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ON THE DEFINITION OF THE TERM 'METEOROID'

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SUMMARY

It is argued that the term 'meteoroid' is best defined as being applicable to any natural solid object moving in space, and having a size between 100 μm and 10 m ($10^{-4} - 10^1$ m). This definition reflects modern-day instrumentation limitations and recognizes the physical constraints that dictate the production of a meteor in the Earth's atmosphere. Our argument also has implications for the definitions of the terms 'asteroid' (synonym 'minor planet'), 'micrometeorite', and 'interplanetary dust.'

1 INTRODUCTION

The words 'meteor', 'meteoroid' and 'meteorite' are often used incorrectly. They are not, in spite of popular belief, interchangeable expressions. One can, for example, 'see' a meteor, but not a meteoroid (unless one were an astronaut who was unlucky enough to have a very close encounter with such a body). More precisely, the occurrence of a meteor can be discerned with the eye, recorded on a photographic plate, registered by an electro-optical system, or detected with a suitable radar, while a meteoroid is understood to be any interplanetary body that can potentially produce a meteor if it chances to enter the (usually, Earth's) atmosphere. On this basis, the Solar System contains 'meteoroid streams', but not 'meteor streams' [sic], which is an oft-met malapropism that seems to have gained a foothold in the meteor community through the title of the prominent book by Porter (1952). A 'meteor shower' occurs when the Earth passes through a meteoroid stream. Meteorites are identified as those fragments of a meteoroid that have survived their passage through the Earth's atmosphere and have consequently landed on the planet's surface. The present terminology allows for the term 'meteorite shower', but such displays, given that they even exist (see, e.g. Halliday *et al.* 1990), are again a consequence of the Earth passing through a meteoroid stream.

The definitions that presently apply to the terms 'meteor', 'meteoroid' and 'meteorite', along with 17 other words related to meteor astronomy, were adopted at the XI General Assembly of the International Astronomical Union (IAU) 34 years ago, in 1961 (Millman 1961; this is a verbatim copy of the official IAU report: Sadler 1962). While Beech & Youngblood (1994) have discussed the ambiguous use of the word 'meteorite' in relation to meteoroid impacts on Earth-orbiting space platforms, we wish to point out here that the term 'meteoroid', as presently defined by the IAU, is out-dated and requires some refinement. Any re-definition would require action at a General Assembly of the IAU, and it is hoped that this letter will promote a consensus allowing such a re-definition at the next General Assembly in 1997.

2 HISTORICAL BACKGROUND

The term 'meteoroid' was first coined by H.A.Newton in 1864 (Newton 1865). Newton explained that:

> It will be assumed that the phenomenon called a shooting or falling star is caused by a small body (probably solid) which originally was moving in its own orbit in the solar system, or in space; that this body coming into the atmosphere of the earth elicits light by the loss of velocity, and is usually dissipated before reaching the earth's surface. The term meteoroid will be used to designate such a body before it enters the earth's atmosphere.

Not quite a century after Newton published the above – remarkably insightful – description, the IAU adopted the following definition for the term 'meteoroid' (Millman 1961, Sadler 1962):

> *Meteoroid* – a solid object moving in interplanetary space, of a size considerably smaller than an asteroid and considerably larger than an atom or molecule.

The point we wish to make here is that the upper and lower size limits currently applied to the definition of 'meteoroid' can each be made more determinate, the former due to technological advances in observation methods made during the past three decades, and the latter from our improved knowledge of the meteoroid ablation process.

3 UPPER SIZE LIMIT: METEOROID OR ASTEROID?

In relation to determining the upper size limit, the essential question to ask is where do meteoroids end, and asteroids begin. The term 'asteroid' was introduced by Sir William Herschel around the start of the nineteenth century (Herschel 1802), the implied meaning behind the word being 'of a star-like appearance'. (Rather than 'asteroid', 'minor planet' is the term sanctioned by the IAU for such objects.) The key observational attribute of an asteroid, therefore, is that it reflects sufficient sunlight to produce a star-like image in a telescope. The recognition of an asteroid is also dependent upon the efficiency of any particular telescope's instrumentation.

The upper size limit of a meteoroid may reasonably be set according to the minimum detectable size of an asteroid. The lower asteroid size limit is in turn determined by the present-day observational limitations. Until quite recently, no asteroids smaller than a few hundred metres had been observed telescopically. Therefore, back in 1961 it was reasonable to define a meteoroid as being something 'considerably smaller than an asteroid'. Today, however, the *Spacewatch* telescope at Kitt Peak (Gehrels 1991, Rabinowitz 1991, 1994) frequently detects asteroids as small as 10 m in size in cis-lunar space. The sizes of these objects are estimated using an assumed albedo; it is possible that a few as small as 5 m have been detected, if their albedos are as high as 0·2, but it seems likely that the typical smallest-sized objects detected by *Spacewatch* are ~ 10 m in size.

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If an object a few metres in diameter chances to enter the atmosphere a spectacular fireball is produced, and a meteorite dropping event will probably take place. The parent body of the fireball would almost certainly not be detected, however, before it encountered the atmosphere; although some military sensors, such as the US Air Force GEODSS (Groundbased Electro-Optical Deep Space Surveillance) system, are capable of detecting objects only a few metres in size as they approach within a few Earth radii, these sensors scan only a small area of the sky. Objects a few metres in size are best described, therefore, as 'meteoroids' rather than 'asteroids'.

In light of the above discussion it does not seem unreasonable to adopt 10 m as the dividing line for an object to be considered to be either an asteroid or a meteoroid. We therefore propose that any natural object in space, which is solid and neither cometary in nature or planetary in size, but larger than ten metres, be defined as being an 'asteroid', 'minor planet' being a synonym; any object smaller than 10 m (which might indeed be cometary in nature, although volatiles are rapidly lost by such small objects), but larger than the proposed 100 μm limit discussed below, would be defined as being a 'meteoroid'.

4 LOWER SIZE LIMIT: METEOROID OR DUST?

In order for a meteoroid to produce a meteor (i.e. a phenomenon detectable by optical or radar means) upon entering the atmosphere, it must be larger than about 100 μm in size (e.g. see Bronshten 1981). Meteoroids smaller than 100 μm essentially lose their kinetic energy through radiation, rather than ablation, in the Earth's atmosphere, and consequently they do not produce any light or an ionization train. This size is dependent upon the particle speed and angle of entry, composition and density/structure. In essence the limit is set by the surface area to volume/mass ratio which allows the energy to be radiated away sufficiently rapidly such that the melting/ablation temperature is not reached. Thus, we acknowledge the fact that this size limit depends upon various parameters specific to any individual particle, but argue that 100 μm is a convenient, order-of-magnitude lower limit for the size of the meteoroid that can produce a meteor.

The zodiacal light (sunlight scattered by interplanetary particles) is primarily produced by particles in the size range 10–100 μm, and these particles are commonly referred to as 'zodiacal (or interplanetary) dust' (see various papers in Levasseur-Regourd & Hasegawa 1991). It seems reasonable, therefore, to set 100 μm as the dividing line for a particle to be either a dust particle, if smaller than 100 μm, or a meteoroid, if larger.

5 DISCUSSION

By adopting the upper and lower size limits discussed above, a new definition for the term meteoroid might read as follows:

Meteoroid: A solid object moving in space, with a size less than 10 m, but larger than 100 μm.

By adopting the above definition, it will be necessary to alter slightly the IAU-approved meanings for the words 'dust' and 'micrometeorite'

(Millman 1961, Sadler 1962). Presently, 'dust' is taken to mean 'finely divided solid matter, with particle sizes in general smaller than micrometeorites', while a micrometeorite is 'a very small meteorite, or meteoritic particle with a diameter in general less than a millimetre'. These definitions might be altered to read:

Dust: Particles originating or existing in space with sizes smaller than 100 μm.

Micrometeorite: A small meteorite that exceeds 100 μm in size.

We have imposed a lower limit of 100 μm to the size of a micrometeorite on the understanding that they have the same implied origin as meteorites. That is, they are derived from meteoroids. The cross-over from micrometeorite to meteorite may be set in a purely arbitrary fashion. An upper micrometeorite limit of a few millimetres does not seem unreasonable. While dust particles will also survive their passage through the atmosphere, these are best described simply as 'dust', irrespective of where they are sampled. The IAU approved definition of the word 'meteorite' does not need to be modified under our new definition of the term 'meteoroid'.

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