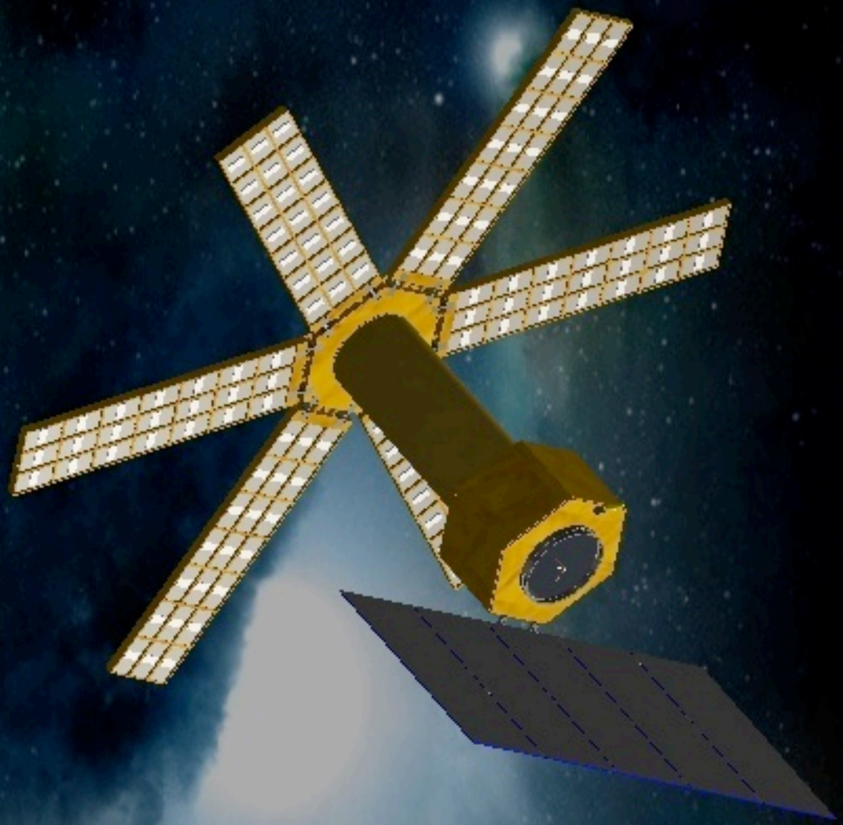
LOFT
Large Observatory For x-ray Timing

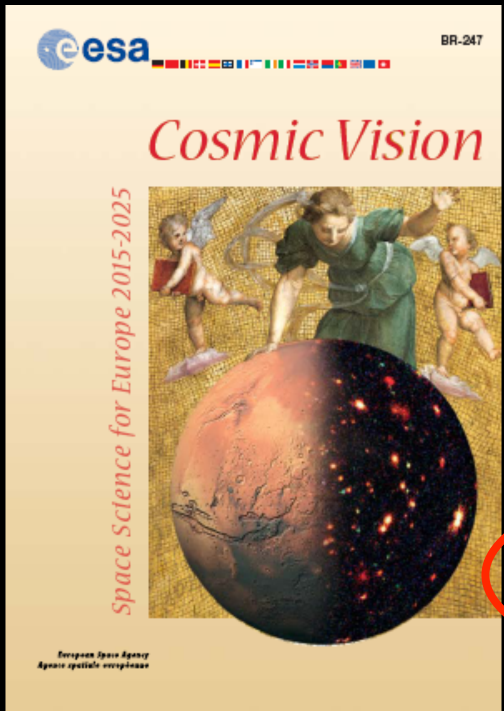


LOFT is mission proposal selected by ESA as a candidate Cosmic Vision M3 mission

LOFT is mainly devoted to X-ray timing and designed to investigate space-time around collapsed objects and the properties of matter at supernuclear densities

Luigi Stella (INAF-OAR)
on behalf of the LOFT Consortium

LOFT will address Fundamental Question 3.3 “Matter under extreme conditions” in ESA’s Cosmic Vision program



3. What are the fundamental physical laws of the Universe?

3.1 Explore the limits of contemporary physics

Use stable and weightless environment of space to search for tiny deviations from the standard model of fundamental interactions

3.2 The gravitational wave Universe

Make a key step toward detecting the gravitational radiation background generated at the Big Bang

3.3 Matter under extreme conditions

Probe gravity theory in the very strong field environment of black holes and other compact objects, and the state of matter at supra-nuclear energies in neutron stars

ESA Cosmic Vision Theme: Matter under extreme conditions

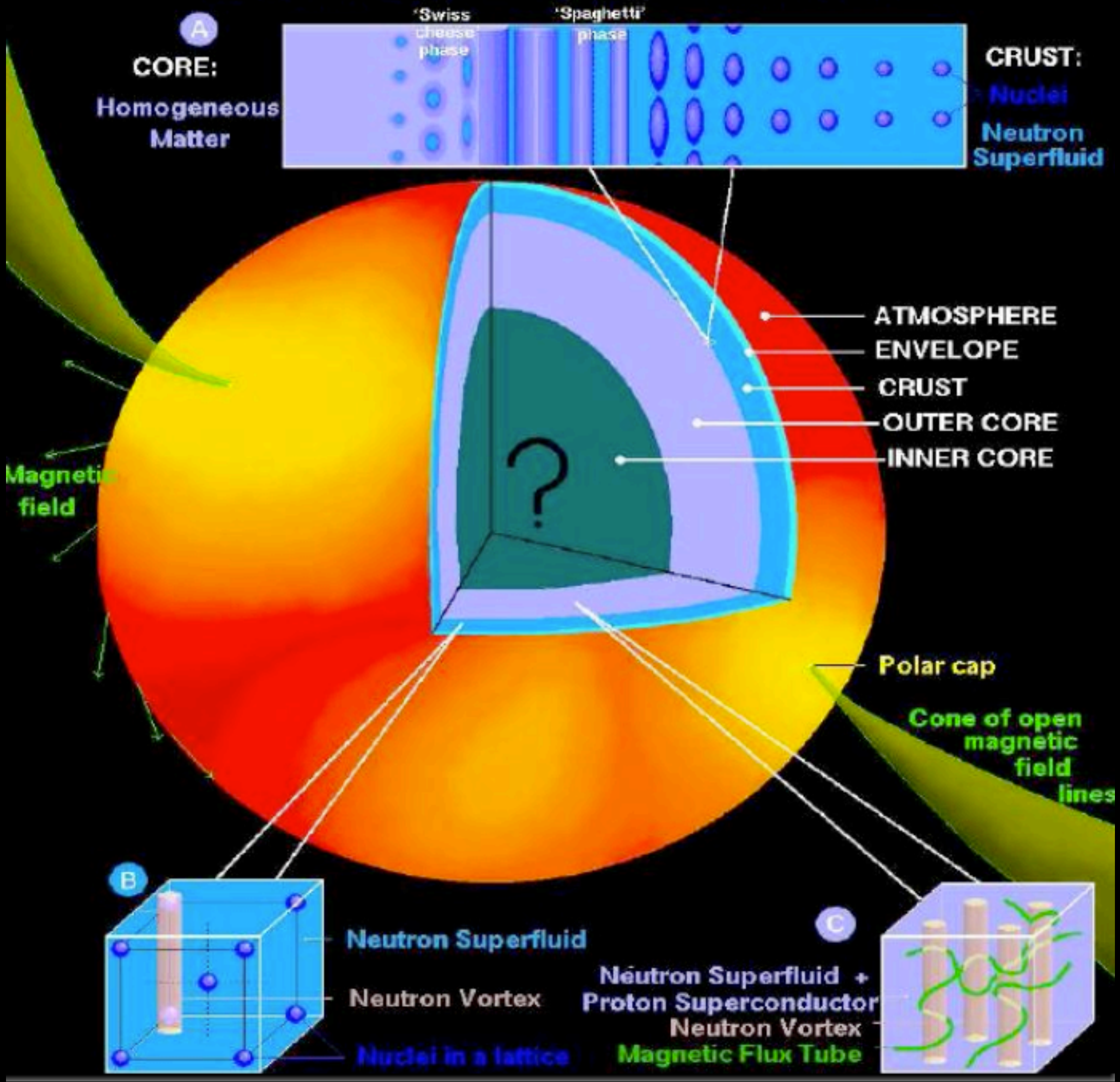
Strong Gravity

- Does matter orbiting close to a Black Hole event horizon follow the predictions of General Relativity?

Dense Matter

- What is the Equation of State of matter in Neutron Stars?

Dense Matter Diagnostic:
Neutron star structure and equation of state (EOS)



QCD Phase Diagram

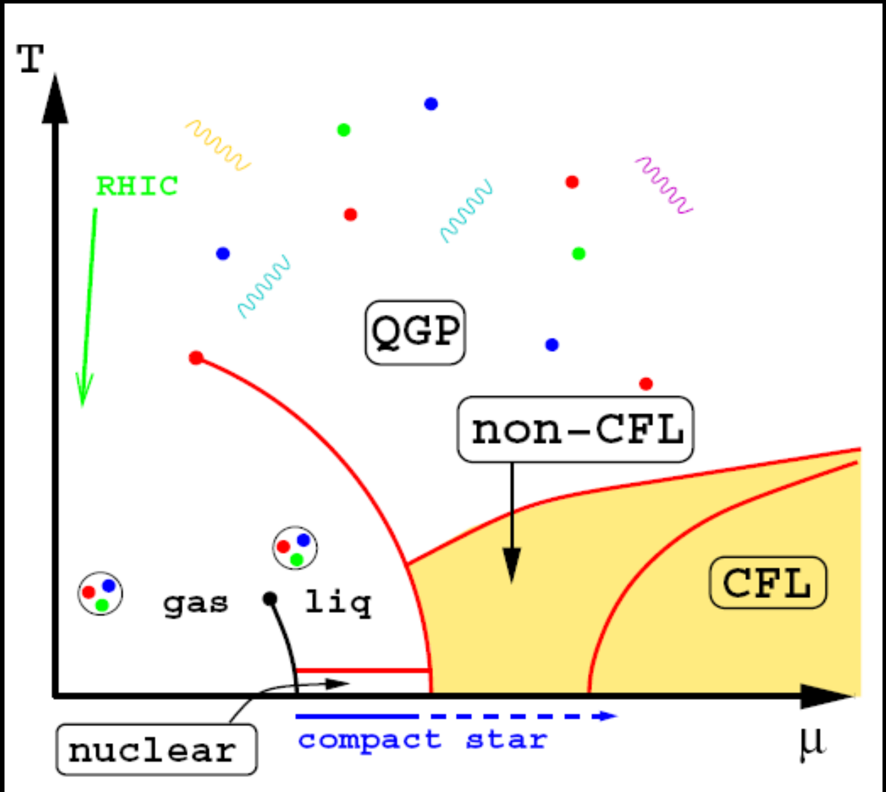
- Little known on the properties of bulk matter at supernuclear densities

- Color Flavor Locked (CFL) phase expected asymptotically (high mu)

- Quark Gluon Phase at high T and mu

- Gas and liquid phases of nuclei at low mu

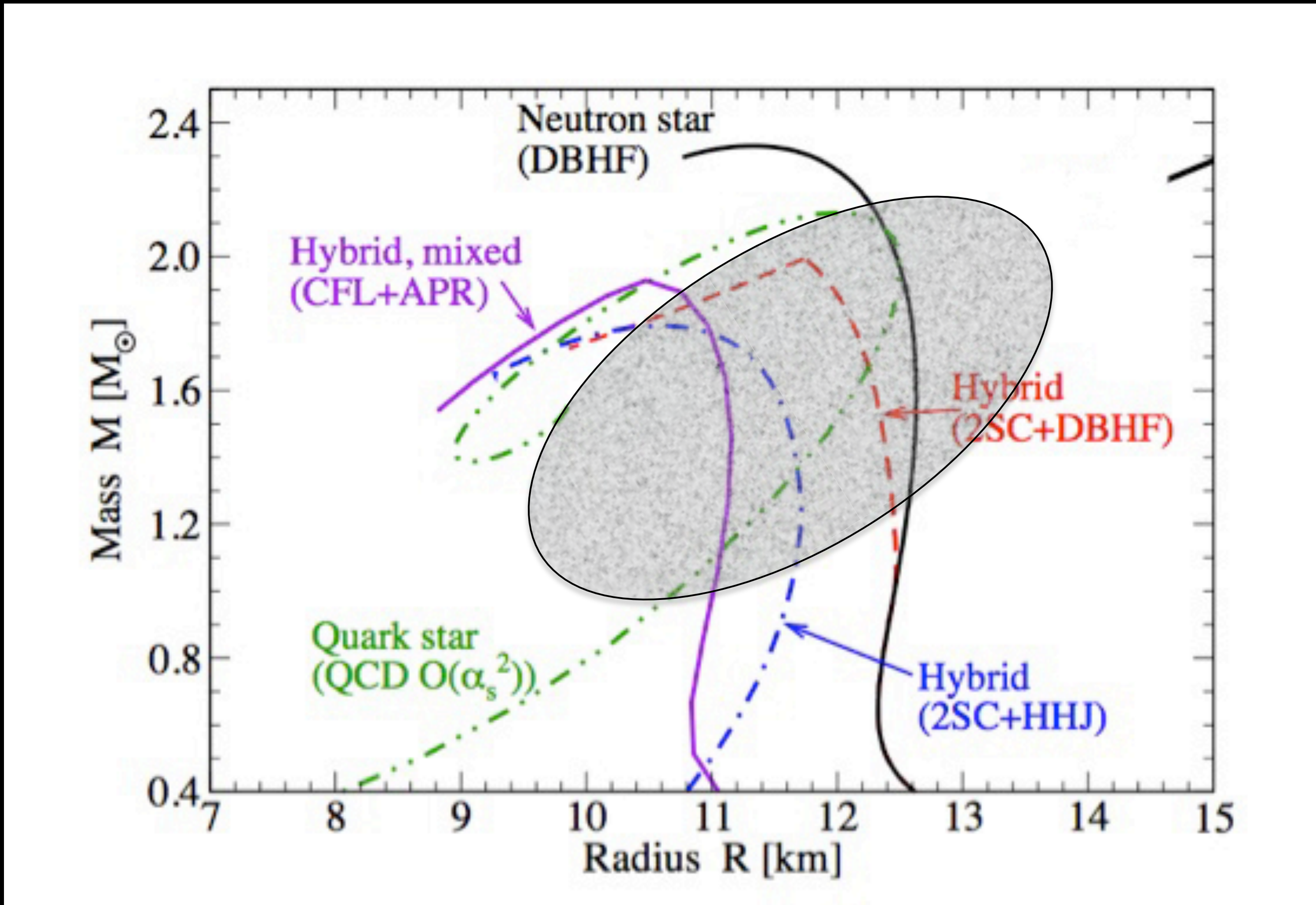
- Normal Quark phase or other exotic Phases in between (e.g. two-flavor color superconducting phase(2SC), gapless 2SC phase)



Heavy ion collision experiment sample only the high-energy regime (> 100 GeV/nucleon, i.e. high T in the diagram)

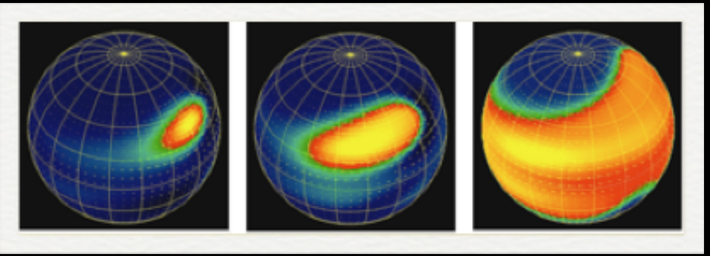
Low energy regime can only be studied through compact stars

Mass Radius Relation for Collapsed Stars



(Schaffner Bielich 2007)

Pulse Shape Modelling and Fitting in Fast Spinning Accreting Neutron Stars



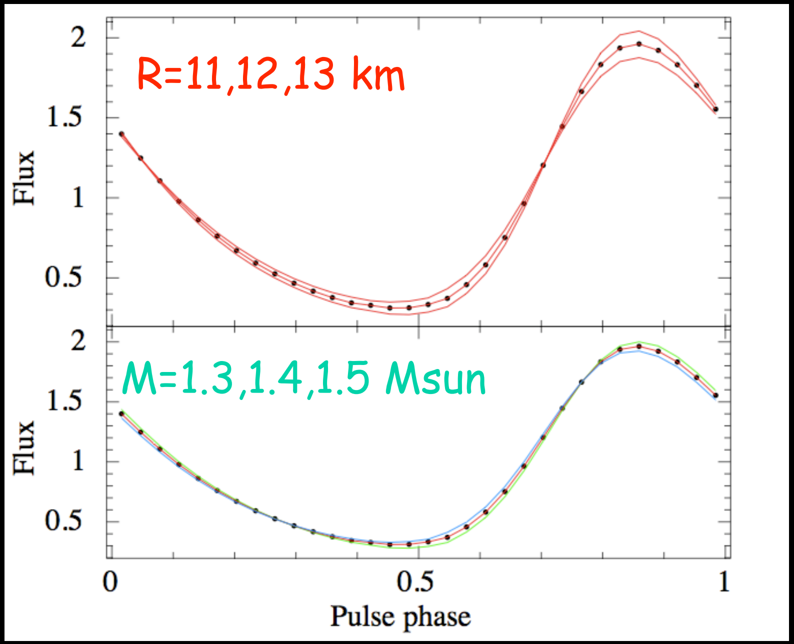
- X-ray signal produced by hot spots on the surface of fast rotating neutron stars (magnetic pole or propagating burning front).

- Modeling of the pulses (shape, energy dependence) taking into account Doppler boosting, time dilation, gravitational light bending and frame dragging

-> M and R of the NS.

<u>LOFT simulation: SAX J1808.4-3658</u> (401 Hz) pulse profile measurement

Poutanen Gierlinski 2003 Morsink et al 2010

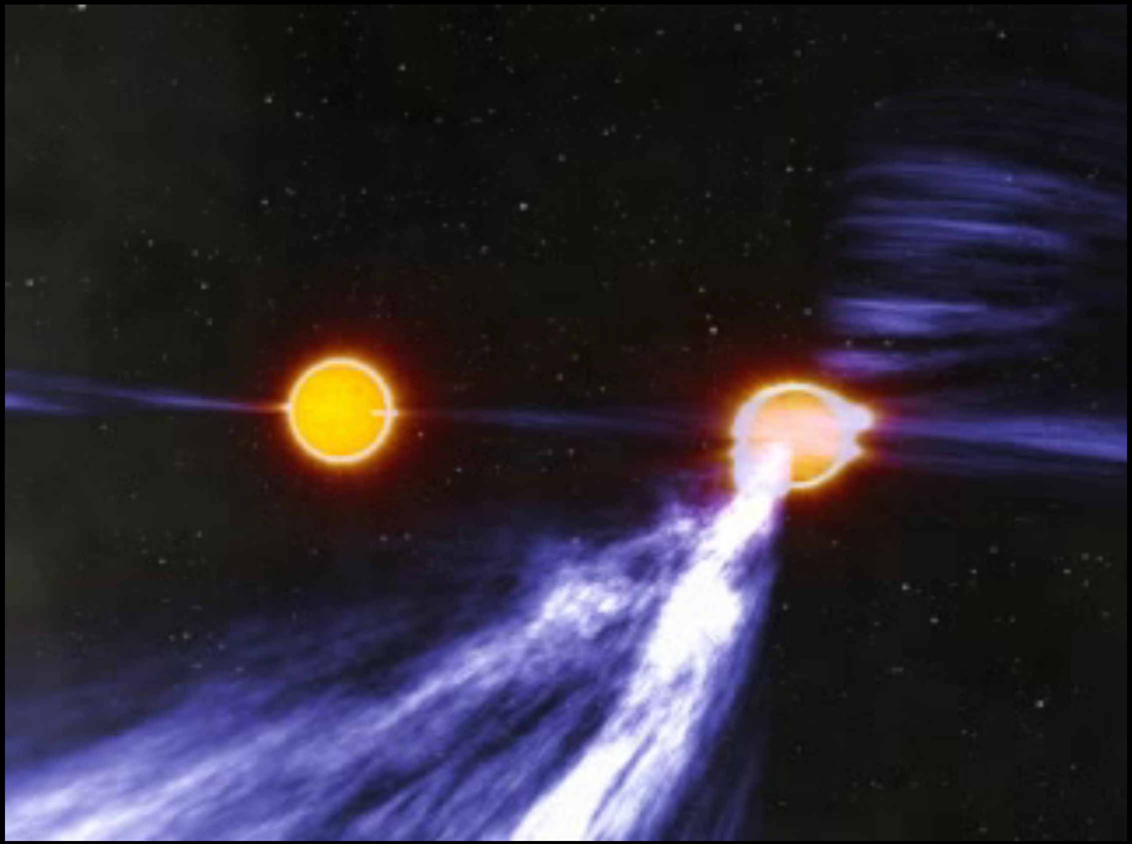


Determine NS
- NS mass: 4% uncertainty
- NS radius: 2-3 % uncertainty

Strong Gravity

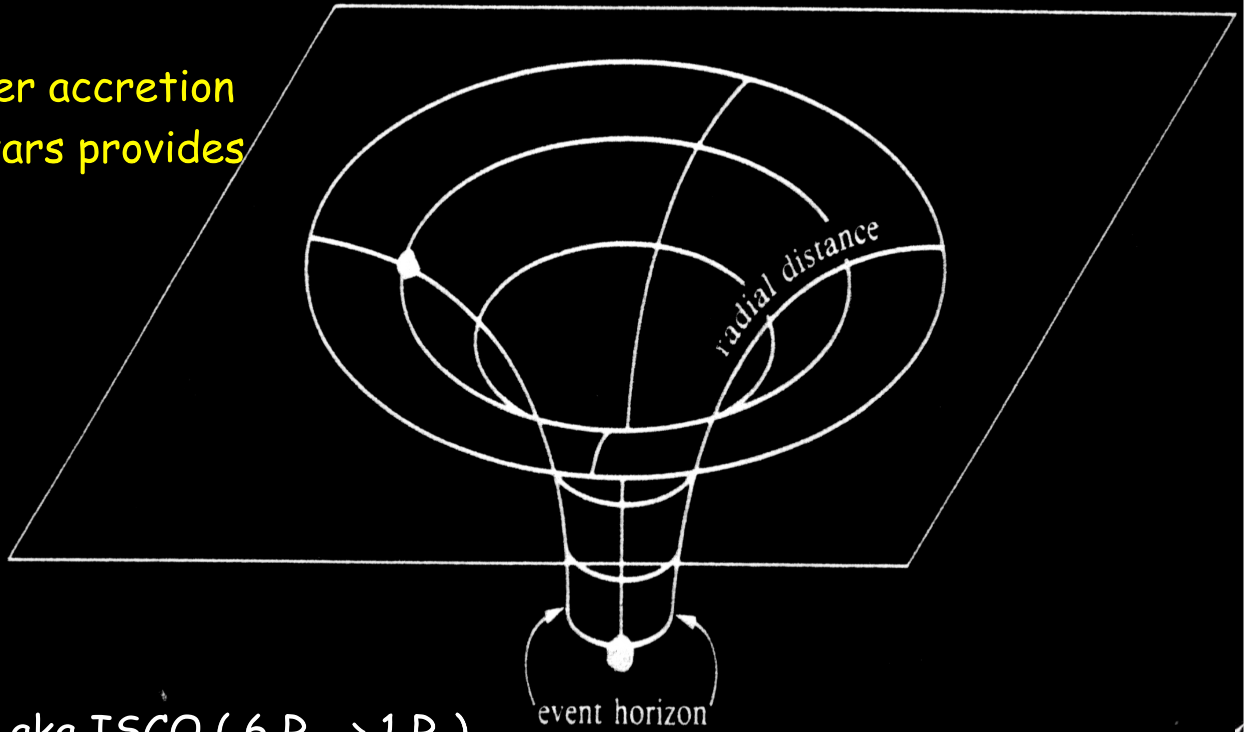
Relativistic binary radio pulsars

- Accurate test of gravity; several GR effects confirmed with very good accuracy
- BUT: direct measurements only at large radii (R~10^6 - 10^7 Schwarzschild radii)

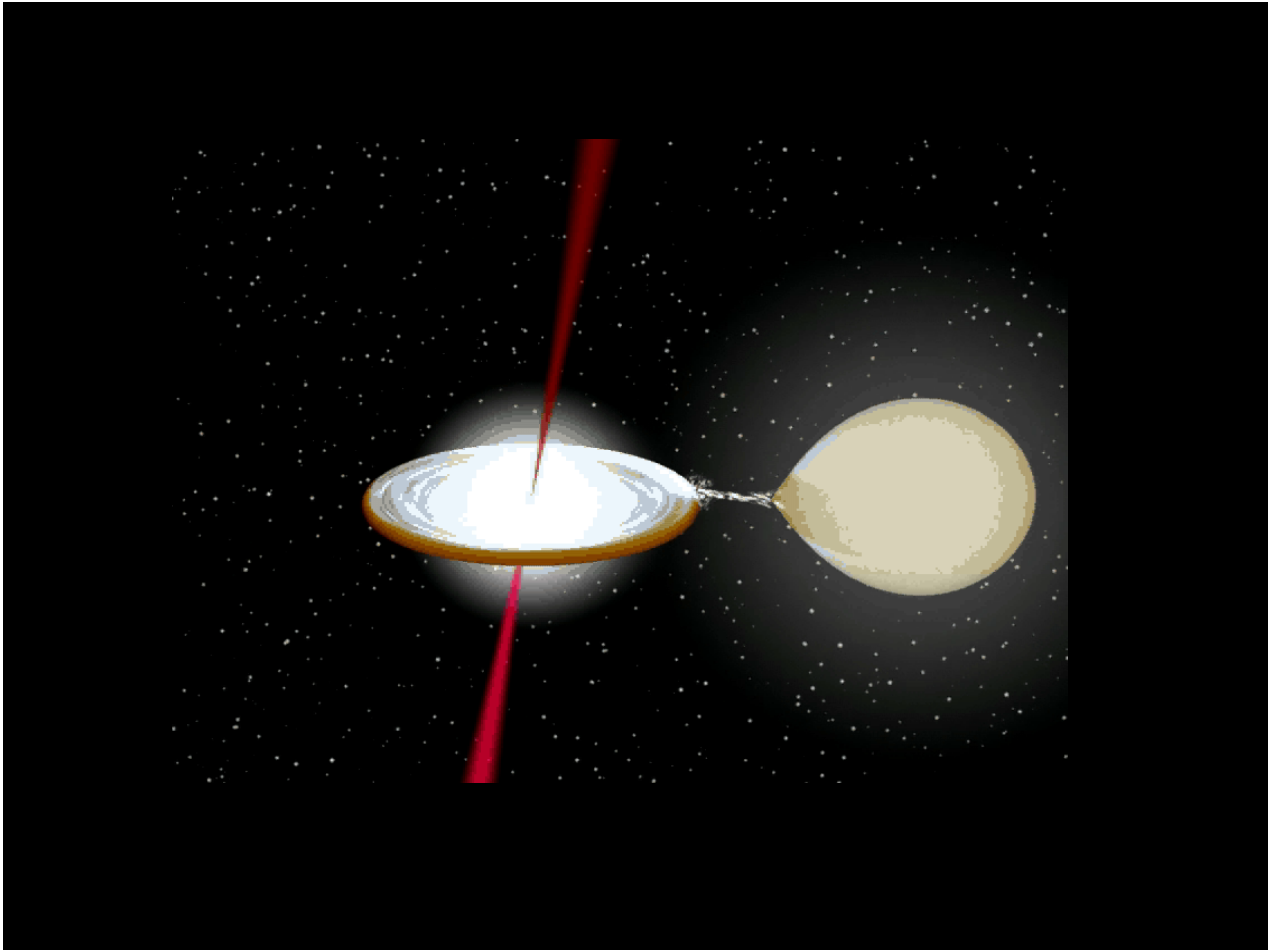


Strong Field Effects

Need to sample Radii close to the horizon ($R_g \sim GM/c^2$): matter accretion into black holes and neutron stars provides the best tool.



- Last Stable Circular orbit, aka ISCO (6 R_g -> 1 R_g)
- Particle motion around ISCO and fundamental frequencies of motion
- Dragging of inertial frame
- Strong field light deflection
- Black hole mass and spin



Strong field diagnostic
Fe-lines from accretion disks

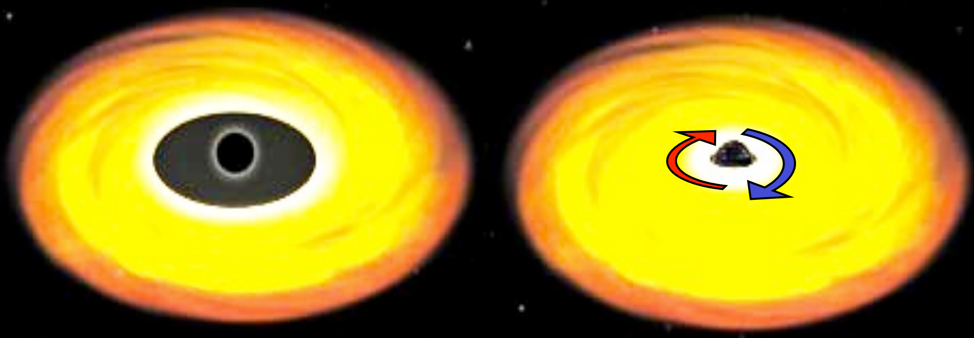
- Strong field relativistic effect: Doppler shifts and boosting, gravitational redshift, strong field lensing

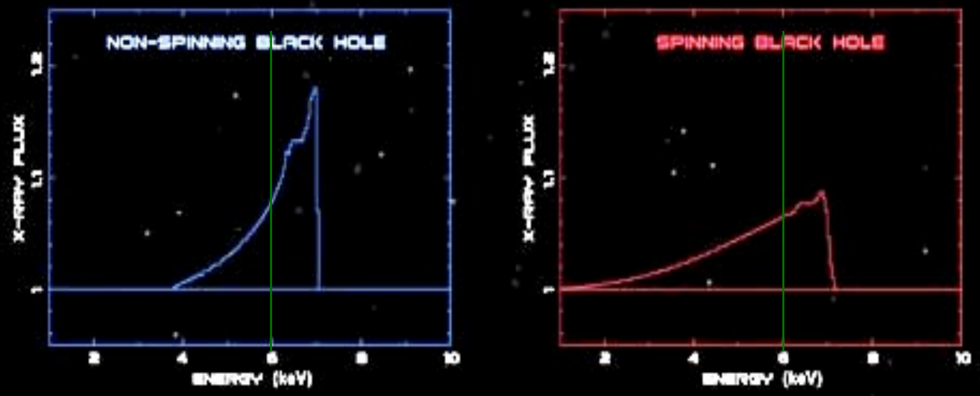
- Observed in manyActive Galactic Nuclei and X-ray binaries

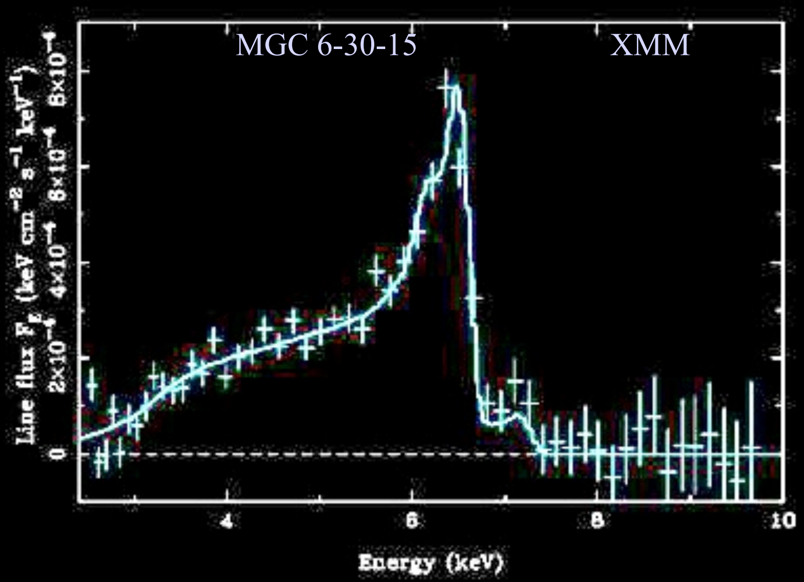
Line profile and time variability
black hole mass and spin

In situ probing of strong field gravity
(~few Rs)

e.g. MCG 6-30-15:
- Kerr BH required to fit line profile

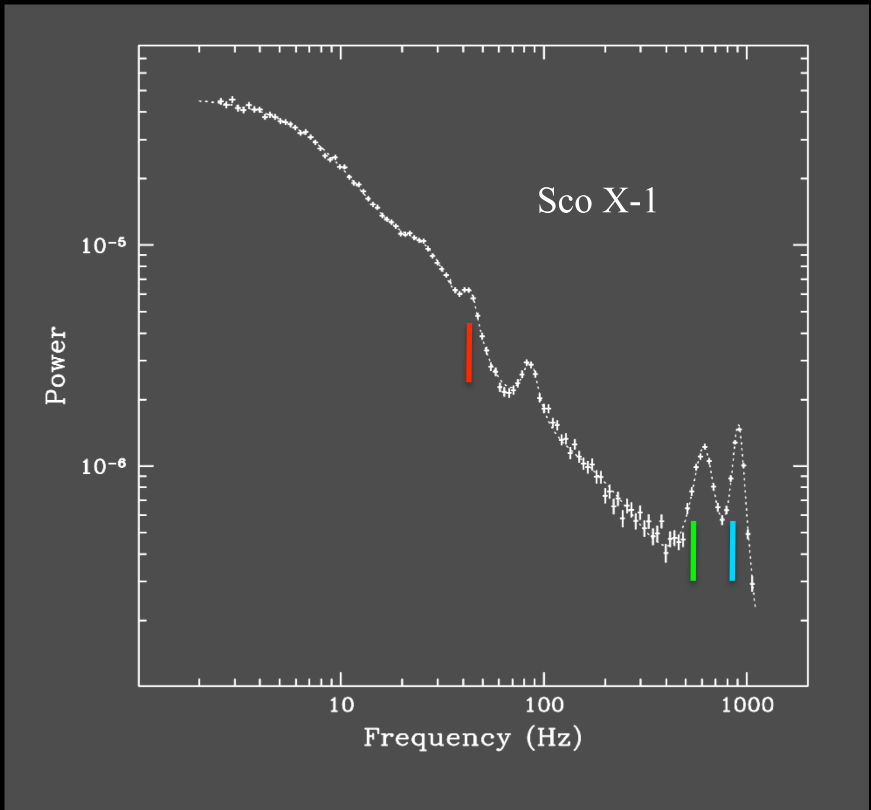




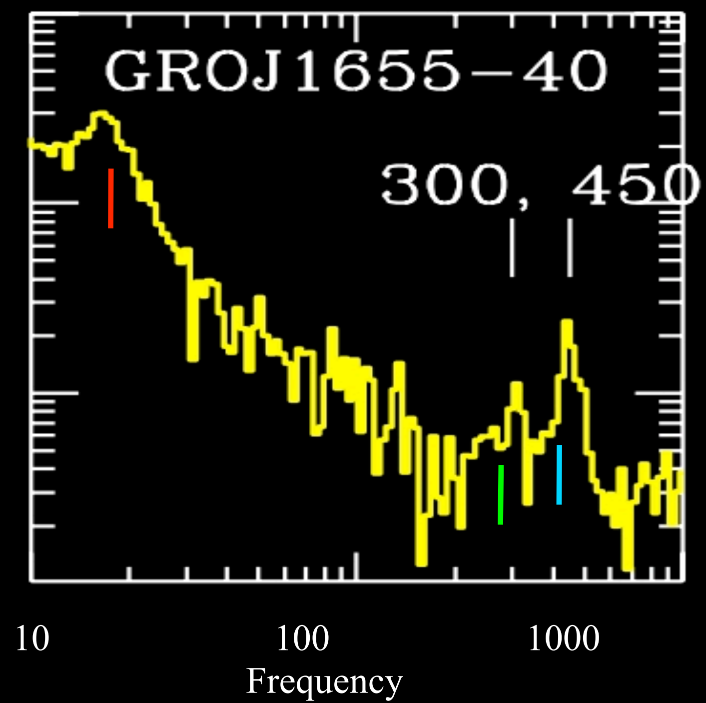


Stong Field Diagnostic: Quasi Periodic Oscillations

Accreting neutron stars



Accreting black hole candidates



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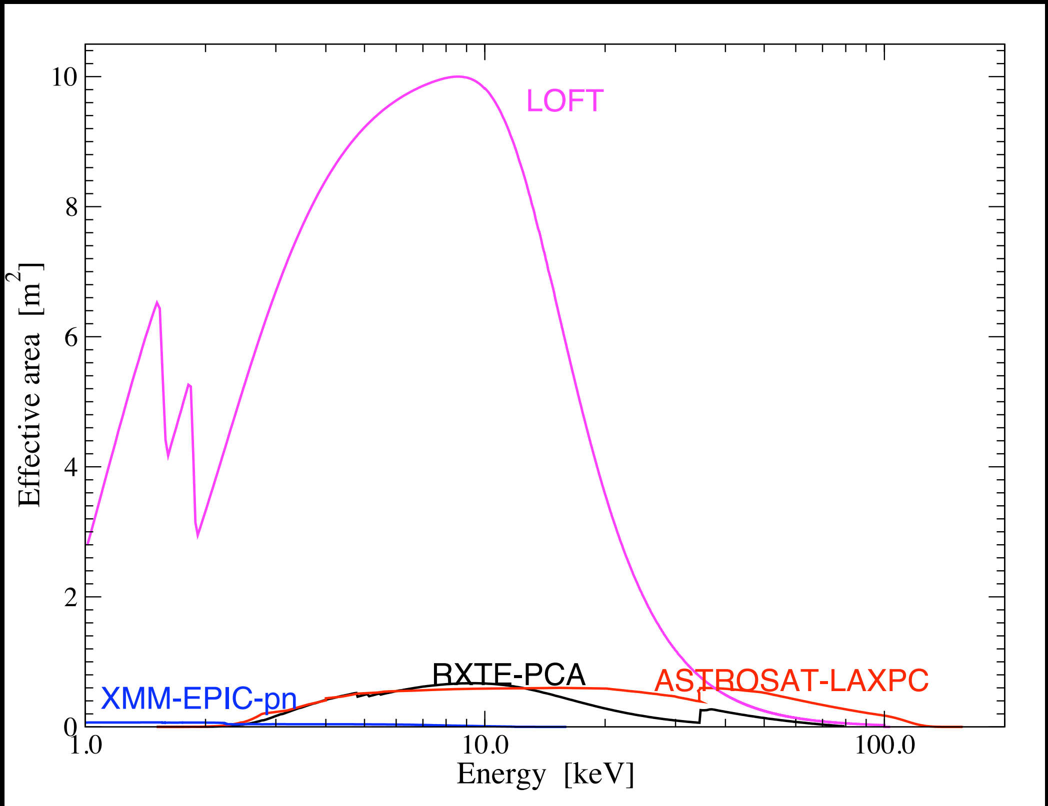
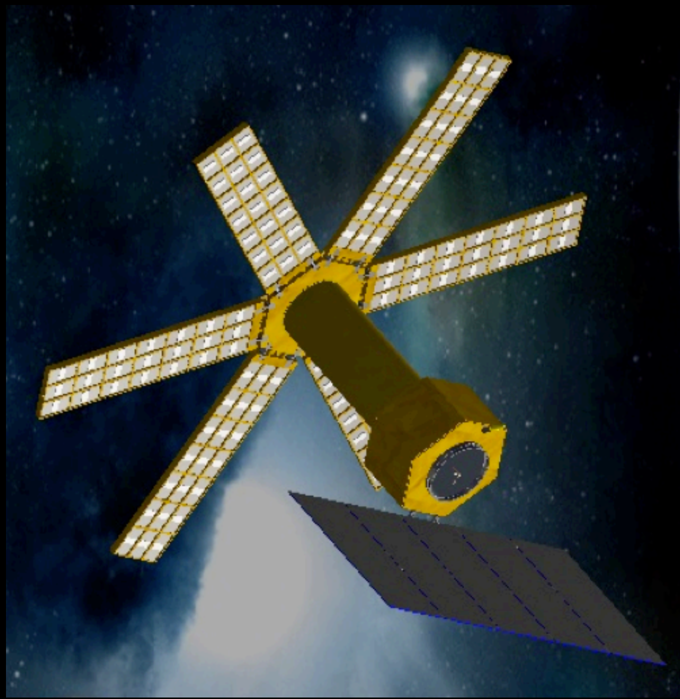




~ 10 m^2 effective area
~ 200 eV energy resolution
- Wide field monitor

(Feroci et al 2010 http://arxiv.org/abs/1008.1009)

Timing with large area instruments: one of the most prominent lines of research in which italian scientists are at the forefront **(see "Feasibility Study in High Energy Astrophysics" 2005 Costa, Perola, Puglierin et, Sect. 5 p.324-325)**

The LOFT Consortium

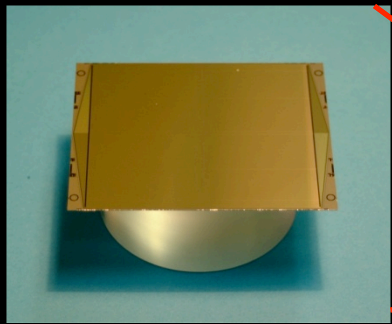
Jan-Willem den Herder	SRON, the Netherlands
Marco Feroci	INAF/IASF-Rome, Italy
Luigi Stella	INAF/OAR-Rome, Italy
Michiel van der Klis	Univ. Amsterdam, the Netherlands
Thierry Courvousier	ISDC, Switzerland
Silvia Zane	MSSL, United Kingdom
Margarita Hernanz	IEEC-CSIC, Spain
Søren Brandt	DTU, Copenhagen, Denmark
Andrea Santangelo	Univ. Tuebingen, Germany
Didier Barret	IRAP, Toulouse, France
Renè Hudec	CTU, Czech Republic
Andrzej Zdziarski	N. Copernicus Astronomical Center, Poland
Juhani Huovelin	Univ. of Helsinki, Finland
Paul Ray	Naval Research Lab, USA
Joao Braga	INPE, Brazil

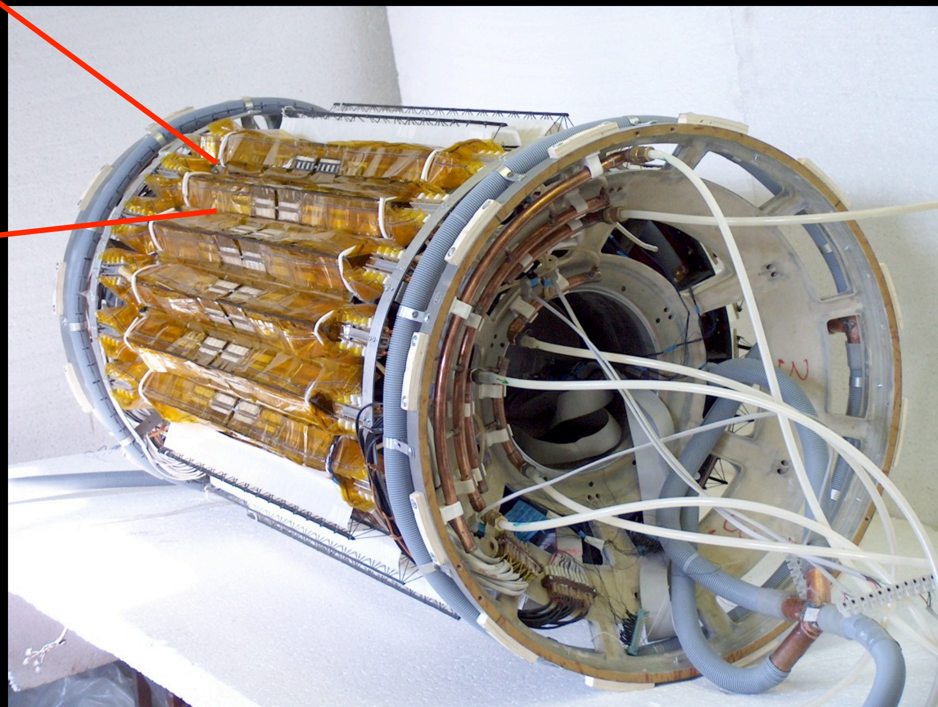
on behalf of more than 250 scientists from:
Brazil, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Japan, the Netherlands, Poland, Spain, Switzerland, Turkey, United Kingdom, USA

Silicon Drift Detectors (SDD)

A heritage of the Inner Tracking System of the ALICE experiment at the Large Hadron Collider (CERN)

INFN Trieste, in collaboration with Canberra Inc., designed, built, tested and calibrated 1.5 m^2 of SDD detectors (approximately 300 units), now operating since ~2 years. High Technical Readiness Level (TRL). Proven mass production.



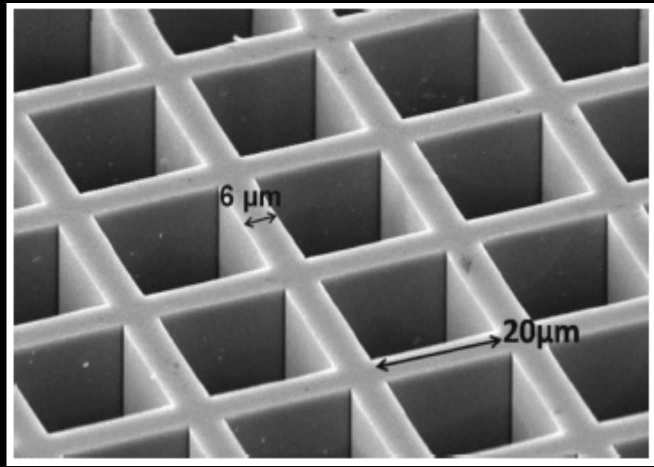


LOFT Baseline

Thickness	450 μm
Monolithic Active Area	76 cm^2
Drift time	<5 μs
Single-channel area	0.3 cm^2

LAD: collimators and panels

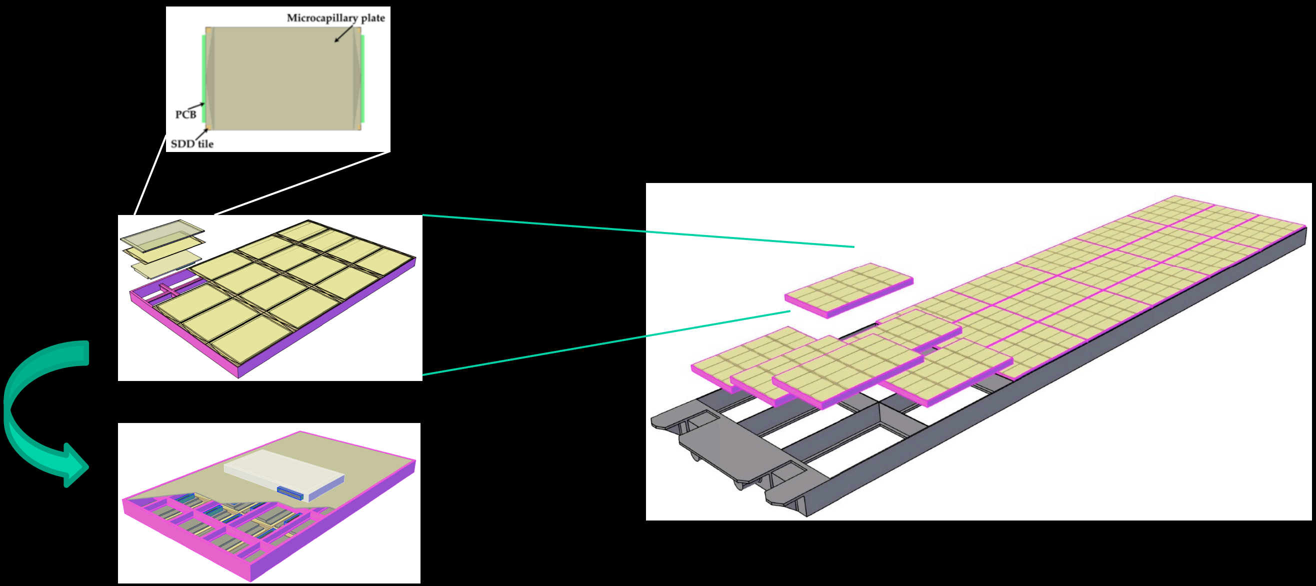
- Capillary plate
- High Pb content glass
- FoV ~40'



126 modules,

6 panels

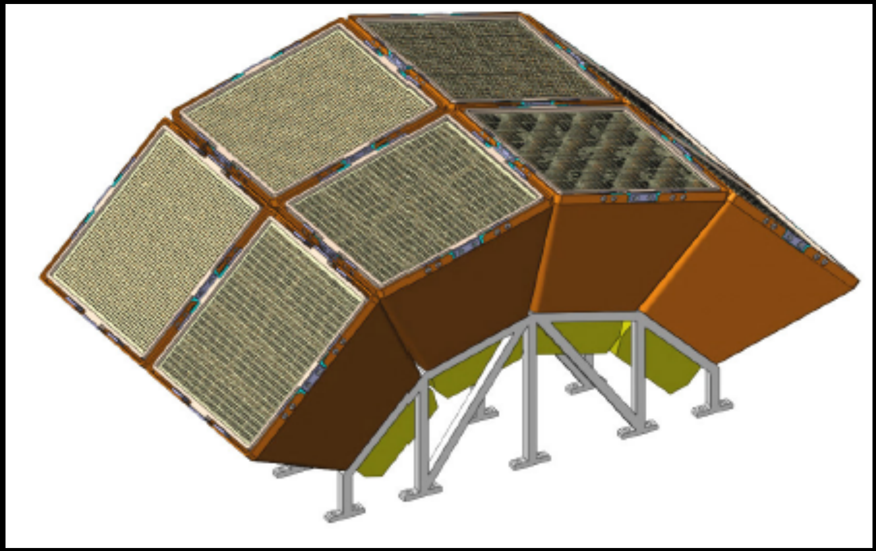
Total panel surface 21 m^2

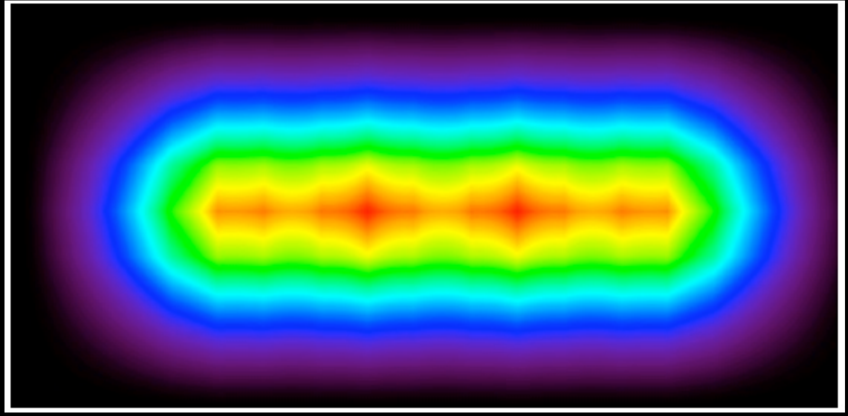


Silicon Drift Detectors 1.5D

Imaging:

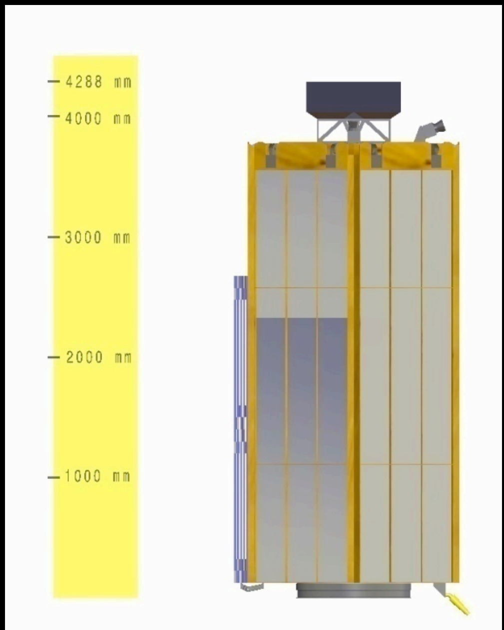
- coded mask
- Elements are 250µmx16mm
- 2 orthogonal projections
- FoV 90° x 90° (zero response)
- Resolution of 1 camera: 5’ x 5°
- Combination of 2 orthogonally oriented cameras gives 5’ x 5’
- 2 cameras form 1 Unit
- Mask also integrates thermal shield/light filter (Kapton/Al/ Si_2O)



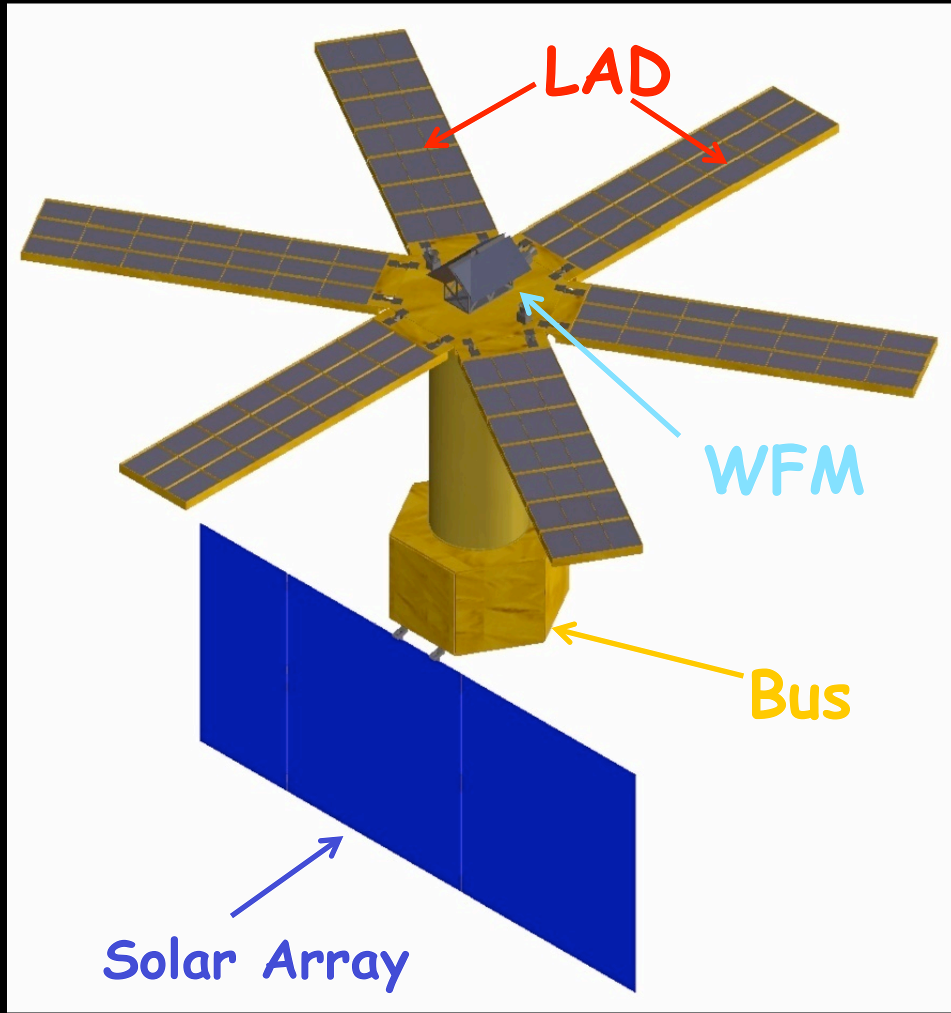


The LOFT satellite

Industrial study by Thales Alenia Space - Italia



folded



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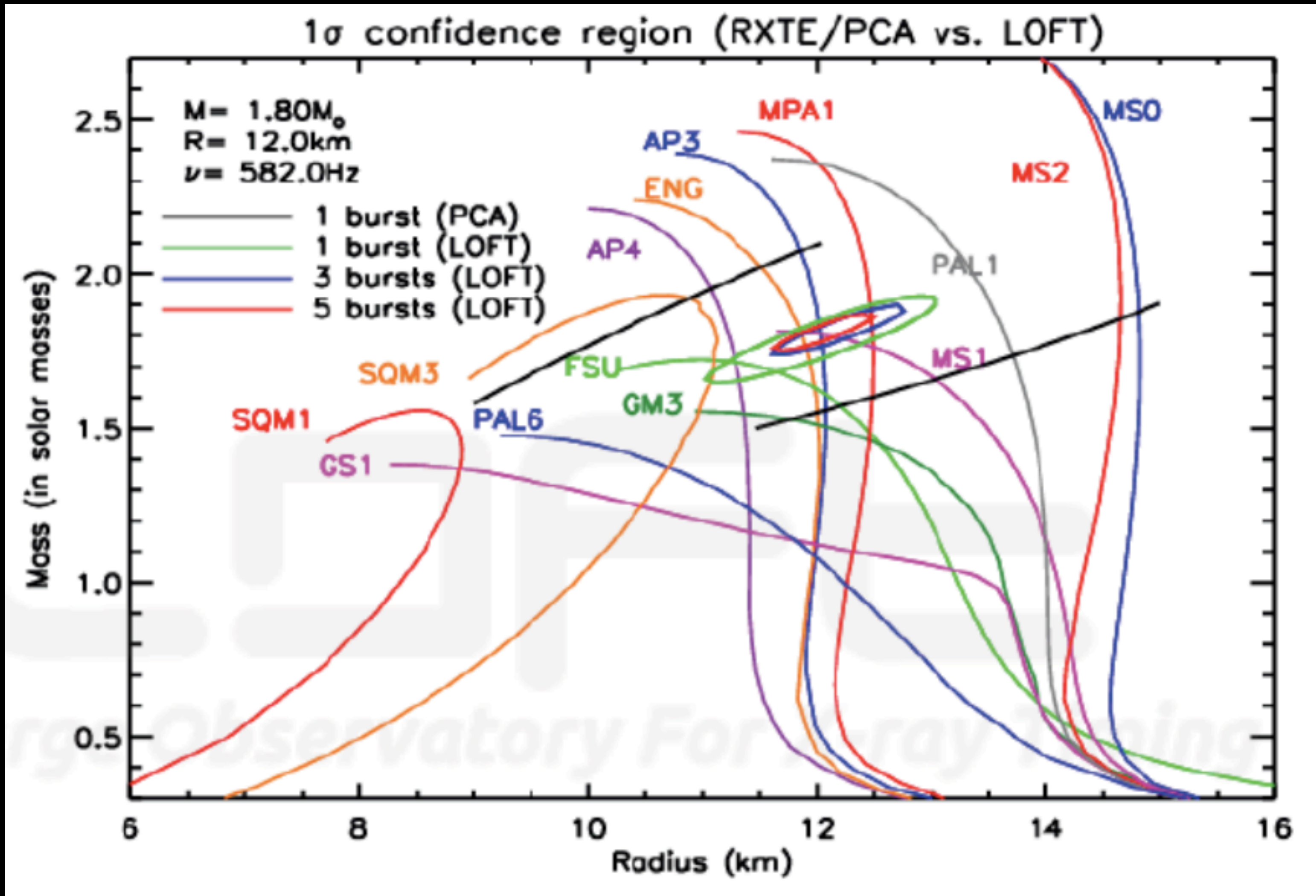
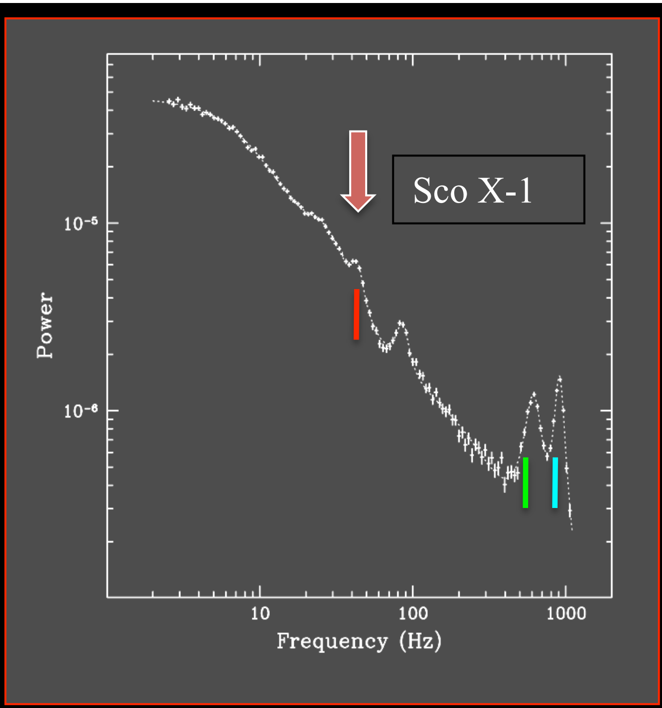


(Watts et al 2012)

Relativistic nodal precession
(from frame dragging)
of the innermost disk regions



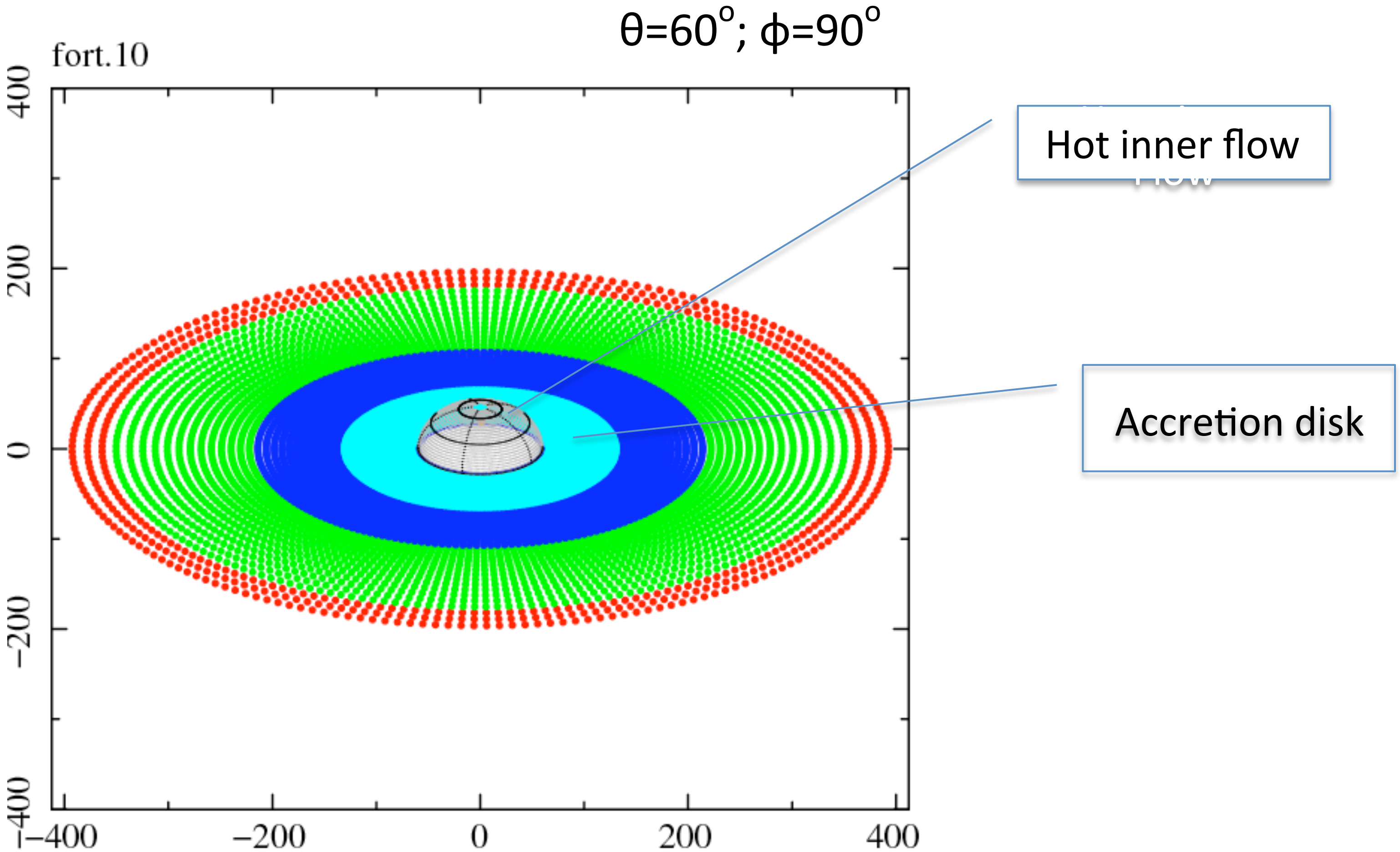
m = 1 HFGM Mode

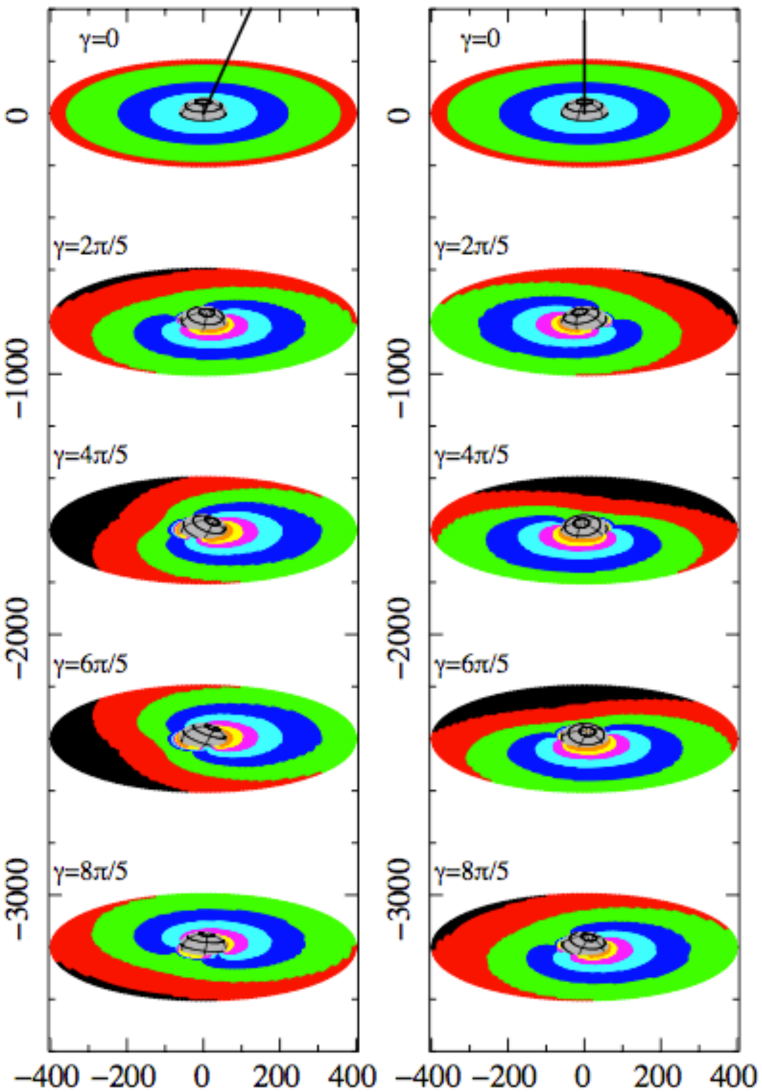
Frequency = 29 Hz

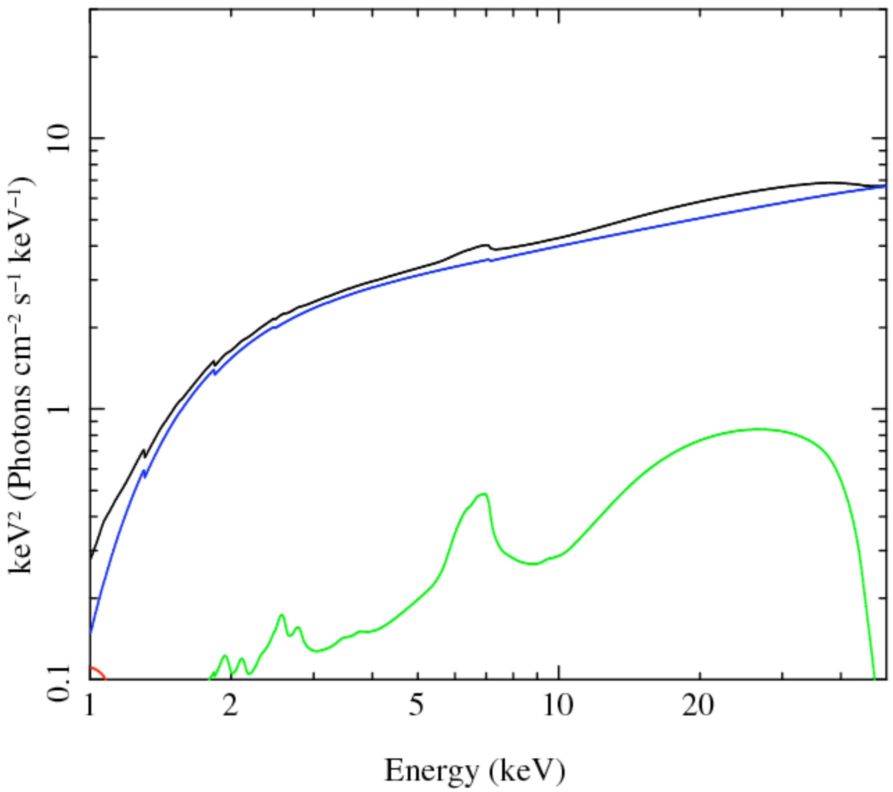
Growth Rate = –0.6 Hz

Q = 48

Relativistic nodal precession (from frame dragging) of the innermost disk regions
(Ingram & Done 2012)



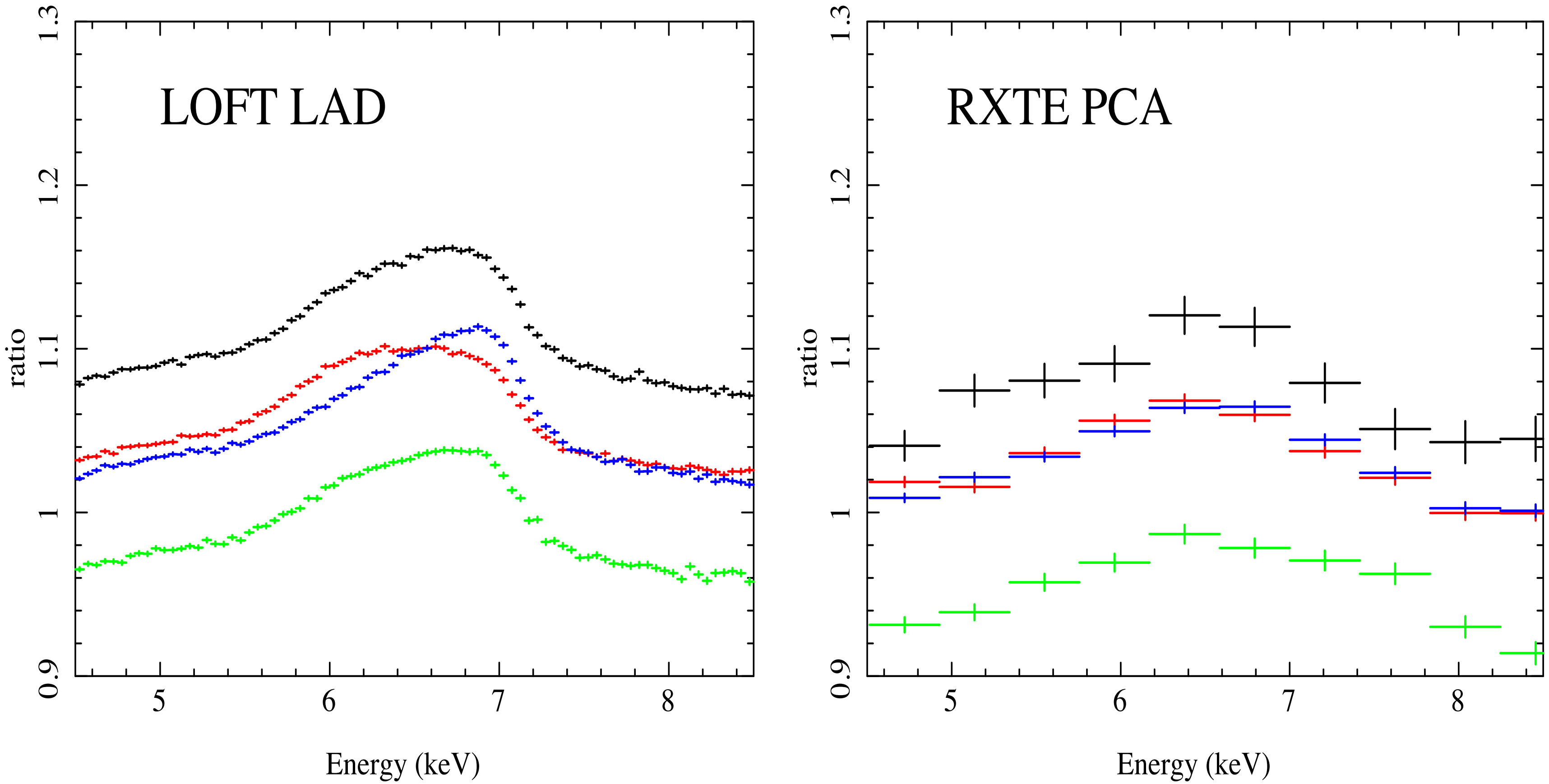




Full spectral model

-continuum oscillates

- reflection spectrum shifts in energy



LOFT LAD
RXTE PCA
ratio
Energy (keV)
0.9
1
1.1
1.2
1.3
5
6
7
8

Observatory Science

LOFT will also be an Observatory for virtually all classes of relatively bright sources

These include:

- X-ray bursters,
- High mass X-ray binaries
- X-ray transients (all classes)
- Cataclismic Variables
- Magnetars
- Gamma ray bursts (serendipitous)
- Nearby galaxies (SMC, LMC, M31, …)
- Bright AGNs

Activities

- ESA is studying mission in house
- Industrial studies in 2012
- Instrument consortium is working on payload:
  - WFM: Hernanz (IEEC/CSIC) and Brandt (DTU)
  - LAD: Zane (MSSL)
- Science case
  - Coordinated by LS (INAF), vd Klis (UvA) and Jonker (SRON)

    3 Working Groups:

    Dense Matter (A. Watts)

    Strong Gravity (D. Barret)

    Observatory Science (J. Wilms)
  - 2nd LOFT Science meeting in Toulouse (Sept 24-27, 2012)

    http://www.isdc.unige.ch/loft/index.php/meetings

-> Yellow book for ESA down selection end 2012

Down selection of M3 missions first half 2013

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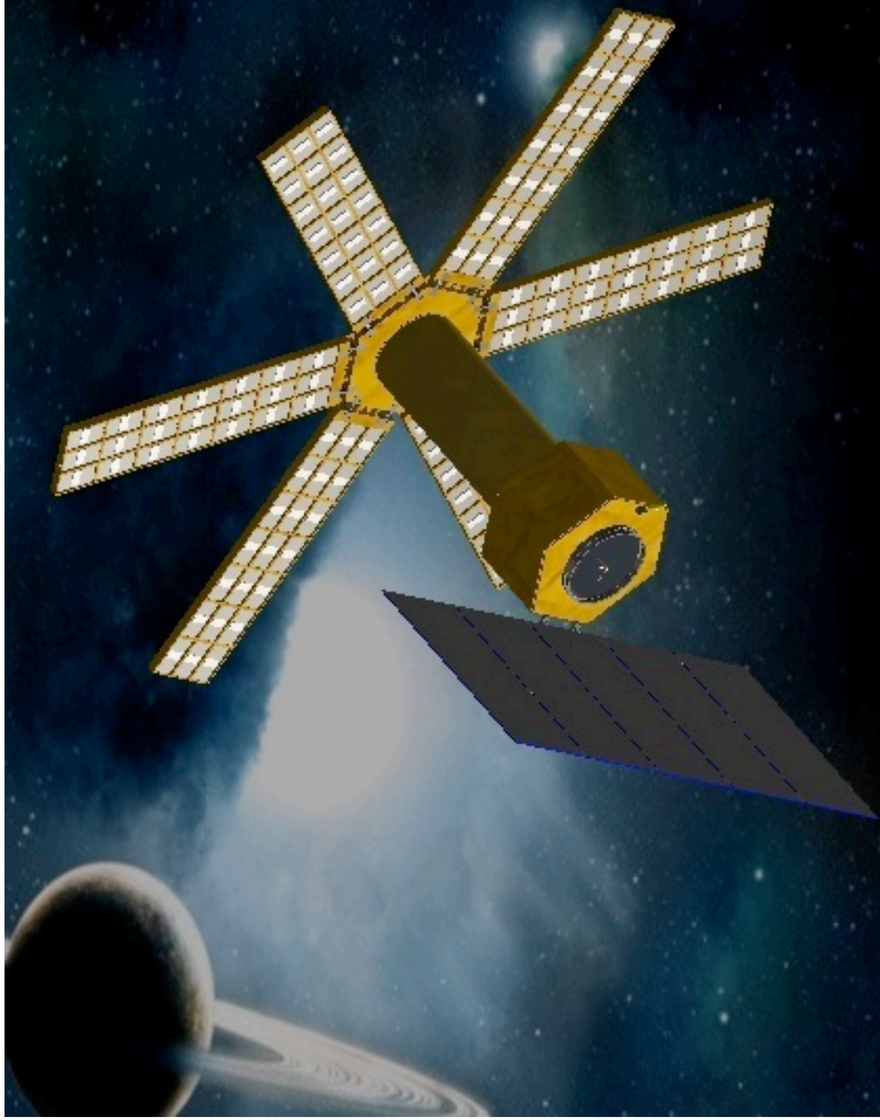

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