Big black holes cook flambéed stellar pancakes (Forwarded)

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- *From*: Andrew Yee <ayee@xxxxxxxxxxxxxxxxxxxxxxx>
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Observatoire de Paris
Paris, France

Contact:
Jean−Pierre Luminet
Observatoire de Paris, LUTH and CNRS
Tél: 33 1 45 07 74 23 Fax: 33 1 45 07 79 71

Matthieu Brassart
Observatoire de Paris, LUTH and CNRS
Max−Planck−Institut für Astrophysik, Garching
Tél: 33 1 45 07 78 91 Fax: 33 1 45 07 79 71

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Big black holes cook flambéed stellar pancakes

According to two astrophysicists from Paris Observatory, the fate of stars that venture too close to massive black holes could be even more violent than previously believed. Not only are they crushed by the black hole's huge gravity, but the process can also trigger a nuclear explosion that tears the star apart from within. In addition, shock waves in the pancake star carry a brief and very high peak of temperature outwards, that could give rise to a new type of X−ray or gamma−ray bursts.

Scientists have long understood that massive black holes lurking in galactic nuclei and weighing millions of Suns can disrupt stars that come too close. Due to intense tidal forces, the black hole's gravity pulls harder on the nearest part of the star, an imbalance that pulls the star apart over a period of hours, once it gets inside the so−called "tidal radius".

Now, Matthieu Brassart and Jean−Pierre Luminet of the Observatoire de Paris (section of Meudon), France, say the strain of these tidal forces can also trigger a nuclear explosion powerful enough to destroy the star from within. They carried out computer simulations of the final moments of such an unfortunate star's life, as it penetrates deeply into the tidal field of a massive black hole.

When the star gets close enough the black hole (without falling into), the tidal forces flatten it into a pancake shape. Previous studies already performed by Luminet and collaborators twenty years ago had suggested this flattening would increase the density and temperature inside the star enough to trigger intense nuclear reactions that would tear it apart. But other studies had suggested that the picture would be complicated by shock waves generated during the flattening process, and that no nuclear explosion should occur.

The new simulations investigate the effects of shock waves in detail, and find that even when their effects are included, the conditions favour a nuclear explosion which will completely destroy the star, and which will be powerful enough to hurl much of the star's matter out of the black hole's reach.

Stellar fireworks

The tidal disruption of stars by black holes may already have been observed by X−ray telescopes such as GALEX, XMM and Chandra, although at a much later stage: several months after the event that rips the star apart, its matter starts swirling into the hole, heats up and releases ultraviolet light and X−rays. However, if pancake stars really do explode, then they could in principle allow these events to be detected at a much earlier stage. Future observatories, such as the Large Synoptic Survey Telescope (LSST), which will detect large numbers of supernovae, could turn up some explosions of this type.

But this might be not the only hazard facing the doomed star. Brassart and Luminet calculated that the shock waves inside the stellar pancake carry a brief (< 0.1 s) but very high (above 10**9 K) peak of temperature outwards from the centre to the surface of the star. This last result is very promising since it could give rise to a new type of X−ray or gamma−ray burst, making it possible to see the disruption of the star immediately if it gets hot enough.

The rate of such 'flambeed pancake stars' is estimated to about 10**−5 event per galaxy. Since almost every galaxy −− including our own Milky Way −− harbors a massive black hole in its centre, and since the universe is transparent to hard X and gamma radiation, several events of this kind per year should be detectable within the full observable universe.

Conclusion

The planned high−energy, all−sky surveys are the best suited to detect more flares of this type because of their large sky coverage. By providing a quick localization of flambeed stellar pancakes, followed by the detection of the corresponding afterglows in the optical, infrared, and radio bands, these missions could bring as much to the understanding of stellar disruptions by black holes as the Beppo−Sax and Swift telescopes did for the comprehension of gamma−ray bursts. References

[1] Shock Waves in Tidally Compressed Stars by Massive Black Holes, M. Brassart & J.−P. Luminet, Astron. Astrophys. 481 (2008) 259−277

[2] For a popular account of tidal disruption and massive black holes, see also J.−P. Luminet, Le destin de l'univers: trous noirs et énergie sombre, Fayard (Paris, 2006), chap. 21

IMAGE CAPTIONS:

[Figure 1:
http://www.obspm.fr/actual/nouvelle/may08/crepe−f1_en.gif (99KB)]
The disruption of a star by the tidal forces of a massive black hole. The diagram illustrates the progressive deformation of the star when it plunges deep inside the so−called 'tidal radius' (the size of the star has been considerably enlarged for clarity).

The upper view shows the deformation of the star in its orbital plane (seen from above), the middle view shows the deformation in the perpendicular plane (seen from the side), and the lower view depicts the magnitude of flattening. From (a) to (d) the tidal forces are weak and the star remains practically spherical. At (e) the star penetrates the tidal radius and is doomed to be destroyed. First it become cigar−shaped, then from (e) to (g) the squeezing of the tidal forces flattens the star in its orbital plane to the shape of a pancake. Next the star rebounds, and as it leaves the tidal radius in (h), it starts to expand. A little further on its orbit the star finally breaks up into gas fragments. Detailed hydrodynamical simulations taking account of shock waves have been performed during the crushing phase (e) to (g). © J.−P. Luminet

[Figure 2:
http://www.obspm.fr/actual/nouvelle/may08/crepe−f2.gif (18KB)]
Increase in central temperature (in units of initial temperature T* = 10**7 K) for pancake stars penetrating within the tidal radius by factors respectively 7, 10, 12 and 15. Time is in seconds, t = 0 corresponds to the passage of the star at the closest distance from the black hole. The maximum central temperature increases as the square of the penetration factor.

[Figure 3:
http://www.obspm.fr/actual/nouvelle/may08/crepe−f3.gif (11KB)]
Evolution of the stellar temperature (in eV ~ 10**4 K) as a function of time (in seconds) in case of a deep plunging. The solid red line corresponds to the temperature at the centre of the star. The dashed line corresponds to the increase in temperature (up to 10**9 K) produced by the shock wave as it propagates outwards. The duration at half maximum of the peak of temperature at the shock front is only 0.05 sec.

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