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between its 'low-index' and 'high-index' extremes. The slowness and persistence of that atmospheric evolution¹¹ suggests that the thermal inertia of the ocean is contributing 'memory' to the process; as if in confirmation, our longest instrumental and proxy measures of the NAO index show that its spectrum has actually reddened over the past 100 years or so^{12–14}, with an ingrowth of spectral energy at periods of a few years to decades. Very recently, a range of new model runs suggests that the system may indeed be coupled (ref. 15; A. Timmerman, M. Latif, R. Voss and A. Grotzner, personal communication).

Making the link, finally, from the regional to the global level, we have evidence from multivariate linear regression analysis¹⁶ that the NAO and El Niño Southern Oscillation (ENSO) between them have accounted for much (44 per cent) of the variance in Northern Hemisphere extratropical (20°N–90°N) winter temperatures since 1935, with the NAO contributing by far the larger share (31 per cent).

Seen in this light, the coolings, freshenings, deepenings and spreadings of Labrador Sea Water no longer seem parochial. Far from being a small deal in the northwest Atlantic, these changes may well be playing the major role in the largest deal of all — protracting, repeating or in some way structuring the short-term behaviour of the NAO into the long, slow shifts of global change. As the Scientific Steering Group of the Climate Variability (CLIVAR) Program meets in Toronto and Washington to draw up its initial implementation plan (March and April 1997), the oceanographic component will certainly include our best ideas as to how to encompass and quantify change in the mode waters of the North Atlantic. But if our recent experiences are anything to go by, they had better build in some redundancy. □

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Gamma-ray astronomy

The first visible burst

Bohdan Paczyński and Ralph Wijers

Only a few things in astrophysics are as mysterious as γ -ray bursts — one might add to their company dark matter and the energy density of the vacuum (the cosmological constant). There is still debate over whether these rapid, one-off flashes of high-energy photons come from the neighbourhood of our Galaxy or from far greater, cosmological distances. But now the first optical counterpart to a burst is reported on page 686 of this issue by Van Paradijs *et al.*¹. At the same location there may be a fuzzy object, so faint that it stretches even the capabilities of our most powerful telescopes. If it is indeed a distant galaxy, the distance scale is almost certainly cosmological, and γ -ray bursts are confirmed as the brightest objects in the Universe.

Bursts were first discovered in 1973, by the Vela spy satellites², and they are now routinely registered at a rate of about one a day by the BATSE (Burst and Transient Source Experiment) instrument on board the Compton Gamma Ray Observatory³. Most of their energy is in γ -rays, hence the name. While bursting they dominate the sky — if that much energy was released in the optical domain, the brightest events would outshine any star for a few seconds. Bursts appear randomly in time at any location in the sky, and they are extremely diverse: the shortest yet seen lasted only 5 milliseconds, the longest a few hours, though most of them last between 1 and 100 seconds⁴. Some have rapid variability down to millisecond time-scales, some appear to be made of many independent components, and others vary smoothly, with a relatively rapid rise followed by a gradual decline.

There is no shortage of theories to explain

bursts — in fact, there are hundreds of them. During the two decades between 1973 and 1992, it was generally assumed that the bursts came from old neutron stars, at distances of about 100 parsecs from us, but there was no consensus about the mechanism. Comets falling onto neutron stars, star-quakes, nuclear explosions, magnetic flares and many other energy sources were suggested.

The situation changed dramatically in 1992, with the announcement of results³ from BATSE. This was the first experiment able to measure burst positions directly, and it is very sensitive. All bursts, strong and weak, were found to be distributed randomly over the sky, with no apparent bias towards the Galactic plane or centre. Also, there were relatively few weak bursts, indicating that beyond some distance their number density declines. In other words, the BATSE data demonstrated that we are located at the centre of a spherically symmetrical distribution of bursts. That was a shock to the astronomical community. The observed distribution clearly excluded the previously favoured Galactic disk origin, because the weak and presumably distant sources were not concentrated in the Galactic plane.

Today, the distance scale is still an issue. Judging from the number of papers published on the subject, a clear majority of investigators place γ -ray bursts at cosmological distances, a few gigaparsecs from us. A vocal minority puts them in the extended corona of our Galaxy, at about 100 kiloparsecs. There is no support for the distance of 100 parsecs, which had been considered firmly established before 1992. Now we wonder, is the distance only 1,000 times larger, or is it 30,000,000 times larger^{5,6}?

No matter which number we choose, all pre-BATSE models are firmly excluded; a small disturbance on the surface of a neutron star just wouldn't produce enough energy. Many of the new theories for cosmological-distance bursts involve instead the collision of neutron stars, and an ensuing relativistic fireball. Other models involve active galactic nuclei and their surroundings. But we have no direct evidence to support any of these theories. The strength of the argument for the cosmological-distance scale has nothing to do with physical models of the bursts; it rests entirely on their observed distribution properties.

The most serious difficulty in understanding γ -ray bursts is the absence of emission in any other part of the electromagnetic spectrum. But that is now changing, following the launch of the Italian–Dutch BeppoSAX satellite⁷ (Fig. 1). Its wide-field cameras can pin-

Figure 1 The BeppoSAX instruments. BeppoSAX can provide rapid and accurate burst positions with its wide-field cameras (silver-coloured).

Figure 2 Burst afterglow. The optical counterpart to GRB970228 is in the centre; the bright object to the left and below is a cool star in our own galaxy, and there is a faint distant galaxy towards the upper right.

point bursts in 1–3 hours, and follow up with its X-ray telescopes. In the past, BATSE provided instant but inaccurate positions⁴, whereas the network of small γ -ray detectors on board interplanetary probes could measure very accurate positions by triangulation, but with a long delay⁴. In both cases the follow-up observations saw nothing.

The burst GRB970228 was reported⁸ by the BeppoSAX team on 2 March 1997, and four days later they reported an X-ray transient within the burst's position error box⁹. Van Paradijs and colleagues¹ describe how an optical transient was detected^{10,11} on 1 March, with an apparent magnitude of about 21, fading to fainter than about 23rd magnitude on 8 March. The Hubble Space Telescope detected the optical transient¹² at about 26th magnitude on 26 March, and slightly fainter¹³ on 7 April (Fig. 2). The 10-metre Keck Telescope and Hubble may also have found a very faint fuzz around the optical variable^{12–14}. But any of the definite galaxies that appear near the transient could be hosts — there will usually be a galaxy within such an area, so their presence doesn't favour an extragalactic origin.

It may take time before the counterpart problem is solved, as another similarly bright BeppoSAX burst, GRB970111, had no X-ray or optical transient source associated with it¹. X-ray luminosities are known to vary substantially between bursts with similar γ -ray brightness, and the variations in the optical band could be even greater. Fortunately, BeppoSAX has just reported¹⁵ yet another burst, GRB970402, from which it again saw an X-ray afterglow¹⁶. The first attempts to find an optical transient from this somewhat weaker burst were not successful¹⁷. But more robust statistics should be at hand before too long. If we are lucky — that is, if some obvious pattern becomes apparent — then we should have some understanding of the counterparts when a few more cases are dis-

covered, which may take another year or so.

What is the meaning of this exciting development? Many theoretical models predict X-ray and optical transients after Galactic or extragalactic γ -ray bursts. The very simplest model for the afterglow of a blast wave¹⁸ fits the X-ray and optical data from GRB970228 remarkably well. But theory is at an early stage, and hence flexible; and we should not forget that all of the pre-BATSE models turned out to be wrong.

It is unlikely that a definite theoretical understanding will be possible without new observations. We have yet to learn how common these transients are, how often there is a fuzzy patch near the burst location, what the spectra are, whether there are any spectral lines, and whether the redshift (if any) can be measured. BeppoSAX has provided the first breakthrough since BATSE. Now the critical issue is whether the earliest 10-arcminute positions can be made available to all interested observers on the 1–3-hour timescale on which they become known, to maximize

the chance of frequent and diverse follow-up observations. Timing is everything. □

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Palaeontology

Genesis of snakes in exodus from the sea

Nicholas C. Fraser

In the Garden of Eden, the serpent — portrayed complete with limbs by Michelangelo on the ceiling of the Sistine Chapel — was commanded to go on its belly and eat dust for the rest of its life (Fig. 1). But it seems that it took to the sea before it finally (more-or-less) settled down to an existence on land; at least, that's the view of Caldwell and Lee¹, who describe (on page 705 of this issue) a snake that has legs.

Searching the fossil record for clues as to the origin of snakes is a frustrating business. Snake skeletons are very delicate structures that are not readily fossilized. Most of the snake fossil-record comprises vertebrae, and "there is no fundamental difference between

the vertebral morphology of snakes and other modern Lepidosauria"². So it is little wonder that the search for the origin of snakes has proved to be a thorn in the side of vertebrate palaeontologists.

In looking for a plausible ancestor, we can certainly narrow the odds. Snakes (Ophidia) are clearly highly derived members of the order Squamata ('scaly reptiles'), which also includes the lizards (Lacertilia) and amphisbaenids (the worm-lizards). But within the Squamata, where is the safest bet? It seems unlikely that forms with well-developed limbs or a marine habit could be the ancestors of modern-day snakes. However, Caldwell and Lee lean towards just such a long shot. ►

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Figure 1 The fall of the serpent. In his famous scene, *The Fall of Man*, on the ceiling of the Sistine Chapel, Michelangelo depicted the serpent as having forelimbs.