A hypothesis of space debris removal

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Abstract

Satellites with a laser could hit space debris to reduce the debris velocity using the photons impulse, without ablation.

A method to reduce the space debris is use solar panels, on satellites in the space, to power a laser to hit with photons a single space debris.

A space debris in geostationary orbit has a velocity of $3 \cdot 10^3$m/s, so that the kinetic energy of a 1kg debris is $4.5 \cdot 10^6$J; a 3kW solar panel in a day give an energy of $2.6 \cdot 10^5$J, so that the time necessary to reduce a zero the energy of the 1kg debris is 17.4 days; the total time of emission must be minor to obtain an impact with the atmosphere: this is true if the laser strike the debris against the direction of the motion (this is an estimate of the entry time, in the Compton effect appendix there are the true value of power absorption), and if there is not a reflected photons (the reflected photons reduce the time for the atmospheric entry because of the increase change of the momentum).

Some laser satellites could collectively reduce space debris, transmitting to each other the information of the diverted debris, and hitting the same space debris in the orbit; if the direction of emission is the same of the absorption, then the laser satellite maintains the geostationary orbit.

The problem is the melting of the debris because of the laser power (the power is of the order of magnitude of laser cutter). The problem could be solved if there is an initial measure of frequencies that give the maximum reflectance (reducing the absorbed energy and obtaining the maximum impulse on the debris): the time for the atmospheric entry could be halved, and the debris should be not melted by the laser.

Compton effect

The Compton scattering for the debris and the photon, if the photon is emitted, and adsorbed, in the direction of the motion is (in the rest frame of the debris):

$$\begin{cases} h\nu = pc + h\nu' \\ h\nu + mc^2 = h\nu' + \sqrt{p^2c^2 + m^2c^4} \end{cases}$$
$$h(\nu - \nu') + mc^2 = \sqrt{h^2(\nu - \nu')^2 + m^2c^4}$$
$$h^2(\nu - \nu')^2 + m^2c^4 + 2mhc^2(\nu - \nu') = h^2(\nu - \nu')^2 + m^2c^4$$
$$2mhc^2(\nu - \nu') = 0$$
$$\nu = \nu'$$

so that there is not a scattering

$$\begin{cases} h\nu = pc + h\nu' \\ h\nu + mc^2 = \delta + h\nu' + \sqrt{p^2c^2 + m^2c^4} \end{cases}$$
$$h(\nu - \nu') + mc^2 - \delta = \sqrt{h^2(\nu - \nu')^2 + m^2c^4}$$
$$h^2(\nu - \nu')^2 + m^2c^4 + 2mhc^2(\nu - \nu') - 2\delta h(\nu - \nu') - 2\delta mc^2 + \delta^2 = h^2(\nu - \nu')^2 + m^2c^4$$
$$2mhc^2(\nu - \nu') - 2\delta h(\nu - \nu') - 2\delta mc^2 + \delta^2 = 0$$
$$\nu' = \nu - \frac{\delta(2mc^2 - \delta)}{2h(mc^2 - \delta)}$$

so if there is an energy absorption from the debris (thermal, vibration, etc.), then the scattering without deviation is possible

$$\begin{cases} h\nu = pc - h\nu' \\ h\nu + mc^2 = h\nu' + \sqrt{p^2c^2 + m^2c^4} \end{cases}$$
$$h(\nu - \nu') + mc^2 = \sqrt{h^2(\nu + \nu')^2 + m^2c^4}$$
$$m^2c^4 + 2mhc^2(\nu - \nu') + h^2(\nu - \nu')^2 = h^2(\nu + \nu')^2 + m^2c^4$$
$$mc^2(\nu - \nu') - 2h\nu\nu' = 0$$
$$mc^2\nu - mc^2\nu' - 2h\nu\nu' = 0$$
$$\nu' = \frac{\nu}{1 + 2\frac{h\nu}{mc^2}}$$

this is a scattering with total reflection, that is the minimum energy of the deflected photon, and the maximum energy transfer to the debris.

The complete photon conversion in momentum is not possible:

$$-\lambda = \frac{h}{mc^2}(1 - \cos\theta)$$
$$\cos\theta = 1 + \frac{\lambda mc^2}{h} = 1 + \frac{mc^3}{h\nu}$$