

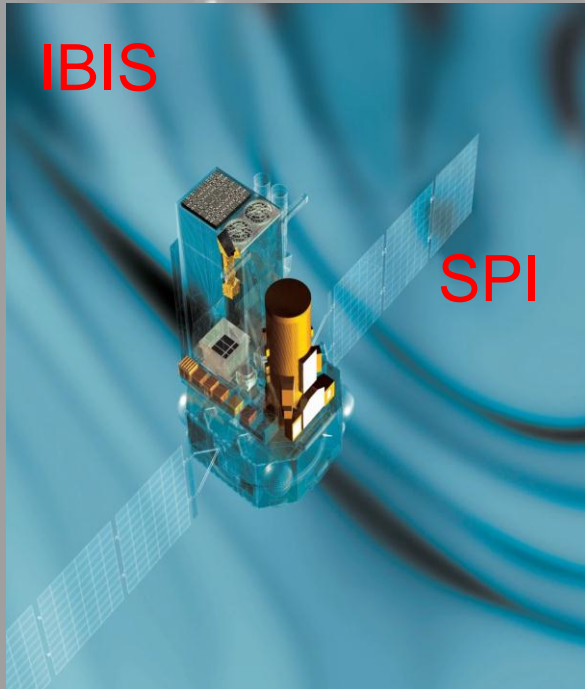
**AGILE 9th Science Workshop:
"Astrophysics with AGILE: five years of surprises"**

INTEGRAL and gamma-ray galactic sources

**M. Fiocchi (IAPS-INAF)
on behalf of the IBIS Survey Team**

- The INTEGRAL/IBIS galactic sky**
- The keV/GeV connection**
- Vela PWN: the AGILE and INTEGRAL synergy**
- The SuperGiant Fast X-ray transient**

INTEGRAL overview



IBIS and SPI are the main instruments

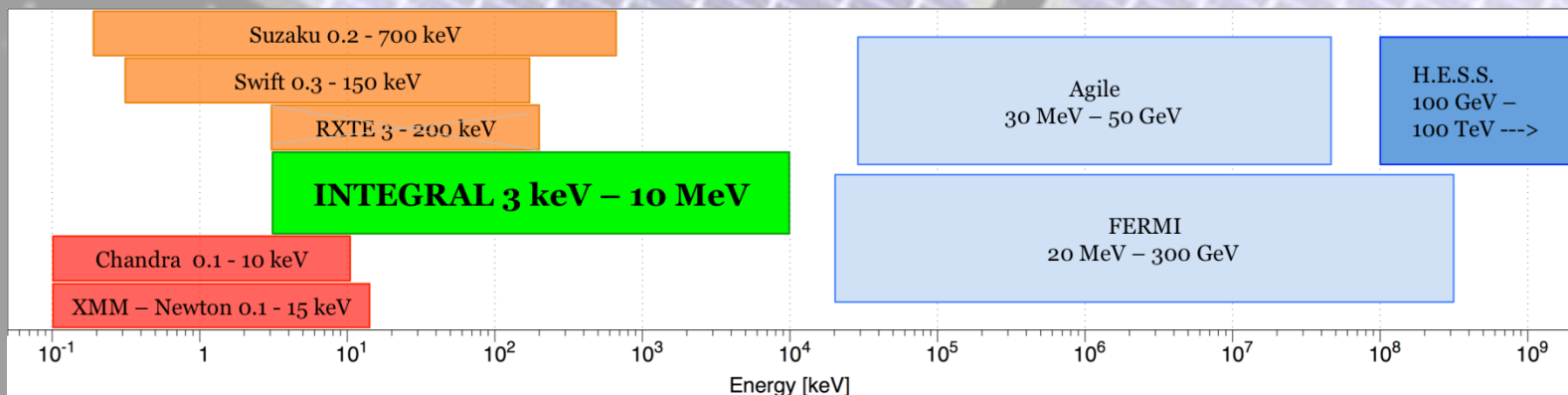
- SPI optimised for spectra: 20keV-MeV
- IBIS optimised for imaging: 17keV-10MeV

IBIS is the primary **survey** instrument

- Wide FOV (30x30 degrees)
- ISGRI detector mainly operates 17-600 keV
- Sensitivity ~ 0.1 mCrab for deep exposures (>10 Ms)

- JEM-X and OMC are the Monitors

Credit: ESA



INTEGRAL STATUS

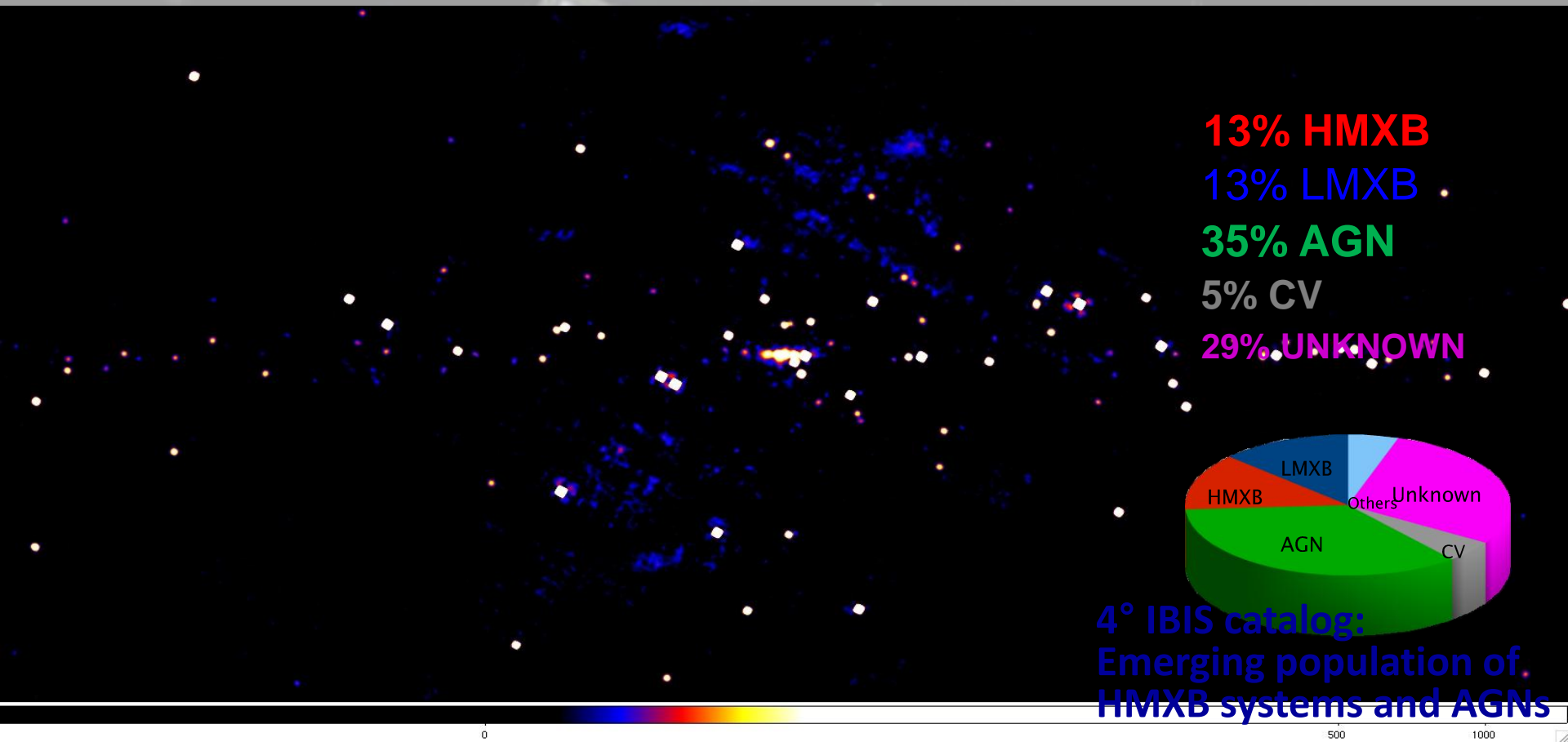
- Spacecraft, ground and flight operations: **nominal**
- Payload: **in good shape after 9 years in orbit !**

Instrument	Healthy detectors (%)	Change in sensitivity compared to launch (%)
SPI	15/19 = 79%	12%
ISGRI	96 %	2 %
PICsIT	98 %	1 %
JEM-X	77 %	13 %

As of 10 October 2010 (rev 976) both JEM-X units are being operated simultaneously again.

The soft gamma-ray sky according to IBIS...

> 700 sources in the IBIS Sky (Bird et al. 2010),
today more than 1000...



18-60 keV band

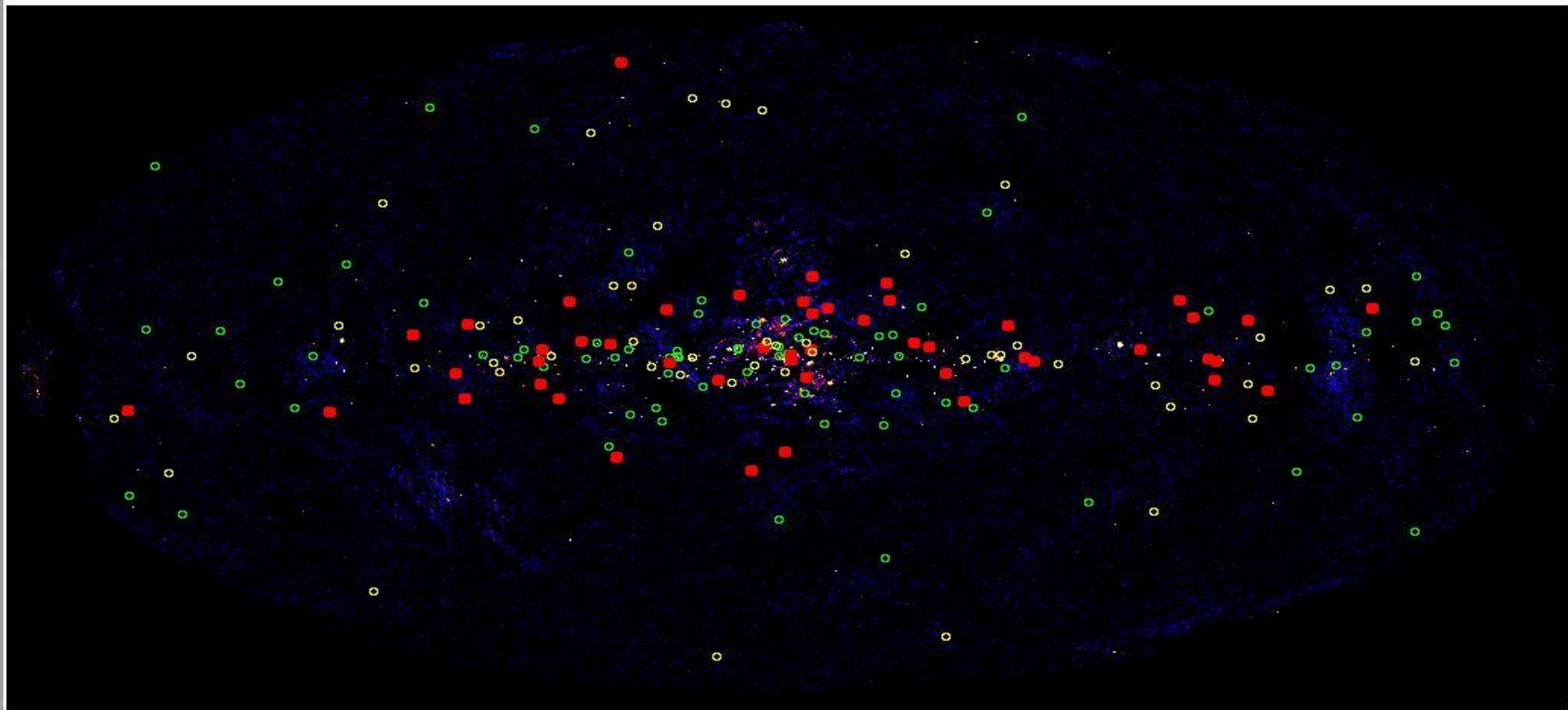
IGRs/unknown transients in the Cat 4

378 INTEGRAL sources

262 IGR unidentified in cat4

68% are transient and strongly variable sources

- 49 Bursticity > 4
- 76 Bursticity > 1.2
- 48 Bursticity < 1.2



The IBIS/AGILE connection

Previous review outlined the “common” galactic sources:

- PULSAR/PWN systems (Crab, Vela, PSRJ1420-6048, PSRJ1826-1334 and B1509-58)
- MicroQsos: Cyg X-3, LSI +61 303 (a Be in a HMXB), Cyg X-1
- colliding wind binary : Eta Carinae
- SFXTs/HMXB system possibly associated to MeV Transient

PSRJ2229+6114



Unclassified

CygX-3

Pulsar PSRJ2021+3651

CygX-1



Unclassified

Unclassified

Unclassified

Based on spatial proximity and similar flaring behaviour Sguera et al., 2009, proposed the SFXT AX J1841.0-0536 as best candidate counterpart of 3EG J1837-0423. Also, the 2 SFXTs IGR J20188+3647 and IGR J11215-5952 could be associated to AGILE transient in Cygnus and to EGRET EGR 1122-5946, respectively.

-1.3

2.4

9.9

24.9

54.7

-4.9

What is new compared to 2009

•MAGNETARs

7

•PSRs and PWN

13

OK, AGILE

•NSs and BHCs in LMXB

59+14

•NSs and BHCs in HMXB

49+4

OK, AGILE

•CVs

21

•IGRs still under ispection

140

•AGNs

272

OK, AGILE

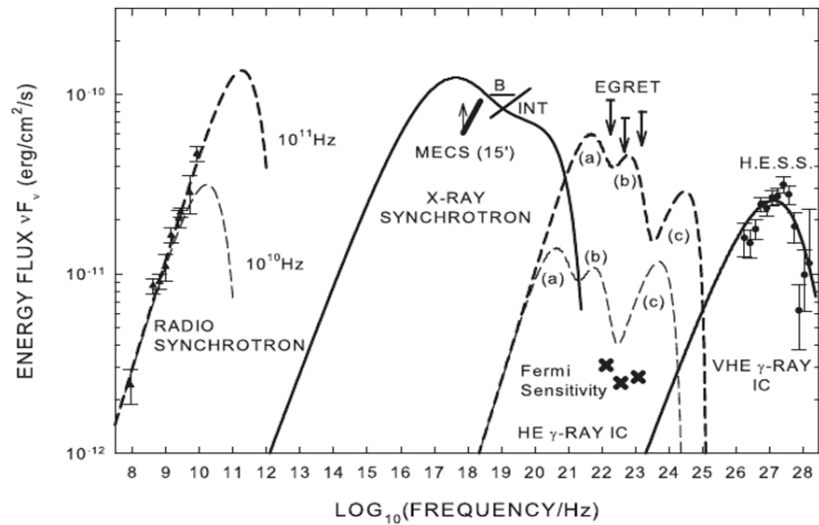
Mainly BLLacs

- Detection of extended hard X-ray emission from the Vela PWN
- The CRAB as unreliable calibration source

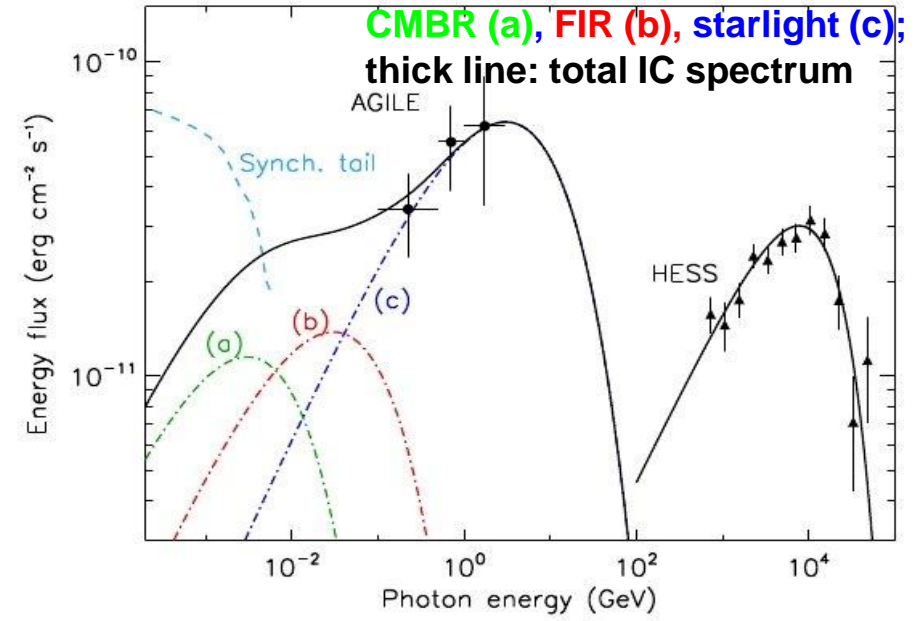
- At the IBIS sensitivity and energy band, the HMXBs seems to be the emerging GALACTIC population
- Outburst from HMXB/Be and cyclotron line detections
- New SFXT and Candidate SFXT

The PWN VELA: the SYNERGY INTEGRAL/AGILE

From radio to TeV without X and Gamma data (de Jager et al. 2008)



From radio to TeV with AGILE data
(Pellizzoni et al. 2010)



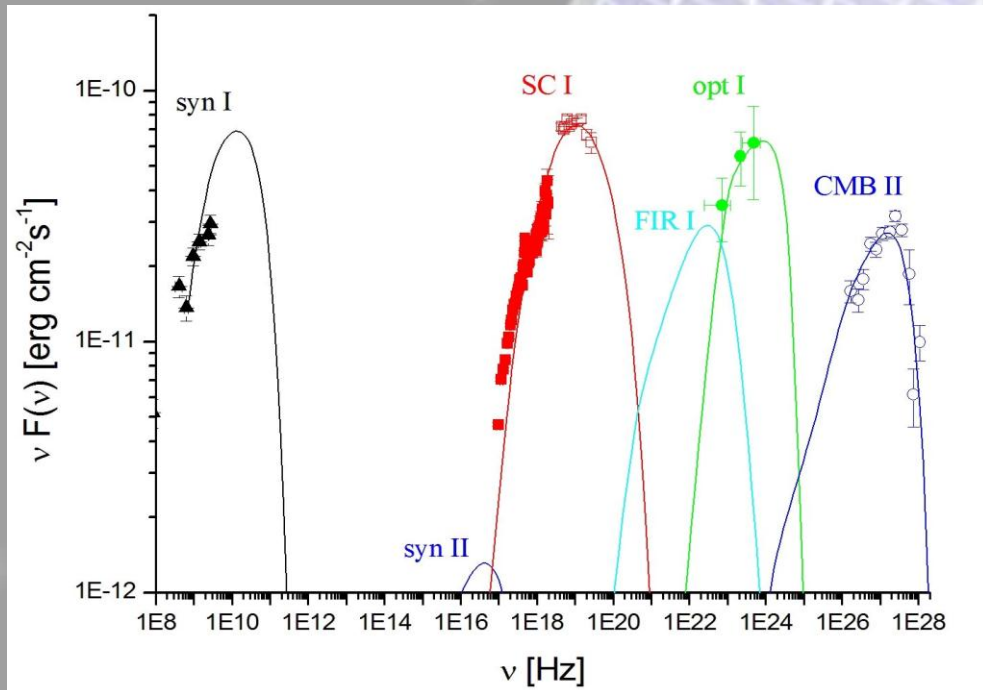
The lack of information in the X and gamma-ray band precludes drawing a comprehensive multiwavelength picture of the phenomenology and emission mechanism

HESS data fit an IC process scattering on CMBR related to electron power-law index 2.0 with a break at 67 TeV. AGILE data are compatible with IC emission from the additional electron component, scattering on FIR and starlight photon fields

The PWN VELA: the SYNERGY INTEGRAL/AGILE

From radio to TeV with CHANDRA, INTEGRAL and AGILE data
(Fiocchi et al. COSPAR 2010)

Assuming a magnetic field of few μ gauss, two electron populations are needed to fit data from radio to TeV:



- ◆ the radio synchrotron is responsible for:
 1. the IC bump in the GeV band arising from scattering on galactic and starlight photon fields
 2. the SSC bump in the hard-X/soft Gamma ray

- ◆ the very energetic X-ray synchrotron is responsible for the IC bump in the GeV band arising from scattering on the CMB photons.

HMXBs before the INTEGRAL era

□ accreting compact object (black hole BH or neutron star NS)
massive companion donor ($M > 10 M_{\odot}$) of early spectral type
(OB)

□ ~80 HMXBs known in our Galaxy before the launch of
INTEGRAL in 2002 (Liu et al. 2000)

□ HMXBs classified into two groups: (depending on the
evolutionary state of the donor star):

85% Be HMXBs

15% Supergiant HMXBs (SGXBs)

HMXBs in the INTEGRAL era

Two new HMXB classes

- highly obscured HMXB
- super-giant fast X-ray transients.



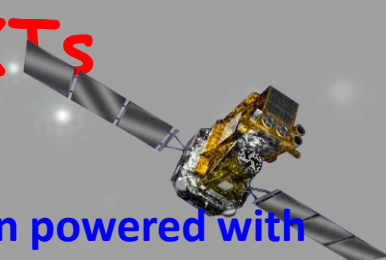
The SFXTs Sample

□11 firm SFXTs reported in the literature

- 7 firm SFXTs are newly discovered sources by INTEGRAL
- The remaining 4 SFXTs were previously discovered by other X-ray satellites (ASCA, BeppoSAX, RXTE), however INTEGRAL detected several fast outbursts unveiling or strongly confirming their fast X-ray transient nature

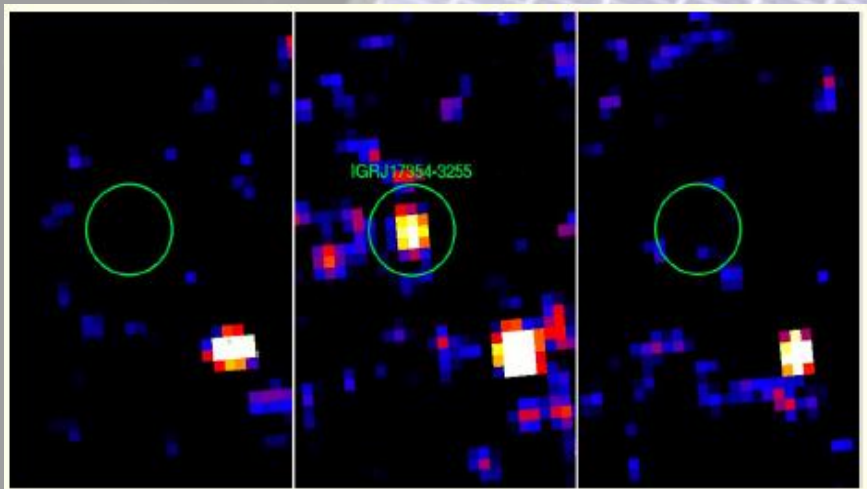
□11 Candidate SFXTs

General Characteristics of SFXTs

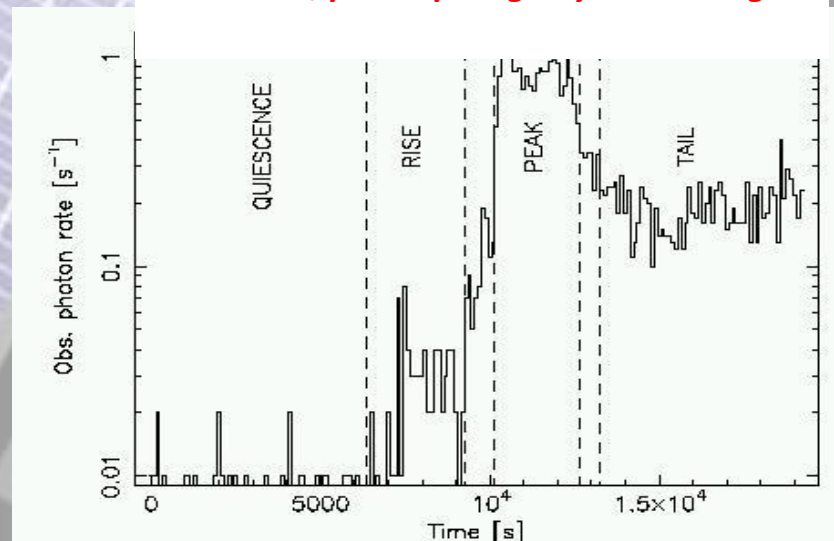


1. Short (a few hours) and intense ($L \approx 10^{36-37} \text{ erg s}^{-1}$) flares, accretion powered with X-ray pulsar like spectrum
2. Sporadic, hard and low intensity $L \approx 10^{33-34} \text{ erg s}^{-1}$ X-ray flares as revealed from *SWIFT* monitoring campaign
3. Soft quiescent emission (10^{32} erg/s)

High dynamic range : 3-5 orders of magnitude with respect to the quiescent soft emission emission (10^{32} erg/s) i.e. greater than that of classical persistent variable supergiant HMXBs (< 20)



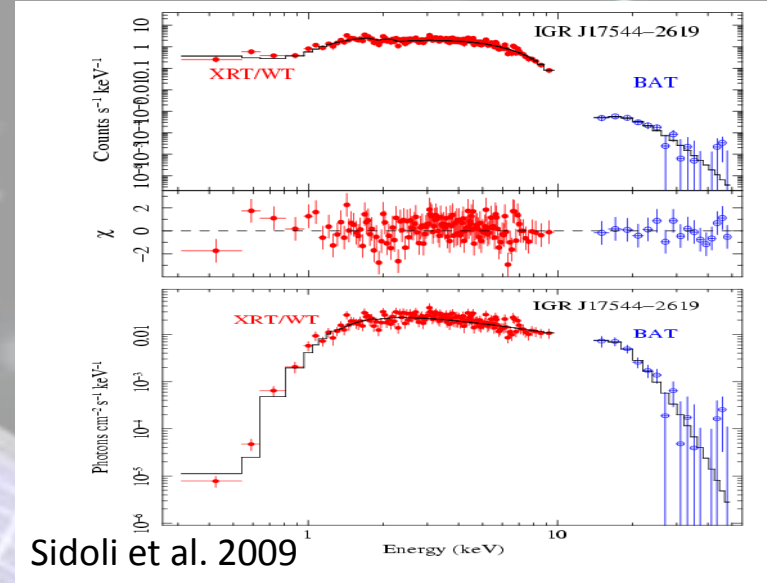
CHANDRA, piled up! High dynamic range



General Characteristics of SFXTs

In outburst, the broad band X-ray spectrum (0.2-100 keV) is typical of accreting NS in HMXB: **absorbed power laws with high energy cut-offs**

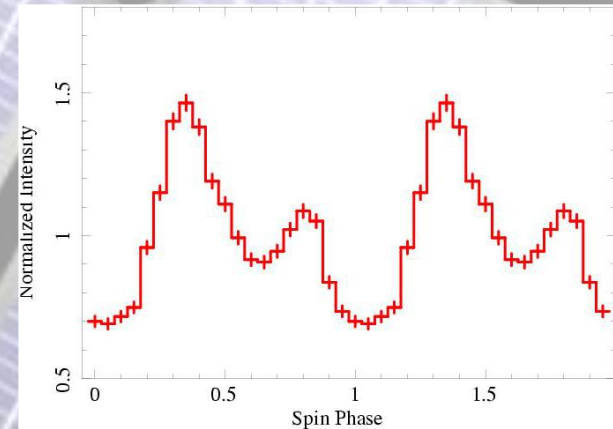
- $N_{\text{H}} \sim 10^{22} \text{ cm}^{-2}$ (in a few cases variable, sometimes in excess of the Galactic one)
- $\Gamma \sim 0-1$
- $E_{\text{c}} \sim 10-30 \text{ keV}$



Good reasons to believe it is a neutron stars (NS)

In 4 SFXTs the X-ray pulsations are detected:

- | | | |
|-----------------|----------------------|---|
| AX J1841.0-0535 | $\sim 4.7 \text{ s}$ | (Bamba et al. 2001) |
| IGR J18483-0311 | $\sim 21 \text{ s}$ | (Sguera et al. 2007) |
| IGR J16465-4507 | $\sim 228 \text{ s}$ | (Lutovinov et al. 2005) |
| IGR J11215-5952 | ~ 187 | (Swank et al., 2007,
Sidoli et al. 2007) |



Summary of SFXTs Characteristics



SFXT	Porb(day)	spin rate	dynamic range	NH (cm-2)x 10 ²²
IGR J08408-4503	35?		104	0.1
*IGR J11215-5952	164.6	186.78s	>103	~1
IGR J16465-4507	30.32	228s	30-80 (<i>inter.</i>)	60
IGR J16479-4514	3.3194		3.5x10 ³	4-10
IGR J17354-3255	8.447			5-10
XTE J1739-302	51.47		103	3-38, 4.2
recent				
IGR J17544-2619	4.926		104	1.2-4.3
SAX J1818.6-1703	30.0		3x10 ³	~6
AX J1841.0-0536		4.7394s	103	~6
AX J1845-0433			102	~2
IGR J 18483-0311	18.55	21.0526s	1.2 x10 ³	7.7
<i>Candidate SFXT</i>				
AX J161929-4945				4-12
IGR J16328-4726			>170	8.1
IGR J16418-4532	3.753	1246	70	10
XTE J1743-363				
IGR J17536-2339				
IGRJ 11321-5311?				

* First SFXTs with periodic outburst, Sidoli et al., 2006

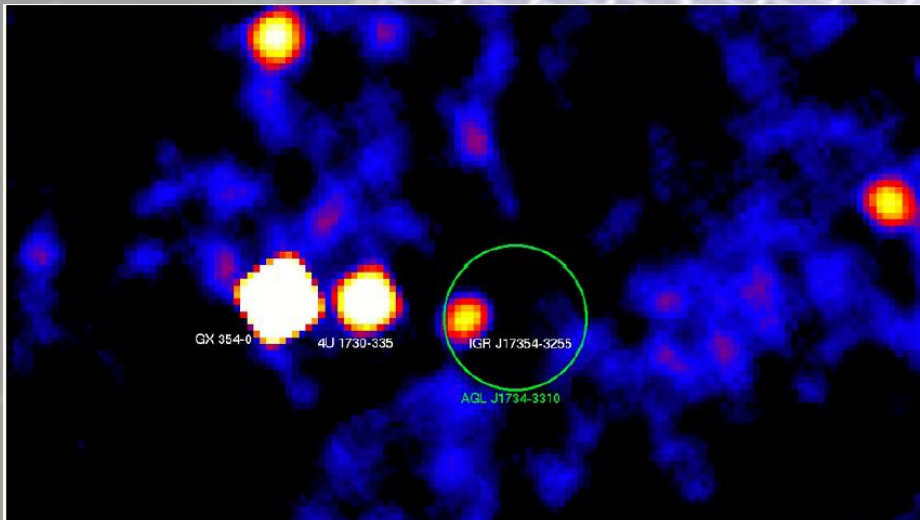
SFXTs as candidate MeV Sources

Outbursts of **IGR J17354-3255**:

- Duration 0.5-10 hours, occasionally a few days
- 18-60 keV flux of 20-40 mCrab, rarely brighter than 100mCrab
- Detection significance of 5-10 σ
- Similar X-ray spectral shape, powerlaw $\Gamma=2.4$

Outbursts of **AGL J1734-3310**:

- Fast MeV flare lasting 1-2 day (Bulgarelli et al. in prep.)
- >100MeV flux of $3.5 \times 10^{-6} \text{ph cm}^{-2} \text{s}^{-1}$
- Super AGILE 3 σ upper limit of 60mCrab (20-60 keV)
- Detection significance of 3-5 σ



IBIS/ISGRI deep mosaic significance image (~ 10 Ms, 18-60 keV)

The intermediate SFXT IGRJJ17354-3255 is the best candidate counterpart of the transient MeV AGL J1734-3310, based on spatial correlation and similar transient behaviour on short timescale

SFXTs: a challenge to theory

The X-ray behaviour of SFXTs cannot be explained in the framework of standard theories for homogeneous and spherically symmetric wind accretion (Bondi-Hoyle theory)

Alternative theoretical models focussed on:

1) the X-ray variability is driven by properties of the NS compact object (gated mechanisms) (Bozzo et al. 2008, Grebenev & Sunyaev 2007)

2) the clumpy wind with different geometry:

- spherically symmetric clumpy wind (Negueruela et al. 2008)
- anisotropic clumpy wind (Sidoli et al. 2007)

The Gamma-ray behaviour of SFXTs needs of new deep inspection of the extreme physical mechanisms able to accelerate particles up to MeV/TeV energies. Recently, a physical model was proposed by Mirabel et al. 2012.

Conclusions

1) which is the accretion mechanisms at work, magnetic effect or clumpy models?

2) which are the evolutionary paths and links between the different kind of HMXBs?

3) Are SFXTs the prototype of a new class of Galactic MeV transients?

Their answer represents one of the most important challenge in the field of accreting galactic compact object and could have important consequences for other astrophysical studies (GRBs, gravitational waves emitters, stellar evolution, chemical enrichment of the Galaxy)

IGR and SFXT: 805
citations

- Sguera et al.: 2005, A&A 444, 221
- Sguera et al.: 2006, ApJ 646, 452
- Walter et al.: 2006, A&A 453, 133
- Lutovinov et al.: 2005, A&A 444, 821
- Walter et al.: 2007, A&A 476, 335
- Masetti et al.: 2006, A&A, 459, 21
- Rahoui et al.: 2008, A&A 484, 801
- Walter et al.: 2003, A&A 411, 427
- Sidoli et al.: 2007, A&A 476, 1307

The image features two solar panels, one slightly behind and to the right of the other, set against a dark grey background filled with numerous small, bright white stars. The solar panels are tilted and have a grid of white lines on a blue surface. The text 'Thanks for your attention' is written in a bold, black, sans-serif font at the bottom of the image.

Thanks for your attention