Solar Type III radio bursts at Saturn's orbit: Case study of stereoscopic observations by Cassini/RPWS and Wind/WAVES experiments

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Type III radio bursts are produced by electron beams accelerated in active regions and following open magnetic field lines. Type III observed frequency is found to be nearly equal to the plasma frequency directly linked to the local electron density. The source regions of such solar bursts are the solar corona and the interplanetary medium where, respectively, higher and lower frequencies are generated. In this work, we consider specific Type III solar bursts simultaneously observed by Cassini/RPWS and Wind/WAVES experiments. Despite the distance of Cassini spacecraft to the Sun such Type III bursts have been detected at Saturn's orbit, i.e. at about 10AU. Those considered bursts are covering a frequency bandwidth from about 10 MHz down to 100 kHz. We attempt in this study to characterize the spectral pattern, i.e. the flux density versus the observation time and the frequency range, and the visibility of the source regions to the observer (i.e. Wind and Cassini spacecraft). In this context, we analyze the evolution of the Type III bursts from the solar corona and up to Saturn's orbit taking into consideration the Archimedean spiral which is the geometrical configuration of the solar magnetic field extension in the interplanetary medium. We principally discuss the physical parameters, i.e. solar wind speed and the electron density, which lead to constraint the location of the source region and its visibility to both spacecraft.

Visibility of Type III burst source location as inferred from stereoscopic space observations

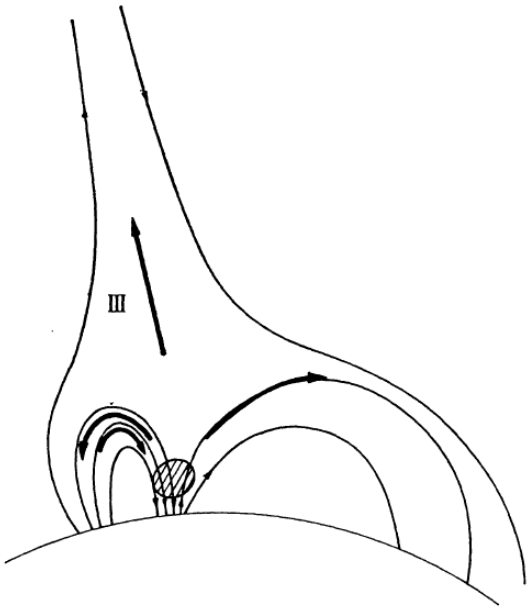
- Type III bursts result from streams of electrons travelling out from active regions along open magnetic field lines (Wild, 1950).

- Electrons generate at each height Langmuir waves whose frequency is nearly the local plasma frequency fp (MHz) = $9.10^{-3}.ne^{1/2}$ (cm^{-3}) where ***ne*** is the local electron density.

- Some of the energy in the Langmuir waves is converted into electromagnetic waves (Ginzburg and Zheleznyakov, 1958).

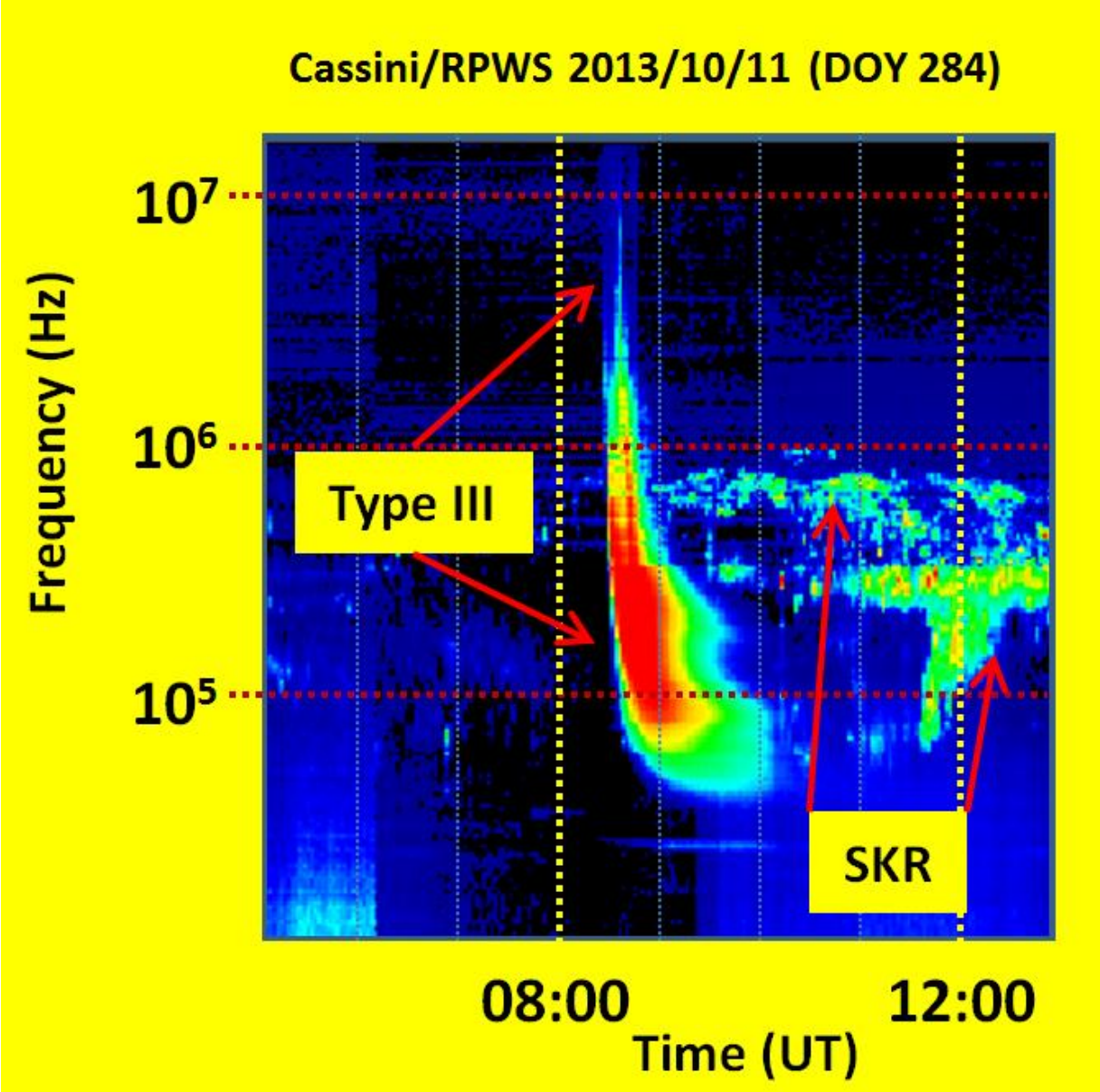
- In the interplanetary space, both the electrons (Lin, 1974) and the waves (Gurnett and Franck, 1975) have been observed directly.

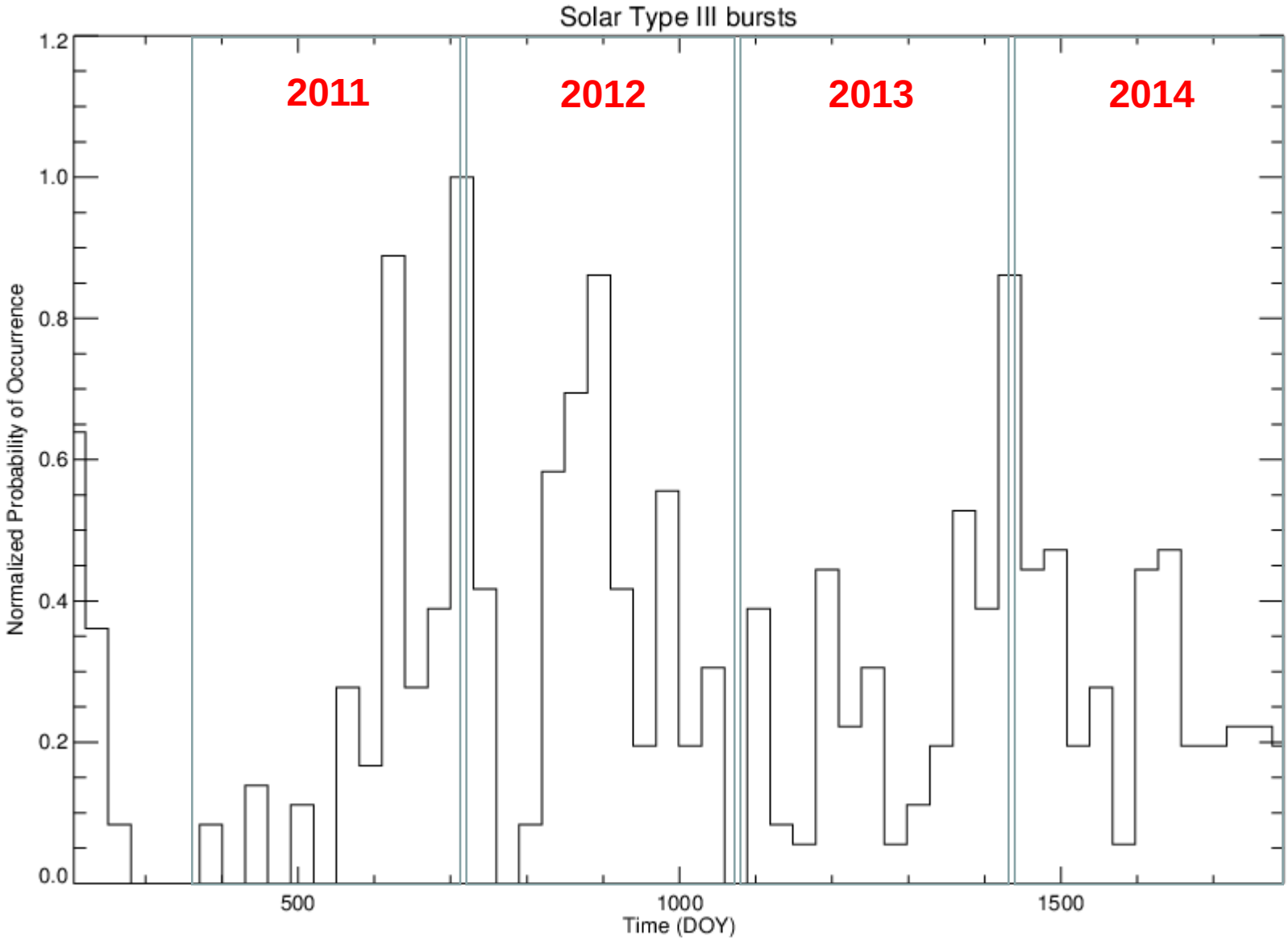
Visibility of Type III burst source location as inferred from stereoscopic space observations

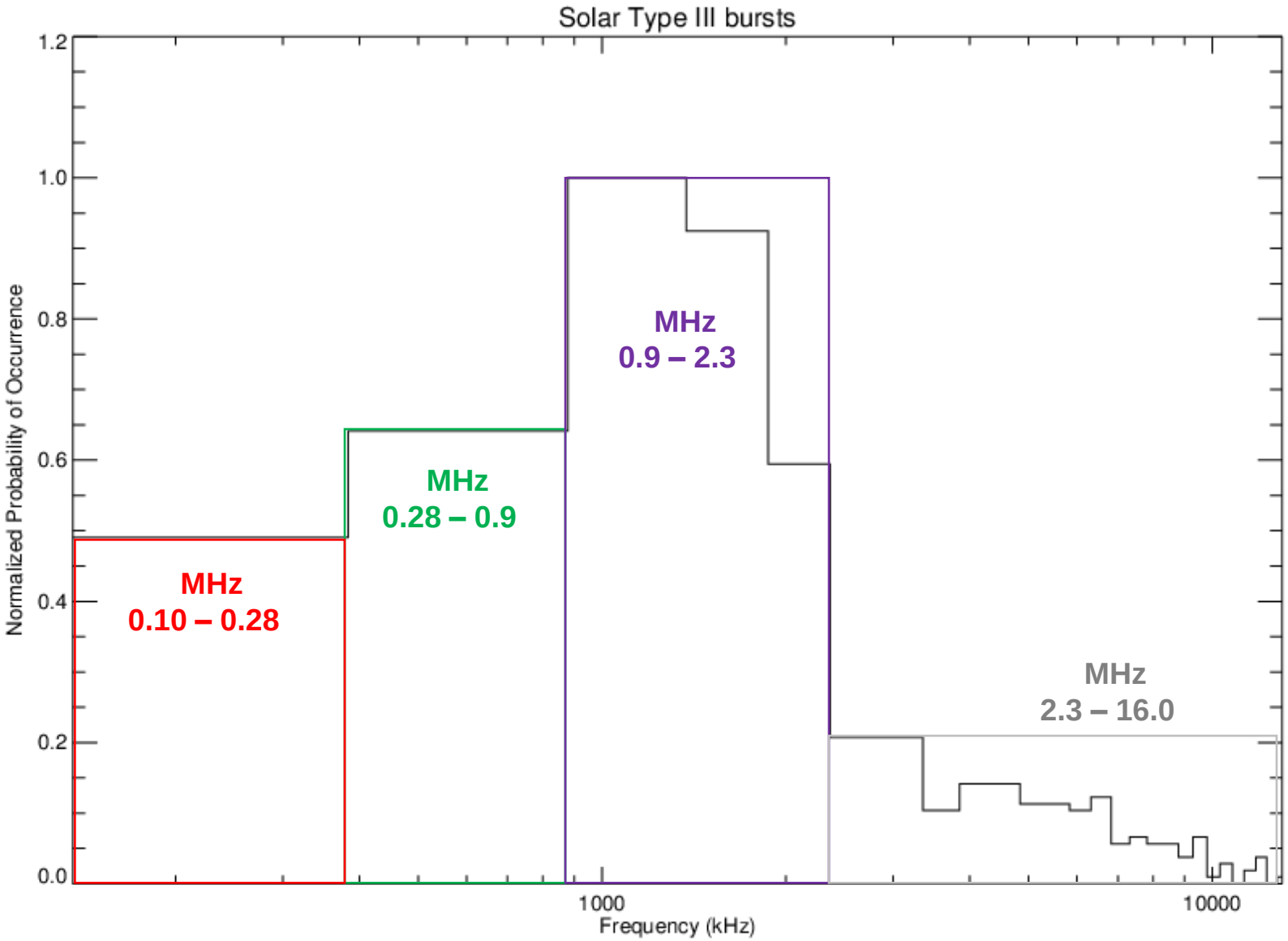


Source size of solar Type III bursts for metric, decametric and hectometric ranges

Frequency MHz	Radial height Solar radius	Source size Angular	Source size Solar radius
169	1.3	5.7′	0.2–0.5
80	1.7	11′	0.4–0.9
43	2.2	20′	0.8–1.6
0.9	12.5	6°	12


Cassini/RPWS 2013/10/11 (DOY 284)
Frequency (Hz)
10^7
10^6
10^5
Type III
SKR
08:00
12:00
Time (UT)


Solar Type III bursts
2011
2012
2013
2014
Normalized Probability of Occurrence
0.0
0.2
0.4
0.6
0.8
1.0
1.2
500
1000
1500
Time (DOY)


Solar Type III bursts
Normalized Probability of Occurrence
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1000
10000
Frequency (kHz)
MHz
0.10 – 0.28
MHz
0.28 – 0.9
MHz
0.9 – 2.3
MHz
2.3 – 16.0

Type III geometry: Archimedes spiral

We analyse the geometry of the Type III solar burst source with regards to the spacecraft locations.

- This relation allows us to estimate the distance at which occurred the observed frequency using:

$$f_{pe}(r) = 22.5 r^{-1.05} kHz$$

where f_{pe} is the local plasma frequency (Bougeret et al., 1984)

- Then we consider that the electrons at the origin of the Solar Type III bursts follow the interplanetary magnetic field.

Type III geometry: Archimedes spiral

- The trajectory of the solar bursts is an Archimedes spiral contained in the ecliptic plane. The equation of the trajectory is:

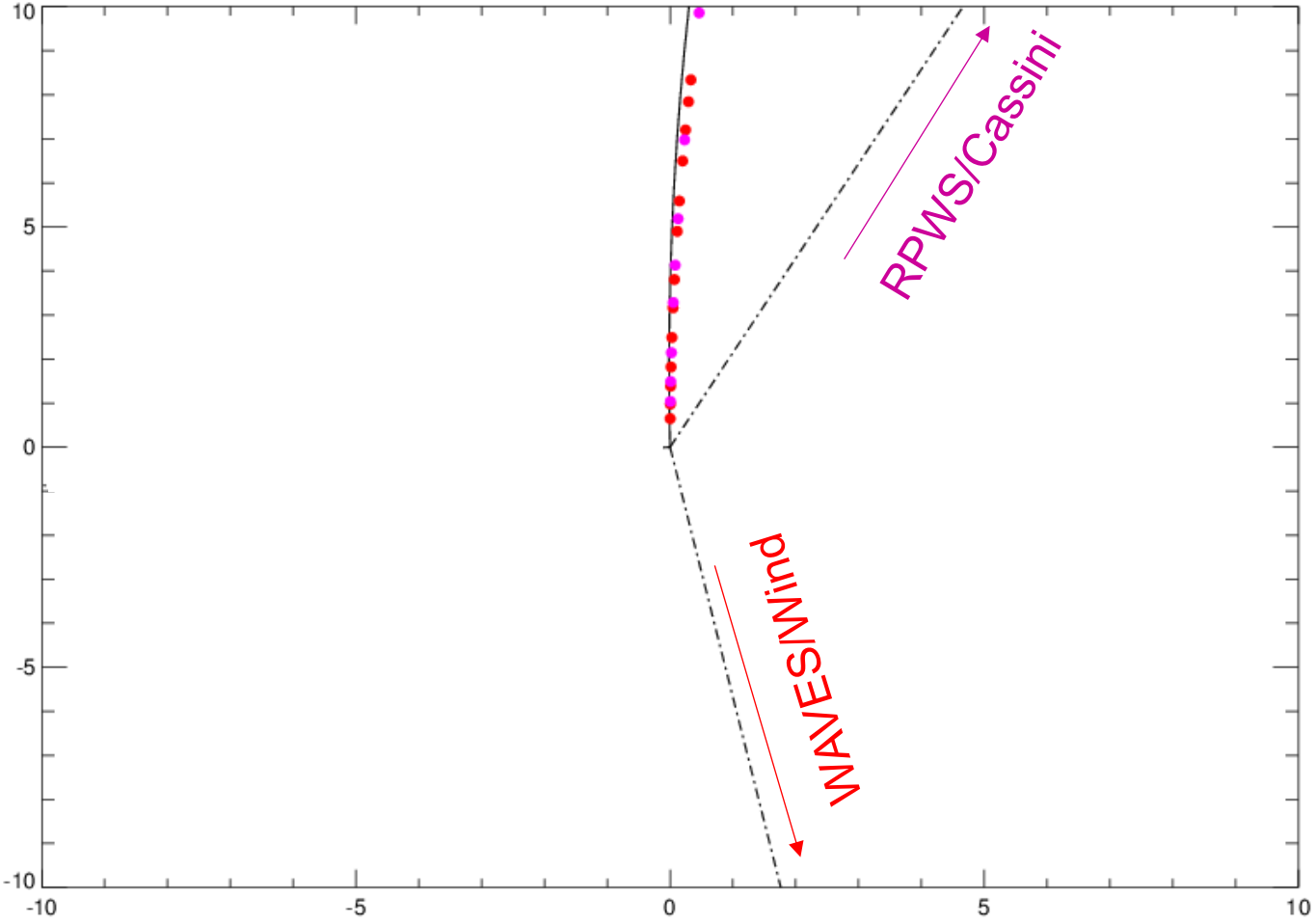
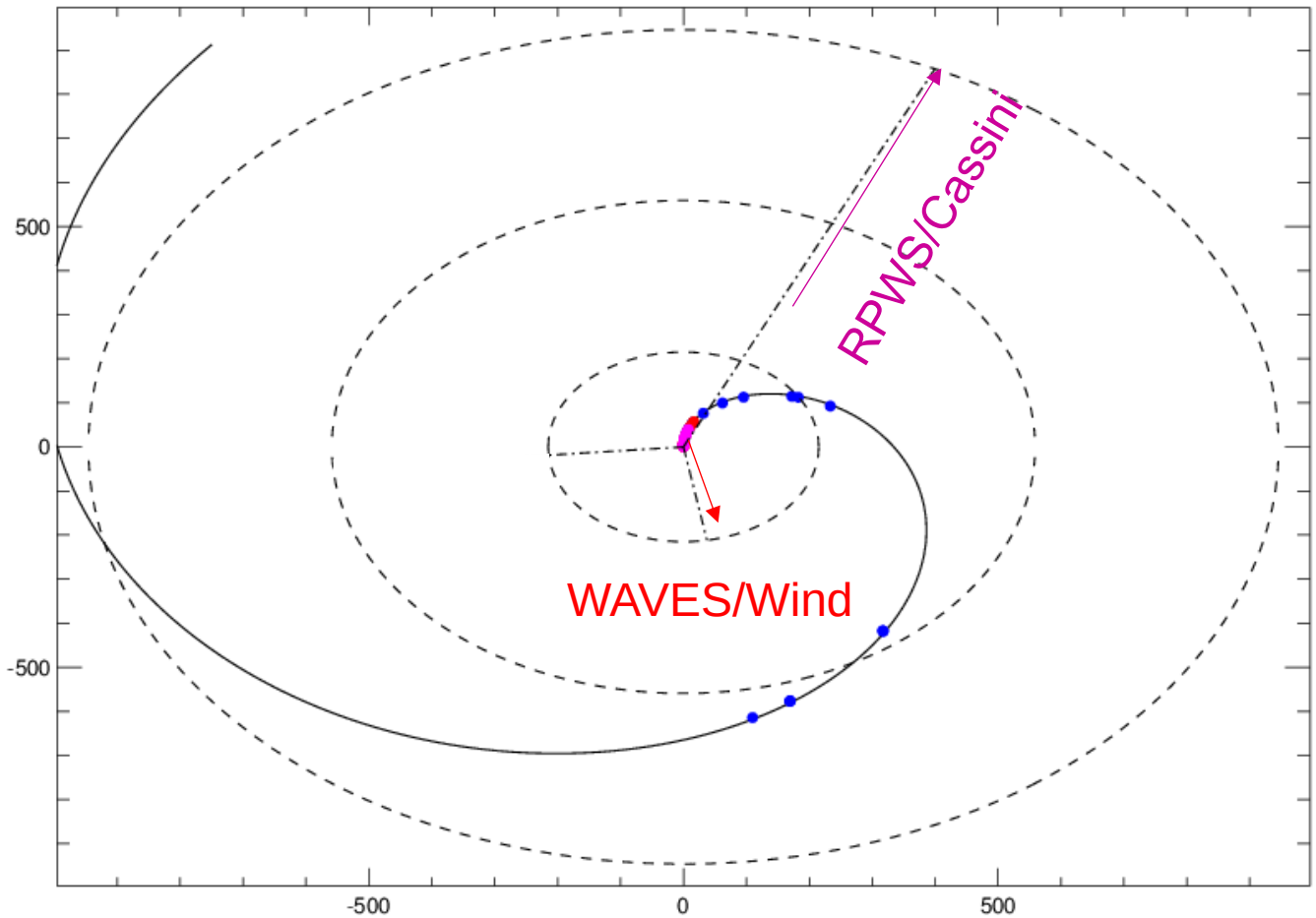
$$\phi = \left(\Omega / V_{sw} \right) . \left(r / 215 \right)$$

where Ω, V_{sw}, and r are, respectively, the solar angular rotation, solar wind speed and the distance to the Sun in Solar radii.

- We assume a Solar wind speed of 400 km/s and source location for each event.

- This equation includes the foot of the spiral on the Sun's surface, and gives the orientation of the spiral with respect to the Sun-Earth line.

Archimedes spiral: 10 solar radii



Archimedes spiral: Cassini's orbit