# Obscured HMXBs and SFXTs discovered by *INTEGRAL*

**How infrared observations allow to unveil the most obscured high energy objects of our Galaxy…**

Sylvain CHATY

(Université Paris 7 / Service d'Astrophysique, France)

P. Filliatre, L. Pellizza, F. Rahoui, J. Rodriguez, J. Tomsick, R. Walter, J.A. Zurita Heras

INTEGRAL 5th Anniversary Workshop

**Sardenia, 18 October, 2007**

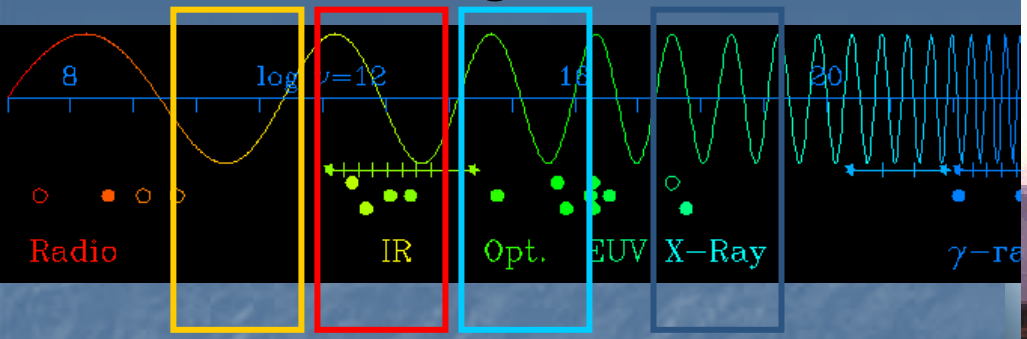
# Discovery of new high energy objects


- How to reveal their nature?
  - X/$\gamma$-ray localisation not accurate enough
  - Optical difficult: too much absorption in Galactic plane


=> Observe in INFRARED

Lebrun et al. 2004

# Multi-wavelength observations



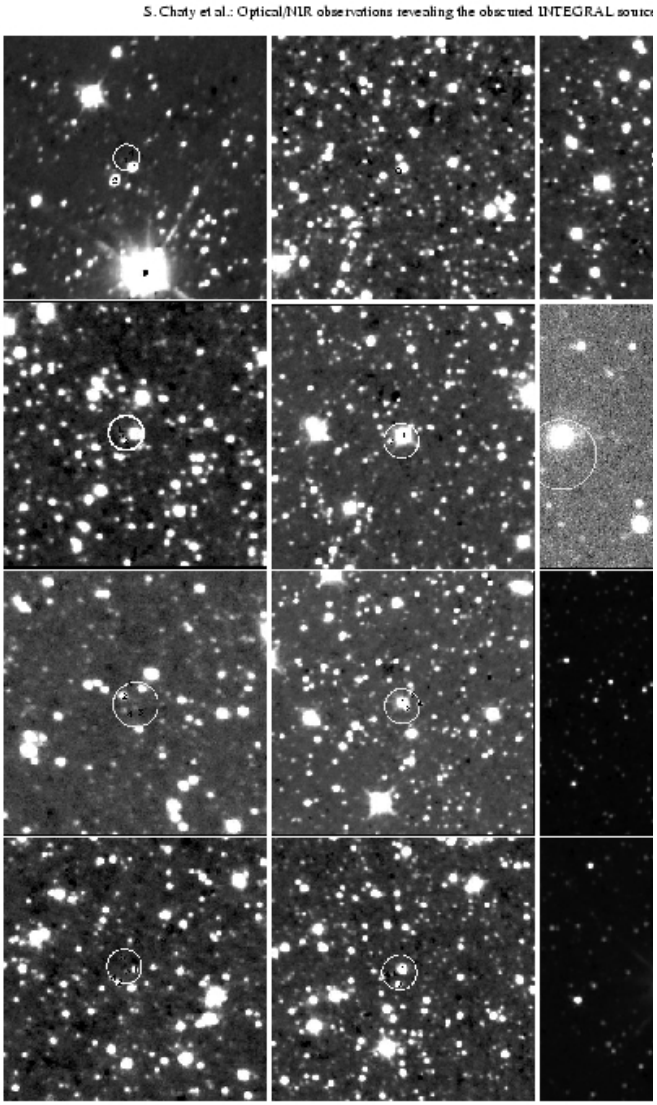

- From Space to Ground:
  - 20 INTEGRAL sources at **ESO (European Southern Observatory)**
  - Identification/nature of counterparts
  - ToO & Visitor mode (2004-2007)
  - Photometry/Spectroscopy:
    - Optical / Near-infrared (0.4-2.5μm):
      - La Silla (3.5m-NTT/EMMI-SOFI)
    - Mid-Infrared (5-20 μm):
      - Paranal (8m-VLT/UT3/VISIR)

Sample of studied INTEGRAL sources

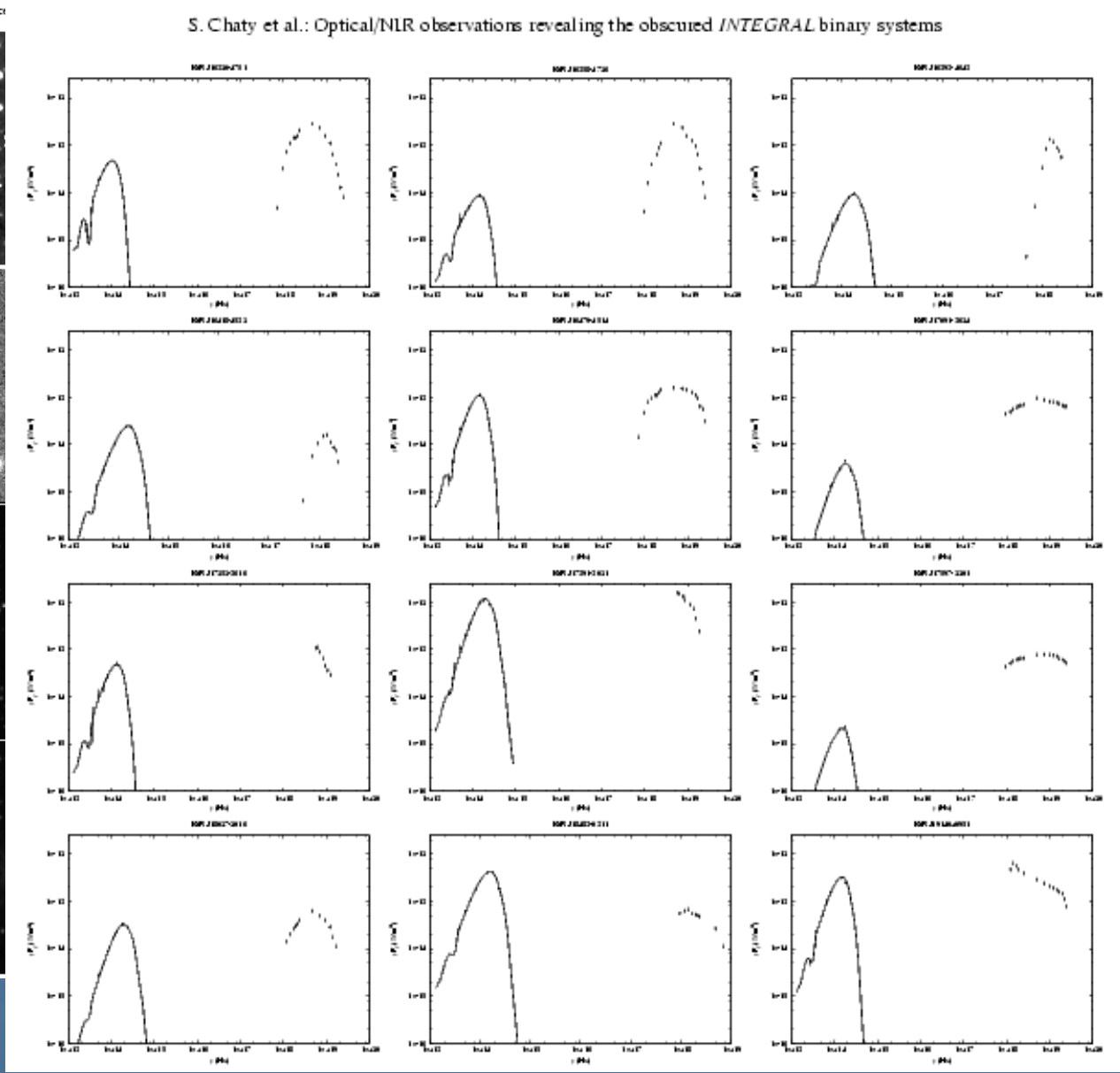
| Source | Region | Type | Pspin(s) | Porb(d) |
|---|---|---|---|---|
| IGR J16195-4945 | Norma | SFXT/OBS | | |
| IGR J16207-5129 | Norma | | | |
| IGR J16318-4848 | Norma | P, OBS | | |
| IGR J16320-4751 | Norma | T, OBS | 1250 | 9 |
| IGR J16358-4726 | Norma | T, OBS | 5880 | |
| IGR J16393-4641 | Norma | T | 912 | 3.6875 |
| IGR J16418-4532 | Norma | SFXT | 965 | 3.75 |
| IGR J16465-4507 | Norma | SFXT/OBS | 228 | |
| IGR J16479-4514 | Norma | SFXT | | |
| IGR J16558-5203 | - | AGN | | |
| IGR J17091-3624 | GC | BHC | | |
| IGR J17252-3616 | GC | P, OBS | 413 | 9.7 |
| IGR J17391-3021 | GC | SFXT | | |
| IGR J17544-2619 | GC | SFXT | NS | ? |
| IGR J17597-2201 | GC | LMXB | | |
| IGR J18027-2016 | GC | T | 139 | 4.57 |
| IGR J18483-0311 | GC | | | |
| IGR J19140+0951 | - | OBS | | 13.55 |

- Sample of 18 sources:
  - 2004 ESO NTT SOFI/EMMI
  - 2005/2006/2007 VLT/VISIR
- NIR Astrometry
- Opt/NIR/MIR Photometry & Spectroscopy
- Chaty et al., subm.
- Rahoui, Chaty et al., subm.

# Optical to MIR results

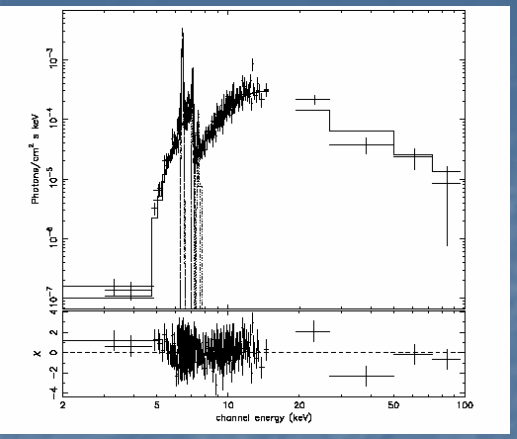



NIR astrometry, photometry, spectroscopy

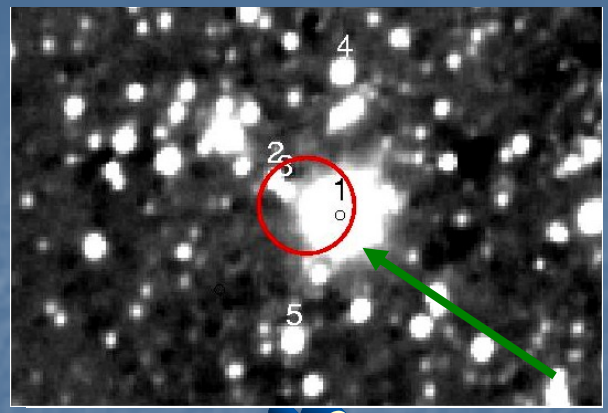



Optical->MIR SEDs

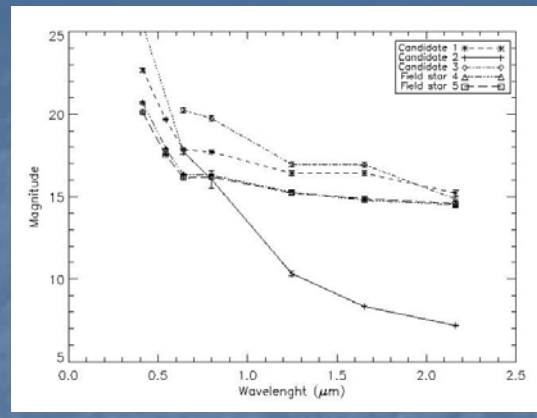
# The obscured source IGR J16318-4848




EPIC PN/MOS2 & ISGRI
(Matt & Guainazzi 2003; Walter et al. 2003)




Target of Opportunity

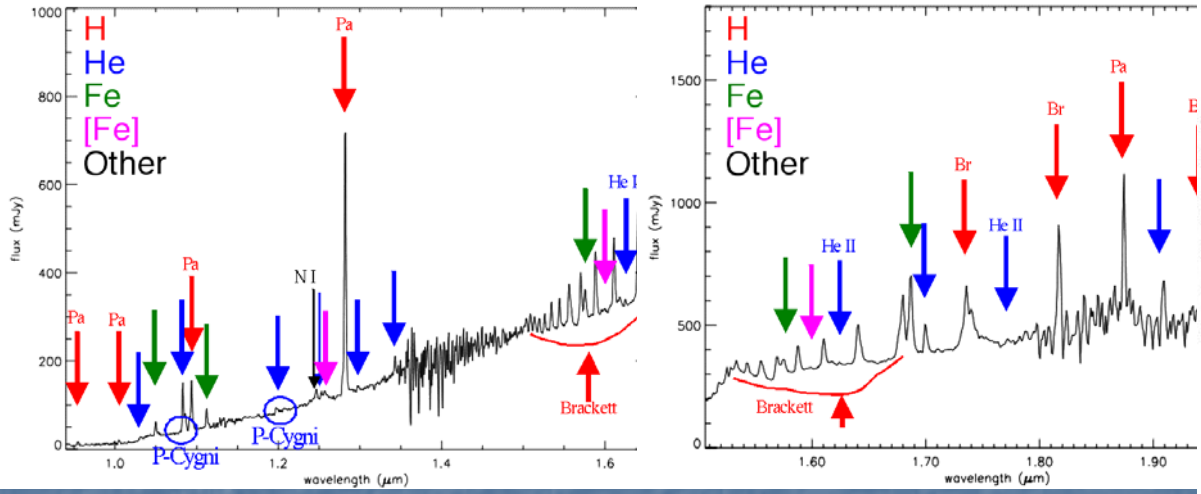


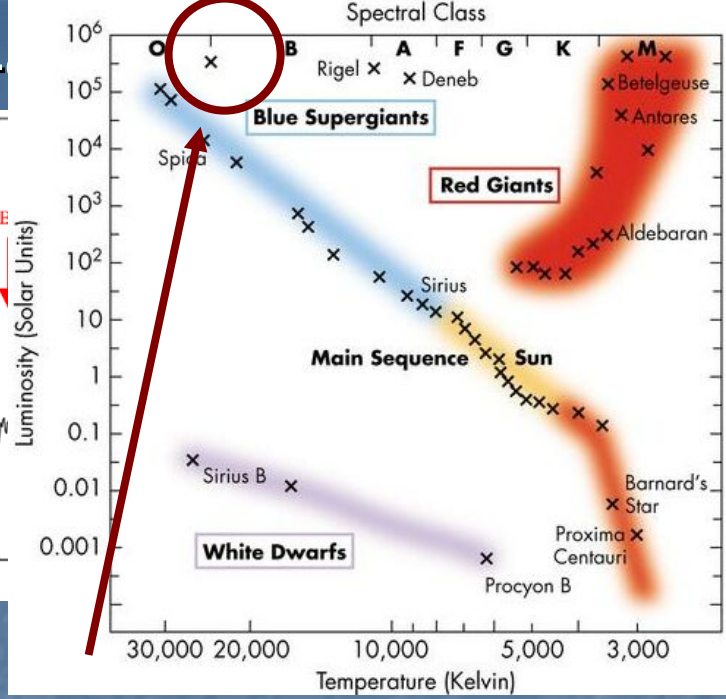

- 1st INTEGRAL/IBIS source discovered 29 January 2003 (2' unc.)
  - XMM-Newton: comptonised spectrum, strong absorption ($N_h$=1.84x10$^{24}$ cm$^{-2}$)
- Discovery of the optical counterpart, confirmation of NIR (23/02/2003)
  - B>25.4+/-1; I=16.05+/-0.54, Ks=7.20+/-0.05
- Unusual 17.4 mag opt/NIR absorption
  - 100x stronger than interstellar; but 100 x lower than X-rays!
  - Material absorbing in X-rays concentrated around compact object



Chaty & Filliatre, Ap&SS, 2005
Filliatre & Chaty, ApJ, 2004

# The obscured source IGR J16318-4



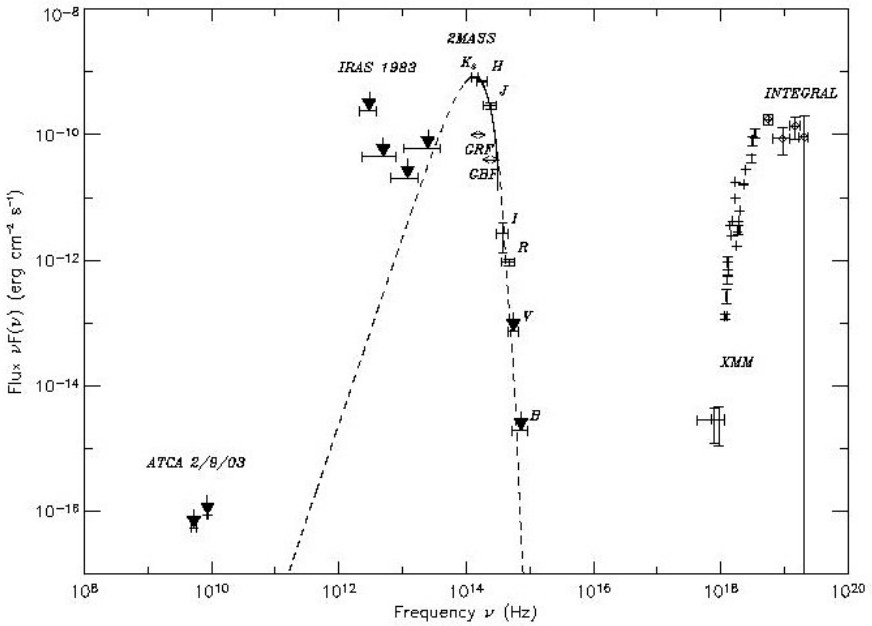



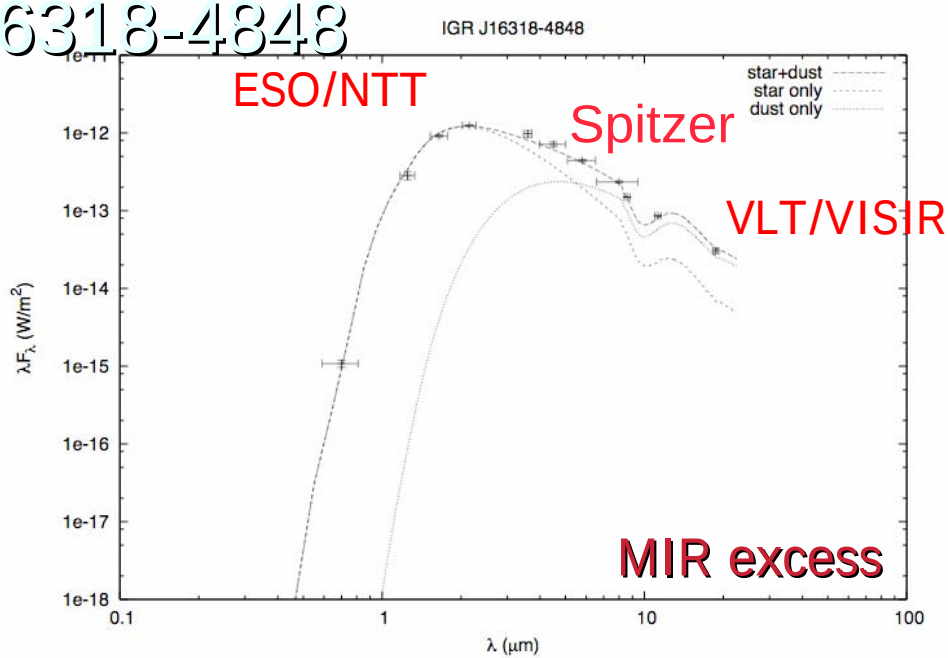

- Unusual NIR spectrum: many strong emission lines:
  - complex, stratified circumstellar environment + enveloppe, wind...
    ⇒luminous supergiant star: sgB[e]: sgHMXB

- VLT MIR spectrum: many emission lines (H, He, Ne, PAH, Si)
  - Cocoon of dust enshrouding IGR

QuickTime™ et un décompresseur TIFF (non compressé) sont requis pour visionner cette image.

# The obscured source IGR J16318-4848

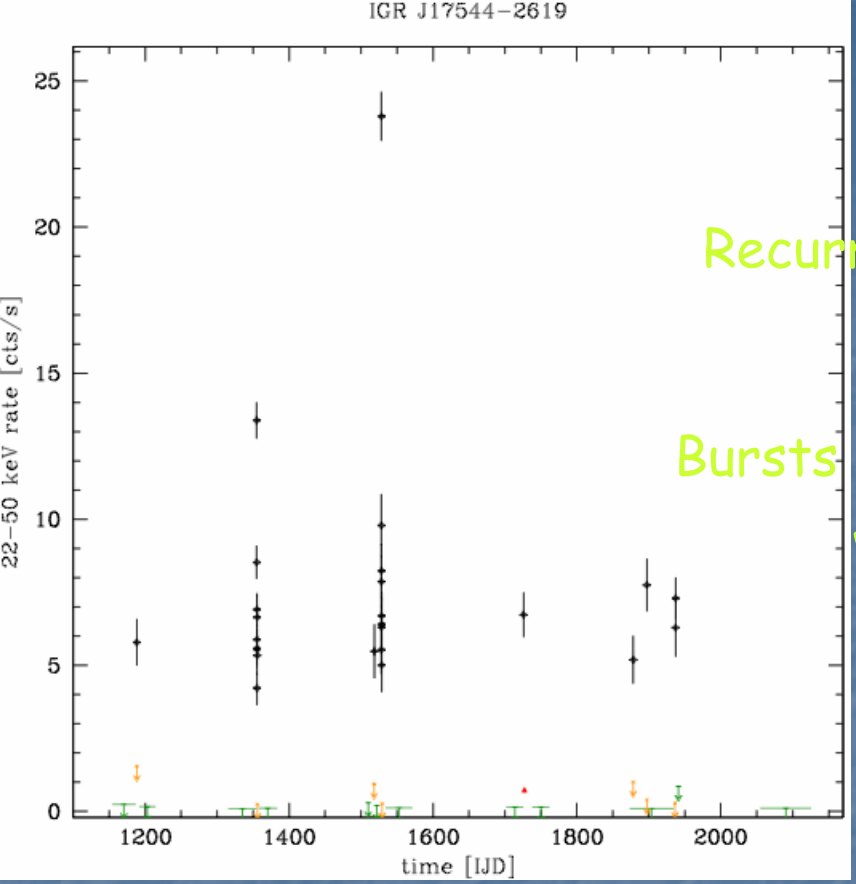



Chaty & Rahoui, INTEGRAL proc. 2006

- Fit parameters:
  - L ~ $10^6$ $d^2_{6kpc}$ $L_\odot$; T = 23 500 K; M = 30 $M_\odot$
  - High L, T, M: Supergiant star @ 6 kpc
  - Unusual absorption Av = 17.5 mag: dust cocoon
- HMXB system:
  - Supergiant star: sgB[e], T=23500 K, R=20.5$R_\odot$ = 15x$10^6$km
  - +Cocoon of dust/cold gas: T=900K, R=11.9$R_*$ = 1a.u.

Extra component (dust cocoon) enshrouding the whole binary system




Zurita Heras & Chaty in prep.

# The SFXT IGR J17544-2619

Recurrent transient X-ray source discovered by INTEGRAL (09/2003)
(Sunyaev et al. 2003, ATel 190)

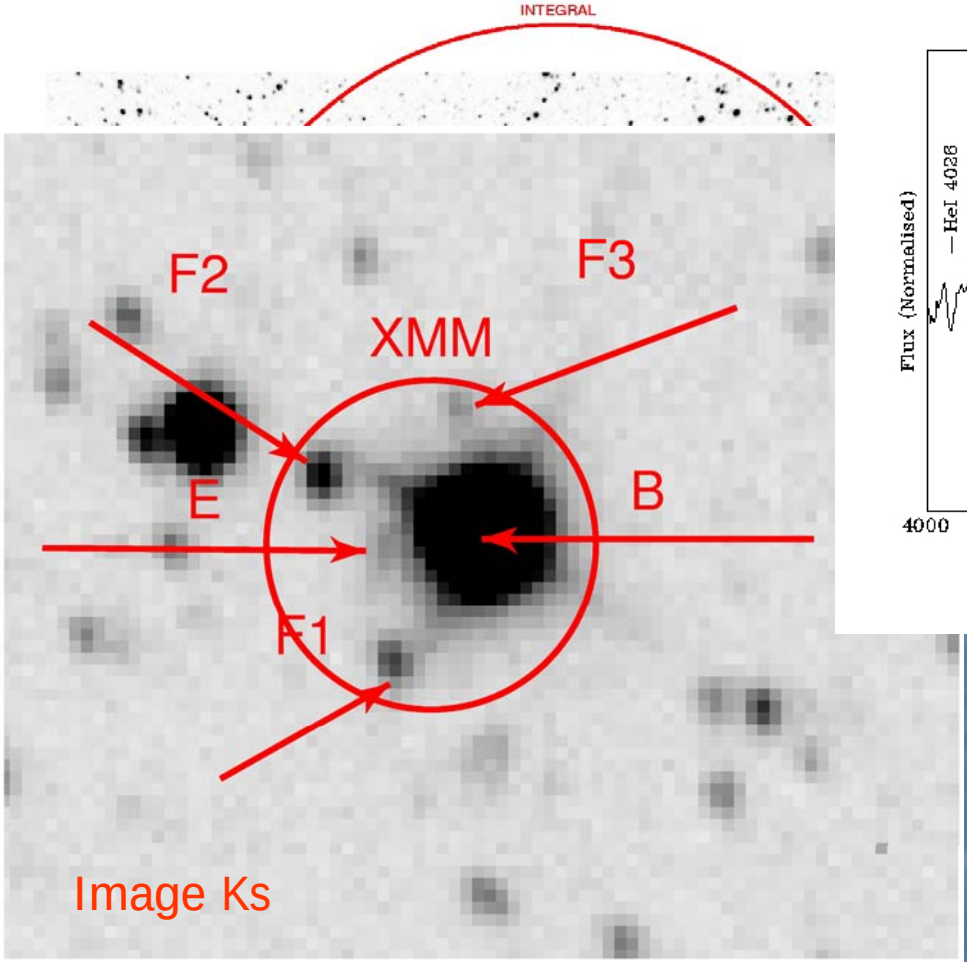
Bursts last ~hours, long quiescence periods (70d)

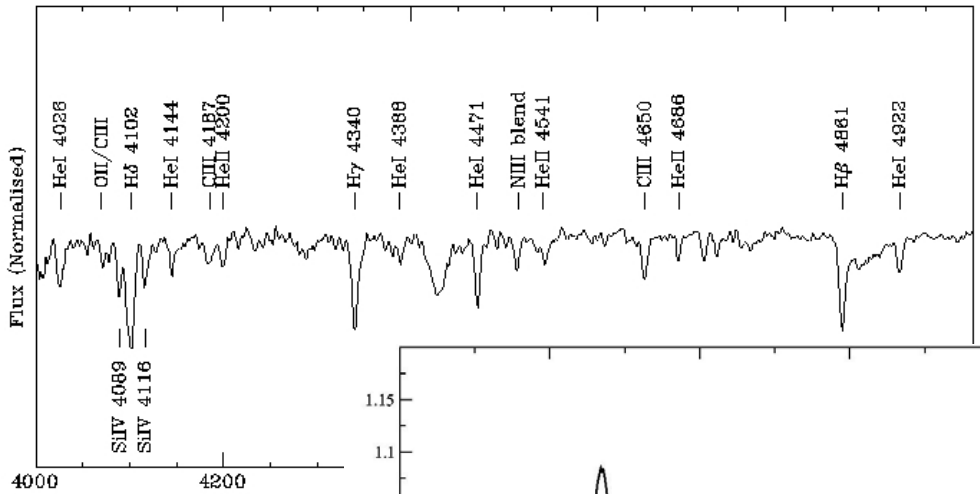
Very hard X-ray spectrum, Faint intrinsic absorption (Nh~2 $10^{22}$cm$^{-2}$)
(Gonzalez-Riestra et al. 2004, A&A 420, 589)

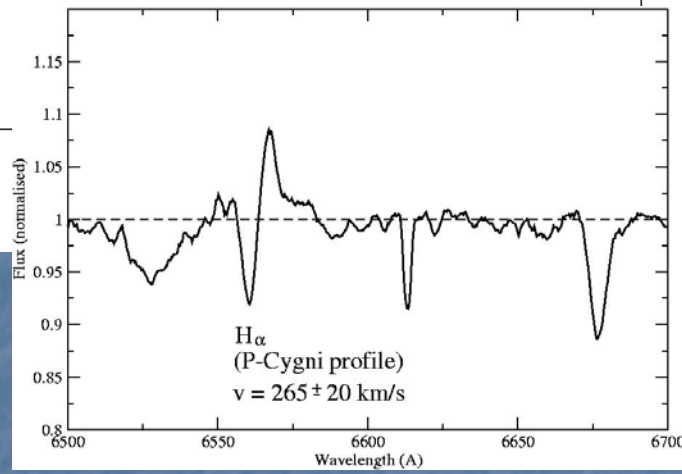
Compact object: likely neutron star
Distance 3-4 kpc
(in't zand 2005)

- Archetype of "SFXTs": Supergiant Fast X-ray transients:
  - O/B supergiant companions,
  - Compact object = BH or NS,
  - Outbursts lasting only hours,
  - Faint quiescent emission

# The SFXT IGR J17544-2619




Opt/NIR ToO 1 day after discovery!

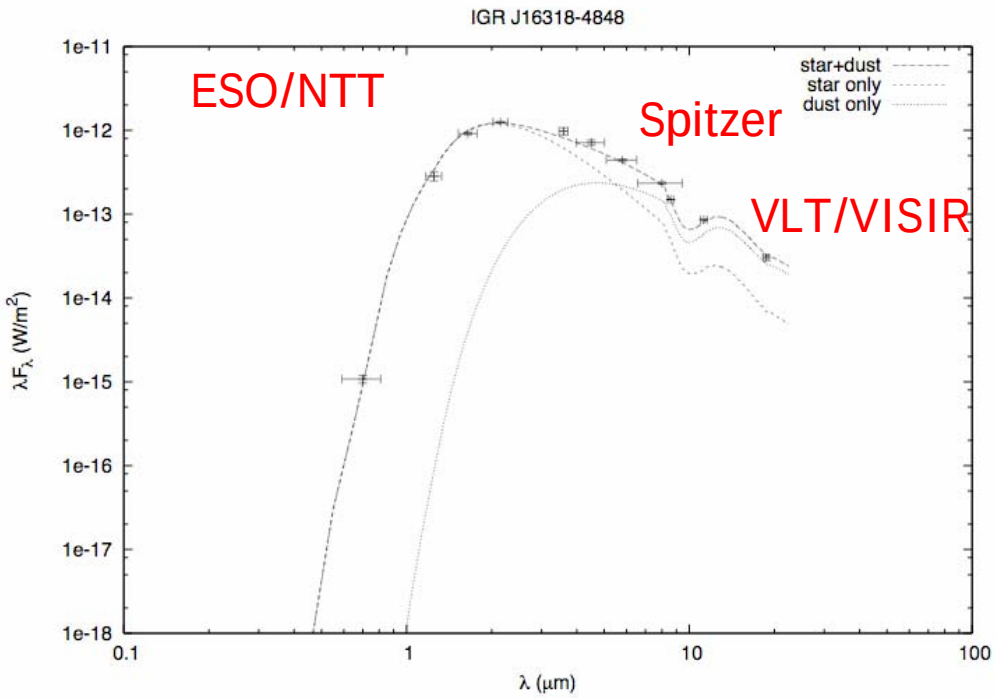
- Blue sgO9 Ib (25-28 $M_\odot$, T~32000K)
  - with stellar wind: 265 ± 20 km/s (unusually low for O stars)

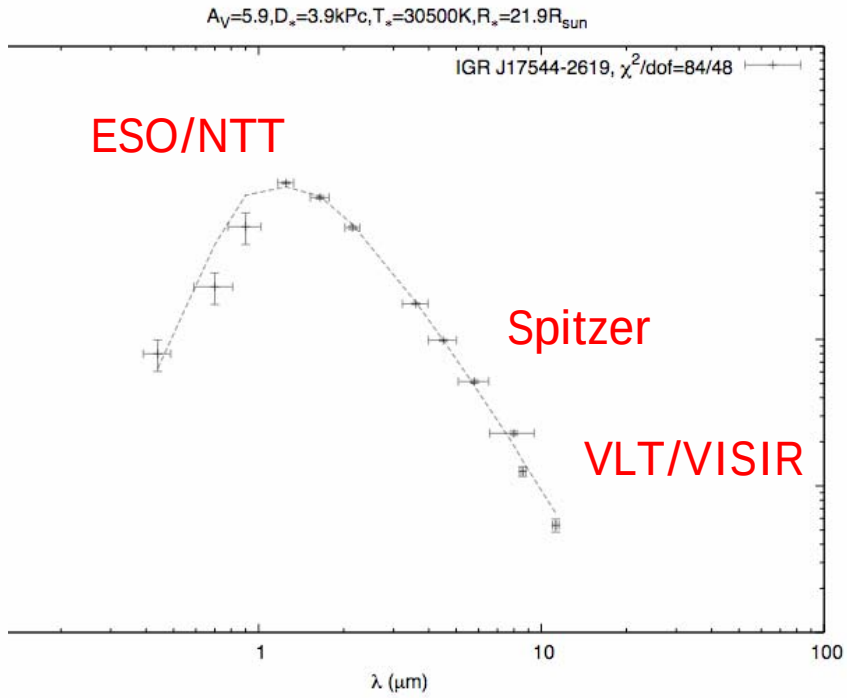
=> Supergiant HMXB



Pellizza, Chaty, Negueruela, 2006, A&A

# Obscured vs SFXTs: dusty or not dusty?




- IGR J16318-4848:
  - Companion star: sgB[e]

    T=23500K, R=20 $R_\odot$
  - + Cocoon of Dust: T=900K, R=12$R_*$

  (Filliatre & Chaty, 2004, ApJ; Chaty & Rahoui 2006)

- IGR J17544-2619:
  - Companion star: O9Ib

    T=30500K, R=22$R_\odot$, Av=5.9, D=3.9kpc

    Fit result: $\chi^2$/dof=84/48
  - No need for extra component

    (Pellizza, Chaty, Negueruela, 2006; Chaty & Rahoui 2006, INTEGRAL proc.)

# Summary of results

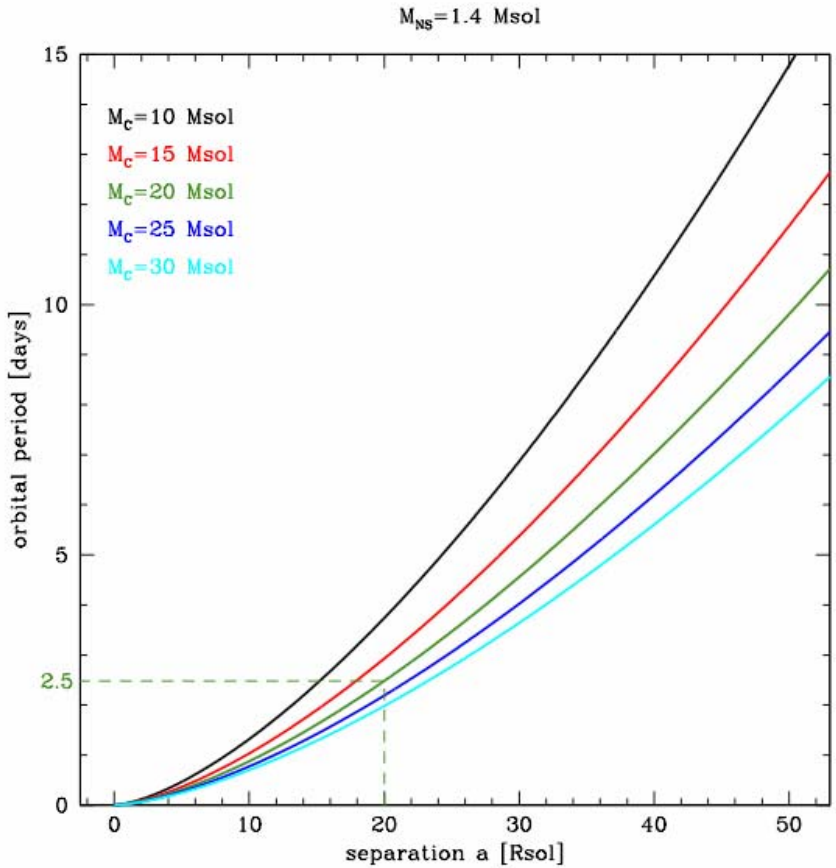
| Source | Spectral type | Nhi | NhV | NhX | Star T (K) | Star R (R*) | Dust T (K) | Dust R (R*) |
|---|---|---|---|---|---|---|---|---|
| IGR J16195-4945 | OB | 2.18 | 2.9 | 7 | 23100 | 22.6 | 1160 | 6.1 |
| IGR J16207-5129 | B0I | 1.73 | 2 | 3.7 | 32500 | 21.2 | | |
| IGR J16318-4848 | sgB[e] | 2.06 | 3.3 | 200 | 23500 | 20.5 | 1100 | 11.9 |
| IGR J16320-4751 | OBI | 2.14 | 6.6 | 21 | 32600 | 22.6 | | |
| IGR J16358-4726 | sgB[e]? | 2.20 | 3.3 | 33 | 24800 | 20.5 | 810 | 10 |
| IGR J16393-4643 | BeV | 2.2 | <2.7 | 24 | | | | |
| IGR J16418-4532 | OBI | 1.88 | 2.7 | 10 | 27000 | 20.2 | | |
| IGR J16465-4507 | B0.5I | 2.12 | 1.1 | 60 | 27500 | 20.1 | | |
| IGR J16479-4514 | OBI | 2.14 | 3.4 | 7.7 | 32000 | 20.3 | | |
| IGR J16558-5203 | AGN Sy1.2 | | | | | | | |
| IGR J17091-3624 | HMXB | 0.77 | 1.03 | 1.0 | | | | |
| IGR J17252-3616 | OB | 1.56 | 3.8 | 15 | 30000 | 20.6 | | |
| IGR J17391-3021 | O8Iab(f) | 1.37 | 1.7 | 30 | 32100 | 22.9 | | |
| IGR J17544-2619 | O9Ib | 1.44 | 1.1 | 1.4 | 30700 | 22 | | |
| IGR J17597-2201 | LMXB | 1.2 | <2.9 | 5 | | | | |
| IGR J18027-2016 | OBI | 1.1 | <2.1 | 9 | | | | |
| IGR J18483-0311 | OB | 1.62 | 2.45 | 28 | | | | |
| IGR J19140+0951 | B0.5I | 1.68 | 2.9 | 6 | 20000 | 21.2 | | |



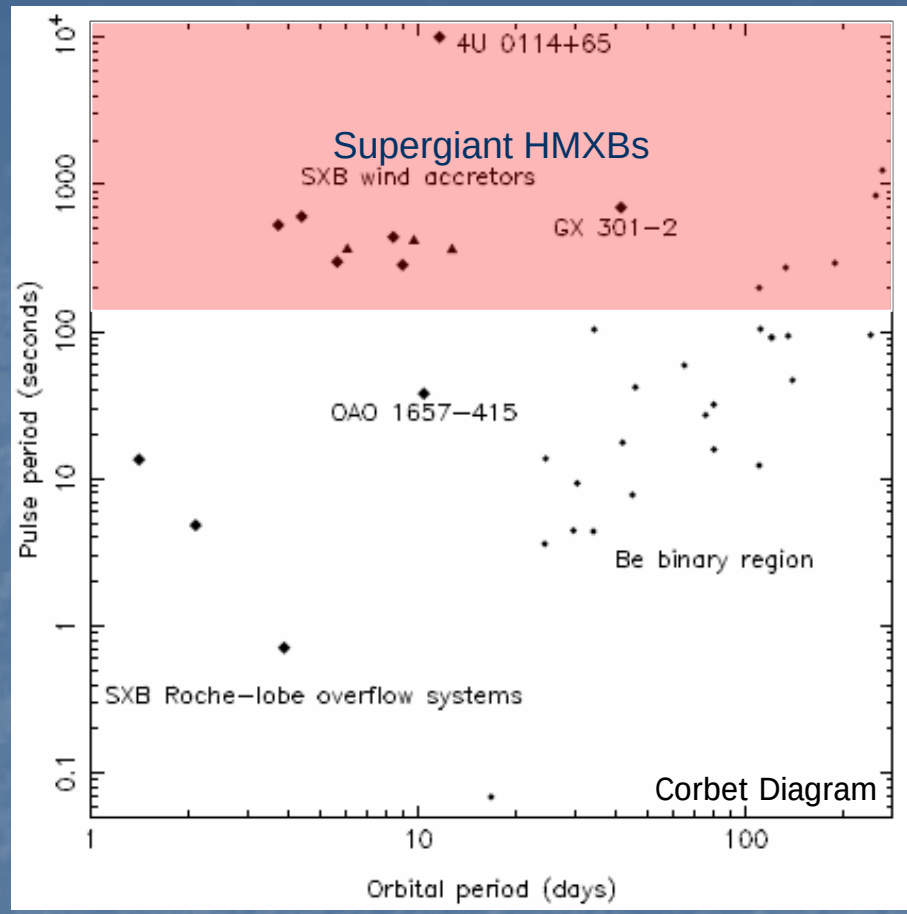
Chaty et al. subm.; Rahoui, Chaty et al. subm.

# Nature of INTEGRAL HMXBs

- X-ray pulsars, high $P_{spin}$
  $P_{orb}$=10d, M=20$M_\odot$, a=50$R_\odot$ <$R_{dust}$
  ($R_{dust}$=240$R_\odot$ for IGR J16318)



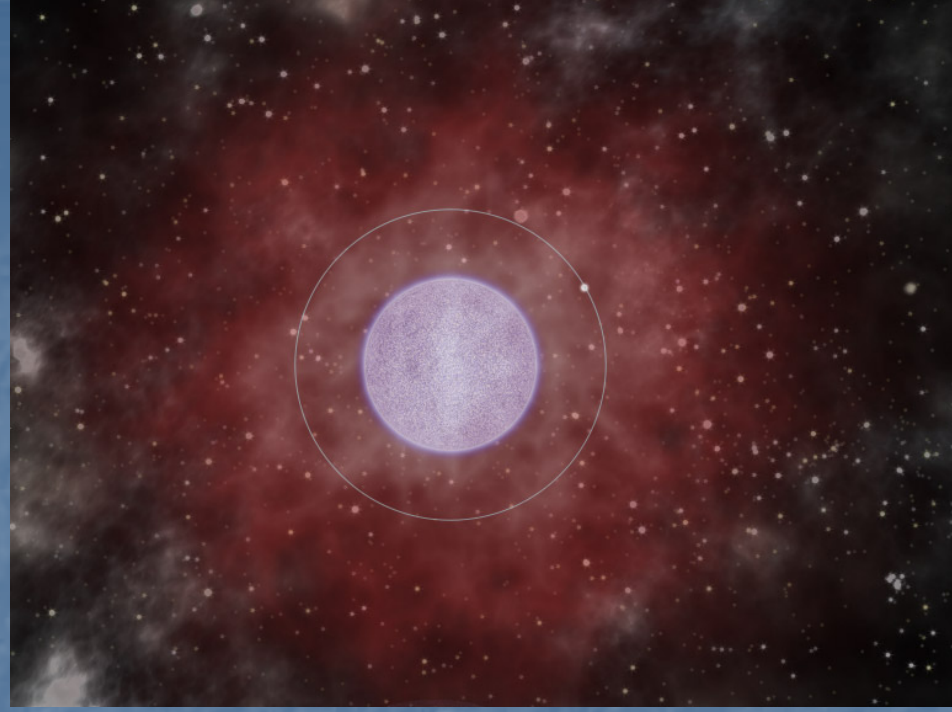

Courtesy J.A. Zurita Heras

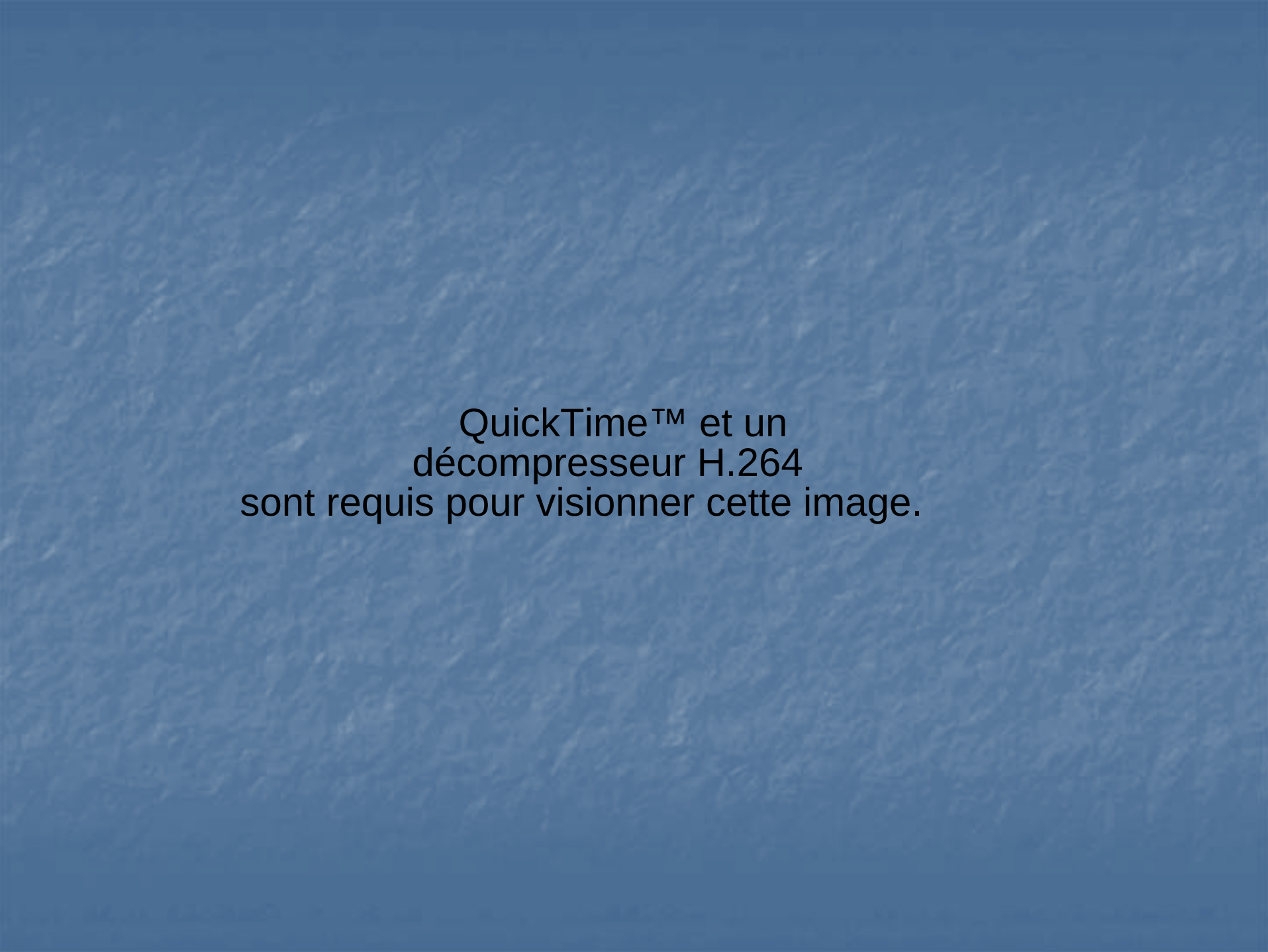



- HMXBs $P_{spin}$ vs $P_{orb}$:
  - Be Binaries
  - sg Roche lobe overflow systems
  - sg wind accretors

# Different geometries, different scenarii

- Presence of dust cocoon:
  - 1) Enshrouding the whole system (obscured HMXBs ~IGR J16318):
    - NS orbits within the cocoon: persistent X-ray emission
    - Extension ~10R* - 1 a.u.
  - 2) Only around the star:
    - Eccentric orbit, NS crosses the cocoon: transient X-ray flares?
- No dust cocoon: (~IGR J17544)
- The answer will be given by $P_{orb}$…




QuickTime™ et un
décompresseur H.264
sont requis pour visionner cette image.

# Conclusions and prospects...

- INTEGRAL tripled the sgHMXBs known in our Galaxy revealing a class of highly absorbed binaries.

- Common characteristics:
  - sgO/B HMXBs + NS with high $P_{spin}$
  - Associated to rich SFRs

- Differences:
  - Absorption around NS or whole system (MIR excess)
  - X-ray transient/persistent
  - Spectral types & circumstellar environment

- This population questions formation/evolution of HMXBs:
  - Birth of 2 massive components in rich SFRs?
  - Primary progenitors of NS/NS or NS/BH mergers:
    - Gravitational wave emitters? / Link with short/hard GRBs?

**Multi-wavelength study decisive to unveil the nature of high-energy objects...**