The pulsar inside SN1987A

SIR—The discovery[1] of a pulsar inside the remnant of supernova 1987A is not in itself surprising. The initial neutrino burst[2,3] suggested the formation of a neutron star, and the low-energy X-ray flux (6–16 keV) observed by Ginga[4] has been interpreted as evidence for an active pulsar. Apart from fluctuations on timescales of days, the soft X-ray flux has remained constant at about 6×10^{36} erg s^{-1} since its first appearance in January 1988 (Y. Tanaka, personal communication). The harder emission, above 20 keV, has declined in the past few months[5], in accordance with the radioactivity model[6].

We have suggested that the soft X-ray flux could be synchroton emission from a non-thermal nebula, fed by the remnant pulsar at a rate of about 10^{38} erg s^{-1} in the form of relativistic particles and magnetic field[7,8]. The emission could be detected if the supernova envelope had undergone early fragmentation, shortly after the explosion. The pulsar input would amount to a significant fraction of the present bolometric luminosity of the supernova, and deviations in the decay of the light curve should be expected: preliminary indications of an extra energy input may already be available[8].

The finding of the pulsar lends strong support to these ideas. The properties of the pulsar, however, are rather surprising, especially its extremely short period and the small value of the surface magnetic field.

The strength of the magnetic field at the light cylinder radius, $\sim 2.4 \times 10^6$ cm, where field lines corotating with the pulsar would move tangentially at the speed of light, is bracketed by the requirements that the electromagnetic energy output be less than SN1987A's present bolometric luminosity, 2.1×10^{38} erg s^{-1}, and more than the pulsed optical luminosity, 6.4×10^{35} erg s^{-1}. Thus 2.3×10^6 G $< B <$ 4.2×10^7 G, corresponding to a surface field between 3.3×10^7 and 6×10^8 G if dipolar geometry is assumed.

The SN1987A pulsar thus belongs to the class of weakly magnetized, rapidly rotating objects for which a 'recycling' scenario is accepted as canonical. Clearly, we have here first-hand evidence that at least some objects of the class are 'primordial'[10]. One may then wonder about the size of the millisecond pulsar population, because a new production mechanism has been found and since the radio surveys performed so far have not covered adequately the submillisecond range. Also, we note that, if pulsars such as this one are born frequently, their magnetic field cannot be amplified up to 10^{12} G later on by thermoelectric instabilities[11], because this would entail a huge, delayed release of rotational energy, for which we have no astrophysical evidence.

In the discovery observations a weak sinusoidal modulation of the pulsar frequency is noted. If confirmed and interpreted at face value as evidence for a binary companion, the modulation would imply a companion mass of $\sim 10^{-3}$ times the mass of the Sun. At any rate, whether the claimed modulation is real or only an upper limit, the interpretation that the soft X-rays from SN1987A result from accretion[12] appears unlikely.

Concerning the nature of the optical radiation mechanism, we note that the brightness temperature of the observed pulses, even including the entire speed-of-light surface, corresponds to an electron Lorentz factor of at least 1.6×10^4, whereas the Lorentz frequency in the minimum magnetic field is already 6×10^{12} Hz. Then, in order to satisfy the thermodynamical constraint, one has to invoke either synchrotron radiation by protons, or by coherent processes, or, perhaps, electron synchrotron radiation well beyond the speed-of-light distance.

Another puzzle concerns the variations observed in the average pulsar optical luminosity. One could imagine a single physical cause for them and for the 8-h period of the frequency modulation, if the latter is confirmed. More likely, they could be attributed to the effect of the inhomogeneous nebular medium, in the same way as postulated for the fluctuations of the soft X-ray flux[7,8]. Although homogeneous models of the supernova envelope become transparent to optical radiation a few months after the explosion[13], the optical spectra of SN1987A still show clear signs of opacity effects, probably due to bound–bound and bound–free transitions of metals (E. Oliva, personal communication); if the envelope material is clumpy, and if the clumps have some non-radial motion, temporary occultations of the pulsar are a reasonable possibility.

Finally, we recall that a rotation frequency of 2 kHz is close to the hard limit of the virial theorem, and strains the predictions of certain stellar interior models on the onset of non-axisymmetric instabilities[14]. The mere fact that such a rotation is observed after two years implies a mass quadrupole moment smaller than 5.3×10^{40} g cm^2. The above limit corresponds to a gravitational wave luminosity of 6.1×10^{14} erg s^{-1}, which still would be the main energy output channel by a very large margin. A measurement of the first and second derivatives of the period would establish the relative importance of gravitational radiation losses.

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Hair light guide

SIR—During studies on the staining of whole plucked hairs for use in biological dosimetry, we have observed that grey hairs illuminated at one end emit light at the other (J. Wells, *Stain Technol.* **63**, 189; 1988). An example of this phenomenon is illustrated in the figure. A 6-mm-long grey hair was mounted through a piece of card, ensuring that light could not pass between the card and hair, and the card was placed on a microscope stage and illuminated from below. Of the 2 mm of hair protruding through the card, only the cut end emitted sufficient light to be seen down the microscope. Reduction in light intensity was noted with increased hair length but by far the most important factor was hair colour; little or no light was transmitted by brown hair.

Thus, grey hair acts as a natural fibre optic which can transmit light to its matrix, the follicular epithelium and to the dermis. Whether light transmission down hairs affects skin and hair needs investigation.

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