TRANSPARENCY OF THE INNER HELIOSPHERE TO THE INTERSTELLAR DUST STREAM DURING SOLAR MAXIMUM: ULYSSES MEASUREMENTS AND MODELLING. M. Landgraf, *European Space Agency, ESOC, Robert-Bosch-Straße 5, 64293 Darmstadt, Germany, (Markus.Landgraf@esa.int)*, H. Krüger, N. Altobelli, E. Grün, *Max-Planck-Institut für Kernphysik, Postfach 103980, 69029 Heidelberg, Germany*.

1 Introduction

As our Sun moves through its galactic environment (Frisch, 2000) only a fraction of the surrounding material reaches the space between the planets. The reason is the filtering effect of the solar wind plasma that is expelled from the Sun. This plasma, consisting of charged particles immersed in a magnetic field (Parker, 1958), deflects the ionised component of the local galactic gas (Holzer, 1989), a large part of the energetic particle spectrum (Kota & Jokipii, 1995), and galactic interstellar dust grains below a certain size (Linde & Gombosi, 2000). Larger dust grains (Grün et al., 1993; Baggaley, 2000) as well as neutral gas atoms (Witte et al., 1993) penetrate the heliopause and the solar wind plasma and can thus be detected by spacecraft in interplanetary space. On long time scales the accretion of cosmic dust changes the chemical composition of planetary surfaces (Flynn, 1991) or atmospheres (McNeil et al., 1996; Moses et al., 2000).

Galactic dust can also be captured into closed orbits around the Sun (Jackson, 2001). The amount of galactic dust in interplanetary space depends strongly on the efficiency of the solar wind filtering. Here we report the observation of the variation of the galactic interstellar dust measured by the dust instrument on board the Ulysses spacecraft. An increasing number of interstellar grains has been detected since beginning of 2000. According to our model calculations the increase of interstellar dust in the solar system marks the the beginning of large-scale disturbances of the solar wind magnetic field polarity during solar maximum. The configuration of the solar wind magnetic field will cause the number of interstellar dust grains in the solar system to steadily increase until the next solar maximum.

The Ulysses spacecraft circles the Sun on an elliptical orbit that is inclined at 79° with respect to the ecliptic plane. Its closest point to the Sun is at $1.3\ AU$, and the furthest point is at $5.4\ AU$. Ulysses carries an impact ionisation dust detector (Grün et al., 1992a,b), which measures the plasma cloud released on impact of cosmic dust grains onto its sensitive target. The plasma cloud is separated by an electrostatic field, and the charge signals are measured at the electrodes. A detection is confirmed by multiple coincidence of three independent charge signals. Masses and impact speeds of the impactors are determined from the measured amplitudes and rise times of the impact charge signals (Grün et al., 1995). In addition to the mass and speed of the impacting grains the coarse impact direction can be determined from the time of the impact, since the dust detector has a limited circular field of view of 140° (full angle) that scans directions perpendicular to the spacecraft's spin axis as the spacecraft rotates.

The discovery (Grün et al., 1993) of interstellar dust grains in the Ulysses data was achieved by observing the dust impact direction, impact speed, and the dependence of the dust impact rate as a function of the ecliptic latitude of the spacecraft. It was found that interstellar dust arrives from the opposite (retrograde) direction as dust from interplanetary sources like short period comets or asteroids (prograde). In addition the impact speeds of dust grains from the retrograde direction have been above the local solar system escape speed, even when radiation pressure effects are neglected. The observation that the impact rate of small dust grains did not decrease steeply after Ulysses left the ecliptic plane (Baguhl et al., 1996), where most interplanetary sources are concentrated, shows that the impacts detected by Ulysses are in fact dominated by interstellar grains (Krüger et al., 1999).

Since Ulysses left the ecliptic plane in February 1992, it monitors the stream of interstellar dust grains through the Solar System. It was found that the solar wind filtration causes a deficiency of detected interstellar grains with sizes below $0.2\ \mu m$ (Grün et al., 1994). An additional filtration by solar radiation pressure, that deflects grains with sizes of $0.4\ \mu m$, was found to be effective at solar distances below $4\,AU$ (Landgraf et al., 1999a). Besides the distribution of grain masses the flux density is monitored. In mid 1996 a decrease of the interstellar dust flux density from initially $1.5\times10^{-4}\,m^{-2}\,s^{-1}$ to $0.5\times10^{-4}\,m^{-2}\,s^{-1}$ was observed (Landgraf et al. (1999b), see figure 1), that was attributed to the increased filtering of small grains by the solar wind during solar minimum conditions (Landgraf, 2000; Landgraf et al., 2000). It was expected that the interstellar dust flux will stay low until about 2005 when the polarity of the solar wind magnetic field of the new solar cycle will focus the interstellar dust stream to lower heliographic latitudes. Since early 2000, however, Ulysses has detected interstellar dust flux levels above $10^{-4}\,m^{-2}\,s^{-1}$ again. Here we present the data analysis and interpretation of the observed phenomena.

2 Measurements with the Ulysses dust detector

Ulysses' unique, highly inclined interplanetary trajectory mostly avoids the ecliptic plane, where the dust population is dominated by grains from asteroids, short-period comets, as well as the Kuiper belt. Other, probably less prolific dust sources, however, can contribute to the impacts detected by the Ulysses dust detector. Mainly grains from Oort cloud comets like 1P/Halley are likely to orbit the Sun on highly inclined orbits. Due to their large semi-major axis and thus high orbital energy, most grains in the size range below $10\ \mu m$ will not stay on bound orbits after their release from the comet. As the size distribution of cometary grains decreases steeply with size (Mazets et al., 1986), the spatial density of interplanetary dust grains on highly inclined orbits is believed to be low.

In order to separate the interstellar dust population from possible other contributors, we selected only impacts from the dataset, for which the coarse impact direction is known and for which the interstellar upstream direction was in the field of view of the detector. The interstellar upstream direction was determined by Witte et al. (1993) from measurements of the velocity vector of interstellar neutral He atoms.

In order to determine a statistically significant flux value, we split the data set into time intervals of $6\ months$. The flux is then given by the number of impacts in each time interval, divided by the effective sensitive area of the detector, averaged over the respective period.

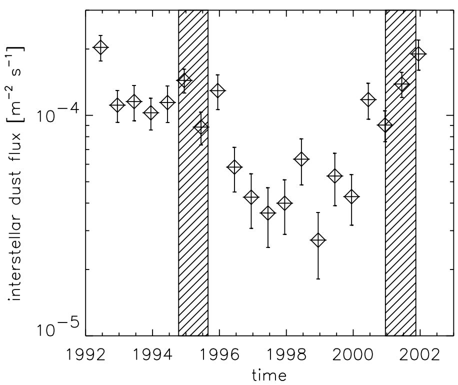

Figure 1: Flux of interstellar dust as measured by the Ulysses dust detector. The data points give the flux averaged over half a year with the 1σ uncertainty indicated by the error bars. The shaded regions represent the times around Ulysses' perihelion when interplanetary dust could not be well separated from interstellar dust.

The flux of interstellar dust measured by Ulysses between beginning of 1992 (after Jupiter fly-by) and end-2002 (most recent data) is shown in figure 1. From 1992 to mid-1996 the flux of interstellar dust stayed between 1×10^{-4} and $2 \times 10^{-4}\ m^{-2}\ s^{-1}$. After that it decreased by a factor of 2 to 3 until early 2000, when the spacecraft approached its perihelion again. The first data point after the perihelion passage shows, that the interstellar dust flux is indeed back to the level before 1996.

3 Model Prediction

In an effort to reproduce the unexpected rebound of the interstellar dust flux early 2000, we have modelled the dynamic interaction of interstellar dust grains of various sizes with the interplanetary gravity, radiation, and electromagnetic fields. We found that, as expected, grains with radii larger than $0.1\,\mu m$ with charge to mass ratio smaller than $5\ C\ kg^{-1}$ do not show a strong enough increase in 2000. Even smaller grains, however, reproduce the strong increase in flux along the Ulysses trajectory between 2000 and 2002.

4 Conclusion

The increase in interstellar dust flux starting early 2000 measured by the Ulysses dust detector can be attributed to the weakening of the diversive interplanetary magnetic field around the current solar maximum. The new configuration of the field after the maximum will lead to an even stronger increase in interstellar dust flux after 2005. Dust grains with charge to mass ratios below $5\ C\ kg^{-1}$, which have radii of more than $0.1\ \mu m$ if assumed spherical, however, cannot account for the observations. We conclude that probably smaller grains with higher charge to mass ratios must be responsible for the observed increase in flux. It is believed, however, that only grains larger than $0.05\,\mu m$ can penetrate the heliopause region Linde & Gombosi (2000). Future work will have to pinpoint the grain size that dominates the detections of interstellar dust by the Ulysses dust instrument.

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