

Revisiting the Strongest Martian X-Ray Halo Observed by XMM-Newton on 2003 November 19–21

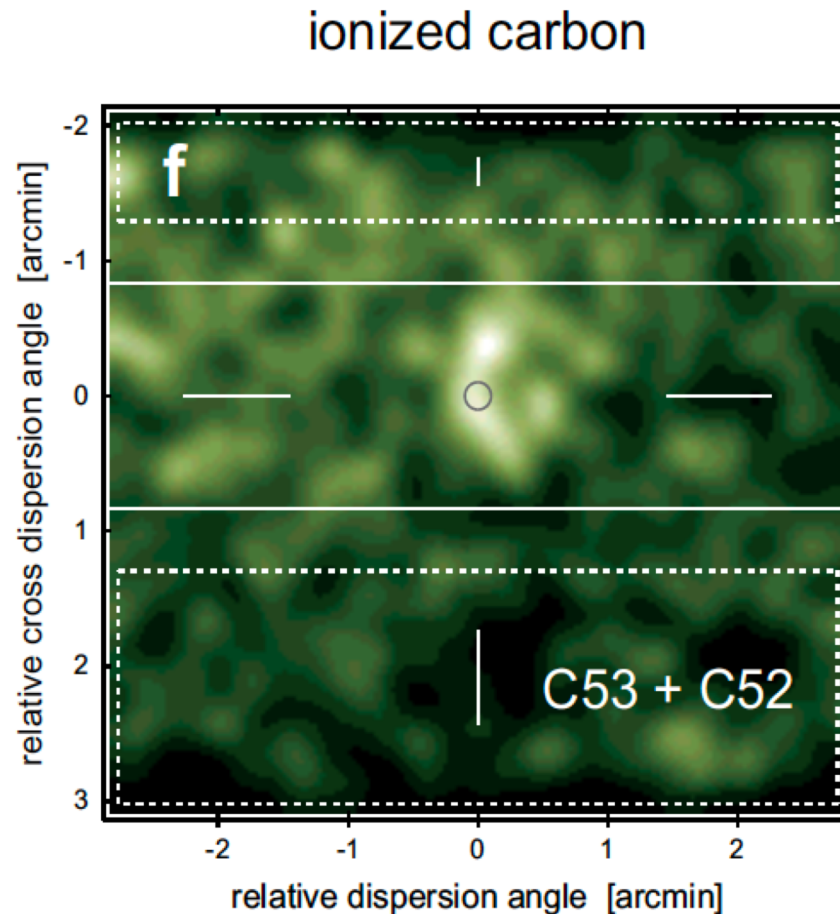
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Martian X-ray halo:

X-ray emission which is produced by charge exchange interactions between neutral particles in the Martian exosphere and highly charged heavy ions in the solar wind [Dennerl et al. 2006]



[Dennerl et al. 2006]

Observation of the Martian X-ray halo

- Chandra observation on 2001 July 4 at Solar maximum:

The Martian X-ray halo was first detected and found to be extended to 3 Mars radii with a total luminosity of 0.5 ± 0.2 MW in the energy range 0.5–1.2 keV. [Dennerl 2002]

- XMM-Newton observation on 2003 November 19–21 at Solar maximum:

The Martian X-ray halo extended up to 8 Mars radii with a luminosity of 12.8 ± 1.4 MW in the energy range 0.365–0.88 keV. [Dennerl et al. 2006]

- Suzaku observation on 2008 April 3–5 at Solar minimum:

No significant X-ray halo emission was detected. [Ishikawa et al. 2011]

Therefore, the Martian X-ray halo observed by XMM-Newton is the strongest ever observed.

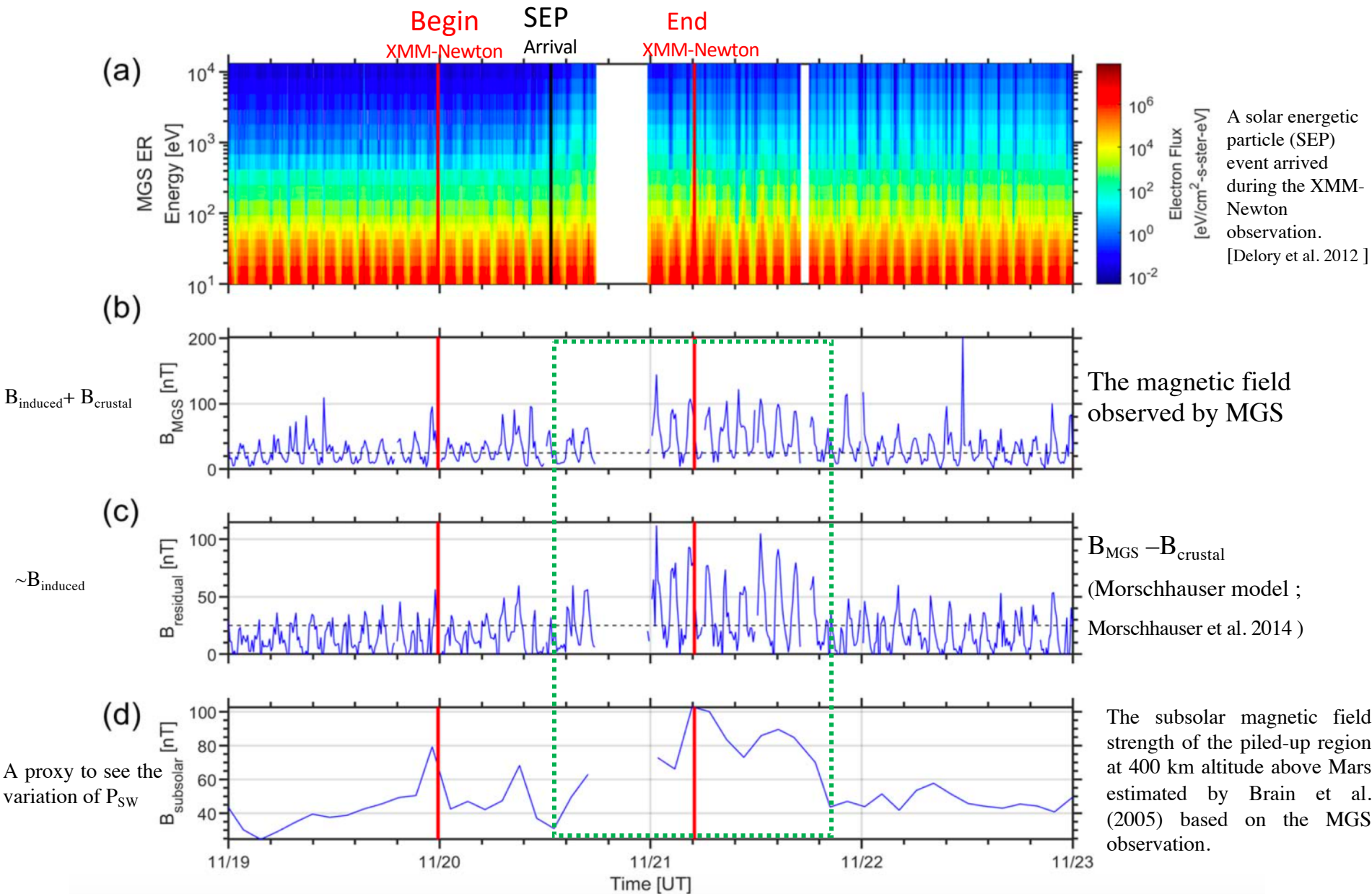
The drivers of the strongest Martian X-ray halo still remain unclear

- The flux of the Martian X-ray halo was highly variable, but the variability was different from that of the solar X-ray flux, suggesting that this event may be subject to unusual solar activity. [Dennerl et al. 2006; Dennerl 2006]
- The simulated Martian X-ray emission (~ 0.23 MW) based on the usual solar wind parameters was much lower than that observed by XMM-Newton (~ 12.8 MW). [Koutroumpa et al. 2012]
- The sun was extremely active: several coronal mass ejections (CMEs) and X-class flares were erupted before and during the XMM-Newton observation. [Grechnev et al. 2013, 2014]
- Direct observational evidence of the impact of unusual solar wind is still lack, which is mainly because there was no solar wind monitor available in the upstream of Mars.

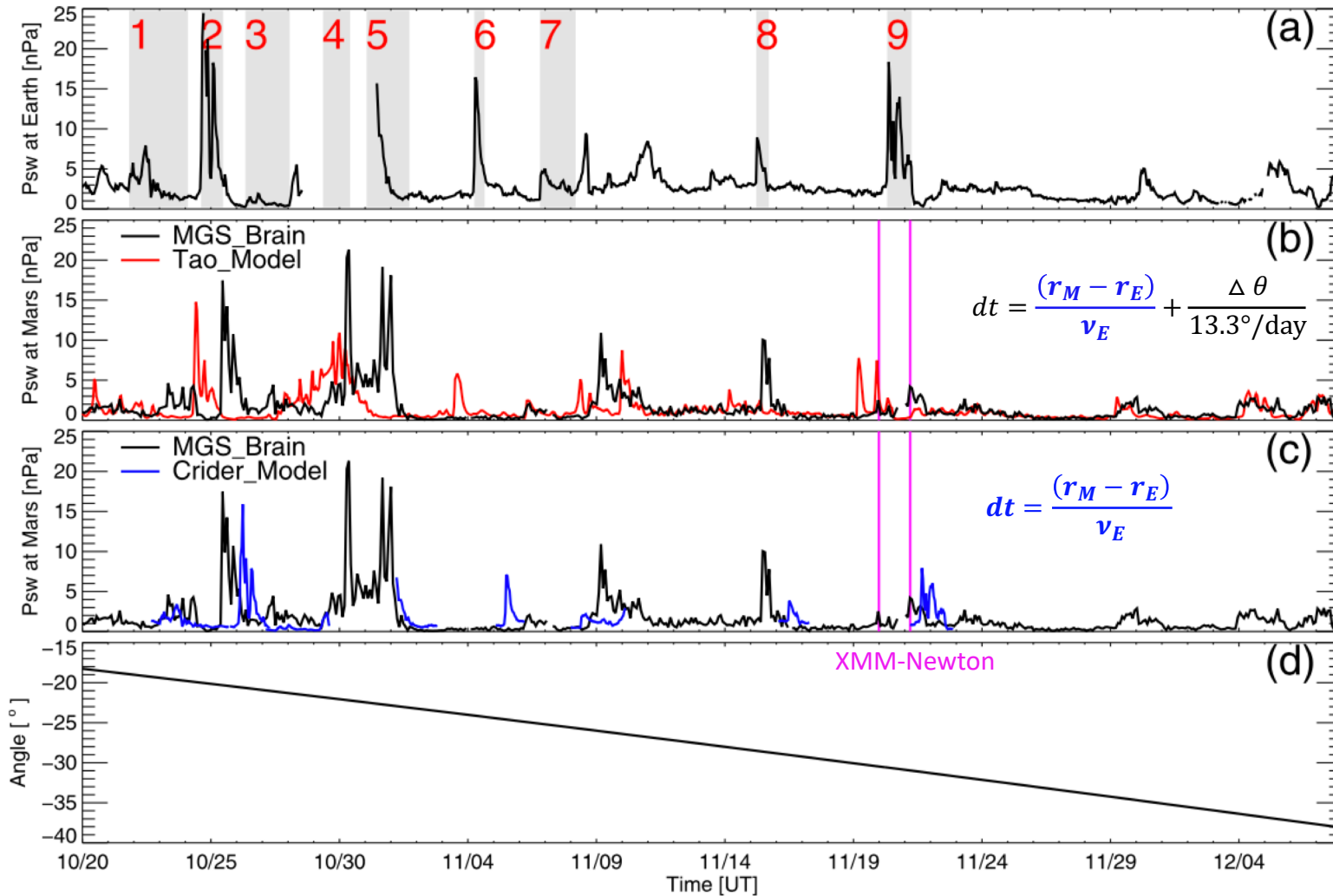
Based on the Martian magnetic field provided by Mars Global Surveyor (MGS), the unambiguous evidence for the impact of unusual solar wind with enhanced dynamic pressure during XMM-Newton observation was found. Details will be given in the following slices.

unambiguous evidence for the impact of unusual solar wind:

The whole induced magnetosphere was highly compressed.



The solar wind dynamic pressure (P_{sw}) at Mars estimated from MGS observation and that predicted by different solar wind propagation models:



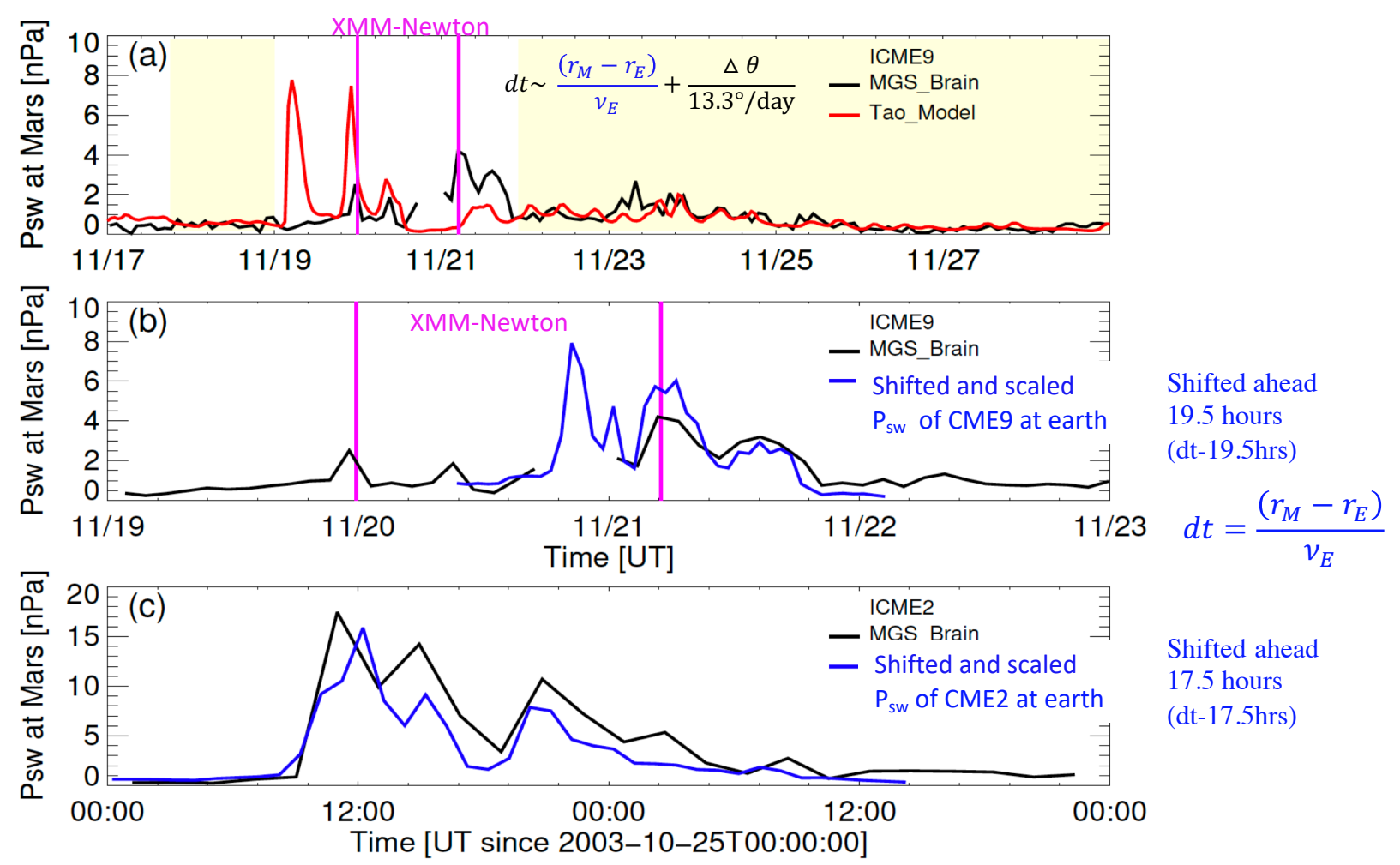
Tao-model is applicable for the usual solar wind, while Crider model is more suitable for the impulsive events, such as CME.

The predicted arrival time (blue) of ICME2 and ICME9 was later than that observed (black)

Panel (a): the P_{sw} at Earth from OMNI. The light grey filled rectangles label the ICMEs at Earth identified by Jian et al. (2006). Dark curves in panels (b)–(c): the P_{sw} estimated from the MGS observation ($\sim \frac{B_{sub\text{solar}}^2}{2\mu_0}$). Red curves in panel (b): the P_{sw} predicted by the Tao model. Blue curves in panel (c): the P_{sw} predicted by the Crider model. Panel (d): the Earth–Sun–Mars angle.

The unusual solar wind at Mars is probably related to the ICME observed at earth:

The variability of the shifted and scaled P_{sw} of ICME9 agree well with that of the P_{sw} estimated from MGS (panel b).



Summary and discussion

- Here, we examined the Mars Global Surveyor (MGS) observations and found unambiguous evidence of unusual solar wind impact during that XMM-Newton observation: the whole induced magnetosphere of Mars was highly compressed.
- The observational evidence suggests that the ICME observed at Earth on 2003 November 20 is the possible origin of the unusual solar wind with enhanced dynamic pressure at Mars. However, the possibility of other ICMEs or stream interaction regions (SIRs) could not be fully excluded.
- A SEP event also impacted Mars during the XMM-Newton observation and lasted for several days. Whether the SEP could also influence the production of the X-ray emission from Mars or not is worth investigating in future.

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