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Light from Shattered Worlds: Debris from Giant Impacts

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Abstract. Large impacts in the outer parts of a planetary system will produce debris discs that display a strong, distinctive, asymmetry, which will last for 10^5 year timescales. Debris resulting from a large impact may be able to explain the asymmetries in some known debris discs that have hitherto been difficult to understand.

Keywords. circumstellar matter, planetary systems, planetary systems: formation

1. Introduction

Impacts between planetary embryos drive the final stage of terrestrial planet formation (Kokubo & Ida 1998). Impacts can be erosive or destructive (Agnor & Asphaug 2004), and even efficiently accreting impacts produce debris equal to $\gtrsim$1 per cent the mass of the colliding bodies. Giant impacts occur not only in the terrestrial zone but anywhere in a planetary system; Pluto-Charon (Canup 2011) and Haumea (Brown *et al.* 2007) in the Kuiper belt are both believed to have experienced large impacts. Debris production through giant impacts is thus an implicit component of planetary system formation.

Jackson & Wyatt (2012) showed that debris produced in a Moon-forming like event around a nearby star should be detectable for tens of millions of years by typical *Spitzer* 24μm surveys. Detectable lifetime varies with the size of the largest fragments, but is over a million years even if these are only a few kilometres in size. The Moon-forming impact is a fairly low debris production event (Stewart & Leinhardt 2012), and thus this is a reasonable baseline level of expected debris from planetary scale giant impacts. In the outer reaches of a planetary system orbital timescales are much slower, and collision velocities generally lower, and as such the lifetime of a debris disc of constant mass will increase as its semi-major axis is increased. Debris discs resulting from giant impacts in the outer reaches of a planetary system may thus be very long lived.

2. Disc morphologies

Since all debris fragments in a giant impact debris disc are produced at the original impact point, the orbits of these fragments must, at least initially, pass through the impact point. As a result the disc will have a strong asymmetry, which lasts for typically around 1000 orbits before precession of the debris orbits smears it out. In the terrestrial zone this leads to asymmetry lifetimes of $\sim$1000 years, but in the outer regions the asymmetry can last for over 10^5 years and, around a nearby star, can be readily resolved by modern instruments.

In Fig. 1 we show an example of a debris disc produced by an impact at 85AU from the host star, both face-on and at several edge-on viewing angles, at 10^5yr after the impact. Dynamical evolution is followed using the MERCURY N-body package (Chambers 1999). The width of the debris ring is controlled by the velocity dispersion of the debris, in Fig. 1 we use an isotropic dispersion of 4 km s^{-1}; appropriate for roughly Mars size impactors. The progenitor is assumed to have been on a circular orbit. We also assume there are no massive (∼Jupiter mass) planets nearby, but they may exist elsewhere in the system, e.g. the $7M_J$ β-Pic. b at 8.5 AU, without disrupting the disc. Bodies equivalent to the impactors can exist within the disc itself. These could be additional members of a primordial population, or the largest remnants of the impact.

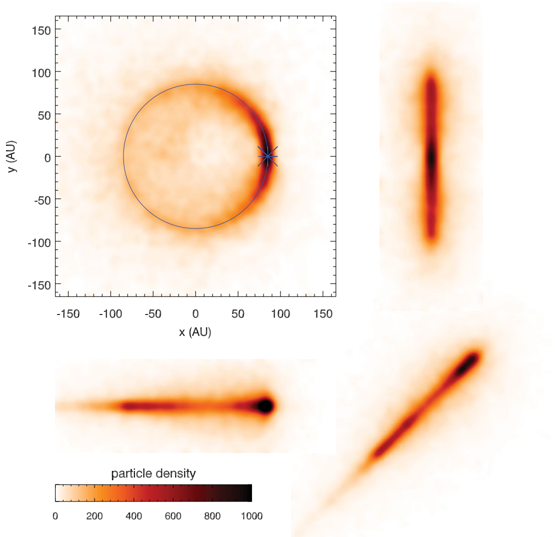

Figure 1. Images of a debris disk generated by a giant impact occuring at 85AU from the host star at 10^5yr after impact. Resolution is 10AU (0.5" at 20pc). At top left we show a face-on view of the disk, with impact-point and progenitor body orbit indicated. Arranged around this we show edge-on views of the disk. Clockwise from top right the lines of sight are at 0°, 45°, and 90° to the impact-point – star line. Spatial and colour scales are consistent between images, with the exception that the density in the face-on image is enhanced by a factor of 2 to aid visibility.

For impacts in regions where ambient temperature is below 50K and bodies contain significant quantities of CO ice, collisional grinding at the impact point may also produce a comet-like tail of CO gas that decays as it moves away from the impact point due to photo-dissociation, producing an even stronger asymmetry.

3. Conclusions

Dust from giant impacts is bright and detectable for ten million year timescales. Impacts in the outer reaches of a system will display distinctive asymmetries that last for 10^5 year timescales and can be resolved around nearby stars. A number of known debris discs, such as the well known disc of Beta Pictoris, display large asymmetries that may be explainable as the result of a large impact, and with new facilities such as ALMA the number of such discs is only likely to increase.

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