ify the complexion of the meteorite-sized portion of the population by making a significant part of the latter from a few large asteroids. Thus most meteorites sampled in a limited time would be the product not of a mean population of source asteroids but of a few random ones. They would not be representative of the asteroid belt or even of that part of the belt that feeds into Earth-bound trajectories, unless sampled over a very long time.

We have modelled collisional evolution of asteroids en route to Earth to determine the statistics of time variation in the Earth-impacting population. Our preliminary model includes a flux of asteroids injected into potentially Earth-crossing orbits, collisional breakup of larger asteroids into smaller ones, and parameterized orbital evolution. The larger asteroids are labelled so that their products can be followed as the system evolves collisionally. Using parameters for the size distribution and collisional lifetimes from Wetherill (1985, *Meteoritics* **20**, 1), we find that for a substantial part ($> 50\%$) of the time, 4 to 6% of all meteorite-sized (10^2–10^6 g) bodies come from only three parent bodies in the main belt. Ten percent of the time more than 15% do. The particular set of dominant contributors at Earth changes on time scales $< 10^6$ yr. Thus stochastic collisions change the arriving population enough to explain the Antarctic meteorites, but not enough to yield 80% of arrivals (*e.g.* ordinary chondrites) from only a few asteroids.

15.14

Collisional Evolution of the Spin of a Non-Spherical Body

A.W. Harris (JPL/Caltech)

In the model of the collisional evolution of asteroid spins (A.W. Harris, Icarus 40, 145-153, 1979), an equilibrium value for the spin rate of a spherical asteroid was derived. Since that time, several authors have speculated on the difference in equilibrium spin rate which might apply for a non-spherical body. The extension of the original model to non-spherical bodies is straightforward, and the result can be stated simply by:

$$(f/f_s) = (l/l_s)(I_s/I),$$

where f is the equilibrium spin frequency, l is the rms value of the impact parameter of colliding particles, I is the moment of inertia of the body, and the subscript "s" refers to the values of the parameters for a sphere, which are compared to the parameters for an irregular body, unsubscripted. In general, deforming a sphere results in increasing both l and I by similar amounts, depending upon the shape, so the result is that the equilibrium spin rate is not much dependent upon the shape of the body. The table below summarizes the results for several geometric figures:

Shape	l/r	I/mr^2	f/f_s
Sphere	$\sqrt{1/2}$	2/5	1.00
Long rod	1/2	1/3	0.85
Prolate ellipsoid	$\sqrt{3}/4$	1/5	1.22
Flat disk	$\sqrt{3/8}$	1/2	0.69
Oblate spheroid	$\sqrt{3/8}$	2/5	0.87

Probably of greater importance than the 10-20% differences implied from the table above is the threshold for catastrophic disruption. The equilibrium spin rate depends on this threshold, and it can be surmised that highly irregular bodies could be disrupted many times more easily than a spherical body of the same size and strength. If this is the dominant difference, then the equilibrium spin of an irregular body should be slower than for a comparable spherical body.

15.15

Asteroid Photomorphography

K. Lumme, M. Kaasalainen, L. Lamberg (University of Helsinki), E. Bowell (Lowell Observatory)

We have coined the word "photomorphography" to denote determination of the three-dimensional shape of a body from disk-integrated photometry. Attempts to derive the shapes of asteroids from their lightcurves date from Russell (*Astrophys. J.* **26**, 1, 1906), who gave a partial solution for the case of opposition geometry. More recently, Ostro and Connelly (*Icarus* **57**, 443, 1984) proposed a "convex-profile inversion" method to obtain an asteroid's average profile. We show that the shape can be uniquely determined (in the mathematical sense) provided the surface is an ovaloid (that is, convex and having no planar sections), that the asteroid's albedo is constant, and that the four-dimensional data (polar coordinate pairs for the directions of both the Sun and Earth) are sufficiently accurate and complete. The functional form of the light-scattering law need not be known. If albedo variegation is present, and if the functional form of the scattering law is known and is independent of the albedo, then both the shape and the albedo variegation can be recovered from the data.

Two independent mathematical techniques have been used. One utilizes certain limiting values obtained from the Laplace-Beltrami operator; the other makes use of spherical harmonics. The procedure of shape determination is carried out in two steps. First, the Gaussian curvature K is calculated from the lightcurve data; and second, the radius vector of the surface is derived from K. Unfortunately, even small errors in the data greatly affect K. In the second step, three linear, simultaneous partial differential equations must be solved. This is a fairly stable procedure. We present some examples and computer simulations of our photomorphographic techniques, and outline some ideal observational conditions for shape studies.

15.16

Why Do Meteorites Break Up at Low Stagnation Pressures?

R.S. Rajan (JPL/CalTech), D.O. ReVelle (N. Ill. U.)

It is well known that meteor fireballs break up at substantially higher altitudes than would be expected from static breaking strength considerations. We have developed a cumulative stress model which successfully explains this long-standing enigma. Our approach also allows a prediction to be made for the onset of fragmentation that can be directly tested.

In our model the key parameter is the cumulative stress which is obtained by integrating the stagnation pressure until the onset of fragmentation. We have used the data from the three photographed chondritic meteorites (Lost City, Innisfree and Pribram) to empirically calibrate the integral of the stress at the altitude of the initial break-up. The resulting average integral of $3.9 \pm 0.8\times10^6$ N/square meter, is in remarkable agreement with the values determined experimentally for the breaking strength of chondritic meteorites. Thus, it is not the instantaneous stress that controls the fragmentation process but rather its cumulative effect. Previously, the initial altitude of break-up in meteor fireballs has been commonly attributed to cracks/flaws within the bodies due to prior space collisions, but the meteorite samples that have been tested in the laboratory also contain cracks. The instantaneous stagnation pressures calculated at the initial break-up altitudes are about 20 times lower than the measured static breaking strengths of chondrites. Our approach has thus successfully resolved this discrepancy without solely resorting to cracks. Further, our approach explains conceptually why some objects successfully surpass the peak stagnation pressure region only to extinguish themselves at lower heights, either violently in a terminal flare event, or as a gradual fading of the light curve.

There are only 17 fireballs which have been previously identified as chondritic for which detailed luminosity data are available. All of these were examined in detail using our model and the fragmentation behavior was well predicted for 13 of them. The details of intercomparison between theory and observations will be presented at the meeting.

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15.17-P

CCD Observations of 2060 Chiron, 1984–1985

R. L. Marcialis (LPL/U. of Arizona)

The LPL CCD and University of Arizona 1.54 m Catalina Station telescope were used to observe 2060 Chiron on the nights of 1984 December 30, 31, and 1985 January 05, 17, 18, and 19. Most of the observations were performed at Johnson V, although some images also were obtained at R and I. Although the signal-to-noise ratio of the data set is insufficient to discern the light curve, nightly means can be determined to $\pm \lesssim 0^m.05$. Differential magnitudes are consistent with those measured by Bus *et al.* in 1987, however, further calibration of the comparison stars should be performed before quoting specific values.

Image profiles are consistent with a point source; no trace of coma is evident during the 1984–5 apparition. Apparently, Chiron was not in its "active" state at the time. Final reductions will be presented at the meeting.

THURSDAY