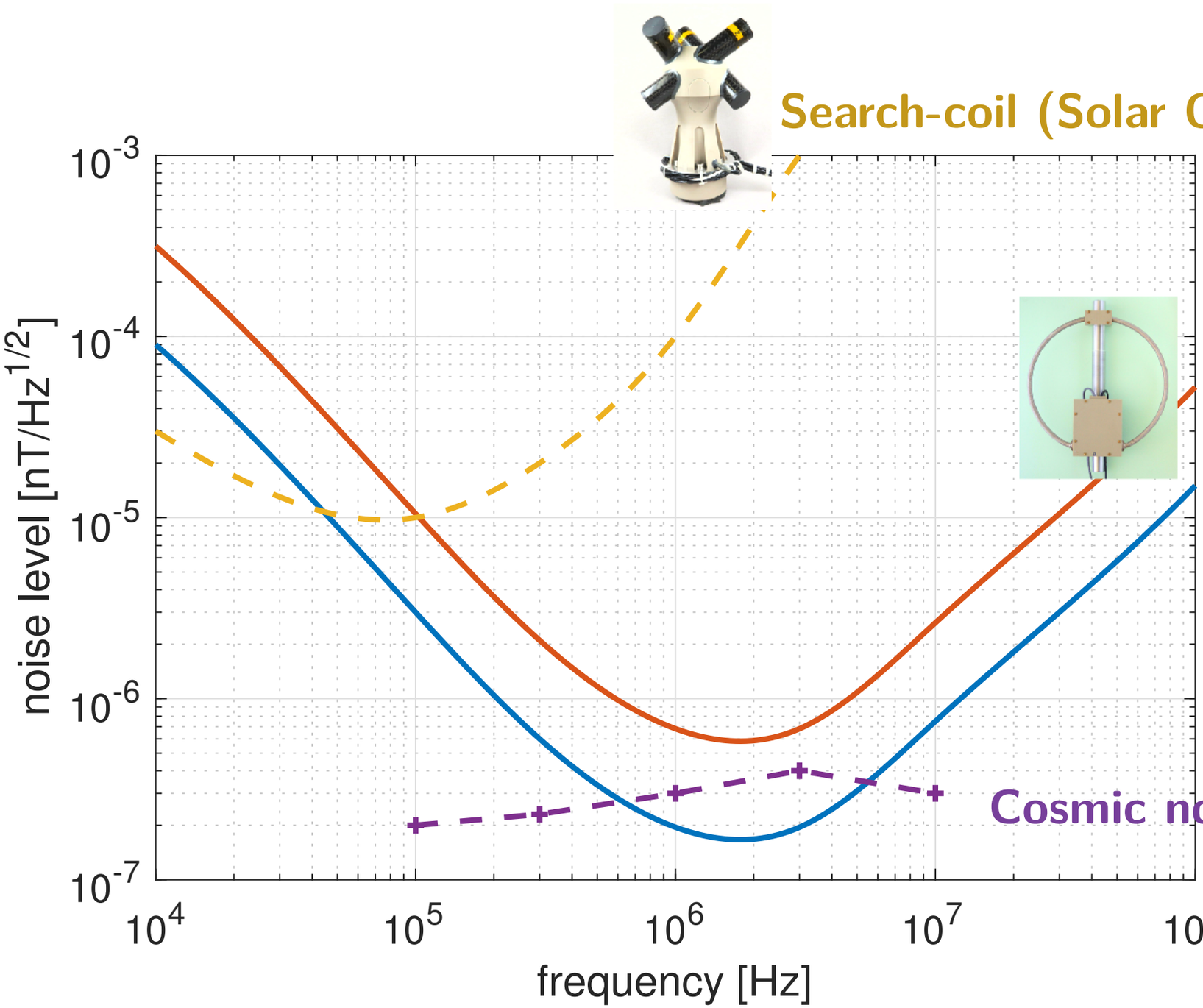
## CHARM sounding rocket (2008)



Magnetic loop antenna (LPC2E). Area 0.03 m²

# Sensitivity

- Diameter of the loop antenna = sensitivity



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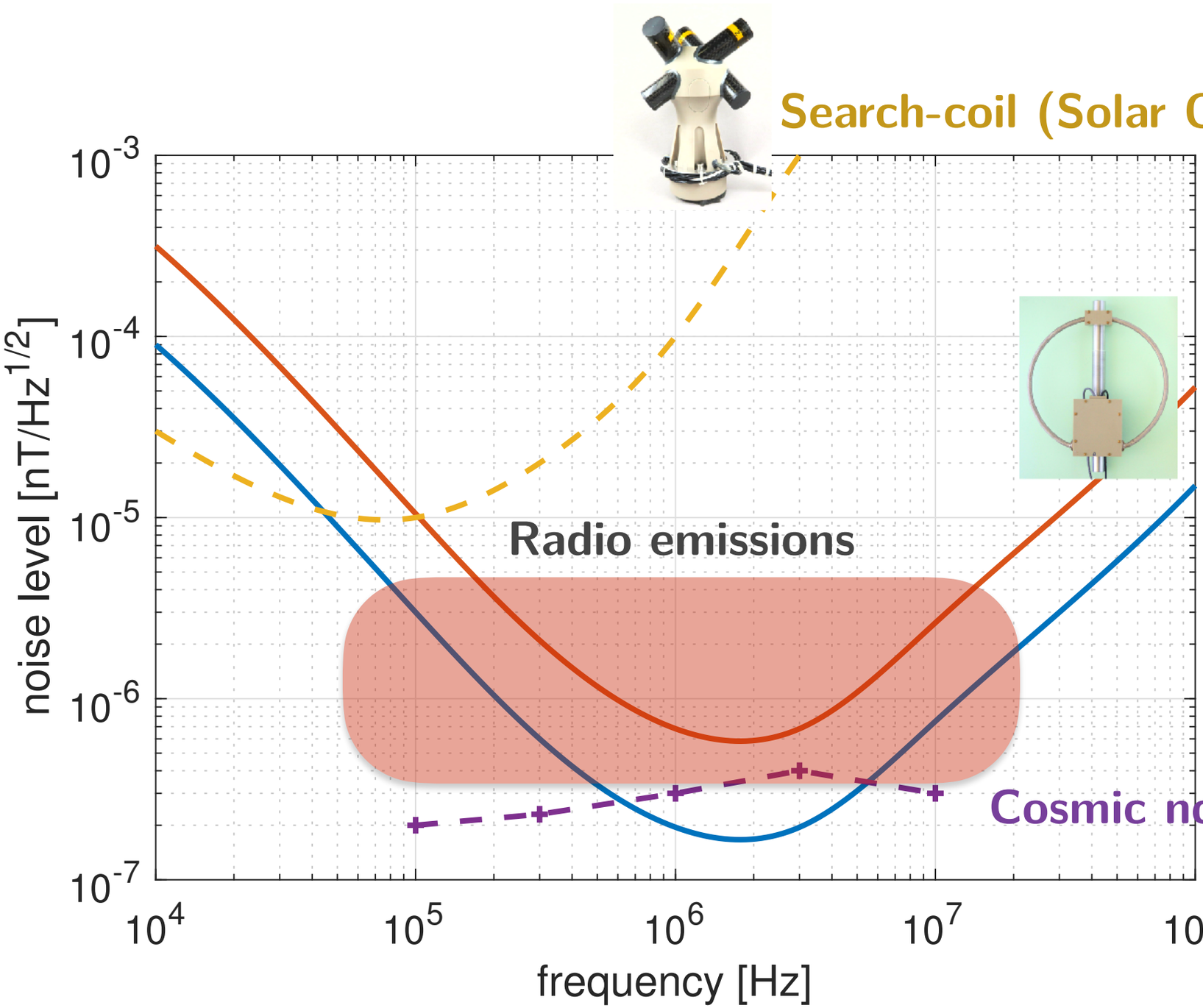
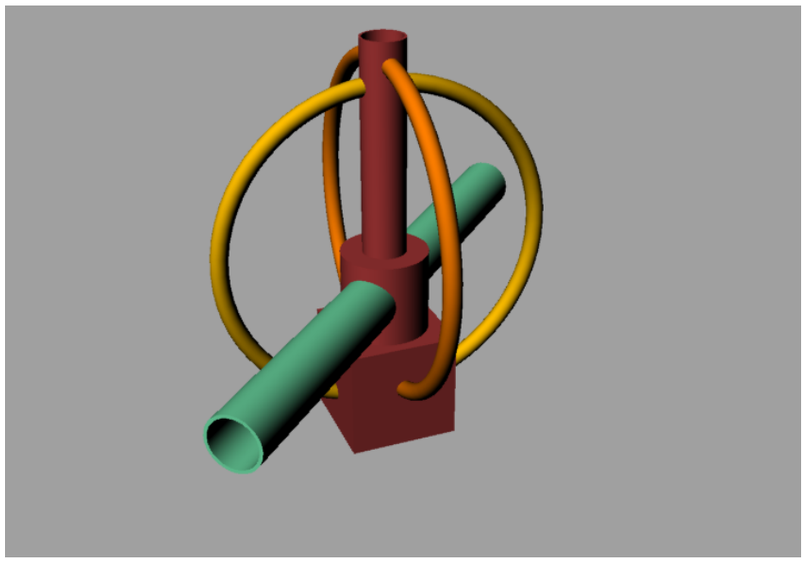
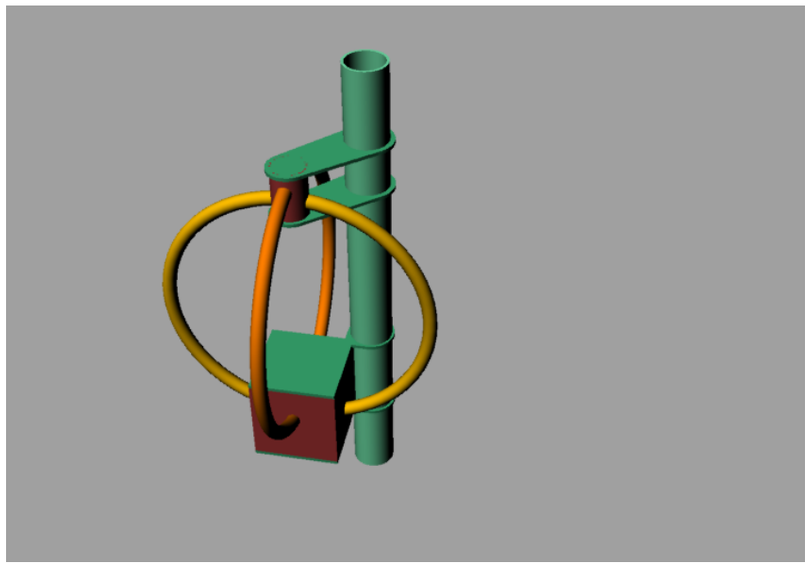


# Direction finding

- To locate the source of the radio emissions, two (three) orthogonal antennas are required.
  - needs larger volume or unfolding system





- with several spacecraft : source location by **triangulation**

# Requirements / Accommodation

- Requires electromagnetic cleanliness $>$ 100 kHz
  - Synchronised clocks, shielded cabling (beware of harmonics)
  - Better but not mandatory to place the sensor on a boom
- Instrument output is processed by a multichannel spectral analyser
  - Used routinely on multiple missions
  - May include artificial intelligence to automatically identify type II/III emissions
- High TRL ($\geq$ 6)

# Conclusions

- Coronographs + monitoring of solar radio bursts are the **only means for detecting geoeffective events**

- **Magnetic** field measurements offer an interesting alternative to **electric** field measurements
  - lighter, more compact
  - better adapted for a distributed system (triangulation)