X-RAY SURVEYS OF THE MAGELLANIC CLOUDS

David J. Helfand
Columbia Astrophysics Laboratory, Columbia University

The proximity, well-determined distance, and low foreground obscuration of the Magellanic Clouds makes them an ideal target for the study of galactic X-ray source populations. Steady progress since the initial detection of X-rays from the LMC in 1968 culminated in the recent Einstein Observatory surveys from which over three dozen supernova remnants and ~10 compact binaries have been identified. In this review, we record the 15-year history of Magellanic Cloud X-ray research, summarize our current knowledge, and offer a brief prospectus of what the next 15 years may hold.

1. INTRODUCTION

The last IAU Symposium dedicated to the Magellanic Clouds was held just one year after the discovery of the first extrasolar X-ray source in 1963. The detection of any radiation above 10 eV from the Clouds in those days would have required a trip with a rocket to Australia and a target source with a luminosity in excess of 10^{41} ergs s^{-1}. Twenty years later, we have entered (and perhaps exited) a new era in X-ray astronomy. Instrumental sensitivities have increased a millionfold and angular resolution approaching that of optical astronomy is now attainable, although, at the present time, opportunities for studying X-rays from the Clouds are extremely limited. In this paper we will review the progress that has been made in studying the X-ray source populations in our neighbor galaxies from the first detection of X-rays in 1968 through the most recent optical and radio work on the ~150 sources catalogued in surveys carried out the Einstein Observatory. A brief prospectus outlining the future of Magellanic Cloud X-ray research, including a discussion of the contribution which could be made by an AXAF-class facility, concludes this review.

2. THE EARLY YEARS (1968-1971)

A two-page Astrophysical Journal Letter published in early 1969 marks the beginning of the X-ray study of the Magellanic Clouds (Mark et

S. van den Bergh and K. S. de Boer (eds.), Structure and Evolution of the Magellanic Clouds, 293–304.

https://doi.org/10.1017/S0074180900040407 Published online by Cambridge University Press

al. 1969). It reported on the results of a five minute rocket flight from Johnston Atoll in the South Pacific on October 29, 1968; the proportional counter detectors on board had a 5° field of view and a limiting sensitivity in the 1.5-10.5 keV band of $\sim 10^{-9}$ ergs cm^{-2} s^{-1}. In an 80° scan through the positions of the Clouds, the LMC was detected as a ~4 sigma excess in two adjacent 5° bins with a flux of $\sim 1.5 \times 10^{-9}$ ergs cm^{-2} s^{-1} and a spectrum slightly softer than that of the diffuse X-ray background; the SMC was not detected. The authors estimated that the LMC flux corresponded to an X-ray luminosity of $\sim 4 \pm 1 \times 10^{38}$ ergs s^{-1} and, using an estimate of the Milky Way's luminosity in the same band (which was rather uncertain at the time), concluded that "the relative populations of X-ray sources are apparently the same in our Galaxy and the LMC." While some subtle differences in these populations are beginning to emerge from the ensuing fifteen years of X-ray research, we now know that the numbers of bright X-ray binaries and supernova remnants do indeed roughly scale with the mass ratio of these two glaxies.

A similar rocket flight two years later by the same group from Lawrence Livermore Laboratory obtained further information on the spatial and spectral distribution of the X-rays from the Large Cloud and reported the first evidence of emission from the SMC (Price et al. 1971). A few months later, Leong et al. (1971) published the first Uhuru results on the Cloud sources, resolving the LMC emission into three steady and one possible highly variable source (designated LMC X-1, X-2, X-3, and X-4) plus a possible diffuse component extending over much of the galaxy. The three SNRs known at the time (N49, N63a, and N132d) were not detected, and upper limits of 2×10^{-11} ergs cm^{-2} s^{-1} were placed on their emission in the 2-7 keV Uhuru band. The SMC flux was found to be consistent with a single, rapidly variable source in the wing of the galaxy. Fluctuations on timescales as short as a few minutes were observed, leading the authors to claim SMC X-1 as the first confirmed example of a stellar X-ray source in an external galaxy. No diffuse emission from the Small Cloud was detected and a limit of $\sim 1 \times 10^{-11}$ ergs cm^{-2} s^{-1} was set on any additional individual sources in either galaxy.

3. THE 2-10 KEV SURVEYS (1971-1978)

Over the ensuing seven years, it became clear that, in fact, all five of these Magellanic Cloud X-ray emitters were binary systems consisting of a normal star and a collapsed companion. Nonperiodic variability on a variety of timescales was established for all four LMC sources through observations made with _Uhuru_, _SAS-3_, and _Ariel V_ (Griffiths and Seward 1977 and references therein). More recently 1.4 day X-ray eclipses (Li, Rappaport, and Epstein 1978), 13.5 s X-ray pulsations (Kelly et al. 1982) and a 30.5 day flux modulation reminiscent of that in Her X-1 (Lang et al. 1981) have all been seen in LMC X-4. X-ray pulses (0.7 s) and binary eclipses (3.9 d) are also present in SMC X-1 (Lucke et al. 1976; Schreier et al. 1972). Optical counterparts to all five sources have been identified (see Hutchings, this volume, and references therein); four have massive, early type components similar to the Population I X-ray sources in the Milky Way, while LMC X-2 is associated with a faint blue object in which the visible light may well be dominated by an accretion disk as in the Sco X-1 type Population II sources in the Galaxy. Clark et al. (1978) have noted that the X-ray luminosities of the Cloud binaries are systematically higher than those of the comparable galactic systems and suggest that the lower metal abundance (and, thus, lower opacity) of the accreting material may be responsible. We discuss the comparison of the Clouds' X-ray binary populations with those of the Galaxy further below.

The only other sources detected in the direction of the Clouds during this period were a number of transients, only one of which has been seen since. Two new sources (SMC X-2 and X-3) were reportd in the Small Cloud by Clark et al. (1978). They were detected by _SAS-3_ and had X-ray fluxes a factor of ~5 less than SMC X-1. An SMC-member O star was found in each ~1' error box (Crampton, Hutchings and Cowley 1978) although these identifications remain most uncertain. Both sources had disappeared six months later (Clark, Li, and van Paradijs 1979) and neither was detectd in the _Einstein_ Observatory SMC survey of 1979-80 to a level at least 10^2 times lower than the original detections. Three similarly elusive sources have been reported in the direction of the LMC. LMC X-5 was first seen by Markert and Clark (1975) and was apparently confirmed in _Ariel V_ data (Griffiths and Seward 1977); however, it did not appear in several _Einstein_ pointings at a flux level 150 times below its reported value. LMC X-6 was observed only once (Griffiths and Seward 1977); 0544-665, first reported on the basis of a 1977/78 _HEAO-1_ modulation collimator survey (Johnston, Bradt, and Doxsey 1979), had dropped by a factor >500 during a single _Einstein_ observation two years later.

The one transient Cloud X-ray source, concerning whose existence there is no doubt, is the remarkable source A0538-66. First reported by _Ariel V_ (White and Carpenter 1978), a number of outbursts reaching a peak luminosity in excess of 10^{39} ergs s^{-1} and lasting from a few hours to several days were seen by _HEAO-1_ (Johnston et al. 1979; Johnston, Griffiths, and Ward 1980); an outburst recurrence time of 16.7 days was indicated, although X-rays are not seen at every predicted maximum. The source was not seen in the initial _Einstein_ survey of the LMC, which set a minimum on- to off-state luminosity ratio of $\sim 10^4$:1. However, subsequent observations did detect 0538-66, confirming the suggested B star optical counterpart (Skinner et al. 1982) and revealing an X-ray pulsation period of 67 milliseconds. Although the underlying system of a B-star/neutron star binary is typical of Pop I X-ray systems, the extreme pulse-period, luminosity, and variability sets this source apart from all known galactic sources, marking it as an important object for further study.

All of the observations reviewed above were conducted in the ~2-10 keV X-ray band. This is the energy range in which the all-sky surveys carried out during the 1970s revealed accreting binary systems as the

https://doi.org/10.1017/S0074180900040407 Published online by Cambridge University Press

dominant galactic source population. However, other source classes were also discovered during this period, including SNR, white dwarfs, novae and star formation regions for which the dominant flux appears in the soft X-ray (0.1-2 keV) band (see Gorenstein and Tucker 1976 for a review). At these energies, interstellar absorption becomes important: X-rays below 1 keV can penetrate only a few kiloparsecs in the galactic plane (to $N_H \sim 10^{22}$ cm^{-2}). The line of sight to the Magellanic Clouds, however, has a foreground column density of only $\langle N_H \rangle \sim 3 \times 10^{20}$ cm^{-2}; column densities through the Clouds themselves range from 0.1 to 3×10^{20} cm^{-2} for the LMC and 1 to 10×10^{21} cm^{-2} for the SMC, rendering sources in the Clouds good targets for observation in this band.

Soft X-ray emission from the LMC was first detected in a series of rocket flights in the mid-seventies, although its interpretation remained confused (Rappaport et al. 1975; Long, Agrawal, and Garmire 1976; Borken 1976). The only detection of a discrete source of ~1 keV X-rays prior to the launch of _Einstein_ (the SNR N132D) was reported by McKee et al. (1980; the other two sources suggested by their data were not confirmed by the _Einstein_ results). Observations of the SMC in this band were directed primarily at attempts to determine the extragalactic component of the soft X-ray background through the diminution in its intensity by the interstellar medium of the Cloud (McCammon et al. 1971; Bunner, Sanders, and Nousek 1979). The _Einstein_ results discussed below confirm the conclusion of McCammon et al. (1976) that the failure to detect such a diminution resulted not from a bright population of SMC soft X-ray sources which compensated for it, but from the fact that most of the diffuse background at these energies is local in origin. No discrete soft sources were detected toward the SMC during these observations.

In summary, as of early 1979, seven discrete sources of X-ray emission had been detected in the direction of the Magellanic Clouds: six X-ray binaries and one SNR. Another five or so transient sources had also been reported. At the detection threshold characteristic of this work (~5×10^{37} ergs s^{-1}), the results were not inconsistent with a simple extrapolation from Galactic source populations scaled by the mass ratios of the galaxies. The characteristics of these sources, both individually and collectively, were interesting - short pulse periods, high luminosities, extreme variability - and the extension of these surveys to flux levels 1,000 times lower held great promise for comparative studies of celestial X-ray emitters.

4. THE _EINSTEIN_ SURVEYS (1979-1981)

The _Einstein_ Observatory, the first satellite-borne imaging X-ray telescope, was launched in November of 1978. It carried a complement of four focal plane instruments for soft X-ray imaging and spectroscopy and 2-30 keV monitor proportional counter. The imaging proportional counter (IPC) provided 1' spatial resolution over a 1 square degree field of view and modest spectral resolution ($\Delta E/E \sim 1$) in the 0.15 to 4.0 keV band. Typical sensitivity in a 3,000 second observation was $\sim 10^{-13}$ ergs cm^{-2} s^{-1}. The IPC was the prime instrument for survey work and was used extensively in the Magellanic Cloud surveys discussed below. The count rate-to-flux conversion for a typical (kT ~ 1 keV) spectrum with low interstellar absorption is $\sim 2.5 \times 10^{-11}$ ergs cm^{-2} s^{-1} (IPC ct)$^{-1}$. The high resolution imager (HRI) complemented the IPC by offering ~5" spatial resolution over a 25' field of view in the slightly softer, 0.1 to 3.0 keV band. With this instrument, absolute positions could be obtained to ~3".5; the HRI was used extensively in followup observations to determine accurate source locations and to map diffuse sources such as SNR. The count rate-to-flux conversion for this instrument is $\sim 10^{-10}$ ergs cm^{-2} s^{-1} (HRI ct)$^{-1}$. The two spectrometers on board included the solid state spectrometer (SSS) used for obtaining moderate resolution spectra ($\Delta E \sim 250$ eV) between 0.5 and 4.0 keV, and the focal plane crystal spectrometer which achieved high resolution ($\Delta E/E \sim 10^3$) over narrow bandpasses near lines of astrophysical interest. Both of these instruments were used to observe the brighter SNR detected in the LMC (Clark et al. 1982; Winkler, private communication). Further details concerning the Observatory and its instrumentation may be found in Giacconi et al. (1979).

The LMC and SMC surveys were carried out as part of the Einstein programs of the Columbia Astrophysics Laboratory and the Smithsonian Astrophysical Observatory, respectively, with extensive follow-up observations by a number of participants in the Guest Observer Program. The observations were conducted between 1979 February and 1981 March; a total of 1.0×10^6 s of good data were accumulated, representing ~25 days of telescope time or ~3% of the satellite's life. The initial IPC surveys were designed to provide complete coverage over the bulk of both Clouds to a sensitivity $\sim 10^2$ times that previously available; these results are described in Long, Helfand, and Grabelsky (1981) for the LMC and Seward and Mitchell (1981) for the SMC. Deeper IPC pointings were then undertaken in optically prominent regions such as the Bar regions of both galaxies and around 30 Doradus; these data have been (or will be) reported by Inoue, Koyama, and Tanaka (1983; 1984) and Gull and Bruhweiler (1984) for the SMC, and by Long, Helfand, and Grabelsky (1981) and Hamilton and Helfand (1984) for the LMC. The survey statistics are summarized in Table 1; the number of known sources in the direction of the Clouds has increased 30-fold and the flux of the weakest source is a factor of ~1,000 below previous survey limits.

Extensive optical and radio follow-up observations have been in progress over the past few years with the aim of identifying as many Cloud members as possible and separating out the numerous foreground and background X-ray sources which appear superposed against both galaxies. Many new SNRs in both the LMC (Mathewson et al. 1980; Tuohy et al. 1982) and SMC (Dopita, Tuohy, and Mathewson 1981; Mills et al. 1982) have been discovered as a result of this work. In addition,

TABLE 1: The *Einstein* Observatory Magellanic Cloud Surveys.

Survey		LMC	SMC
Area covered (sq. deg.)		37	40
Strongest source detected	(IPC ct s^{-1})	11	5
Weakest source detected	"	0.006	0.003
Completeness limit	"	~0.03	~0.05
	(ergs s^{-1})	$\sim 3 \times 10^{35}$	$\sim 10^{36}$
Sources detected		103	45
Above completeness limit		52	9
Cloud members		~40	~5

several new binary source candidates have been located and nearly twenty interlopers have been identified (Cowley et al. 1983; Hutchings, this volume; Pakull, this volume). At the present time, then, we have a rather complete picture of the X-ray source populations above luminosities of 3×10^{35} ergs s^{-1} for the LMC and 10^{36} ergs s^{-1} for the SMC, and considerable information on sources a factor of ~5 fainter. These results are summarized in Table 2 and discussed by source class below.

4.1 Interlopers

Roughly half of the ~150 X-ray sources now known in the direction of the Clouds are interlopers - either background galaxy clusters and active galactic nuclei (AGN) or foreground galactic stars. The numbers of expected and identified sources in each category are summarized in Table 2. The extragalactic objects are consistent with expectations. In the LMC, however, the number of foreground stars seen is considerably higher than expected from other surveys of stellar X-ray emission (see Cowley et al. 1983 for a detailed discussion). We have investigated the possibility that a young open cluster lies in the direction of the LMC and contributes a number of sources to the foreground population. Although one such cluster is known (Sanduleak and Philip 1968), it contributes none of the detected stars (nor would we expect it to, based on its distance and richness). Thus, we conclude either that there is an unrecognized young ($\lesssim 10^8$ yr) group of stars at ~100 pc in the direction of the LMC, or our detection of 11 X-ray emitting stars in the flux-limited portion of our survey (~3 were expected) is a statistical fluke. While few other foreground stars remain to be identified (since they are all brighter than $m_v \sim 15$ and have already been found) the number of remaining background interlopers among the weaker portions of both samples is still fairly large. The difficulty of detecting these faint AGN and clusters in the crowded MC star fields is likely to be a permanent limitation on the completeness of identification programs for the fainter sources.

https://doi.org/10.1017/S0074180900040407 Published online by Cambridge University Press

TABLE 2: X-Ray Source Populations of the Magellanic Clouds

Galaxy:	LMC		SMC	
Sample:	X-ray Complete (>0.032 IPC ct s^{-1})	Total	X-Ray Complete (>0.05 IPC ct s^{-1})	Total
Number of sources:	52	102	8	45
INTERLOPERS:				
AGN				
Identified:	2	3	0	0
Candidates:	1	3	0	3
Addt'l no. expected	~3	(~12)*	~2	(~4)
GALAXY CLUSTERS				
Identified:	0	0	0	0
Candidates:	0	0	0	0
Addt'l no. expected:	~2	(~7)	~1	(~2)
STARS				
Identified:	10	12	2	4
Candidates:	1	7	0	2
Addt'l no. expected:	~0	(~1)	~0	(~1)
TOTAL				
ID plus candidates	14	25	2	9
Addt'l no. expected:	~5	(~20)	3	(~5)
SNRs				
Identified:	17	24	2	9
Candidates:	1	4	0	0
POP I BINARIES:				
Identified:	4	4		1
Candidates:	2	3	0	0
POP II BINARIES:				
Identified:	2	2	0	0
Candidates:	0	0	0	0
UNIDENTIFIED:				
Expected interlopers:	~5	(~20)	3	(~5)
Expected Cloud members:	~7	(~20)	0	(~20)

*Estimates in parenthesis are uncertain by a factor ~2 owing to uncertainty in the completeness level of the surveys.

https://doi.org/10.1017/S0074180900040407 Published online by Cambridge University Press

4.2 Supernova Remnants

In view of their accurately determined distances (and, thus, luminosities and diameters), the sample of Magellanic Cloud SNR will prove uniquely important in future studies of remnant evolution. Twenty-four LMC and nine SMC objects are now detected in all three (radio, optical, and X-ray) bands, with five more seen in two of the three regimes; half of the total were discovered first as X-ray sources. The statistics of these samples are becoming particularly well defined with planned or recently finished complete, flux-limited surveys in both the radio and X-ray bands. For example, an analysis of all data for the flux-limited portion of the LMC X-ray survey shows that there are 19 ± 1 remnants with $L_x > 3 \times 10^{35}$ ergs s^{-1} in that galaxy. The only remaining sources of incompleteness are the lack of observations in the outermost regions of the Cloud and the possibility that we have missed a few of the largest diameter remnants of low surface brightness (this latter defect will be rectified in future analysis, but we are stuck with the former for ~5 years).

The full implications of these results for the Clouds' SN rate and the evolution of remnants in general is only just now beginning to be explored. Several authors have noted that the cumulative number-diameter relation for the LMC remnants (which exhibits a slope of order unity) is in conflict with the conventional assumption of adiabatic remnant expansion and suggests a relatively long-lived phase of free expansion for the SN shock (Clarke 1976; Mills 1983, 1984; Mills et al. 1983; Mathewson et al. 1983). More recently, however, Fusco-Femiano and Preite-Martinez (this volume) and Hughes, Helfand, and Kahn (1983) have pointed out that, for the X-ray sample at least, the effect of a finite flux threshold (in this case, equivalent to a luminosity threshold) is to introduce a diameter cutoff which is dependent on the initial explosion energy and the density of the surrounding medium. This fact can flatten the N(D) curve from the slope of ~2.5 expected for the adiabatic case to a slope of ~1 as is observed, even when most remnants are actually seen during their adiabatic phase. Further work on this problem, coupled with an analysis of the luminosity function (and L(D) relation) for Magellanic Cloud remnants should prove useful in problems ranging from a determination of the supernova rate, to the effects of nonequilibrium ionizaton and a cloudy, multiphase interstellar medium on SNR evolution.

4.3 Binary X-Ray Sources

There are now six confirmed and two candidate binary X-ray sources in the flux-limited portion of the LMC sample; SMC X-1 remains the only confirmed nontransient such source in the Small Cloud. Six of the LMC systems contain a bright early type stellar companion, analogous to the Pop I binaries of the Galaxy. There are ~50 such Galactic systems implying that this population, representative of recent ($\lesssim 10^7$ yr) star formation history, scales simply with the galaxian mass ratios of ~10:1. Our optical identification program is relatively complete for objects with $M_v \lesssim 0$ (Cowley et al. 1983) implying few if any new identifications will be made to this scaling. The single, bright SMC binary is also consistent with this rule.

Only two of the known binaries have faint companions similar to the Pop II X-ray binaries of the Galaxy where ~75 exist above our X-ray luminosity limit. Here, however, the optical identifications are far from complete. We estimate above (see Table 2) that there remain ~7 unidentified LMC members in the complete portion of the sample; all but 1 or 2 are excluded from being SNR as a result of observed variability or anomolously high IPC/HRI flux ratios. Thus, we expect that most of these will ultimately be identified as Pop II binaries (faint blue candidates exist for many) bringing the total to ~8. For this much older population ($\gtrsim 10^9$ yr) then, we again see simple scaling by mass.

While the number of MC binaries per unit mass appears to be very similar to that for the Galaxy, there are important differences in the populations. The two fastest of the 14 known Pop I X-ray pulsars (and three of the four fastest) are found amongst the Cloud sources. Also, the luminosities of the Cloud binaries are substantially higher than the mean of their Galactic counterparts (Clark et al. 1978; Hutchings, this volume); the peak luminosity of A0538-66 is higher than that of any other known binary X-ray source. Both of these facts are most likely related to the accretion process, possibly, as first suggested by Clark et al. (1978), the lower metallicity of the accreting gas in the Cloud sources. Also, Hutchings (this volume) has pointed to an apparent higher frequency of black hole companions in the Cloud sources. Further observational and theoretical work on all of these questions may provide important new insights into a number of problems in galaxy evolution.

5. THE NEAR FUTURE (1983-1988)

While few opportunities for observing the Clouds at X-ray wavelengths will exist during the next five years, continuing optical and radio followup work, as well as a more complete analysis of the Einstein X-ray database, will allow for significant progress during this interval. The complete radio survey of the LMC planned by Mills and his collaborators (Mills, this volume) may well identify a number of the remaining X-ray sources as SNR, in addition to answering important questions about the selection effects in the present sample and the coevolution of remnant X-ray and radio emission. More detailed comparisons of the optical and X-ray maps of the brighter SNR are also planned. Considerable optical work on the new identified and candidate binaries in the Large Cloud will be needed to define these orbital parameters, testing, in the process, the intriguing suggestion that the Cloud sources harbor more black hole companions than their galactic counterparts. Should better X-ray positions become available (see below) more optical identifications may be forthcoming. The background AGN we have discovered could be exploited as useful probes of the Clouds' ISM through 21 cm and optical absorption line studies.

We are currently in the process of constructing a single X-ray map of the LMC from the newly reprocessed IPC data. Overlapping and redundant pointings, as well as better background rejection and spectral selectivity, will provide an improvement in our point source ($D \lesssim 2'$) sensitivity by a factor of $\gtrsim 2$ throughout the survey regions with up to a factor of ~4 enhancement in heavily observed areas; the result will be another ~50 new sources in the luminosity range 3×10^{34} to 3×10^{35} ergs s^{-1} (for the Cloud members). More importantly, however, this new map will allow us to search for larger scale features - both the large diameter SNR ($40 \lesssim D \lesssim 100$ pc) so important to remnant evolution studies, and features tracing the hot regions of the Cloud's interstellar medium (e.g., bubbles and superbubbles blown by young star clusters). Analysis of the four deep IPC exposures in the Wing of the SMC will also expand the number of known sources in that galaxy.

Only two X-ray satellites capable of obtaining data on the Cloud sources are now in orbit. TENMA, the Japanese timing and spectroscopy mission could obtain some data on the bright Cloud binaries, but little of startling import is likely to result. The ESA satellite, EXOSAT, has experienced some difficulties since its launch in June, but its high resolution imaging detectors are still operating and could be used, albeit with rather long exposure times, to obtain ~5" positions for as many of the remaining unidentified sources as time allows; observation of all 12 unidentified sources in the complete, flux-limited sample of the LMC is an achievable goal. Other than a handful of rocket flights and Shuttle missions with maximum experiment durations of minutes to hours, there will be no other opportunity for further X-ray studies of the Clouds until ~1988 when the German ROSAT mission will give us a soft X-ray (0.03 to 2 keV) imaging capability similar to that of Einstein with sensitivities higher by a factor of ~2.

6. PROSPECTUS FOR THE FUTURE (1988-)

The next major advance planned in X-ray astronomy instrumentation is the Advanced X-ray Astronomy Facility (AXAF), currently scheduled for launch in the early 1990s. It will provide arcsecond resolution with a sensitivity ~10^2 times that of Einstein over a broader, 0.1 to ~8 keV band. High sensitivity, high resolution spectroscopy and X-ray polarimetry will also be possible. The advances such an observatory would bring to Magellanic Cloud research are legion. Surveys similar to those carried out on Einstein with perhaps a factor of 3 increase in exposure time (the scheduled mission life is five times that of Einstein) could:

1. Detect all main sequence and post-main sequence stars individually for types earlier than O6 in the LMC
2. Detect most Wolf-Rayet stars in both Clouds
3. Detect all of the predicted ~200 Be stars with collapsed companions in their quiescent state
4. Detect the brightest ~10% of cataclysmic variable systems in both Clouds

5. Determine the frequency of low luminosity X-ray sources in Magellanic clusters
6. Map all SNR through a substantial portion of their radiative phases (a factor of ~4 older than currently possible) yielding a sample of perhaps 200 remnants as the definitive test of SNR evolution models.
7. Detect many of the ~100 radio pulsars with ages $\lesssim 5 \times 10^4$ yr via their surrounding synchrotron nebulae
8. Map, on all scales, the structure of the hot phase of the LMC interstellar medium.

Clearly, this partial list of discoveries would go far beyond the important questions of X-ray source population studies we are addressing in the current era; it would represent a contribution of fundamental importance in problems of stellar and galactic evolution.

The author wishes to acknowledge the support of the National Aeronautics and Space Administration under contract NAS 8-30753 and the United States Air Force under grant AFOSR 82-0014. This is Columbia Astrophysics Laboratory Contribution No. 255.

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