

XMM observations of  
**IGR J11014-6103:**  
a new peculiar 'double-head' bow-shock PWN

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Lucia Pavan (ISDC)

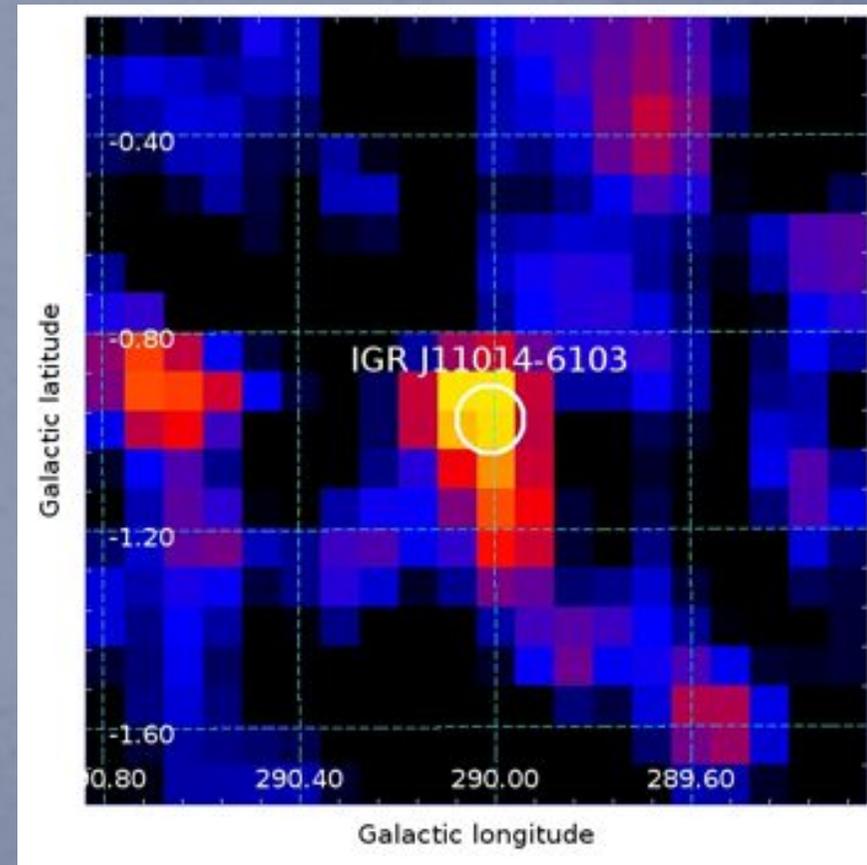
E. Bozzo (ISDC), G. Pühlhofer (IAAT), C. Ferrigno (ISDC),  
M. Balbo (ISDC) and R. Walter (ISDC)

(A&A accepted)

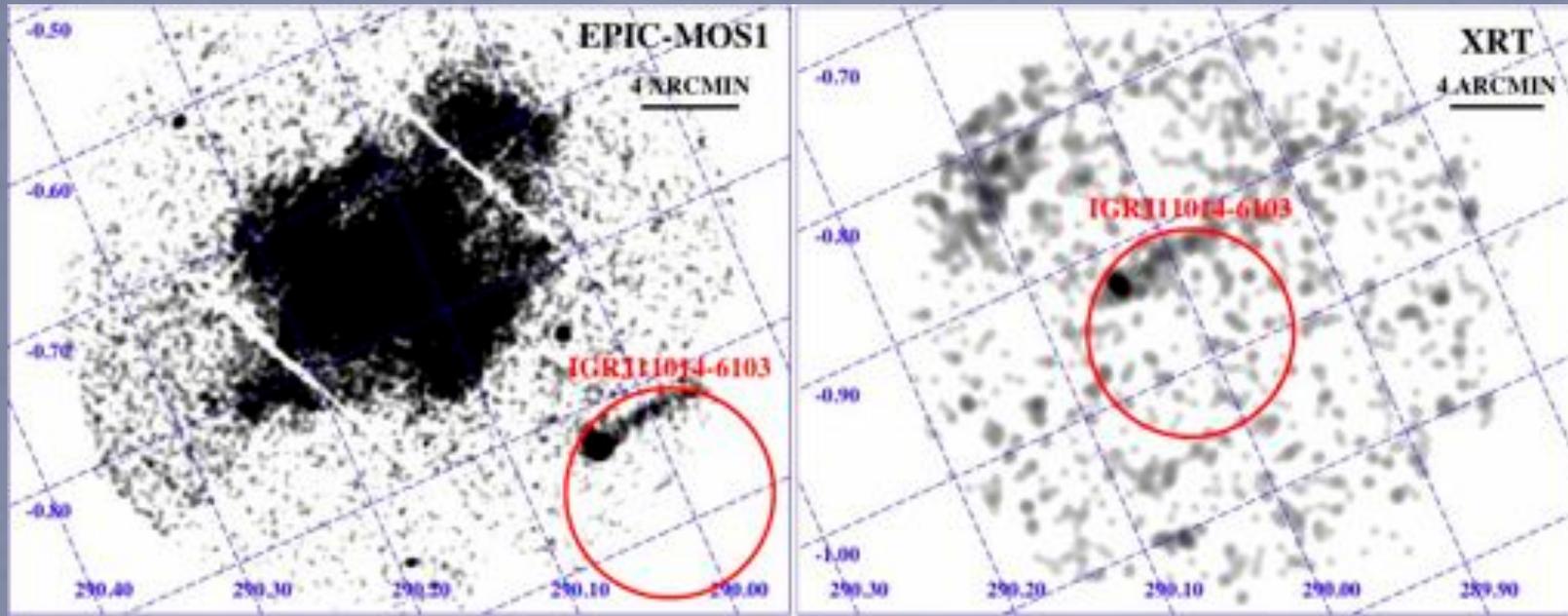
# IGR J11014-6103

In collaboration with E. Bozzo, G. Pühlhofer, C. Ferrigno, R. Walter, M. Balbo

- Unidentified source, in the 4<sup>th</sup> INTEGRAL catalog (5.4 signif.),
- quite strong emission in 40-100 keV  
( $F_{40-100} = 5.6 \times 10^{-12}$  erg/cm<sup>2</sup>/s  
 $F_{20-40} = 3.0 \times 10^{-12}$  erg/cm<sup>2</sup>/s)
- low galactic latitude  
( $l$  290.0,  $b$  -1.0,  
RA= 65.341, Dec= -61.056 +/- 4.3 arcmin)
- 2288 ks exposure



# X-ray counterpart



XMM (0.2-12 keV)

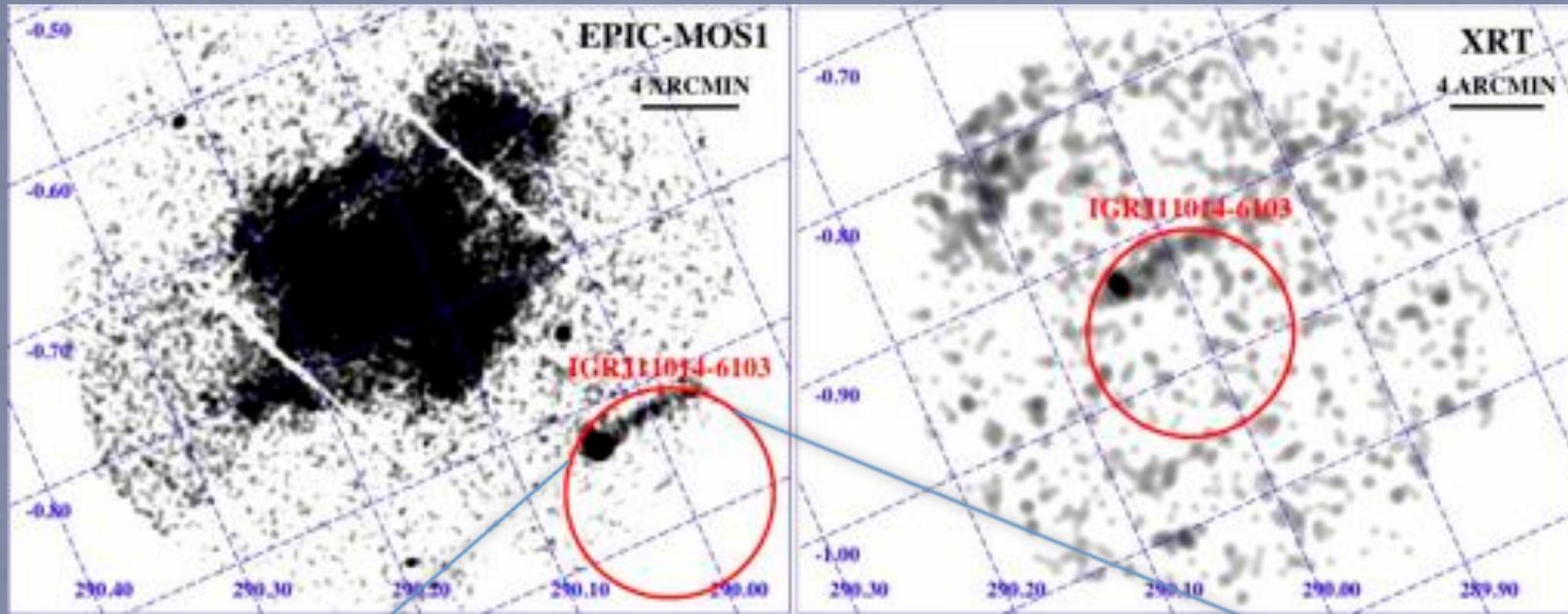
- obs. 0152570101 (2003) ~60 ks  
PN in small window mode
- obs. 0111210201 (2000) ~11 ks  
SNR MSH 11-61A

SWIFT/XRT (1-9 keV)

2 obs. March 2011  
tot. 3+2 ks

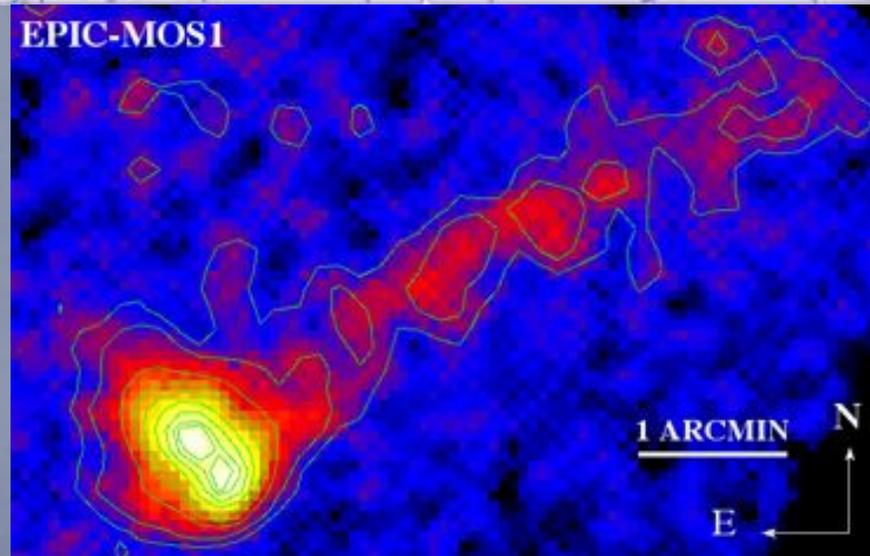
(Malizia et al. 2011 Atel 3290)  
(165.44, -61.022 +/- 6")

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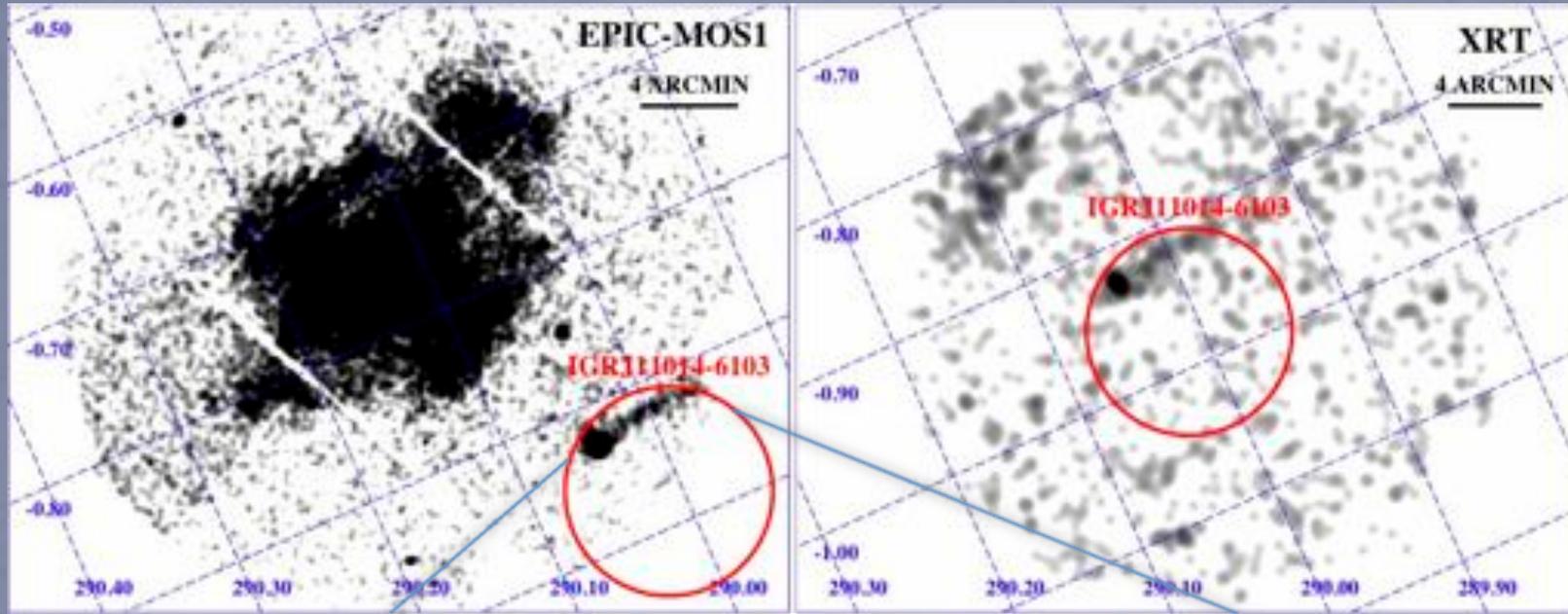


SWIFT/XRT (1-9 keV)

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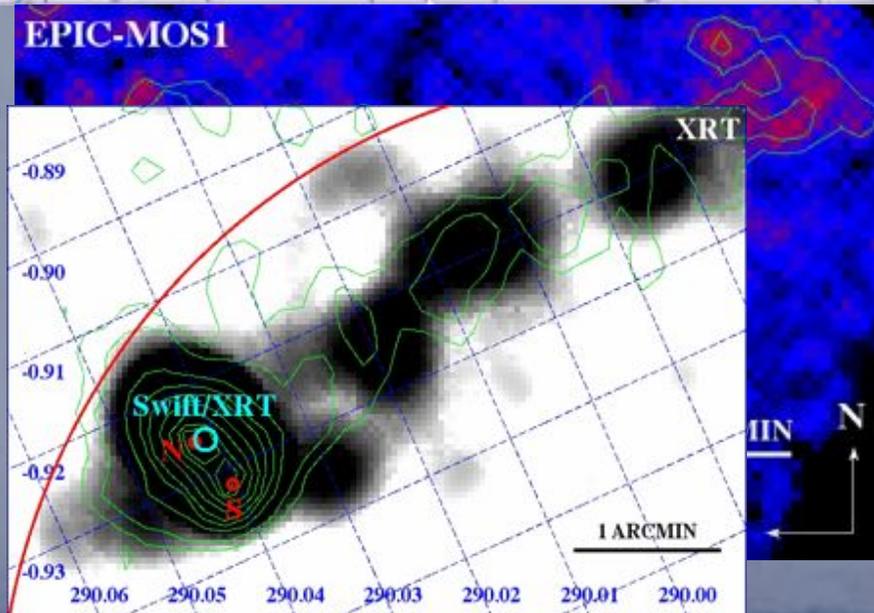
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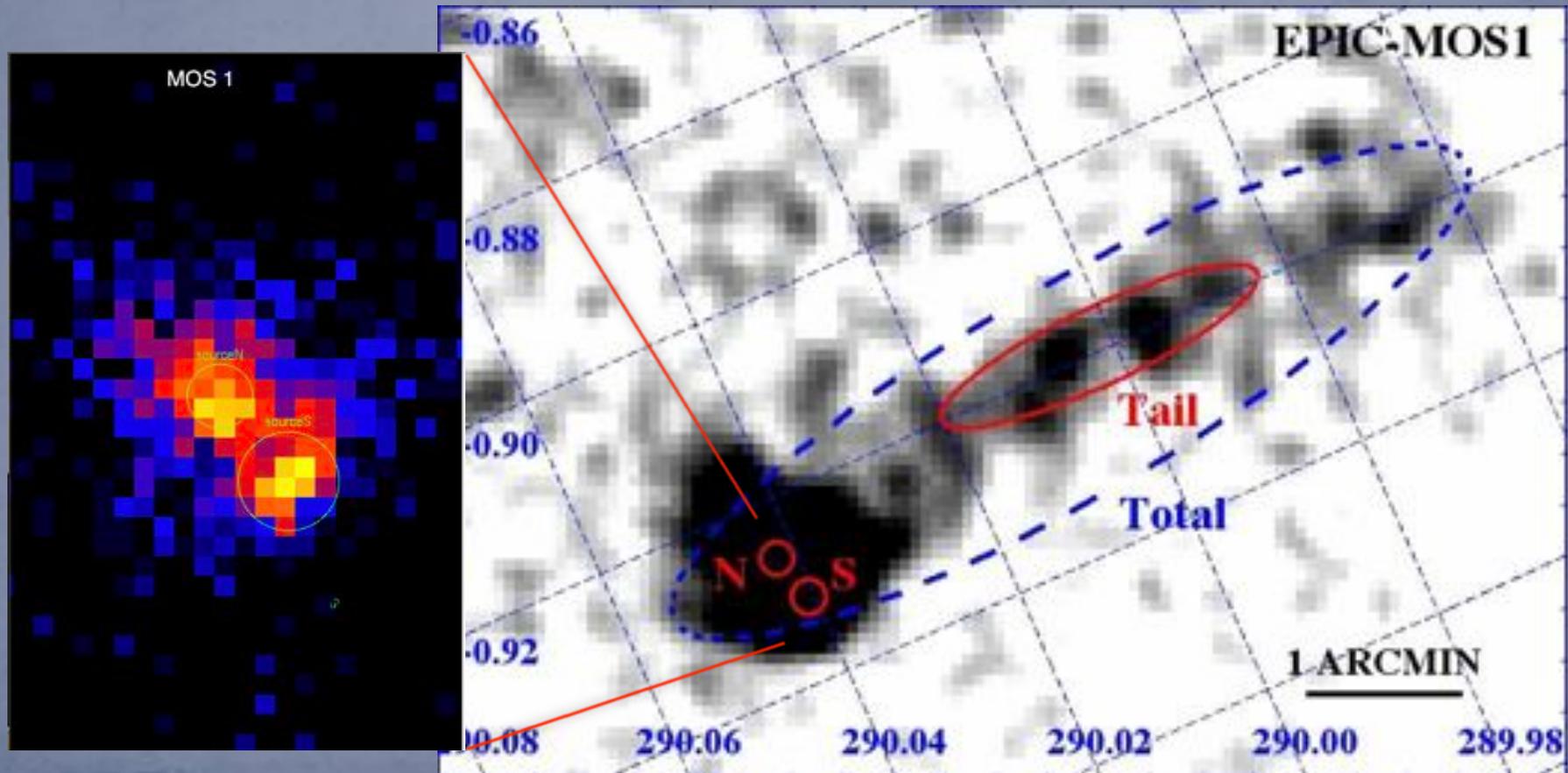
# XMM analysis

source N: 2XMM J110147.1-610124 (RA=165.4465, Dec= -61.0234)

8.1 arcsec extended source

source S: 2XMM J110145.0-610140 (RA=165.4377, Dec=-61.0279)

tail ~4 arcmin



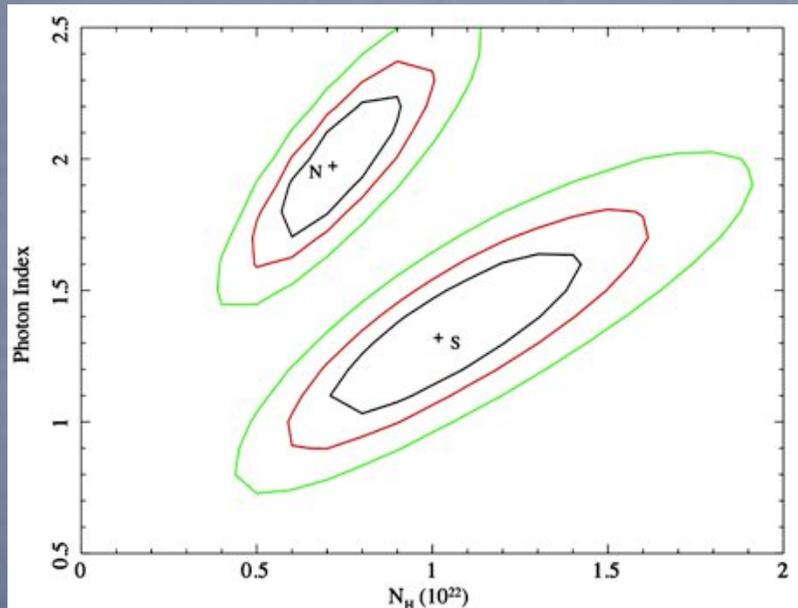
# XMM spectral analysis

powerlaw model

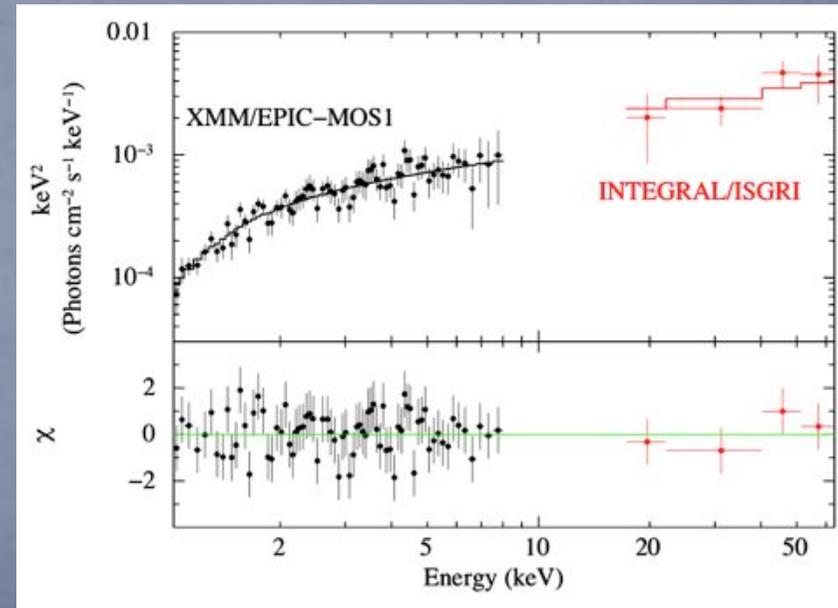
	$N_H$	$\Gamma$	$F_{2-10 \text{ keV}}$	$F_{0.2-2.4 \text{ keV}}$	C-stat/d.o.f.
N	$0.7 \pm 0.2$	$2.0 \pm 0.3$	$3.7^{+0.6}_{-1.1}$	$1.2^{+0.2}_{-0.5}$	68.2/68
S	$1.0 \pm 0.4$	$1.3 \pm 0.4$	$6.2^{+0.9}_{-2.6}$	$0.8^{+0.2}_{-0.4}$	73.3/62
Tail	$1.3^{+0.7}_{-0.8}$	$2.2^{+0.7}_{-0.8}$	$1.9^{+0.3}_{-1.0}$	$0.5^{+0.2}_{-0.3}$	31.1/21
Total	$0.7 \pm 0.1$	$1.6 \pm 0.15$	$17^{+1.2}_{-1.4}$	$3.9^{+0.3}_{-0.5}$	68.60/85

$(10^{22} \text{ cm}^{-2})$                        $(10^{-13} \text{ erg/cm}^2/\text{s})$

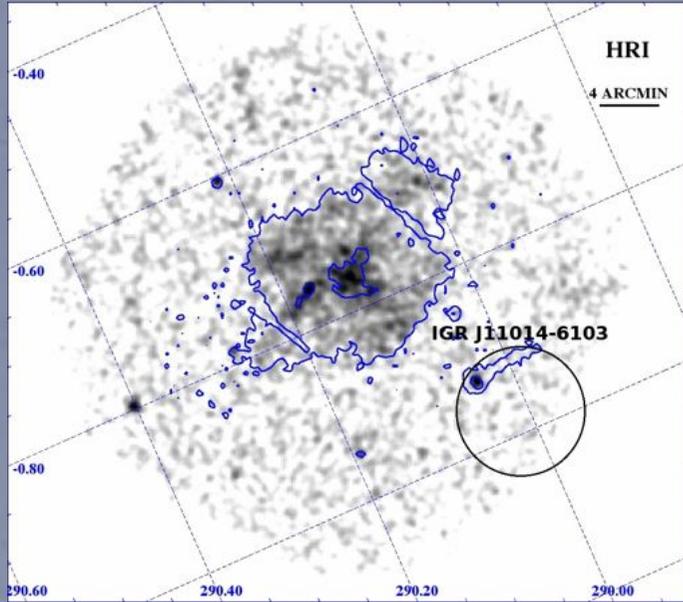
sources N and S



total emission



# other X-ray observations ROSAT - ASCA

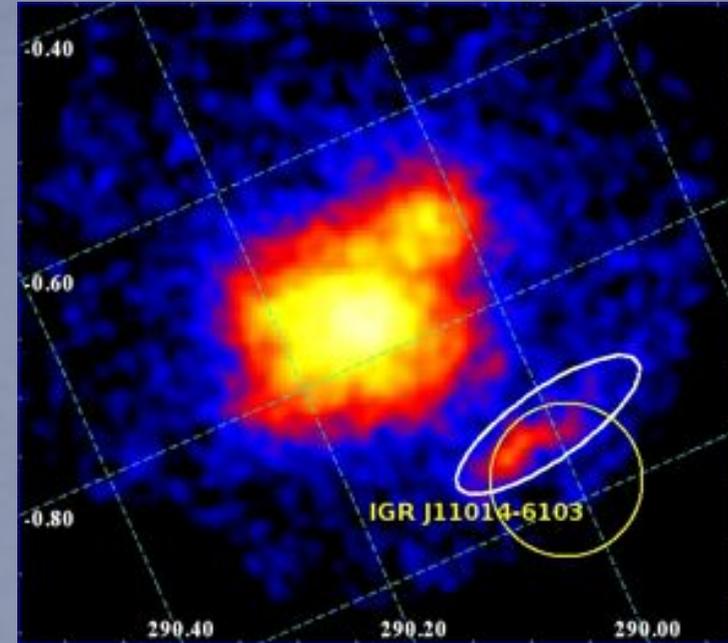


ROSAT: (5" resolution, 0.2-2.4 keV)  
(1997, ID. RH500445A01, ~46ks)

1RXH J110146.1-610121 (HRI catalog,  
Voges et al. 1999

RA=165.442 , Dec=-61.022 (+/- 10") →  
source N

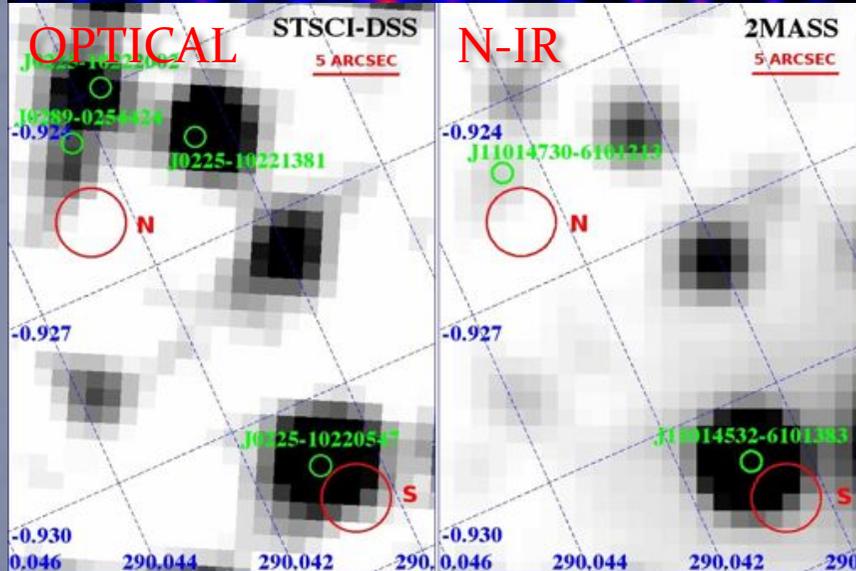
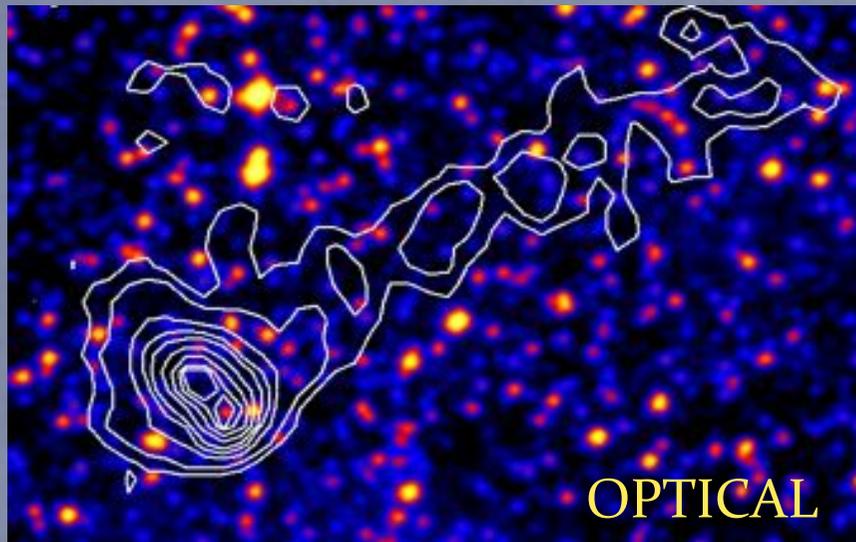
$0.0038 \pm 0.0004$  cts/s. →  $(9 \pm 1) \times 10^{-13}$  erg  
 $\text{cm}^{-2} \text{s}^{-1}$  (2-10 keV)



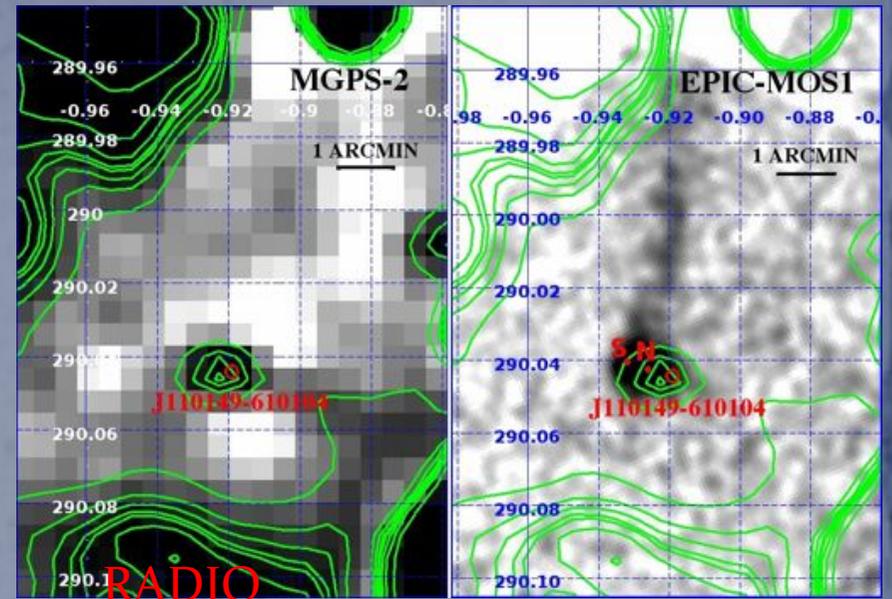
ASCA – GIS2 (obs.ID. 51021000,  
1994, 43.4 ks)  
(1995, ID. 51021010, 40.5 ks)

$F \sim (2.1 \pm 0.2) \times 10^{-12} \text{ erg/cm}^2/\text{s}$

# Counterparts

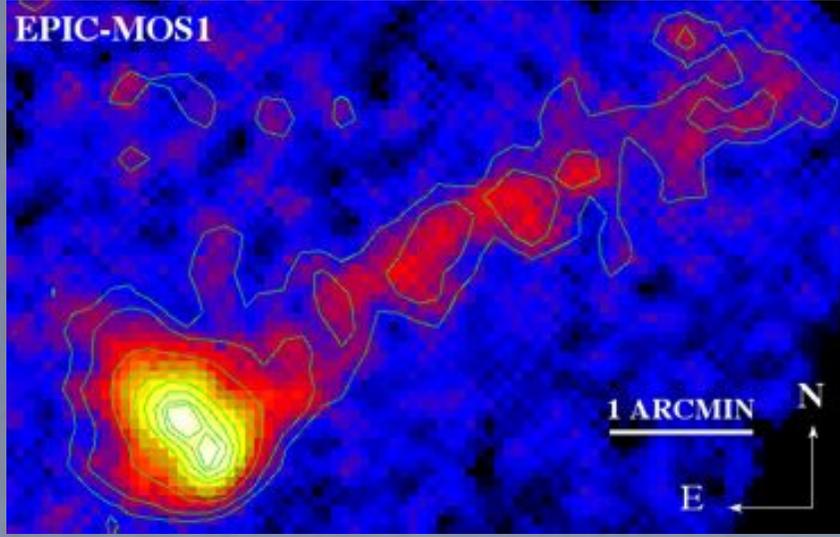


OPTICAL: DSS image + USNO B-1 catalog  
 NIR: 2MASS survey

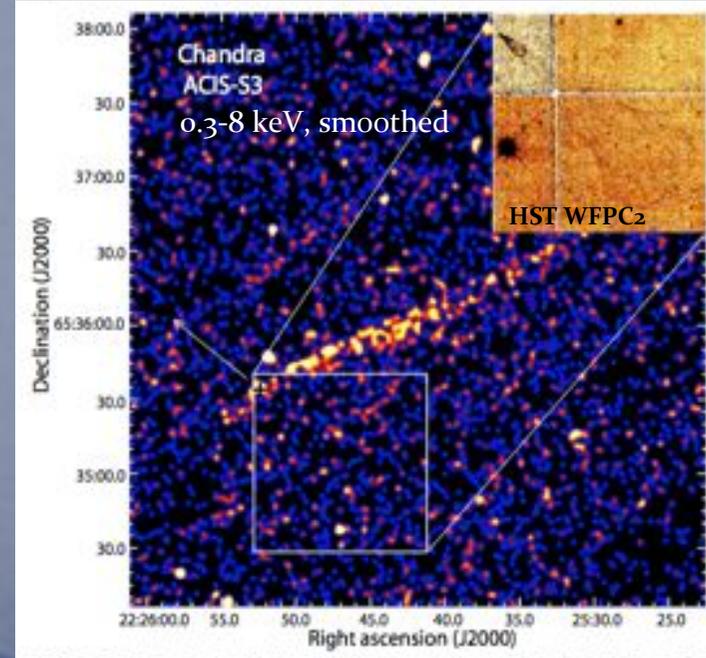
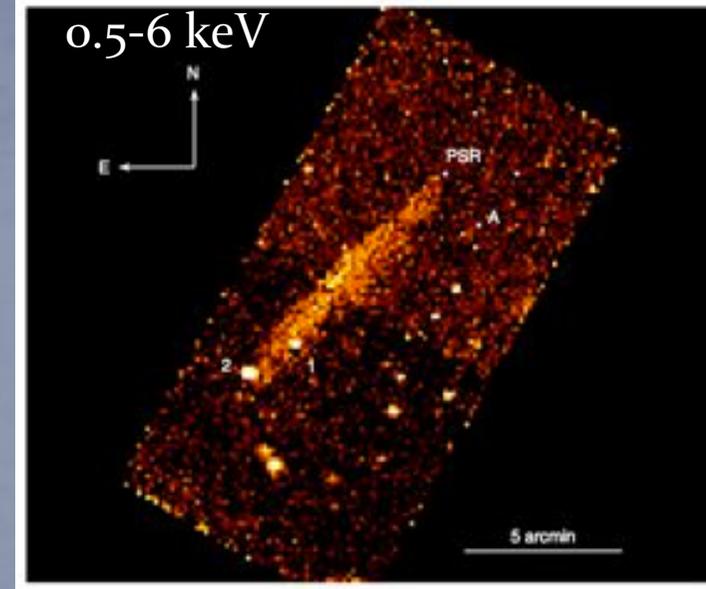


MGPS-2 survey,  
 843 MHz  
 J110149-610104 (MGPS catalog,  
 “compact” source)  
 (165.4559, -61.0178)  
 $F_{843\text{MHz}} = 24.2 \pm 4.8 \text{ mJy}$   
 $= (2.04 \pm 0.40) \times 10^{-16} \text{ erg/cm}^2/\text{s}$

# Other similar objects

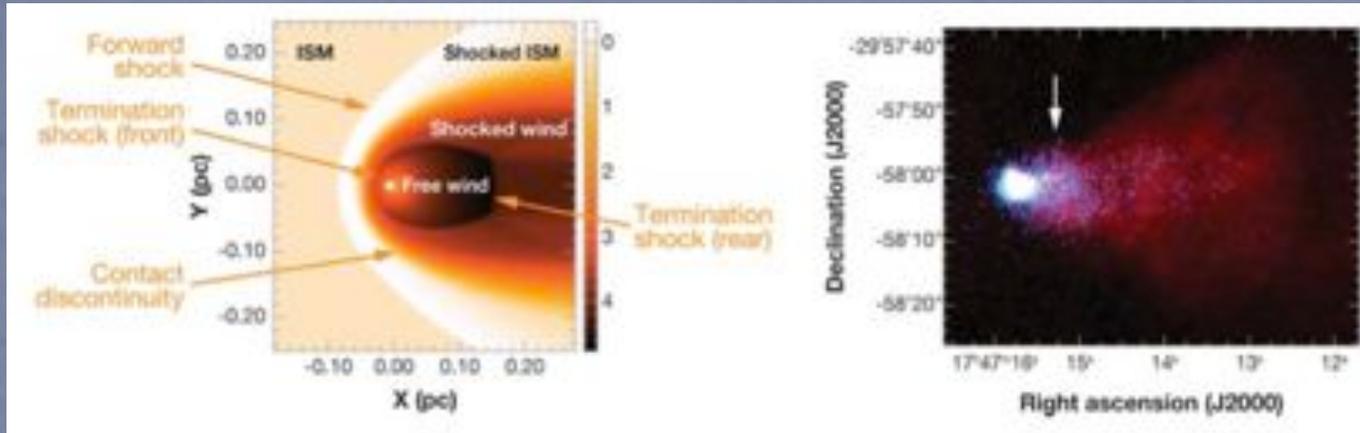


- ~4 arcmin
- no radio/optical emission
- non-thermal X-ray spectrum
- similar to X-ray tails in the Guitar nebula (~2 arcmin) and PSR J0357+3205 (~9 arcmin) (radio quiet, middle age  $\tau_C \sim 0.5\text{My}$  PSR)



Hui & Becker 2007 A&A 467, 1209 De Luca et al. 2011 ApJ 733, 104  
old PSR B2224+65  $\gamma$ -ray only PSR J0357+3205

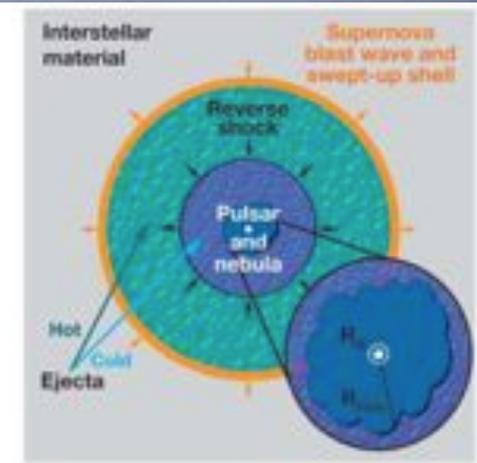
# (bow shock) PWN



Gaensler & Slane  
2006 ARA&A 44, 17

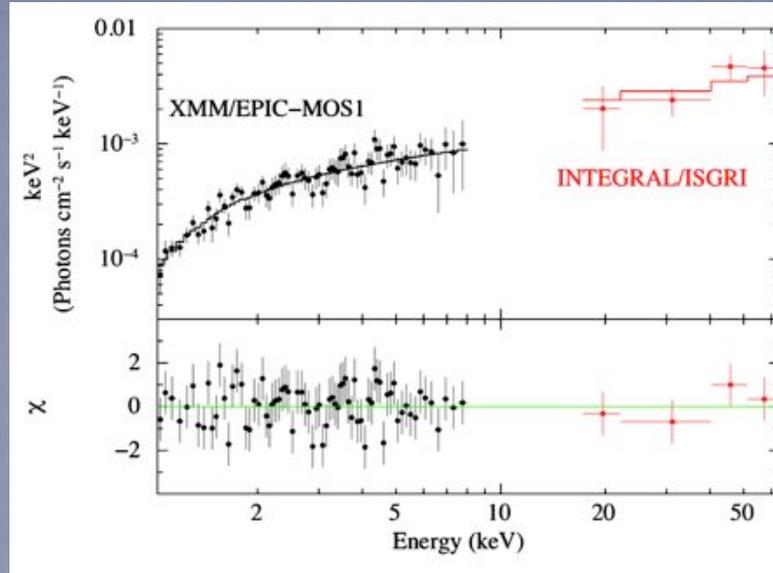
highly supersonic PSR (A pulsar will typically cross its SNR shell after  $\sim 40,000$  years, Gaensler & Slane 2006)

- relativistic wind  $\rightarrow$  under-luminous X-ray cavity
- synchrotron emission  $\rightarrow$  X-rays and radio emission
- PSR moves ( $\sim 100-1000$  km/s) in the ISM  $\rightarrow$  formation of a bow-shock in front of the PSR + flow back along direction of motion
- formation of elongated cometary structures



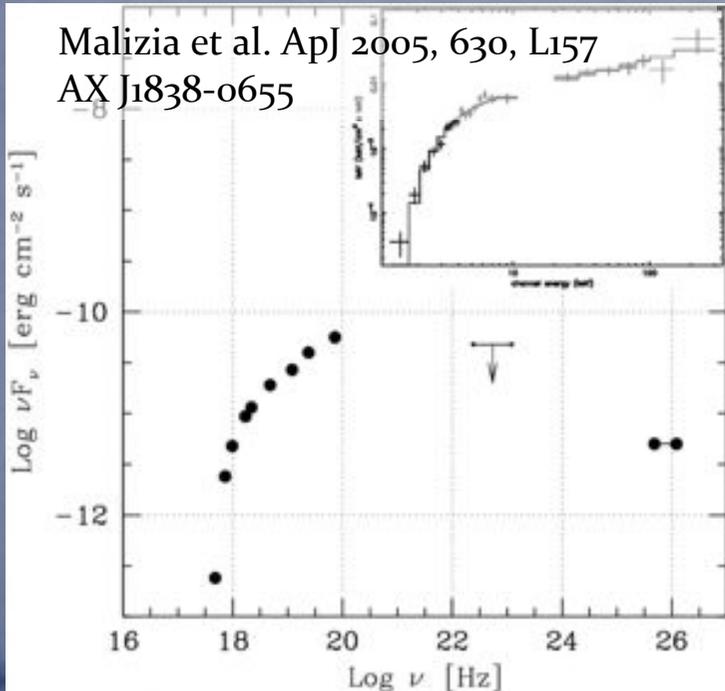
# X- to gamma- ray spectrum

$\Gamma = 1.5 \pm 0.2$   
 $N_H = 0.6 \pm 0.2 \times 10^{22} \text{ cm}^{-2}$   
 $(C = 1.7 \pm 1.1)$   
 $F(2-10 \text{ keV}) = (1.9 \pm 0.2) \times 10^{-12} \text{ erg/cm}^2/\text{s}$

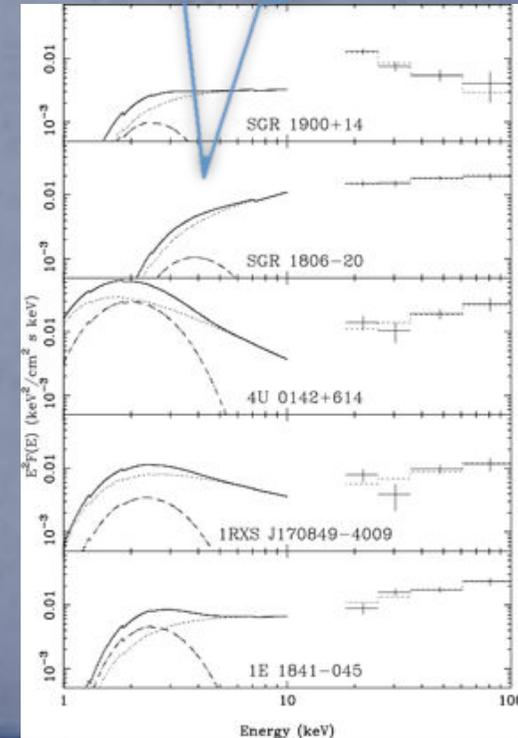


Esposito et al.  
 A&A 476, 321-330 (2007)  
 (1.5-12 keV)  
 $\Gamma = 1.6-1.7$   
 $kT = 0.6$   
 $F = 1.8 \times 10^{-11} \text{ erg/cm}^2/\text{s}$

Malizia et al. ApJ 2005, 630, L157  
 AX J1838-0655

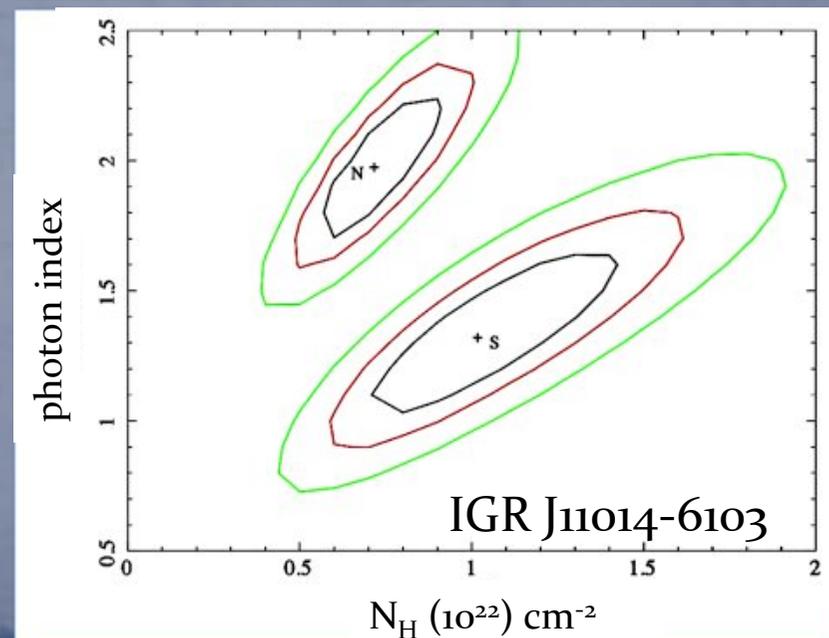
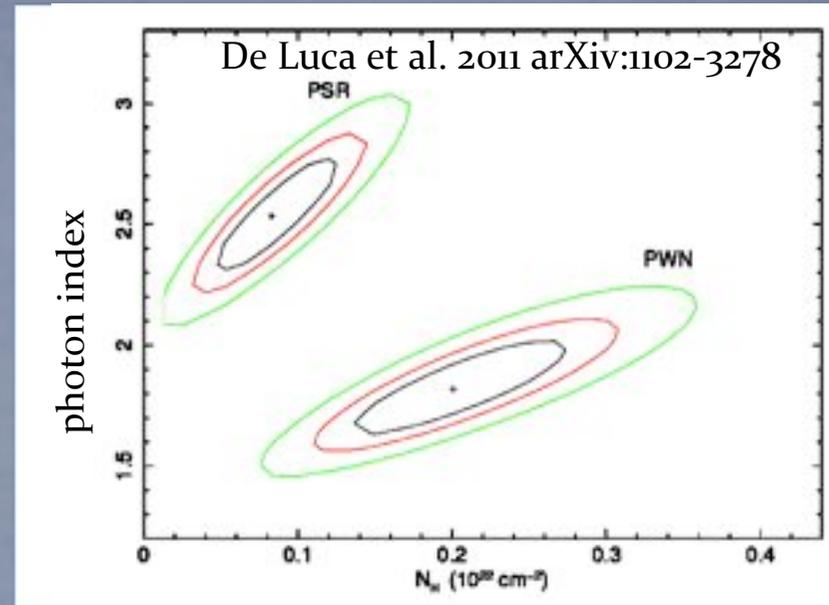


ASCA+INTEGRAL  
 $\Gamma = 1.5 \pm 0.2$   
 $N_H = (6.7 \pm 1.3) \times 10^{22} \text{ cm}^{-2}$   
 “persistent and possibly non variable high-energy source.”  
 rotationally powered PSR,  
 PWN detected with Chandra  
 Gotthelf & Halpern (ApJ 2008, 681, 515)



# Possible interpretation

- in the bsPWN scenario:
- tail is a relic trail of PWN around a high-velocity PSR
- source N:
  - extended in XMM (8.1")
  - close to radio emission
  - compact PWN
- $\Gamma = 2.0 \pm 0.3, 2.2 \pm 0.8$



# Possible interpretation - source S

- hard 2-10keV spectrum ( $\Gamma=1.3 \pm 0.4$ )
- point-like

## 1<sup>st</sup> HYPOTHESIS

NOT assoc. to source N+tail

- source S spectrum might be compatible with a field AGN, PSR ?, ...
- the PSR is not resolved and mixed in source N emission

## 2<sup>nd</sup> HYPOTHESIS

associated to source N+tail

- source S hard X-ray spectrum is compatible with a young PSR (AX J1838-0655)
- present data cannot exclude a magnetar (SGR 1806-20) (possibly PWN around 1E1547.0-5408 Vink & Bamba ApJ, 707:L148, 2009)

-> timing information and precise imaging needed

# conclusions

- analysis of IGR J11014-6103 lead to detection of an extended X-ray source, with possibly 3 components
- PWN
- more observations are needed to better understand the nature of the source (timing + Chandra observation needed)
- observation request submitted to Chandra