Anticipation of the Ulysses Interstellar Dust Findings

Paul A. LaViolette, The Starburst Foundation, 1176 Hedgewood Lane, Schenectady, NY 12309

Eos **74**(44) (1993): 510-11

It has long been thought that dust particles making up the zodiacal cloud come predominantly from sources within the Solar System such as short-period comets, asteroids, and Jupiter's moons. However, data received recently from the Ulysses spacecraft calls this assumption into question, indicating that most of the dust particles encountered beyond the asteroid belt are of interstellar origin (Grün et al., 1993). The particles were found to be entering the Solar System at high speed ($v \geq 26$ km/sec) from the general direction of the Galactic center, approximately the same ecliptic direction from which the interstellar gas wind originates.

These results do not surprise me. In my 1983 Ph.D. dissertation and in subsequent papers I had stated reasons for believing that interstellar dust has recently entered the Solar System in large quantities specifically from the direction of the Galactic center. I will take a moment to explain some of the reasons that led me to this conclusion because they may be helpful to the interpretation of the Ulysses findings.

My dissertation presented astronomical evidence indicating that about every 10^4 years the Solar System has been impacted by volleys of cosmic ray electrons coming from the Galactic center. One such cosmic ray episode, or "superwave," would span about 10^3 years or more. It presented further evidence that a major Galactic cosmic ray superwave may have passed us as recently as the end of the last ice age with an estimated intensity of up to 90 ergs/cm^2/sec, about 10^3 times that of the current cosmic ray background radiation and equivalent to the average pressure which the solar wind exerts at ~2 AU from the Sun. Upon impacting the heliopause magnetic sheath, the superwave cosmic ray volley would form an upwind bow shock front and would strongly couple with the magnetized plasma in its vicinity to form propagating hydromagnetic fronts. These fronts, in turn, would electrodynamically propel forward electrically charged dust particles and gas ions, thereby inducing a wind of dust and gas to blow into the Solar System from the direction of the Galactic center. Details of the transport mechanism are given in the dissertation.

A test of this cosmic ray theory was conducted in 1981 and 1982 which involved determining the concentration of extraterrestrial dust in several samples of ice age polar ice to search for possible evidence of past interstellar dust incursions. The results were positive. Out of eight Camp Century, Greenland ice core samples spanning the period 71 to 34 kyrs BP, six were found to contain unusually high concentrations of the cosmic dust indicator elements iridium and nickel (LaViolette, 1983a,b,c, 1985). Cosmic dust accumulation rates determined for these samples projected Solar System dust mass concentrations in the

Earth's vicinity that in some cases were more than two orders of magnitude higher than present concentrations.

Asteroid or meteorite impacts may be ruled out as a likely source of the dust because of the high frequency of the events in the ice record, the prolonged duration of the influx (up to 10^2 yrs in individual ice samples), and because of the lack of high concentrations of cosmic spherules resulting from boloid ablation. Moreover, dust samples having high Ir and Ni concentrations were also found to have anomalously high concentrations of heavy metals such as Ag, Au, Sn, and Sb, indicating that the cosmic dust component was compositionally different from meteorites and from cosmic dust presently found in the Earth's vicinity (LaViolette, 1983a,c, 1987b). In fact, a sample dated at around 44.4 kyrs B.P. which exhibited the highest Ir and Ni concentrations, was found to be composed predominantly of Sn which contained anomalies in the ratios of four of its isotopes, an indication of extraterrestrial origin. So, these polar ice findings led me to conclude that compositionally anomalous interstellar dust had entered the Solar System in relatively recent geological time.

The Ulysses project's detection of a Galactic center interstellar dust radiant was further anticipated in a 1987 paper in Earth, Moon, and Planets in which I cited IRAS (Infrared Astronomy Satellite) observations of the zodiacal dust cloud as additional evidence supporting the theory that large quantities of interstellar dust may have recently entered the Solar System. The IRAS data showed that the orbital plane of the outer zodiacal dust cloud is tilted 3° with respect to the ecliptic with nodes positioned at ecliptic longitudes 87° and 267° (see Figure 1). Recognizing that this nodal axis is aligned within a few degrees of ecliptic longitude 265.5°, the point where the ecliptic makes its closest approach to the Galactic center, I noted that such an alignment is consistent with dust having entered the zodiacal cloud from outside the Solar System from an ecliptic direction lying toward the Galactic center. The Ulysses observations appear to substantiate this earlier conclusion.

Interestingly, the interstellar hydrogen wind radiant reported by Fahr falls close to this same ecliptic position at longitude $265 \pm 5°$, although the helium wind radiant deviates from this position by about 15°. I have suggested that this gas influx, like the zodiacal dust influx, may be a residual of a more intense inflow that occurred during the last ice age (LaViolette, 1983a, 1987a).

In the absence of the above evidence, some might be inclined to surmise that the interstellar dust discovered by Ulysses, originally approached the Solar System from the direction of Hercules, opposite to the Sun's movement through the interstellar medium, and that it had subsequently become deflected by some 60° to its present Galactic center radiant as a result of solar magnetic field interactions. Such an interpretation would attach no particular significance to the Ulysses observation that the dust is currently passing through the Solar System from the Galactic center direction. However, evidence pointing to the prolonged entry of interstellar dust and gas from a Galactic-center/ecliptic direction, compels us to conclude that it is no

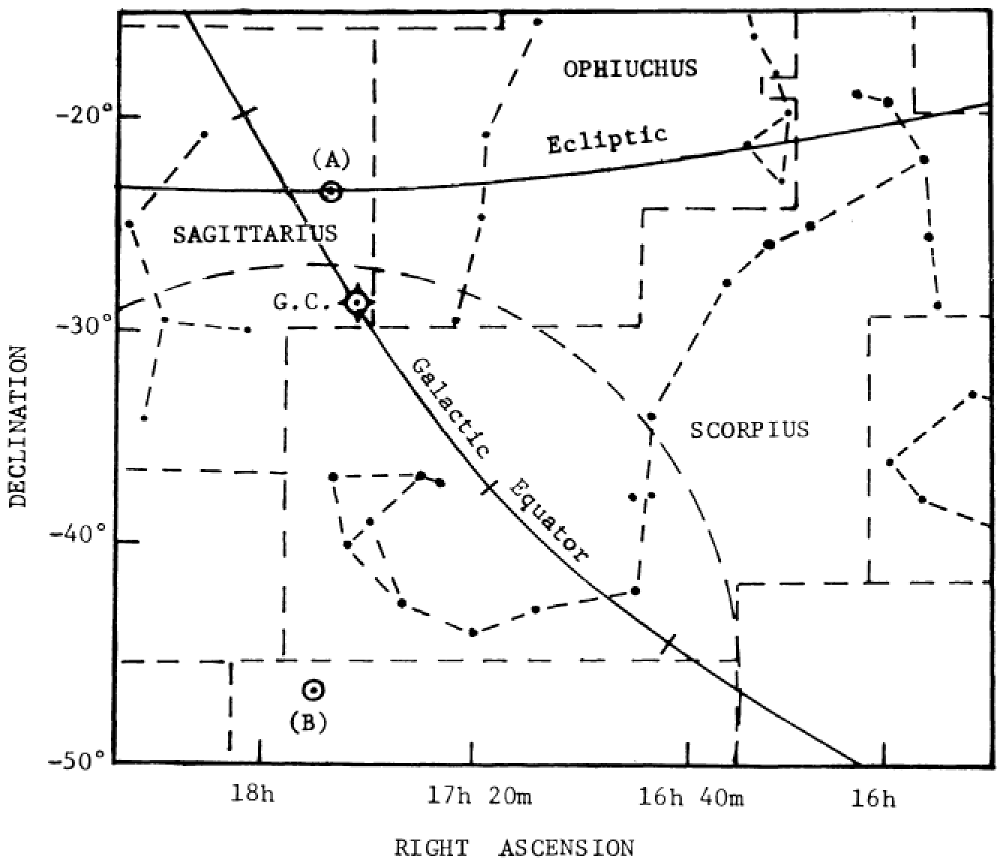

Figure 1. Sky map of the Scorpius region showing: a) the location of the zodiac dust cloud's descending node determined from IRAS data, and b) the direction from which the interstellar hydrogen wind enters the Solar System. GC marks the location of the Galactic center.

mere coincidence that Ulysses has observed dust coming from this particular heading and that some other agent is responsible for directing the dust on its present course. I would suggest that the dust originates from a circumsolar dust sheath that is concentrated toward the plane of the ecliptic in a fashion similar to the disk girdling the star Beta Pictoris and that is co-moving with the Sun. Infrared observations confirm the existence of dust sheaths around other stars in the solar neighborhood, leading to the conclusion that our Solar System is similarly shrouded. I would further suggest that the dust obtained its present momentum relative to the Solar System from hydromagnetic fronts periodically driven by superwave cosmic ray volleys arriving from the Galactic center, and that its trajectory has not been appreciably altered by solar magnetic effects.

Unlike the cometary dust particles that presently populate the inner Solar System and whose mass distribution peaks at a particle diameter of around 300 μm, the interstellar dust particles presently entering the Solar System are observed to have masses which place them in the photoactive submicron size range (0.1 - 1 μm).

If large quantities of this same population of interstellar dust had flooded the inner Solar System during the last ice age and had increased the local dust mass concentration by just one hundred fold, the number concentration of photoactive submicron particles would have risen by over 10^6 fold producing optical depths sufficiently high to have had a substantial impact on the Earth's climate.

Lately there has been increased concern about the ultimate cause of abrupt climate change, particularly following the announcement of the recent Greenland Summit GRIP ice core findings which call attention to the uniqueness of the present interglacial and show that the Earth has not experienced a similarly long period of undisturbed warmth for over 250,000 years. Interestingly, the present interglacial also happens to be one of the few extended periods during which there have been no large increases in the rate of atmospheric ^{10}Be production, an indirect indication that the Galactic cosmic ray background intensity has maintained a relatively constant lull during the Holocene. The recent discovery of the ongoing influx of photoactive interstellar dust particles should warn us that the Earth's climate may be quite vulnerable to events occurring in the Sun's immediate interstellar environment and that answers to the cause of abrupt changes in climate in the past may lie out in space, rather than on Earth.

Hopefully, future experiments carried out in the outer regions of the Solar System will provide much tighter direction and magnitude parameters for the cosmic dust influx than those Ulysses has provided. Meanwhile the Cassini spacecraft, due to be launched in 1997, will carry equipment capable of analyzing the compositions of individual dust particles it encounters. It would be interesting to see whether it finds that interstellar dust beyond the asteroid belt is enriched in heavy metals like the dust found in some ice age polar ice samples.

Bibliography

Anklin, M., et al. Climate instability during the last interglacial period recorded in the GRIP ice core. Nature, 364, 1993, 203-207.

Aumann, H. H., Spectral class distribution of circumstellar material in main-sequence stars. Astronom. J., 96, 1988, 1415-1419.

Fahr, H. J., The extraterrestrial UV-background and the nearby interstellar medium. Space Sci Rev, 15, 1974, 483.

Grün, E. et al., Discovery of Jovian dust streams and interstellar grains by the Ulysses spacecraft. Nature, 362, 1993, 428-430.

Hauser, M. G. et al. IRAS observations of the diffuse infrared background. Astrophys.J., 278, 1984, L15.

LaViolette, P. A. Galactic explosions, cosmic dust invasions, and climatic change. Ph.D. dissertation, Portland State University, 1983a.

LaViolette, P. A. The terminal Pleistocene cosmic event: Evidence for recent incursion of nebular material into the Solar System. Eos Trans. AGU, 64, 1983b, 286.

LaViolette, P. A. Elevated concentrations of cosmic dust in Wisconsin stage polar ice. Meteoritics, 18, 1983c, 336-337.

LaViolette, P. A. Evidence of high cosmic dust concentrations in Late Pleistocene Polar ice. Meteoritics, 20, 1985, 545-558.

LaViolette, P. A. Cosmic-ray volleys from the Galactic center and their recent impact on the Earth environment. Earth, Moon, Planets, 37, 1987a, 241-286.

LaViolette, P. A. The cometary breakup hypothesis re-examined. Mon. Not. R. Astron. Soc., 224, 1987b, 945-951.

Raisbeck, G. et al. Evidence for two intervals of enhanced ^{10}Be deposition in Antarctic ice during the last glacial period. Nature, 326, 1987, 273-277.