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PSR B0656+14: Combined Optical, X-ray & EUV Studies

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Abstract.
PSR B0656+14's high energy emission is consistent with that of combined magnetospheric and thermal (surface & polar cap) emission. Uncertainties with the radio-derived distance and X-ray instrumentation sensitivities complicate a definitive thermal characterisation however. A re-analysis of combined ROSAT/EUVE archival data in conjunction with integrated & phase-resolved optical photometry is shown to constrain this characterisation.

1. Introduction

Considerable uncertainty remains regarding the fundamental thermal parameters ($T, N_H \& R/d$) for PSR B0656+14. Radio derived DM estimates (790 $\pm$ 190 pc) disagree with the best N_H model fits (250 – 550 pc). Reported calibration uncertainties associated with the low energy channels of the *ROSAT* PSPC compromise the latter - although agreement between other *ROSAT* PSPC & observed *EUVE* fluxes obtained via a correction (e.g. for RX J185635-3754, Walter & An, 1998). We outline the results of such a correction to the existing PSPC datasets archived for PSR B0656+14 via substitution of the low energy channels with measured *EUVE* fluxes, and by incorporating independently derived constraints to the Rayleigh-Jeans tail in the optical, discuss the implications for the neutron star's thermal parameters.

2. Technical & Analytical Overview

Optimum thermal fits for $T_{soft}, T_{hard}, N_H, R/d$ were obtained for the archived *ROSAT* PSPC data alone and the PSPC data with the suspect low energy channels substituted with the archival normalised EUVE flux. This substitution results in a significant change in solution space, as shown in Figure 1 (Edelstein et al. 1999). Based on integrated optical photometry, Pavlov et al. (1997) fitted a two component nonthermal/thermal model, the thermal fit defined by a parameter $G \equiv T_{10^6\mathrm{K}}(R_{10\mathrm{km}}/d_{500\mathrm{pc}})^2$ where $G = [1 - 7]$ (see Figure 1). A 1σ upper limit on the unpulsed component from the optical B band light curve

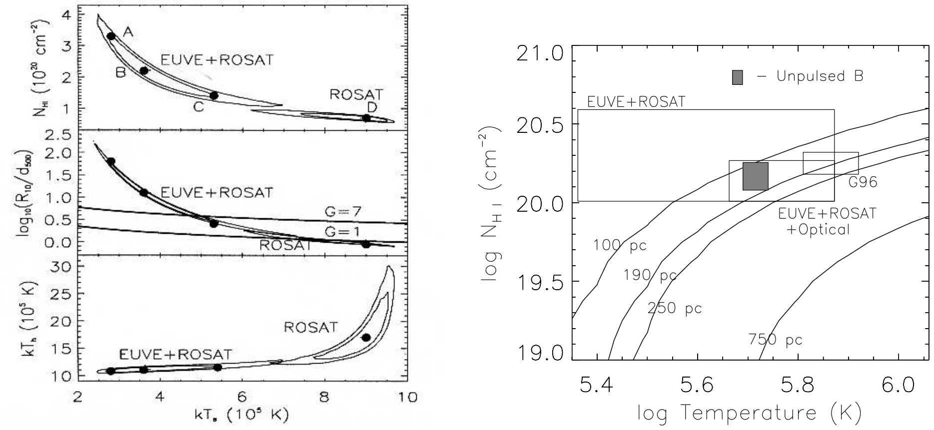

Figure 1. **Left:** Model Fits to $T_h, N_H, R/d$ vs. T_s at the 90% and 99% confidence interval for ROSAT and EUVE+ROSAT datasets. The range of best-fit G parameters are indicated. **Right:** (N_H, T_s) space constrained by EUVE & ROSAT, and incorporating the optical constraints to G. Curves are locii of constant (N_H, T_s) based on the observed EUVE count rate. Previous solution of Greiveldinger et al. (1986) is marked.

of Shearer et al. (1997) limits $G \leq 4.4$, 4.8 and 5.2, based on various optical extinction models to the pulsar (Golden, 1999). These optical results yields tighter constraints on parameter space, as can be seen.

3. Discussion & Conclusions

Combining the EUVE & ROSAT datasets in this way yields new solutions in parameter space that are further constrained *independently* via recent optical work. Assuming a simple blackbody form then $T_{surface} \geq 5.0\times10^5$ K and for the N_H-derived distances of [250 – 280] pc, $R_\infty \leq [17.7 - 14.7]$ km. Using the estimate of $R_\infty \sim 9.5^{+3.5}_{-2.0}$ km for Geminga as a working upper limit (Golden & Shearer, 1999) places PSR B0656+14 at a distance of no less than $d = 152^{+55}_{-32}$. This suggests the possibility of parallax observations to independently derive d, with immediate implications for the R parameter, and consequently models of the condensed matter equation of state.

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