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their calculations are in agreement with the results of a simple effective-mass theory.

Photoluminescence measurements of porous silicon samples (~80% porosity) with average wire widths of ~30 Å (as determined by transmission electron microscopy) show a peak photon emission energy of 1.48 eV (red light), and the calculated band-gap for a wire thickness of 30 Å is about 1.8 eV (bulk silicon has a band gap of 1.1 eV which is in the infrared). The difference between the band-gap and photoluminescence energies (0.32 eV) corresponds to the sum of the binding and localisation energies of the luminescent exciton (an exciton is a bound electron-hole pair). In these conditions, the results are consistent with the explanation that the increase in the band-gap, and thus the "blue shift" of the photoluminescence, are due to quantum confinement.

It was also shown that the direct band-gap is not the only reason for the high luminescence efficiency; the efficiency is also enhanced by other parameters such as the low refractive index of porous silicon, the remarkable passivation of its surface by hydrogen terminations which lower the non-radiative process, and the increase of the exciton binding and localisation energies caused by quantum confinement. Furthermore, the well known high resistivity of porous silicon are consistent with those deduced from their calculations.

However, the debate on the exact origin of the luminescence of porous silicon is only just beginning.

### Modellers clash over gamma ray bursters

From Virginia Trimble currently visiting the Astronomy Department, University of Maryland, College Park, from the Physics Department, University of California, Irvine, US

One slide comfortably held all the facts about cosmic gamma ray bursts that a panel of four theorists could agree on during the Compton Gamma Ray Symposium held at Washington University, St Louis, in October (where Arthur H Compton did his Nobel-prize scattering).

The most striking fact is that we are at the centre of the source distribution; and yet we see the edge.

Like a hunter who finds that there are fewer trees far away from him than up close and deduces that he is near the edge of the forest, we see more bursts nearby than far away, and so conclude that we are seeing the edge of the source distribution, but equidistant in all directions.

Very few astronomical systems can make this claim - the Oort cloud of comets; an unexpectedly extended halo to the Milky Way; or the observable Universe as a whole. The edge in the cosmological case is not a real one, but an effect of universal expansion on photon energies and every other observer is just as much at the centre as we are. Unfortunately, no known class of object in any of these three systems, behaving in previously known ways, will produce anything like the bursts seen. One result has been a flood of papers and preprints invoking new objects, new processes, or both. Another is genuine puzzlement and vigorous disagreement within the community. A vote among the Symposium participants before the burst session showed 40% or so supporting galactic models, a comparable number favouring extragalactic models, and 20% abstainers. In this context, "galactic" means sources associated somehow with the Milky Way, even if outside its visible parts, and "extragalactic" means sources very far outside the Milky Way, quite probably inside other galaxies, but at distances comparable to the size of the visible universe, otherwise known as "cosmological" distances.

Observations about which there is consensus include (a) time scales of <0.01 to \(10^{3}\) s, (b) characteristic photon energies of 0.1-1 MeV, (c) no known recurrences (apart from three low-temperature sources called the soft gamma repeaters), (d) arrival rates at Earth of a few per day, (e) energy at

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\text{Earth from } 10^{-7} \text{ erg cm}^{-2} \text{ per burst, (f) no confirmed transient or persistent emission at any other wavelength (apart from X-ray tails and precursors), and (g) uniform spatial distribution of the brightest, presumably closest, sources, giving way to a relative deficiency of the fainter, presumably more distant, ones. These properties, apart from the last, were usually explained by quakes, glitches, impacts, or nuclear reactions on neutron stars, up until October 1991. Nearby neutron star models could also provide explanations of an assortment of spectral features at 10-70 and 400-500 keV, whose interpretation was not among the items agreed upon by the panel. The explanations were peculiar to nearby neutron stars and do not easily carry across to ones in distant galaxies, or even hypothetical ones in a galactic halo. According to these nearby neutron star models, when we looked at faint enough bursts, we would see the edge of the distribution of the sources in our galaxy, and simultaneously see an anisotropy on the sky, with more sources toward the galactic centre and in the galactic plane than in other directions.
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When Gerald Fishman, Charles Meegan, and their colleagues at Marshall Space Flight Centre, Huntsville, Alabama, reported last year sighting an edge to the distribution of the gamma ray bursters in space, but no anisotropy on the sky, confusion set in (C Meegan et al. IAU Circular (1992) 5478). The year since has nearly tripled the data base - some 445 burst locations shown at St Louis, compared to 153 in the first announcement - without changing the statistics of isotropy or the fall-off at large distances. The events (see figure) are not concentrated toward either the centre or plane of the Milky Way.
As the limits on anisotropy have become more restrictive, models have become more exotic. A combination of two sorts of galactic sources (Physics World March 1992, pp27-28) was being ruled out even as the print dried. Joseph Silk of the University of California, Berkeley, and David Eichler of Ben Gurion University, Beersheva, invoked otherwise unknown neutron stars, produced and given high velocities within an extended galactic halo (Science (1992) 257 937). A maximum-likelihood analysis of the CGRO (Compton Gamma Ray Observatory) events by Jon Hakkila of Mankato State University already says that the characteristic size scale of the distribution must exceed 22 kiloparsecs. This is three times our own distance from the galactic centre and at least four times the scale length of the most extended galactic component seen in any other way (the dark matter halo). And the limit on this characteristic distance will grow rapidly as more bursts are recorded. Hui Li and Charles Dermer of Rice University create their new hypothetical population of neutron stars in the galactic disk, but give them large enough velocities to escape into an extended halo (Nature (1992) 359 514).

The model requires that the bursting behaviour turn on gradually as the neutron stars depart. In a last-ditch attempt to save the phenomenon with a galactic disk model, Wolfgang Kundt of the Institut für Astrophysik, Bonn, has proposed (possibly tongue-in-cheek) that the sources, wherever they are in the galaxy, systematically beam their emission up or down toward the galactic plane, so that we (living nearly in the planes) see the same fluxes coming from all directions (submitted to Astrophys. Space Sci.).

But extragalactic models, while guaranteeing isotropy, are not a wholly happy choice either. The problem is not primarily the sobering energy requirement of $10^{52}$ ergs per event seen. (If the gamma rays are beamed into a small cone, you need fewer ergs per burst, but more bursts per year.) At least two kinds of energetically adequate astronomical events must occur at roughly the right rate, including mergers of neutron star binaries, favoured by Bohdan Paczynski of Princeton University (Astrophys. J. (1986) 308 143), and failed supernovae (stellar collapses that fail to eject their envelopes), favoured by Stanford Woosley of University of California, Santa Cruz (submitted to Astrophys. J.). These arise from binary pulsars and massive stars, whose numbers in our own galaxy are roughly known.

More detailed calculations by Martin Rees of Cambridge, Peter Meszaros of Pennsylvania State University, and others have even identified processes that can convert the necessary energy into gamma rays (via neutrino interactions) and get it out without losing everything to the second law of thermodynamics (P Meszaros and M J Rees Mon. Not. Royal Astron. Soc. (1992) 257 29).

The real difficulty is that all the stars we know about are in galaxies. A few bursts have been located well enough that it makes sense to hunt around on the sky in their vicinity. No more galaxies have turned up at those places than in randomly selected bits of sky, according to Bradley Schaefer of Goddard Space Flight Centre. Straightforward cosmological models, with the sources in distant galaxies, are already in some trouble, and the number of precise, searchable positions will continue to increase.

You say that at this point you are prepared to consider the Oort cloud, even though the association between comets and MeV events is not an obvious one? There are other problems as well. The nearer comets are probably concentrated toward the plane of the solar system. And the more distant ones are not uniformly enough distributed with distance from the Sun to account for statistics of the brighter bursts.

What lesson can we draw from this confusion? Well, the symposium participants were asked to vote again at the end of the talks and panel discussion on gamma-ray bursts. Support was still fairly evenly divided between galactic and cosmological models. But the fraction of abstainers had gone way up. Members of the panel were Roger Blandford of CalTech, Dieter Hartmann of Clemson University, Don Lamb of the University of Chicago and Bohdan Paczynski of Princeton. The author served as moderator.

A seemingly simple model developed in 1967 in which exponential springs connect a line of particles is now being applied to problems such as critical phenomena in statistical mechanics, quantum field theory, string theory and dynamical systems.

**Toda's amazing lattice**

From Edward Corrigan, currently visiting the Isaac Newton Institute for Mathematical Sciences, Cambridge University, from the Department of Mathematical Sciences, Durham University, UK

In 1955, in the early days of electronic computation, Fermi, Pasta and Ulam (FPU) decided to test the hypothesis of the equipartition of energy in a numerical experiment. They considered a one-dimensional system of many identical particles, each connected to its two nearest neighbours by a nonlinear spring. Integrating the equations of motion numerically, they found that if the system started with its energy concentrated in one of its fundamental modes of vibration then other, low-lying, modes very rapidly shared the energy as expected.

However, they also found that after a longer time, the system returned surprisingly close to its initial configuration and then repeated the cycle. If the interaction between the particles had been linear the energy would have remained in the initial mode of vibration but, it seemed, a nonlinear interaction did not lead inevitably to the random behaviour which had been expected. Recently, these numerical experiments have been reviewed and set in the context of dynamical systems (J Ford Physics Reports (1992) C213 271).

Following FPU, in 1967 Toda pointed out that a similar system with exponential springs was likely to be "integrable" (see below) and, hence, that the nonlinear springs of FPU might be "close" to integrable, despite their nonlinearity (for a review see M Toda Physics Reports (1975) C18 1).

Since then, much work has been done to explore and understand systems of this type, and their classical and quantum field theory generalisations. The Toda theories are remarkable because they have been the subject of sustained interest over many years, with relationships to structures in mathematics – such as Lie, Jac-Moody and Virasoro algebras – and to topics in physics such as two-dimensional statistical mechanics, gauge theories and string theory. Most of these applications were not anticipated by Toda.

There are several types of Toda system in which identical particles interact via (not necessarily identical) exponential springs. The simplest of these, and the one with the greatest symmetry, is the periodic Toda chain. It is described by the Hamiltonian:

$$H = \frac{1}{2} \sum_{n=1}^{N} \left( \phi_n^2 + e^{-\phi_n - \phi_{n+1}} \right)$$

where the particles are described by coordinates, $q_n$ and momenta, $p_n = \dot{q}_n$. For simplicity, all masses and the spring constants have been set equal to one, but it is quite clear that the force between each particle and its neighbour depends exponentially on their separation. The periodicity can be visualised by thinking of the coordinates, $q_n$, as angles representing the particles in a circle with $q_{N+1} = q_1$. The