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The shifting centre

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method to reconstruct trees, so the difference may be an artefact of that method. The authors do not discuss the location of the root of the tree.

MacClure *et al.* built a composite tree from 4 sequences for 17 viruses[4]. This allows them to identify five groups of retroviruses. Some groups have been recognized previously (C- and E-type leukaemia viruses) where others are more diverse. Again the results are interesting, although no quantitative analysis is possible.

Comparing the papers of Smith *et al.*[3] and McClure *et al.*[4] highlights the advantage of a thoroughly tested tree as a basis for analysis. And, as Smith *et al.* remark, "The reconstruction of the phylogenetic history of HIV-1 and HIV-2 is an important component for the understanding of the epidemiology of the spreading disease, AIDS." □

1. Reanney, D.C. *Nature* **307**, 318–319 (1984).
2. Kimura, M. *The Neutral Theory of Molecular Evolution* (Cambridge University Press, 1983).
3. Smith T.F. *et. al. Nature* **333**, 573–575 (1988).
4. McClure, M.A. *et al. Proc. natn. Acad. Sci. U.S.A.* **85**, 2469–2473 (1988).
5. Felsenstein, J. *Evolution* **39**, 783–781 (1985).
6. Penny, D. & Hendy, M.D. *Molec. biol. Evol.* **3**, 403–417 (1986).
7. Mulder, C. *Nature* **333**, 396 (1988).

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Astrophysics

The shifting centre

Virginia Trimble

EUROPEAN and American astrophysicists have been in the habit of supposing that their Japanese colleagues are thinking and doing more or less the same things they are, but perhaps a year or so later. At a recent conference* it was made abundantly clear that this supposition is badly out of date and that the centre of astronomical research is no longer unambiguously in the mid-Atlantic. A major part of the varied programme consisted of new, wholly or partly Japanese results in the areas of neutrino astronomy, X- and γ-rays, the microwave background and data-processing technology.

The solar neutrino problem[1] is almost as old as many of the conference participants. From 1968–69 onwards, the unique ^{37}Cl experiment operated by Raymond J. Davis Jr and co-workers has persisted in detecting only about one-third as many neutrinos with energies above 0.814 MeV as the standard solar models predict. Most of us ceased to doubt the essential correctness of the experiment many years ago.

Confirmation is nevertheless very welcome. The Kamiokande II experiment, though designed primarily for other purposes, records the energy and incident direction of neutrinos above 9 MeV and so can detect a portion of those emitted by ^{8}B decay in the Sun. Yoji Totsuka (University of Tokyo) reported that the current count rate from the direction of the Sun is about 0.1 event per day, whereas the standard solar model predicts 0.3. Allowing for the still-limited statistics, this translates into ruling out a flux larger than 62 per cent of the standard model at the 90-per-cent confidence level and ruling out zero flux at the 95-per-cent level. John Bahcall (Institute for Advanced Study, Princeton), discussing solar neutrino theory immediately thereafter, began by saying he had waited 20 years to hear Dr Totsuka's talk.

The Ginga X-ray satellite[2] has been returning data in the 4–30 keV band since summer 1987. Among its products are the first X-ray spectra above 2 keV for a number of quasars and Seyfert galaxies (active galactic nuclei or AGNs). Hajime Inoue and Katsuji Koyama (Institute of Space and Astronautical Science, Tokyo) described both the continua and the line spectra. The continua are generally well fitted by power laws whose slopes we very much want to know to decide whether we can account for the nearly-isotropic X-ray background by adding up the faint, distant AGNs, or whether we must invoke hot intergalactic gas as well. The few AGNs studied earlier seemed to have a canonical slope near 1.7, too soft (meaning too few of the highest-energy X-rays) to match the 1.4 slope of the background. Ginga now finds a range of slopes, 1.5–1.9 for quasars, 2–3 for BL Lac objects and 1.4–2.4 for Seyfert galaxies. That is, a few spectra are hard enough to match to the background radiation, but most are not. Several of the objects are variable on timescales from minutes to days.

These X-ray continua are thought to arise from non-thermal processes like Compton or synchrotron radiation. But many of the detected AGNs also showed an iron emission line between 6 and 7 keV, revealing the presence of hot gas. The exact energy of the (de-redshifted) line tells us how many electrons still orbit the atoms. In the quasars 2C273 and E1821+643, the iron must be fairly heavily ionized and thus close to the central quasar engine. The Seyfert lines, on the other hand, appear at a slightly lower energy, implying X-ray fluorescence by neutral gas. The case of NGC1068, a Seyfert 2 (the less spectacular kind), is particularly interesting. Its X-ray spectrum greatly resembles that of the nearby stellar source Vela X-1 during eclipses, when we see X-rays from the central source indirectly, reprocessed by surrounding cooler gas. Thus the Ginga data support a recent hypothesis that Seyfert 2 galaxies are much like other more active objects, but with our view of the central engine obscured, presumably by an accretion disk.

Ginga also recorded X-rays from supernova 1987A in energy bands of 6–16 and 16–28 keV beginning in July[3]. The hard X-rays, also seen by the Kvant module on the Soviet Mir satellite[4], are thought to be scattering-degraded γ-rays emitted as ^{56}Co decays to excited states of ^{56}Fe. But the turn-on was 6 months or more earlier than expected. Even more unanticipated were the apparent variability of these X-rays and the simultaneous turn-on and flaring in the softer band.

Yasuo Tanaka (Institute of Space and Astronautical Science) and Kuniaki Masai (Nagoya University) provided updates on the data and their interpretation. Tanaka suggested that the observed X-rays can be deconvolved into two components. One has the spectrum expected from degraded γ-rays obscured by 10^{25} atoms cm^{-2} and has remained nearly constant from July to February. (This is, in itself, surprising, and requires the decaying ^{56}Co to have been mixed through most of the supernova ejecta rather than being concentrated in a layer near the bottom.) The other component has a thermal spectrum and has undergone a couple of minor flares and a major one in January when it brightened by a factor of 6 to 10^{38} erg s^{-1} and heated up from 12 to 50–60 keV.

The January flare included a 6.7–6.9 keV iron line, indicating at least some hot-gas emission. It was obscured by less than 10^{23} atoms cm^{-2} and so must have arisen well outside the zone of the hard source. These points present difficulties for a model in which the X-rays come from a central pulsar or pulsar-driven nebula (Franco Pacini, Astrophysical Observatory, Florence). But the obvious alternative of ejecta colliding with pre-existing dense gas is not fully satisfactory either. The peak flux declined in only a couple of days, requiring very rapid cooling of the shocked gas and thus expansion at the unlikely speed of 10^{9} cm s^{-1}. The absence of associated radio emission and still softer X-rays is also puzzling. Masai noted the collision with a single dense cloud rather than a symmetric shell reduces the discrepancies.

Photons at much higher energies (greater than about 1 TeV) from SN1987A have also been widely predicted (ref. 5 and many others) on the belief that high-energy cosmic rays must be accelerated early in supernova events. Just possibly these TeV γ-rays have been seen,

* Twentieth Yamada Conference: *Big Bang, Active Galactic Nuclei and Supernovae*, 28 March–1 April 1988, University of Tokyo.

according to Tadashi Kifune (University of Tokyo), reporting for a Japanese–Australian–New Zealand collaboration. Their Cerenkov light detector saw a modest increase above background in the direction of the supernova during the January X-ray flare. If real, it corresponds to a luminosity of about 3×10^{38} erg s^{-1} above 3 TeV, persisting for only a couple of days.

The search for spatial and/or spectral lumpiness of the relict 3-K microwave background radiation is also about 20 years old. The most persuasive spectral data so far come from a February 1987 rocket flight mounted jointly by Nagoya University and University of California, Berkeley[6]. Analyses of the data have continued since initial theoretical discussions[7] found that the excess 480- and 710-μm radiation could be attributed either to inverse Compton scattering of longer wavelength photons or to thermal emission from dust heated by pregalactic starlight.

Toshio Matsumoto (Nagoya University) showed the observed fluxes as a function of ecliptic latitude. For the 100–200 μm range, there is a correlation with interstellar hydrogen density and with zodiacal emission (interplanetary dust), as seen by the Infrared Astronomy Satellite. At wavelengths longer than 400 μm, the fluxes are essentially isotropic, with possible fluctuations on a scale of degrees. The residual excess emission, according to Matsumoto, is then best fitted by dust emission at $3.7 \times (1+z)$ to $4.4 \times (1+z)$ K, where z is the redshift at which the dust was heated, and the exact temperature depends on how the dust absorption coefficient varies with wavelength. The necessary energy input is sizable in any model, amounting to about 10 per cent of the $(1+z)^4$ eV cm^{-3} contained in the total microwave background.

Finally, several of the contributed papers and posters touched upon issues of modern technology and data-processing techniques. For instance, Tsuneaki Daishido and colleagues from Waseda University, Nobeyama Radio Astronomy Observatory and Sony Corporation's Information Systems Research Center reported on a technique for rapid processing of radio signals from arrays of antennae.

Their prototype processor, intended to look for transient radio sources, is capable of 2.7 billion (10^9) operations per second and has been used for studying solar radio bursts. I ought to be able to tell you more about it, as the authors provided a seven-page, 1988 reprint, complete with extensive circuit diagrams. As I examined the pages, Satio Hayakawa (Nagoya University) remarked that Americans have been complaining that Japanese researchers do not send state-of-the-art information promptly. He suggested the alternative interpretation that they are sending, but we are not receiving very well. This must be true, for I cannot tell you even the name of the journal that published this forward-looking paper — in Japanese. □

1. Bahcall, J.N. & Ulrich R.K., *Rev. Mod. Phys.* **60**, 297–372 (1988).
2. Makino F. *et al. Astrophys. Lett. Commun.* **25**, 223 (1988).
3. Makino F. *et al.* IAU Circular No. 4532.
4. Sunyaev, R. *et al. Nature* **330**, 227–229 (1987).
5. Gaisser, T.K., Stanev, T. & Halzen, F. *Nature* **332**, 314 (1988).
6. Matsumoto, T. *et al. Astrophys. J.* (in the press).
7. Hawakawa, S. *et al. Publ. astr. Soc. Japan* **39**, 941 (1987).

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Quantum optics

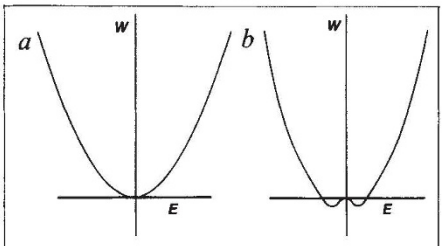
Noise-driven phase for lasers

Peter Knight

PHASE transitions between different output states are common for lasers. The most important is that between ordinary fluorescent behaviour of the laser medium and coherent amplifying laser action. Another occurs at the onset of chaotic fluctuations in the output field at higher powers. J.H. Hannay and D. Field suggest elsewhere in this issue (*Nature* **333**, 540–542; 1988) that a third transition can be driven by noise fluctuations of the output electric field. They liken this transition to the Curie–Weiss transition in a ferromagnetic material, in which cooperative interactions between individual atomic magnetic dipoles makes the whole ensemble very sensitive to small thermal fluctuations.

The laser is often regarded as a nonlinear oscillator driven by an external pump mechanism which attempts to maximize the excitation of the atoms forming the source of radiation. The excited atoms form a fluctuating polarization which in turn creates the laser electric field. If the pump rate is insufficient to overcome the relaxation of the atoms and field, the electric field dies away. The decaying transient fields from each atom are randomly phased and add to form mere noise with a zero mean amplitude. When the pump rate is raised sufficiently to overcome the losses in the laser cavity, gain is possible and a steady-state electric-field amplitude can be maintained. The critical pump rate here defines a first threshold, which is that necessary to provide sufficient excitation to balance the losses.

A second threshold occurs (Haken, H. *Phys. Lett.* **A53**, 77; 1975) when, for very high levels of pumping, the evolution of the laser electric field becomes completely chaotic, an effect seen in many nonlinear systems. The phase transition discussed by Hannay and Field in this issue is distinguished from both of these through its reliance on fluctations in the atomic polarization of the laser. Their results indicate that small changes in the laser parameters can lead to very large changes in the average intensity of the laser output.



The first phase transition of a laser. Below threshold (*a*), the 'potential' (*W*) of the laser is minimum at mean electric field (*E*) zero; corresponding to chaotic, incoherent fluorescence. Above threshold (*b*), the well bifurcates, giving two minima, one of which is picked spontaneously to generate a non-zero laser electric field, responsible for the coherent laser output. In the new phase described by Hannay and Field, the form (width) of the bifurcated well is extremely sensitive to polarization fluctuations.

The method used by Hannay and Field is a straightforward extension of the theory used by Haken and H. Risken (see Haken, H. *Laser Theory* 2nd edn, Springer, Berlin, 1984) to describe the transition from noise to order in passing through the first threshold. In this standard approach, 'Langevin' equations, which model the fluctuations of the polarization, inversion (the degree of excitation of the atoms) and the laser electric field about their mean values, are used to define a 'Fokker–Planck' equation which describes how the probability distribution of the electric-field strength evolves. This distribution is governed by the size of the electric-field loss and gain in the laser. As a function of electric field, the probability distribution behaves rather like a potential well which can have a single minimum (*a* in the figure) when the laser is below threshold, or a double minimum when it is above threshold.

The evolution of the laser electric field behaves rather like a ball rolling in this potential and below threshold will roll to the bottom of the well. Above the threshold, the well bifurcates (*b* in the figure): two minima symmetrically displaced from zero represent the positive and negative stable equilibria of the ball. Spontaneous symmetry breaking allows