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# Dynamics of Low Luminosity Accretion onto Neutron Stars: Spherically Symmetric Models

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## 1. Introduction

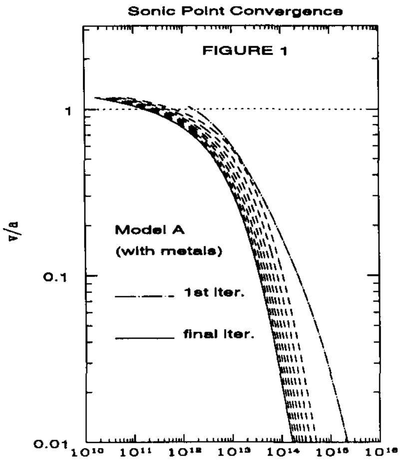
The $\sim 10^8$-$10^9$ old neutron stars in the Galaxy may be undergoing low luminosity accretion from the interstellar medium (Ostriker *et al.* 1970; Shvartsman 1971). It was first recognized by Shvartsman (1971) that the accretion induced radiation from the stellar surface can heat the infalling material, which in turn inhibits further accretion. This preheating instability has been studied in detail in the high luminosity regime where *equilibrium* ionization and heating holds (e.g., Buff & McCray 1974; Ostriker *et al.* 1976; Cowie *et al.* 1978). In the low luminosity regime, however, dynamical timescales are typically much shorter than atomic timescales so the accretion flow dynamics is strongly coupled to *non*-equilibrium (NEQ) atomic processes (cf. Blaes *et al.* 1995).

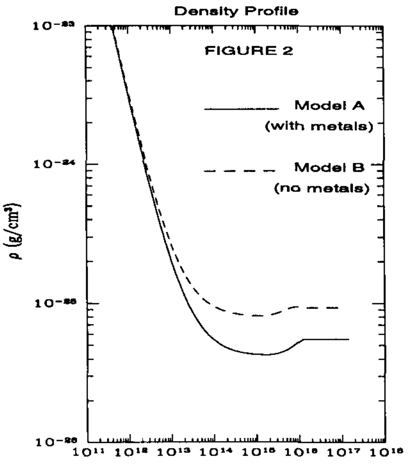
## 2. Method, Results, and Discussion

The method we devised to couple dynamics with NEQ atomic physics involves successive iterations between a 1-D spherical flow code and the MAPPINGS-II photoionization code. Given a mass accretion rate, the flow code generates density and velocity profiles given heating/cooling functions, while MAPPINGS-II generates heating/cooling functions given flow profiles. Successive iterations are continued until the flow profiles and nebular structure converge, typically after $\sim 10$ iterations (see Figure 1; in this figure $v$ is flow speed and $a$ is the local sound speed). Upon convergence, one automatically obtains the asymptotic density $n_\infty$ and temperature $T_\infty$ consistent with the given $\dot{M}$.

In Table 1, we show the parameters and results of two low luminosity models calculated using this scheme; preheating substantially reduces the mass accretion rate (compare columns 3 and 8) regardless of metallicity even at such low luminosities.

In Figure 2, we show the (converged) density profiles for Models A and B. The kink at $\sim 10^{16}$ cm indicates the onset of preheating. (A corresponding kink is present in the velocity profile as required by mass conservation.) The flow at this distance ($\gg$ accretion radius $\sim 10^{13}$ cm) is roughly isobaric. The rise in temperature due to heating as a fluid parcel moves in therefore results in a drop





in density, as shown. At distances ~ the accretion radius, gravity dominates and the density begins to assume the well-known $r^{-3/2}$ profile.

These results suggest that preheating alone can substantially reduce the number of directly observable accreting old neutron stars (cf. Blaes *et al.* 1995). It can also reduce significantly the contribution of these objects to the X-ray background (cf. Zane *et al.* 1995).

Table 1. Model parameters and results.

| Model | Metals | $\dot{M}$, g/s (given) | $L$, erg/s[a] | $T_{BB}$, $K$ (given)[b] | $n_\infty$, cm$^{-3}$ | $T_\infty$, $K$ | $\dot{M}_B$, g/s[c] |
|---|---|---|---|---|---|---|---|
| A | Yes[d] | $3 \times 10^8$ | $6 \times 10^{28}$ | $2 \times 10^5$ | ~ 0.03[e] | ~ $10^4$ | ~ $3 \times 10^9$ |
| B | No[f] | $3 \times 10^8$ | $6 \times 10^{28}$ | $2 \times 10^5$ | ~ 0.06[e] | ~ $1.5 \times 10^4$ | ~ $3 \times 10^9$ |

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[a] $L = GM\dot{M}/R$; $M = 1.4\,M_\odot$, $R = 10\,\mathrm{km}$.

[b] Assume blackbody ionizing spectrum from star.

[c] Bondi rate with $\Gamma = 5/3$.

[d] Assumed solar abundance.

[e] Flow remains hydrodynamic, though this will not be the case at much lower densities.

[f] H 90%, He 10% by number.

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