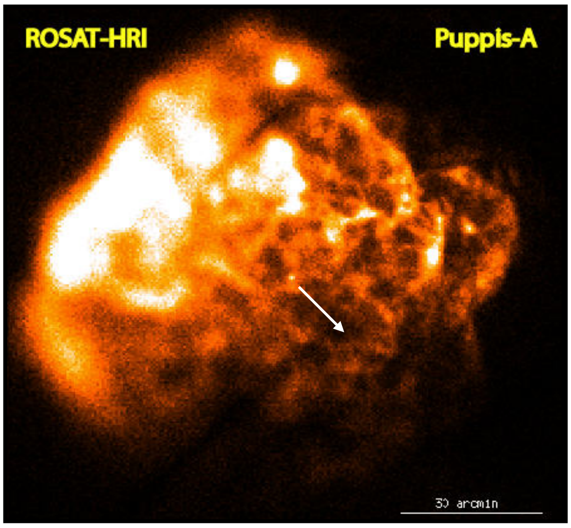
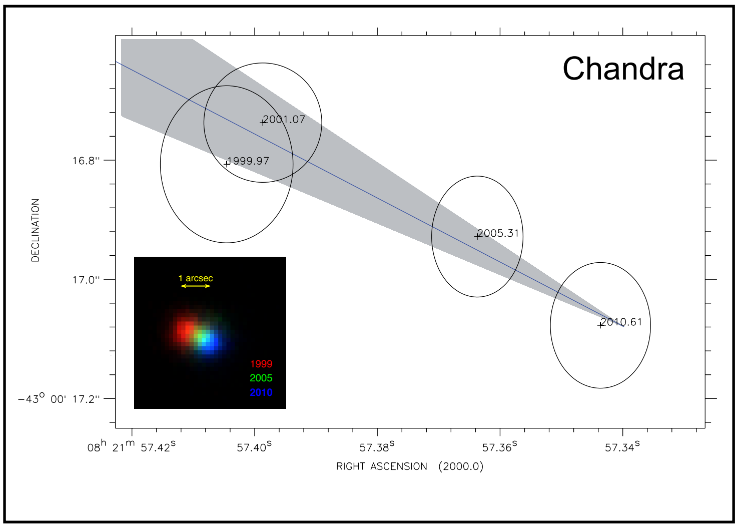
Proper Motion of the CCO RX J0822-4300 in the SNR Puppis-A

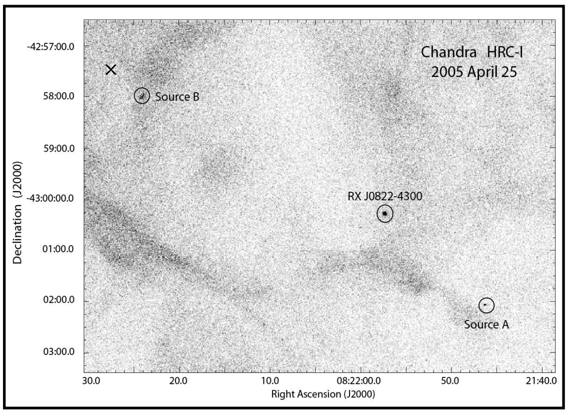
W. Becker[1,2], T. Prinz[1], P.F. Winkler[3], R. Petre[4]

[1]Max-Planck Institut für extraterrestrische Physik, Giessenbachstrassse, 85741 Garching, Germany
[2]Max-Planck Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany
[3]Department of Physics, Middlebury College, Middlebury, VT 05753
[4]NASA Goddard Space Flight Center, Greenbelt, MD 20771

Abstract: Using the High Resolution Camera aboard the Chandra X-ray satellite, we have re-examined the proper motion of the central compact object (CCO) RX J0822-4300 in the supernova remnant Puppis-A. New data taken in summer 2010 along with three additional archival data sets, of which the oldest dates back to December 1999, provide a baseline of 3886 days (>10 ½ yrs) to perform this measurement. Correlating the four neutron star positions measured in each data set implies a projected proper motion of $\mu = 71 \pm 12$ mas/yr (Becker et al. 2012). For a distance of 2 kpc this proper motion is equivalent to a recoil velocity of 672 ± 115 km/s. The position angle is found to be 244 ±11 degrees. Both the magnitude and direction of the proper motion are in agreement with the birth place of RX J0822-4300 being near to the optical expansion center of the supernova remnant. For a displacement of 371 ± 8 arcsec between its birth place and today's position we deduce an age of 5.2 ± 1.8 kyrs for RX J0822-4300 and hence for the supernova remnant Puppis-A.







Upper left: X-ray image of the supernova remnant Puppis-A as seen by the ROSAT HRI. The central point source RX J0822-4300 (seen only in X-rays) is the compact remnant which was formed in the supernova event. The arrow indicates its proper motion direction.

Upper right: Four positions of RX J0822-4300 measured over a baseline of 3886 days. The circles indicate the position uncertainty. Observation dates are labeled. The gray shaded bar depicts the direction to the remnant's optical expansion center, i.e. to the birth place of the RX J0822-4300. The straight blue line indicates the CCO's proper motion path as fitted from the four positions. The inset is a color representation of actual Chandra data for the CCO, after registration onto a common coordinate system; the proper motion to the SSW is evident. Using the first three observations Hui & Becker (2006) found that the CCO may have a recoil velocity of 1122 ± 354 km/s. Winkler & Petre (2007) deduced 1570± 240 km/s using the same data. Chandra provided a fourth position measurement in Aug. 2010 which finally improved the recoil velocity to be 71 ± 12 mas/yr, corresponding to 672 ± 115 km/s at 2 kpc.

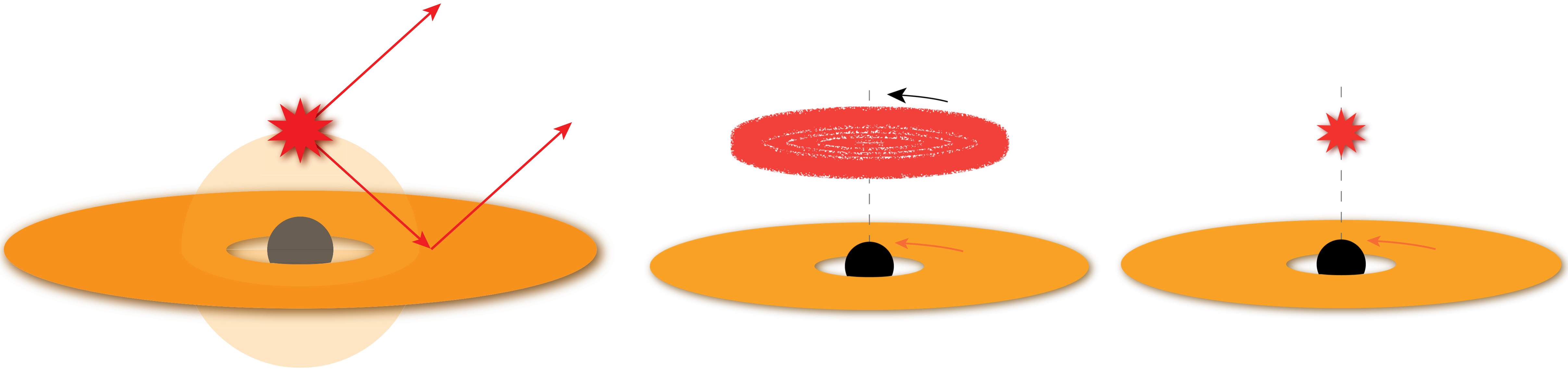
Left: Chandra's view on the central point source RX J0822-4300 and the two reference stars (source A and B). The existence of these stars is essential to perform absolute astrometry and reach the required accuracy to measure the proper motion of RX J0822-4300 at the arcsecond level. The birth place of RX J0822-4300 and the remnants optical expansion center is indicated by a cross.

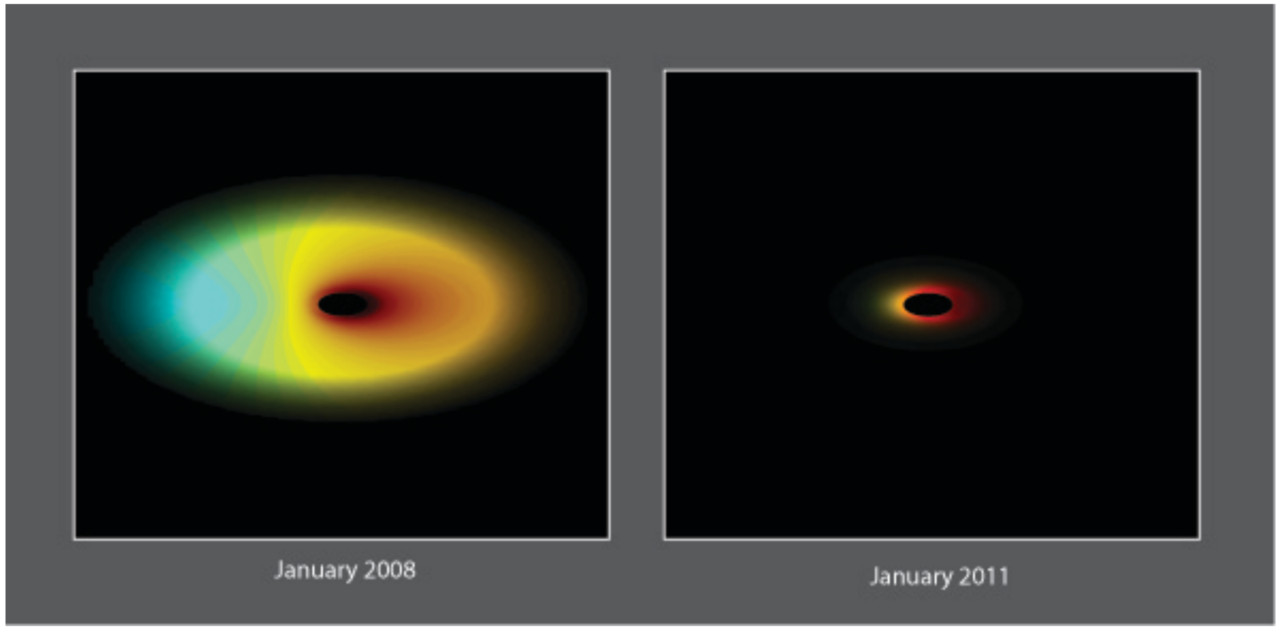
References:

- Hui, C.Y., Becker, W., 2006, A&A, 457, L33
- Winkler, P.F., Petre, R., 2007, ApJ, 670, 635
- Becker, W., Prinz, T., Winkler, P.F., Petre, R.,2012, in prep.

Understanding X-ray Reflection in AGN

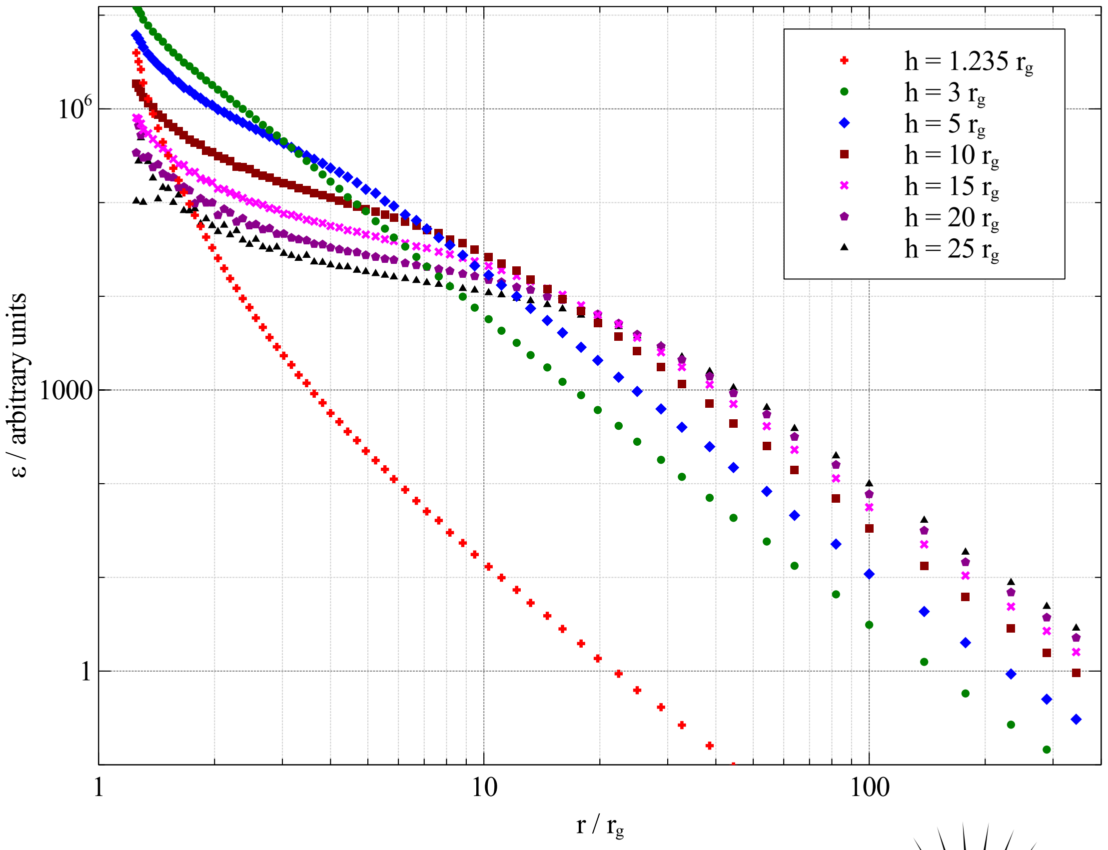
Dan Wilkins





January 2008

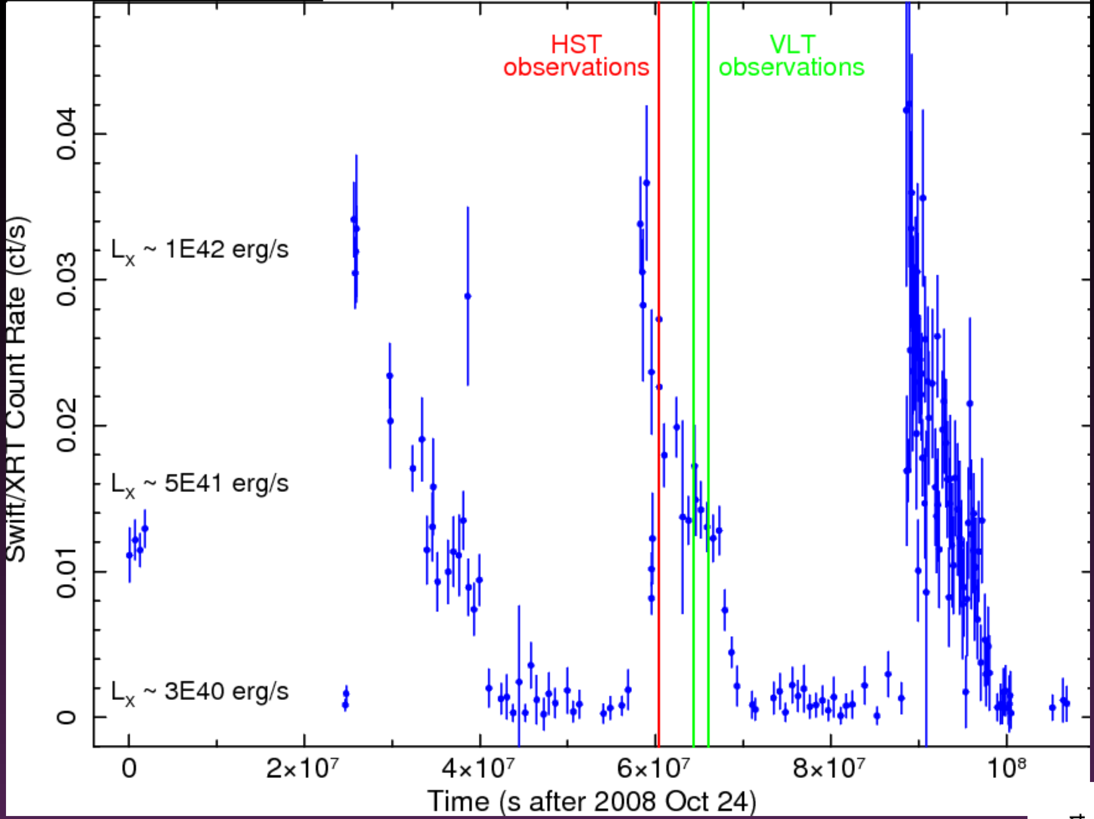
January 2011



UNIVERSITY OF CAMBRIDGE

Mysteries of HLX1
(intermediate-mass BH?)

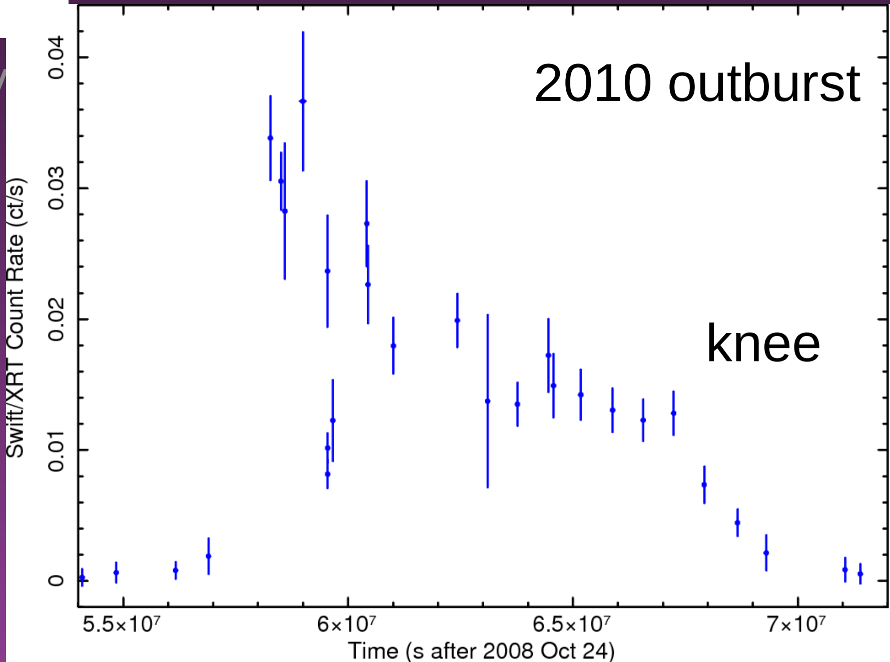
Roberto Soria (ICRAR)
Pasi Hakala (Turku)
George Hau (ESO)
Jeanette Gladstone (Alberta)
Albert Kong (NTHU)
Guillaume Dubus (Grenoble)
Paul Kuin (MSSL)



Optical/UV comes from the disk, not from a star cluster

Why is the disk so small? (scaling from Galactic BHs)

Donor on eccentric orbit, or pulsating AGB star?



Magnetars are super hot and super cool

***Wynn Ho**, Kostas Glampedakis, Nils Andersson*

Magnetars (neutrons stars with magnetic field > 10^{14} G) have high surface temperatures, suggesting extra internal heat (from field decay)

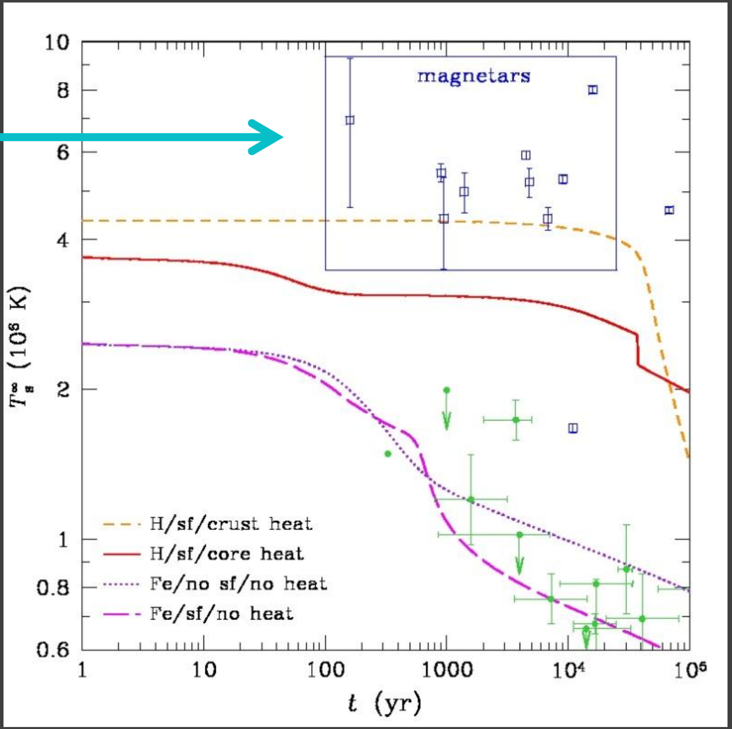
We perform neutron star cooling simulations and find:

1. Heat in crust powers high surface brightness

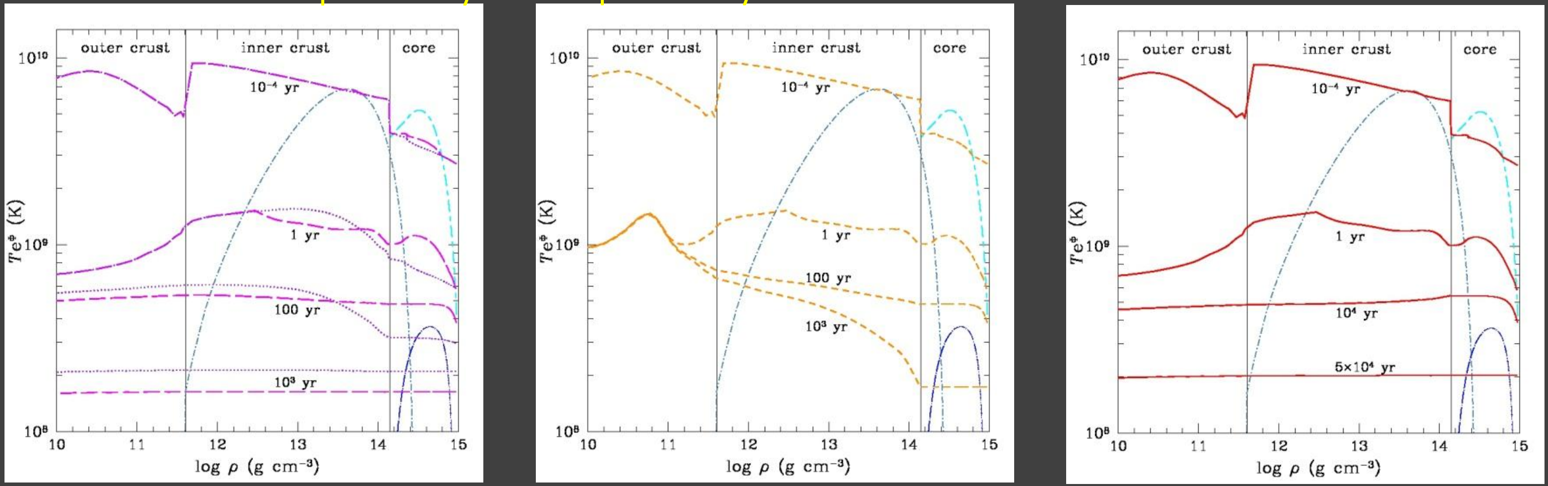
2. Field decay in core cannot delay superfluidity/superconductivity onset

3. **All neutron stars older than a few hundred years have a core of superfluid neutrons and superconducting protons**

Evolution of surface temperature



Interior temperature profiles



with and without superfluidity

superfluidity and crust heat

core heat*

LOFT: Large Observatory For X-ray Timing

S. Zane, R. P. Mignani, D. Walton, T. Kennedy. B. Winter, P. Smith (MSSL, UCL, UK)
on behalf of the LOFT team

Loft Consortium and UK partnership

The LOFT Consortium includes several institutes across the UK, Europe, Israel, Turkey, Canada, the US, and Brazil. In addition to MSSL, the UK participation include the Space Research Centre (SRC) in Leicester, the University of Southampton, the University of Durham, the University of Manchester, and the University of Cambridge. The UK participation is sponsored by the UK Space Agency.

A New X-ray Mission

LOFT is one of four M3 missions that have been selected by ESA for an Assessment Phase and be considered for a possible launch in 2020-2022. LOFT is a 10 m^2-class telescope, specifically designed to study the very rapid X-ray flux and spectral variability that directly probe the motion of matter down to distances very close to black holes and neutron stars.

High-time-resolution X-ray observations of compact objects provide direct access to strong-field gravity, black hole masses and spins, and the equation of state of ultra-dense matter. They provide unique opportunities to reveal for the first time a variety of general relativistic effects, and to measure fundamental parameters of collapsed objects. They gain unprecedented information on strongly curved space times and matter at supra-nuclear densities and in supercritical magnetic fields. In turn, this bears directly to answer several fundamental questions of both the ESA's Cosmic Vision Theme *"Matter under extreme conditions"* and the STFC road map *"What are the law of the physics under extreme conditions?"*.

A 10 m^2-class telescope as LOFT, in combination with good spectral resolution (<260 eV @6 keV) is required to exploit the relevant diagnostics and holds the potential to revolutionise the study of collapsed objects in our galaxy and of the brightest supermassive black holes in active galactic nuclei. The timescales/phenomena that LOFT will investigate range from sub-millisecond, quasi-periodic oscillations to year-long transient outbursts, and the relevant objects include many that flare up and change state unpredictably. Thus, relatively long observations, flexible scheduling and continuous monitoring of the X-ray sky are essential elements for success.

Payload

LOFT will be launched on a Soyuz rocket at a ~600 km equatorial orbit. It will carry two main instruments: a Large Area Detector (LAD, operating in the range 2-50keV, energy resolution <260eV @6keV) and a Wide Field Monitor (WFM). The LAD consists of 6 panels deployable in space which provide a total effective area of ~10 m^2 (@8 keV), improving by a factor of ~20 over all its predecessors (Fig.1). The ground-breaking characteristic of the LAD is a mass per unit surface of ~10 kg/m^2, a factor of 10 lower than for the RXTE/PCA, enabling a ~10 m^2 area payload at reasonable weight. The ingredients for a sensitive but light experiment are the large-area Silicon Drift Detectors, and a collimator based on lead-glass microchannel plates. An unprecedently large throughput (~3x10^5 cts/s from the Crab) will be achieved, while making pile-up and dead-time secondary issues. The WFM is a coded-mask telescope mounted ot the top of the telescope axis at the centre of the LAD deployable array. The WFM will operate in the energy range 2-50 keV and with a field of view of 3 steradians, corresponding to about ¼ of the whole sky. The WFM angular resolution (5 arcmin) will enable it to locate sources with an accuracy of 1 arcmin, with a 5σ sensitivity of 2mCrab (50 ks).

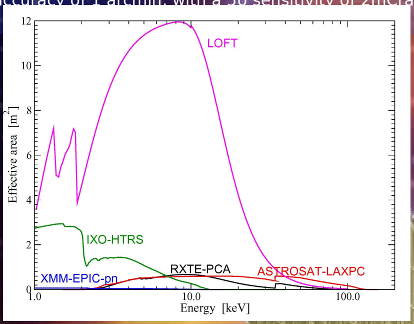


Fig. 1: Effective area of LOFT compared to that of other missions

Parameter	Requirement	Goal
	Large Area Detector	
Energy Range	2-50 keV	1.5-50 keV
Effective Area (2-10 keV)	10m^2@8keV	12 m^2@8keV
Energy Resolution (@ 6 keV)	260 eV @6keV	200 eV @6keV
Field of View (FWHM)	<1° and transparency ~1% at 30 keV	<0.5 °
Time Resolution	10 μs	7 μs
Dead Time	<1% (@ 1 Crab)	<0.5% (@ 1 Crab)
Background	< 10 mCrab	< 5 mCrab
Maimum source flux (continuous and re-binned in energy >30keV,continuos re-binned)	>500 mCrab, 15 Crab	>750mCrab, 30 Crab
	Wide Field Monitor	
Energy Range	2-50 keV	1-50 keV
Energy Resolution (FWHM)	500 eV	300 eV
Field of View	50% of the sky accessible to the LAD	Same, with improved sensitivity
Angular Resolution	5 arcmin	3 arcmin
Point Source Localization	1 arcmin	0.5 arcmin
Sensitivity (5σ, 50 ks)	5 mCrab	2 mCrab

The LOFT Science Driver: study of matter under extreme conditions

- Neutron Star Structure and Equation of State of ultradense matter (mass, radius and crustal properties of neutron stars)
- Strong Gravity and the mass and spin of the black holes (QPOs in the time domain, relativistic precession, Fe line riverberation studies in AGNs..)
- Small amplitude periodicities in X-ray transients, millisecond pulsars, etc..
- Discovery of new X-ray transients, early trigger of jets over many astronomical scales
- X-ray flashes
- And many others!!!

The LAD ~10 m^2 effective area in the 2-50 keV energy range will allow timing measurements of unprecedented sensitivity, leading for instance the measure the mass and radius of neutron stars with ~5% accuracy, or to reveal blobs orbiting close to the marginally stable orbit in active galactic nuclei.The LAD energy resolution will also allow the simultaneous exploitation of spectral diagnostics, in particular from the relativistically broadened 6-7 keV Fe-K lines. The WFM will monitor a large fraction of the sky and constitute an important resource in its own right. The WFM will discover and localise X-ray transients and impulsive events and monitor spectral state changes with unprecedented sensitivity. It will then trigger follow-up pointed obs as with other multi-wavelength facilities.

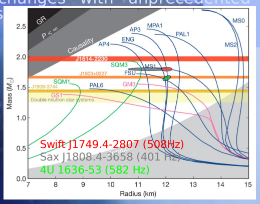


Fig 2. Mass-radius curves for different neutron star EOS: nucleonic (blue), nucleonic plus exotic (pink) and strange quark (green) matter. Green ellipse: the 90% confidence level limits on M, R from a simulated pulse profile rising phase of a type I X-ray burst (Stromayer, 2004). Uncertainty is <5% on both M and R. Gray and red ellipses show similar constraints from simulated pulse profiles of two accreting millisecond pulsars.

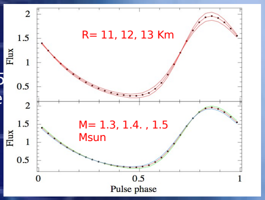


Fig. 3 Simulated pulse profile measurements from burst oscillations during the rising phase of an X-ray burst or from an accreting millisecond pulsar. The spin frequency is 400 Hz, as in SAX J1808.4-365 The dots mark the input profile, with errors as large as the dot size. These panels demonstrate the very high sensitivity to mass and radius measurements that can be reached with LOFT.

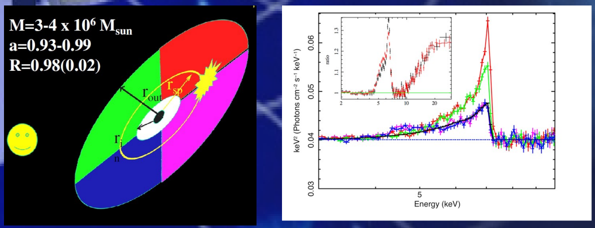


Fig. 4: Iron reverberation studies in bright AGNs. The figure is illustrative of the case of MCG-6-30-15, different coloured lines correspond to 4 different orbital phases for a line emitted at 10rg. LOFT can map the 4 phases in four cycles, with 1000s each, allowing to measure the black hole mass and spin (M=3-4 x10^6 Msun, a=0.93-0.99).

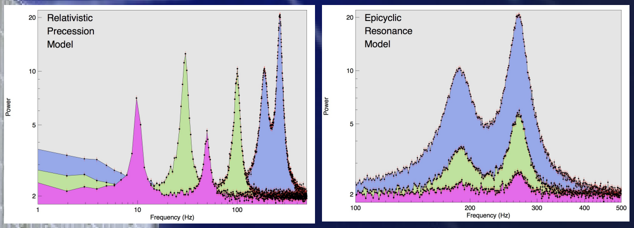


Fig. 5: LOFT study of the QPO evolution with flux (blue 1 Crab, green 400mCrab, violet 300mCrab) in two different scenarios → LOFT will solve the ambiguity in the interpretation of the QPO phenomena, providing access to genuine general relativistic effects (e.g. Lense-Thirring or strong field periastron precession) and to the mass and spin of the black hole.

Jan Willem Den Herder, Marco Feroci, Enrico Bozzo, Luigi Stella, Michiel van der Klis on behalf of the LOFT team
Silvia Zane, Dave Walton, Roberto Mignani, Tom Kennedy on behalf of the LAD team

Note: MSSL/UCL will lead the LOFT LAD instrument within the consortium (Silvia Zane, Dave Walton, Tom Kennedy) as well as will have a major role in the hardware/software development and system engineering (thermal, mechanical, electronics and software). This effort will be supported by Leicester SRC (G. Fraser) who lead the development of the collimators. Southampton, Durham. Manchester, and Cambridge are among the other UK institutions currently involved in the LOFT Science consortium.

http://www.isdc.unige.ch/loft/index.php/the-loft-mission