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DISRUPTION OF GIANT COMETS IN THE SOLAR SYSTEM AND AROUND OTHER STARS;

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In a standard cometary mass distribution ($(dN/dM) \propto M^{-a}$, $a = 1.5-2.0$) most of the mass resides in the largest comets. The maximum mass M_{max} for which this distribution holds uncertain but there are theoretical and observational indications that M_{max} is at least $\sim 10^{23}$g. Chiron, although formally classified as an asteroid, is most likely a giant comet in this mass range. Its present orbit is unstable and it is expected to evolve into a more typical short period comet orbit on a timescale of $\sim 10^{6}-10^{7}$yr. The breakup of a Chiron-like comet of mass $\sim 10^{23}$g could in principle produce $\sim 10^{5}$ Halley-size comets, or a distribution with an even larger number. If a giant comet was in a typical short period comet orbit, such a breakup could result in a relatively brief comet shower (duration $\lesssim 10^{6}$yr) with some associated terrestrial impacts. However, the most significant climatic effects may not in general be due to the impacts themselves but to the greatly enhanced zodiacal dust cloud in the inner Solar System. (Although this is probably not the case for the unique KT impact).

Clube and Napier (1) have previously emphasized the role of giant comets on the global climate. They assumed giant comets would undergo multiple splittings and considered the subsequent direct accretion of dust onto Earth's atmosphere. We have investigated a specific mechanism for breakup (tidal/thermal disruption of massive sun grazers) and the subsequent evolution of the debris into a thin disk taking into account collisions and PR drag. We find that the dominant climatic effect is the reduction of the solar constant by as much as 1-10% for $10^{2}-10^{3}$yr as the dust cloud collisionally relaxes to a thin disk. The frequency of such an event in the Solar System is highly uncertain but assuming $M_{max} = 10^{23}$g, $a = 1.8$, and that Chiron and the present sun grazers are not anomalous, we estimate $\sim 1/10^{7}$yr.

The occurrence and frequency of giant comet breakup may be testable by searching for the phenomenon around other stars. The amount of mass in the form of small grains that can be observed is often surprisingly small. To produce significant cooling on Earth the radial optical depth τ_R of the dust disk within 1AU must be $\gtrsim 10^{-2}$. The corresponding vertical optical depth τ_Z (= fraction of star's luminosity absorbed and reradiated by dust) is $\sim \tau_R \sin\theta$ where θ is the disk wedge angle. For $\theta \sim 0.1$rad, $\tau_Z \gtrsim 10^{-3}$. Values of τ_Z in this range are potentially observable (depending on average dust temperature) especially around hot low luminosity stars.

Numerous nearby main sequence stars (e.g. Vega, beta Pic) are observed in the far IR (12-100 μm) to have cool disks with τ_Z's in this range.(2) However, most of these disks are probably too massive and extensive and too cool to be related to giant comet breakup. Also, with the possible exception of ϵ - Eridanus, they all have large cleared central gaps within $\sim$ 10AU.

A more interesting possible candidate is the white dwarf Giclas 29-38 which has recently been found to have a 2-5 μm IR excess (3), corresponding to $\tau_Z \approx 2\text{x}10^{-2}$ if the excess is due to absorbed stellar luminosity. Modeling the excess as a single black body gives a temperature $\approx$1100K which is about the relevant sublimation temperature of silicates. The hot inner edge of the disk would be at $\approx 1R_\theta$ and the implied total observed mass of 1μm particles is only $\sim 10^{18}$g $\sim$ comet Halley. Zuckerman and Becklin (3) have interpreted the IR excess in terms of a brown dwarf companion, rejecting a dust disk on the basis of the short PR lifetime of $\sim 1\mu$m grains at $\approx 1R_\theta$. However, this argument is relevant only if there are no local sources of the observed small grains. This is not the case, for example, in the main sequence star disks noted above. If the WD excess is due to grains then the effective destruction timescale of these grains $\sim t_{coll} \sim t_{orb}/2\tau_Z \sim 10^{-2}$yr (which is shorter than the PR timescale). The required production rate is then 10^{18}g/10^{-2}yr = 10^{20}g/yr. Sources of total mass $\sim 10^{23}$g could produce grains at this rate for $\sim 10^{3}$yr.

We have used a least Chi square program with error analysis to confirm that the 2-5 μm excess spectrum of Giclas 29-38 can be adequately fitted with either a disk of small inefficient (or efficient) grains or a single temperature black body. Further monitoring of this star may allow discrimination between these two models. If present, it is highly likely that the transient dust disk is the result of giant comet breakup since there would be no chance that any primordial material anywhere near $\sim 1R_\theta$ would have survived the earlier red giant phase.

1. Clube, S. V. M. and Napier, W. M. (1984) Mon. Not. Roy. Astron. Soc. 208, 575.

2. Gillett, F. C. (1986) in Light on Dark Matter, ed. F. Israel, Reidel, Dordrecht, p. 61.

3. Zuckerman, B. and Becklin, E. E. (1987) Nature 330, 138.