Evidence for enhanced neutrino emissivity from a neutron star soft X-ray transient

Peter Jonker
(SRON & CfA)
Cartoon image of a soft X-ray transient

- Neutron star
- Jet
- Accretion disc
- Hot spot
- Accretion stream
- Disc wind
- X-ray heating
- Companion star
Lightcurves of NS SXTs

XTE J1709-267

IGR J00291+5934

Jonker et al. 2003, 2004, 2005
Masses from NS X-ray transients in quiescence

Heating of neutron stars: Brown et al. 1998, Colpi et al. 2001

\[ ^{34}\text{Ne} + ^{34}\text{Ne} \rightarrow ^{68}\text{Ca} \]

\[ ^{48}\text{Mg} + ^{48}\text{Mg} \rightarrow ^{96}\text{Cr} \]

\[ M_{\text{NS}} = 1.4 M_\odot \]

\[ \langle \dot{M} \rangle = 1.46 \times 10^{-10} M_\odot \text{ yr}^{-1} \]
Neutrino cooling processes: fast or slow?

Direct URCA

Nucleon matter  \( n \rightarrow pe\bar{\nu} \quad pe \rightarrow n\nu \)

Quark matter  \( d \rightarrow ue\bar{\nu} \quad ue \rightarrow d\nu \)

Modified URCA

Nucleon matter  \( nS \rightarrow Spe\bar{\nu} \quad Spe \rightarrow Sn\nu \)

\[ \log \rho \quad g \text{ cm}^{-3} \]
Chandra and/or XMM-Newton X-ray observations of Q NS SXTs:

4U 1608-52

IH 1715-321

Absorbed NSA fit

T \sim 1.26 \text{ million } K

T \sim 1.2 \text{ million } K

Jonker, Wachter & Mendez et al in prep.
Observed quiescent properties

IH 1905+000

Ariel-5, SAS-3, HEAO-1, Einstein, EXOSAT,

Persistent, $L \sim 4 \times 10^{36}$ erg/s$^{-1}$

10.9 yr

Quiescent luminosity
$L_{0.5-10 \text{ keV}} < 2 \times 10^{31}$ erg/s$^{-1}$ implies $T < 7.5 \times 10^5$ K

Jonker et al. in prep
IH 1905+000  KS 1731-260

Fluence (0.01-20 keV)
$\sim 0.3$ erg cm$^{-2}$  $\sim 2.3$ erg/cm$^{-2}$

Fig. from Rutledge et al. 2002, calculated for KS 1731-260
EoS constraints from cold neutron stars

Adapted from Yakovlev & Pethick 2004
\[ \Sigma = \left( \frac{L_X}{L_{Edd}} \right)^{1/2} \left( \frac{P_{orb}}{1\text{hr}} \right)^{2/3} \]

van Paradijs & McClintock 1994

Porb 1H1905+000 \sim 20-30\text{ min}
Verbunt 1993
Conclusions:

Either

Evidence is mounting that EoS with significant softening can be excluded

The time averaged mass accretion rate is much lower than the mass transfer rate

The pycnonuclear reactions do not heat the NS core as much as thought