Extragalactic Investigations

Dark Matter in the Universe. J. KORMENDY and G. R. KNAPP, Eds. Reidel, Dordrecht, 1987 (U.S. distributor, Kluwer, Norwell, MA). xxx, 596 pp., illus. $104; paper, $43. International Astronomical Union symposium 117 (Princeton, NJ, June 1985).

By combining measurements of the sizes and internal velocities of astronomical objects, Newton's laws can be applied to derive dynamical masses. Major improvements have occurred in space- and ground-based observational facilities in the last 20 years, and, as a result, dynamical masses have now been measured for a wide range of extragalactic systems. A remarkable result emerges from these observations: in most cases the dynamically determined masses exceed by substantial factors those expected from models based on the light radiated by stars and gas. Thus we deduce that galaxies and systems of galaxies contain "dark matter," the subject of the symposium whose proceedings are reported in this volume.

Dark Matter in the Universe is unusually informative to both experts and interested bystanders. Its framework consists of 31 review papers by well-regarded researchers, which are skillfully introduced by S. Faber's overview of dark matter problems in astrophysics. Reviews are enriched by transcripts of discussions and short poster papers, which help the reader to assess the level of confidence at which the various facets of the dark matter problem are held.

Discussions of dark matter can be logically divided according to spatial scales and masses associated with various classes of extragalactic objects. For example, clusters of galaxies have been recognized to contain dark matter since the pioneering dynamical studies by F. Zwicky and S. Smith in the 1930s, whereas the detection of dark matter in individual galaxies took place in the 1970s. Most of the papers deal with this more recent aspect of dark matter, starting with our own Milky Way. J. Bahcall considers the evidence for nonluminous mass within the thin stellar disk of the Milky Way, where the dynamical mass apparently exceeds the luminous mass by a factor of 2. This is an important indication that some dark matter experienced the gaseous dissipation necessary to become trapped in the Galactic disk and thus is likely to consist of ordinary baryonic matter.

A number of papers cover the now very strong case for extensive dark matter components in spiral galaxies as a class. A variety of observations including escape velocities of Galactic stars, forms of rotation curves for both gas and stars, and the presence of "warps" in outer gas disks are discussed in terms of the presence of spheroidal dark matter halos surrounding the optically visible components of spirals. There are several spirited discussions of the precision to which the shapes and sizes of dark halos are known, but a consensus dark halo would probably have a radius of approximately 100 kiloparsecs and ten times the mass of the visible spiral galaxy. V. Rubin presents arguments that dark matter dominates the dynamics of galaxies even in the optically bright inner regions, stimulating an unresolved debate as to whether this could reasonably occur within the framework of present models. Working on the other side of the fence, A. Kalnajs demonstrates that massive dark matter halos are probably not necessary to stabilize galactic disks, even though this argument motivated much of the early study of dark halos.

The situation regarding dark matter in other structural classes of galaxies is not so well defined as in spirals, primarily as a result of observational difficulties in probing galactic gravitational potentials at large galactocentric radii. The extent of hot gaseous atmospheres of elliptical galaxies and clusters of galaxies depends on the amount of mass in these systems, but the interpretation of the relevant x-ray observations is model-dependent. Similarly, a number of factors complicate dynamical mass estimates for small dwarf galaxies, although the data are again suggestive of the presence of dark matter. A key issue is then whether all galaxies contain roughly the same fractions of luminous and dark mass. This point, though widely discussed in the symposium, remains unresolved.

The larger scale systems of galaxies, which have been the traditional domain for dark matter investigations, receive less emphasis than individual galaxies. Discussions of clusters of galaxies are mainly centered on the interpretation of x-ray data. A summary of the current understanding of the dynamics of galaxies in the cores of dense clusters of galaxies is the one obvious omission from the proceedings. The progression of dynamical properties as one moves from small systems of galaxies up to large segments of the universe, however, is well covered by several reviews spaced through the second half of the book. Observational estimates for the local mass density in our supercluster of galaxies are summarized and show that, despite theoretical prejudices for a closed universe with density equal to the critical density for closure (to permit currently popular inflation models, for example), the universe appears to be open.

Two factors are considered that may compromise the local observational estimates of the cosmological mass density. (i) Galaxy formation may be "biased" in the sense that on large scales mass does not follow light, which can happen in the plausible galaxy-formation scenarios reviewed by J. Silk. If the light from galaxies is more clustered than the total density, then the observations will yield a mean density that is smaller than the true mass density. (ii) A. Yahil's paper provides an example of a second line of argument, in which mass and light are correlated but density fluctuations occur over scales that are much larger than the size of our local supercluster. Under these circumstances, local measurements underestimate the total mass density, whereas the first sketchy data on spatial distributions of galaxies on larger scales can be used to argue that the mean mass density is actually consistent with a closed universe. Determining whether the universe is dense and closed or less dense and open is considerably complicated by the discovery of large amounts of dark matter, and the current level of uncertainty surrounding this key cosmological problem is fairly represented by the papers and discussions.

While symptoms of the presence of dark matter abound, the composition of dark matter remains a mystery. Some people, such as J. Gott, E. Turner, and A. Tyson, have used the ability of a distribution of mass to act as a gravitational lens for more distant objects as a means to try and place limits on the amount and distribution of dark matter and thus to better understand its nature. These projects, though promising, have yet to come to full fruition. The radical approach of modifying the law of Newtonian gravity has been attempted by M. Milgrom and J. Bekenstein, who have also developed tests of their theory. More conventional models for hiding normal baryons to produce dark matter are presented by several authors, but on account of the constraints on the total density of baryons provided by light element abundances, baryonic dark matter in the standard Big Bang cosmological model cannot provide a closed universe. One then turns to the colorful world of particle physics (see M. Turner's frontispiece and review) for exotic, nonbaryonic forms of dark matter. Although hard evidence for particle contributions to dark matter has not been found, the connection between the inner space of particle physics and the outer space of cosmology is leading to innovative ways of thinking about both old and new problems in extragalactic astronomy.

Dark matter is being recognized as a fundamental phenomenon in the structure of the universe. The organizers of the conference and the editors of the book have provided an excellent topical summary of research in this exciting field.

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A Life in Physics

Rabi. Scientist and Citizen. JOHN S. RIGDEN. Basic Books, New York, 1987. xiv, 302 pp. + plates. $21.95. Alfred P. Sloan Foundation Series.

"Isn't physics wonderful?" I. I. Rabi wrote to Ernest Lawrence in 1948. Physics had indeed been wonderful to a boy raised in the lower East Side of Manhattan by immigrant parents with a weak grasp of English who, according to the author of this biography, changed the course of his adoptive country's physics in the 20th century from ordinary to extraordinary. Only in America? No, only by Rabi.

Rigden, himself a notable physicist and teacher, has produced a superb account that comes very close to being an actual autobiography of Rabi—indeed, it is part of the Sloan Foundation's series of autobiographies. He has made extensive use of taped interviews and frequently quotes Rabi directly. Rigden has a special knack for giving lucid explanations of arcane technical matters. Thus without mathematics or jargon, and without compromising the physics, he tells how in the late '20s at Columbia Rabi educated himself as well as his colleagues in the new quantum ideas being developed in Europe, and how he then went to Europe to participate himself in the quantum excitement. It seems to me that Rigden reaches poetic heights in explaining the intricacies and subtleties of Rabi's famous molecular beam experiments. If to my mind Rigden's explanations are about the best I have ever read, I do worry a little that his uncompromising honesty and close reasoning may still be a bit too difficult for the general reader, may turn the reader away from the nontechnical but equally important material that is to follow.

Rabi's talents were full of contradictions. Was he a great teacher? According to Rigden, his students uniformly testify that he was "simply an awful lecturer." Even so, some of his many students are now among the most illustrious of physicists. If they did not like his lectures, they still praise the inspiration he gave them, provoking them to think independently and deeply about physics. I personally remember the many times I have seen Rabi pocket a prepared speech (which I probably would not have liked) and then deliver a spirited talk full of wit and insight. Some of the phrases coined by Rabi have become a part of history: "What do you want—mermaids?" he asked the prosecutor in the matter of J. Robert Oppenheimer. In his 80s, at the 40th anniversary at Los Alamos, just the title of his speech, "We Meant So Well," summed up the sentiments of us who were there.

Was Rabi a theorist or an experimenter? He seemed to be so maladroit with his hands, we are told, that he was sometimes not allowed by his colleagues even to come near the apparatus. Was Rabi painstaking? Easily bored by the drudgery of an experiment he had initiated, he would show up, as if by magic, just as the results were emerging—just in time to analyze their meaning and to decide what should be done next. He has always insisted that he is a whole physicist, that he has done what it has been necessary to do to get on with revealing the underlying nature of physics. His students have especially learned this Rabiesque unity of approach to physics: it is in the great tradition but it is not too often in evidence today.

Religion too is a leitmotif of the book. We learn that Rabi seems never to have adopted the orthodox Jewish views of his parents. In place of a conventional Bar Mitzvah, his father invited in some friends to listen to Rabi's comments not on the Torah but on science. Yet he did inherit the sentiment of religion, for he says, "When I chose physics I was no longer practicing the Jewish religion, but the basic attitudes and feelings have remained with me. Somewhere way down, I'm an Orthodox Jew." Rabi goes on, "The whole idea of God, that's real class . . . real drama. When you're doing good physics, you're wrestling with the Champ." He is also quoted as having said, "I think that God is a good heuristic principle—a standard by which you judge things." These few quotations are but an enticing part of Rigden's fascinating treatment of this aspect of Rabi's life.

Rigden compares the creative brilliance of Rabi with the astonishing quickness, breadth of mind, and talent for lucid expression of J. Robert Oppenheimer. The two were lifelong friends with complementary talents who first met in the Europe of the '20s. Both returned from Europe determined to raise the level of American physics. This they did, Oppenheimer by establishing in California the first school for theorists and Rabi by training generations of superb experimenters in his Columbia laboratory. During World War II both played critical roles, Rabi in the development of radar and Oppenheimer with the atomic bomb. After the war both men become important in national as well as international affairs. Oppenheimer used his fame as the "father of the nuclear bomb" to promote his plan for international control of nuclear energy and then to oppose the hydrogen bomb. Rabi, characteristically working behind the scenes, was a driving force in the creation of the Brookhaven National Laboratory, of CERN, of Eisenhower's Atoms for Peace conference, and of the President's Scientific Advisory Committee and in many other such enterprises. Rigden's analysis of these two mutually supporting but very different friends is the best chapter of the book.

Jeremy Bernstein has produced, with his usual elegance and eloquence, a biography of Rabi (published in *The New Yorker* in 1975), but Rigden, by going into greater detail and by going deeper into Rabi's nonscientific life and thoughts has more thoroughly fleshed out and captured Rabi, both as scientist and as citizen, and set him neatly in his time.

The 20th century has been a time of high adventure in physics. It is no wonder that Rabi, with his ebullience and complex genius and wisdom, found his profession "wonderful." As Rigden demonstrates in this complete and very good book, physics was wonderful for Rabi and Rabi was wonderful for physics.

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Modernization and Health

The Changing Samoans. Behavior and Health in Transition. PAUL T. BAKER, JOEL M. HANNA, and THELMA S. BAKER, Eds. Oxford University Press, New York, 1986. xii, 482 pp., illus. $49.95. Research Monographs on Human Population Biology.

As more and more traditional societies grapple with the problems introduced by acculturation to Western technology, certain generalizations about the process of modernization and its health consequences have achieved the status of dogma. The first is the concept of demographic transition: High