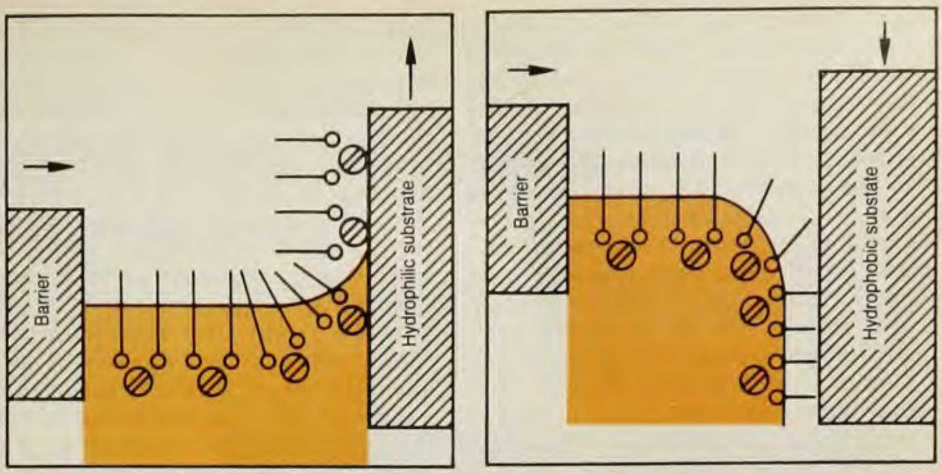
tron source at Risø. They found that for coverings of a monolayer or more, oxygen molecules apparently line up with the molecules perpendicular to the plane, and arranged in the plane in a close-packed array of equilateral triangles. The presence of a second diffraction peak that appeared below 11.9 K indicated a doubling of the unit lattice, and thus an antiferromagnetic ordering: Oxygen molecules in neighboring rows have oppositely directed spins. Subsequently, Gregory's measurements[3] of the susceptibility confirmed the antiferromagnetism of the low-temperature phase, although his other results did not entirely agree with all the details from the neutron-scattering work.

Most recently a collaborative effort of researchers from MIT, Washington and IBM has investigated oxygen on ZYX graphite using heat capacity and x-ray diffraction measurements.[4] The group included Birgeneau, Stoltenberg, Vilches, Peter Stephens and Paul Heiney of MIT, and Paul Horn of IBM. Birgeneau told us that their results indicate that the phase diagram of thin oxygen films is apparently much more complicated than one had thought. At the lowest temperatures, it appears that oxygen molecules lie flat on the surface in a rectangular array, incommensurate with the substrate, with molecules in neighboring rows staggered, like bricks. For somewhat thicker systems (with an average depth of 1.5 monolayers or more) the molecules appear to stand up and arrange themselves in a slightly distorted triangular structure. There are still some differences between the results of these x-ray and heat-capacity studies and the results of detailed neutron-diffraction studies by Nielsen and McTague,[5] Birgeneau told us; so the structure of the phases and the phase diagram must still be regarded as uncertain. The antiferromagnetism of the low-temperature two-dimensional phase, however, appears to be certain. For coverages between 1.5 and 3 monolayers there is a clear magnetic transition at 11.9 K, but no magnetic transition has yet been seen for the single monolayer phase, Birgeneau said.

Theory. Pomerantz told us that he had hoped to confirm the theorem that a two-dimensional Heisenberg system exhibits no long-range order at finite temperatures. Because the interaction among manganese atoms is isotropic, the manganese films should behave according to the Heisenberg model. Pomerantz, however, found that his monolayers exhibit a phase transition; the Heisenberg model apparently does not apply.

There are several reasons why the theoretical result may not apply to his system, Pomerantz told us. The theorem is proven only for infinite sheets and for truly isotropic interactions: It essentially says that for such systems there are spin waves of arbitrarily low energy that can be excited to a significant extent at arbitrarily low temperatures. Thus, the finite size of the experimental system, any anisotropy of the interactions, or any tendency to three-dimensional ordering can violate the assumptions of the theory. With his preparation, Pomerantz said, the only one of these possibilities that is ruled out is the possibility of a three-dimensional ordering. The other conditions of the theory may, however, be impossible to achieve. The fact that there is little or no film–surface interaction to affect the structure or ordering of the film makes this an attractive system for future investigations, Pomerantz said; there are, however, still some experimental problems to be resolved.



Formation of Langmuir–Blodgett monolayers. When stearic acid is dropped onto the surface of a neutral solution of a manganese salt, manganese ions (large circles) bind to stearate ions (circles with long tails). Compressing this layer forms a compact monolayer of manganese, which can be picked up on a rigid substrate. Figure from M. Pomerantz.

The oxygen films are, apparently, a realization of the two-dimensional Heisenberg model with cubic anisotropy. In contrast to the isotropic Heisenberg model, this model has discrete symmetry and, therefore, exhibits long-range order in two dimensions. Eytan Domany and Eberhard Riedel at the University of Washington identified the magnetic transition in oxygen films with the cubic Heisenberg model using Landau symmetry analysis.[6] According to this approach the order parameter describing the ordered phase is determined by the symmetry group of the system. This permits one to construct model Hamiltonians with relatively few adjustable parameters once the underlying structure of the physical system is known. Because their analysis was based on the earlier interpretation of the neutron scattering data, the model may not apply, Riedel told us.

The long-range crystallographic order of these two model systems is not yet well defined, Birgeneau and Pomerantz told us, which makes their theoretical interpretations even more difficult. In spite of these ambiguities, Birgeneau and Pomerantz both told us that their techniques will prove useful for investigating two-dimensional systems as well as the change-over from two- to three-dimensional systems; they may also illuminate the general problems of phase transitions. The MIT group, for example, is especially interested in using oxygen monolayers to study two-dimensional melting. The oxygen-monolayer studies have already had the effect of resolving some long-standing questions about the magnetic structure and transitions of bulk oxygen. —TVF

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New light on Novaya Zemlya polar mirage

While seeking a Northeast Passage to the Orient, the explorer Willem Barents and his crew were stranded for the winter at Novaya Zemlya (76°12'N). During the perpetual night of their arctic winter, one noontime in January 1597 the explorers were astonished to see the Sun appear two weeks sooner than expected at that latitude. At the time, the Sun's actual position was still about 5° below the geometrical horizon.

This unexpected appearance of the Sun, the Novaya Zemlya effect, is now explained in terms of long-range optical ducting in the lower atmosphere. At the Optical Society of America meeting in Chicago in October, Waldemar Lehn and Borys German of the University of Manitoba in Winnipeg showed what they believe to be the first collection of documented photographs of this polar mirage.

After the original observation of Barents, most scientists were skeptical that it had been seen at all, although Kepler in 1604 did try to attempt an explanation for the effect. During Ernest Shackleton's last expedition to Antarctica, on 8 May 1915, seven days after the Sun had set for the Antarctic winter, he saw the Sun reappear. As had Barents, Shackleton saw the Novaya Zemlya effect a second time during this polar winter.

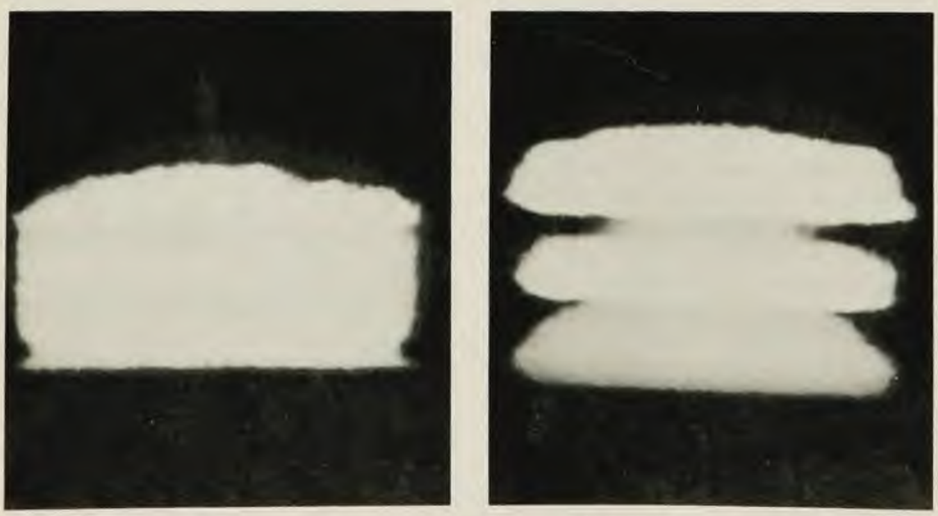
Last year Lehn analyzed[1] data taken by G. H. Liljequist during a 1951 Antarctic visit; he had seen and sketched several cases of the Novaya Zemlya effect and measured temperature profiles of the lower atmosphere. In one case, he reported a very strong temperature inversion of 25 °C, extending up to 1000 meters elevation. Lehn developed a model to trace rays through the atmosphere for different temperature distributions that reproduced the weird shape seen by Liljequist.

Lehn explains that in the Novaya Zemlya effect, the limit on viewing distance imposed by the Earth's curvature is overcome and the horizon distance is greatly extended because light rays are trapped beneath a fairly sharp temperature boundary (thermocline) of large horizontal extent. Within the thermocline layer the coefficient of refraction, k, must be greater than one, while above and below it k must be less than one. Then certain rays will return to Earth in a fashion similar to total internal reflection or light being transmitted in an optical fiber. If conditions are right, these rays, trapped in the atmospheric duct, can bounce back and forth between the thermocline and a region close to the Earth many times, provided the ground is very level. The image, however, is completely distorted because individual rays are refracted by different amounts.

The effect is easiest to see in polar regions because the reappearance of the Sun during the winter night is so dramatic. Also in winter the characteristically flat polar regions are ideal for generating the required uniform widespread temperature inversion.

Lehn and German visited Tuktoyaktuk, Canada (69°26'N, 133°02'W) a week before the Midnight Sun was due to begin, essentially reversing the time when Barents made the first Novaya Zemlya observation. The second time they looked, in the early morning on 16 May 1979, they saw the effect—the Sun did not set. It remained above the horizon, within a rectangular strip that is characteristic of the effect. Lehn and German saw an assortment of images. One was essentially a rectangle whose width was 32 min of arc (normal for the Sun) but whose height was 10–14 min of arc. (See the figure.) Another resembled a Big Mac, Lehn told us, with three pancake-thin images, one above the other; in between was no light. From clear superior mirages of distant landmarks in other directions, the pair knew that the uniform temperature inversion responsible for the effects covered a very large geographical area. (Typical distances were about 100 km.) Using photographs, site surveys and ground-level meterological data, the pair did a simulation study. They assumed various temperature distributions (strength of the inversion and height of the thermocline) until they duplicated each of the observed solar images.

The same kind of optical ducting has been proposed[2] by Lehn and Irmgard Schroeder (Manitoba) to explain why Eric the Red, when exiled from Iceland, set out so confidently toward Greenland. The sagas relate that he was seeking some islands seen by Gunnbjorn off northwest Iceland, about 100 years earlier. However, Lehn and Schroeder note, Gunnbjorn's "skerries" (flat rocks projecting just above a water surface) never existed in that location. Instead his skerries have an appearance and location consistent with a ducted image of the Greenland coast that was transmitted to observers in northwest Iceland. —GBL



Novaya Zemlya effect photographed in the Arctic on 16 May 1979. Because of atmospheric ducting, rays bounce back and forth between a thermocline and the Earth, and a distorted solar image is visible when no image at all is expected. In both images the horizontal extent is 32'. At left, the rectangular image is 13' high at either side and higher in the middle. At right, the stack of three images (Big Mac) is a total of 19' high. Photos by W. H. Lehn, B. German.

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in brief

NASA has chosen Ford Aerospace and Communications for the negotiation of a contract for the Space Telescope that is to be launched into orbit from the Space Shuttle. Ford is to undertake design engineering of the preliminary-operations and test-support systems that will be located at the Goddard Space Flight Center (Greenbelt, Maryland).

DOE has selected McDonnell Douglas as the builder of the Elmo Bumpy Torus proof-of-principle experimental facility (EBT-P) at Oak Ridge (PHYSICS TODAY, October 1979, page 18). The 4½-year project is expected to cost \$70–100 million. EBT-P will be an upgraded version of the original EBT, a hybrid magnetic-confinement fusion machine in operation at Oak Ridge since 1973.

The Tristan mass separator is now in operation at Brookhaven's High-Flux-Beam Reactor. This facility, said to be the only reactor-based, online mass separator in the US, was moved to Brookhaven in 1978 after 12 years of operation at the DOE Ames (Iowa) Laboratory. It is used to study unstable nuclides produced in fission reactions.