# Final Report for NASA RXTE AO-2 Proposal: "Studies of Long Period Variability in Neutron Star HMXB Systems"



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The purpose of this effort was to investigate the long term, quasi-periodic variability of the X-ray emission from the accreting X-ray pulsars LMC X-4 and SMC X-1. These high mass X-ray binary (HMXB) sources are known to vary in a nearly periodic fashion with cycle lengths of about 30 and 60 days respectively. The prevailing model for such behavior is that it is due to the precession of a tilted accretion disk around the neutron star which is the source of the X-ray emission. As the disk precesses, it periodically obscures the emitting region, resulting in reduced flux as observed at the Earth. The obscuration is not strictly periodic, as the disk precession period changes as the total mass and size of the disk change through variable accretion processes. This model is well established for the long-period variability in the X-ray pulsar Her X-1. With this work, my collaborators and I sought to test whether this model works for LMC X-4 and SMC X-1.

Observations with the pointed instruments on the *Rossi X-ray Timing Explorer* (*RXTE*) were carried out in order to observe changes in the X-ray spectrum and total flux which were correlated with the long period cycles in these objects. One of the main predictions of the precessing disk model is that the periods of low emission are caused not by changes in the central source, but by increased absorption of that flux as seen at the Earth. Such behavior would be observed in the X-ray spectrum as a relative lack of low energy X-rays (which are more easily absorbed) as compared to high energy X-rays. This is what was observed for SMC X-1, lending strong support to the precessing disk model for this system.

For LMC X-1, however, the absorption was consistent with zero at the time of minimum flux. The entire spectrum appeared to be equally reduced. This is not supporting evidence for the model. However, it also does not rule out a precessing disk. If at the time of minimum flux, the intervening disk is so thick that *no* flux, even high energy X-rays, can penetrate, and if there is material above the disk which can scatter X-rays, then a small scattered spectrum will be seen which is indistinguishable from the unobscured source flux. This is quite

possibly the case in LMC X-1.

To summarize, this work has provided confirmation that the long term variability in SMC X-1 is caused by the presence of a precessing accretion disk. LMC X-1 may have a precessing accretion disk (this work does not exclude one), but there must then exist scattering paths which circumvent the disk.

The work done at UCSD by W. Heindl consisted of accumulation, analysis, and interpretation of the RXTE/PCA data in parallel with co-investigators at the Goddard Space Flight Center. He has been responsible for contributing to presentations of this work at scientific conferences and for contributing to a publication of results of this work which is currently in progress.

The results of this work have appeared as conference papers and are the subject of a paper in preparation by co-investigators at the NASA/Goddard Space Flight Center for a refereed journal.

# PUBLICATIONS

Lang, F.L., Crannell, C.J., Kaplan, L., Heindl, W.A., Gruber, D.E., and Rothschild, R.E., 1997, proceedings of "Accretion Processes in Astrophysical Systems: Some Like It Hot" (College Park, MD, October 13-15)

Lang, F.L., Crannell, C.J., Kaplan, L., Heindl, W.A., Gruber, D.E., and Rothschild, R.E., 1998, BAPS, v43, No. 2, p1086