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Annual Report for

"An X-Ray Search for PMS Stars in Translucent Molecular Clouds"

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Although our work on this project is not yet completely finished (we still need to obtain and analyze optical spectra for the candidate counterparts to the X-ray sources discovered through our study of the ROSAT All-Sky Survey data), we have published a preliminary report on our progress to date. The reference to this report is as follows:

"ROSAT Observations of MBM 40 & MBM 55" by Thomas Hearty, J.-P. Caillault, Loris Magnani, & J.H.M.M. Schmitt, Eighth Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun, ed. J.-P. Caillault, Astronomical Society of the Pacific Conference Series, Volume 64, page 92.

I have attached a copy of the paper to the report.

It is our expectation that, once the optical data have been processed, we will publish the complete results of the project in the Astrophysical Journal, where the results of our previous related investigations have appeared.

Cool Stars, Stellar Systems, and the Sun, Eighth Cambridge Workshop
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ROSAT ALL-SKY SURVEY OBSERVATIONS OF MBM 40 & MBM 55

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MOTIVATION

The recently identified category of translucent clouds presents some compelling questions for the study of small molecular clouds and the diffuse interstellar medium. Translucent molecular clouds are an intermediate population of small clouds situated between diffuse and dark clouds as regards H_2 column density, visual extinction, and astrochemical complexity. The conventional astronomical wisdom postulates that dark clouds and Bok globules are the sites of low-mass star formation (but not exclusively; giant molecular clouds can give rise to low mass stars), while the traditional diffuse molecular clouds such as the cloud along the line of sight to ζ Ophiuchus cannot form stars. The principal reason for this inability to form stars is the dearth of high-density cores in the diffuse clouds.

However, the presence or absence in translucent clouds of high-density cores similar to those found in dark clouds is still open to debate. Van Dishoeck *et al.* (1991) argue that the maximum density in translucent molecular clouds is of order a few times 10^3cm^{-3}, while Turner, Rickard, & Xu (1989) argue that densities of several times 10^4cm^{-3} are present in small, localized regions of a given translucent cloud. The existence of these cores bears directly on the presence of low-mass stars in these objects. If dense cores are present in the translucent molecular clouds, then low-mass star formation is possible in these objects and any inventory of the local star formation rate must include the non-negligible number of translucent clouds in the local interstellar medium.

X-ray observations of known star forming regions have revealed large numbers of X-ray sources (Walter *et al.* 1988), most of which had not been previously known to be PMS stars. Therefore, we have analyzed the ROSAT All-Sky Survey (RASS) data in the regions of the high-latitude translucent molecular clouds MBM 40 and MBM 55 in the hope of finding X-ray sources which might be tracers of recently formed pre-main sequence stars.

THE SAMPLE

We have chosen the clouds MBM 40 and MBM 55 since these clouds contain dense cores that are excellent candidates for star formation (Magnani, Blitz, & Mundy 1985). H_2CO and CS observations of the two cores in MBM 40 and two of the cores in MBM 55 indicate that the core density can range as high as $\sim 4 \times 10^4 \text{cm}^{-3}$ within a radius of ~ 0.1 pc (Magnani *et al.* 1994). The hydrogen column density toward these cores has been estimated to range from $\sim 6 \times 10^{20} \text{cm}^{-2}$ (van Dishoeck & Black 1989) to $\sim 1.2 \times 10^{22} \text{cm}^{-2}$ (Turner *et al.* 1989). The mass of MBM 40 probably lies between 15 and 50 $M_\odot$ (depending on which density regime is appropriate) and the mass of MBM 55 ranges between 170 and 500 $M_\odot$. The masses of the cores within these clouds are probably $\leq 10\ M_\odot$, so it is likely that if star formation occurs only low mass stars will be found.

RESULTS

We have detected (with a maximum likelihood > 8) 18 X-ray sources near MBM 40 and 154 X-ray sources near MBM 55. The point source detection sensitivity was $\sim 1 - 2 \times 10^{-13}$ergs cm^{-2} sec^{-1} for both clouds. This corresponds to a minimum detectable luminosity of $\sim 10^{29.3}$ergs sec^{-1} at the distance of MBM 40 ($\sim$ 100 pc) and $\sim 10^{29.6}$ergs sec^{-1} at the distance of MBM 55 ($\sim$ 150 pc); we have assumed a spectrum characterized by a Raymond-Smith thermal plasma of temperature 10^7 K and a column density of $\sim 10^{20.5}$cm^{-2} (less than that of the core regions).

Since the RASS X-ray source density in the galactic plane is $\sim$ 1.1 sources deg^{-2} (Motch *et al.* 1991), we expect fewer sources at high galactic latitude. Moreover, the increased interstellar extinction toward these translucent molecular clouds should also decrease the number of X-ray sources detected. Therefore, our detection rate of 1.2 and 1.4 sources deg^{-2} for MBM 40 and MBM 55, respectively, indicates an excess over the mean RASS source density.

We have cross-referenced all of our X-ray sources through the SIMBAD and NED databases and visually inspected the Palomar Sky Survey Prints in an effort to determine those X-ray sources which cannot be PMS objects and to estimate visual magnitudes for uncatalogued optical counterparts; the results of this preliminary investigation are in Table I. The X-ray sources with non-PMS counterparts are divided into three categories: extragalactic objects, foreground and background stars, and catalogued non-PMS stars.

TABLE I Breakdown of X-ray Source IDs

Cloud		MBM 40	MBM 55
Number of X-ray sources		18	154
Sources with non-PMS counterparts	Extragalactic	2	45
	Foreground and background stars	0	13
	Catalogued non-PMS stars	2	2
Sources with possible PMS counterparts		14	94

Maccacaro *et al.* (1988) point out that X-ray sources with Galactic and extragalactic counterparts can be separated at a high confidence level (> 90 %) prior to any optical spectrosopy. Results of the *Einstein* Extended Medium Sensitivity Survey show that among extragalactic sources all but a few have

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$\log(f_x/f_v) > -1.0$, while almost all normal stars (except for a few dMe stars) have ratios less than that (Stocke *et al.* 1991). Since we are looking for X-ray active low-mass PMS stars and in many cases are making rough estimates of the visual magnitude as seen on the POSS plates, we have adopted a more conservative cut-off. We consider sources which have $\log(f_x/f_v) > 0.0$ to be extragalactic and those with $\log(f_x/f_v) < -2.0$ to be stellar; X-ray sources with an intermediate $\log(f_x/f_v)$ are retained in our list of possible PMS candidates.

CONCLUSION

The work outlined in this paper identifies 108 plausible T Tauri candidates in the regions of two high latitude translucent molecular clouds. Follow-up optical spectroscopy of these candidates is needed to resolve the question of whether or not star formation is present in these clouds. We have recently submitted a proposal to use the Kitt Peak National Observatory 2.1 meter telescope to take medium resolution spectra of the 14 PMS candidate X-ray sources in MBM 40 to determine spectral types and search for indicators of youth (strong Li absorption; $H\alpha$ emission) and we will submit a similar proposal to study the X-ray sources in MBM 55. Only spectra will provide an unambiguous determination of their pedigree. As part of an ongoing study of star formation at high galactic latitude we intend to analyze data in the ROSAT archives to investigate the possibility of star formation in all of the high latitude translucent molecular clouds observed. We believe that this project may yield a significant increase in our understanding of the star formation process for low-mass stars and of the nature of the translucent clouds.

ACKNOWLEDGMENTS

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