the nature of the Moon, which he recorded in his wash drawings based on observations made with a telescope in November and December 1609. Galileo's conclusions are famous: "I have been led to the . . . conviction that the surface of the moon is not smooth, uniform and precisely spherical . . ., but it is uneven, rough, and full of cavities and prominences, being not unlike the face of the Earth, relieved by chains of mountains and deep valleys".

Finally, Edgerton bolsters his basic hypothesis by using it to show why Chinese scientists, the inventors of gunpowder, printing and the magnetic compass, did not attain the logico-mathematical conditions of a scientific revolution in the seventeenth century. This provides a fitting conclusion to an ambitious and largely persuasive book. □

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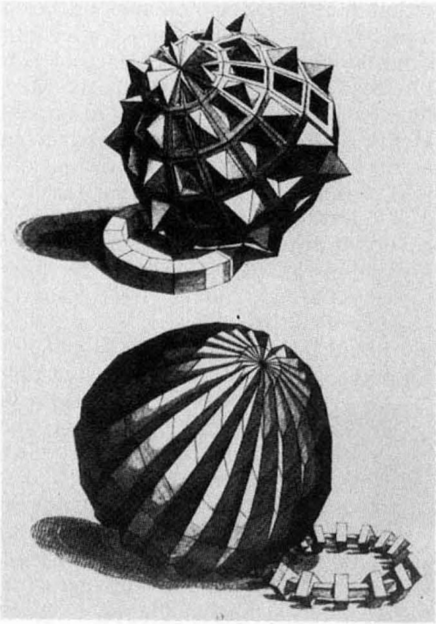

An engraving from Lorenzo Sirigatti's *Pratica di prospettiva* (1596) used to illustrate chiaroscuro.

Particles to the rescue

Michael L. Cherry

Neutrino Physics. By Klaus Winter. *Cambridge University Press: 1992. Pp. 670. £75, $125.*

It is appropriate that Klaus Winter has published this authoritative and comprehensive book on neutrinos within a few months of the announcement that this year's prestigious Panofsky and Sakurai prizes have been awarded to Ray Davis, Fred Reines and Lincoln Wolfenstein for their contributions to the physics and astrophysics of neutrinos. The idea of the neutrino was invented by Wolfgang Pauli in 1930 as "a desperate remedy" to save the law of conservation of energy in nuclear β-decay. But it took a quarter of a century before Reines and Cowan finally presented evidence for the direct detection of the neutrinos (actually the electron antineutrinos) produced by the Hanford and Savannah River reactors. And it was only in 1962 that Lederman, Schwartz, Steinberger and their colleagues used a high-energy accelerator beam at Brookhaven to demonstrate the difference between electron and muon neutrinos. Since then, experiments at reactors, accelerators, underground and on the Earth's surface have been done to study the neutrino's properties and to use the neutrino as a probe of weak interactions and subnuclear structure.

Recently, experiments at CERN and Stanford have led to the important discovery that there are three (and only three) families of neutrinos. Unlike any other particle, the neutrino is subject to only the weak nuclear interaction and is therefore a unique probe of the weak nuclear force. Nevertheless, the structure of the three neutrino families closely parallels the structure of the three families of quarks. But the quark families are not distinct (they mix together), so the natural suggestion is that the neutrinos mix as well (despite the experimental evidence so far to the contrary). For 50 years, though, studies of the weak interaction have proceeded on the assumption that neutrinos are neutral, highly penetrating and massless. Mixing, on the other hand, requires neutrinos to have some mass.

The neutrino mass is clearly small. Direct studies of the endpoint energy in tritium β-decay set an upper limit to the electron antineutrino mass of less than 10 electronvolts, a factor of 50,000 less than the mass of the corresponding charged electron. This is consistent with the arguments from cosmology, the observations of neutrinos from the 1987 supernova in the Large Magellanic Cloud, and the inability so far to find neutrinoless double β-decays. Solar neutrino experiments, however, seem to be suggesting the existence of mixing at mass levels near 10^{-4} electronvolts.

If the neutrino is massive, and in particular if it is a Majorana particle (that is, if the neutrino is its own antiparticle), then the origin of the neutrino mass may be related to the existence of new physics at energies beyond the 10^{12}-electronvolt energy scale to which accelerators have so far allowed us to probe. In other words, the neutrino mass is small because there is some new mass scale (presumably related to grand unification) that is large. Much of the current interest in neutrinos stems from the hope that laboratory and astrophysics studies of relatively low-energy neutrinos may actually shed light on fundamental new physics beyond our standard model of particle physics and at energy scales beyond those of current or planned accelerators.

Professor Winter is a leader in accelerator studies of neutrinos and weak interactions. As a senior member of the CERN Laboratory in Geneva, he has assembled an expert, generally well-written and exceedingly well-planned set of essays into a very useful overview of neutrino physics and astrophysics. The profusion of excellent recent books on neutrinos is a reflection of the topic's popularity. Winter's book, however, fits into its own special niche. With an emphasis on the experimental results and their significance, *Neutrino Physics* begins with a historical review by Pauli himself (translated here for the first time into English) and steps through the individual experiments up to the observation of neutral currents in CERN's Gargamelle detector. This introduction is followed by a combination of chapters on the theory and experiments relating to the fundamental properties of neutrinos, including discussions of the differences between Majorana and Dirac neutrinos, double-β-decay and tritium-endpoint experiments, oscillations and neutrino counting, and astrophysical and cosmological constraints.

Even at 600 pages, the book cannot cover everything: nuclear β-decay and standard Fermi theory, for example, are deliberately omitted because fine treatments of these topics can be found elsewhere. But there is an extensive discussion of neutrino interactions in matter followed by a series of articles on accelerator studies of the weak interaction and nucleon structure, and a concluding section on solar neutrinos, supernovae and cosmology. A second volume, on neutrino detectors and neutrino beams, is promised. If it is anywhere near as thorough, complete and as useful as this first volume, I look forward to seeing it too. □

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■ New from World Scientific is *The Relations of Particles* by L.B. Okun, a collection of reviews on elementary particle physics £22.