ASTROPHYSICS

Blasts from the past

The coalescence of neutron stars in compact binaries could produce the intense, short flashes of high-energy radiation observed in gamma-ray bursts. Models suggest that dynamical evolution in old dense stellar clusters, rather than galaxies, may form many of these rare systems.

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We have known about gamma-ray bursts (GRBs) — brief but extremely intense flashes of high-energy radiation — for several decades[1]. GRBs are divided into two distinct phenomenological types: the 'short-hard' and 'long-soft' types, with the former characterized by emission lasting less than 2 s and a hard, or energetic, photon spectrum. On page 116 of this issue[2], Grindlay and co-workers propose a possible source for these short GRBs.

In the last decade, observations by space missions such as BeppoSAX and Swift have revealed their source to be the relativistic collimated fireballs that are emitted as rapidly rotating black holes form[3–5]. A common theme in gamma-ray bursts is the interaction of strongly relativistic collimated outflows with surrounding matter. To produce such highly energetic events requires the conversion to electromagnetic radiation of an amount of matter comparable to a significant fraction of a solar mass — on a timescale short enough to require the engine to be confined to a region smaller than a solar radius. This naturally leads to the speculation that a common 'central engine' for the process is the formation of a low-mass black hole — possibly a very rapidly rotating black hole.

There were multiple hypotheses for the origin of long GRBs before the discovery of the first optical counterpart to a long GRB in 1997 (previous viewings had been at X-ray and gamma-ray energies) revealed their association with extreme supernovae in star-forming galaxies at cosmological distances. Until 2005, however, no counterpart to short GRBs had been localized, and their source engine was open to speculation. Subsequently, observations by Swift and another space mission, HETE have localized several short GRBs within old quiescent galaxies in the local universe, strongly supporting the model for their origin in the coalescence of a neutron star with either another neutron star or a low-mass black hole, bound to it in a compact binary[6,7]. Forming such compact binaries through stellar evolution is difficult, and Grindlay and collaborators conjecture that a substantial fraction of the observed short GRBs come from double-neutron-star (DNS) binaries that are dynamically modified in the crowded stellar environment of globular clusters[7].

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Figure 1 Ancient neighbour. About 40,000 light-years from Earth lies M15, also known as NGC 7078 in the Pegasus constellation, one of the brightest globular clusters in the Milky Way. Among the first objects in our galaxy to form, some 12 billion years ago, the crowded conditions within M15 could be just right for the merging of double-neutron-star binaries.

Several DNS binaries are known in the Milky Way galaxy, one of which is in the globular cluster M15 (Fig. 1). Globular clusters are old (11–13 billion years), dense stellar systems of typically several hundred thousand stars. There are a couple of hundred globular clusters, containing about 0.1% of all the stars in the Milky Way, and the abundance of DNS binaries — and other similar unusual compact stellar systems — is a hundred times larger than in the 'field' of the galaxy. The overabundance of rare stellar binaries in globular clusters has long been known to be due to the dynamical evolution of stellar systems in these densely packed systems. Encounters between stars and binaries lead to changes in membership and orbital parameters, with a tendency to form compact, tightly bound systems with degenerate stellar remnant members. Globular clusters can then produce exotic stellar systems, such as tight DNS binaries, with an abundance two orders of magnitude higher than that found in dynamically isolated stellar systems. Once a DNS forms with — or is dynamically moved to — a short-enough orbital-period system, gravitational radiation emission drives the binary to coalescence on a timescale of few hundred million to few billion years[8,9].

Grindlay *et al.* show through numerical models that the expected rate of production of DNS binaries in the globular clusters in the local universe is consistent with them producing 10–30% of the observed short GRBs[2]. This scenario predicts an observable difference in the distribution of short GRBs between different galaxy types in the local universe, and a distinct difference in the 'lag time' between the formation of the stars and their final coalescence. With a large number of well-localized short GRBs and associated counterparts expected from Swift over the next few years, this model will be stiffly tested. The model also predicts a distinct difference in the beaming angle, and hence detectability and energetics, of the GRBs from dynamically modified DNS binaries, compared with those formed in isolation. As coalescing compact binaries are also a prime source for the LIGO gravitational radiation observatories (located at Livingston, LA, and Hanford, WA, USA), future observations of gravitational radiation bursts in the local universe may provide an additional test of these theories.

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