AUTHORS: N. Meyer-Vernet [1] - A. Zaslavsky [1] - S. Belheouane [1] - K. Issautier [1] - G. Le Chat [1] - M. Maksimovic [1]
F. Pantellini [1] - I. Zouganelis [2]

Sun, Heliosphere and Magnetospheres

Laboratory contribution

Detection of interplanetary nanodust with STEREO

Détection de nanopoussières interplanétaires avec les sondes STEREO

[1] LESIA-Observatoire de Paris, CNRS, UPMC Université Paris 06, Université Paris-Diderot.
[2] I2LPP, UPMC, Ecole Polytechnique, CNRS, Université Paris 11e.

Abstract

The S/WAVES instrument onboard the STEREO spacecraft in orbit at 1 AU from the Sun has detected a large flux of dust particles of nanometer size. This serendipitous discovery was made possible by the high speed of nanodust particles, which reach nearly the solar wind speed. When they impact the spacecraft, nanoparticles release ionized material, which induces large electric pulses on the antenna. In this way, the radio receiver serves as a sensitive nanodust detector.

Résumé

L'expérience "ondes" à bord des sondes Stereo en orbite à 1 AU du Soleil a détecté un flux important de nano poussières. Cette découverte inattendue a été possible grâce à la grande vitesse de ces particules qui atteint presque la vitesse du vent solaire. Des impacts à cette vitesse sur une sonde spatiale produisent du plasma dont les charges modifient transitoirement le potentiel électrique des antennes. Le récepteur radio devient ainsi un détecteur de nanopoussières.

The solar system contains bodies and dust particles of mass extending over more than 35 orders of magnitude, from asteroids to sub-micron dust grains (Fig. 1). Nanoparticles lie near the low end of the mass distribution, at the frontier between macroscopic objects and atomic structures; their small size gives them peculiar properties and a privileged role for surface interactions. Since nanoparticles lie outside the calibration range of conventional dust detectors in space, it is not surprising that their first in situ detection in the solar wind [1] was performed serendipitously by a wave instrument, which had been designed to study solar radio emissions.

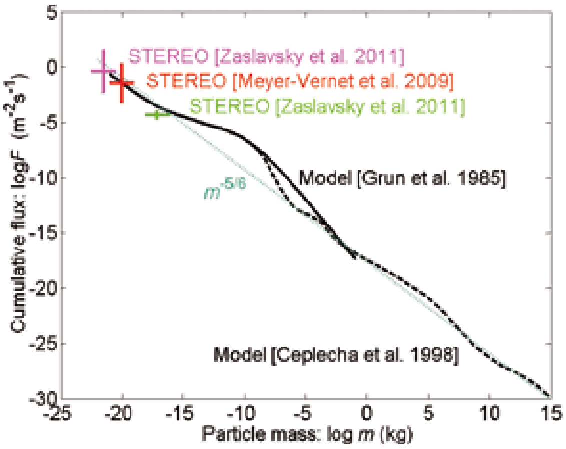
A similar story happened nearly thirty years ago, when the first in situ detection of micro dust in Saturn rings [2] was performed by a wave instrument aboard the spacecraft Voyager, which had been designed to study planetary radio emissions. In both cases - the solar wind and Saturn rings - the radio instrument served as a dust detector, in the absence of a dedicated dust instrument.

Interplanetary nanoparticles are thought to be produced in the inner Solar System, mainly by collisions between larger particles. They are charged by photoelectron emission due to solar radiation, and then picked-up by the magnetized solar wind and accelerated to about the solar wind speed [3].

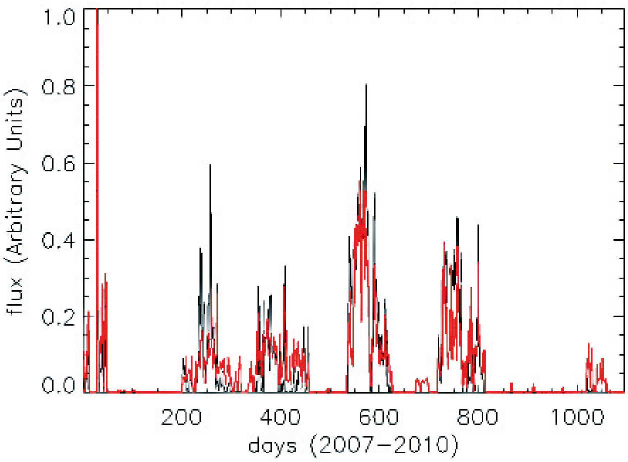
This is so because their electric charge is proportional to their size, making their charge-to-mass ratio increase steeply with decreasing size, so that the Lorenz force governs their dynamics and they move roughly at the speed of solar wind ions. Their high-velocity impacts on a spacecraft produce large craters.

The resulting material is vaporized and ionized, yielding an expanding plasma cloud whose electric field destabilizes the photoelectrons surrounding the antenna [4]. This produces a transient pulse of potential and a steep power spectrum, which are detected by the radio receiver [1][5].

[Fig. 1]



[Fig. 2]



[Fig. 1] - Cumulative flux of interplanetary dust and bodies at 1 AU. The dust measurements on STEREO from [1] and [5] are superimposed on the models for dust from Grün et al. (1985) (continuous line), small bodies from Ceplecha et al. (1998) (dashed), and collisional equilibrium $\propto m^{-5/6}$ (dotted). Reproduced from [6].

[Fig. 2] - Nano-dust flux (day-averages) given by two independent sub-systems of the instrument S/WAVES on the spacecraft STEREO A in 2007-2010. Data from the time-domain sampler (in red) and the low-frequency receiver (in black) show a similar intermittent flux. Adapted from [5].

This has enabled us to deduce the flux of interplanetary nanodust [1] [5]. The detected flux is highly variable (Fig. 2), being made of streams whose flux can be as high as several tens per square meter per second, for particles of a few nanometers in size or larger. The average measured flux lies close to the extrapolation towards small masses of the mean interplanetary dust flux model (Fig. 1).

In addition to nanodust, the STEREO/WAVES instrument has also detected a much smaller flux of submicron interstellar dust, whose variation with the spacecraft solar longitude reveals the interstellar dust velocity direction [5][7]. The main advantage of radio and plasma wave instruments over traditional particle detectors for in situ measurements in space is their large detection cross-section, which is much greater than the physical cross-section of the electric antennas [6]. These instruments have measured in situ the electron density and temperature via thermal noise spectroscopy on a number of spacecraft in various space environments, as well as microdust.

The recent detections of nanodust by wave instruments aboard STEREO in the solar wind, and aboard Cassini near Jupiter [8], broaden the perspectives for future missions. In particular, the FIELDS instrument onboard Solar Probe Plus, due to explore the solar corona as close as 9.5 solar radii, will be able to measure nanodust, as a by-product of dedicated plasma measurements.

References

[1] Meyer-Vernet N., et al. (2009), Dust Detection by the Wave Instrument on STEREO: Nanoparticles Picked up by the Solar Wind?, *Solar Physics,* **256**, 463.

[2] Aubier M.G., Meyer-Vernet N., Pedersen B.M., (1983), Shot Noise from Grain and Particle Impacts in Saturn's Ring Plane, *Geophys. Res. Lett,*. **10**, 5.

[3] Mann I., et al. (2010), Dust in the interplanetary medium, *Plasma Phys. Control. Fusion,* **52**, 124012.

[4] Pantellini F., et al. (2012), *Ann. Geophys.,* submitted.

[5] Zaslavsky A., et al. (2012), *J. Geophys. Res,* submitted.

[6] Meyer-Vernet N., Zaslavsky A., (2012), in "Nanodust in the solar system: discoveries and interpretations", Mann I., et al. (2012), *Eds., Springer,* in press.

[7] Belheouane S., *et al.* (2012), *Solar Phys.,* in press.

[8] Meyer-Vernet N., *et al.* (2009), Detecting nanoparticles at radio frequencies: Jovian dust stream impacts on Cassini/RPWS, *Geophys. Res. Lett.,* **36**, L03103.