poor statistical accuracy, due to spatial limitations on the sensitive area which can be installed at any given location. Above about $5 \times 10^{12}$ eV air shower detectors on the surface are used. However, these also have experimental drawbacks. In general, the equipment requirements in relation to stability and reliability are severe, bearing in mind the lengthy periods of continuous operation and the very small (—0.05%) amplitude of the phenomenon under investigation. In spite of these problems, however, a tentative picture is beginning to emerge. Table 1 lists results from a number of papers presented to the International Cosmic Ray Conference held in Bulgaria in August 1977, as interpreted by Wolfendale (1978).

Table I

| Station             | Detector Type | Mean Energy ($\times 10^{12}$ eV) | Sidereal Amplitude | Anisotropy R.A. |
|---------------------|---------------|----------------------------------|--------------------|-----------------|
| London              | Underground Muon | 0.2                             | 0.03%              | 5               |
| London              | Underground Muon | 0.3                             | 0.03%              | 3               |
| Poatina, Tasmania   | Underground Muon | 1.5                             | 0.04%              | 2               |
| Norikura, Japan     | Air Shower     | 9                                | 0.05%              | 2               |
| Musala Peak, Bulgaria | Air Shower   | 50                               | 0.06%              | 2               |

The table suggests that rough agreement has been reached, at least to one significant figure, with the amplitude increasing, and direction possibly changing, as energy increases. The agreement does not, at present, extend to estimates of the actual declination of the anisotropy (Wolfendale 1978) and it is clear that higher precision is required before this matter can be resolved.

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**Spectroscopy**

*The Measurement of f-values for Lines of Astrophysical Interest by Beam-Foil Spectroscopy.*

J. E. Ross and B. J. O'Mara *Department of Physics, University of Queensland*

The necessity of having accurate oscillator strengths in astrophysical applications is well known. The apparent discrepancy which existed between the solar and meteoritic abundance of iron is just one example of the problems which can arise from poor $f$-values. An excellent critique of methods for determining both absolute and relative $f$-values has been given by Blackwell & Collins (1972). Their comments on lifetime techniques provide a clear indication of both the advantages and difficulties associated with these techniques: “In principle, a life-time method, as exemplified by the technique of beam foil spectroscopy, described for example by Wiese (1970), has the fundamental advantage that in some restricted circumstances its application does not depend upon a temperature measurement or any assumption of thermodynamic equilibrium in the source: in addition it gives an absolute result without the need of an absolute number density of atoms. The hope is sometimes expressed that the method of beam foil spectroscopy will yield oscillator strengths of the required accuracy. In practice, the technique suffers from the difficulty that although the life-time of an excited state can be measured with reasonable accuracy, it is also necessary to measure in a separate experiment the branching ratios for radiative de-excitation. As these ratios are usually measured by an arc method, the accuracy of the final oscillator strengths is limited by the deficiencies of this source. Also, some atoms in the beam may be excited to higher levels than the one being examined, and because of the nature of the initial excitation is unknown, radiative de-excitation (cascading) takes place to this lower level in a way that is wholly unpredictable. This difficulty is especially important for levels of low excitation.”

In this talk techniques will be described for overcoming the cascading problem in beam foil spectroscopy and for measuring the associated branching ratios.
In a conventional life-time experiment such as that described by Whaling et al. (1969) the intensity of a particular spectral line is measured as a function of distance downstream from the foil and from the known beam energy this is converted to \( I(0,t) \), the intensity as a function of time \( t \) after excitation. \( I(0,t) \) is then analysed to determine the life-time of the upper level of the transition. Some indication of the effects of cascading can be obtained by repeating the measurements at a different beam energy to see if the measured life-time is a function of the beam energy. If such a dependence on beam energy is found the measured life-time must be discarded.

Because of the short duration of the beam-foil interaction a small fraction of the atoms (usually ~10%) emerge from the foil in a state which is a coherent mixture of the magnetic substates of the level of interest. If a magnetic field \( B \) is applied transverse to the beam then, due to the presence of the coherent state, quantum beats are observed and the intensity as a function of \( B \) and \( t \) is \( I(B,t) = aI(t) + bI'(B,t) + c e^{-\gamma t} \), where \( I(t) \) is contribution from non-coherently excited atoms, \( I'(B,t) \) is contribution from unknown \( B \)-dependent mechanisms (e.g. "coherent cascades"), which is expected to be negligibly small and which has been looked for experimentally but not observed, and the last term is the signal of interest, the decaying quantum beats, where the beat frequency is the usual Larmor frequency \( \omega_L \). Thus by observing

\[
I(B,t) - I(0,t) = K e^{-\gamma t}(1 - \cos 2\omega_L t)
\]

it should be possible to measure the cascade free life-time \( \tau \).

The first measurements of this kind were by Liu & Church (1972) who measured the life-time of the upper state of the 4189.79 Å line of OII and found \( \tau = 6.8 \pm .2 \) ns compared with \( \tau = 20 \) ns determined by the conventional technique.

One of the disadvantages of life-time measurements based on the decay of quantum beats is that the signal to noise ratio is poor as only ~10% of the atoms in the beam are coherently excited. This difficulty can be overcome by using tilted foil excitation. When the beam is sent through a tilted foil coherent orientation of the magnetic substates occurs, i.e., the magnetic substates are populated unequally and an analysis of the decay of circularly polarized light as a function of distance downstream from the foil can be employed to obtain the level life-time. Again there are good theoretical reasons to believe that atoms which reach the level of interest by cascades do not exhibit coherent orientation and therefore do not contribute to the signal. The advantage of the tilted foil method is that it is not unusual for as many as 50% of the atoms in the beam to exhibit coherent orientation thus increasing the signal to noise ratio.

Life-times are at present being measured by both of these techniques in the Department of Physics at the University of Queensland. Details of the experimental setup are given by Christiansen et al. (1977).

Once the life-time of a level of interest has been determined by beam foil spectroscopy it is necessary to partition the reciprocal life-time between the various downward transitions from this common upper level. This partitioning is realized by measuring the relative intensities of the lines in the downward branch of transitions. We are currently setting up a conventional branching ratio experiment in which the lines in a branch produced by a hollow cathode source are selected by a long focal length monochromator and their intensities compared photoelectrically. One of the lines in the branch (usually the strongest) is selected by a short focal length monochromator and its intensity is monitored to permit corrections to be made for variations in the output of the hollow cathode source during the measurements. Corrections for the change in response with wavelength are determined by substituting a calibrated tungsten ribbon filament lamp for the hollow cathode source. The experiment is controlled by an M6800 microprocessor which should relieve the tedium involved in the routine measurement of a large number of branching ratios of astrophysical interest.

The life-time measurements are in progress and the branching ratio experiment is in the final stage of development. We hope to present \( f \)-values of interest at future meetings.

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### Initial Observations with the 4-Metre Millimetre-Wave Telescope at Epping

**F. F. Gardner, R. A. Batchelor, M. G. McCulloch, L. W. Simons and J. B. Whiteoak** Division of Radiophysics, CSIRO, Sydney

A 4-m telescope for mm-wave observations, particularly of spectral lines, was erected in mid-1976 at Epping by Krupp Ltd., Rheinhausen. A cooled mixer receiver was installed on the telescope in April 1977 and a series of test observations made during the remainder of the year, subject to the availability of the receiver and the multi-channel filter bank which were shared with the Parkes 64-m telescope.

Table I gives some of the particulars of the 4-m telescope. The telescope is Cassegrain with an alt-azimuth mount. The basic drive and control system were provided by Siemens Ltd., Munich, while the control desk and computer control were developed by J.G. Able and A.J. Hunt at the CSIRO Division of Radiophysics. Two linked Digital Equipment Corporation PDP/11 computers are used for data collection and to enable the telescope to be driven in various coordinate systems. The receiver, which incorporates a mixer cooled to liquid nitrogen temperature (80 K), has been described by McCulloch et al. (1977).

The focal adjustments, the beamwidth determination and the pointing investigation were made using observations towards