Meteoroids and Meteors – Observations and Connection to Parent Bodies

S. Abe

Institute of Astronomy, National Central University, 300 Jhongda Road, Jhongli, Taoyuan 32001, Taiwan,
shinsuke.avell@gmail.com

Abstract Meteoroids are small rocky bodies traveling through interplanetary space. Meteors are phenomena caused by the interaction of meteoroids with the Earth’s upper atmosphere. In this chapter, the author will briefly discuss observational methods and then concentrate on optical observations of meteors. First, the basic properties of meteor phenomenon in the atmosphere and classification of meteoroids are introduced and then coincidental phenomena, e.g., wake, jets, and train, are mentioned. Scientific observations (imaging and spectroscopy) carried out using various observational techniques allow measuring characteristics of meteoroids, e.g., orbits, density, strength, compositions. All information are potentially useful for investigating parent bodies of meteoroids, such as comets and asteroids. Searching for organics-related CHON and water in meteoroids is of particular interest for astrobiology.

5.1 Introduction of Meteoroids and Meteors

Comets (solar system small bodies) are planetesimals that somehow did not grow into bodies as large as the major planets. They are thought to be remnants of planetesimals were formed in the protoplanetary disk and thus they reveal important information about the formation of our solar system. Dust grains about sub-micrometer to centimeter in diameter are ejected from these bodies and are moving around the Sun as meteoroids.

Meteoroids can be observed during atmospheric entry as a meteor phenomenon. Most meteoroids are weakly bound highly porous chunks of rocky material. These meteoroids enter the Earth’s atmosphere at hypervelocities (approximately several tens of kilometer per second), so they reach very high temperatures (1,800–2,000 K) during entry that they ablate nearly fully. In other words, the terrestrial upper atmosphere is a natural detector of meteoroids. The groups of meteors that appear annually are called ‘meteor showers’ (see Fig. 5.1). On the night of a meteor shower, any naked-eye observer can recognize that the majority of the visible meteors seem to emanate from a
specific point in the sky. The direction where the meteors comes from is traditionally called ‘radiant.’ All dust streams, whether of cometary or asteroidal origin, show this ‘radiant’ phenomenon. Many such streams have been identified as meteor showers throughout the year. The general nomenclature for a meteor shower and a meteoroid stream are using the Latin name of the constellation from which the radiant emanates, e.g., Geminids, Perseids, and Quadrantids.

Typical meteors are associated with meteoroid sizes between 0.05 mm and 20 cm in diameter, which are ejected from a small solar system bodies. A meteor brighter than approximately −3 magnitude is called a ‘fireball.’ An exceptionally bright fireball (−8 magnitude or brighter) is eventually called a ‘bolide.’ Some meteors are related with the fall of a meteorite. The term ‘meteorite’ should be exclusively used only for meteoroids recovered on the Earth’s surface. The geocentric entry speed of the meteoroid varies from 11 to 72 km s\(^{-1}\), which depends on gravity of the Earth (11 km s\(^{-1}\); escape velocity from the Earth) and the parabolic velocity (42 km s\(^{-1}\); escape velocity from the solar system) relative to the Earth’s motion (30.3 km s\(^{-1}\)), respectively. For example, the head-on meteor shower ‘Leonids’ shows nearly the maximum speed of about 72 km s\(^{-1}\) [35].

A meteor shower occurs when the Earth’s path crosses a dense dust trail generated by its parent comet, which has approximately the orbital period of the parent. The Leonid meteor shower is one of the most interesting meteor showers and has shown strong activity roughly every 33 years at least in the last 100 years. This corresponds to the orbital period of the comet, 55P/Tempel–Tuttle. Meteor streams that form as a result of cometary activity around perihelion are often referred to as trails. A trail is created at each perihelion passage of the parent comet. On the other hand, non-shower meteors are called ‘sporadic meteors.’

Meteoroids are ejected from a cometary nucleus when the comet approaches the Sun within a distance of about 2 AU. Surface sublimation of nucleus material ejects both gas and meteoroids. Since meteoroids are ejected in random directions from the nucleus with relative velocities about few meters to few hundred meters per second, the meteoroids gradually separate from the comet and form a dust stream. Both comets and meteoroids move around the Sun in elliptical orbits. The orbit of a comet is generally perturbed strongly by the gravitational field of planets. Moreover, non-gravitational force induced by the sublimating gas will modify the orbital period of a comet, further complicating the orbital evolution. Thus, the orbit of dust streams generated by a comet at different perihelion passages is slightly different. Some streams are named ‘dust trails.’

Dust trails were detected by the Infra-Red Astronomical Satellite (IRAS) [61]. Reach et al. (2000) observed the dust trail of comet 2P/Encke with the Infrared Space Observatory ISOCAM [82]. While Ishiguro et al. (2007) detected dust trails and its structures of short-period comets from ground-based observations in the visible wavelength [46]. The central core of a dust