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ROSAT X-Ray Survey Observations of Active Choromspheric Binary Systems and Other Selected Sources

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Our purpose in this grant was to investigate the connection between processes that produce optical chromospheric activity indicators and those that produce x-rays in RS CVn binary systems by taking advantage of the *ROSAT* All-Sky Survey (RASS) results and our unique ground-based data set. In RS CVn systems, excess emission in the Ca II resonance (K & H) and infrared triplet (IRT) lines and in the Balmer lines of Hydrogen is generally cited as evidence for chromospheric activity, which is usually modeled as scaled up solar-type activity. X-ray emission in RS CVn systems is believed to arise from coronal loop structures (see Rosner, Tucker, & Vaiana 1978).

Results for RASS observations of a large sample of RS CVn binaries have been presented by Dempsey et al. (1993). Their results may be summarized as follows: X-ray surface flux, F_x, decreases with increasing rotational period, but is level for $P < 3$ days. For dwarf systems F_x is independent of P, different from the behavior of single dwarfs. No correlation is seen between F_x or L_x and v_{rot} or $v \sin i$. There is no dependance of F_x on spectral type. Neither did they find any dependence of F_x on Roche lobe filling factor, which would indicate that the secondary does not influence activity. They quote a *ROSAT* PSPC counts-to-x-ray luminosity conversion factor for use when spectral information is lacking, and present x-ray luminosities for all 112 of their detected systems.

We obtained spectra of 39 RS CVn binaries with the 1.6m telescope at Penn State's Black Moshannon Observatory, and with the Coudé Feed telescope of the Kitt Peak National Observatory. The former has $R = 5000$, and the latter $R = 12000$. Wavelength coverage spanned the optical region, but there were gaps between echelle orders. This incomplete coverage, and poor signal-to-noise ratio for most systems limited us to the Hα line and the 8542 Å IRT line for BMO targets; for KPNO targets those two lines and Hβ were useful. The acquisition and reduction of the optical spectra was funded by a grant from the National Science Foundation.

Our optical spectra were reduced in the usual manner for fiber/echelle/CCD data. To isolate the portions of the spectra arising from stellar active regions, we used our technique spectral subtraction to determine the non-photospheric contributions to activity sensitive lines. Spectra of two non-active stars are shifted in velocity, artificially rotationally broadened, and weighted to fit the "quiet" regions of an object spectrum. The photospheric component to activity sensitive lines is calculated with the best fit parameters and subtracted from the object spectrum, yielding the spectrum of the active region spectrum.

All spectra were obtained during the *ROSAT* All-Sky Survey, although few are simultaneous with RASS observations. Because results from the RASS were not immediately available, we initially compared our optical results with *Einstein* IPC luminosities. Those results were presented at the Seventh Cambridge Workshop on Cool Star, Stellar Systems, and the Sun, and published in the conference proceedings. Recently, RASS luminosities for most of our targets have become available, and this report contains these updated results accordingly.

In Figure 1 we show excess Hα luminosity vs. *Einstein* IPC x-ray luminosity. We use x-ray fluxes from Schmitt et al. (1991) when available, x-ray luminosities from Strassmeier et al. (1988) otherwise. Distances, V magnitudes, and colors (used to convert flux to luminosity) are those reported in Strassmeier et al. (1988). Each point represents a single observation of a program object. We estimate the uncertainties in the excess line luminosities to be 20%. Triangles are for mass transfer systems known to us; pentagons are for AR Mon.

The most striking result from Figure 1 is that known mass transfer systems all populate the high range of the x-ray luminosity distribution. Excluding the high x-ray luminosity points ($L_x < 2 \times 10^{31}$ erg/s; mostly mass transfer systems), points for AR Mon (mass transfer and highly variable Hα), and points with $L_{\mathrm{H}\alpha} < 0$, a correlation (slope 0.63 ± 0.06) is present in Figure 1, suggesting physical connection between x-ray and excess Hα emission in the non-transfer systems.

Complicating interpretation of the data is the apparent presence of circumstellar material that produces absorption in some subtracted spectra (e.g., Hall & Ramsey (1992); other scenarios are possible). Also, the excess Hα luminosity can be highly variable in a single system, as evident in AR Mon.

Figure 2 is the same as Figure 1 except that the RASS x-ray luminosities (Dempsey et al. 1993) replace *Einstein* x-ray luminosities. We are surprised that neither the correlation described above nor the segregation by mass transfer status is as apparent. We expected differences for individual sources, but also expected that the trends for the ensemble of sources would remain the same.

Three explanations for this discrepancy come to mind. First, it is possible, though highly unlikely, that all of the mass transfer systems happened to be emitting less x-ray radiation during the RASS observations. Second, the energy sensitivities of *Einstein* and *ROSAT* are different. So our data may provide evidence that mass transfer systems are intrinsically harder sources than are the non-transfer systems (given that the counts to luminosity conversion factor does not take the x-ray energy distribution into account). The third possibility is that high neutral column density toward the mass transfer systems produces an apparently harder spectrum.

Modeling of the *Einstein* spectra (Schmitt et al. 1990) of our targets has enabled us tentatively to distinguish between the latter two options. Five of the six mass transfer systems have hydrogen column densities $\log N_{\rm H} \geq 20$, while only one other target in our sample has a similarly high $\log N_{\rm H}$. Those mass transfer systems are, not surprisingly then, among the most distant of our targets. Also, three of the five other systems which are underluminous in the RASS with respect to *Einstein*, but at lower L_x, also have relatively high $\log N_{\rm H}$.

This raises more questions, which we are investigating in part with a current *ROSAT* program targeting mass-transfer systems. For example: Are the mass transfer systems simply behind clouds? If so, why are *they* preferentially behind clouds? Do the mass transfer systems expel enough material to account for the high $N_{\rm H}$? On the other hand, we may ask: does mass transfer induce flare-like activity, in the sense that the induced activity produces copious hard x-ray emission but Hα emission small compared to the stellar total.

Figure 3 shows excess Hα vs. excess Hβ luminosity. The Balmer line measurements include the entire non-photospheric contribution to the lines, and may consist of multiple components arising from different physical mechanisms. Solid circles are for objects with $L_x > 2.0 \times 10^{31}$ erg/s (RASS), asterisks for objects with L_x less than that value, and stars represent AR Mon. The presence of extended or distributed material causes some "excess absorption." The slope, 3.49 ± 0.48 from a chi-square minimization straight line fit (Press et al. 1986) to non-transfer system, first quadrant points (for which the "excess" in the Balmer lines is positive, i.e., not dominated by absorption components), gives a clue to the origin of excess Balmer emission. Buzasi (1989) found that excess Hα/Hβ luminosity ratios greater than about 3 can be obtained only when viewing material similar to solar quiescent prominences off-limb. The observed Hα/Hβ ratio would be larger if no absorption components were present.

In Figure 3, first quadrant points for mass transfer systems share the slope defined by non-mass transfer systems, but with larger uncertainty. Thus, the Balmer lines do not appear to be greatly affected in strength by mass transfer.

This result and the segregation seen in Figure 1 suggest that the mechanism for mass transfer produces x-rays, in addition to the coronal x-rays that correlate with excess Hα emission.

Our excess Hα vs. excess 8542 Å luminosity data is consistent with that seen in a recent study of solar active regions and a small sample of the most active RS CVn systems (Chester 1991).

In summary, our conclusions based on *ROSAT* data are: 1) The correlation we find between excess $L_{\mathrm{H}\alpha}$ and L_x for the non-mass transfer systems (using L_x (*Einstein*)) suggests that the Hα excess and coronal x-ray emission are closely related. That is, the bulk of x-ray emission appears to arise when prominence-like structures are present. 2) From comparison of *Einstein* and RASS x-ray luminosities and modeling of *Einstein* spectra, the apparently relatively hard spectra of mass transfer systems arise largely as a result of high neutral hydrogen column density, whose spatial location has yet to be determined. 3) Other types of activity likely are present. In particular, we can not rule out the possibility that mass transfer in semi-detatched systems may induce production of some x-ray radiation without a significant Hα signature.

REFERENCES

Busazi, D. L. 1989, Ph. D. Thesis, Pennsylvania State University

Chester, M. M. 1991, Ph. D. Thesis, Pennsylvania State University

Dempsey, R., Linsky, J., Fleming, T. A., & Schmitt, J.H.M.M. 1993, ApJS, in press

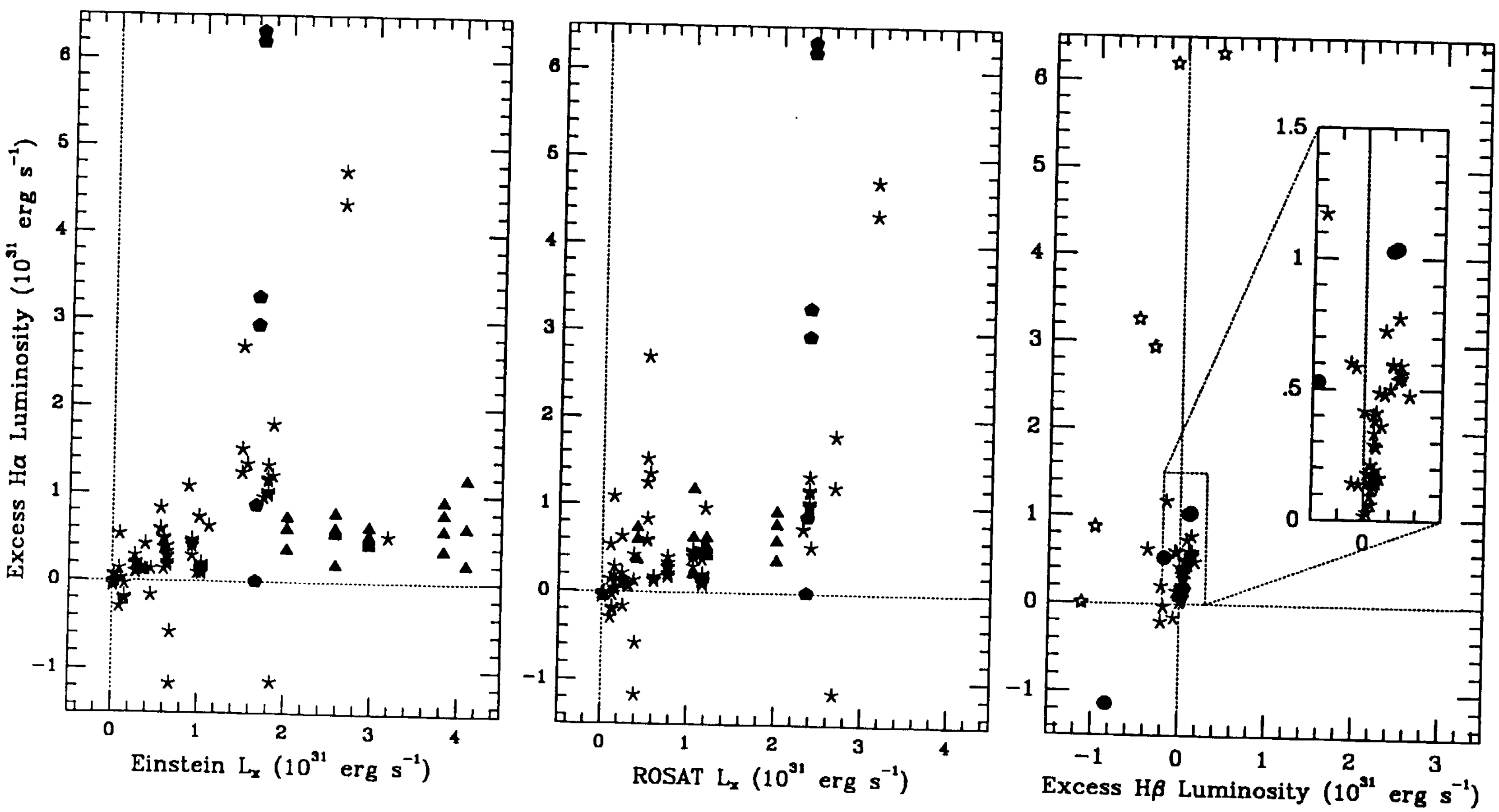
Hall, J. C. & Ramsey, L.W. 1992, PASP Conf. Ser. #26

Schmitt, J.H.M.M., Collura, A., Sciortino, S., Vaiana, G. S., Harnden, F. R., & Rosner, R. 1990, ApJ, 365, 704

Strassmeier, K. G., Hall, D. S., Zeilik, M., Nelson, E., Eker, Z., & Fekel, F. 1988, A&ASS, 72, 291

Press, W. H., Flannery, B. P., Teukolsky, S. A., & Vetterling, W. T. 1986, "Numerical Recipes," (Cambridge Univ. Press: New York)

Rosner, R., Tucker, W. H., & Vaiana, G. S. 1978, ApJ, 220, 643



Excess Hα Luminosity (10^{31} erg s^{-1})
Einstein L_x (10^{31} erg s^{-1})
ROSAT L_x (10^{31} erg s^{-1})
Excess Hβ Luminosity (10^{31} erg s^{-1})