THE CRAB NEBULA AND OTHER ANOMALOUS ASTROPHYSICAL ARTHROPODS

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1. Supernovae and Their Remnants

The Crab Nebula is expanding and its pulsar is slowing down, both on time scales that indicate some very interesting real-time stellar evolution must have occurred about 1000 years ago, as indeed we know from Chinese and other ancient records. The Crab was, in fact, the first SNR to be confidently identified as such and to have its expansion rate measured and the first pulsar to have its first and second time derivatives measured. Among the interesting related details are (a) the current expansion is a bit faster than the average since the 1054 explosion, indicating outward pressure from the relativistic electrons and magnetic field responsible for the synchrotron emission, (b) some of the central synchrotron emission features wiggle and oscillate around at much larger speeds than the expansion but in a non-secular way, (c) the braking index of the pulsar is about 2.5 rather than 3.0 (as predicted for a pure magnetic dipole emitter), (d) energy is conserved (it wasn't obviously so before 1968), in that the pulsar is losing rotational kinetic energy fast enough to keep up the supply of optical and X-ray emitting electrons, and (e) glitches in the slowing of the pulsar (for which data go back to a 1964 balloon flight) indicate complex coupling of crust to interior, presumably a magnetic one.

Many other supernova remnants show net outward motion (for instance as revealed by radio images of Cas A) on time scales like their ages. Some also have slower moving features, presumably a result of pre-SN mass loss. The very interesting case of SN 1987A (which has both of these and other activity as well, but no pulsar yet) is presented here in Nomoto's paper.

Other recent advances in our understanding of supernovae include (a) two- and three-dimensional calculations of core collapse and neutrino propagation in evolved massive stars, which indicate that neutrino-driven turbulence, Rayleigh-Taylor instabilities, and convection can probably eject the outer layers of the star (thus solving the longstanding problem that one-dimensional models usually didn't explode) and (b) possible identification of SN Ia progenitors in the form of supersoft X-ray sources (see paper by Kahabka in proceedings of JD18), whose accreting stars are quite massive white dwarfs that do not seem to expel as much material as they accrete (thus solving the ancient problem that we knew SN Ia progenitors had to be white dwarfs driven above the Chandrasekhar limit somehow, but could not find any real binary or single stars that would do it).

J. Andersen (ed.), Highlights of Astronomy, Volume 11A, 366.