cene and chromocene among the "pure" metallocenes of the first row of the first transition series.

If in the intercalation compound we visualize the metallocenes as spinning freely about an axis parallel to the c-direction, they can be approximated as cylinders with a diameter of about 6.6 to 6.8 Å (and heights of about 5.5 Å). This value for the circle swept out by a spinning guest is very nearly equal to twice the a_0 distance of the host lattices (effectively the diameter of the chalcogen). Therefore, the experimentally implied stoichiometry of the products can be accounted for simply by projecting on the close-packed chalcogen layer circles having radii r equal to the chalcogen diameters (see Fig. 3). Since there are two chalcogen layers per metallocene layer, one predicts a value of 4 : 1 for the host-to-guest ratio. The presumed motion of this model has been verified by broad line nuclear magnetic resonance experiments which will be reported elsewhere (*5*). Details of the structures are presently being investigated and will be reported later.

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References and Notes

1. F. R. Gamble, J. H. Osiecki, M. Cais, R. Pisharody, F. J. DiSalvo, T. H. Geballe, *Science* **174**, 493 (1971).
2. G. E. Coates, M. L. H. Green, K. Wade, *Organometallic Compounds* (Methuen, London, ed. 3, 1968), vol. 2, chap. 4.
3. M. R. Litzow and T. R. Spalding, *Mass Spectrometry of Inorganic and Organometallic Compounds* (Elsevier, New York, 1973), p. 511.
4. An investigation of the magnetic and transport properties of these compounds will be presented elsewhere (A. H. Thompson and F. R. Gamble, in preparation).
5. B. G. Silbernagel, in preparation.

13 December 1974

Ganymede: Observations by Radar

Abstract. *Radar cross-section measurements indicate that Ganymede scatters to Earth 12 percent of the power expected from a conducting sphere of the same size and distance. This compares with 8 percent for Mars, 12 percent for Venus, 6 percent for Mercury, and about 8 percent for the asteroid Toro. Furthermore, Ganymede is considerably rougher (to the scale of the wavelength used, 12.6 centimeters) than Mars, Venus, or Mercury. Roughness is made evident in this experiment by the presence of echoes away from the center of the disk. A perfectly smooth target would reflect only a glint from the center, whereas a very rough target would reflect power from over the entire disk.*

We have made radar observations of Ganymede, Jupiter's largest satellite, on six nights in late August 1974. The radar that we used for this experiment is located at the Goldstone Tracking Station in the Mojave Desert and is operated for the National Aeronautics and Space Administration by the Jet Propulsion Laboratory. We transmitted a 400-kw, monochromatic beam of microwaves to Ganymede. After the round trip time-of-flight (1 hour and 7 minutes), we switched the antenna to receive and collect power spectrograms of the very weak echoes for an equal time. We could complete three to four such send-receive cycles in each of the six nights during which we collected data.

During the send part of the cycles, the transmitter frequency was switched alternately to +540 hertz and −540 hertz on a 60-second cycle. The phase of this cycle was carefully noted for use one round trip time later. This was done to enable us to remove from the spectrograms the background noise level (which was some 800 times the signal level). All of the spectra for which the signals were low in frequency were subtracted from those for which the signals were high. This resulted in an inverted signal spectrum displaced to the left 540 hertz, followed by the normal spectrum displaced equally to the right. The resultant base line was very flat and free from effects of the system background.

We improved the signal-to-noise ratio by combining the two halves of each spectrum by the operation of shift (1080 hertz) and subtract. This final processing yields the normal spectrum but also results in a half-amplitude, inverted spectrum on either side of the normal one.

Figure 1 is an example of the effects of the processing. It is a theoretical spectrogram, computed for the rough surface which best fits our data. The bracket along the abscissa marks the maximum Doppler shift, 854 hertz, between the approaching and receding limbs of Ganymede, the shift having been computed from the radius (2635 km) as determined by Carlson *et al.* (*1*) and a rotation period of 7.155 days.

Figure 2 shows a set of received spectrograms, each averaged over one night. Although these signals are very noisy, the telltale signature of Fig. 1 can be seen in each. The error bars in Fig. 2 represent ± the standard deviation and are computed for the specific processing system. When the area under each spectrum is calculated, the center frequency being estimated from the average of all the spectra, the total signal power is obtained. The powers are corrected for distance, antenna gain, system noise temperature, and transmitter power, and are converted to radar cross section.

These results are plotted in Fig. 3, expressed as the percentage of the cross section as compared to that of a perfectly conducting sphere. The abscissa is the orbital phase angle. Since Ganymede is in synchronous rotation (*2*) about Jupiter, the part viewed from Earth changes with the phase angle. The variations in the radar cross section in Fig. 3 do not appear to be statistically significant, however; as in Fig. 2, the error bars are calculated.

The spectrograms are computed over a bandwidth of 4 khz and with a resolution of 187 hertz. The signal, of course, is expected to be in the center. Because of the orbital motions of Ganymede and Earth and the rotation of Earth, there is a Doppler shift in the echo of hundreds of kilohertz. A precomputed ephemeris was used to automatically tune the radar receiver so that the echo would be centered in the passband. The ephemeris must be accurate enough to prevent significant frequency drift over each night of observation.

The ephemeris we used, computed by P. A. Laing of the Jet Propulsion Laboratory, had such accuracy that we could average the data over all six nights and thereby realize a much needed improvement of $\sqrt{6}$ in the signal-to-noise ratio.

Figure 4 is the average spectrogram. It is the principal result of our measurements and is admittedly noisy. It represents, however, a clear radar detection of Ganymede

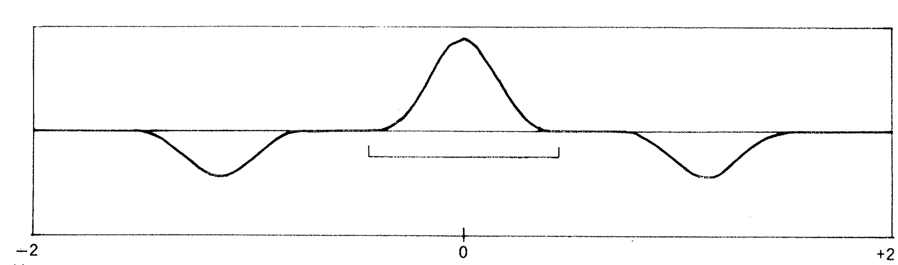

Fig. 1. Calculated spectrogram for the Ganymede surface based on the assumed backscattering function $F(\theta) = \cos^{10}\theta$, where θ is the angle of incidence. The instrumental response is included.

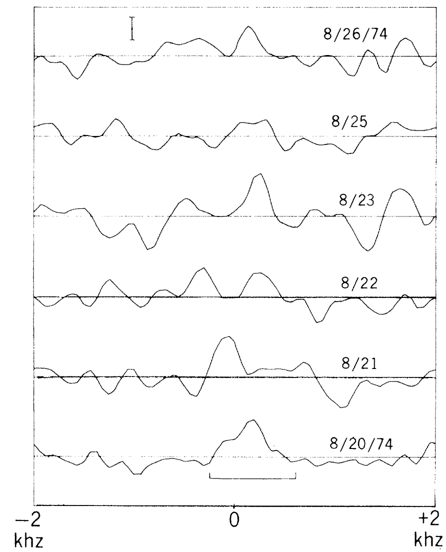

Fig. 2. Spectrograms measured from the Ganymede echo, each averaged over one night.

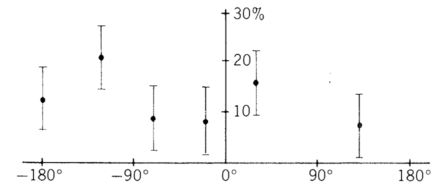

Fig. 3. Radar cross section of Ganymede as a function of phase angle (Jupiter-Ganymede-Earth). Error bars represent ± the formal standard deviation.

Table 1. Radar measurements at 12.6 cm.

Object	Radar cross section (%)	Roughness measure: half power angle (°)
Ganymede	12	21°
Mars	8	1° to 3°
Venus	12	4° to 6°
Mercury	6	7° to 8°
Toro	~8	~30°

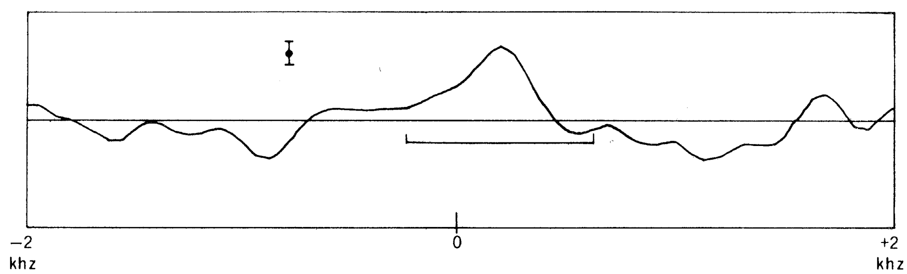

Fig. 4. Average of all the Ganymede spectra of Fig. 2.

which contains two kinds of information.

The first item of information is the total signal power, which corresponds to a radar cross section of 12 ± 2.5 percent. The second kind of information is the width of the spectrum. It corresponds to the power, reflected from an average surface element, which drops by half when tilted 21° from the line of sight. Because of this, the surface must have a considerable degree of roughness. The measured radar cross section is close to the value we have found for the terrestrial planets. The roughness of Ganymede, however, differs markedly from that of the terrestrial planets, being similar to our measurements of the small asteroid Toro. Table 1 summarizes these data.

What kinds of surface material have these qualities? Johnson and McCord (*3*), Pilcher *et al.* (*4*), and Fink *et al.* (*5*) have found strong evidence of water ice on the surface of Ganymede from their infrared spectra. Polarization studies by Veverka (*6*) show similar results. In addition, theoretical reasons have been advanced by Lewis (*7*) for expecting Ganymede to be composed largely of ice. A simple sphere of ice, however, does not fit well with the radar data. Such a sphere would have a radar cross section of less than 8 percent. If the surface were softened by an icy regolith or snow (which is likely for a planet of ice), then the radar cross section would be much smaller and the fit to the data would be worse.

Large, irregular blocks of ice could, by internal reflections, return more energy to Earth and thereby account for both the roughness and cross-section data. It is hard to find a mechanism whereby such blocks would be produced, however, and such a surface seems unlikely.

A second possibility might be a hard rocky surface similar to that of Mercury, but much rougher. Such rocks would have to be confined to the surface, since the density of Ganymede (2.0 g/cm^3) (*1*) is far too low for a rocky interior. Meteoritic influx could supply the material, but then one might expect the surface to be similar to that of Mercury, contrary to the data.

Perhaps the most likely possibility for the surface is rocky or metallic material embedded in a matrix of ice. Such a surface could be relatively smooth, with a top layer of ice rubble, but it could be rough to radar since the ice would be nearly transparent. As in the earlier case, the rocky material could result from meteoritic bombardment.

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References and Notes

1. R. W. Carlson, J. C. Bhattacharyya, B. A. Smith, T. V. Johnson, B. Hidayat, S. A. Smith, G. E. Taylor, B. O'Leary, R. T. Brinkmann, *Science* **182**, 53 (1973).
2. D. Morrison, N. D. Morrison, A. R. Lazarewicz, *Icarus* **23**, 399 (1974).
3. T. V. Johnson and T. B. McCord, *Astrophys. J.* **169**, 589 (1971).
4. C. B. Pilcher, S. T. Ridgway, T. B. McCord, *Science* **178**, 1087 (1972).
5. U. Fink, N. H. Dekkers, H. P. Larson, *Astrophys. J.* **179**, L155 (1973).
6. J. Veverka, *Icarus* **14**, 355 (1971).
7. J. S. Lewis, *ibid.* **16**, 241 (1972).
8. This paper presents the results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract NAS 7-100, sponsored by the National Aeronautics and Space Administration.

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Chronotypic Action of Theophylline and of Pentobarbital as Circadian Zeitgebers in the Rat

Abstract. *In the rat the deep body temperature rhythm, monitored by telemetry, can be reset in a predictable direction by a stimulant (theophylline) and by a depressant (pentobarbital). When the drugs are applied immediately before or during the early active phases of the circadian cycle, the rhythm is set back (phase delay). When applied later, past the thermal peak, theophylline, but not pentobarbital, shifts the rhythm ahead (phase advance). Theophylline and pentobarbital in addition to having a number of already established pharmacological properties are now further identified as* chronobiotics: *they are drugs that may be used to alter the biological time structure by rephasing a circadian rhythm.*

It has been well established in a number of studies that a single stimulus delivered at the right time can advance or delay ("reset") the phase of a circadian oscillation (*1*, *2*). The relationship between the induced phase change and the circadian time of administration of the external stimulus has been called a phase response curve. In the