INTEGRAL OBSERVATION OF TWO X-RAY ACCRETING MILLISECOND PULSARS IN OUTBURST

XTE J1807-297 & IGR J00291+5934

M A U R I Z I O F A L A N G A

(Service d'Astrophysique, CEA –Saclay, France)

Collaborators:
J. Poutanen, L. Kuiper, J. M. Bonne-Bidaud, R. Farinelli, M. Finger,
P. Goldoni, A. Goldwurm, L. Stella

MSPs hosted in LMXBs

lose X-ray binaries: Companion: M < M_{sun}, Accretion disk, Compact object NS: B~10^8G

SXT which show X-ray millisecond coherent modulation.

pin frequencies lye between 180 and 600 Hz.

review by Wijnands 2004, astro-ph/0403409)

ich time variability, such as twin QPOs at kHz frequencies (400 300 Hz, increasing with M); kHz QPOs are thought to reflect $_{epler}$ at the inner accretion disk. *(Van der Klis, 2000, astro-ph/00001167)*

he Power spectra obtained for SAX J1808.4-3658 during 2002 outburst.)

ype-I X-ray bursts, with nearly coherent oscillations in the range 0-600 Hz .

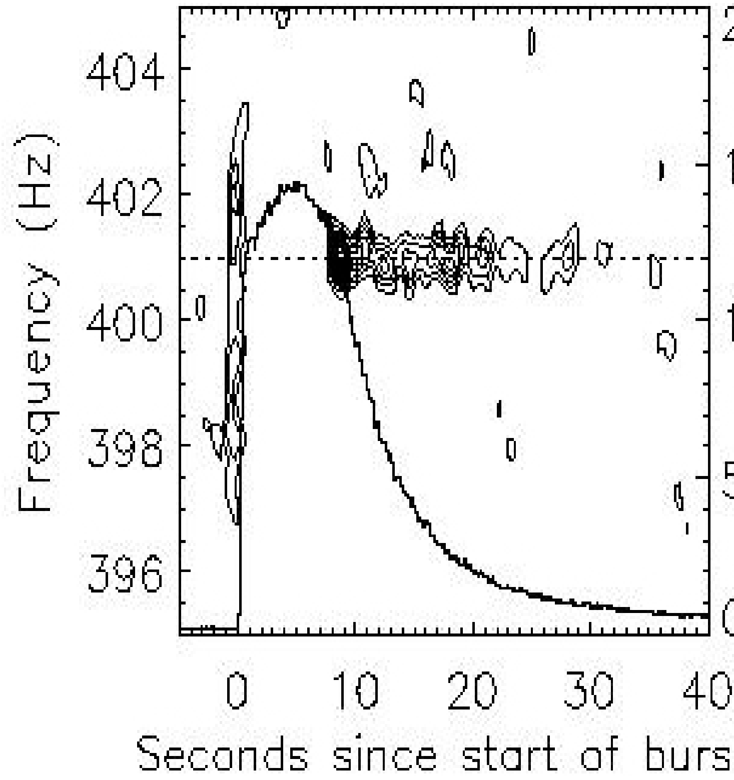
urst oscillations reflect the NS spin frequency (D. Chakrabarty, Nature, 2003)

urst oscilation from SAX J1808.4-3658 during 2002 outburst.)

XT:

~ 10^{32}-10^{33} erg/s in quiescent

~ 10^{36}-10^{38} erg/s in outburst

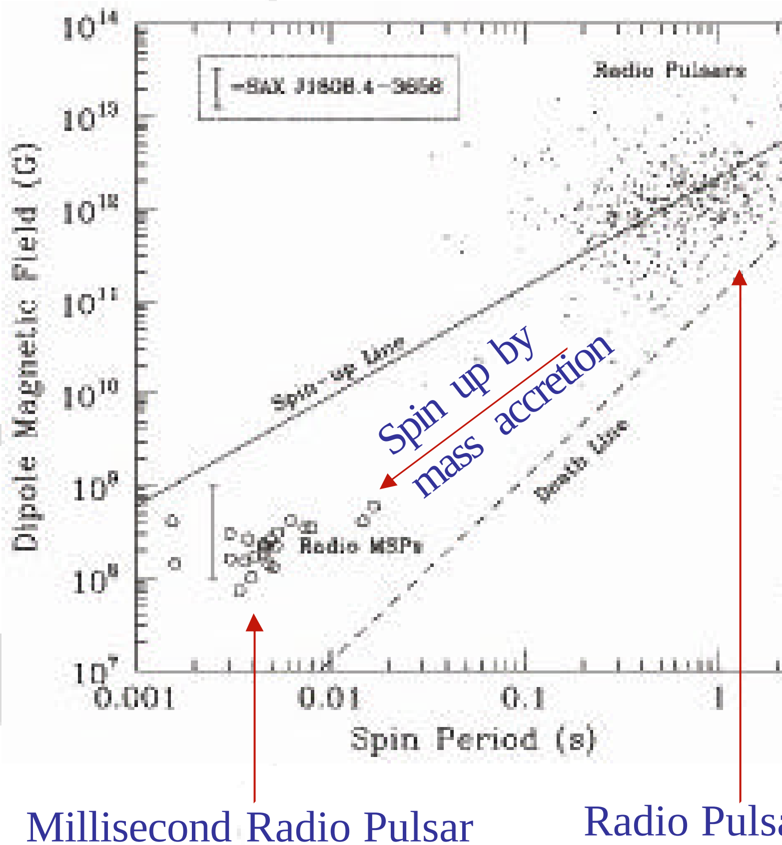


Recycling model for MSPs

- LMXB phase preceding the MSP stage;
  - mass transfer stops;
  - the radio MSP switches on

Old Neutron stars spin up by accretion from a companion

- Most binary MSPs have short orbital periods and mass function identifying the companions as low mass evolved dwarfs



Accreting NS in LMXBs are conventionally thought to be the progenitors of millisecond or „recycled“ radio pulsars (Alpar et al. 1982)

X-ray transients can be the missing link between LMXBs and MSPs!

The growing family of the X-ray millisecond pulsar

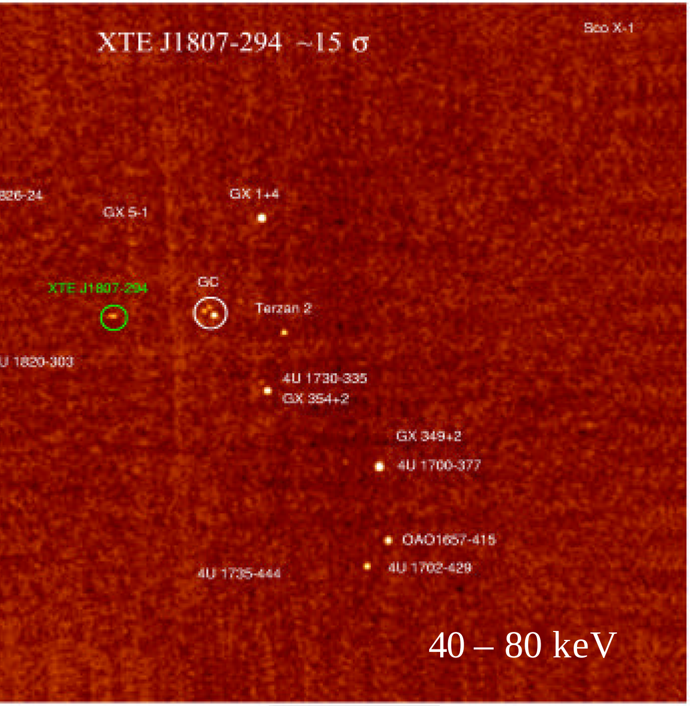
…now we know 6 LMXBs (transients) which show X-ray millisecond coherent modulation:

- *SAX J1808.4-3658:* $P_s = 2.5ms$, $P_{orb} = 2hr$ *(Wijnands & van der Klis 1998)*
- *XTE J1751-306:* $P_s = 2.3ms$, $P_{orb} = 42min$ *(Markwardt et al. 2002)*
- *XTE J0929-314:* $P_s = 5.4ms$, $P_{orb} = 43.6min$ *(Galloway et al. 2002)*
- *XTE J1807-294:* $P_s = 5.3ms$, $P_{orb} = 40min$ *(Markwardt et al. 2003)*
- *XTE J1814-388:* $P_s = 3.2ms$, $P_{orb} = 4.3hr$ *(Markwardt et al. 2003)*
- *IGR J00291+5934:* $Ps = 1.67ms$, $Porb = 2.46hr$ *(Eckert et al. 2004, Markwardt et al. 2004)*

IBIS/ISGRI Observation

v 46; Exposure 160 ks

bruary/March 2003 Outburst



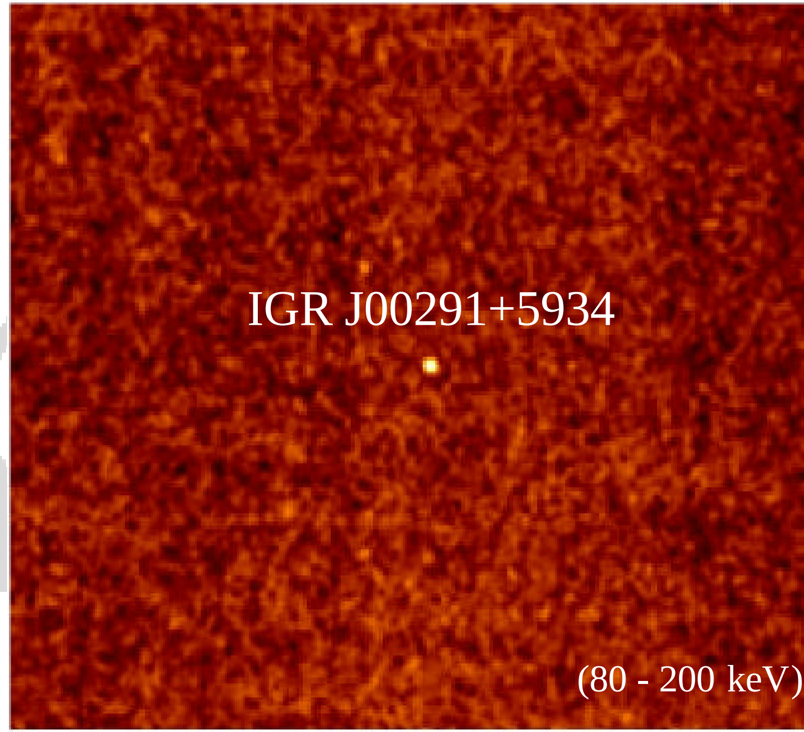
(20-40 keV) significance level ~28s

(40-80 keV) significance level ~15s

(80-200 keV) significance level ~4s

Rev 261/262/263/264; Exposure 343 ks

December 2004 Outburst

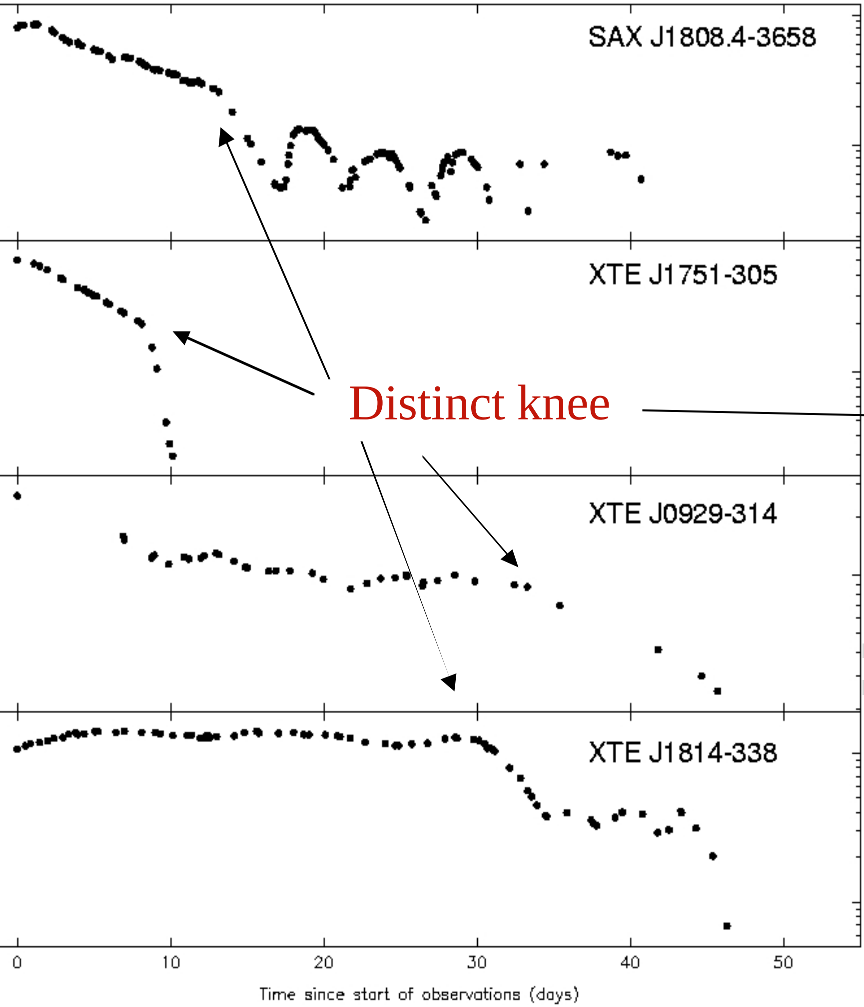


(20-40 keV) significance level ~88s

(40-80 keV) significance level ~51s

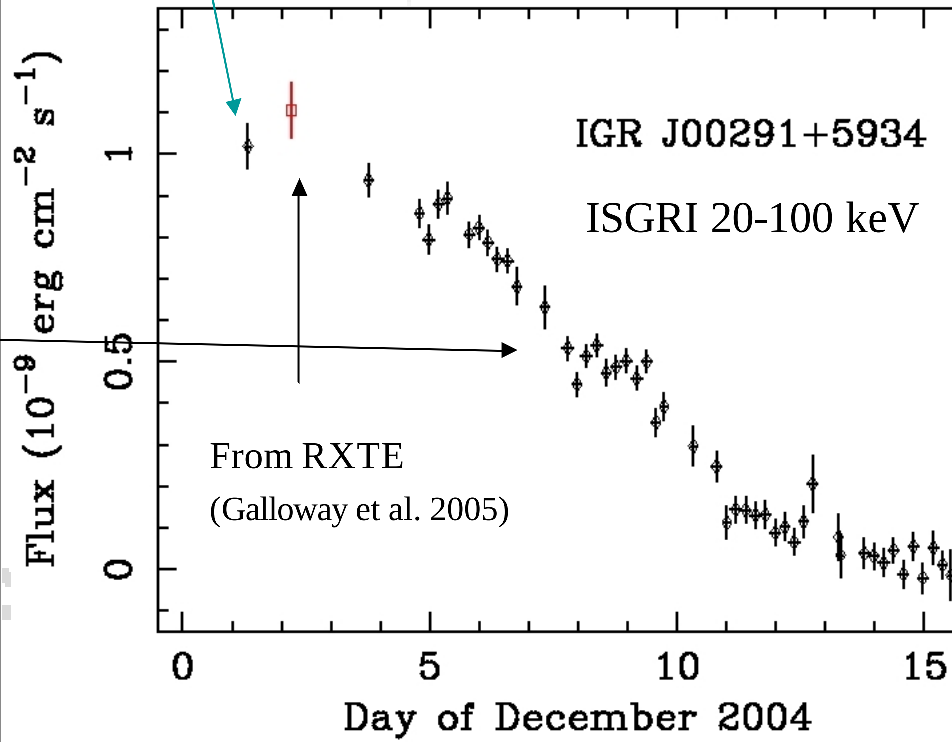
(80-200 keV) significance level ~17s

OUTBURST PROFILE



(Wijnands 2004, astro-ph/0403409)

Discovery (Eckert et al. 2004)



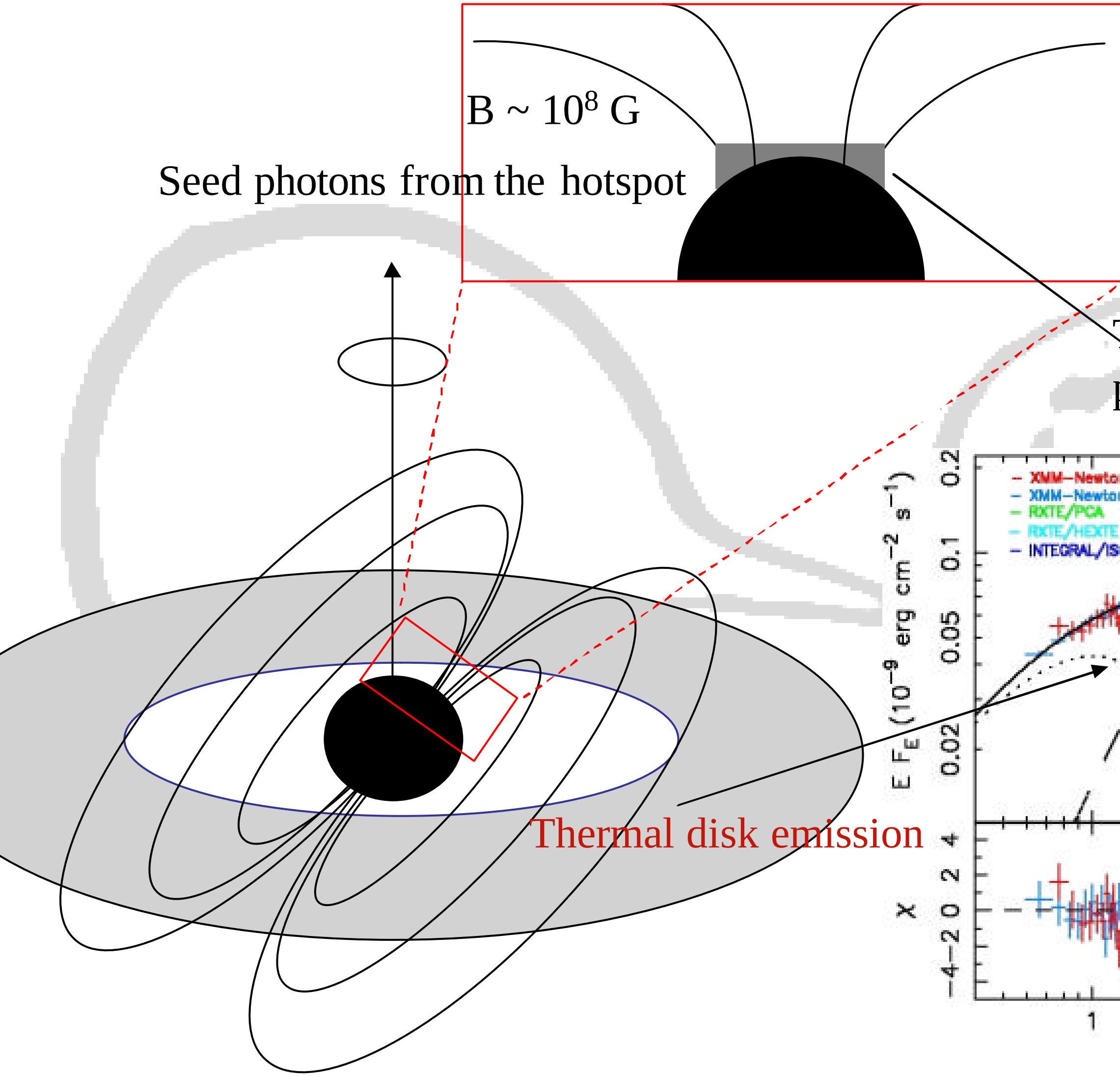
(Falanga et al. 2005, in preparation)

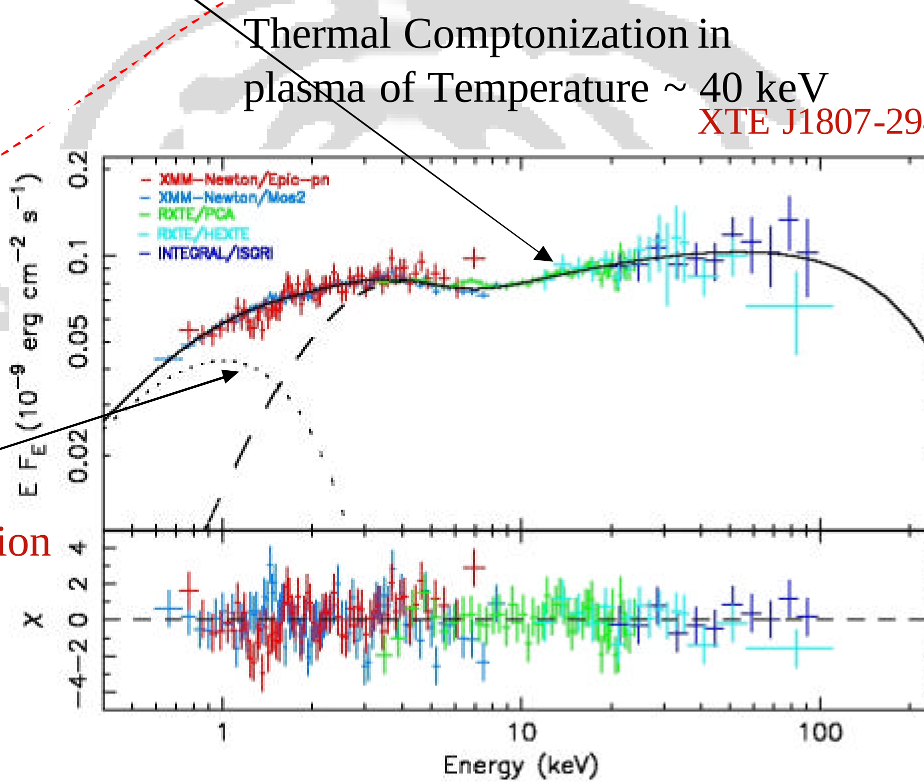
Outburst are extended as a consequence of X-ray irradiation of the disk.

Knee is linked to the outer accretion disk radius. (King & Ritter 1998; Powell, Haswell, Falanga, 2005)

Geometry of the emission region

The plasma is heated by the accretion shock as the material collimated by t hotspot on to the surface The seed photons for Comptonization are provided by the hotspot, NOT by the disk.

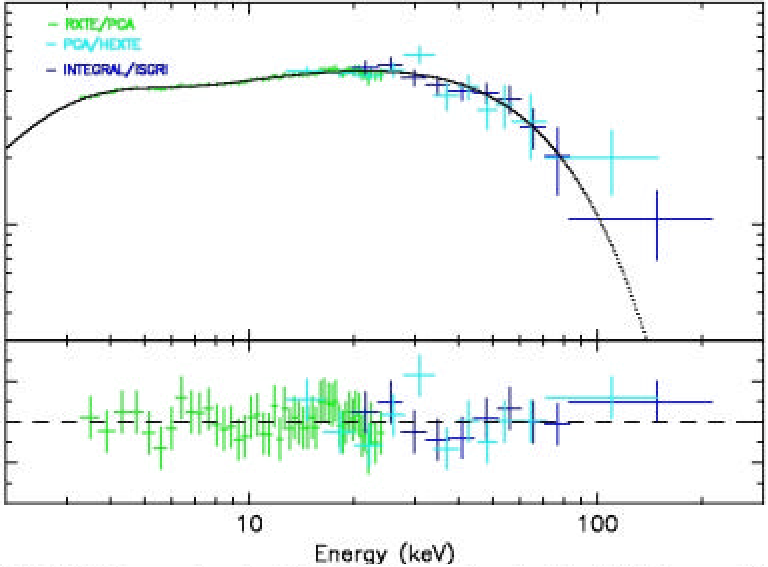


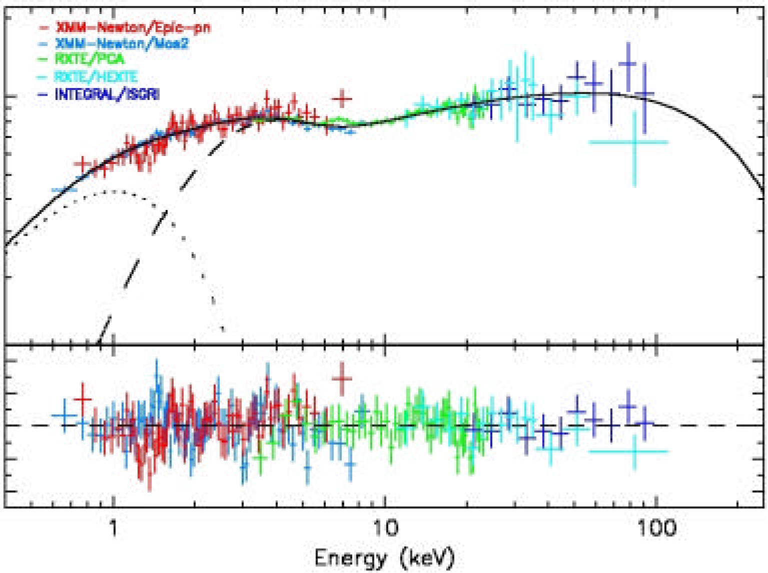


Spectral analysis

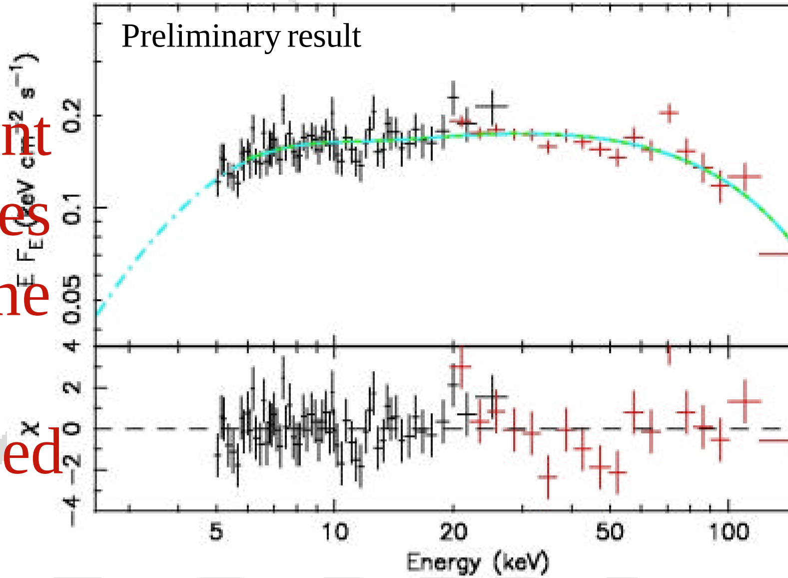
XTE J1807-294

IGR J00291+5934





Hard component contributes 83% of the total unabsorbed flux

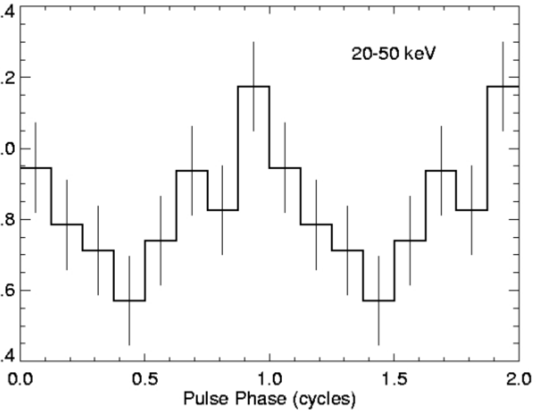


	XTE J1807-294		IGR J00291+5
	COMPPS	COMPPS & DISKBB	COMPPS
N_H (cm^{-2})	0.56×10^{22}		0.28×10^{22} (f)
kT_{disk} (keV)	--	0.43	--
$R_{in}(\cos i)^{1/2}$ (km)	--	13.4	--
kT_e (keV)	18	37	42
kTseed (keV)	0.8	0.75	0.9
Optical depth	2.7	1.7	1.35
$L_{(0.1\text{-}200keV)}$ (10^{36} erg s^{-1})	1.26	0.36	0.44

(Falanga et al. 2004/2005)

SGRI Timing Analysis

XTE J1807-294

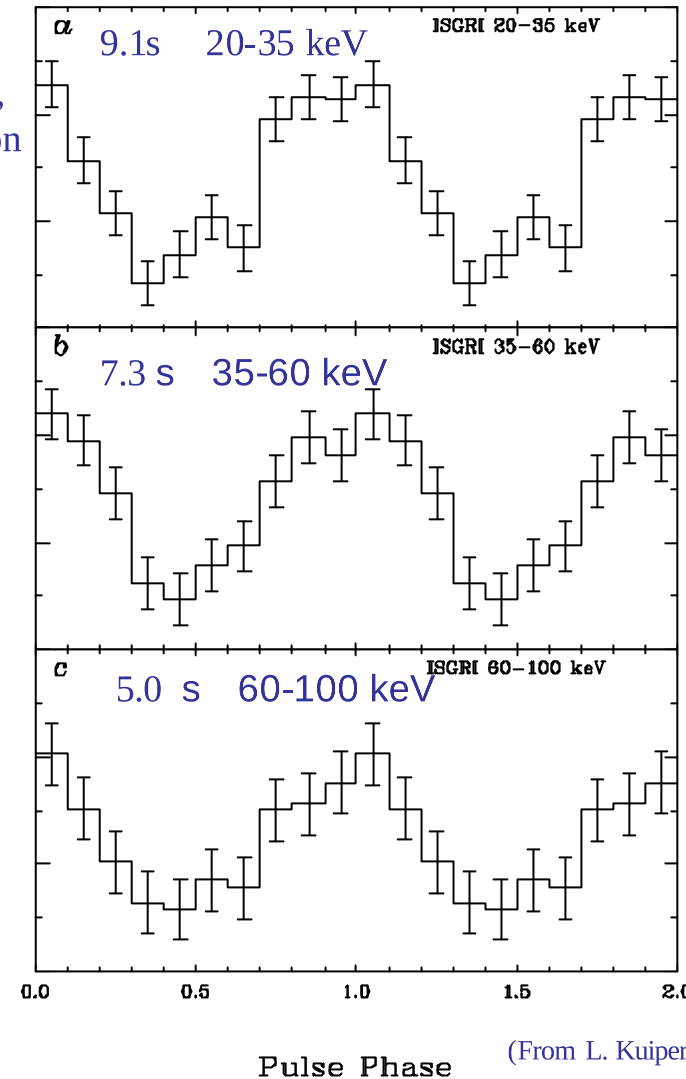


(Finger et al. 2005)

46, 52 scw, pointing <12.5°, epoch-folded, pulse phase
nd at low significance using the PIF.

IGR J00291+5934

Rev 261/262/263, ~205 scw, pointing < 12°, epoch-folded, all the pulse phase distribution found significantly



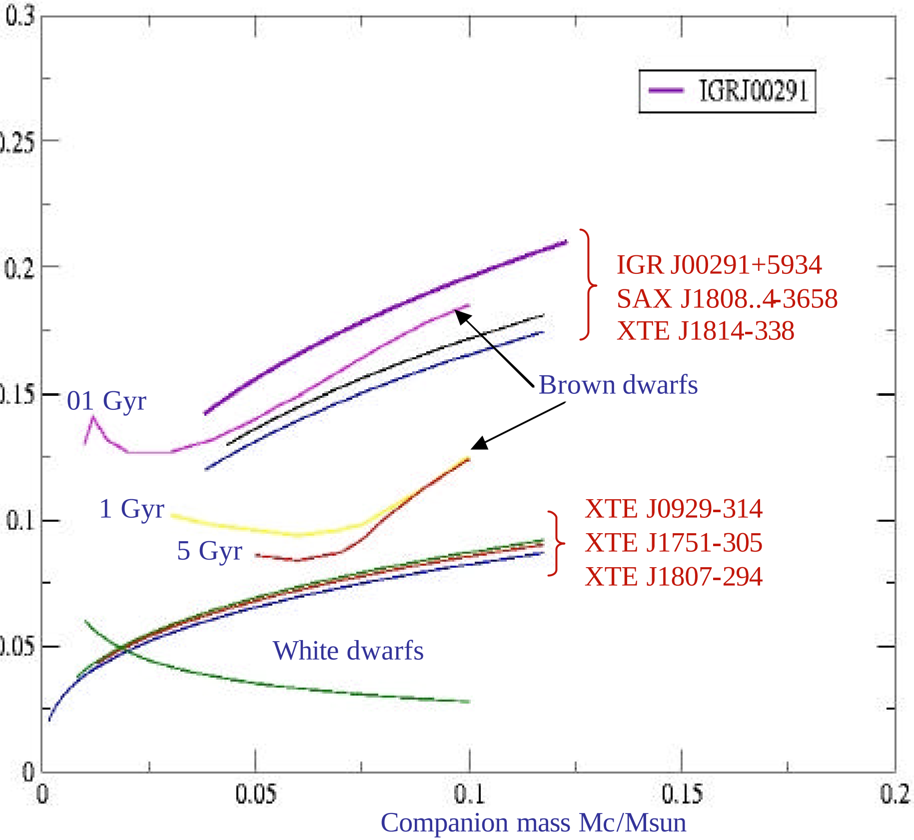
(From L. Kuiper

(Falanga et al 2005, in preparation)

Phase resolved spectroscopy of SAX J1808.4-3658 and XTE J1751-305 show pulsations are stronger in the non-thermal component than the thermal component (Gierlinski, Done & Barret 2002, Gierlinski & Poutanen 2004)

Companion Star

uming that the companion star should fill its Roche lobe to allow sufficient accretion on the compact star



- Brown dwarf models at different ages (Chabrier et al. 2000)
- Cold low-mass white dwarfs with pure-helium composition

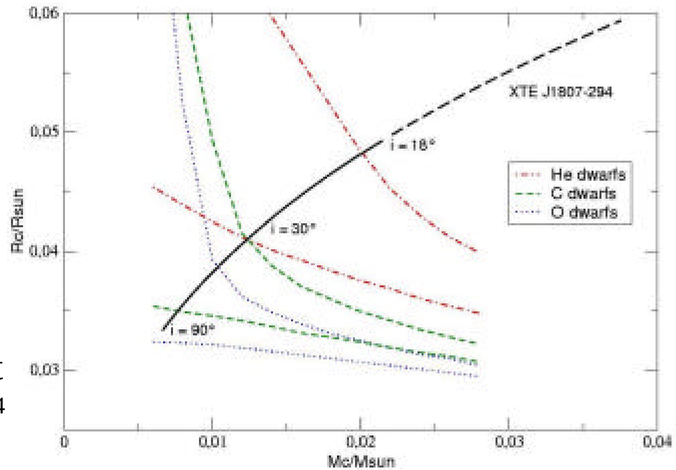
- IGR J00291+5934
- SAX J1808.4-3658
- XTE J1814-338

} H-rich donor, brown dwarf

- XTE J0292-314
- XTE J1751-305
- XTE J1807-294

} H-poor, hihly evolved dwarf

XTE J1807-294



intersection with the possible Mc-Rc values for XTE J1807-294:

white dwarfs having too small radii

own dwarfs too large radii

Eq. of state for different central temperature (10^4 (low) - 10^6 K (high))

Summary

Iissing link between LXMB and ms radio pulsar ?

XT with Coherent pulsation, (kHz QPO's, Burst oscilation)

ight curve can be extended as consequence of X-ray irradiation of the disk

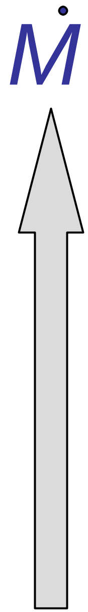
he source luminosity is L_X ~ 10^{37} erg/s, at a fiducial distance

he hard spectral component contributes most to the observed flux, even though a ft component (a disk BB) is needed to fit the data.

or IGR J00291+5934 the pulsed emission has been found up to 150 keV in ISGRI

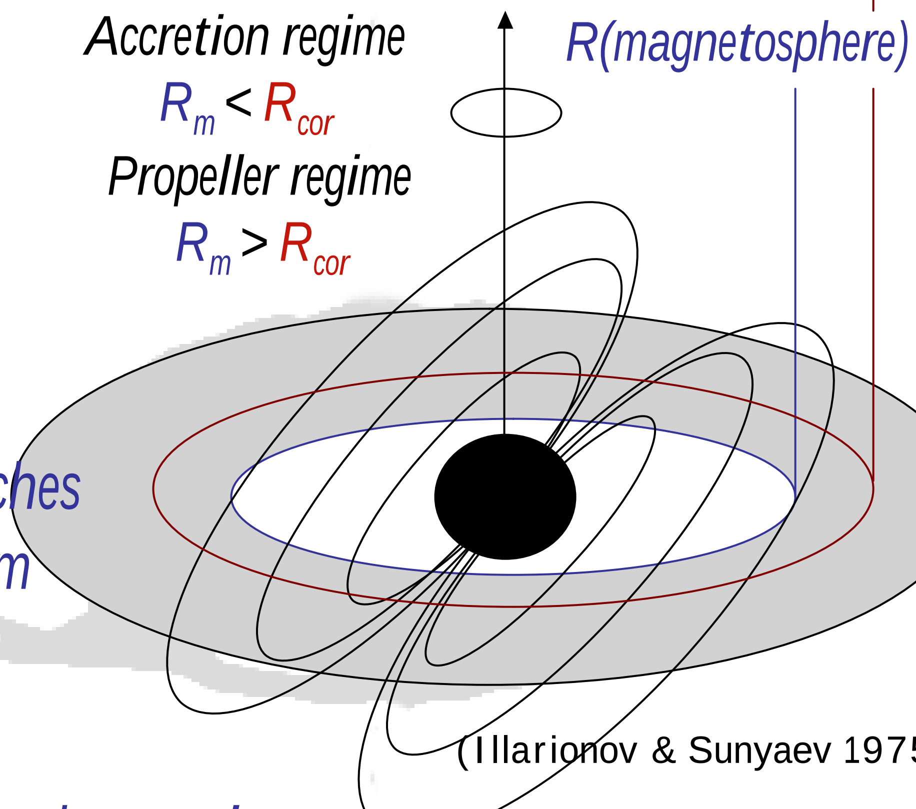
Thank You…

Pulsar spin up



$$\left(\frac{2\pi}{P_{eq}}\right) = \frac{GM}{R_m^3}$$

The accreting matter transfers its specific angular momentum (the Keplerian AM at the magnetospheric radius) to the neutron star: $L=(GMR_m)^{1/2}$



The process goes on until the pulsar reaches the keplerian velocity at R_m (equilibrium period); P_{min} when $R_m = R_{ns}$

The conservation of AM tells us how much mass is necesssary to reach P_{min} starting from a non-rotating NS. A trivial approximation gives $\sim 0.9 M_{sun}$