A Qualitative Model of Meteor Storms

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This work addresses the behavior of rare outbursts of meteor activity colloquially known as meteor storms. During such meteor storms, the observed rate of meteors can jump several orders of magnitude over normal rates. Historically, the largest meteor outbursts have been associated with the return to the inner Solar System of the parent comet of the meteor stream. For example, the Leonid shower tends to show storming behavior every 33 years, coinciding with the approximate time of the perihelion passage of its parent comet P/Tempel-Tuttle. This paper presents a model that describes why and when meteor storms can be expected to occur. The model predicts that the Earth must pass near the meteoroid stream within a computed time window in order for observers on the Earth to observe such a storm; the width and location of the time window being a function primarily of the parent comet's orbit. Using this method, a series of potential storm-producing comets were examined for possible meteor storms in coming years. The model predicts that the Leonid shower should be expected to storm in 1999, and possibly the Giacobinid (October Draconid) shower in 1998. In addition, the model predicts that the Perseid shower should show enhanced activity for the next few years, but the meteor rates should not increase significantly over normal levels. The model predicts that the meteor streams from other potential storm-producing comets should not produce any storms before the year 2000, but may do so early in the next century.

The model assumes that the meteoroid particles seen during meteor storms originated from the parent comet one or two comet orbits ago, and specifically from particles released when the parent comet was crossing the ecliptic plane at a radius from the Sun of approximately 1 A.U. (note that only a few comets have orbits that satisfy this condition). These particles are assumed to leave the comet nucleus with some initial delta-velocity based on their size and follow their own orbits around the Sun under the influence of gravity and solar radiation pressure. The particles are assumed to return to their initial release point (a "pinch" point), but at different times because radiation pressure will sort the particles by size; large ones arriving first, and smaller ones later. The range of possible return times defines the intercept window for the Earth to encounter the enhanced spatial densities of meteoroids that might result in a storm. The model also makes predictions on the likelihood of storms of smaller meteoroids that would be difficult to detect from the ground, but might present an increased hazard to operational Earth-orbiting spacecraft.

The main factor in controlling the width of the Earth-encounter window is the orbital period of the parent comet. Comets with periods of less than a decade will have associated storm time-windows only a few weeks wide. Consequently, the Earth rarely is in the right place at the right time to encounter such a stream, making such storms unlikely. Longer comet orbital periods of a few decades (e.g., P/Tempel-Tuttle) have windows lasting months to years. Such comets should be expected to produce regular storming activity. Comets with periods of many decades to centuries (e.g., P/Swift-Tuttle) produce dust that spreads along the orbit to such an extent that the significant concentrations of meteoroids required to produce a meteor storm simply do not occur. Such comets are not expected to produce significant storming activity.