

Brook) have now carried out a high-resolution CO emission survey between galactic longitudes 24° and 30° , and a more cursory examination of the rest of the first galactic quadrant, out to 70° . In the plane of the galactic disk it is conventional to take our Sun as the origin of coordinates, and to call the direction of the galactic center (in Sagittarius) the zero meridian of longitude. Thus the quadrants 0° to $+90^\circ$ and 0° to -90° include the portion of the galaxy interior of the Sun, but of these only the first quadrant (0° to $+90^\circ$) is accessible to observers in the northern hemisphere.

Solomon and his colleagues have used two millimeter-wave radio telescopes in this survey: the National Radio Astronomy Observatory's 36-foot antenna at Kitt Peak near Tucson, Arizona and the new 45-foot telescope at the University of Massachusetts. Both telescopes have angular resolutions of about one arc minute.

With telescopes of such high resolution, Solomon told us, one can study individual molecular clouds in detail, even at distances greater than 5 kiloparsecs. Both of the earlier surveys had noted a marked concentration of CO radiation from a galactic annular ring, between 4 and 8 kiloparsecs from the center. Solomon and his colleagues have concentrated their recent survey on the distribution and properties of molecular clouds in that ring.

In their high-resolution survey, the Stony Brook-Massachusetts group looked at CO radiation in the galactic plane every two minutes of arc between longitudes 24° and 30° . What one observes in each direction is the Doppler-shift spectrum of the 2.6-mm radiation, which gives the component of the relative velocity of the emitter and the observer along the line of sight. These Doppler shifts arise from the nonuniform rotation of the material in the galaxy about its center. Knowing the general pattern of

this nonuniform rotation as a function of R , the distance from the galactic center (the so-called galactic rotation curve), one can deduce from the Doppler spectrum the distribution of distances from the observer to the radio emitters in a given longitudinal direction.

The stars and gases of the galaxy rotate about the center with a roughly uniform tangential velocity of a few hundred kilometers per second, implying an angular velocity that decreases with increasing distance from the galactic center more or less like $1/R$. The outer reaches of the galaxy lag behind the faster spinning interior. The use of the Doppler shift to deduce distances of radio sources in the galaxy suffers from several uncertainties: A twofold ambiguity comes from the fact that a given longitudinal direction cuts a circle of constant R at two points; near longitudes 0° and 180° the component of relative velocity along the line of sight is too small to yield distance information,

Earthquake at LLL hurts structures more than lasers



When the earthquake struck the Lawrence Livermore Laboratory laser-fusion facility on 24 January, most of the damage it inflicted was to the buildings and support facilities, according to John Emmett, who directs the program. Out of the \$8 million in optical components in the two-armed Argus laser and 20-armed Shiva laser, only \$13 000 worth of damage occurred. Repair of the support equipment will cost \$126 000, a figure that includes electrical and mechanical equipment and the expense of repositioning the laser and target frames. (The target frame, for instance, weighs 400 000 pounds and had to be jacked up and shifted back into place to ensure optimal alignment of beams.)

About \$500 000 will be spent to repair Building 381, which contains both the Argus lab and offices for the staff. Emmett told us,

"Our offices were just trashed." On the second floor, light fixtures and ceiling tiles fell to the floor, and bookcases and file cabinets tumbled. But as the floors performed an oscillatory motion, the office occupants ducked under tables or stood in doorways. So no one was injured, Emmett told us.

"How long did the tremor last?" we inquired. "Subjective time was about an hour and a half." The real time was about a minute for the 5.5-magnitude shock at 11:00 a.m., the 5.2 magnitude at 11:01 and the 4.8 magnitude at 11:03. After determining that no one was buried under the piles of rubble and furniture in Building 381, Emmett went over to the laser area. He found that although the equipment was flexing during the quake, no obvious damage had occurred.

The Shiva system of 20 lasers sits on

frames that stand on roller bearings, which are pinned to the floor with bolts. These bolts were intended to shear between the frame and the floor if a quake occurred in excess of $\frac{1}{4}g$. After inspecting the damage, Livermore staff determined that some tie-down bolts were loosened and support rollers had moved. The Shiva laser space frame settled back to its original position, within the $\frac{1}{16}$ -inch tolerance of the survey measurements. Only minor misalignment of laser components occurred. In fact, Emmett said, when the laser was turned on, 14 of the beams automatically locked into alignment.

Of the 50 $\frac{3}{4}$ -inch bolts securing the Shiva target-chamber space frame, 22 sheared (see photo), but the target frame moved less than an inch relative to the laser space frame. By the first week in February, the target-chamber space frame had been realigned and rebolted to its foundation.

Although the \$50 000 oscillator and one amplifier of the Argus laser fell to the floor, the oscillator was simply picked up, and it worked when turned on. The amplifier was cleaned first as a precaution. The Argus turning mirrors were scratched on the back only; so the damage will not affect beam propagation. Livermore staff may yet decide to replace the mirrors.

Although the computer control systems were operating in two weeks, the capacitor banks had been sprayed by a broken sprinkler line; so the power conditioning system had to be dried off. By mid-February Argus was running at full power and being calibrated and Shiva was being tested at full power. Experiments with both Argus and Shiva were expected to resume by 1 March.

Emmett told us that in the rest of Livermore, the reactors, plutonium and tritium facilities had not been damaged at all. The magnetic-fusion facility experienced minimal damage.

—GBL