Overview of the Observatory Science Working Group

R. P. Mignani[1,2,3], J. Wilms[4]

On behalf of the LOFT OS Working Group

[1]*Mullard Space Science Laboratory, University College London, UK*

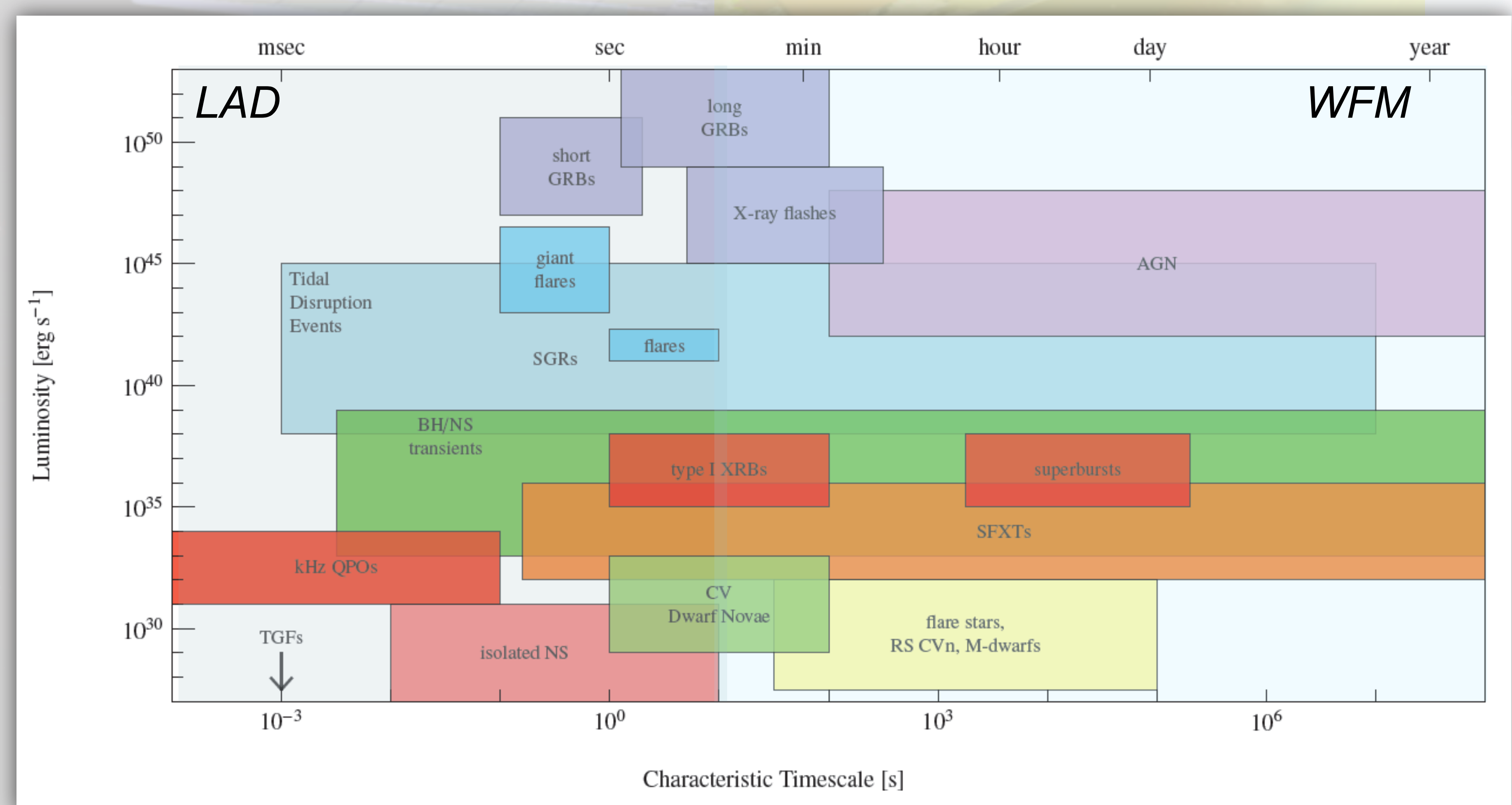
[2]*INAF-IASF, Milan, Italy, Fermi Collaboration*

[3]*Kepler Institute of Astronomy, University of Zielona Gora, Poland*

[4]*University of Erlanger-Nuremberg, Germany*

First UK LOFT Science Meeting, London, June 24-25 2013

The LOFT Time Domain



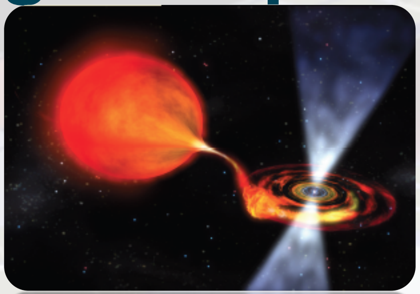
LOFT OS White Book (in preparation)

The LOFT Science Working Groups

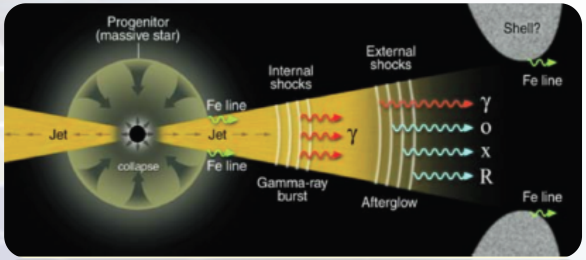
Observatory Science

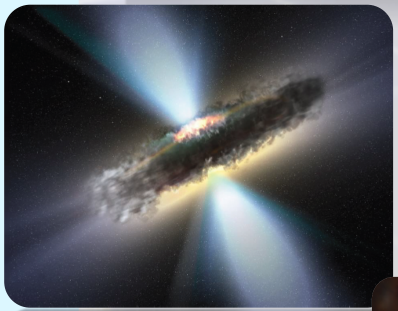
Working Group

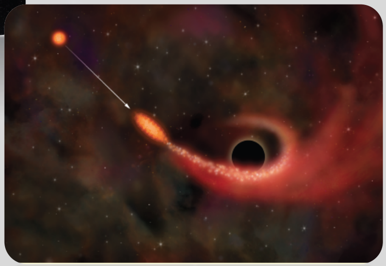
Joern Wilms (U. Erlangen)



White Dwarfs, Novae	Domitilla de Martino
Be X-ray Binaries	Mauro Orlandini
X-ray binaries (non-Be)	Jörn Wilms
X-ray bursts	Jean in’t Zand
Isolated NS, radio pulsars	Roberto Mignani
SNe, Tidal Disruption Events	Peter Jonker
AGN	Ian McHardy
Gamma-Ray Bursts	Lorenzo Amati
Surveys/Multiwavelength	Jörn Wilms
Miscellaneous science	Tom Maccarone







OS Themes

The Observatory Science Section of YB will be structured according to Science Themes

- **Powering High Luminosity Sources: The Physics of Accretion and Ejection**
  - Accretion disk physics, disk/jet connection, accretion regimes
  - -- X-ray/radio connection (AGN/BHB)
  - -- X-ray bursts, burst oscillations
  - Dwarf novae, CVs, HMXB, LMXB, AGN

A. Ingram's talk

W. Ho's talk

P. Wheatley's talk

- **The Physics of Strongly Magnetized Objects**
  - Accretion columns in Neutron Stars and WD
  - Pulsar pulse phase spectroscopy, cyclotron lines
  - Pulsar magnetospheres, magnetars
  - -- Magnetar outbursts and magnetospheres
  - RRATS, blind searches

OS Themes

- **The Physics of Thermonuclear Burning**
  - Novae
  - X-ray Bursts and Superbursts
  - SN shock break out, X-ray flashes

- **Extragalactic Phenomena**
  - prompt GRB emission
  - high-z GRBs
  - WFM GRBs, GRB afterglows
  - high-z blazars
  - Tidal Disruption Events
  - XRB fluctuations

L. Amati's talk

- **Stellar Astrophysics and Miscellaneous**
  - Early-type stellar winds and SFXTs
  - Late-type stellar flares
  - Terrestrial Gamma-Ray Flashes

J.M. Torrejon's talk

OS Themes

- **LOFT as a Discovery Machine: The Transient Sky**

  -- multiwavelength context

  -- erratic/short term phenomena in pulsars

  -- CV outbursts

  – Novae

  – Dwarf novae

  – Blazar monitoring

  – AGN X-ray/radio variability and unification

Synergies with other facilities is an important component of the OS cases

Detailed discussion of all scientific points and simulations in the *LOFT Observatory Science White book* (*in preparation*), to be posted on arXiv

LAD and WFM OS Contributions

(an incomplete)

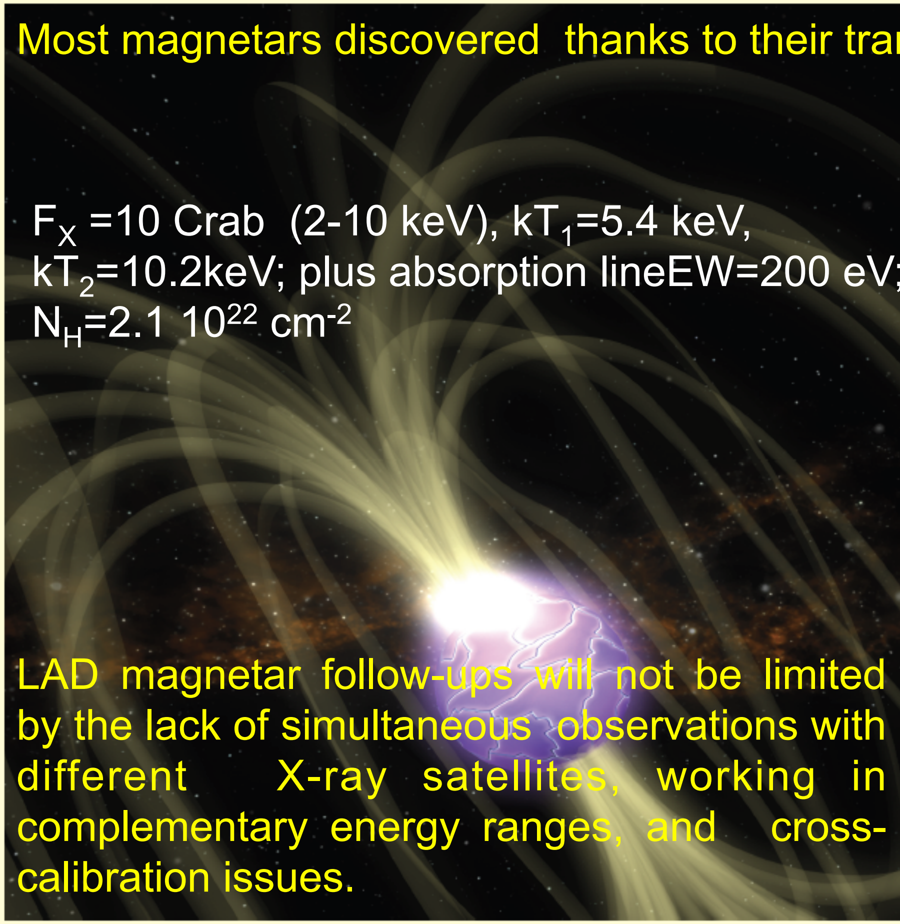
Observatory Science Matrix

($F_x > 0.3$ mCrab $\sim 6 \times 10^{-12}$ erg/cm^2/s)

L = LAD   W=WFM

	Accretion Ejection	Magnetic fields	Cosmology	Evolution	Transient Sky
X-ray Bursters	L W	L		L W	L W
Low Mass X-ray Binaries	L W	L		L W	L W
High Mass X-ray Binaries	L W	L W		L W	L W
Isolated Neutron stars	L	L		L	
Magnetars		L W		L W	L W
Flare Stars		L W			W
Gamma Ray Bursts	W		W	W	W
Tidal Disruption Events	L W		L W		L W
Nearby Galaxies (MCs, M31)	L W	L W			L W
Bright AGNs (Seyferts, Blazars)	L W				L W
X-ray Bkgd Fluctuations			L	L	

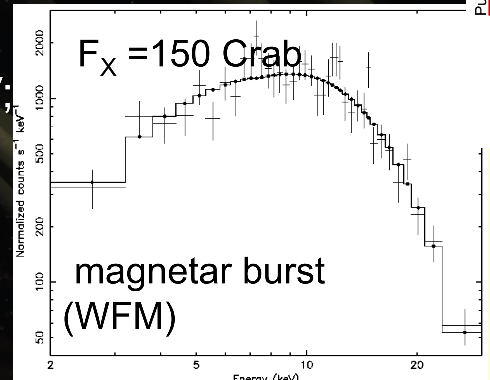
Magnetars and pulsars

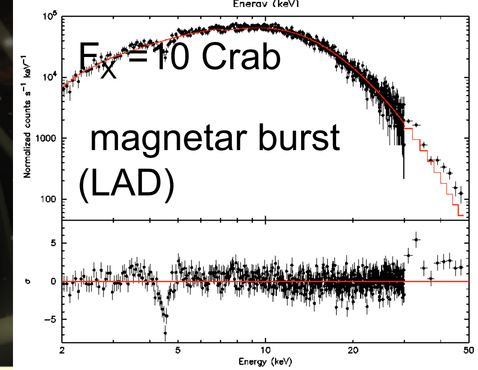


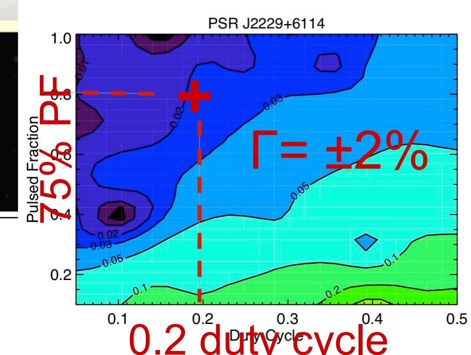
Most magnetars discovered thanks to their transient X-ray emission

F_X =10 Crab (2-10 keV), kT_1=5.4 keV, kT_2=10.2keV; plus absorption lineEW=200 eV; N_H=2.1 10^{22} cm^{-2}

LAD magnetar follow-ups will not be limited by the lack of simultaneous observations with different X-ray satellites, working in complementary energy ranges, and cross-calibration issues.



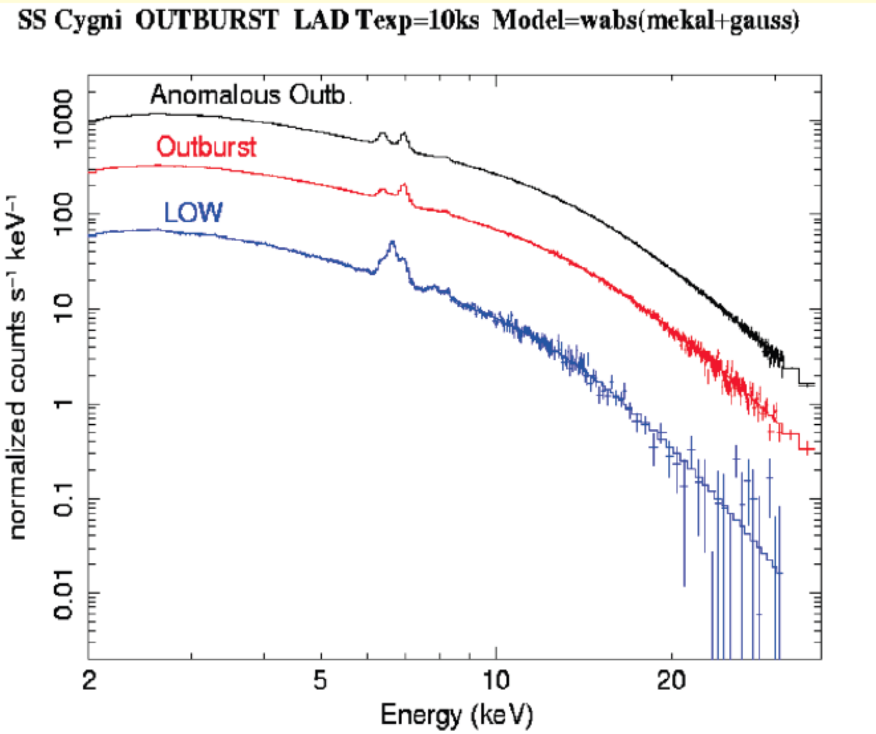


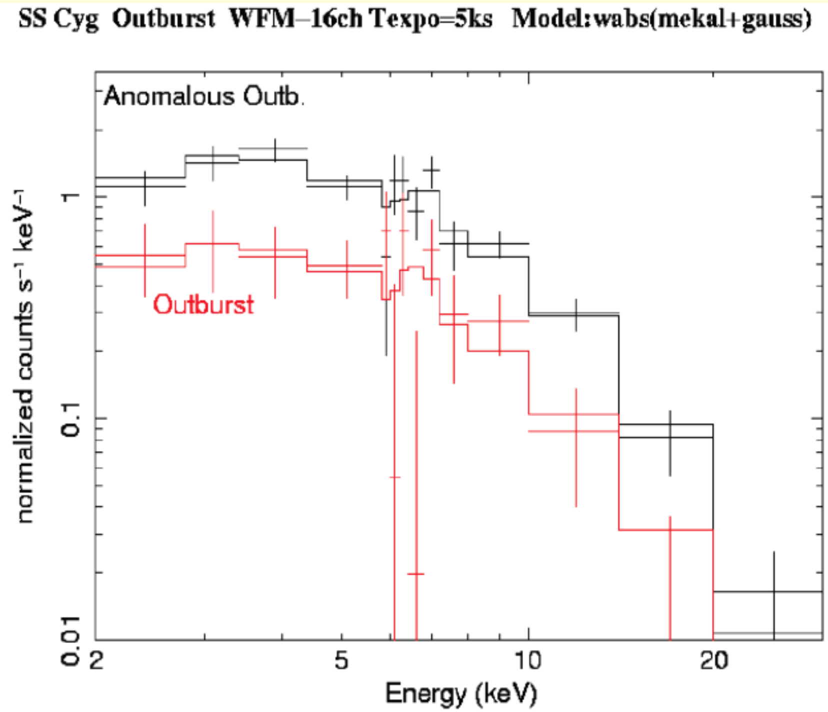


- Evolution of pulse shape in time and E
- spectroscopy, pulses: spectra can be soft, need to go to 1 keV

- Response to short events is important (SGRs, Magnetars)
- Brainstorming: timing of rotation powered pulsars in Andromeda or LMC, SKA

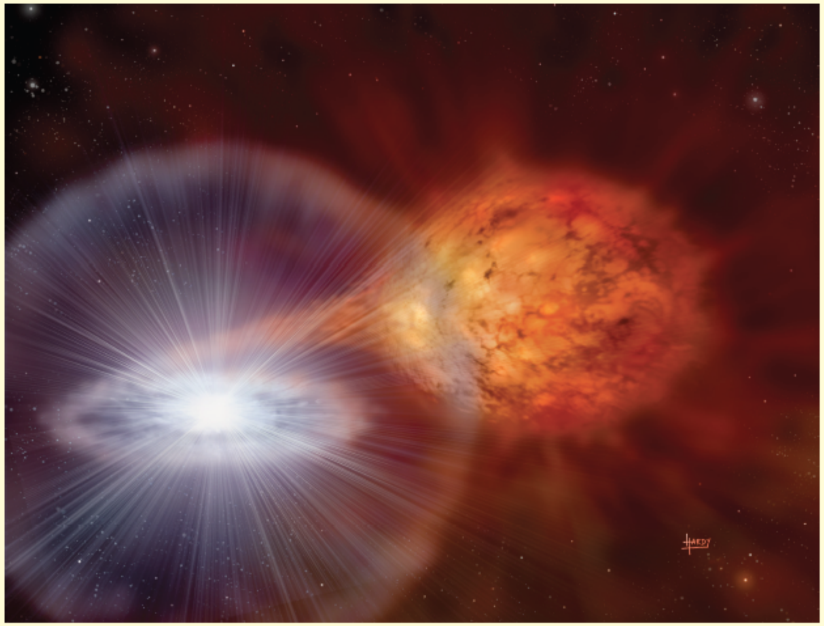
Accreting White Dwarfs

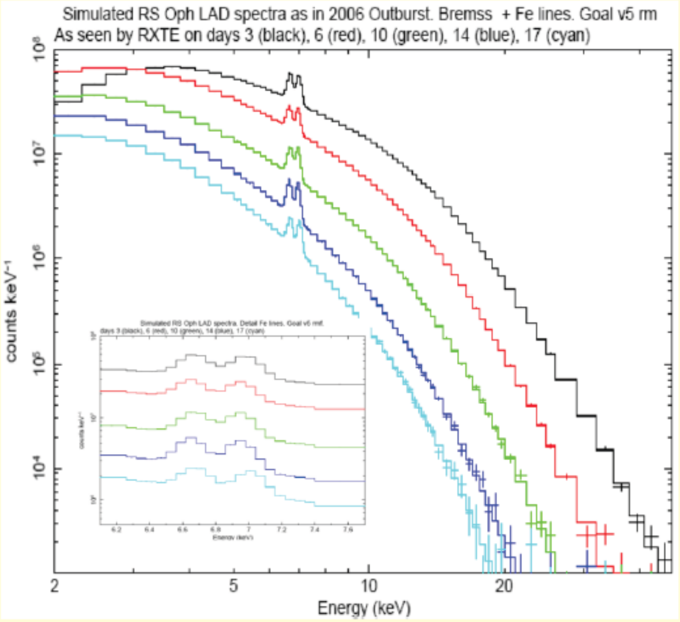




- 1–10 s QPOs in high B CVs in optical, no X-ray detections so far (sensitivity?)
- oscillations at 100s seconds from dwarf nova outbursts (mainly in soft X-rays, but also some observations in the hard X-rays), not well studied yet
- Dwarf Nova outburst X-ray temporal and spectral evolution $\Longrightarrow$ not understood yet
- X-ray flickering in non-magnetic and high-B field WDs
- eclipse mapping $\Longrightarrow$ geometry of X-ray emitting regions

Novae





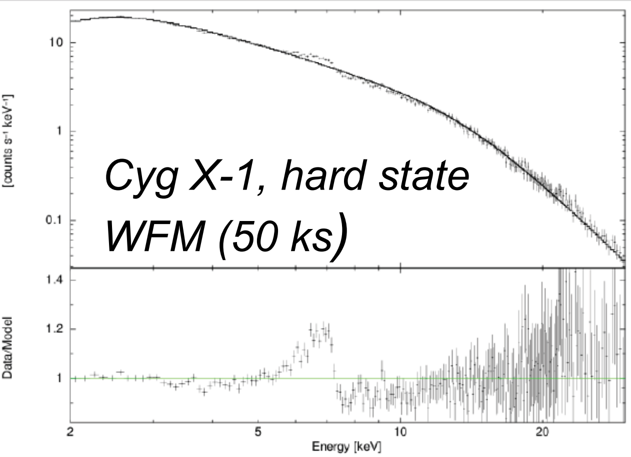
Novae – thermonuclear runaway on White Dwarfs

Symbiotic recurrent novae (WD+red giant): ejecta shock stellar wind, causing *very* hard X-rays

particle acceleration in RS Oph would have been detected with *Fermi* if that had been available at the time; V407 Cyg detected w/*Fermi*, either Compton scattering or π^0 decay

- LAD: study variability caused by mass ejection in such systems, Fe line variability, separate nova ejecta, accretion flow, reflection.
- WFM: catch onset of Nova outbursts

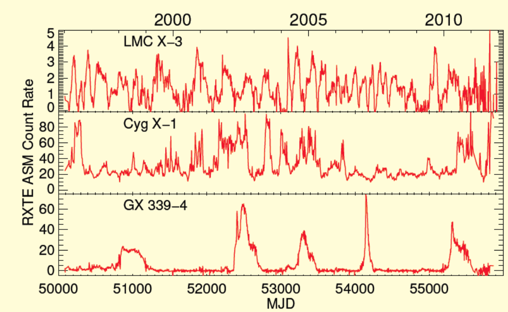
X-ray Binaries



Accretion with X-ray binaries:
- BH XRB states, radio connection
- pulse period evolution (coupling disk-**B**-field)
- short transients

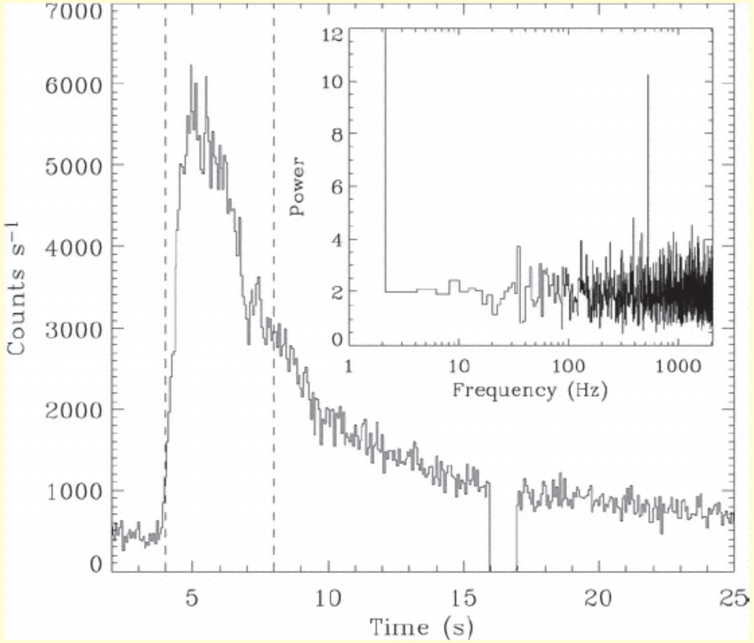
WFM:
- monitoring of spectral evolution of XRB
- detection, monitoring → variation of spectral parameters, state determinations, etc.
- monitoring of cyclotron lines in low-B XRB (bright phases of outbursts)

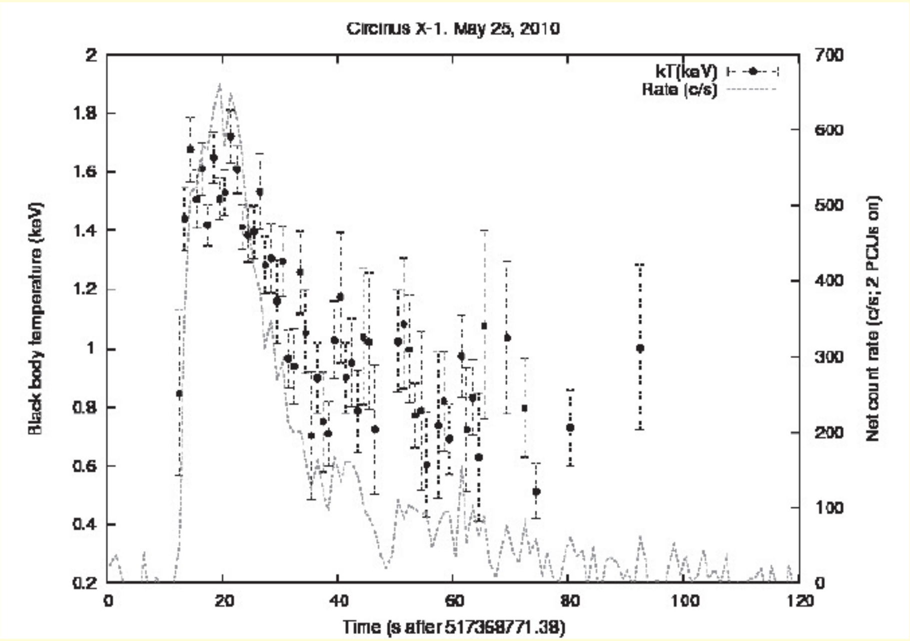
LAD:
- sub msec variability in Be XRB:
- MHD instabilities in disk/coupling to B-field, Mdot variations
- photon bubble oscillations in accretion column



- new science: sub-msec variability in Be HMXRB
- cyclotron lines (for some weak B-field sources)
- WFM: monitoring of Be (WFM), onset of Be outbursts

X-ray bursts



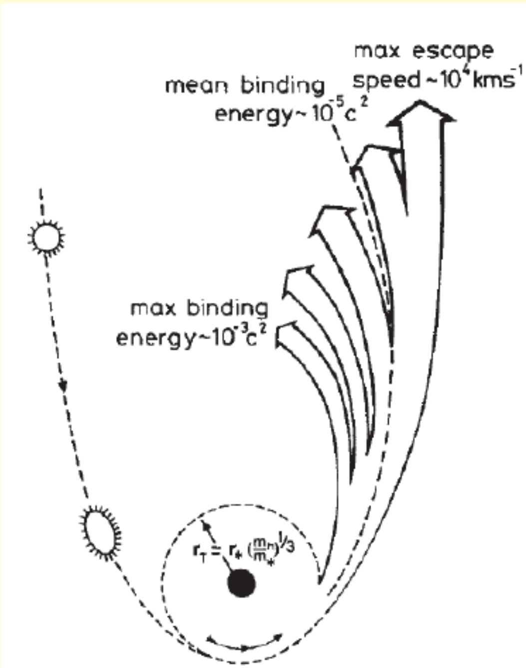


X-ray bursts:

- half of the $\sim$100 bursting sources are w/in 20° of GC
- WFM: dramatic increase in duty cycle of burst observations compared to today, allows to probe rare events such as superbursts
- study interaction of X-ray burst emission and surroundings:
  - cooling of accretion disk corona by burst photons
  - influence of accretion flow by radius expansion (winds, expanding shells)

  should be observable through changes in flux at $>$20 keV which lag soft flux by $\sim$1 s.

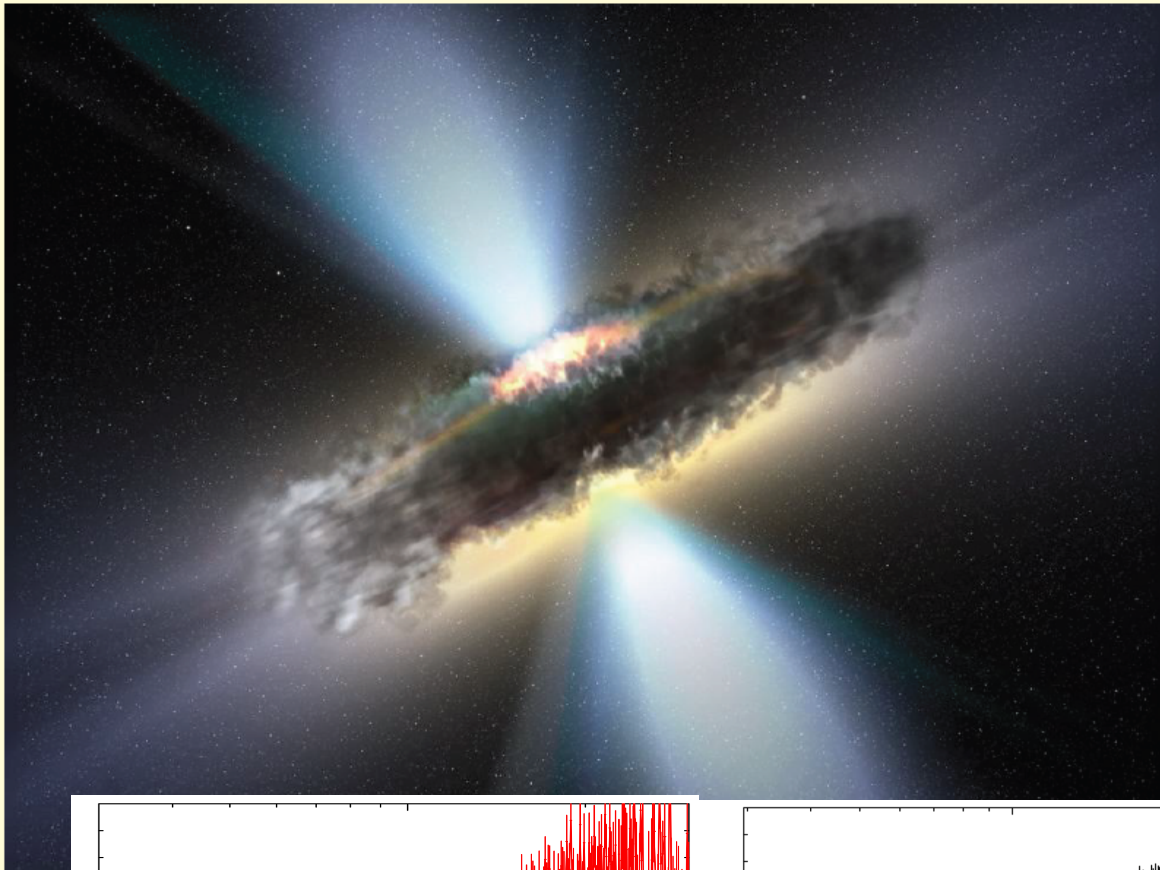
Tidal disruption events, supernovae



- Tidal Disruption Events: Estimate is up to 1000 events out to $z = 1$, strongly dependent on soft X-ray cutoff
- SN breakout events: soft events, not really picked up by BAT (2 in 7 years). WFM will be much better

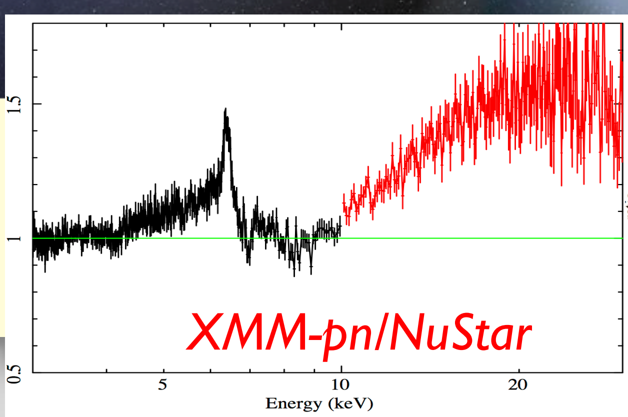
$$R_\mathrm{T} = 0.7\,\mathrm{AU}\cdot\frac{R_*}{R_\odot}\left(\frac{M_*}{M_\odot}\right)^{-1/3}\left(\frac{M_\mathrm{BH}}{10^7\,M_\odot}\right)^{1/3} \quad > R_\mathrm{S} \text{ for } M_\mathrm{BH} \lesssim 6\times 10^7 M_\odot$$

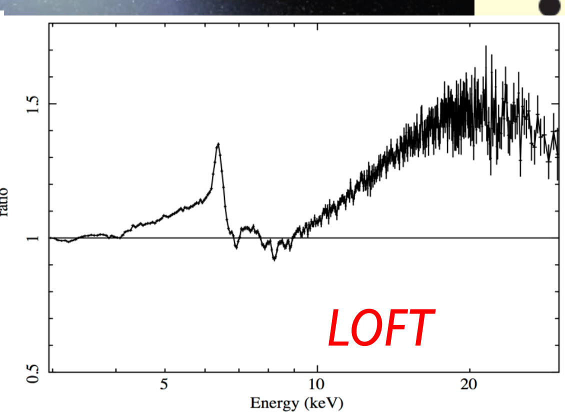
AGN



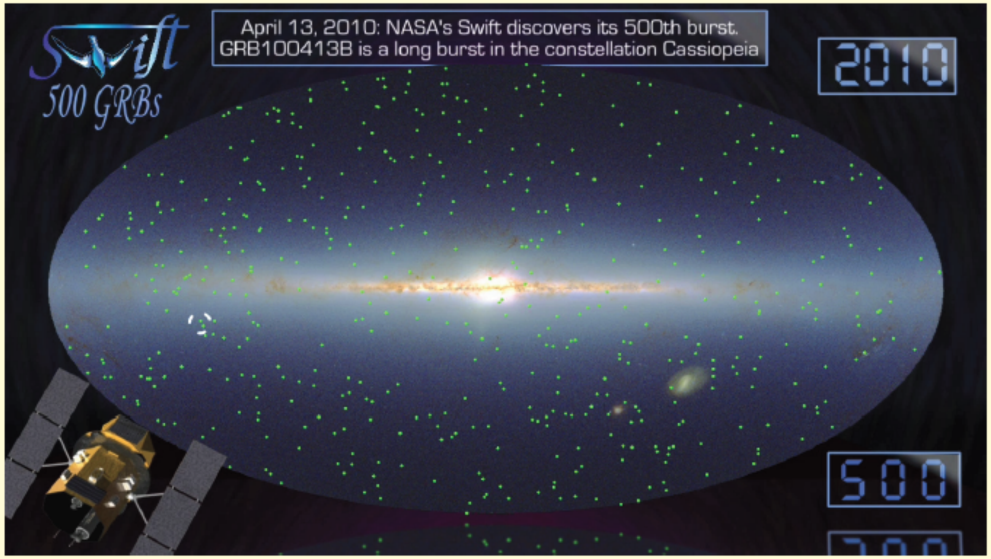
- Importance of AGN monitoring: Visibility is critical!
- AGN QPOs: LAD observations comparable to pointed observations with *XMM-Newton*

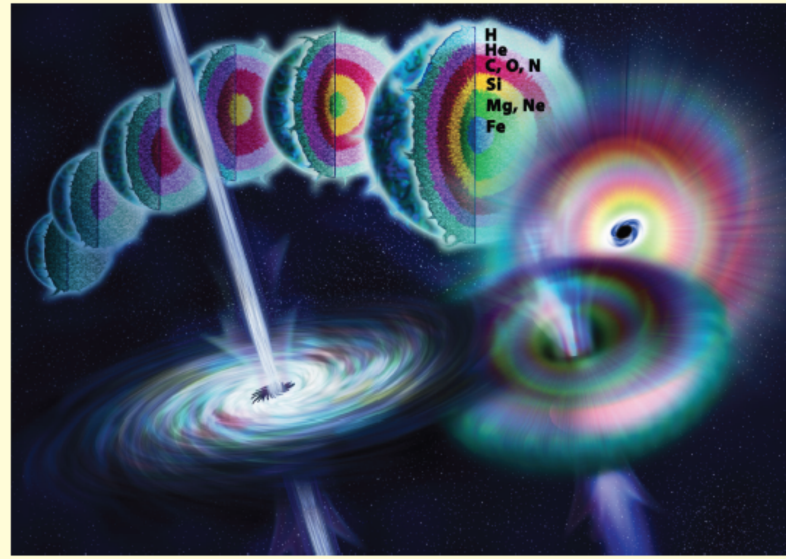
  Incremental, but still something to mention in the science case
- looking into Blazar flares





GRBs





Breakthrough science:

- prompt emission down to 2 keV with WFM

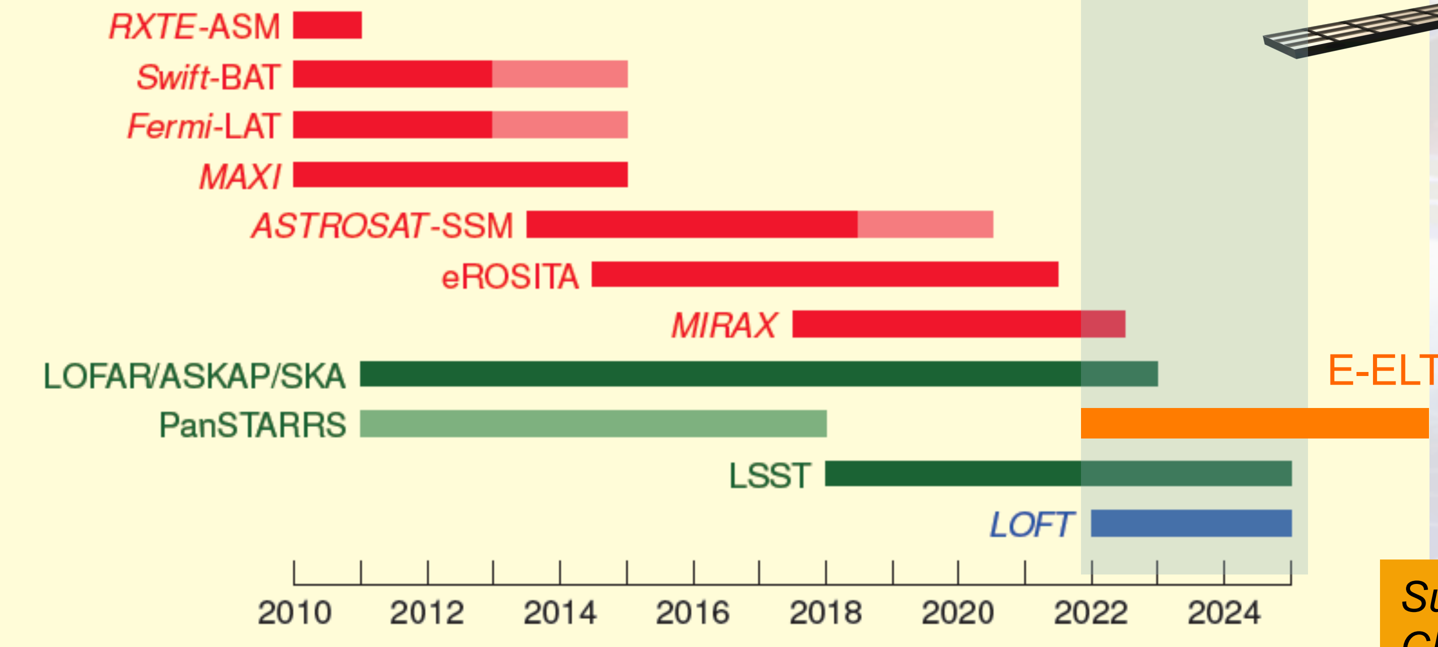
  incl. spectral evolution, N_{H} evolution, very high z GRBs [pop III stars!]; the lower the WFM threshold the better, the higher the energy resolution of the WFM the better!

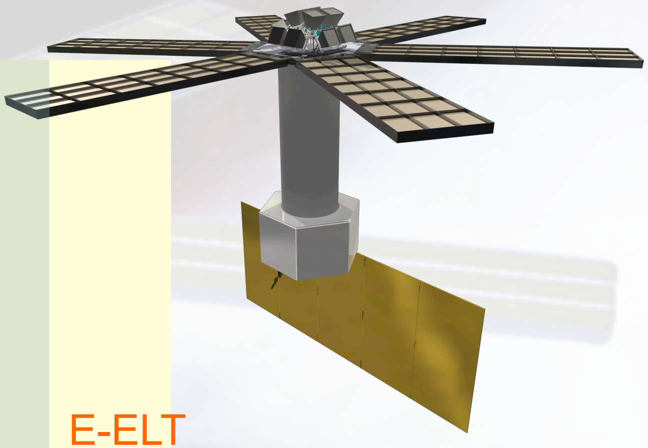
- early afterglow emission with LAD

  plateau phase, emission lines from metal enriched environment

crucial items: GRB alert capabilities, TOO reaction time

LOFT and Multi-λ Synergies





Suzaku, XMM-Newton, Chandra, NuStar, NICER, Astrosat, ASTRO-H,

- Gamma-rays: none in 2020s, *Fermi* follow-up
- VHE Gamma-rays: CTA direct synergy
- X-rays: *Chandra, XMM-Newton, Suzaku* follow-up
- Radio: SKA, LOFAR, direct synergy
- Optical/Infrared: 8m telescopes, ELTs, LSST, direct synergy
- Gravitational Wave: LIGO and Virgo, direct synergy

Talks in Fourth Session

Poster on LOFT and LT2

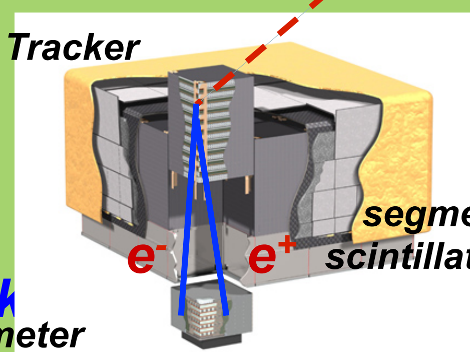
The *Fermi* Gamma-ray Space Telescope

- PI: Peter Michelson (Stanford University), 2011 Rossi Prize of the AAS High-Energy division

- Launched on June 11th 2008 from Cape Canaveral. Circular orbit, Low Earth Orbit (LEO) 565 km, 96m period, 25.6° inclination (Atwood et al. 2008).

- Science operations started August 2008.

LAT (Large Area Telescope)
- *3000 kg*
- ***20 MeV - 300 GeV***
- ***≈0.1° positioning***
- *8250 sq deg FOV ~**1/5 of the sk***
- *$\Delta E/E$ ≈0.1@ 200 MeV*

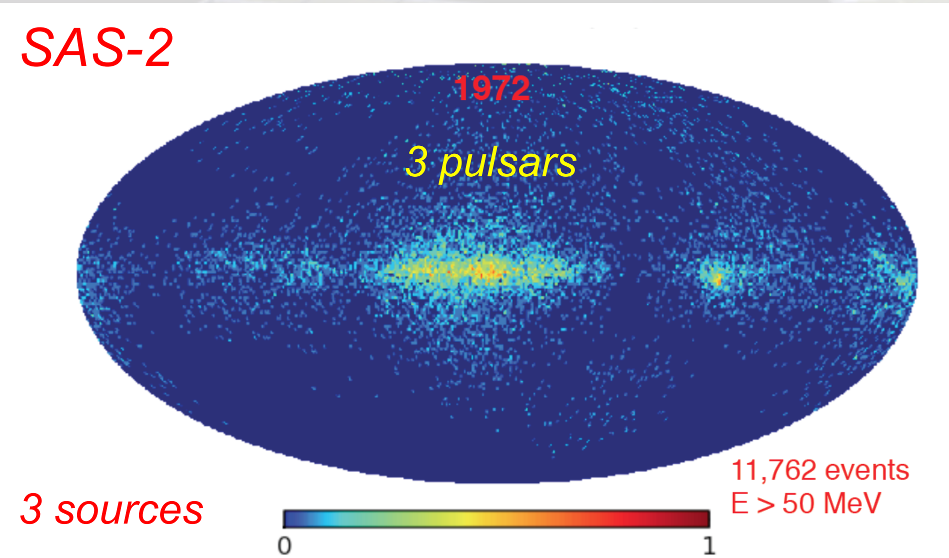


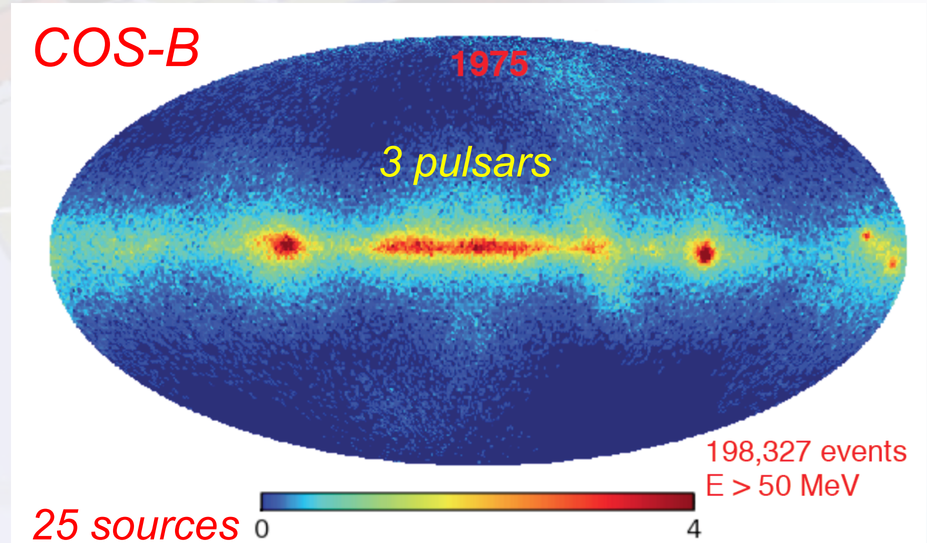
- Largest energy range, sensitivity (x50), and highest spatial resolution (x20) than any other γ-ray satellite ever

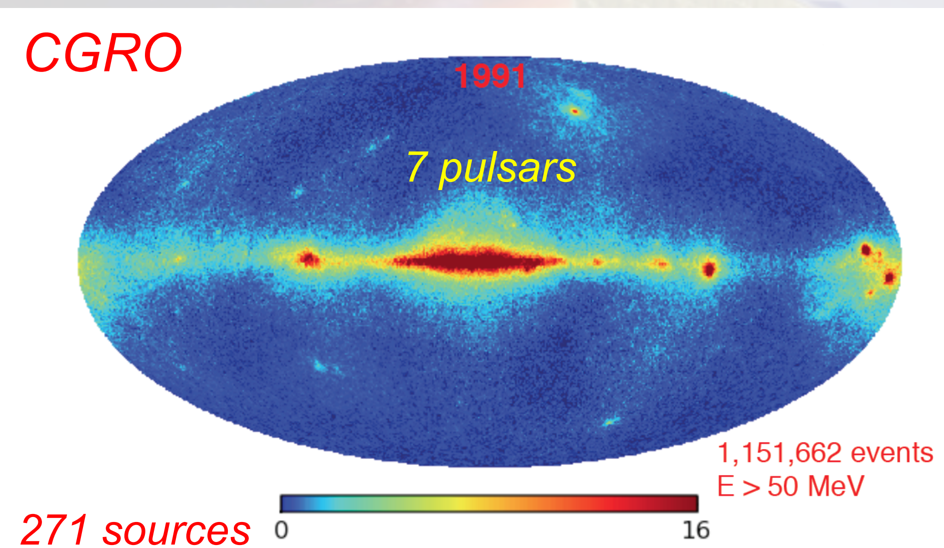
- All LAT observations in **survey mode. 3 hours/scan**

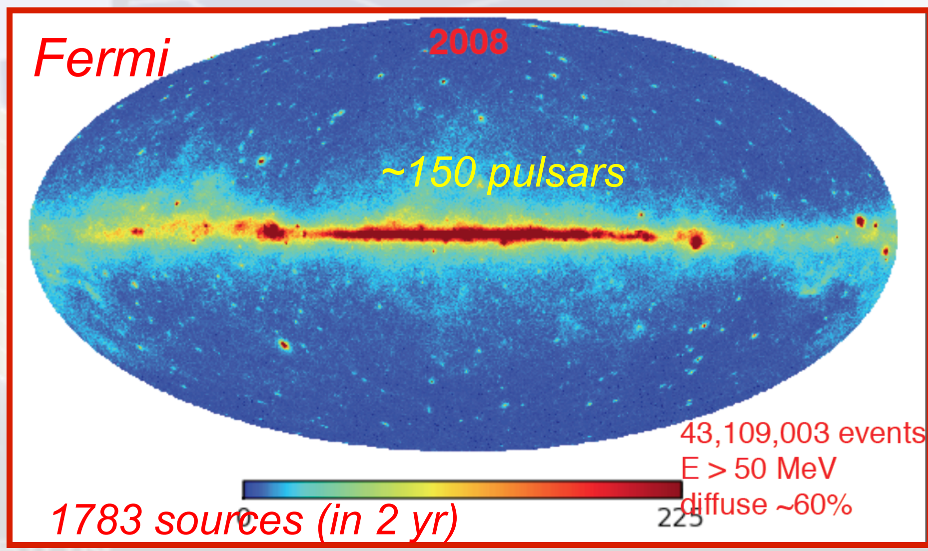
- Mission lifetime at least till 2015 (to be extended)

Pulsar gamma-ray astronomy







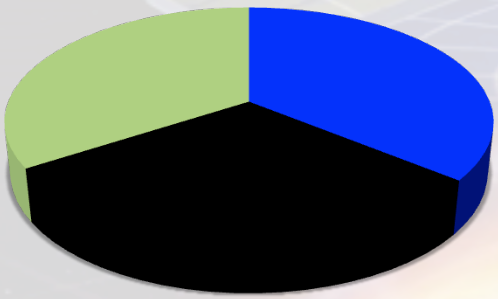


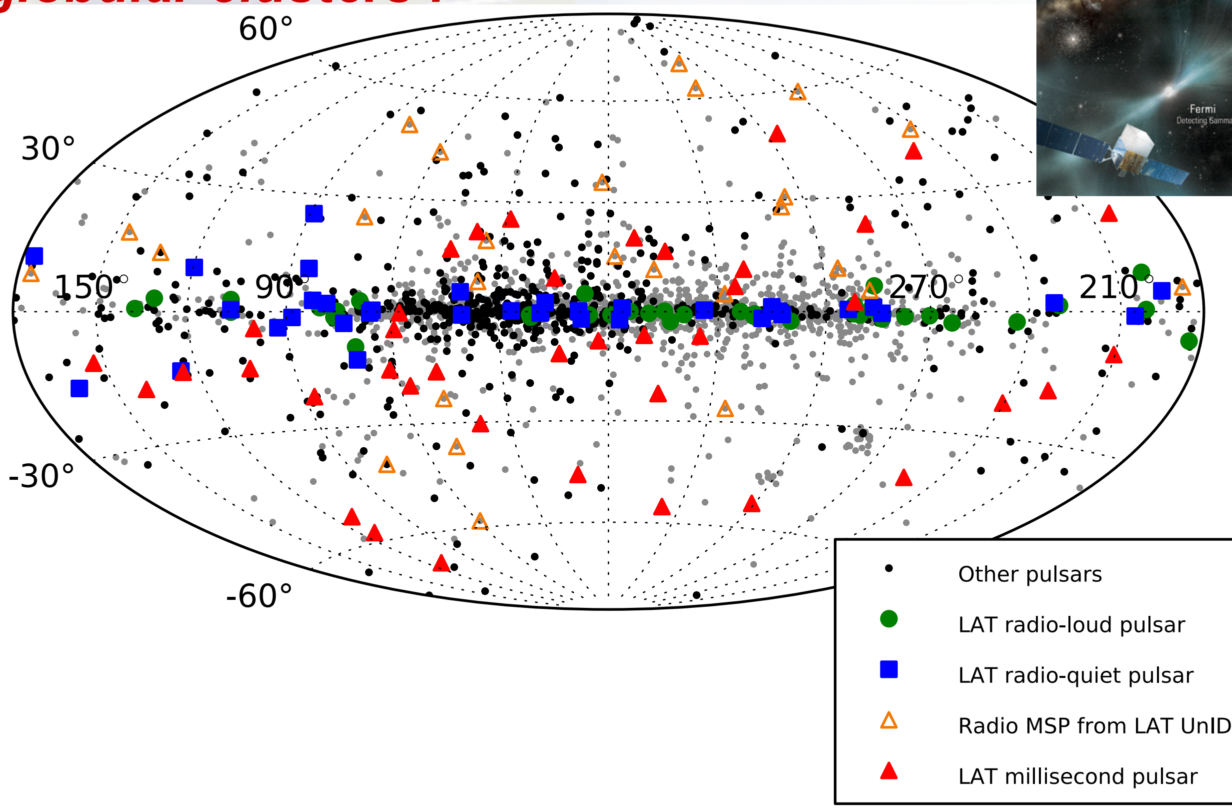
2nd Fermi Pulsar Gamma-ray Catalogue (2PC)

Abdo et al., 2013, ApJ under revision, arXiv:1305.4385

http://fermi.gsfc.nasa.gov/ssc/data/access/lat/2nd_PSR_catalog/

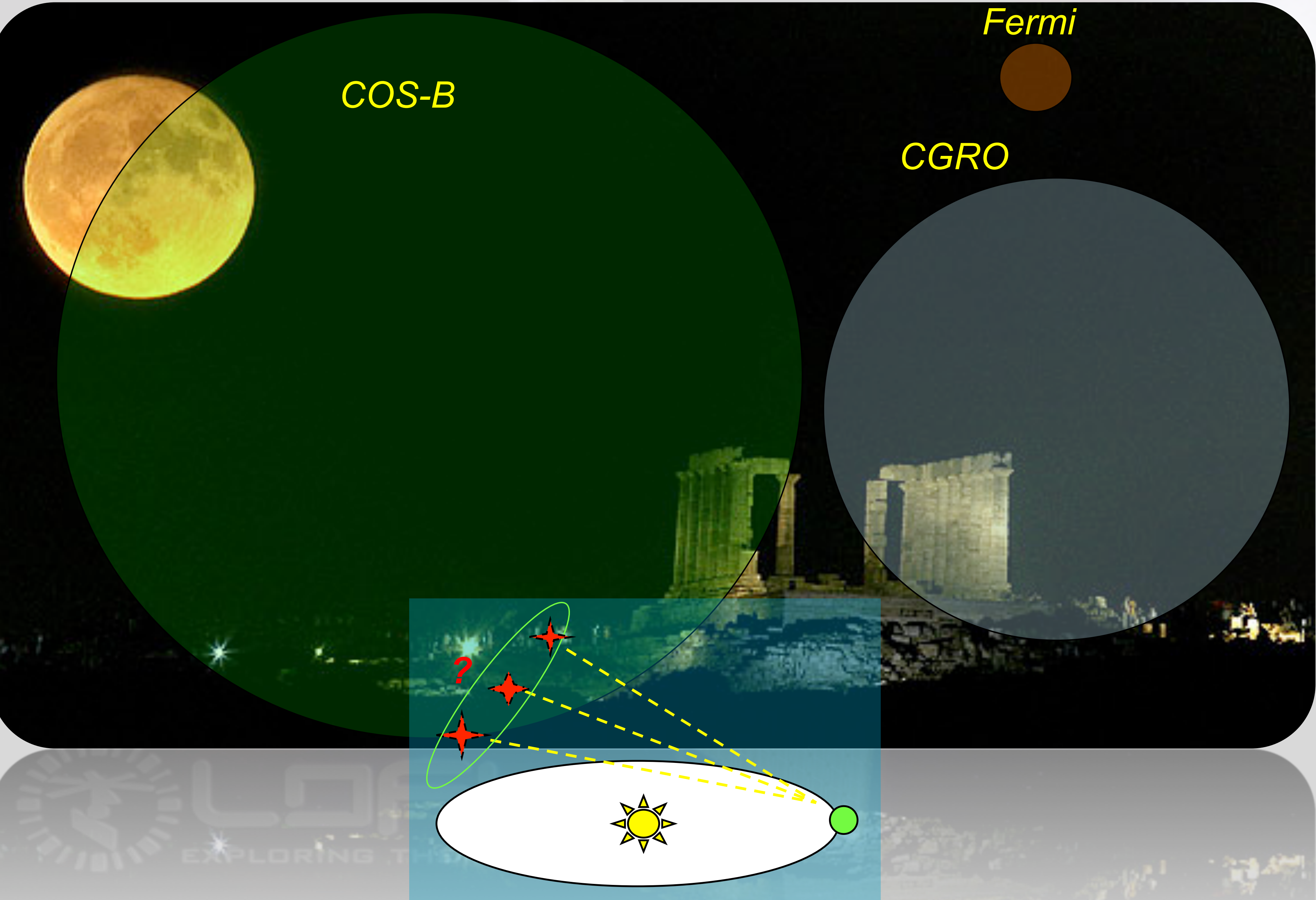
- ***First discovered γ-ray ms-pulsars !***
- ***First γ-ray pulsars in globular clusters !***





117 pulsars(*)
77 young
42 radio-loud
35 radio-quiet
40 millisecond
20 known before Fermi
20 discovered in LAT sources

(*) +28 found while 2PC was almost complete



Fermi
COS-B
CGRO
?

LOFT/LAD and the unidentified Fermi Pulsars

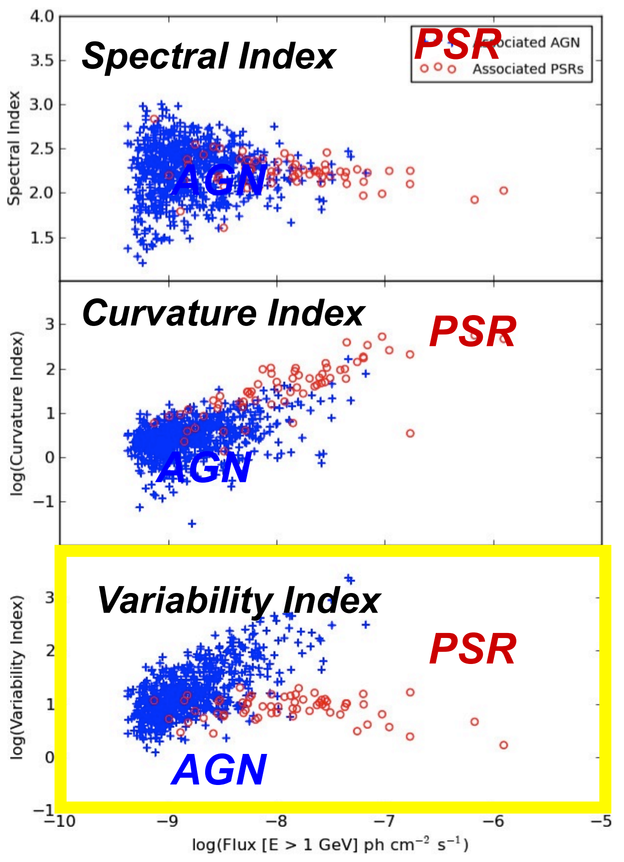
- Not all pulsars can be identified via γ-ray timing

☹ ***1/3** are radio-silent → no radio position, period*

☹ *Several scans needed for fainter sources*

☹ *Difficult to phase-connect multi-epoch scans*

- ~130 pulsar candidates selected from statistical analysis of the γ-ray properties of unidentified *Fermi* sources (Ackermann et al. 2012)



- Candidate X-ray positions from snapshot scans of LAT error boxes (XMM-Newton, CXO, Swift) – γ-ray periodicity search over trial X-ray positions

- Too big time investment for direct X-ray timing of each potential counterpart

- X-ray reference period from LOFT/LAD observations (larger FoV) to be used for direct γ-ray periodicity search and pulsar identification

LOFT/LAD and the unidentified Fermi Pulsars

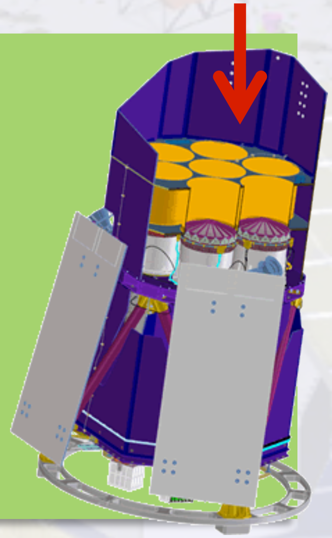
- We simulated the detectability of X-ray pulsations from a LAD source in a **blind search** analysis.
- Single-peak light curve, Lorentzian profile, variable PF and duty cycle, LAD background + Poissonian fluctuations.
- *PL spectrum, Γ=1.5; F_X=2.5 10^{-13} erg cm^{-2} s^{-1} (2-10 keV)*
- *0.001-1.0 s range (2.5 10^{7} test periods) - Rayleigh test.*
- ***PF=0.7** and **duty cycle=10%** pulsations can be detected at the **5σ** in **10 ks**.*
- LAD can study light curve profile for F_X ~2.5 10^{-13} erg cm^{-2} s^{-1}→ **X-ray light curves for 33 of the currently detected X/γ-ray pulsars.**
- LAD can detect X-ray pulsations and measure light for ~10 of the current known **candidate Fermi pulsars** with F_X~2.5 10^{-13} erg cm^{-2} s^{-1}

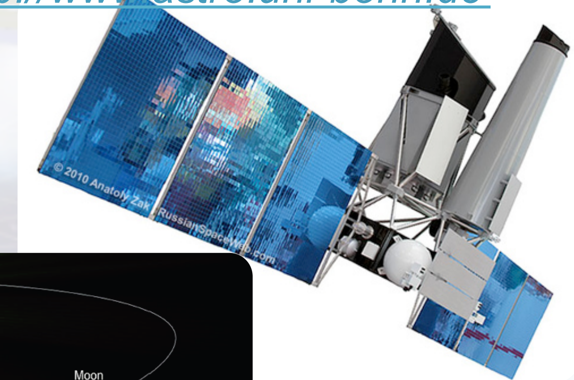
eROSITA

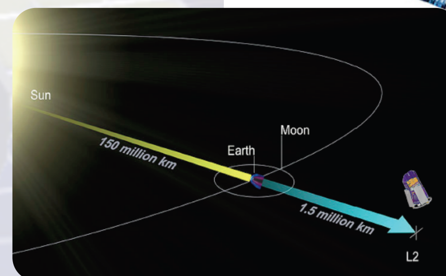
- *eROSITA* is the next Wide Field X-ray Telescope, lead by MPE (Garching). It will fly on the Russian satellite *Spectrum-Roentgen-Gamma (SRG)*

http://www.astro.uni-bonn.de

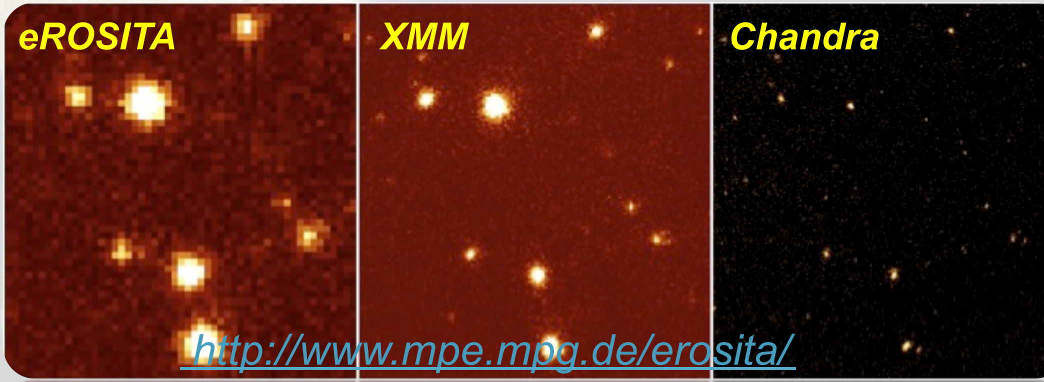
- *7 X-ray telescopes*
- *54 nested Wolter-1 mirrors (36cm)*
- *XMM pn-CCD detectors*
- ***0.5 – 10 keV***
- *Effective area 0.24m^2 @ 1keV*
- *<15" positioning@1kev (on axis)*
- ***1°x1° FOV***
- *$\Delta E/E \approx 1.38$ @ 6 keV*





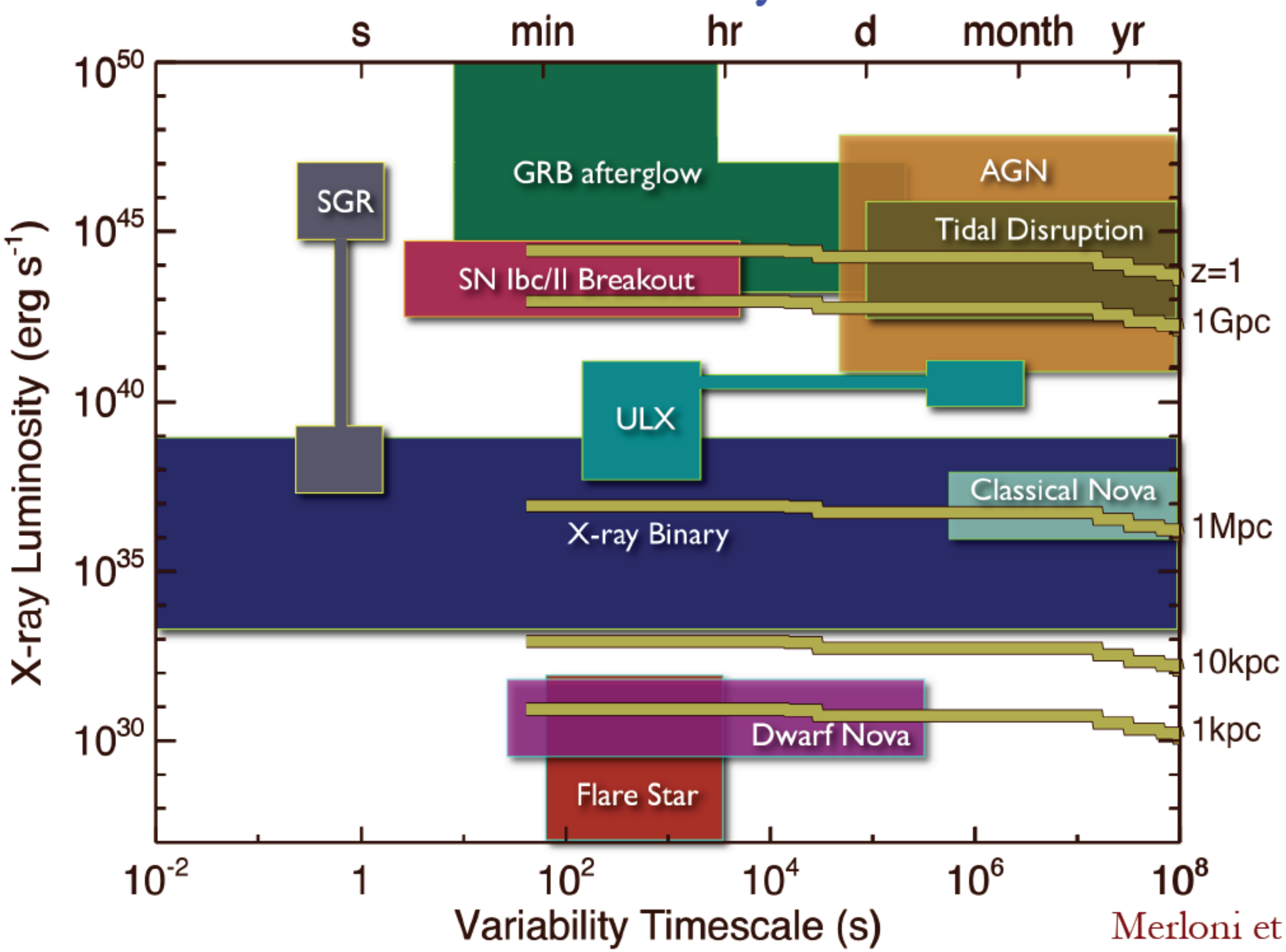


- *SRG* to be launched in 2014 with a Soyus-2 rocket from Baikonur. L2 orbit.
- >7 yr life time, of which **4 yr survey (8 scans)** and 3 yr pointings
- *eROSITA* will perform the first **multi-epoch** 0.5-10 keV all-sky survey with a factor of **30** deeper flux limit than the RASS



http://www.mpe.mpg.de/erosita/

eROSITA sensitivity to variables



Merloni et al. 2012

A. Merloni – Surveys ESO, 10/2012

E-ROSITA

- eROSITA will detect variable/transient X-ray sources over second to year time scales and over the whole sky

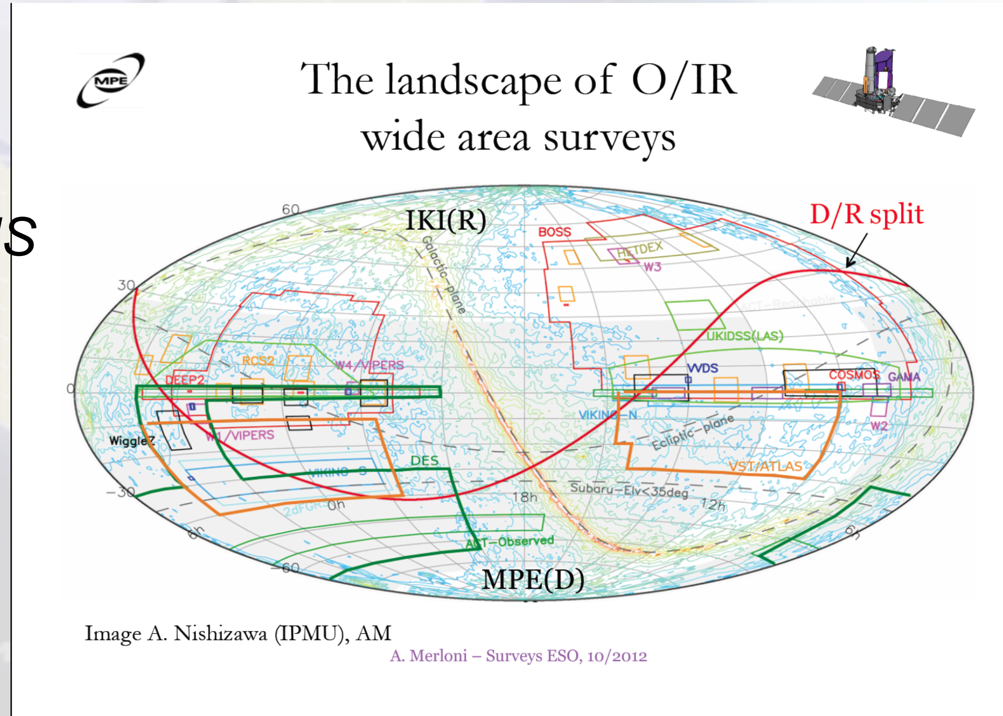
- The WFM will follow up different classes of variable X-ray sources detected by eRosita to monitor their flux evolution on much shorter time scales

- The LAD will follow-up on the many candidate isolated neutron stars discovered by eRosita, selected from their F_x/F_{opt} ratio from running optical/ IR sky surveys

Survey duration	Detections
½ year	43
1 year	55
1 ½ year	66
2 years	72
2 ½ years	82
3 years	90
3 ½ years	93
4 years	~100

Expected INS detection rate

Courtesy: W. Becker



Summary and Conclusions

- LOFT is a key facility for a number of multi-wavelength(messenger) studies in the time domain
- Core Science (SG and DM) is the major driver beyond LOFT, but there is a good balance with Observatory Science. Important! LOFT must not be perceived as a niche mission.
- OS expands the science goals of the LOFT mission
- OS attracts more and more interest from a wider and wider community
- There is a large variety of OS cases (pulsars, XRBs, magnetars, AGN, transients, stars, GRBs, novae, ..) to study a variety of sources/phenomena
- BTW, did we miss something? Good issue for the open discussion
- OS highlights good synergies between LAD and WFM. WFM is a crucial pathfinder to LAD (e.g. discovery of transients)
- OS naturally interfaces LOFT with other facilities, both for follow-ups (Fermi, e-ROSITA) and simultaneous observations (CTA, SKA, LSST, E-ELT)