may be accidental; if it is not, it suggests a link between cosmology and fundamental physics. Dirac's suggestion that the gravitational constant $G$ might vary with time was found to conflict with the known luminosity and lifetime of the Sun. (However, the fact that neutrinos from the Sun have not been detected has left solar-evolution theory in a turmoil.) The 1967 suggestion by George Gamow that the electron charge $e$ could be varying was also dismissed, both by an argument by Denys Wilkinson (then at Oxford University) and Freeman Dyson (Institute for Advanced Study) on isotopic abundances and by the earlier astronomical limits on the variability of $\alpha$.

It was the long-sought-for opportunity to measure both the hydrogen 1420-MHz hyperfine line and an optical line for the same high-redshift object that made the new tests possible. This object is the BL-Lac-type quasar AO 0235 + 164, which flared five optical magnitudes. Spectral lines for an alkali-like atom, $Mg^+$, were measured[2] at Kitt Peak National Observatory by E. Margaret Burbidge and her colleagues from the La Jolla and Berkeley campuses of the University of California. They found a redshift ($\Delta\lambda/\lambda_0$) of $z_{Mg} = 0.52392 \pm 0.00010$ in a doublet with laboratory wavelengths 2795.53 Å and 2802.70 Å. The redshift found[3] by Roberts and his collaborators for the 21-cm hydrogen line was $z_H = 0.52385 \pm 0.00001$.

To obtain the three independent limits, Wolfe, Brown and Roberts made three different tests, as follows:

▶ A comparison of the hydrogen hyperfine splitting frequency with the frequency of either member of the MgII doublet. The ratio of these two frequencies, when terms above first order in $m/M$ and $\alpha$ are neglected, is a constant times $\alpha^2 g_p m/M$. This quantity at the time of photon absorption (thousands of millions of years ago), divided by the corresponding quantity at the present time, is equal to

$$\frac{1 + z_{Mg}}{1 + z_H} = 1.00005 \pm 0.0001$$

This result requires no assumption as to the origin of the redshift. (Some theorists feel that mechanisms other than expansion may contribute to the redshifts, as high as two or three, of quasars.) Assuming now that the absorption redshift is completely cosmological, and using the Friedmann cosmology with a deceleration parameter $q_0$ of zero, Wolfe, Brown and Roberts obtained[1] a look-back time of at least $0.7 \times 10^{10}$ $(50/H_0)$ years and the maximum rate of change already mentioned for this constant, $2 \times 10^{-14}$ per year. ($H_0$ is the Hubble constant in km $sec^{-1}$ $Mpc^{-1}$.)

▶ A comparison of the hydrogen hyperfine frequency with the $Mg^+$ fine-structure separation at the two epochs. Because the expressions for both of these contain $\alpha^2$, Wolfe and his coauthors were able to eliminate $\alpha$ and obtain the quoted ceiling of $8 \times 10^{-12}$ per year on the variability of $g_p m/M$.

▶ An analysis of the observed separation of the $Mg^+$ fine-structure doublet, which leads to the quoted constraint on $\alpha$.

**The implications to astronomy** of measuring at the same high redshift, a 21-cm absorption line and identified optical absorption lines go beyond the question of whether fundamental constants vary. They also include:[3]

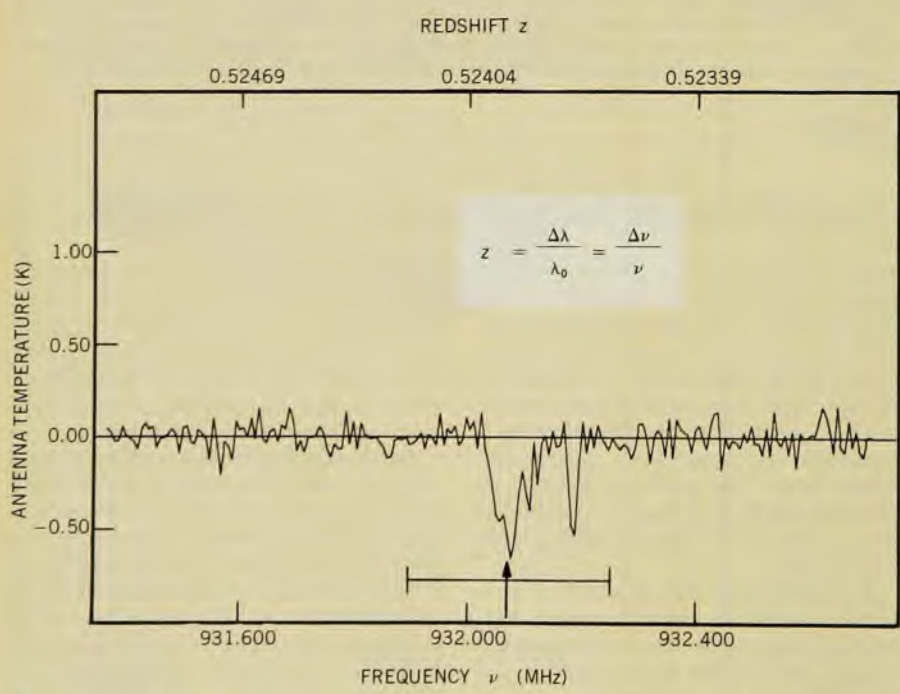
▶ A check on the expression for the Doppler shift over a much larger redshift interval than before;

▶ a verification that the optical lines were identified correctly;

▶ a new means of estimating abundances of heavy elements relative to that of hydrogen, and

▶ clues to the location of the absorbing gas with respect to the continuous emitter behind it.

—HRL




**The absorption-line profile of hydrogen** in the direction of the radio source AO 0235 + 164. The comparison with the optically measured redshift (arrow) and its associated error (reference 2) results in a new, more restrictive limit on the possible variation of some fundamental constants.

### References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## Japanese synchrotron yields 10-GeV protons

The first accelerator for high-energy physics in the Far East was recently dedicated at the KEK laboratory in Tsukuba science city, 60 km northeast of Tokyo. The proton synchrotron, whose construction began in 1971, has exceeded its initial design energy of 8 GeV on 19 March, when it reached over 10 GeV. After the main ring power supply and cooling capacity are modified, the machine is expected to reach a peak energy of 12 GeV.

In July KEK expected to have a 4-GeV negative pion beam from an internal target; in addition, KEK will have a fast external beam for the already operational 1-meter hydrogen bubble chamber. A slow extracted beam is being planned, and counter experiments using internal targets are expected to begin next May.

The machine consists of a 750-keV Cockcroft–Walton preinjector, a 20-MeV linac, a 500-MeV booster synchrotron and the 12-GeV main ring. Extraction from the booster and injection into the main ring are accomplished with fast kicker and septum magnet systems in a single turn. The main ring, with a mean radius of 54 meters, has a circumference nine times the booster circumference so that it can accommodate nine booster pulses. The separated-function lattice has four superperiods and seven cells per period.

Normalized beam emittance from the 12-GeV beam is expected to be $200\,\pi \times 40\,\pi$ $(\text{cm-mrad})^2$.

Each target station of the slow extracted beam will initially support one secondary kaon or antiproton beam, one in the momentum range less than 1 GeV/$c$ and the other 1–2 GeV/$c$.

Special precautions have been taken to maintain the alignment of the KEK linac in the presence of the frequent but minor earthquakes in the Tsukuba region. The linac tanks are supported on steel plates

**KEK laboratory near Tokyo** houses a proton synchrotron expected to reach 12 GeV. The six-story building (center foreground) is the physics department; the adjacent two-story building is the accelerator department. Further to left is the building housing the preinjector, linac and booster accelerators, the main control room and the central machine computer. In left foreground is the 54-m radius main ring; immediately behind it is the experimental hall; the building housing the 1-m bubble chamber is to left of that. Mount Tsukuba is in distance.

mounted on preloaded steel springs that can withstand an acceleration of 0.5 *g;* they reduce the transverse and longitudinal natural oscillation frequencies of the tank to less than 2 Hz. (In that area the frequency associated with the highest amplitude of ground motion is about 6 Hz.)

The KEK laboratory hopes to build a high-energy colliding-beam facility, TRISTAN, which would consist of three or four storage rings, two using superconducting dipoles of 4–5 tesla field (150–180 GeV) and the other of conventional magnets. Initial injection would be into the ring of conventional magnets, which would raise the beam energy from 12 to 50 GeV, thus decreasing the magnitude of acceleration and consequent ac losses in the superconducting rings. The 50-GeV beam could also be used to make antiprotons. Plans call for injection and acceleration of electrons in the conventional magnet ring to 17 GeV, giving the possibility of electron–positron and electron–proton and positron–proton colliding beams in the superconducting rings. Cost of the project is estimated at $330 million.

Another possibility for KEK, which is being proposed by the University of Tokyo, is to construct a 2.5-GeV electron linac, primarily for injection into an electron storage ring, which would be used for synchrotron-radiation experiments. The linac would also be used for injection into the electron (or positron) storage ring; a maximum luminosity of $5 \times 10^{31}$ $cm^{-2}$ $sec^{-1}$ is anticipated for electron-proton colliding-beam experiments.

—GBL

## Heavy ions

*continued from page 17*

of GSI scientists and outside users. Most of these users will be from German universities and research institutions, such as the Max Planck Institute and the federally sponsored research centers. In addition, about 20 positions for guests from foreign countries are provided.

**The linear accelerator,** 120 meters long, consists of a 300-kV dc preaccelerator, followed by a Wideröe structure in the prestripper section, followed by an Alvarez structure and 20 single-gap cavities in the post-stripper section. Two ion sources are provided: for atomic mass up to 140 there is a duoplasmatron, and for heavier ions, the facility has a Penning source.

As the accelerator began operating, the first beams of 5.9 MeV/nucleon argon, krypton and xenon became available at the end of last year. Regular experiments first began in January 1976. By using eight of the 20 single-gap cavities in addition to the Wideröe and Alvarez sections, the GSI workers have taken the UNILAC energy up to 7.5 MeV/nucleon so far. Some time during 1976, GSI expects to have the machine operating at full power, according to P. Armbruster.

When operating at full capacity, UNILAC is expected to accelerate an argon beam of $6 \times 10^{13}$ particles/sec to 14 MeV/nucleon and a uranium beam of $8 \times 10^9$ particles/sec to 10 MeV/nucleon. Energy will be variable continuously from 2 MeV/nucleon up to the maximum. The energy spread of the beam is expected to be ± 0.3% FWHM; when a debuncher is used, this value is expected to be improved by a factor of 10.

The experimental hall has an area of 45 × 56 $m^2$ with about 20 target positions. Shielding walls consist of movable concrete blocks. Beam transport is in three parts: a straight-on beam line for high-intensity experiments and two deflected beam lines in which an achromatic or a dispersive beam transport mode is possible. Next year a beam-splitting system will allow using the beam at three different target positions simultaneously.

**Experiments.** GSI is exceptionally well equipped, according to James B. Ball, director of the Oak Ridge Heavy-Ion Laboratory. Whereas a US laboratory might have one piece of apparatus to do a given kind of experiment, GSI might have two to three. It is expected that GSI will cover the whole field of heavy-ion research: nuclear physics and chemistry, atomic and solid-state physics, ion source and accelerator improvements and technological applications of heavy ions.

In nuclear physics and chemistry, a major emphasis will be on the search for superheavy elements. But the production and spectroscopy of all kinds of new nuclei will be pushed: transactinide elements, neutron-rich and proton-rich nuclei far off the stability line, according to Armbruster. A second field is in-beam spectroscopy of excited states, in particular the population of high angular-momentum states of nuclei by Coulomb excitation and by fusion reactions. A third area is to study nuclear-reaction mechanisms and macroscopic properties of nuclei.

In atomic physics, the main fields of interest at GSI are inner-shell ionization phenomena at the energies offered by UNILAC (1–10 MeV/nucleon) and ion-target systems of nearly any combination.

**A variety of other heavy-ion** accelerators are competing or will be competing with UNILAC. The Super-HILAC at Lawrence Berkeley Laboratory produces 8.5 MeV/nucleon up to $Z = 54$. Average intensities are presently $5 \times 10^{11}$ particles/sec for xenon. Uranium has not been accelerated with the device. Berkeley is proposing to upgrade the Super-HILAC to yield high-intensity beams of all ions. Expected intensities from the improved Super-HILAC range from $3 \times 10^{14}$ particles/sec for krypton to $6 \times 10^{12}$ particles/sec for uranium. At the Joint Institute for Nuclear Studies in Dubna, USSR, two cyclotrons, the U-300 and U-200, have operated in tandem and produced about 8 MeV/nucleon for certain ions—partic-