PUBLISHED: 2 MARCH 2017 | VOLUME: 1 | ARTICLE NUMBER: 0068

news & views

BLACK HOLES

Crime in search of a crime scene

The destruction of stars by supermassive black holes appears to be rarer than predicted. A candidate stellar disruption in a kind of galaxy that is usually obscured may explain why.

James Guillochon

While black holes were theoretically predicted a century ago and have been observed indirectly over the same period of time, the stunning discovery of two merging black holes announced by the LIGO collaboration in 2015 removed all doubt that black holes exist[1]. These merging black holes were weighed by LIGO to be a few tens of solar masses each, an impressive heft until one considers that the black holes residing at the centres of galaxies can weigh up to tens of billions of solar masses[2]. Because of their great gravitational attraction, massive black holes are directly orbited by stars that move at velocities that approach the speed of light for the most tightly-bound stars. Numerous interactions with other stars can shift stellar paths into directions that bring them perilously close to their host black hole. The tidal radius is the critical distance where the gravitational force exerted by the black hole exceeds the star's own gravity. When a star crosses this boundary, it is disrupted violently, often stretching into a long strand that extends large distances.

This disruption process would not only destroy the star, but also bind roughly half of its mass to the black hole, where the matter would be rapidly consumed[3]. As the stellar matter spirals in, the gas heats dramatically and powers a luminous flare, observable from billions of light years away[4]. Many physical processes ebb and wane in importance over the duration of the event, producing complex three-dimensional structures that are amongst the most spectacular displays in nature. Candidate disruptions have now been observed several dozen times over the past two decades (https://tde.space), confirming that black holes regularly destroy and accrete the stars that orbit them. Writing in *Nature Astronomy*, Clive Tadhunter and collaborators[5] present the discovery of a candidate stellar disruption in a massive galaxy that is vigorously forming stars (illustrated). This is an environment that had not yet been observed to host such events, but may be one of the most common locations in which stars are destroyed by tidal forces.

An illustration of a starburst galaxy that is vigorously forming stars and contains large amounts of gas and dust. A clear line of sight allows us to peer into the centre of this galaxy where the tidal disruption of a star by the supermassive black hole residing there is taking place.

The exact mechanics of stellar disruptions remain a subject of debate. In particular, concerns focus on how frequently a disruption might be luminous and short enough in duration to be caught by current observatories[6]. This uncertainty has been amplified by the deficit of stellar disruptions observed; we have only discovered about one-tenth as many disruptions as theoretically anticipated[7,8]. More perplexing still, the disruptions we have observed seem to occur mostly in the particularly rare 'post-starburst' galaxy type (in which star formation has ceased in the last few hundred million years[9]). Only ~1% of galaxies in our local neighbourhood belong to this class. If this type of galaxy dominates as the primary source of stellar disruptions it would indicate a star disruption rate tens to hundreds of times greater than the average galaxy[10]. Such an enhancement is difficult to understand theoretically, as this would require violent dynamical processes to occur within the galaxy — which is unlikely to be happening in most post-starburst galaxies.

The discovery by Tadhunter *et al.*[5] suggests that perhaps the post-starburst disruptions we are witnessing are only the tip of the iceberg when it comes to stellar disruptions. Stars form by condensing out of clouds of gas and dust that are delivered to galaxies over their lifetimes. Starburst galaxies are the most fecund star formers, producing stars at a rate that is hundreds of times greater than that of our own Milky Way. But such a high production rate often means that these galaxies contain so much gas and dust that they are incredibly opaque, obscuring even powerful supernovae that occur within them from optical telescopes. Being at their centres, supermassive black holes are amongst the most obscured objects within these galaxies, with potentially hundreds of millions of solar masses worth of gas and dust between them and our detectors[11]. Yet due to motions of the gas and dust, a starburst galaxy occasionally permits us to glimpse directly into its centre. This is undoubtedly what must have happened to enable the observation of the stellar disruption candidate by Tadhunter and colleagues.

Starburst galaxies may have been disfavoured in prior searches for tidal disruptions as they have a high potential to produce luminous flares, 'impostor' disruptions, by other means. The two greatest sources of concern for impostors are supernovae, which can occur several times per year in such galaxies, and variable accretion by the supermassive black holes of the abundant gas reservoirs that surround them. But the event that Tadhunter *et al.* present is significantly more luminous than most supernovae, being brighter than 99% of them, and presents features in its spectra that greatly resemble previously discovered tidal disruption flares; these lines of evidence strongly suggest that Tadhunter *et al.* have observed the disruption of a star.

Because the majority of black holes in starburst galaxies are heavily obscured, the discovery of even one disruption suggests that the true disruption rate in such galaxies could be immense, with stars being disrupted potentially once per decade. This implies that the presently observed post-starburst disruption excess may simply represent the 'tail' of the process that is ultimately responsible for what may be an ultra-high rate in starburst galaxies. Candidates for such a process include the violent relaxation of the stars surrounding the black hole by the infalling gas, or, perhaps more excitingly, the merger of two supermassive black holes, which has been predicted to be presaged by a period where the stellar disruption rate greatly increases[12]. With the future launch of the LISA mission, which will complement LIGO by being sensitive to the gravitational waves emitted during the mergers of supermassive black holes, we may finally locate the primary sites of disruption in the local Universe, giving us the ability to predict where the next stellar disruption is most likely to occur. ❐

James Guillochon is at the Harvard-Smithsonian Center for Astrophysics, 60 Garden St, Cambridge, Massachusetts 02138, USA.
e-mail: jguillochon@cfa.harvard.edu

References

1. Abbott, B. P. *et al.* (LIGO Scientific Collaboration & Virgo Collaboration) *Phys. Rev. Lett.* **116**, 061102 (2016).
2. Thomas, J. *et al. Nature* **532,** 340–342 (2016).
3. Rees, M. J. *Nature* **333,** 523–528 (1988).
4. Bloom, J. S. *et al. Science* **333,** 203–206 (2011).
5. Tadhunter, C., Spence, R., Rose, M., Mullaney, J. & Crowther, P. *Nat. Astron.* **1,** 0061 (2017).
6. Guillochon, J. & Ramirez-Ruiz, E. *Astrophys. J.* **809,** 166 (2015).
7. van Velzen, S. & Farrar, G. R. *Astrophys. J.* **792,** 53 (2014).
8. Stone, N. C. & Metzger, B. D. *Mon. Not. R. Astron. Soc.* **455,** 859–883 (2016).
9. Arcavi, I. *et al. Astrophys. J.* **793,** 38 (2014).
10. French, K. D., Arcavi, I. & Zabludoff, A. *Astrophys. J. Lett.* **818**, L21 (2016).
11. Mirabel, I. F. & Sanders, D. B. *Astrophys. J.* **335,** 104–121 (1988).
12. Chen, X., Sesana, A., Madau, P. & Liu, F. K. *Astrophys. J.* **729,** 13 (2011).