questions (Rhum vegetation today is not exactly what it was before the advent of humans); but it seems to have given little consideration to the behaviour of reconstituted aurochs and other such beasts, or to the effects of this behaviour on the functioning and persistence of the proposed ecosystems. As long as what is proposed is a kind of upmarket Disneyland, these worrics may be insubstantial. Serious attempts to preserve biological species must, however, deal with vexing questions of preserving not just the species but also its pristine range of behaviour.

In summary, there is a difference between *L. rosalia* securely preserved in the zoo and the golden-lion tamarin with the rich spectrum of learned behaviour necessary for survival in the wild. This difference is more than a topic for philosophical debate; in the long run, such 'cultural' losses may be the most significant problem when and if we try to unload the ark. □

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Anna Marie Lyles and Robert M. May are in the Biology Department, Princeton University, Princeton, New Jersey 08544, USA.

Radioastronomy

Spectra of stellar radio flares

Arnold O. Benz

THE radio emission of stellar flares has attracted increasing attention in recent years as a result of instrumental advances. Red dwarf (dMe) stars are known to be magnetically active and variable on timescales of minutes (and less) in a wide range of emissions including X-rays, optical and radio waves. Now an important development has started with the first spectral measurement, reported by Bastian and Bookbinder on page 678 of this issue[1]. They used the Very Large Array telescope in New Mexico (currently the world's largest radio interferometer) at 21-cm wavelength to record the radio spectra of two outbursts of the flare star UV Ceti (L726-8B). The range of frequencies (bandwidth) accepted by this instrument is rather limited, but is sufficient to show irregular variations in the spectrum of one event. The results show a potential to measure electron density and magnetic field strength in the atmospheres of dMe stars. Various plasma processes seem to be at work which first have to be disentangled. The door is not yet really open, but the glance through the keyhole looks promising.

The situation of the radio observations of flare stars is reminiscent of solar radioastronomy in the early 1950s when Wild[2] introduced radio spectrogrammes, on which the variation of intensity with time as well as radio frequency is shown. This method added a new dimension and unravelled structures which were unrecognized in single-frequency recordings. It quickly led to a number of important discoveries, such as mildly relativistic particle beams (type III bursts); coronal shock waves (type II bursts); and large magnetic loops interconnecting remote active regions on the Sun (type U-bursts).

Later, spectral measurements at microwave frequencies revealed that common solar flares accelerate a large number of relativistic electrons which spiral around magnetic field lines and emit synchrotron radiation. In the following two decades, observations in the low-frequency part of the spectrum brought insights into plasma processes in the outer corona and in interplanetary space. Recently, millisecond spikes with narrow bandwidth have been suggested to be intimately associated with the flare-energy release proper. It is remarkable that all these findings were made by full Sun observations without spatial resolution, just as will be the case for stars.

Flare stars were the first stars after the Sun[3] detected in the radio frequency. They are very abundant, comprising about 10 per cent of all stars in our Galaxy, but only about a dozen, the nearest specimens, are well observed. Early reports were plagued by confusion of terrestrial interference with stellar events. Reliable measurements came with the use of large telescopes such as Arecibo, and of interferometers. Such observations have, for example, revealed a quiescent radio emission[4] of UV Ceti which is 100 times more powerful than that of the Sun, and a slowly varying component[1] even larger. Stellar radio flares, observed at a single frequency, are very frequent and up to 10^5 times higher in luminosity than solar counterparts. It is generally agreed that these flares are a manifestation of a strong magnetic field built up by vigorous convection in late-type, cool and small stars. The highly polarized flare radio emission and the recent discovery of millisecond structures[5] in a similar star strongly indicate that such sources are much smaller than their associated star and have a brightness temperature of at least 10^{18} K. For this to be so, the emission process must be coherent, which might imply that maser-type action occurs in the cyclotron radiation (generated by non-relativistic electrons). That is to say, an electron–cyclotron instability arises because of the distribution of electron spiralling velocities being peaked to the higher velocities — a population inversion.

The new spectral observations[1] independently confirm the small source size. In one event spectral components with width approximately 0.2 per cent of their central frequency were discovered. Such narrow-band emission is only possible in a correspondingly homogeneous source of much smaller dimension than the scale size, because the variation of the parameter that determines the emission frequency (such as the cyclotron frequency) must be within a small margin. This requirement puts an upper limit on the source diameter of 200 km, assuming a scale height of one stellar radius, the largest reasonable. The above emission mechanism implies a magnetic field in the source of 250 gauss (assuming the radio frequency is the second harmonic of the cyclotron frequency, which would be usual) and an upper limit on the electron density of about 10^9 cm^{-3}, which is imposed if the maser is to operate.

It is certainly tempting to associate the observed stellar events with solar-burst types and processes, but the necessary resolution, simultaneously in time and frequency, is not yet available. Narrow-band components have been observed in solar radio spikes, but also as fine structure of decimetric type IV (due to trapped flare particles) and type II bursts. Fast structure in time is present in solar decimetric pulsations, type I bursts (the result of new magnetic flux penetrating the corona) as well as spikes. Broad-band observations have been found to be necessary to assess solar radio bursts. Clearly a time-resolution better than one second is another requirement.

More importantly, the lesson of solar astronomy is that an understanding of turbulent plasmas and particle beams will not come from radio observations alone. The same exciters also produce signatures in hard X-ray and ultraviolet lines. Stellar flares may contribute significantly to the universal soft X-ray background. Finally, radio bursts may reveal the geometry of the powerful magnetic field and related processes in the atmosphere of the probably most abundant variable stars. □

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Arnold O. Benz is at the Institute of Astronomy, Eidgenössische Technische Hochschule, 8092 Zürich, Switzerland.