Diamagnetic cavities at Comet 67P and a proxy for the solar wind dynamic pressure

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Particle signatures of the diamagnetic cavity

(Nemeth et al., 2016)

Rosetta is a magnetically dirty spacecraft, **which makes the calibration of the magnetic field challenging**

→ Magnetic field components are shifted from their actual values

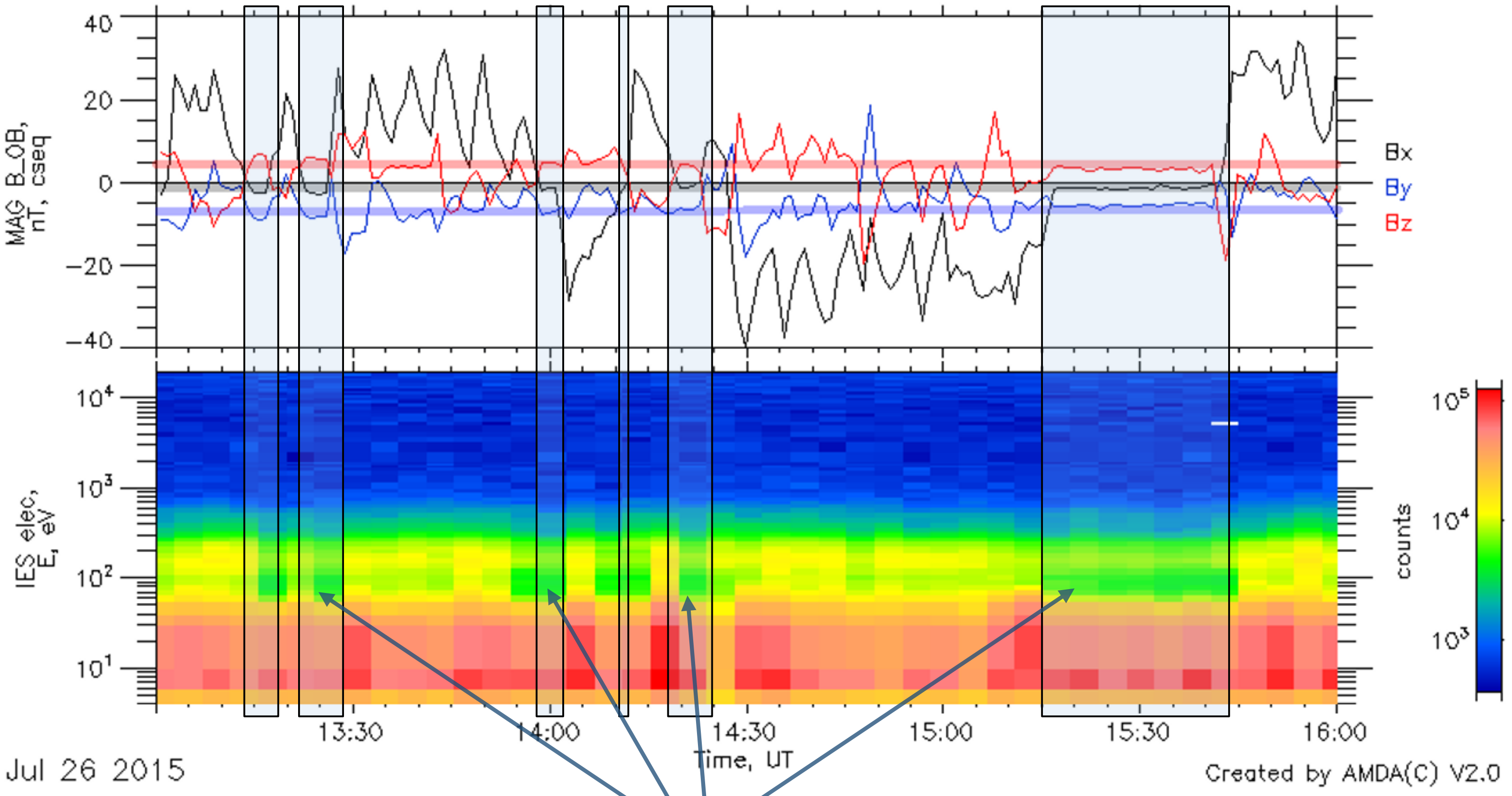
In case of cavity:

1) short **drop-outs in the 150-200 eV component** of the electron spectrum, longer 100 eV attenuation events

2) No or very **small fluctuations** around a constant value **for all three magnetic field components**

3) Close events have the same residual field values.

⇒ We found 127 cavity events in July and August of 2015 using this criteria



Drop-outs in some components of the electron spectrum

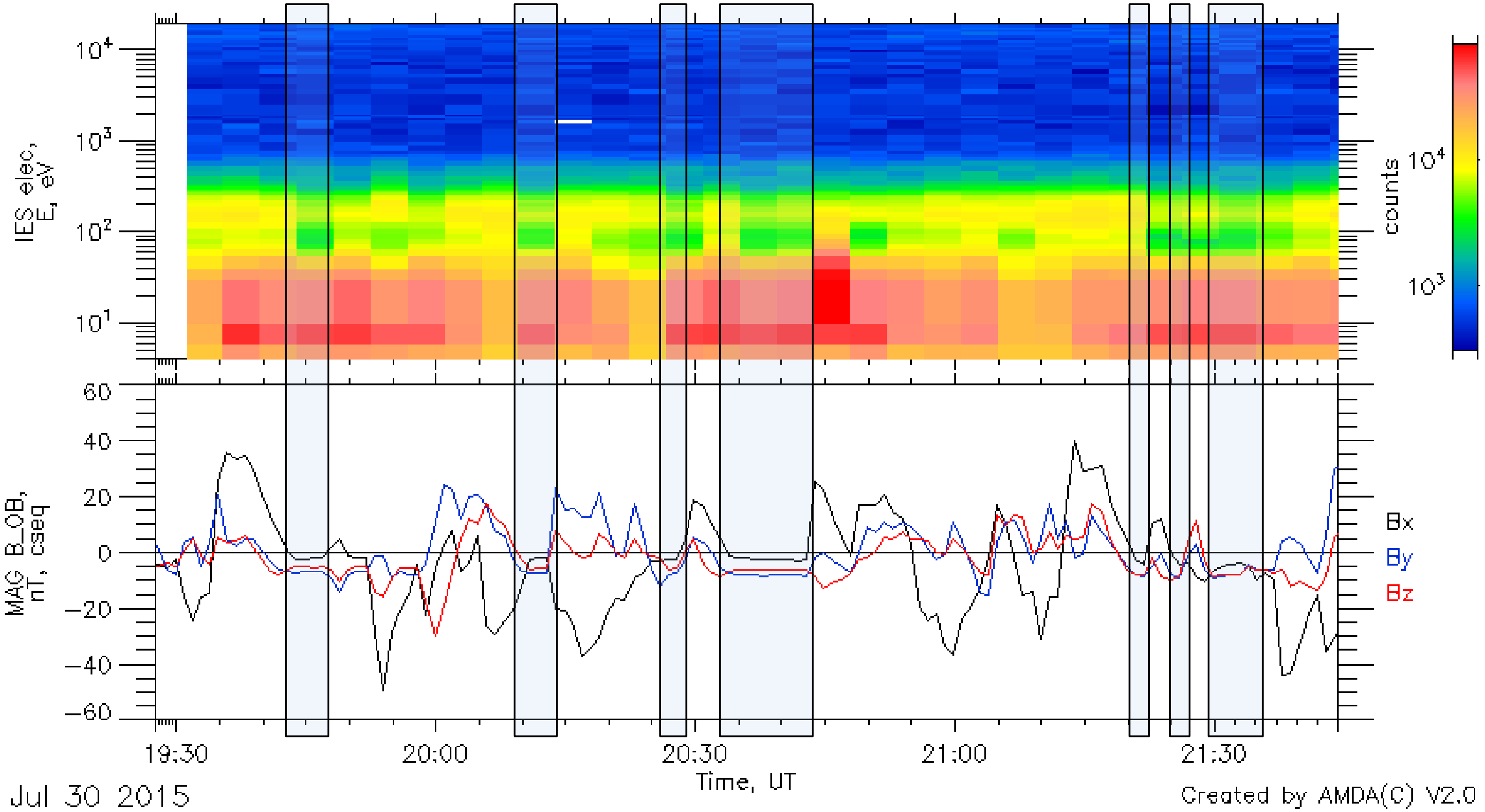
→ Indicates diamagnetic cavity

Electron spectrum

- **150-200 eV:** drops abruptly when the spacecraft enters the cavity
- **100 eV:** Drop-outs indicate that we are close to the cavity, but not necessarily inside it

→ **The electron population is tied to the magnetic field lines**

- They are forced out from the cavity together with the field lines

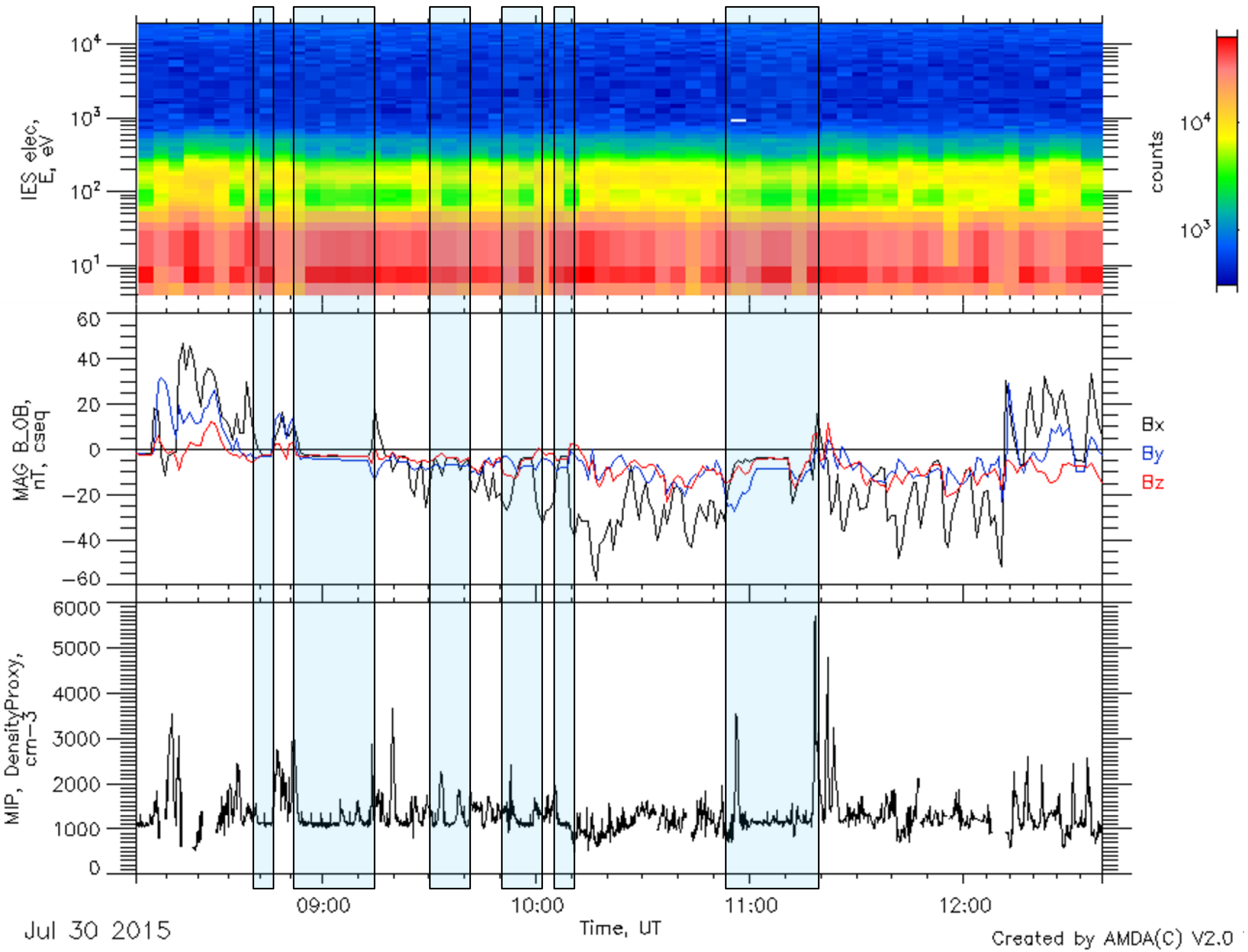


- **Probable source:** Young, 10-15 eV photoelectrons are picked up by the solar wind further away from the comet
- Migrating towards the comet they undergo a betatron-like acceleration
  ⟶ Can be accelerated by a factor of 10-15

Electron density

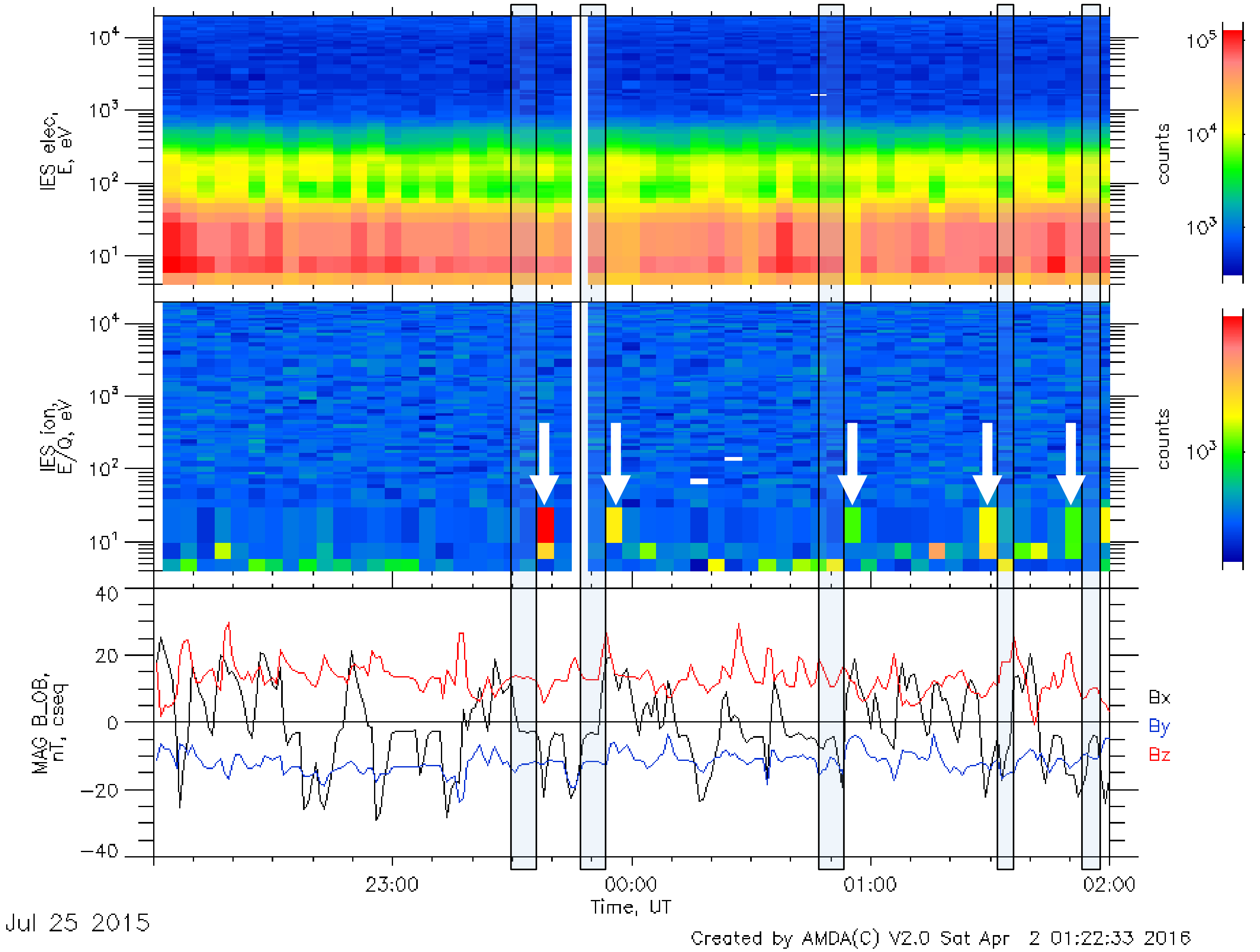
- **Inside the cavity:**
  - **Calm, low**
  - ~500 cm^{-3} – 1000 cm^{-3}
  - **Depends on: local neutral density**
    → Source of the ionization

- **At the cavity border:**
  - **Sudden, short increase**
  - ~2000 cm^{-3} – 6000 cm^{-3}
    → Electrons originated from the comet are grappled by the magnetic field lines at the cavity boundary



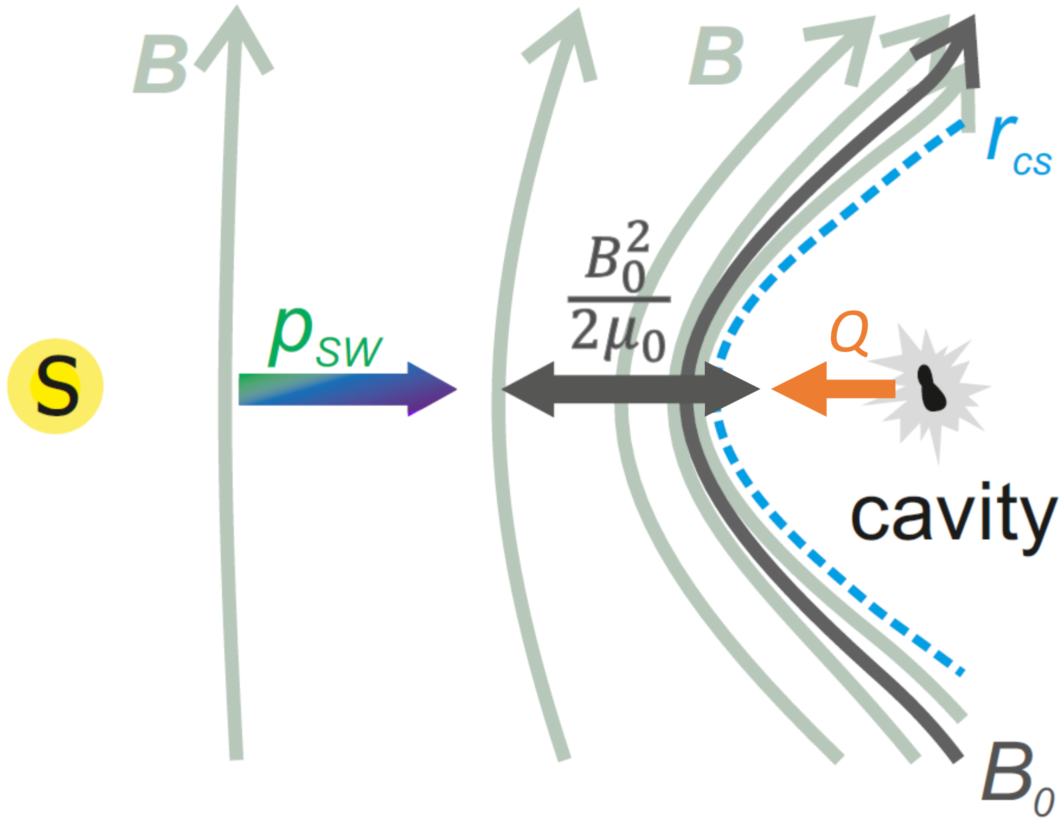
Ion spectrum

- Small increase of the counts at the cavity border
- Accompanied with a **negative spacecraft potential**
  - In more **dense plasmas** (eg. Cavity boundary)
  - **Accelerates cold ions into the range of the sensor**



(Nemeth et al., 2016)

Modeling the size of the diamagnetic cavity



$$p_{sw} = \frac{B_0^2}{2\mu_0}$$

$$r_{cs} = c\frac{Q^{\frac{3}{4}}}{B_0} = c\frac{Q^{\frac{3}{4}}}{\sqrt{2\mu_0 p_{sw}}}$$

(Cravens, 1986)

where $c = 7.08 \times 10^{-18}\ km\, nT\, s^{3/4}$

$\boldsymbol{p_{sw}}$ is the solar wind dynamic pressure

$\boldsymbol{B_0}$ is the maximum of the magnetic field in the pile-up region around the comet

$\boldsymbol{Q}$ is the outgassing rate

=> r_{cs} is the size of the diamagnetic cavity

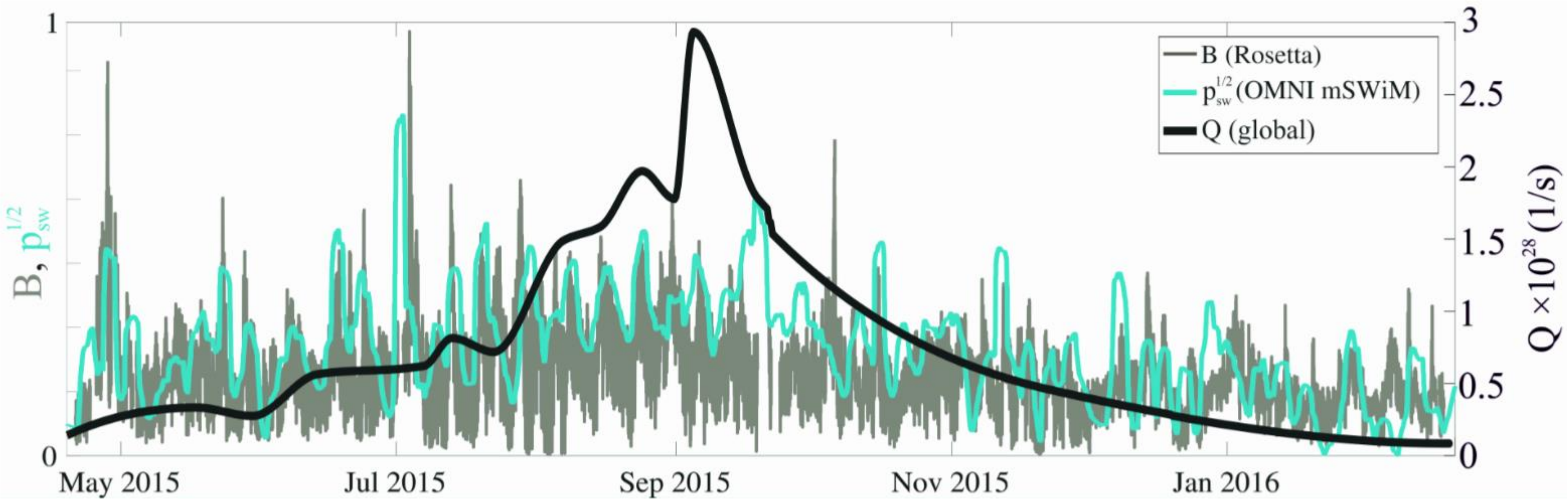
Model inputs

Q outgassing rate:

- Local (ROSINA density measurements)
- Global (Hansen et al., 2016, derived from the above, but rotational and latitudinal effects removed)

p_{sw} solar wind dynamic pressure: propagated from WIND, ACE, STEREO-A, OMNI mSWiM

B_0 maxima: Rosetta magnetic field measurements



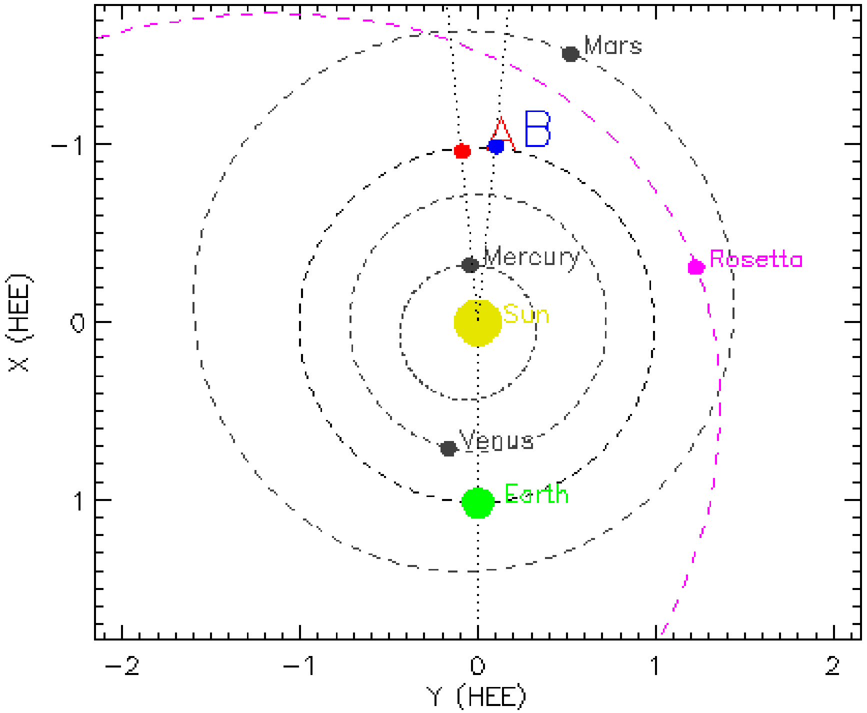
(Timar et al., MNRAS in press)

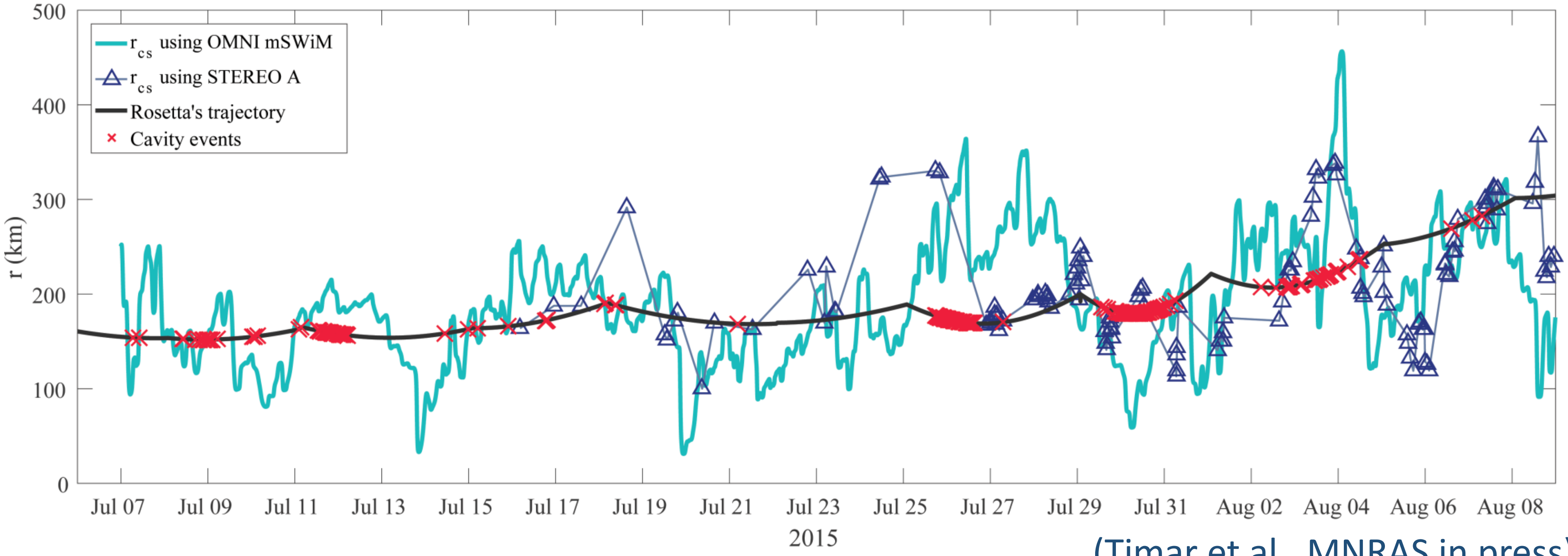
Methods

1. <u>Using propagated solar wind pressure:</u>

The boundary distance can be calculated using propagated solar wind dynamic pressure (p_{sw}) from various solar wind models:

$$r_{cs} = c\frac{Q^{\frac{3}{4}}}{\sqrt{2\mu_0 p_{sw}}}$$





(Timar et al., MNRAS in press)

Methods

2. Peak-selection (Madanian et al., 2016):

- The maximum of the magnetic field in the pile-up region (B_0) can be estimated by searching for local peaks in the Rosetta magnetic field data
- Calculate the boundary distance using: $r_{cs} = c\frac{Q^{\frac{3}{4}}}{B_0}$
- We will find cavity events where this maximum is relatively low (which means low solar wind pressure and extended cavity)

3. Scaled Rosetta magnetic field:

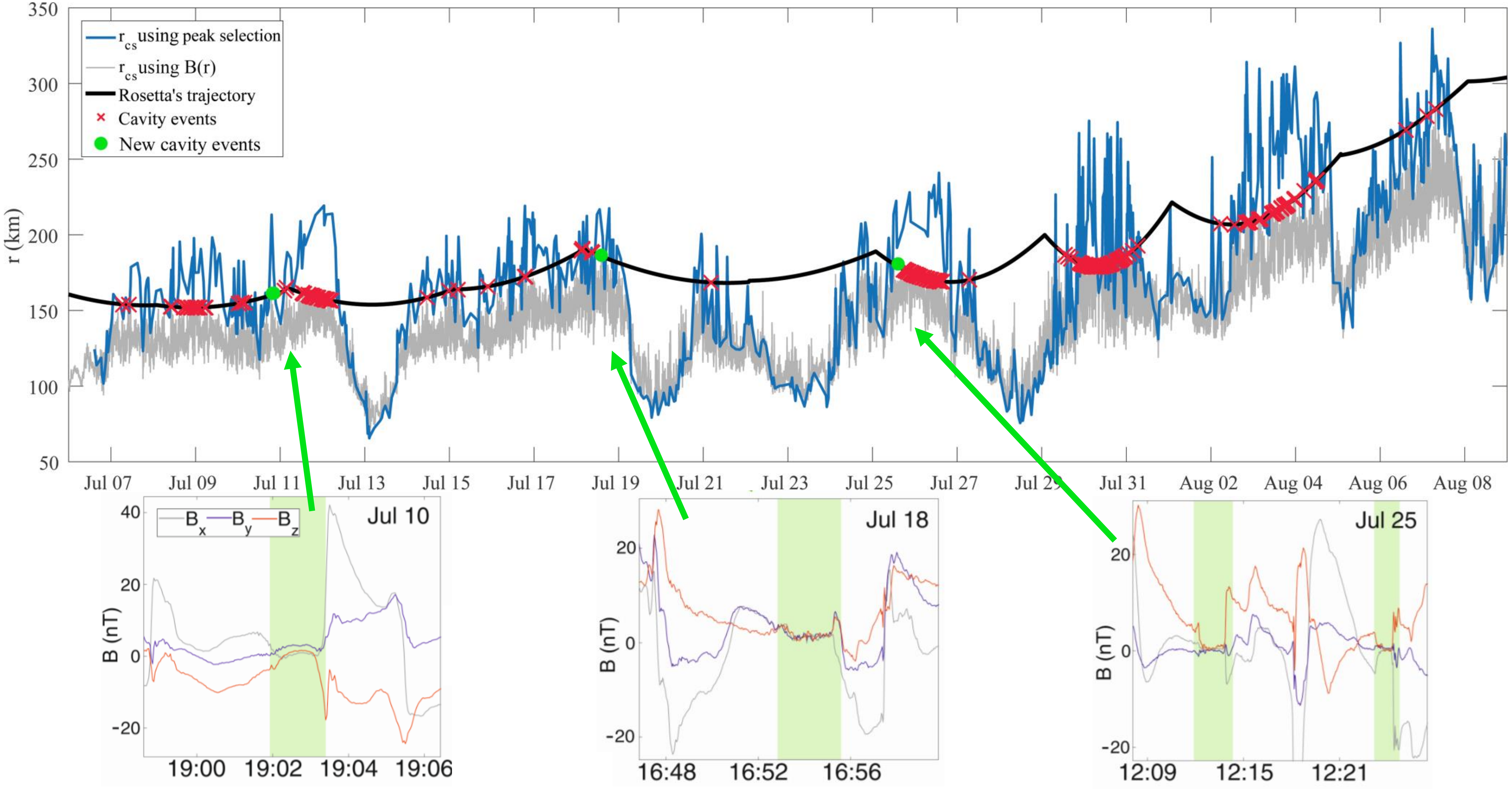
- The exact value of the boundary distance can be calculated from the spacecraft's position (r) and the magnetic field value (B) measured in that position, according to Cravens '86:

$$B(r) = B_0\sqrt{1 - \frac{r_{cs}^2}{r^2}} \longrightarrow r_{cs} = \left(\frac{B(r)^2}{c^2 Q^{3/2}} + \frac{1}{r^2}\right)^{-\frac{1}{2}}$$

- can only be applied outside the cavity, where B≠0, but can be used to test the accuracy of the other methods.

Methods

Peak-selection & Scaled B methods:



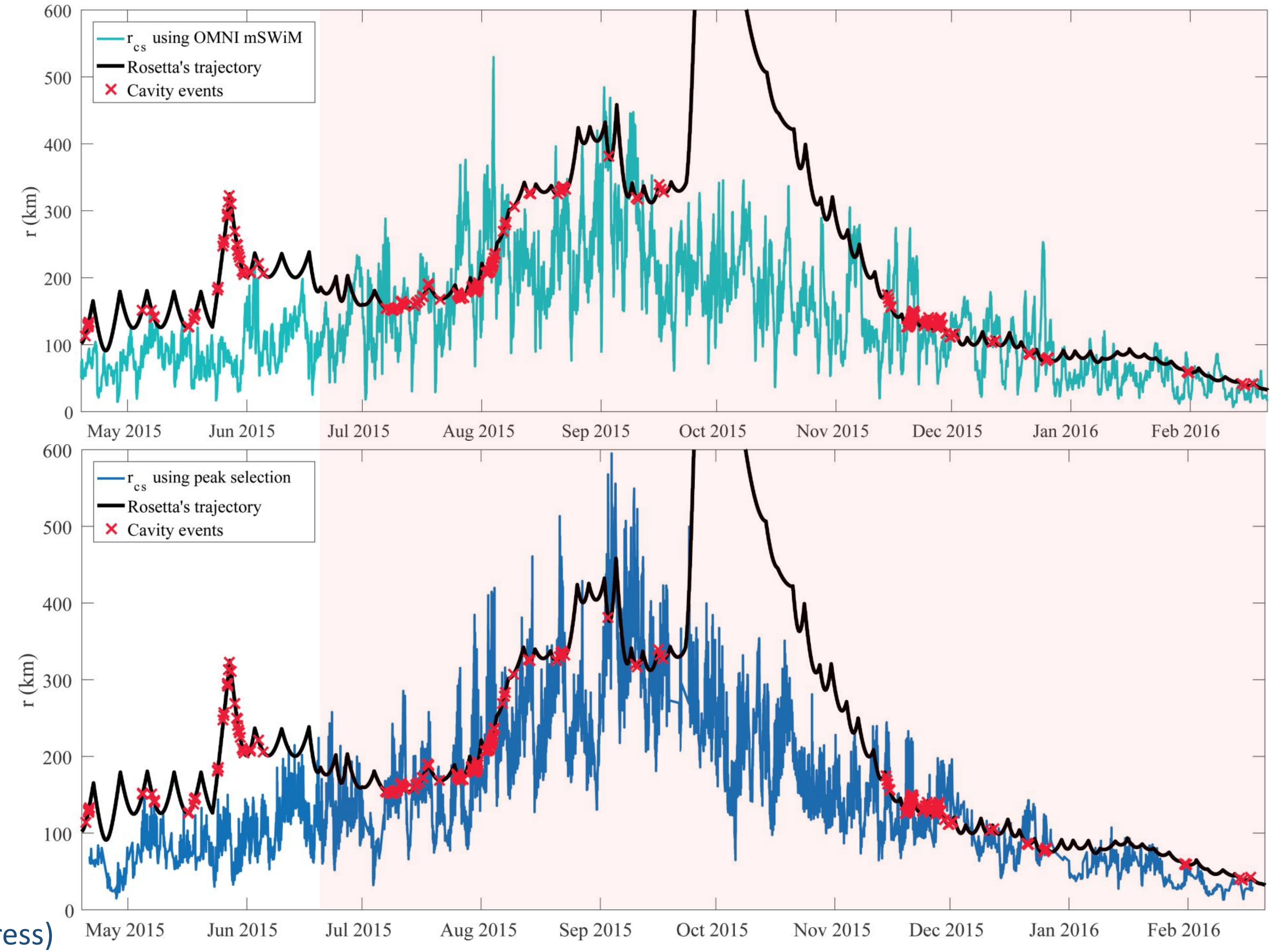
(Timar et al., MNRAS in press)

Global production rate

- The averaged, global outgassing rate drives the size of the cavity!
  - local density is not sufficient to explain the extent of the cavity
  - magnetic tension is probably able to suppress local density variations

Boundary dynamics

- The solar wind pressure is changing rapidly
  - causing fast changes in the boundary distance
  - explains the short duration of the cavity crossings
- Slowly changing cometary activity
  - gradual increase or decrease of the r_{cs} evolving through multiple events

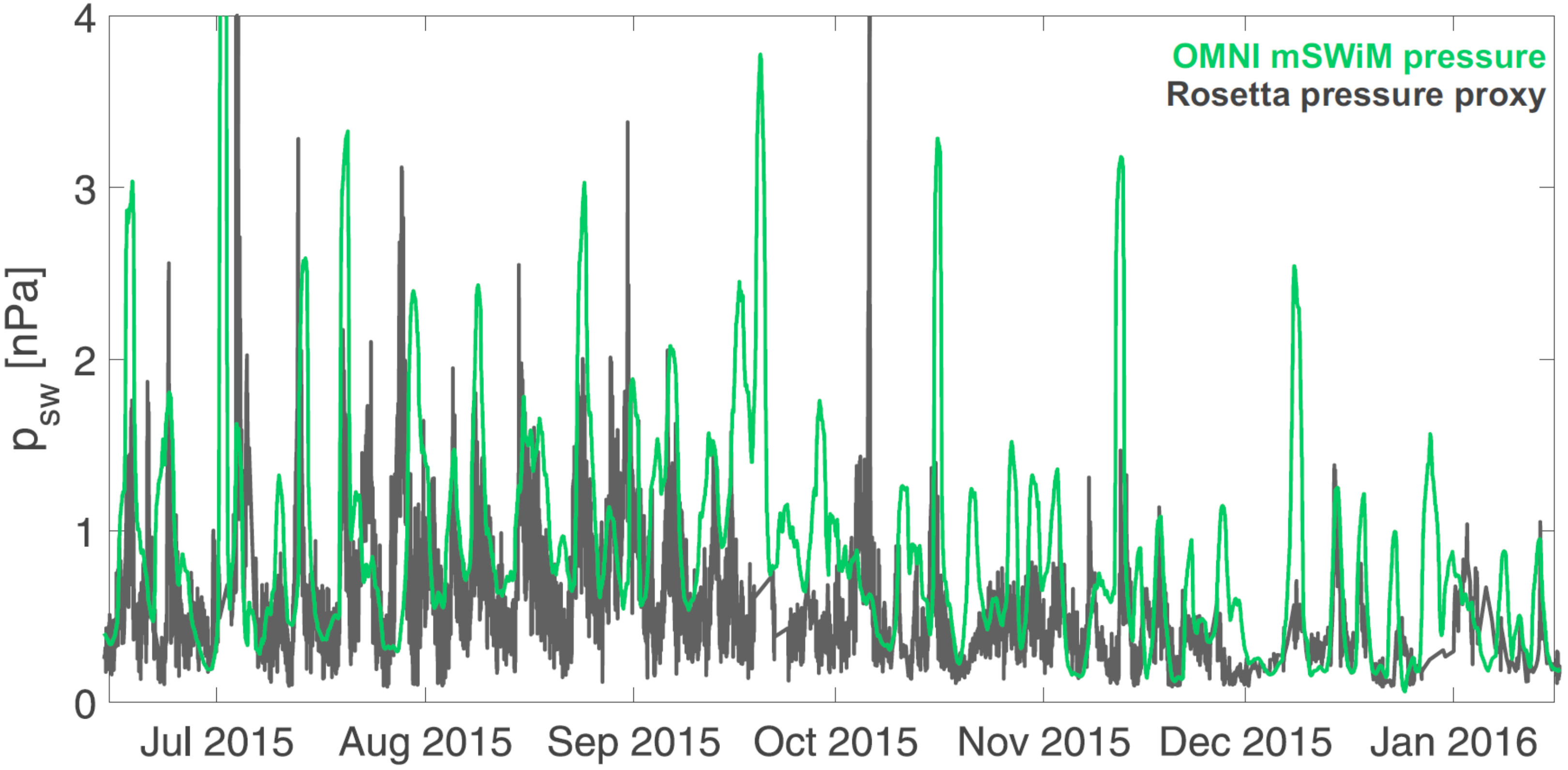


(Timar et al., MNRAS in press)

Estimating solar wind pressure from RPC MAG measurements

$$p_{sw} = \frac{B_0^2}{2\mu_0}$$

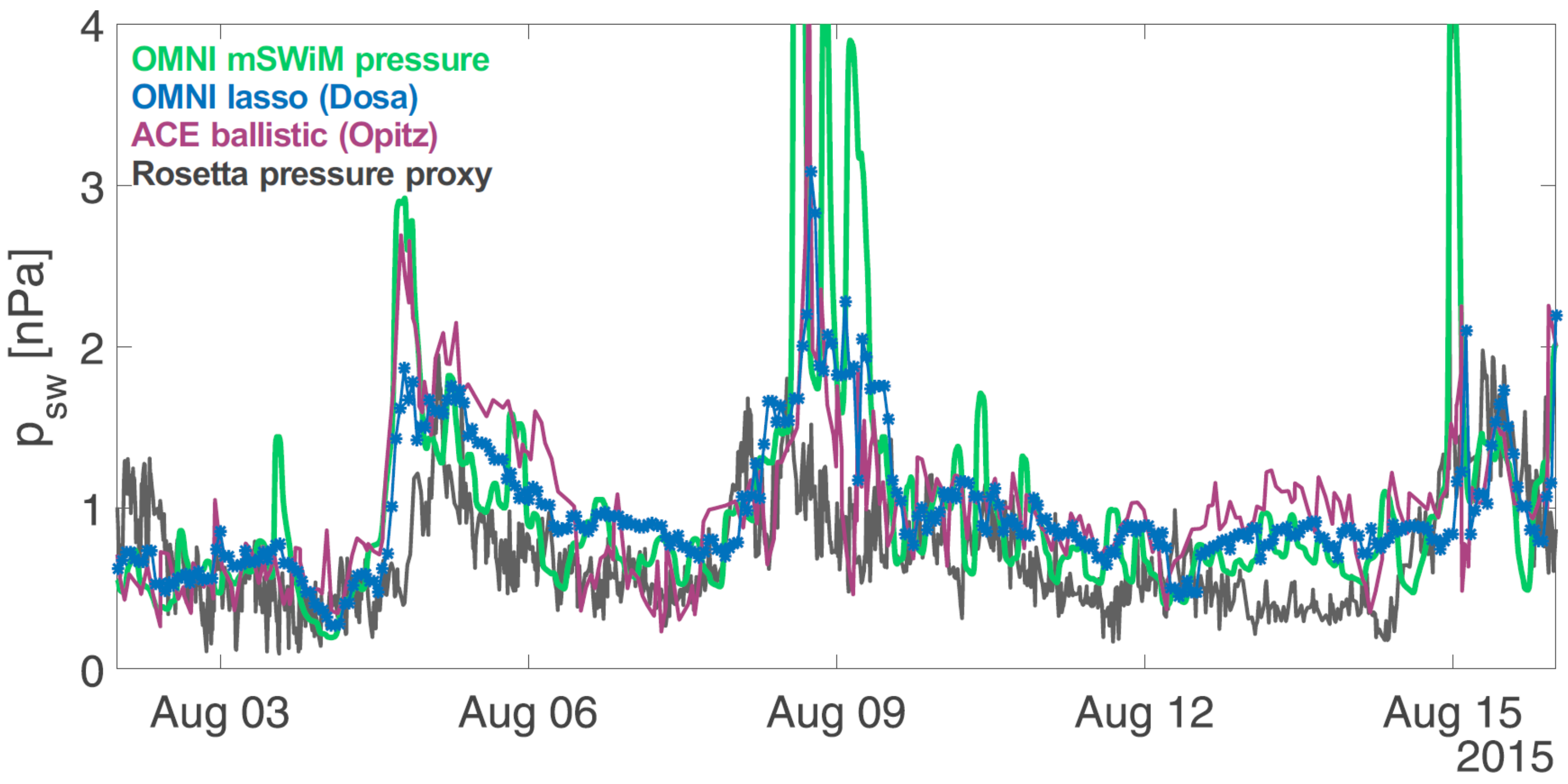
- We've seen that B_0 can be approximated from Rosetta magnetic field measurements, when we are close to the cavity boundary
- $B(r) = B_0\sqrt{1 - \frac{r_{cs}^2}{r^2}}$
- This relationship holds for several months spanning from June 2015 to January 2016



(Timar et al. EPSC2017 poster, paper in prep.)

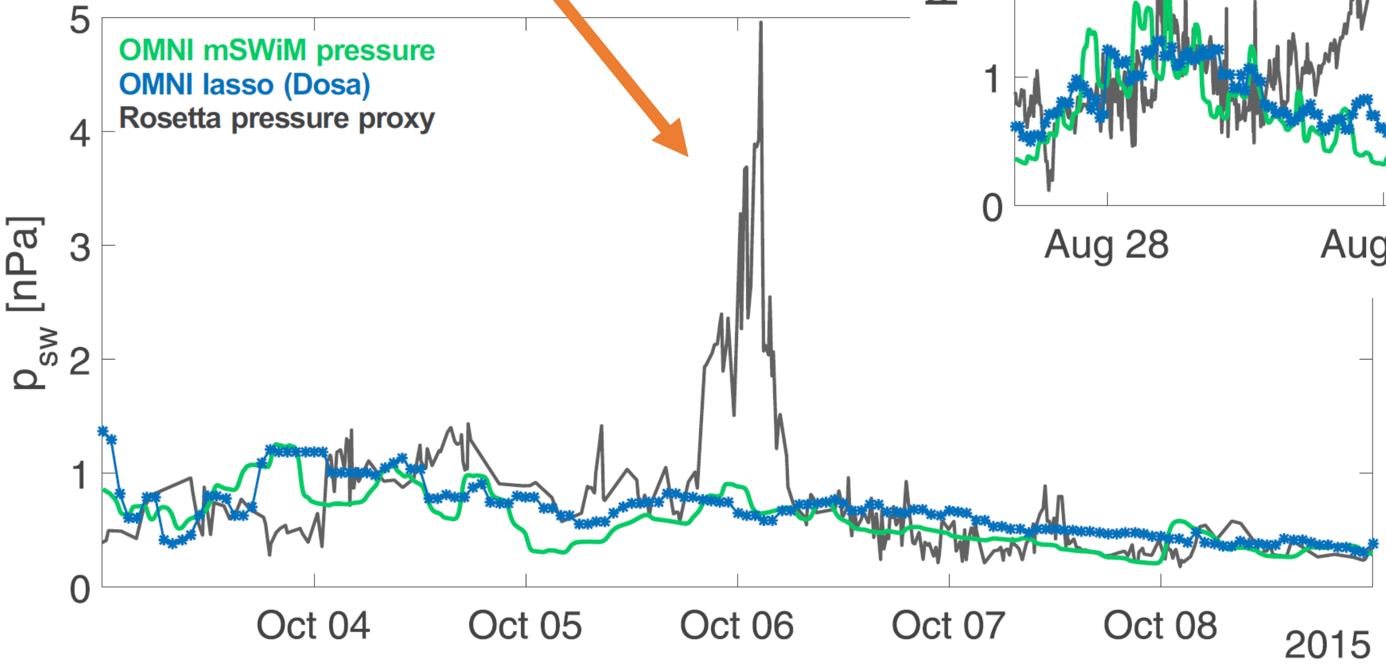
Rosetta pressure proxy

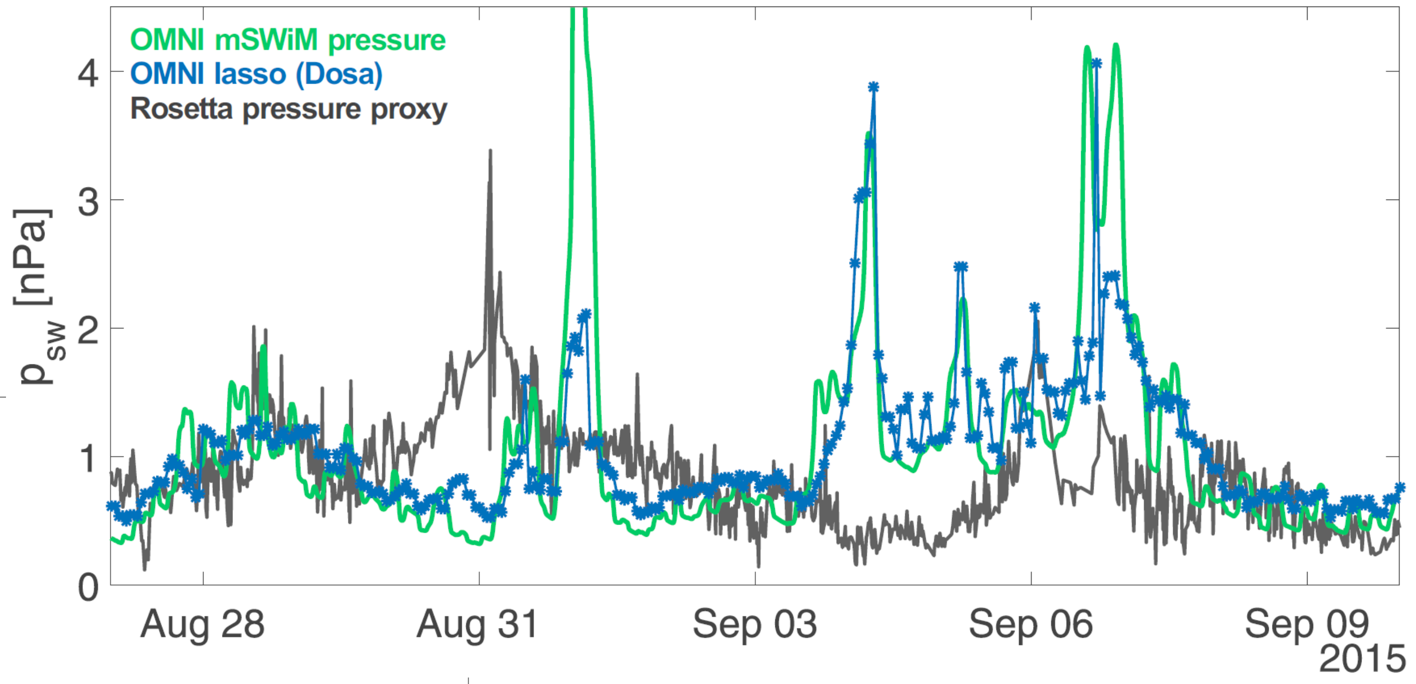
- The **results were compared to OMNI and ACE data propagated using different methods**; the curves are very similar, they agree with our method as far as the accuracy of the propagation based predictions allow



Rosetta pressure proxy

CME at 67P





(Timar et al. EPSC2017 poster, paper in prep.)

Conclusions

- **Drop outs in the 100 eV and 150-200 eV component** of the electron spectrum near the cavity
    - Particle based **method to detect longer cavity events**
- **Increased counts in the ion spectrum and increased electron density** at the cavity boundary
- We **can predict the size of a global, connected diamagnetic cavity** (except before June 2015)
    - The **global outgassing rate** defines the position of the boundary, local pressure variations are suppressed
    - The fast alternation of magnetized and field-free regions can be explained by the rapid changes in the solar wind pressure
    - Using this method we can identify previously undiscovered cavity events
- **From the Rosetta magnetic field measurements** deep inside the cometary magnetosphere **we can deduce the pressure of the solar wind** around the comet