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Table I. Estimated detectability of a gamma ray burst from the collision of a free comet with a neutron star

		low	typical	high
comet mass (g)		10^{15}	10^{18}	10^{21}
collision energy (ergs)		10^{35}	10^{38}	10^{41}
ergs cm^{-2} at neutron star		10^{22}	10^{25}	10^{28}
ergs cm^{-2} at detector at	10^0 pc	10^{-3}	10^{0}	10^{3}
	10^1	10^{-5}	10^{-2}	10^{1}
	10^2	10^{-7}	10^{-4}	10^{-1}
	10^3	10^{-9}	10^{-6}	10^{-3}
	10^4	10^{-11}	10^{-8}	10^{-5}
	10^5 pc	10^{-13}	10^{-10}	10^{-7}

The sensitivity of BATSE was about 10^{-7} ergs cm^{-2} (Meegan et al. 1992).

10^{38} ergs. For the range of comet masses cited above the energy can be 10^{35} to 10^{41} ergs. In Table I are listed the energy of the detected gamma ray burst for a range of comet masses and neutron star distances. The sensitivity of the Burst and Transient Source Experiment on the Compton Gamma Ray Observatory was about 10^{-7} ergs cm^{-2} (Meegan et al. 1992). Every comet collision is visible for nearby neutron stars. Large comet collisions are visible for neutron stars anywhere in the disk or halo.

Comet collisions can produce only short gamma ray bursts less than 1 or 2 seconds in duration with no measureable afterglow. Comet collisions have nothing to do with longer bursts, some of which have been shown to be produced by jets from massive supernovas (van Paradijs, Kouveliotou, & Wijers 2000; Mészáros 2002). Horváth (2002) has tried to distinguish the two classes in the BATSE data but at the 2s crossover it is difficult to determine the type of burst. I estimate from Horváth's figure that 1/4 of the gamma ray bursts are in the class of short bursts and that the count of the members of the class is in the hundreds from BATSE. No afterglow has been found for these bursts or other short bursts and their sources have not been identified. I propose that some or all of the bursts in the short burst class are formed by a free-comet collision with a neutron star in the halo or disk of our galaxy.

Kurucz (2000) predicts that the halo contains 10^{11} initial Population II neutron stars. These neutron stars rotate more slowly and have weaker magnetic fields than typical disk neutron stars because they have decayed for 15 billion years. Old neutron stars are discussed by Ruderman (1986). They may have no magnetic field. They may have accreted substantial atmospheres. In a comet collision the slower rotation and the mixing and heating of the atmosphere may reduce the radiative acceleration and prolong the cooling time to a fraction of a second. A nuclear deflagration of accreted hydrogen may also be possible. These collisions and the characteristics of old Population II neutron stars need to be studied in detail.

One comet collision per neutron star per hundred million years would account for the observed short gamma ray burst rate if every burst were visible. The collision rate might be a hundred times higher because most low mass collisions are not detectable. The location of the collisions in the halo accounts for the observed isotropy. As there are also many Population I neutron stars in the disk, say 10^9, and more free comets, say 10^{21} to 10^{23}, there should be a increase (guess 10%) in the number of short bursts in the plane of the disk. These will become apparent when the number of short bursts mapped exceeds 1000. The disk bursts have physics different from the halo bursts.

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The thickness is great enough to have low inclination Population II neutron stars orbiting "in" it for part of their orbits as well as having high inclination Population II neutron stars passing "through" it.

Free comets can lose mass when they experience near-collisions with stars that break them into smaller comets and with strong radiation fields that can evaporate their surfaces. New comets with the whole range of masses are continually being added to the free comets in the disk and from there scattered to the galactic Oort cloud. The current mass distribution in the galactic Oort cloud is the result of integration over 10^{10} years.

There are probably very few Population II comets mixed into the galactic Oort cloud because the low metal abundances did not provide enough raw material when the Population II stars formed.

I hope that experts on comet dynamics will perform detailed calculations for free comets and for a Galactic Oort cloud.

II. GAMMA RAY BURSTS

The direct collision of a comet with a neutron star produces a gamma ray burst (Harwit & Salpeter 1973; Whipple 1975). No one has computed the case of a 15 billion-year-old, run-down Population II neutron star colliding at high velocity with a Population I comet in the halo. I hope to interest experts in making sophisticated collision models that include as much physical detail as possible. For a qualitative example that can indicate the length and energy of the burst, not the actual physical mechanism, I cite Colgate and Petschek (1981) who did simple calculations for a rapidly rotating Population I neutron star both with and without a strong magnetic field. As it nears the neutron star, tidal forces squeeze the comet into a plume 60 times longer than its original diameter. When the comet finally hits the surface of the neutron star at a speed of about 10^5 km s^{-1}, this lengthening prolongs the collision time by a factor of 60 to about 1 ms. In the case of no magnetic field the comet paints the surface of the spinning neutron star and rapidly radiates away its kinetic energy. Colgate and Petschek assumed that this process would not work because radiative acceleration would blow off the fresh material and that the blow off would take away most of the kinetic energy of the comet leaving little to appear as gamma radiation. However they did not perform detailed calculations or consider mixing of the comet material with the "atmosphere" of the neutron star. Colgate and Petschek went into more detail in the case where the neutron star has a strong magnetic field so that the hot matter is confined and compressed in flux tubes. Regardless of the details of the mechanism it is possible to order-of-magnitude estimate the energy for 100% conversion to gamma radiation. It is unlikely that the efficiency can be less than 10% no matter what the process is. If the radius of the neutron star is 10 km and its mass is solar, the energy released is $0.5\text{x}10^{-6}\text{GM}_{\odot}\text{M}_{comet}$ ergs. A neutron star can be a factor of 2 larger or smaller. For a typical comet mass of 10^{18} g, the energy is

GAMMA RAY BURSTS PRODUCED BY FREE COMETS

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ABSTRACT

I estimate that the Galactic halo contains between 10^{20} and 10^{22} free Population I comets and 10^{11} initial Population II neutron stars. Collisions of comets with neutron stars produce sub-second gamma ray bursts that would be isotropically visible from the earth.

Subject headings: comets — stars: neutron — gamma rays: bursts

I. FREE COMETS

The Oort cloud that surrounds our solar system contains about 10^{12} comets in a sphere with radius about 10^5 AU or 0.5 pc (Oort 1990, Weissman 1986). The comets we see have been ejected from the Oort cloud through some perturbation or collision and have fallen inward where we can observe them. Typical new comet masses range from about 10^{15} g to 10^{21} g (cf. Bailey, Clube & Napier 1990). My colleague Marsden (1992) reports a dearth of smaller new comets. In our anthropocentrism, we tend to ignore the comets from the Oort cloud that have completely escaped from the solar system, which are more numerous than the comets that are still bound. Stern and Shull (1990) have discussed these comets as a source of metals for the interstellar medium. To get a lower population estimate of the escapees in the galaxy, the free comets, assume that the Sun is a typical star and that our Oort cloud is a typical feature surrounding Population I F and G stars. In the 10 billion or so years since the disk was formed there have been, say, 10^9 such stars, and 10^{21} free comets. For a high limit guess that Oort cloud formation is a universal feature of Population I star formation, that there have been, say, 10^{11} Population I stars, and that some Oort clouds are 10 times larger or smaller than ours, but that the average is 10^{12}, so that the number of free comets is 10^{23}. Comets fill the disk of the galaxy. During the last 10 billion years possibly 10% of the free comets have scattered up into the halo and now form a thin oblate ellipsoidal system, the Oort cloud for the galaxy. This scattering is qualitatively similar to the formation of our Oort cloud shown in the computer simulation by Duncan, Quinn, and Tremaine (1987). As a star ages its Oort cloud relaxes from a disk into an ellipsoid becasuse of interactions with the giant planets. Stars and planets in the galactic disk can scatter free comets to high velocity so that they also form an ellipsoid. My guess is that the Galactic Oort cloud has a thickness of 10Kpc and contains between 10^{20} and 10^{22} free Population I comets.

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