Part 1. Overview and Cosmological Context of the Magellanic Clouds

Section A. Invited Reviews

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Sidney van den Bergh with his wife Paulette and the guest speakers at the Symposium banquet. From left to right, Kim Innanen, Paul Hodge, Paulette van den Bergh, Sidney van den Bergh, David Crampton, Gretchen Harris, Yuri Efremov, and Jim Hesser. Paulette van den Bergh is holding an honourary membership in the Euro-Asian Astronomical Society presented by Prof. Efremov, while Sidney holds a framed Symposium poster signed by participants. A "rebellious action" foretold by Gretchen Harris during her banquet reminiscences as Sidney's graduate student is illustrated on page 568.

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Magellanic Cloud Studies, Past and Future

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Abstract. This introduction reviews early observations of the Magellanic Clouds, briefly describes the "Golden Age of Magellanic Discoveries", and looks ahead at promises for dramatic new results from the powerful telescopes of the 21st century.

1. Magellanic Cloud Studies, 1200-1950

Although the Magellanic Clouds were observed for centuries by the peoples of the southern hemisphere, it was not until about the thirteenth century that they came to the attention of northern hemisphere inhabitants. According to von Humbolt (1848), Arab explorers and traders, traveling up and down the east coast of Africa, were well aware of the Clouds. They named the Large Cloud the "White Ox".

Among the first Europeans to comment on the Clouds was the sixteenth century scientist Peter Martyr, who said (Eden 1555):

"But it is most certeyne, that it is not gyuen to anye one man to knowe all thynges...Neuerthelesse, the Portugales of owre tyme haue sayled to the fyue and fyftie degree of the south pole: Where, coompasinge abowte the poynt thereof, they myght see throughowte al the heauen about the same, certeyne shynynge whyte cloudes here and there among the starres, lyke vnto theym whiche are seene in the tracte of heauen cauled *Lactea via*, that is, the mylke whyte waye."

The Clouds first became associated with the Great Circumnavigator when Antonio Pigafetta, who accompanied Magellan on his famous voyage, wrote about them in his published account of the trip and proposed that they be named for Magellan as a memorial, Magellan having lost his life in the Philippines before the circumnavigation was complete. It is popular history that Pigafetta was Magellan's navigator. However, this is not the case; Pigafetta was a free-lance adventurer who joined Magellan in the hopes of having a unique experience (Dennefeld 1998).

By the nineteenth century serious astronomical studies of the Clouds was being done. One such investigation was that of James Dunlop, who observed them from Parramatta (near Sydney, Australia) and published particularly handsome and accurate sketches of each Cloud (Dunlop 1828). At about the same time Sir John Herschel visited Capetown in southern Africa to map the southern hemisphere skies. Setting up his 20-ft telescope (named for its focal length), Herschel identified large numbers of star clusters and nebulae, all to be included in his comprehensive "General Catalog" (Herschel 1864), which was later subsumed

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into the "New General Catalog" (Dreyer 1888), which, of course, is still in use and which lists dozens of Magellanic Cloud objects. Herschel recognized the Clouds as unusual objects and stated (Shapley 1957):

"The two Magellanic Clouds are very remarkable objects. The larger of the two is an accumulated mass of stars, and consists of clusters of stars of irregular form, either conical masses or nebulae of different magnitudes and degrees of condensation.....In no other portion of the heavens are so many nebulous and stellar masses thronged together in an equally small space."

Herschel's African observations were reported widely, even in the popular press (e.g., Locke 1835). Among the users of the General Catalog was Cleveland Abbe, Director of the Cincinnati Observatory (in Ohio, USA). Abbe apparently was impressed by the large density of star clusters and nebulae recorded in the Magellanic Clouds and correctly realized that this implied that the Clouds must be separate, distant systems similar to the Milky Way Galaxy. He went further, extrapolating this conclusion to include smaller and fainter nebulae as separate galaxies, thus anticipating Hubble's work by about 50 years. He wrote (Abbe 1867):

"The visible universe is composed of systems, of which the *Via Lactea*, the two Nubeculae (the Magellanic Clouds - ed.), and the Nebulae, are the individuals, and which are themselves composed of stars and clusters and of gaseous bodies..."

The advent of astronomical photography helped to transfer astronomy from a descriptive to a more quantitative science. The first application of photography to the Magellanic Clouds probably was for purposes of providing accurate stellar positions (Gould 1889). This work was carried out at the great observatories at Cordoba (Argentina), Capetown (South Africa) and Melbourne (Australia). Joining these in the late nineteenth century was Harvard Observatory's southern station at Arequipa, Peru, where the start was made on the magnificent and still valuable plate collection covering the Magellanic Clouds.

The beginnings of modern astrophysical studies of Magellanic Cloud stars can probably be traced to Wilhelmina Fleming's study of S Doradus, the first recognized "luminous blue variable" (or "Hubble-Sandage variable"). She derived its unusual light curve and noted its spectrum as having a P Cygni profile (Shapley 1957).

Another Harvard astronomer, Henrietta Leavitt, began studying the fainter variables in the Magellanic Clouds in 1904. Three years later she made an epochal discovery: while listing the Cepheid variables in order of their periods, she discovered that the list also was nearly in order of magnitudes, thus discovering the Cepheid period-luminosity relation (Wetzel 1955).

In the meantime Herschel's star clusters were to some extent neglected for nearly a hundred years. Shapley (1957) discussed them briefly, listing 10 objects that he considered to be true globular clusters in the Clouds. However, only 2 of Shapley's 10 clusters are known to be true old globular clusters (e.g., Olsen et al. 1999; Johnson 1999), the rest being populous clusters of younger age (see, for example, Hodge 1961). Shapley had suggested that Magellanic globulars might be peculiar, as he pointed out that long ago Annie Cannon had assigned A-type spectra to some of them.

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Progress in Magellanic Cloud research in the first half of the twentieth century was slow, which should not be too surprising considering the small number of astronomers in the world at that time. Most work was concentrated in the South American observatories in Argentina and Chile and in South Africa and Australia, where positional astronomy dominated the staffs' efforts. Harvard's Boyden Station, which moved to Bloemfontein, South Africa, during this period, continued its photographic survey of the variable stars in the Clouds, but interest in other Cloud problems was modest.

2. The 1950's and 1960's: The Golden Age of Magellanic Discoveries

By mid-century developments in stellar and galactic astronomy helped to precipitate a strong new interest in the Magellanic Clouds. Stellar evolution and the meaning of stellar populations was finally becoming understandable and the Clouds offered a myriad of objects, all at the same distance, which could be compared to the new theoretical models. At the same time large telescopes, especially the Palomar 5-m, were probing nearby galaxies and the distant cosmos, making the Clouds important as the foundation of the extragalactic distance scale.

A few of the exciting new Magellanic studies of that era are listed here, though there were many others of equal importance:

- Gascoinge and Kron's use of photoelectric photometry to derive a more precise Cepheid period-luminosity relation (Gascoigne & Kron 1953).
- Arp's derivation of color-magnitude diagrams for clusters and field stars in the SMC, allowing comparison with stellar evolutionary models and age determinations (e.g., Arp 1958).
- Feast, Thackeray, and Wesselink's survey of the spectra, colors and luminosities of the Cloud's brightest stars, providing the first good extragalactic HR diagram (Feast et al. 1960).
- Thackeray's and Wesselink's discovery of RR Lyrae variables in the Clouds, giving a distance determination independent of that from Cepheids (Thackeray 1952).
- Payne-Gaposchkin and Gaposchkin's massive study of Cloud Cepheids, permitting analysis of light curve characteristics and exploring the question of age as a function of spatial distribution (e.g., Payne-Gaposchkin 1971).
- Westerlund's explorations of OB assications and other groups of young stars, illuminating the relationship between these objects and neutral and ionized gas clouds (e.g., Westerlund 1961).
- Kerr and his radio astronomy colleagues' pioneering observations of HI in the Clouds and their discovery of the gaseous bridge connecting them (Kerr et al. 1954).
- Mathewson et al.'s discovery of the Magellanic Stream (Mathewson et al. 1974).

As the second half of the century moved on, tremendous progress was achieved in exploring and exploiting the Magellanic Clouds. I will not describe the current status of this research, as it is amply covered by the papers given at this meeting.

3. Magellanic Cloud Research: 2000 –.

If the late twentieth century saw great strides in Magellanic astronomy, the twenty-first century promises even more marvelous developments. These will largely result from the introduction of several amazingly powerful new telescopes, both on the ground and in space.

Of the ground-based telescopes the most impressive is the VLT (the "Very Large Telescope"), being installed on a northern Chilean desert peak and consisting of four 8-m optical telescopes that will eventually be connected to be used interferometrically. Nearby is the site of a giant millimeter array, which will be the short radio wavelength equivalent of the Australia Telescope Compact Array. Two other giant new telescopes in Chile are the Gemini 8-m and the Magellan 6.5-m, both located in the dry mountains near La Serena. Far to the east will be another large optical instrument, the proposed South African Large Telescope.

The first 10 or so years of the new century also will see several powerful space observatories that will make possible many marvelous new possibilities for Magellanic Cloud research. Already HST has proved an extremely useful instrument, as several papers in this volume attest, and the NGST (the "Next Generation Space Telescope") is expected to do much more. Less well-known, perhaps, is the kind of remarkable new measurements that some of the other spacecraft will make possible. To take one example from the rich alphabet soup of telescope names, which includes AXAF, DIVA, GAIA, SIRTF and others, I will point out some things that will be possible to do with SIM (the "Space Interferometry Mission"). For astrometry SIM is planned to have a global positional accuracy of 4μ arcsec and a narrow-angle accuracy of 1μ arcsec. This kind of phenomenal precision will make it possible not only to determine the transverse motions of the Clouds with great ease, but also to measure proper motions of individual stars and clusters in the Clouds. With an expected parallax for the Clouds of 20μ arcsec, SIM will even be able to measure their distances geometrically.

When we combine this new astrometry with the powerful new optical and radio telescopes' results, it will be possible to do many things unthinkable not long ago. Here is a short list of Magellanic Cloud possibilities:

- construct a three-dimensional map of the cluster systems (and, of course, of stars).
- derive the dynamics of stars and clusters.
- determine the evolutionary and kinematic histories of stars.
- examine low mass star formation.
- explore the bottom of the stellar luminosity function.
- reconstruct the details of tidal encounters and possible mergers.
- discover planets.

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