physics. It is thus pleasing that their result of $H_0=40^{+25}_{-13}$ km s^{-1} Mpc^{-1} is in good agreement with recent determinations by more traditional methods.

EXOTIC NUCLEI

Limits to Growth

from a Correspondent

THE problem of determining the limits of nuclear stability is one of the great challenges in nuclear physics at present, both from a theoretical and an experimental standpoint. It is, however, a problem that is proving difficult to solve experimentally for all save the lightest nuclei, such as the isotopes of beryllium and boron. It is now known, for example, that ^{12}Be is stable against neutron emission. On the other hand ^{13}Be and ^{14}Be are likely to decay in times of order 10^{-23} s by neutron emission, and cannot be regarded as stable. Recently much effort has been invested in developing a formula which will give the masses of all nuclei in the periodic table, from which the stability of any nucleus can be predicted.

One global approach invokes a liquid drop theory, but for nuclei far from stability the level of accuracy is of the order of several MeV, which is also likely to be the order of the binding energy of neutron-rich nuclei. A more accurate technique uses a stratagem relating the existing mass differences of known nuclei to predict masses of new nuclei to an accuracy of 200 keV. This is the basis of the Garvey-Kelson mass formula, which predicts the stability of such neutron-excessive nuclei as ^{28}O (8 protons, 20 neutrons). Other theories predict the limit at ^{24}O, and it is now the task of experimenters to produce these nuclei in order to make a systematic check on the various theories. Ultimately this problem is of fundamental interest to nuclear physics, because it will be important to see if theories of nuclear structure (such as the shell model) are at all reliable when applied far from the regions of stability in which they were developed.

A dramatic advance in this field was made recently by Klapisch and his group of the Laboratoire Rene Bernas at Orsay (*Phys. Rev. Lett.*, **29**, 1254; 1972); they have produced new isotopes of Na and K. The Garvey-Kelson method predicts that the Na isotope (11 protons) with neutron number between 20 and 28 will be stable if the number of neutrons is even, and marginally unstable if odd. Thus ^{31}Na, ^{33}Na, ^{35}Na and so on should be stable. The Orsay group produced the new isotopes by bombarding uranium with 24 GeV protons from the CERN proton synchrotron. Under this bombardment many nuclear species are produced by spallation reactions, but the alkalis, including isotopes of lithium, sodium and potassium, possess the peculiar and incompletely understood property that they will diffuse out rapidly from the heated graphite which surrounded the uranium target. They can then be transported between the beam bursts of the synchrotron to a detector, shielded by a cadmium enclosure to reduce the intense neutron background. The Na and K ions were selected for transmission to the detector by a simple mass spectrometer. The instrument was first set to detect an abundant isotope ^{22}Na, which has a long half-life, and then the voltage and fields on the spectrometer were accurately adjusted to search for new isotopes. Previous studies using this technique have shown the stability of Na isotopes out to ^{31}Na (11 protons, 20 neutrons). Neutron number 20 is a "magic number" and completes a closed shell. It was possible that the extra binding of the shell closure would mark the limit of stability.

In the new experiment, the stability of ^{32}Na was clearly demonstrated, but the production cross-section was a factor of twenty smaller than for ^{31}Na. This made the task of hunting for ^{33}Na rather difficult, but the researchers were also able to provide conclusive evidence for the stability of this isotope, with a half-life between 5 and 35 ms. The stability of ^{32}Na was unexpected, because it marks a departure from the systematics of the Garvey-Kelson predictions, which seem to be over-pessimistic. The stability of ^{33}Na follows because the added pairing energy of the extra neutron leads to greater binding. It is almost certain that ^{34}Na and ^{36}Na will also turn out to be stable. An exciting possibility is the extension of the technique to study these highly neutron-excessive isotopes, because the decrease in yield from ^{32}Na to ^{33}Na is only a factor of five compared with twenty from ^{31}Na to ^{32}Na. The dramatic drop in yield at neutron number 21 seems to be connected with the closure of the shell at 20 neutrons.

This experimental technique seems to hold the greatest immediate hope for advancing the limit in production of neutron-excessive light nuclei. Ultimately the technique will be able to give precise information on nuclear masses for a more detailed comparison with theoretical predictions. Another exciting possibility is that the method can be applied to a mass measurement of ^{11}Li. This nucleus is known to be stable, but almost every theoretical calculation predicts that it should be unstable to neutron emission by several MeV.

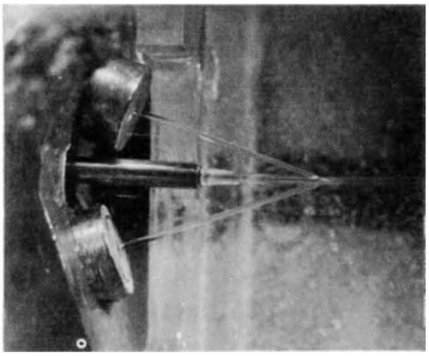
Extensional Viscosity Measured with Three Jets

A NEW way of measuring the extensional viscosity of a liquid (that is the ratio of the time average stress to the extensional strain rate in a jet of the liquid) is reported in next Monday's *Nature Physical Science* (February 12) by Bragg and Oliver. Their apparatus is shown in the diagram; in this so-called "triple jet" system the two outer jets, in which the liquid is travelling at a high velocity, converge on the middle, slower-moving jet and stretch it.

The results and the technique are of particular interest in the context of certain industrial processes, fibre spinning for example, in which stretching flow plays a central part.

Bragg and Oliver were able to obtain extensional strain rates of between 100 and 800 s^{-1}, by comparison with other methods which have either had rather low strain rates (<1 s^{-1}) associated with them, or very high ones ($\sim10^4$ s^{-1}). In the triple jet method the other component parameter in the extensional viscosity, the time average stress, is deduced by measuring the change in force on the central nozzle as the central jet is stretched.

As expected Bragg and Oliver found that the solutions they used—two aqueous solutions of polyacrylamide and one of 'Polyox'—were very resistant to stretching. Solutions of this type that have shear viscosities of a few cpoise may have extensional viscosities of more than 10 poise; that is the Trouton ratio (of extension viscosity to shear viscosity) is often greater than 1,000. The Trouton ratio is three for a Newtonian fluid.



The triple jet arrangement in operation.

The results show that the extensional viscosity for the three solutions tested goes up slowly with strain rate. The 'Polyox' solutions seem to behave quite differently from the polyacrylamide solutions; the former have higher Trouton ratios at lower extensional strain rates. Thus at 488 s^{-1} the Trouton ratio for 0.1 per cent polyacrylamide solution is 284, whereas at 131 s^{-1} the value for 0.1 per cent 'Polyox' solution is 760.