A NOTE ON ANTIMATTER METEORS

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Abstract. It is argued here that unless antimatter meteors can be shown to possess some unambiguously unique characteristic not displayed by ordinary koinomatter meteors, it will be difficult to infer their existence given the standard interpretation of meteoroid structure. It is also argued, however, that the existence of antimatter meteors is extremely unlikely.

1. Introduction

In a recent article Papaelias (1987), once again, raised the question of whether antimatter material can be observed through its interaction with the Earth's atmosphere. Working on the basis that antimatter exists, it is possible that on rare occasions antimatter meteoroids will penetrate the Earth's atmosphere. By drawing an analogy with koinomatter meteoroids, Papaelias (1987) derived a velocity-height relation for antimatter meteors. Comparing the velocities between koinomatter meteors, v_k and antimatter meteors, v_a, he finds for otherwise identical meteoroids, i.e., same size, mass, density and initial velocity, v_{∞}, that $v_k \geq v_a$ at any given height in the atmosphere. The exact expression being a function of the atom-antiatom annihilation cross-section parameter c.

We point out here that the velocity-height relation for antimatter meteors is on its own not sufficient to determine the parameter c, or vice-versa, even if c is known the velocity-height relation is essentially useless unless the structure of antimatter meteoroids is known in detail. The same constraint for that matter applies to ordinary, koinomatter, meteoroids. We also note here that there are reasonably strong observational constraints that argue against the existence of antimatter meteoroids.

2. The Structure of Meteoroids

The classical theory of meteor ablation, developed in the earlier half of this century by Lindemann and Dobson (1922), Sparrow (1926), and Öpik (1958), assumes a meteoroid to be a single dust grain, moving through the Earth's atmosphere under ballistic conditions. The characteristic light curve this theory predicted was found to be in good agreement with the observations of the brightest meteors. It became apparent, however, during the 1950's, that the faint meteors behaved in an anomalous manner, displaying higher deccelerations than could be accounted for by variations in atmospheric density, and in general having 'non-classic' light curves. Jacchia (1955) suggested a solution to the faint meteor anomaly by arguing that meteoroids

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are porous, fragile structures composed of many small grains. This suggestion was in keeping with the then new icy-conglomerate comet model of Whipple (1951). In this 'dustball' picture, meteoroids not only undergo ablation in the Earth's atmosphere but suffer disruption by fragmentation, Hawkes and Jones (1975) developed Jacchia's idea and derived a detailed model of meteor ablation applicable to the 'dustball' concept and a wide range of meteoroid masses. This model considers a meteoroid to be made of an assembly of high melting point stone (or iron) grains of typical mass 10^{-6} g, held together by a lower melting point 'glue'. Using data from Jacchia *et al.* (1950) and Jacchia *et al.* (1967), Beech (1984, 1986) and Hapgood *et al.* (1982) have shown that the predictions of the Hawkes-Jones model is in good agreement with the available observations for the Perseid, Geminid, Southern-Taurid, and Draconid meteor showers. Recent results from the Vega 1 space craft that encountered comet Halley in March 1986 also find that the low mass meteoroids ($10^{-15} - 10^{-111}$ g) have a 'fluffy' fragile structure; Kissel and Krueger (1987).

It is clear then from current observation and theory that the structure of meteoroids is fairly well determined, and that they are open, fragile, fractal structures. This allows a possible criticism of Papaelias's formula, which was derived under the constraints of the classical theory. Furthermore, fragmentation will cause the velocity-height variation to be different from that predicted by the classical theory. Jacchia (1955) has shown that a progressive fragmentation index can be described, where

$$\chi = \mathrm{d}/\mathrm{d}s \log_{10} (\dot{v}_0/\dot{v}_T),$$

in which s is the mass loss parameter

$$s = \log_{10} [(m_\infty/m) - 1],$$

and $\dot{v}_T$ is the theoretical decceleration, as calculated from the classical theory

$$\dot{v}_T = -\text{(structural constants)}\ \mathrm{m}^{1/3}\rho v^2;$$

$\dot{v}_0$ being the observed decceleration. Observations obtained in the Harvard Meteor project clearly indicate that $\chi > 0$ in the majority of cases. Two extremes are the Southern-Taurids with $\chi = 0.04$ (little fragmentation) and the Draconids with $\chi = 1.89$ (extreme fragmentation), but typically $\chi \approx 0.3$. These results indicate that the velocity of a non-fragmenting (classic) meteor with $\chi = 0$, is greater than the velocity of a similar fragmenting meteor with $\chi > 0$, i.e., under the same conditions $v(\chi = 0) > v(\chi > 0)$. Hence, the relation of Papaelias (1987) $v_k > v_a$ for koinomatter and antimatter meteoroids holds only in the unrealistic case of zero fragmentation ($\chi = 0$), or in the case of universal fragmentation where all meteors fragment in the same way. In the absence of a detailed knowledge of antimatter meteoroid structure the velocity-height relation of Papaelias (1987) offers no discriminant between koinomatter and antimatter meteors. Presumably the best discriminant between the two types of meteoroid is through the light curve they produce. It needs to be shown, however, that the antimatter meteors produce a unique light curve. This has not, to the author's knowledge, been done.

3. Do Antimatter Meteoroids Exist?

As Steigman (1976) points out in his review, since any causal quantum theory that is Lorentz invariant must produce particles in pairs, it is possible that this microscopic symmetry is manifest on the macroscopic scale of the Universe. Gamma-ray and cosmic-ray observations, however, clearly exclude the existence of large amounts of antimatter in our Galaxy and neighbouring galaxies. As such then, antimatter seems to play no fundamental role in the astrophysical processes we observe around us today.

The life-time of antimatter against annihilation in the interstellar medium is very short $\lesssim 300$ yr (Steigman, 1976) and as such we would not expect any antimatter present in the pre-solar nebular, from which our solar system formed, to be in existence today. However, if antimatter existed in sufficient quantity and was able to undergo condensation into solid bodies or stars, the life-time against annihilation could be very large. The scenario outlined by Papaelias (1987) envisages the formation of antimatter comets (anti-comets) around antimatter stars (antistars). Gravitational perturbations may then lead the Sun to capture anticomets in the close approach of an antistar. Conversely, comets are expelled into the interstellar medium through the close approach of two stars of which at least one must have a cometary cloud, and as such the Sun may capture a 'wandering' anticomet victim of just some distant encounter. The argument then follows that antimeteoroids are delivered to the inner solar system in the same way as ordinary, koinomatter meteoroids are, through the close solar approach of a comet. Papaelias (1987) argues that this need happen only once in the Sun's history for antimatter meteoroids to occasionally penetrate the Earth's atmosphere. This argument, however, denies the dynamic, non-equilibrium state of the meteoroid complex. Meteoroids with $m \gtrsim 10^{-5}$ g, typical of the meteoroids that can undergo ablation in the Earth's atmosphere, are predominantly destroyed by meteoroid-meteoroid collisions, and the meteoroid complex would be depleted of all such particles on a time scale $\sim 10^4$ yr without replenishment (Grun *et al.*, 1985). In this manner, meteoroids with $m \gtrsim 10^{-5}$ g are 'young' and must have been recently supplied. Hence, if antimatter meteoroids are present within our solar system they must have been deposited within the last $10^4 - 10^5$ yr, and only as such may they occasionally encounter the Earth's atmosphere at the present time. The anticomet delivery method would seem to be the only tenable way in which antimatter meteoroids can be delivered into the inner solar system. An interstellar origin would seem to be ruled out, since, even if antimatter meteoroids could form and survive in the interstellar medium, such objects would have very definite hyperbolic orbits. Accurate photographic determinations of meteor velocities indicate that less than 1% of meteors have slightly hyperbolic velocities, Jacchia and Whipple (1961), Jones and Sarma (1985), and these can be perfectly well accounted for through planetary perturbations.

4. Discussion

In this note, we have argued that unless antimatter meteors display some observably unique characteristic that koinomatter meteors do not, for instance in their light curves, it is not possible to decide whether anomalous effects in the velocity-height relation are due to the presence of antimatter, fragmentation or both. If the cometary delivery method is the only tenable way that antimatter can be delivered to the solar system, this requires that enough antimatter exists to form at least some stars and planetary systems. This requirement would seem to run against all the available observations (Steigman, 1976).

In this 1920 address to the British Association, A. S. Eddington observed, '...It is often supposed that to speculate and to make hypothesis are the same thing; but more often they are opposed...' (Eddington, 1920). Is then the time for speculation over? Can we say antimatter meteoroids do not exist? In this articles we argue that the answer to these questions is yes. Observations indicate that antimatter meteoroids do not exist. A continued null result, however, does not constitute a proof ('Absence of evidence is not evidence of absence', M. Rees) and a single positive detection negates the arguments presented. This, despite our claims and the overwhelming observational evidence against their existence, will clearly not be the last word on antimatter meteoroids.

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