OBSERVATIONAL AND COMPUTATIONAL EVIDENCE FOR GRAVITATIONALLY STABLE PARTICLE ACCRETIONS IN THE PERSEID METEOR STREAM; J. C. Barentine, Cortez High School

Recent results in the field of meteoroid dynamics in Short Period Comet (SPC) streams have yielded a new model of the stream of Comet P/Swift-Tuttle (1992t). Unusually high Zenithal Hourly Rates (ZHRs) noted in the Perseid meteor shower, of which P/Swift-Tuttle is the parent body, in *c.*1861-65 and c. 1988-92 suggest a localized accretion of particles preceding and following the comet during its 135-year period. A computer simulation of the stream appears to confirm the existence of the accretions through gravitational theory. The model was tested in the shower of 1993, in which outside predictions of meteoroid "storm" were not fulfilled. The lack of increased activity conforms well to the projections of the model, in which the particle groupings correspond roughly to the L4 and L5 Lagrange points.

After the apparition of 1862, the orbit of P/Swift-Tuttle was deduced by Sciaparelli with a return postulated for 1982. In 1973, B. Marsden linked the comet with an earlier observation of Comet Kegler 1737III, changing the perihelion date to T=November 1992.

The comet's particle shower, the Perseids features a slow rise and fall in activity about a maximum which occurs on or about August 12 UTC. The reliability of the shower's strength, with normal rate of ZHR ~100, is an indicator that the overall stream density is high. Observers reported a new maximum feature in observations beginning in 1988, with the "early" maximum several hours before the normal peak. This new yearly attribute grew in intensity until1991, when observers in east Asia reported a rate of ZHR>500 on *c.* 1991 August 11.7 UTC. The unusually high rate of the early maximum continued into 1992.

These data suggested a new orbital feature within the particle stream which was moving at or near the orbital velocity of the parent body. The density of this feature was concluded to increase with respect to time by the parallel rise in Perseid shower activity. The apparent relative motion of this particle mass indicates a gravitational relationship which allows the component particles to remain near the mass without being dispersed into the local medium. If the proper forces were exerted on the stream, it is possible that this feature could exist for several thousand years. Observations similar to those of 1988-92 were noted in 1861-62, in advance of P/Swift-Tuttle's 1862 return. This allows that the feature predates the aforementioned perihelion passage. Based on high ZHR's in the showers of1864-65, a similar accretion mass likely exists following the comet as well. The foundation for these proposed accretions was set by way of the observational evidence noted.

The standard correction was applied to data collected from observers worldwide during the 1993 shower and the ZHRs displayed in Fig. 1, showing the high central stream concentration. This central peak, though, does not appear to be of a "storm" nature. The line shown was a smoothing spline fit, with lambda=0.01.

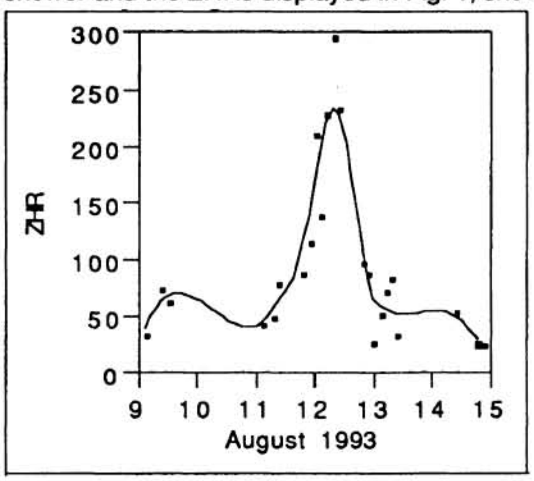

Fig. 1. ZHRs from the 1993 Perseid meteor shower during the period 9 to 15 August UTC. Data points represent averaged values computed in decimal day intervals by the equation in Fig.1.

To test the model against gravitational mechanics theory, a computer simulation was devised. The software used was the commercially-available *Dance of the Planets* (copyright 1989 Applied Research & Computing, Inc.) This program was chosen due to its wide use among both amateur and professional astronomers to facilitate easy reproduction of the results reported here. The orbital elements of P/Swift-Tuttle and 9 test particles included in the simulation are given in Fig. 2. The masses of the particles are assumed to be nearly zero, and are treated in the same manner as the comet itself in relation to the larger masses of the Sun and planets. The dates of perihelion of the particles were set in intervals of 0.1d, five ahead of and four following the comet for a total system of 10 masses. The gravitational influence of the nine planets was allowed to act upon this system and is responsible for the subsequent results. The Poynting-Robertson effect

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lwas not taken into account in this simulation, leading to a purely gravitational solution. Although excluding forces lowers the accuracy of the simulation to a certain extent, the degree of accuracy attained is enough to encompass the results presented herein. No claims are made which place particles in exact locations; the precise margin of error is unknown, but presumed low as gravity is the primary source of displacement. The program effectively solves the equations of motion through Newtonian and Keplerian mechanics and integrates the products over time.

The initial setting of the simulation was for the date 6 January 4609 BC (the setting 06\27.00\-4609 in *Dance* 's mode of time). Execution of the program was performed on apersonal computer operating at 33MHz and independently confirmed on a second computer. The simulation ran ~37500 years of time and was displayed through orbital diagrams. An image at T=34609 years is shown in Fig. 3. Particle compression begins as they fall into three distinct areas of space: ahead of, proximal to, and behind the comet itself. Finally, two main areas of accretion exist, ~60 degrees ahead of and behind P/Swift-Tuttle. During the simulation, individual particles were seen to move from one accretion "lobe", passing the comet, into the other lobe, and back in spirals lasting over 5,000 years. Settling into the final configuration does not appear to halt the particles' passage. Despite repeated passes near the Jovian planets, which ordinarily would severly deform ordinary cometary orbits, these accretions appear to be relatively stable, regardless of Jovian perturbations.

Object	e	q	I	W	w	T
1992t	.958216	.9636	113.4266	139.4442	153.0016	1992.12123
P01	.958216	.9636	113.4266	139.4442	153.0016	1992.12118
P02	.958216	.9636	113.4266	139.4442	153.0016	1992.12119
P03	.958216	.9636	113.4266	139.4442	153.0016	1992.12120
P04	.958216	.9636	113.4266	139.4442	153.0016	1992.12121
P05	.958216	.9636	113.4266	139.4442	153.0016	1992.12122
P06	.958216	.9636	113.4266	139.4442	153.0016	1992.12124
P07	.958216	.9636	113.4266	139.4442	153.0016	1992.12125
P08	.958216	.9636	113.4266	139.4442	153.0016	1992.12126
P09	.958216	.9636	113.4266	139.4442	153.0016	1992.12127

Figure 2. Orbital elements for Comet P/Swift-Tuttle and the nine test particles from the computer simulation described in the text.

As the "storm" feature of the Perseid stream predicted to coincide with a locally-dense region of particles did not appear in 1993, the model can be analyzed to provide information regarding when this predicted feature will actually appear in the shower observations. Assuming that the simulation provides a reasonably accurate description of the orbital features of P/Swift-Tuttle, including the relative positions of the accretion lobes, a feature of this type is most likely to appear in 1994-95, being roughly equidistant in time from the comet's perihelion T=December 12.3 1992 as the 1991 East Asia feature is. The possibility exists that it may go unnoticed; this stems largely from the compression density of the feature, which may cause it to pass the node at Earth's orbit either before or after the August shower date. However, its density is most likely similar to that of the preceeding accretion lobe; if so, it will be observed on time.

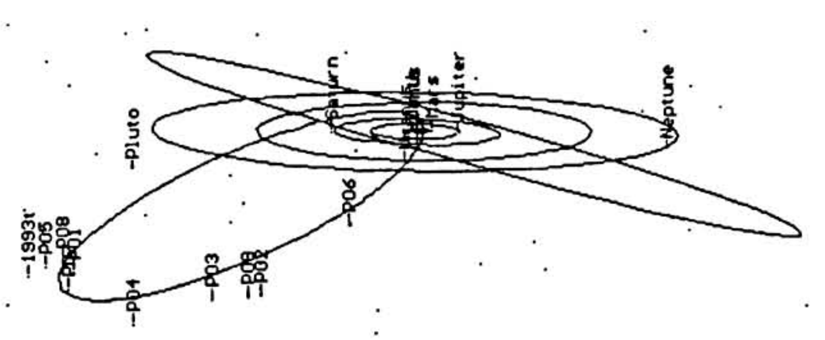

Fig. 3. Orbital diagram from the described simulation at T=34609 yrs., clearly displaying areas of accretion. Test particles are denoted as "P" and a two-digit identification number.

A new view of such particle streams has emerged which suggests an equally novel approach toward studying the gravitational forces acting on these particles. The particle streams of other short-period comets whose parent bodies are still active ejectors should show similar results upon long-term examination of their meteor showers. Currently, the Leonid (P/Temple-Tuttle) and the Taurid (P/Encke) streams are candidates for further work, as well as an examination of the gravitational forces which allow the accretions to remain relatively stable.