Transient phenomena in Young pulsars, low-mass X-ray binaries, and binary millisecond pulsars

Nobuyuki Kawai
(Tokyo Tech)

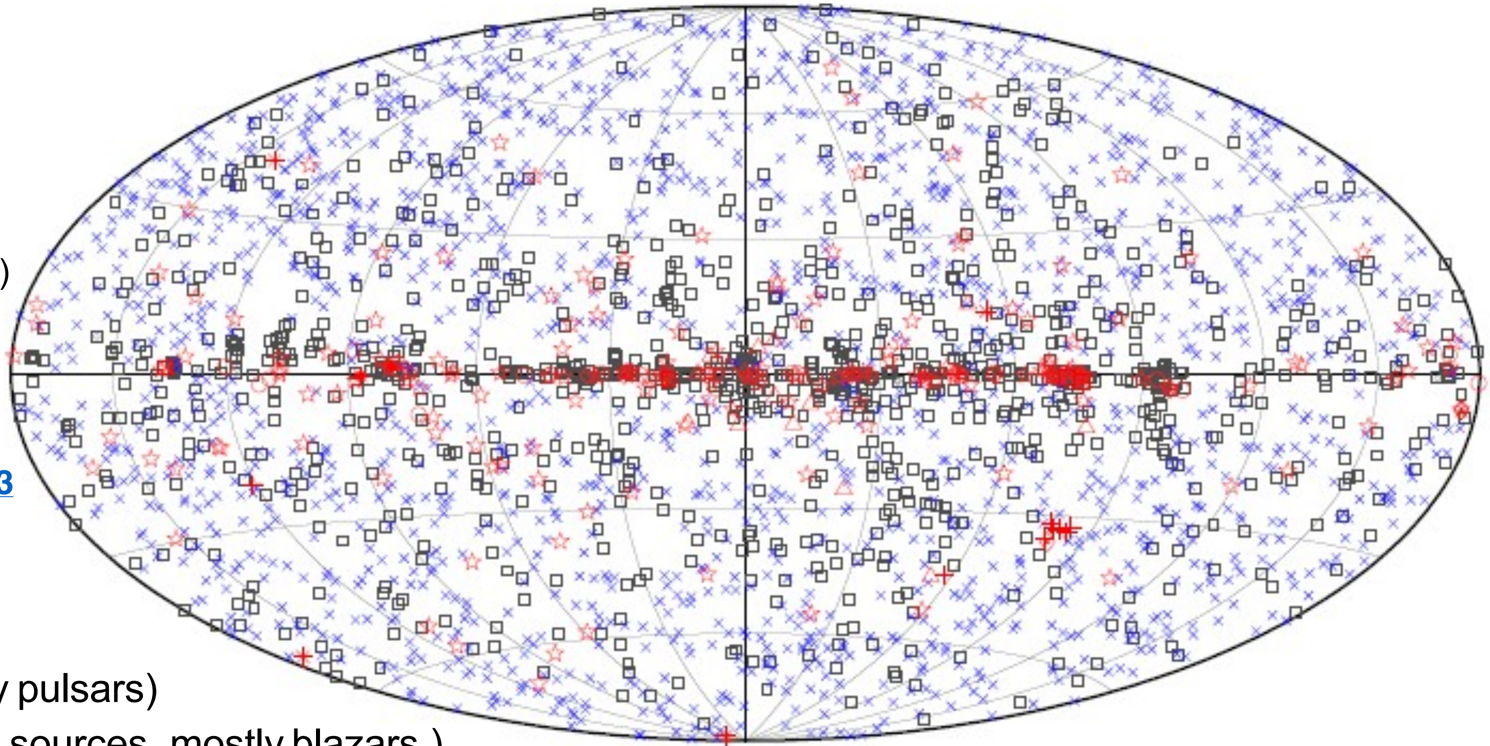
Contents

- 2FGL J2339.6-0532 – Black widow pulsar
  - mode switch from rotation-powered pulsar to intermittent accretion?
  - Simultaneous radio-X-ray observation needed
- PSR J2022+3842 – A young gamma-ray pulsar
  - results from Fermi LAT (by Haruka Ohuchi)
- PSR B1259-63 – Be star - pulsar system
  - results from MAXI/GSC (by Yuki Ono)
- Rapid Burster (X1730-335) – low-mass binary
  - draining matter to multi-pole sink?

3FGL

3rd LAT source catalog

Acero et al. ApJS 218, 23 (2015)

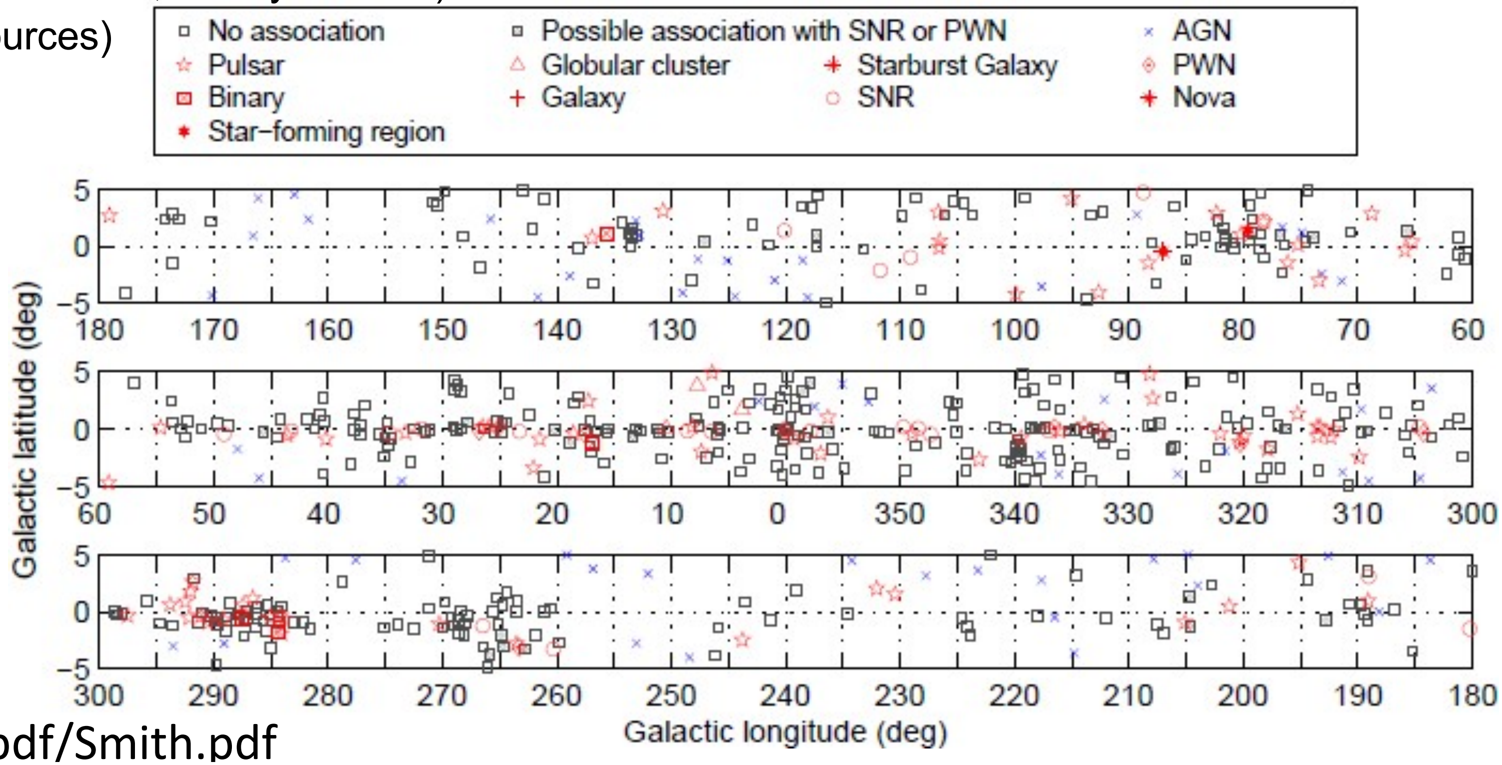


http://arxiv.org/abs/1501.02003

3033 total sources (>4*s*)

Red: Firm I.D. (232, mostly pulsars)
Blue: ‘Association’ (> ⅓ of sources, mostly blazars.)
Black: No I.D. (< ~⅓ of sources)

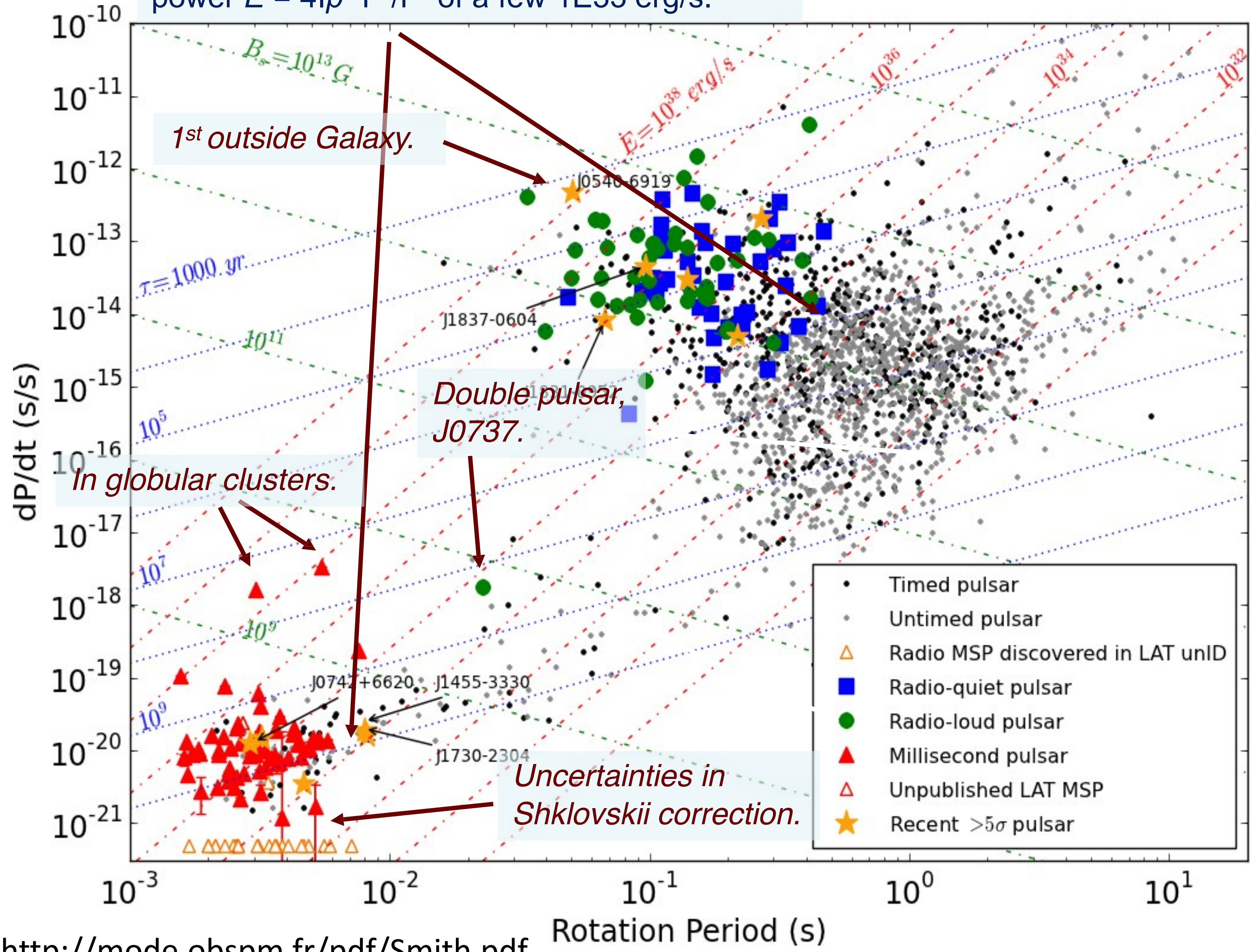
Un Id’s == *Gold* mine!



http://mode.obspm.fr/pdf/Smith.pdf

Gamma-ray deathline seems near spin-down power $\dot{E} = 4I p^2 \dot{P} / P^3$ of a few 1E33 erg/s.

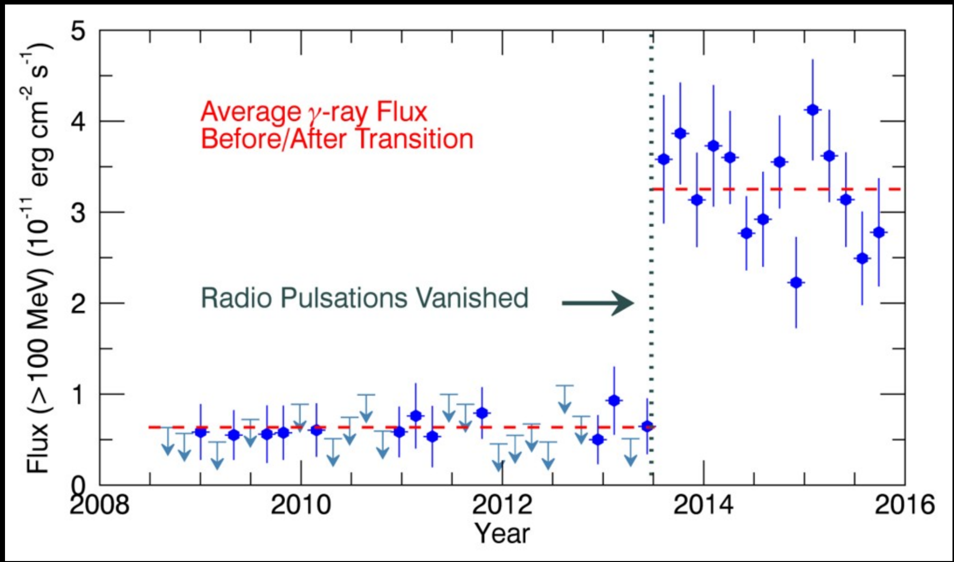
Update of 2PC Fig 1.



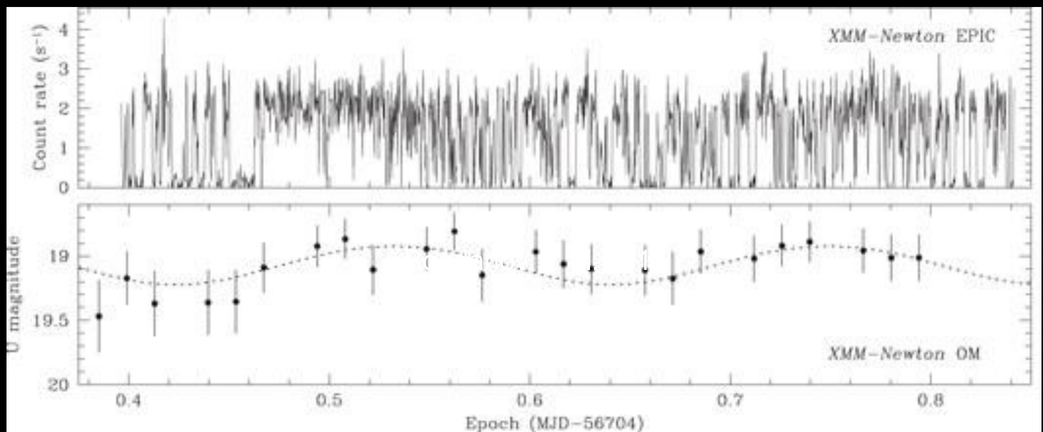
http://mode.obspm.fr/pdf/Smith.pdf

Transitional Millisecond Pulsars

Gamma-ray Transition of PSR J1023+0038



X-ray and U Band Light Curves of 3FGL J1544.6-1125



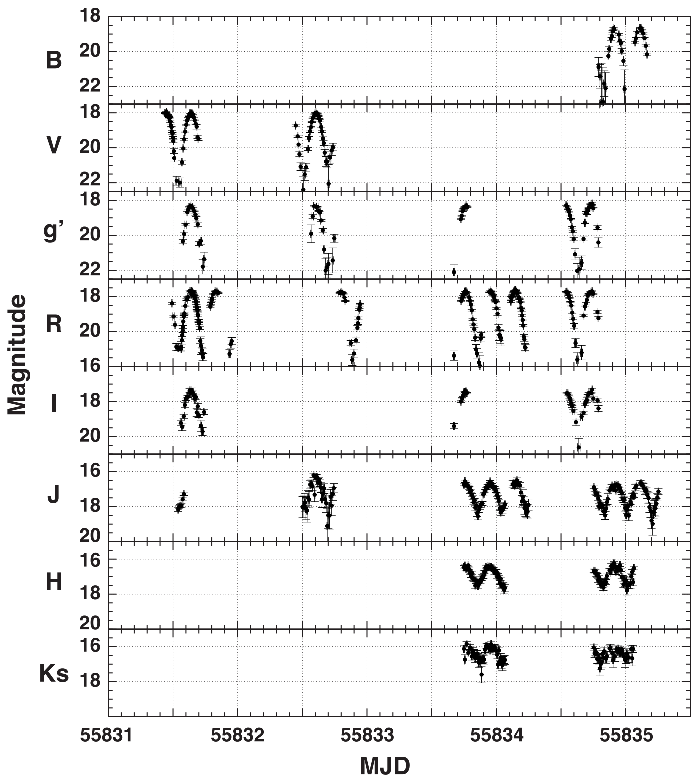
- 40% of MSPs discovered in searches of LAT sources are interacting binaries (`black widows' and `redbacks')
- Prior to *Fermi* only 1 redback and ~6 black widows were known outside of globular clusters (now ~12 and 24)
- More expected - LAT already detected two transitions between accreting and radio MSP states
- γ-ray emission brighter in the accreting state – a mystery since accreting sources are *not* typical γ-ray emitters. What is the mechanism?
- Optical searches of LAT sources have revealed new candidates

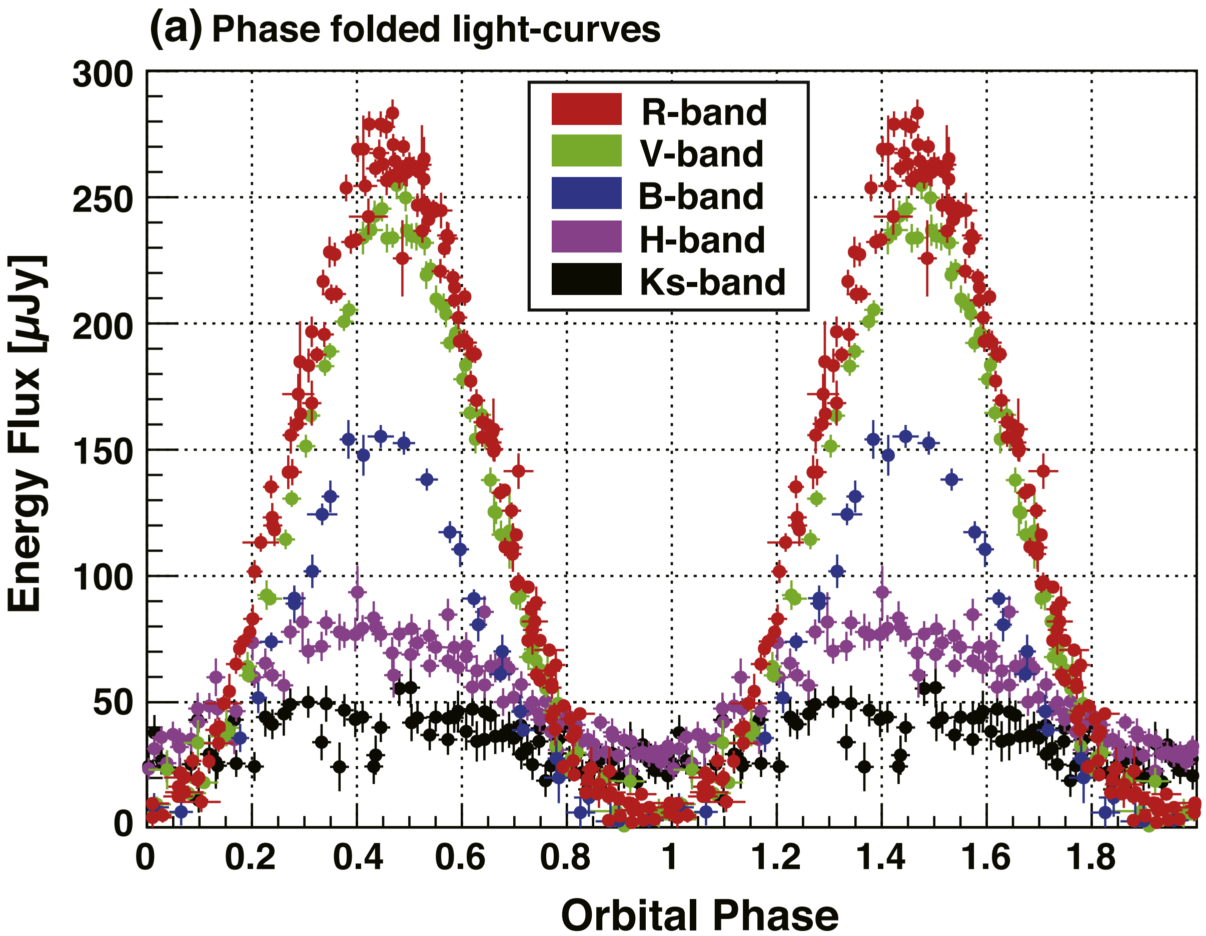
A new area of study for *Fermi*

http://mode.obspm.fr/pdf/Smith.pdf

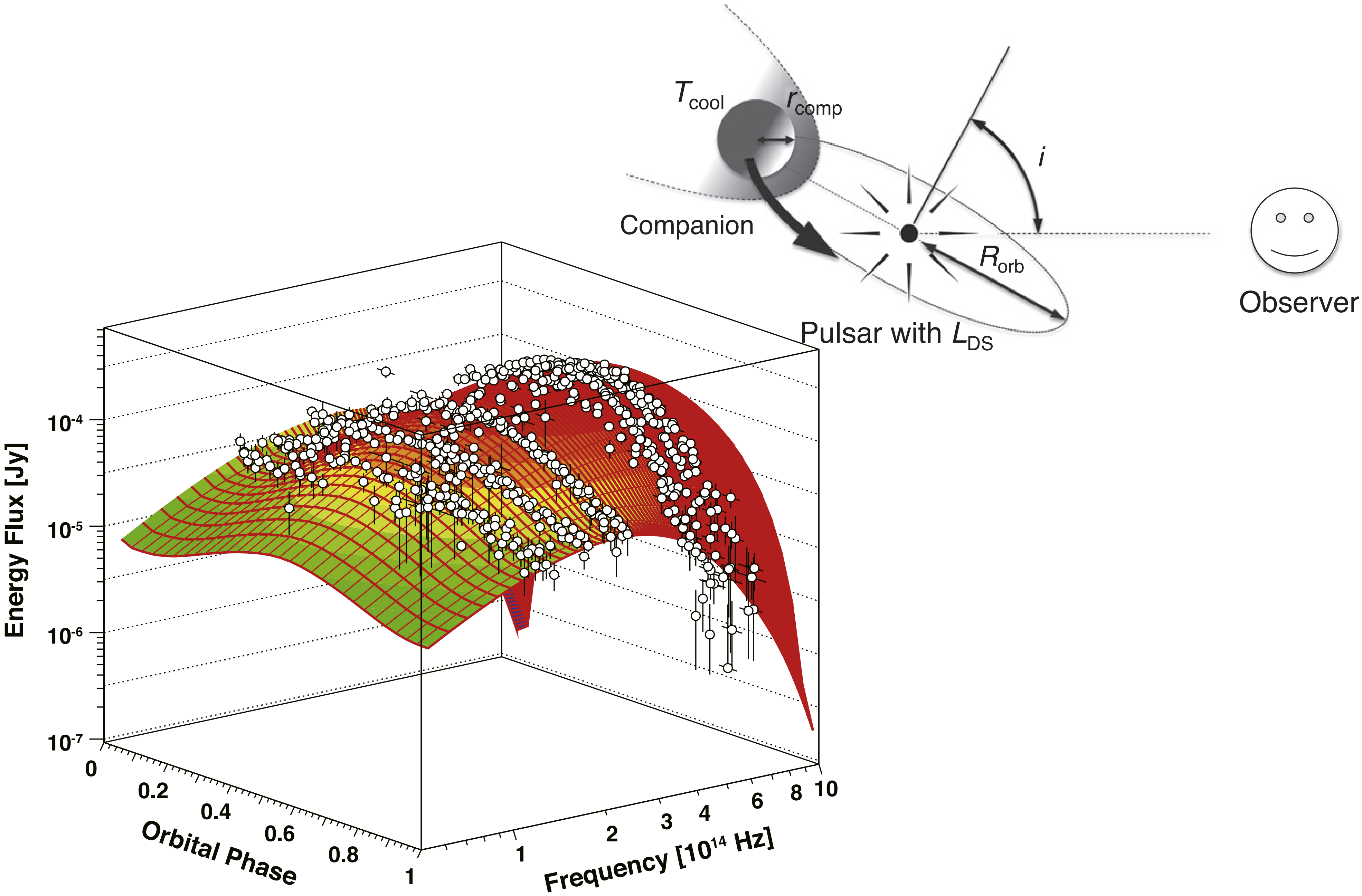
2FGL J2339.6-0532

Optical period: 4.63 h
Pulse period: 2.88 ms
L(Spin-down): 2.3×10^{34} erg/s



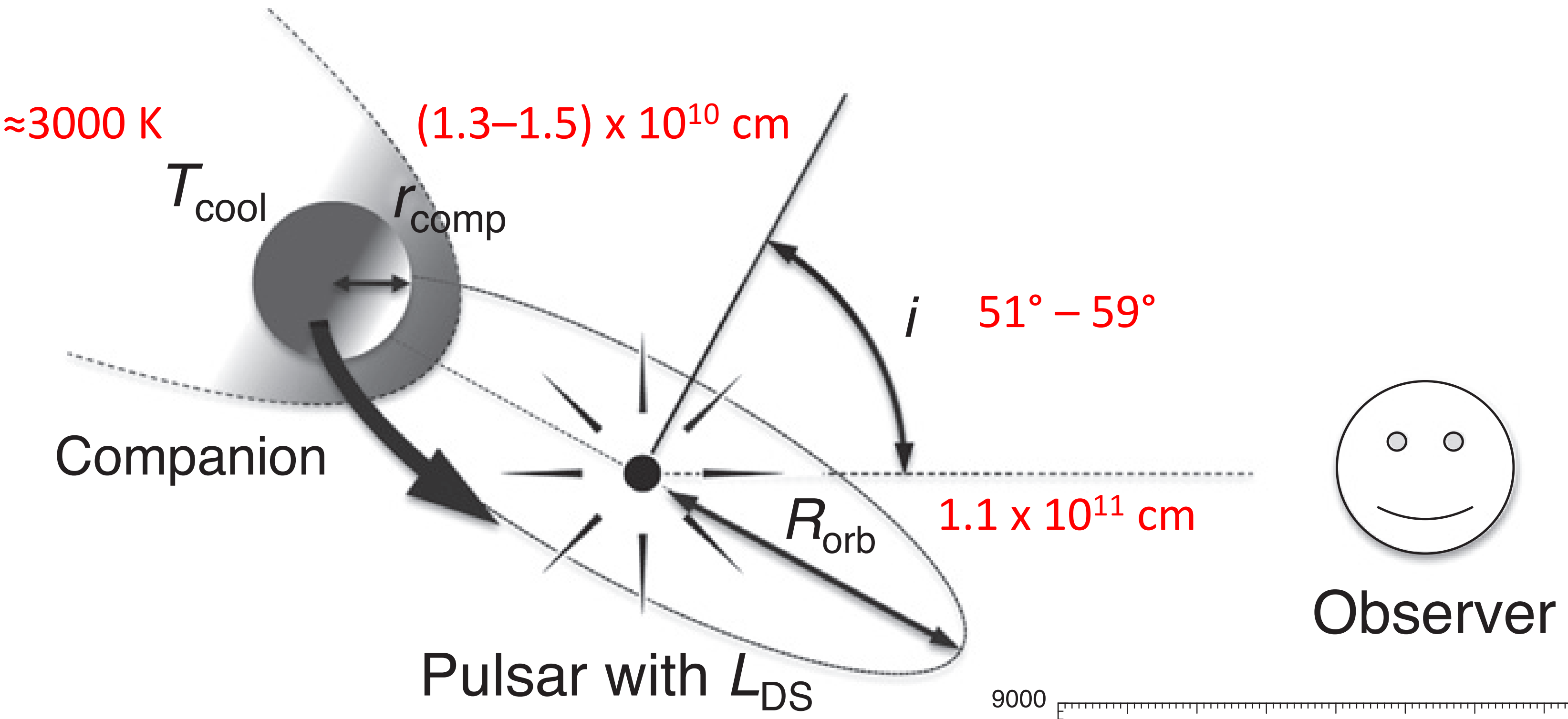


Yatsu et al. 2015

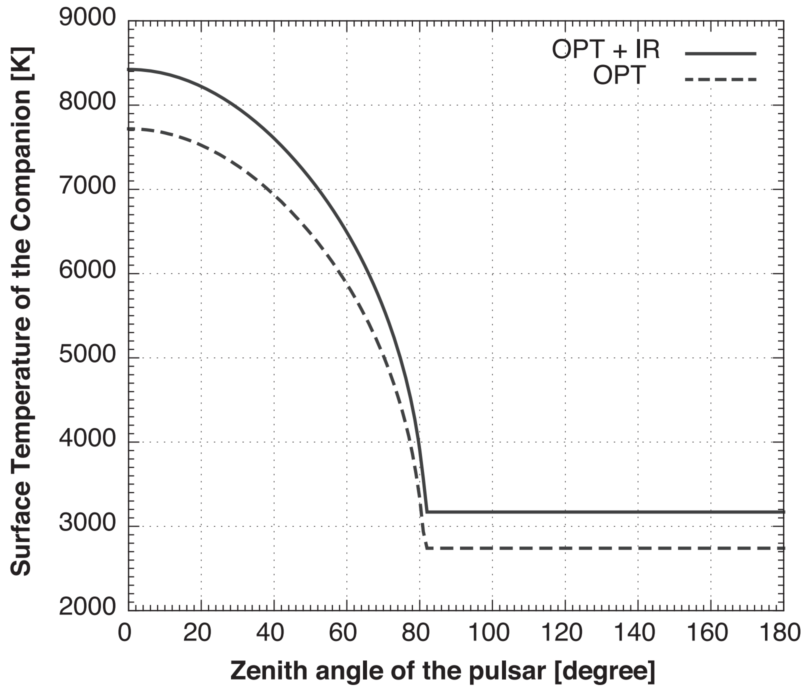


2FGL J2339.6-0532

Yatsu et al. 2015

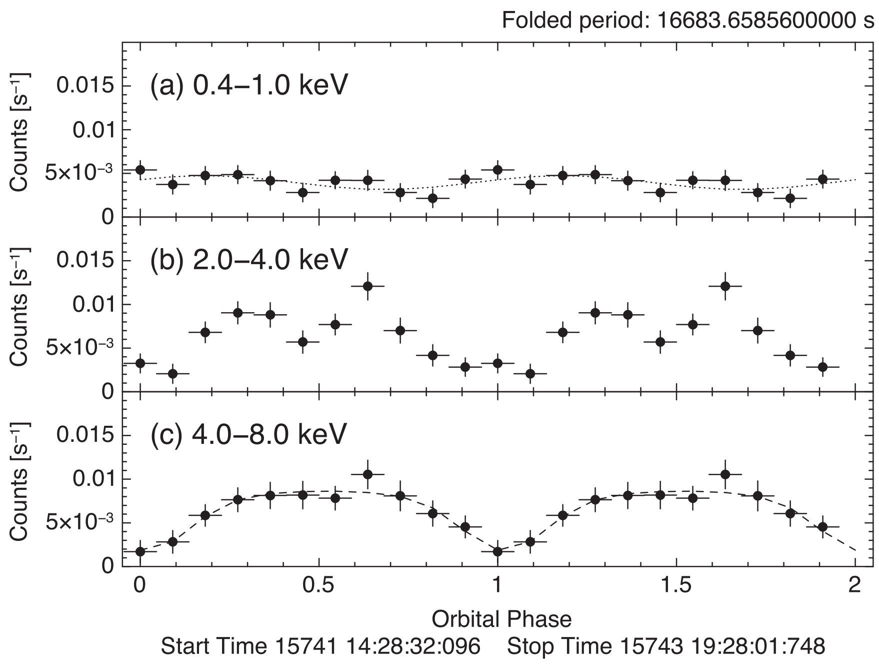


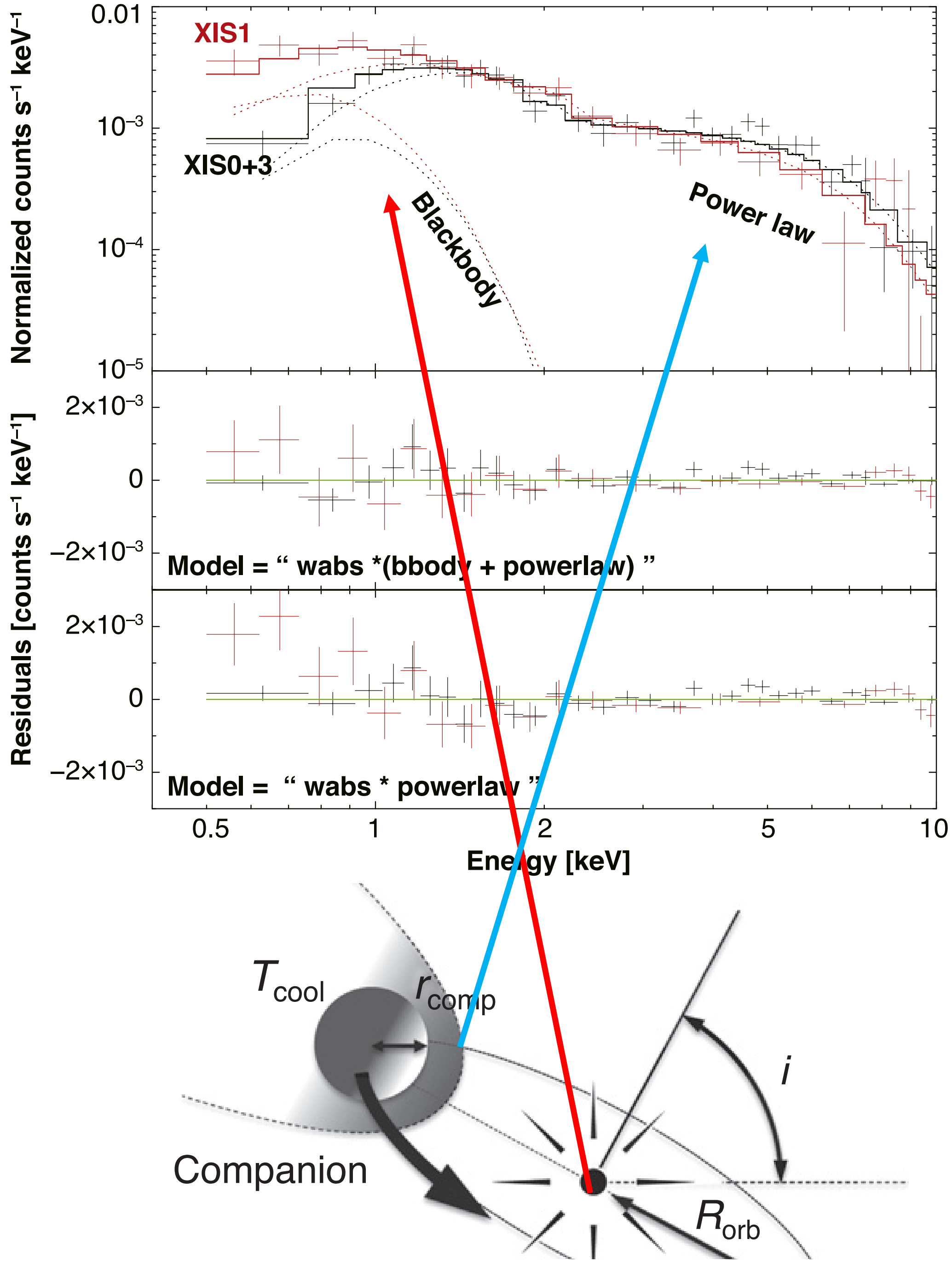
$L(\text{heated}) \approx 1.1 \times 10^{32}\ d_{1.1}^{\ 2}$ erg/s



2FGL J2339.6-0532

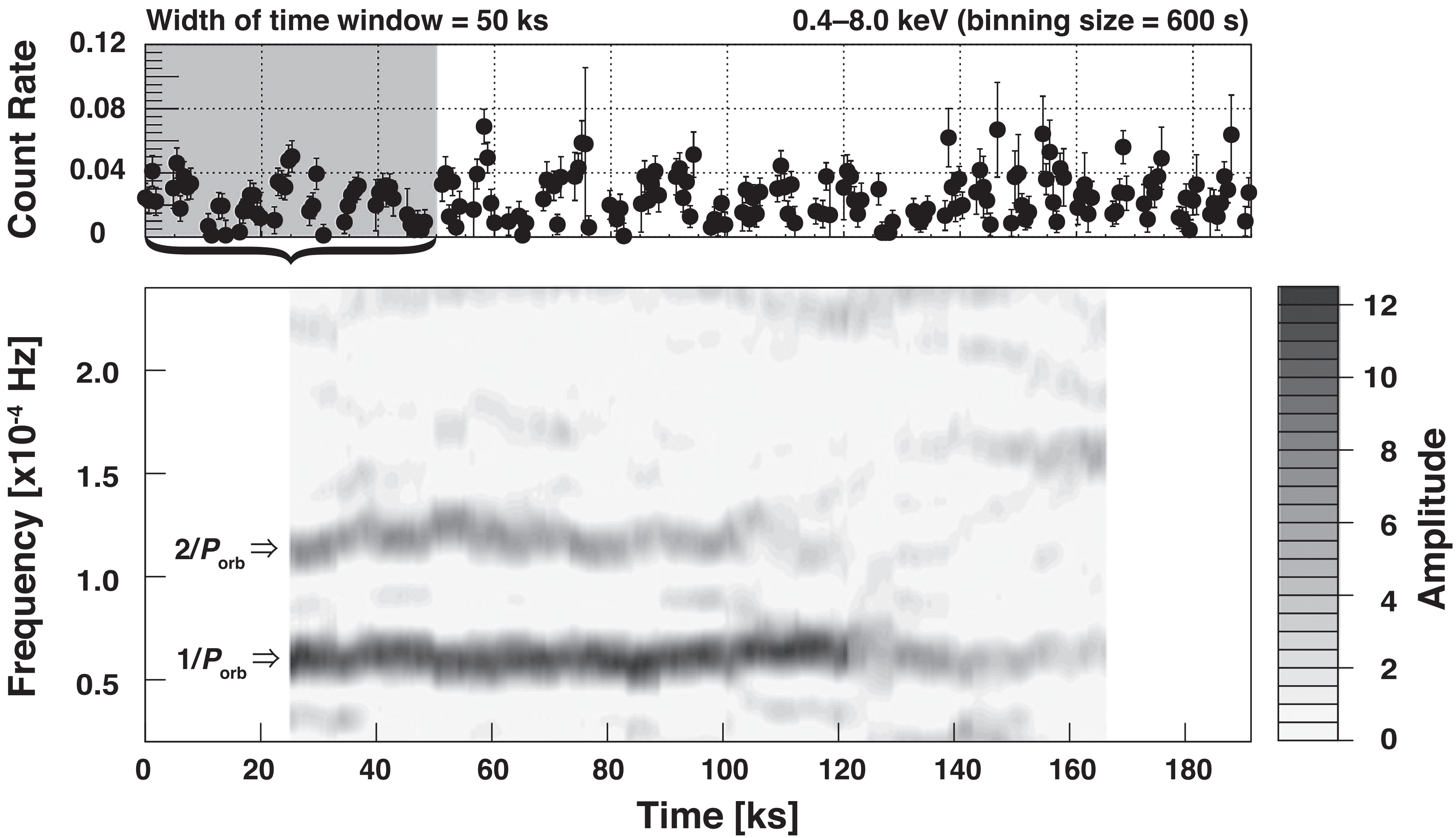
Yatsu et al. 2015





2FGL J2339.6-0532 — X-ray spectra and light curve

Yatsu et al. 2015



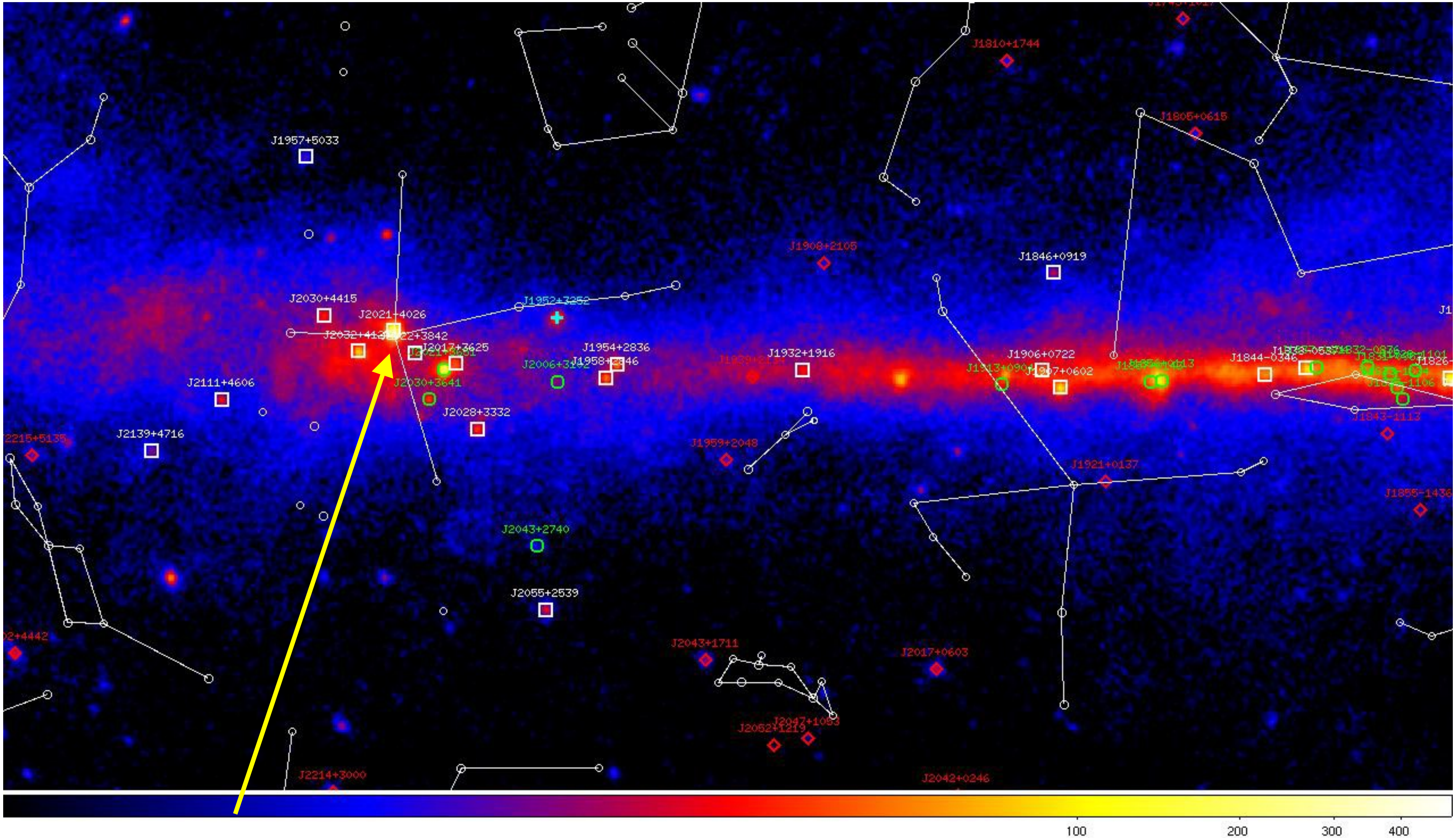
Mode change to intermittent accretion (?)

2FGL J2339.6-0532
— Long-term X-ray light curve

Yatsu et al. 2015

PSR J2022+3842

by 大内遥河 (東工大)



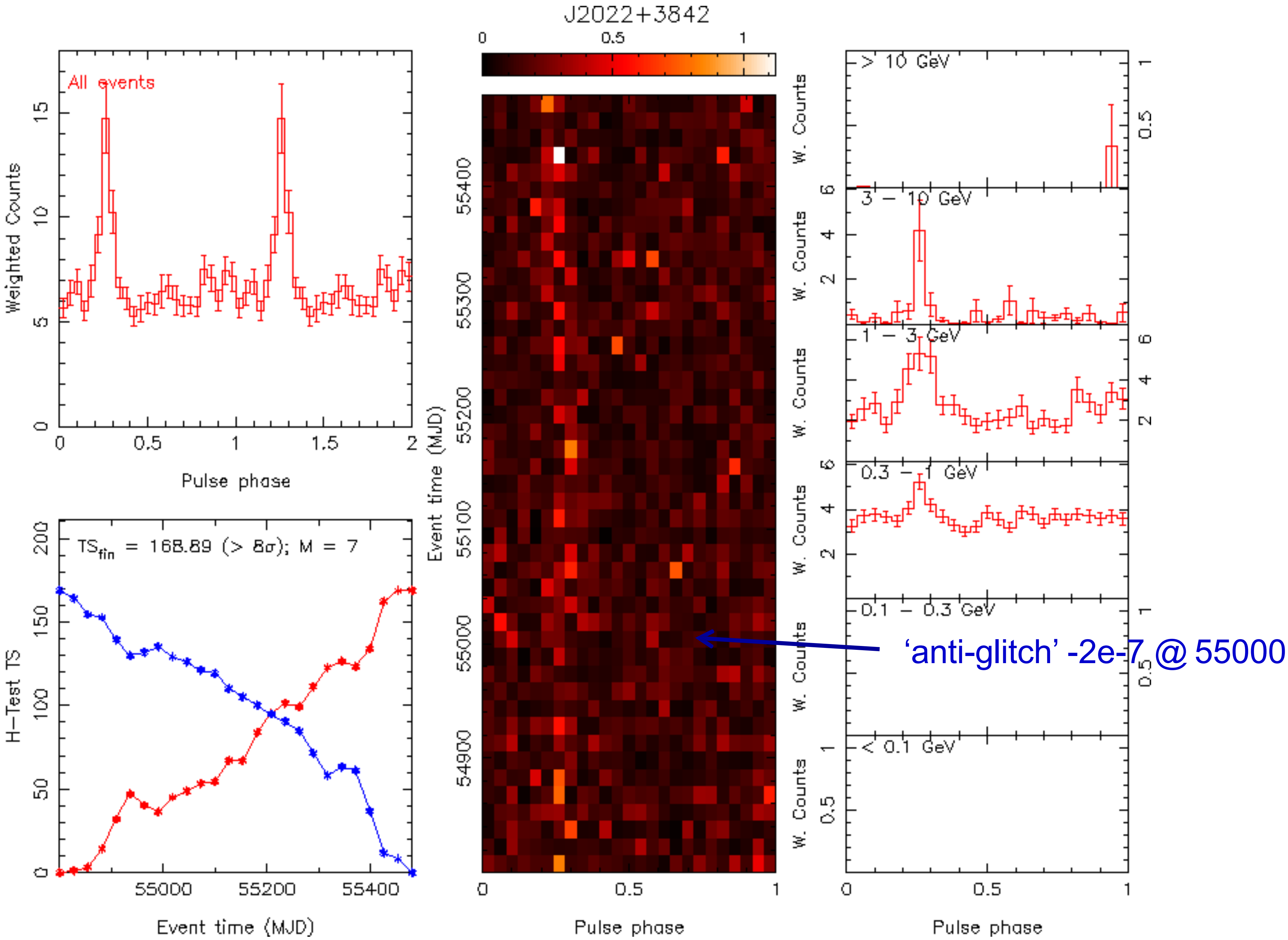
PSR J2022+3842

- Chandra found a pulsar-like source in SNR G76.9+1.0
- Deep GBT radio search: P0=24 ms pulsar discovered
- ~10 kpc, behind Cygnus.
- One week of RXTE observations: one of highest known $\dot{E}$'s. *Arzoumanian et al (2011)*
- XMM observations: P0=48 ms and '*only*' $\dot{E}$ = 3E37 erg/s (#8) *Arumugasamy et (2014)*
- No phase connected ephemeris. 3FGL no, 4FGL yes.

- March 2015: Haruka Ohuchi discovers gamma pulsations using *gtpsearch* in the F0,F1 range around the RXTE, XMM values.
- Haruka also showed , all near MJD ~ 55000:
  1. Evidence for flare
  2. Evidence for glitch
  3. Possible profile change.

- Since September 2015: Smith & Guillemot working to improve the ephemeris.
  Ray, Ransom, Gotthelf, Clark helping at times.

http://mode.obspm.fr/pdf/Smith.pdf



http://mode.obspm.fr/pdf/Smith.pdf

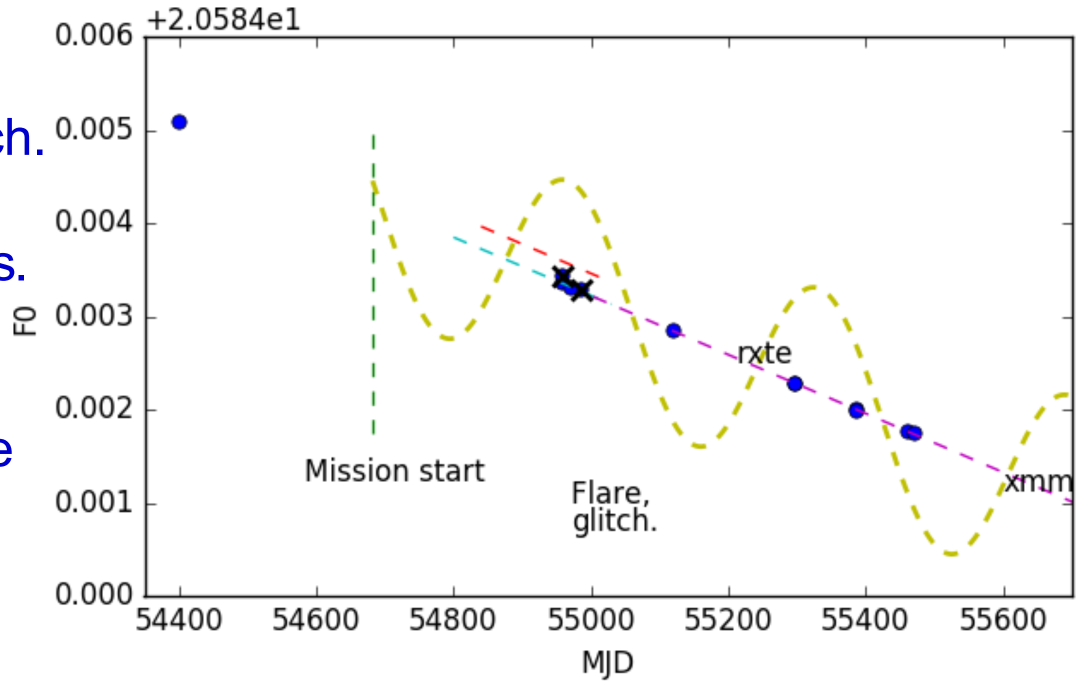
Dots: GBT rotation frequencies.

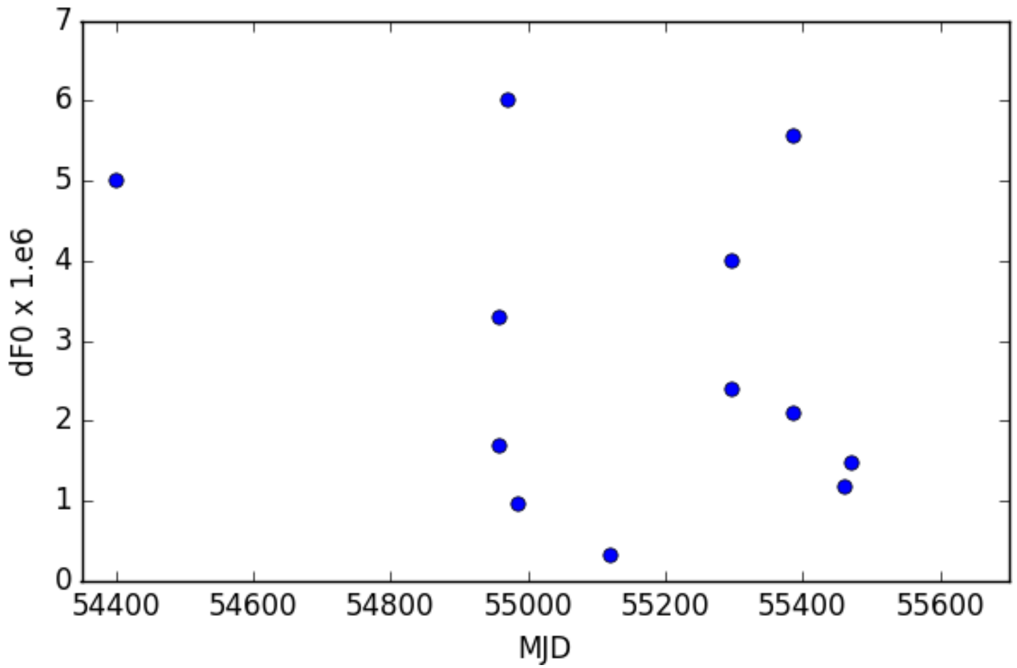
X's: Only 2 of 4 are good at this epoch.

Red-dash: F0,F1 that gives >5*s* in *g*'s.
Huge anti-glitch.

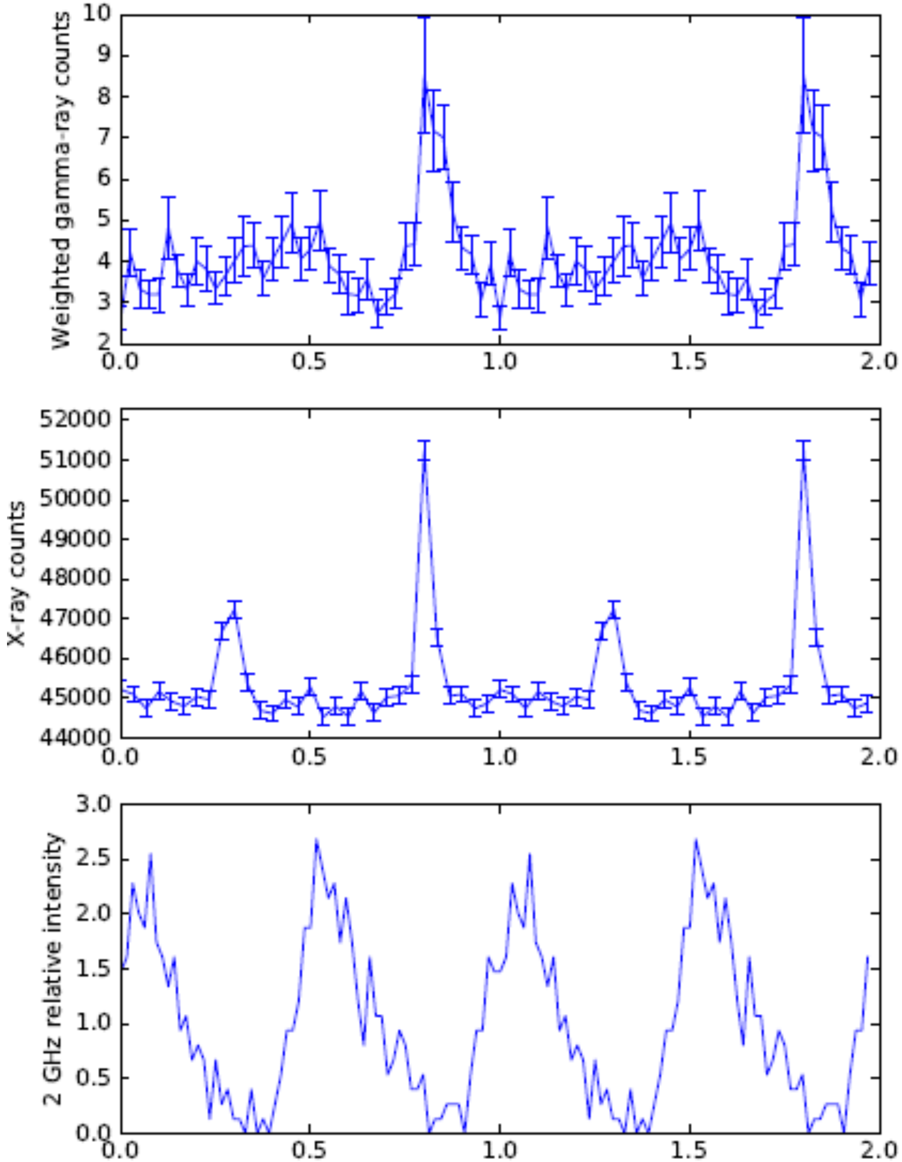
Light blue dash: F0,F1,F2 compatible with radio & X-ray measurements.
Anti-glitch -2e-7.

(sinusoïd: topocentric-barycentric)





http://mode.obspm.fr/pdf/Smith.pdf



>300 MeV gammas

RXTE

GBT 2 GHz

PRELIMINARY

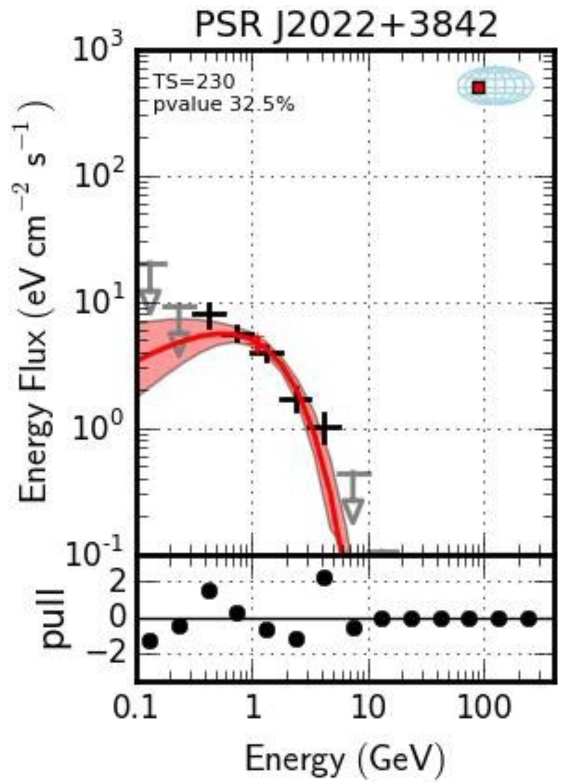
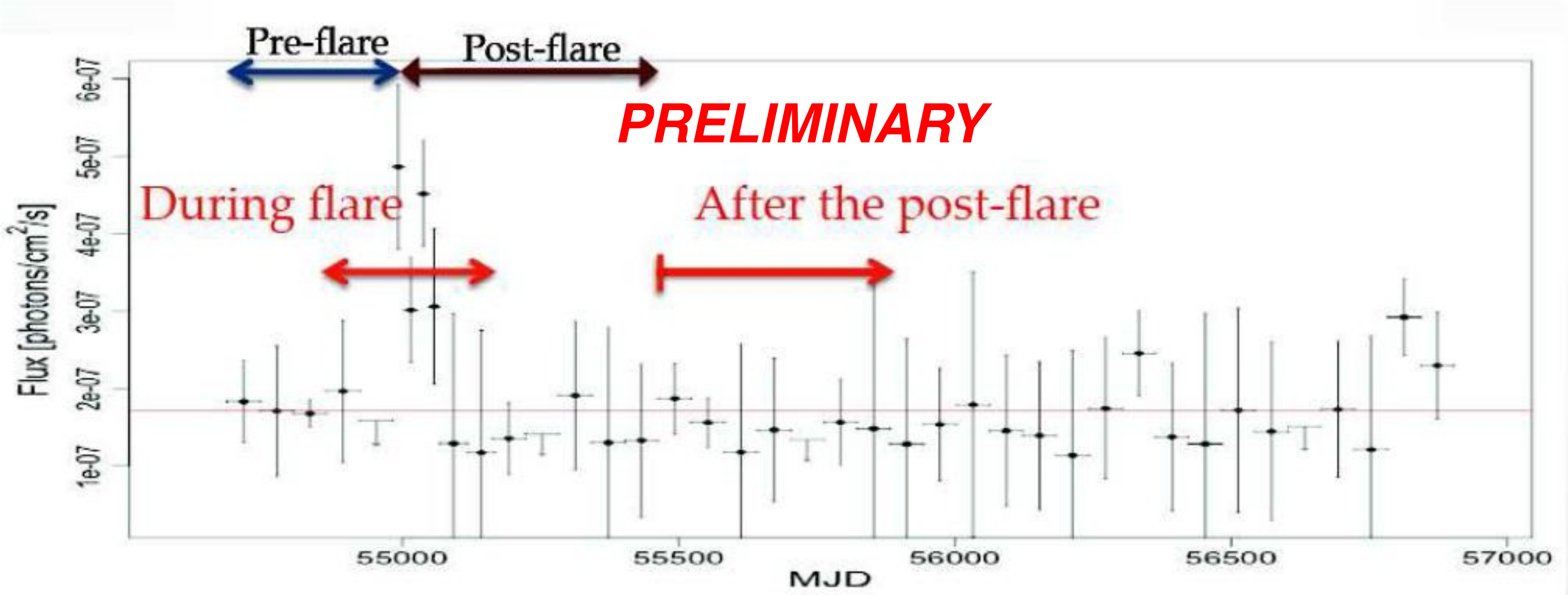


Fig. 3.— Placeholder plot. Top frame: Weighted > 300 MeV gamma-ray profile. Middle frame: RXTE data from Arzou et al (2011), corrected to the 48 ms period using the Fermi rotation ephemeris. Bottom frame: Robert C. Byrd Green Bank Telescope (GBT) 2 GHz profile, corrected to the 48 ms period using the Fermi rotation ephemeris. The X-rays are phase-aligned but the GBT profile needs to be worked on a bit.

http://mode.obspm.fr/pdf/Smith.pdf

Haruka's March 2015 Collaboration meeting presentation



- Haruka showed evidence for a glitch near MJD 55000.
- Pulsar flare at same time as a glitch? Would be the first ever seen.

- Haruka is working on demonstrating that the flare is real.
- Lucas and I working to understand which glitches are real.

http://mode.obspm.fr/pdf/Smith.pdf

Why is J2022+3842 so difficult?

For reasonable cuts, 220 on-peak photons over 450 b'grd counts (8.5*s*), in 730 days .

10 signal photons per month.

Poisson: 6 of the 53 months will have <6 photons.

('*1*450 = 21 -+ b'grd fluctuations larger than the average signal.)

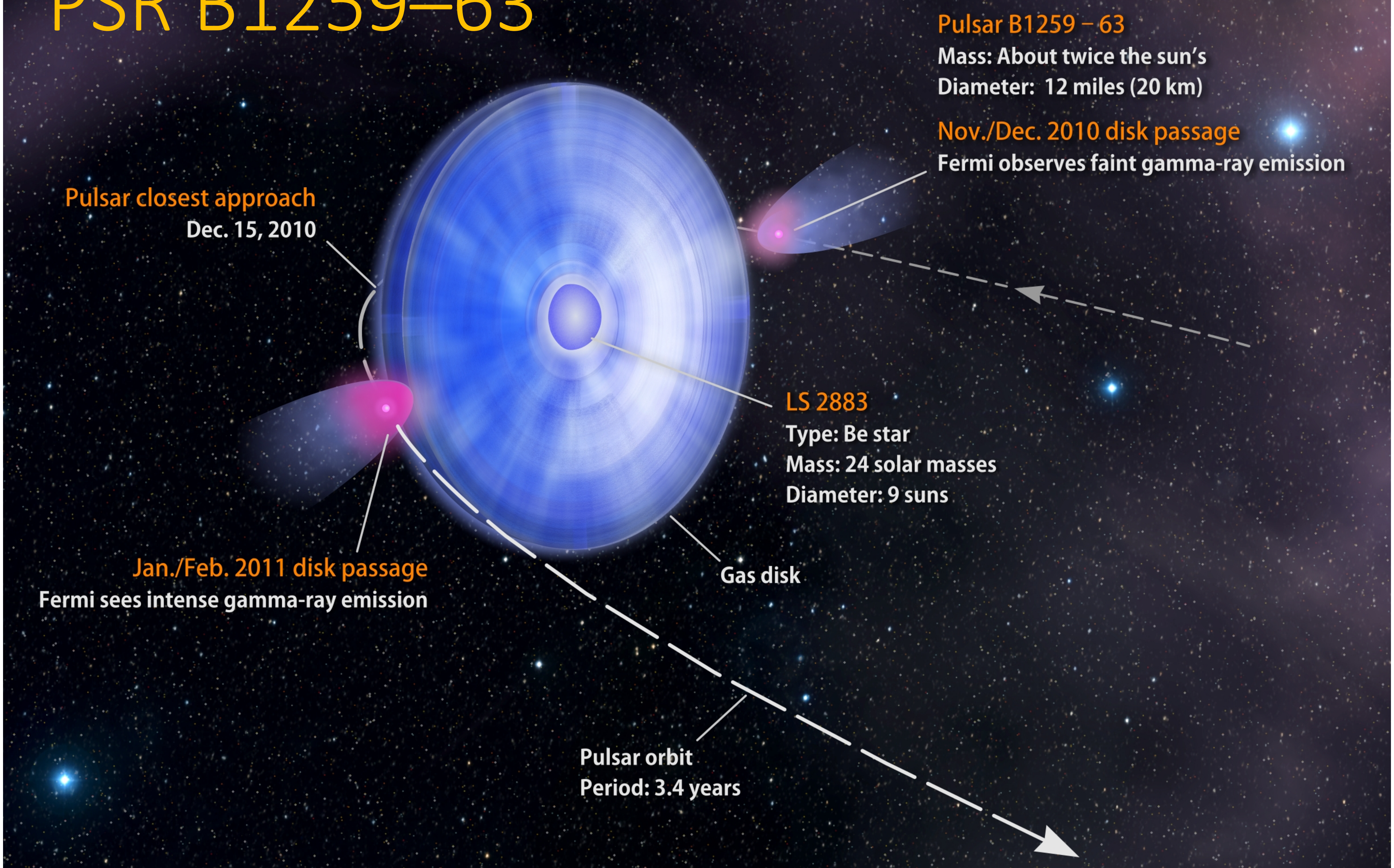
F0, F1 over a sparse sample can be skewed by a few on-source, on-phase background photons in that interval (plus pulsar timing jitter).

When you extend the maybe not-quite-right F0,F1 to an epoch with a downward S/N fluctuation

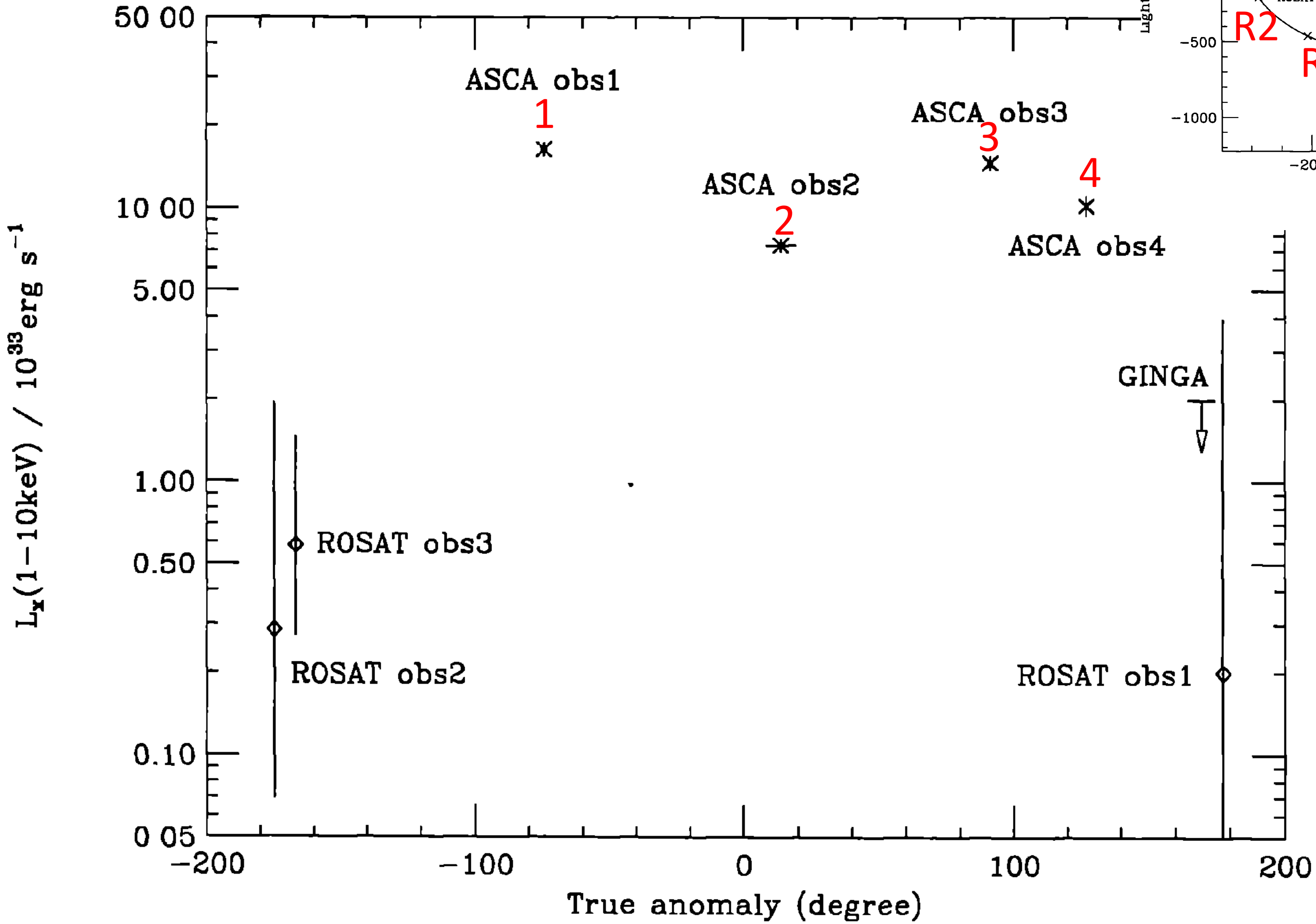
the signal violently disappears!

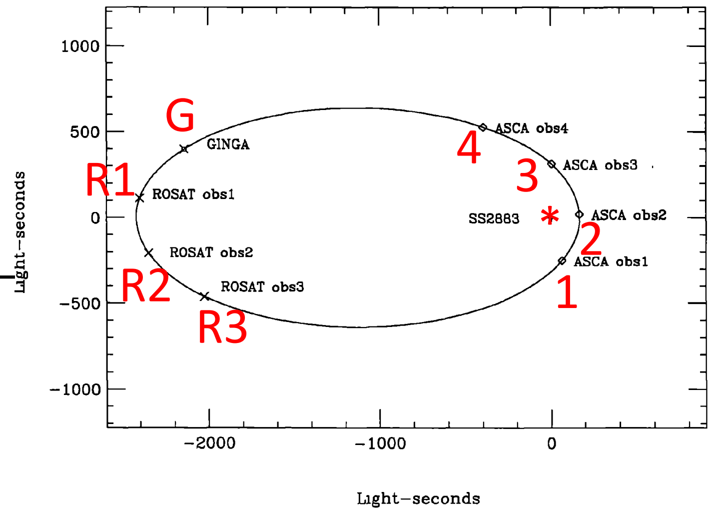
http://mode.obspm.fr/pdf/Smith.pdf

PSR B1259–63



https://www.nasa.gov/mission_pages/GLAST/news/odd-couple.html

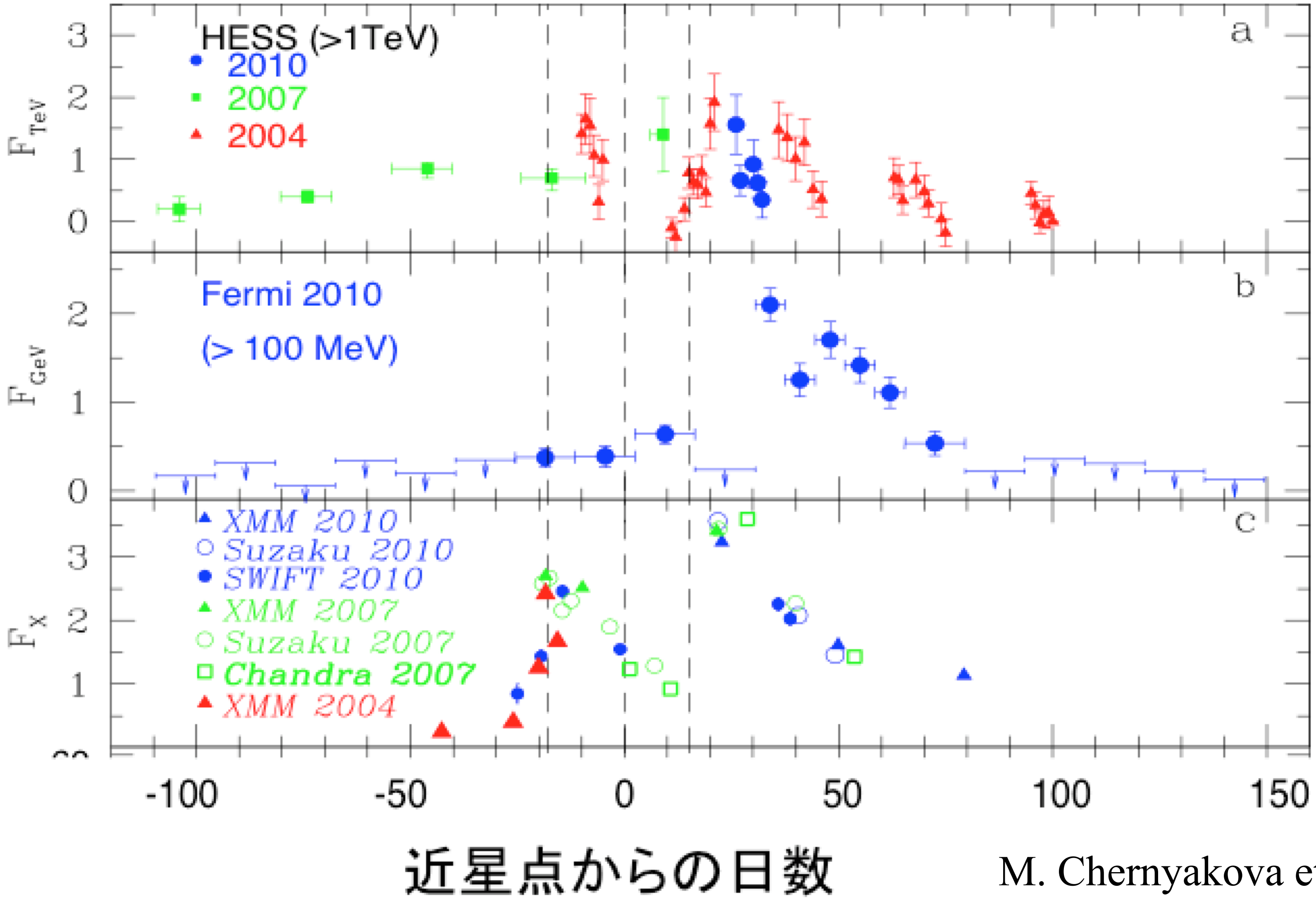




Hirayama et al. 1996

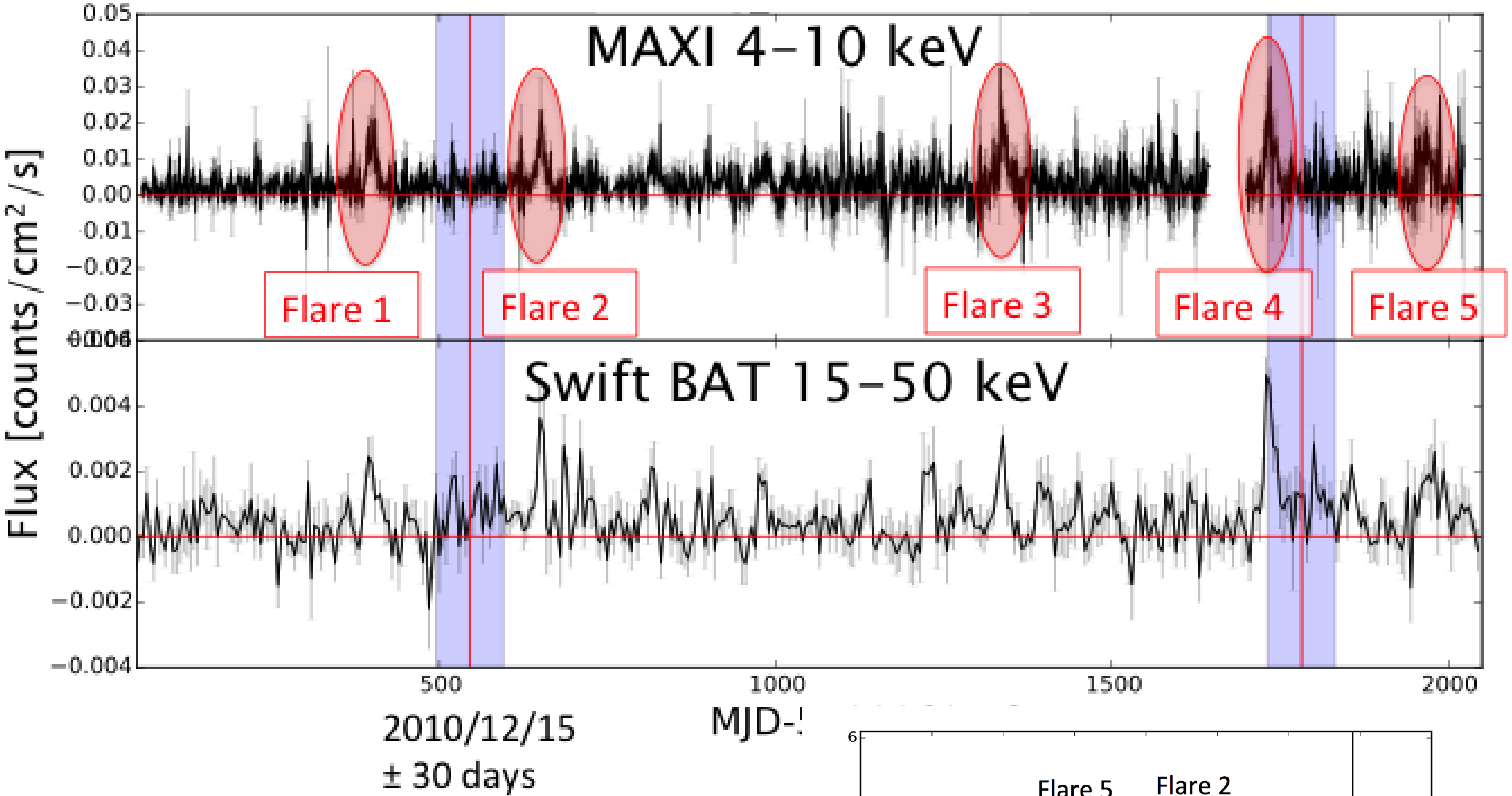
PSR B1259-63 X-ray flux vs. orbital phase

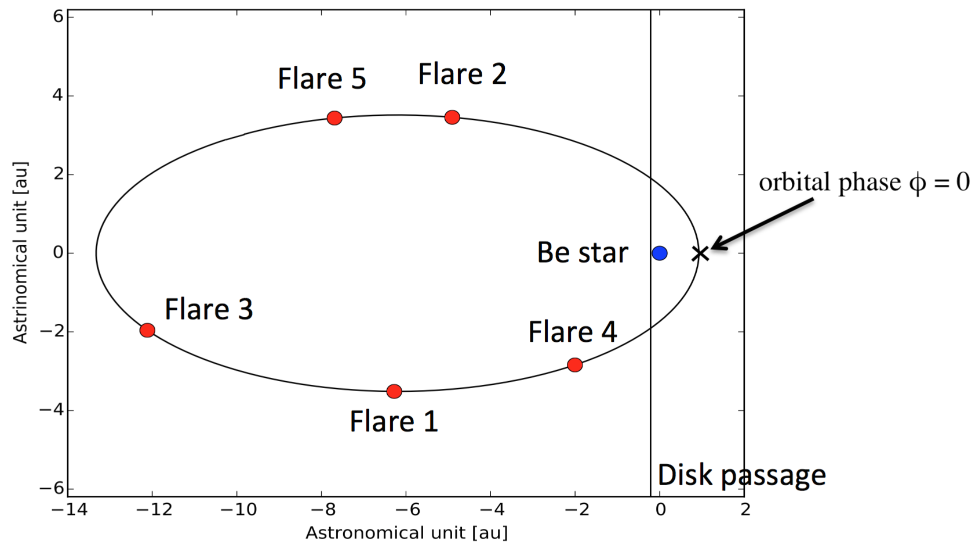
PSR B1259–63
gamma-ray and X-ray emission near periastron



M. Chernyakova et al. (2014)

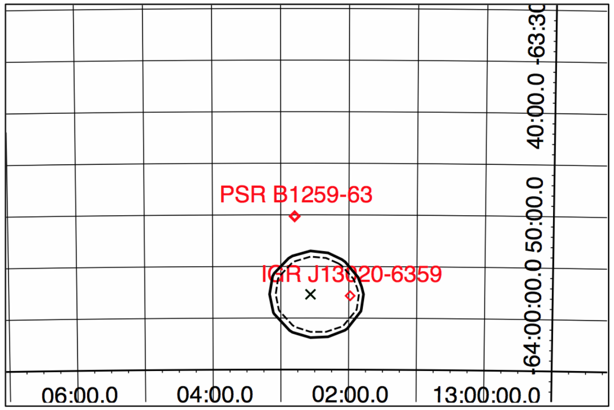
小野雄貴 (2017)





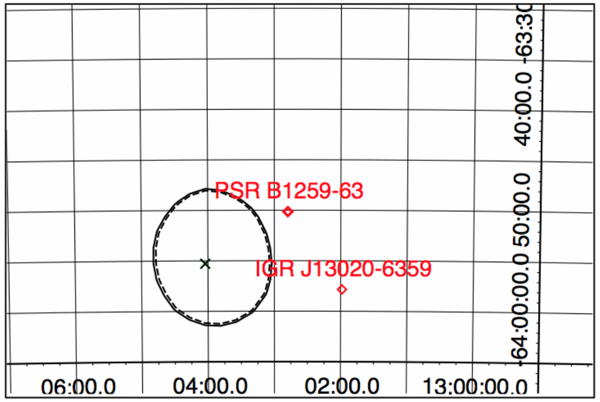
PSR B1259-63
X-ray light curve

Flare 1(MJD 55390-55410)



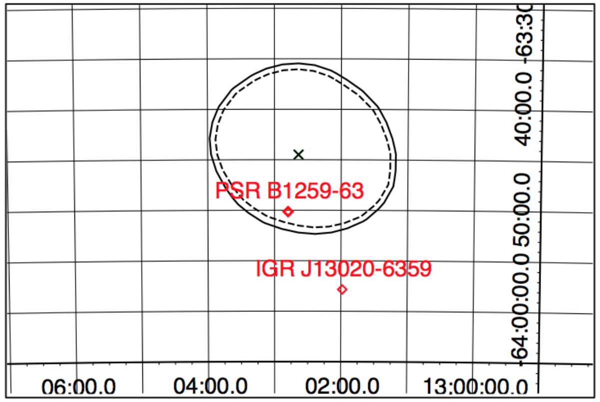
系統誤差 : 0.044°

Flare 2(MJD 55630-55670)



系統誤差 : 0.027°

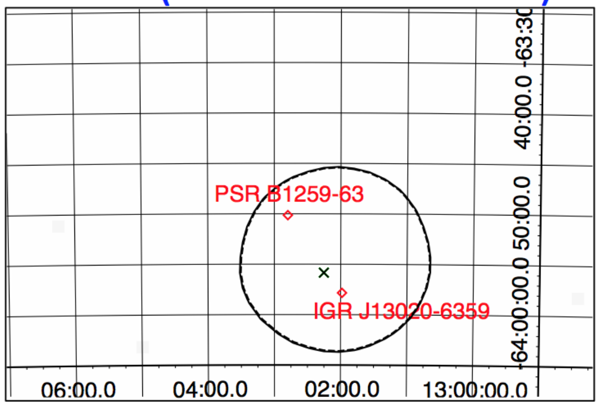
Flare 3(MJD 56330-56345)



系統誤差 : 0.053°

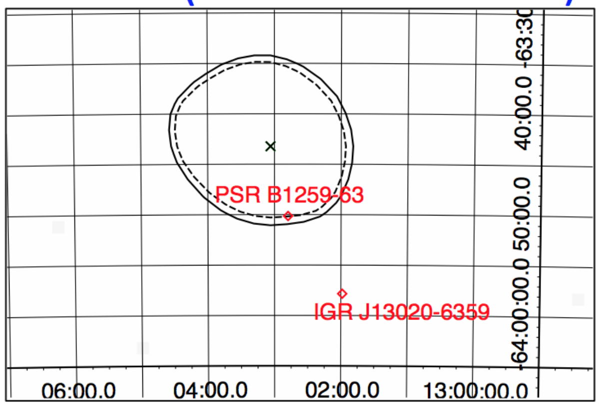
MAXI flare source positions

Flare 4(MJD 56720-56750)



系統誤差 : 0.021°

Flare 5(MJD 56950-56980)



系統誤差 : 0.056°

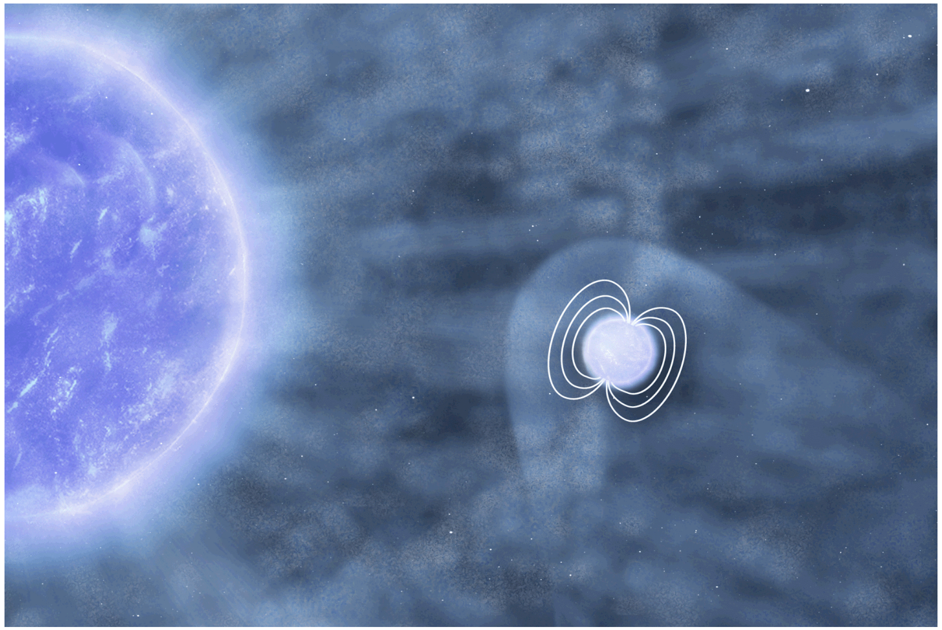
Flare ID	orbital phase ϕ	Flux (1-20 keV) $\times 10^{-10}$ erg cm^{-2} s^{-1}	$L_{1-20\mathrm{keV}}$ $\times 10^{35}$ [erg cm^{-2} s^{-1}]
Flare 2	0.085	$2.81^{+0.51}_{-0.60}$	$1.77^{+0.32}_{-0.37}$
Flare 3	0.641	$4.76^{+0.50}_{-0.71}$	$3.00^{+0.32}_{-0.45}$
Flare 4	0.962	$7.41^{+0.50}_{-2.31}$	$4.67^{+0.32}_{-1.46}$
Flare 5	0.148	$3.83^{+0.21}_{-0.73}$	$2.42^{+0.13}_{-0.46}$

小野雄貴 (2017)

x10 ASCA flux

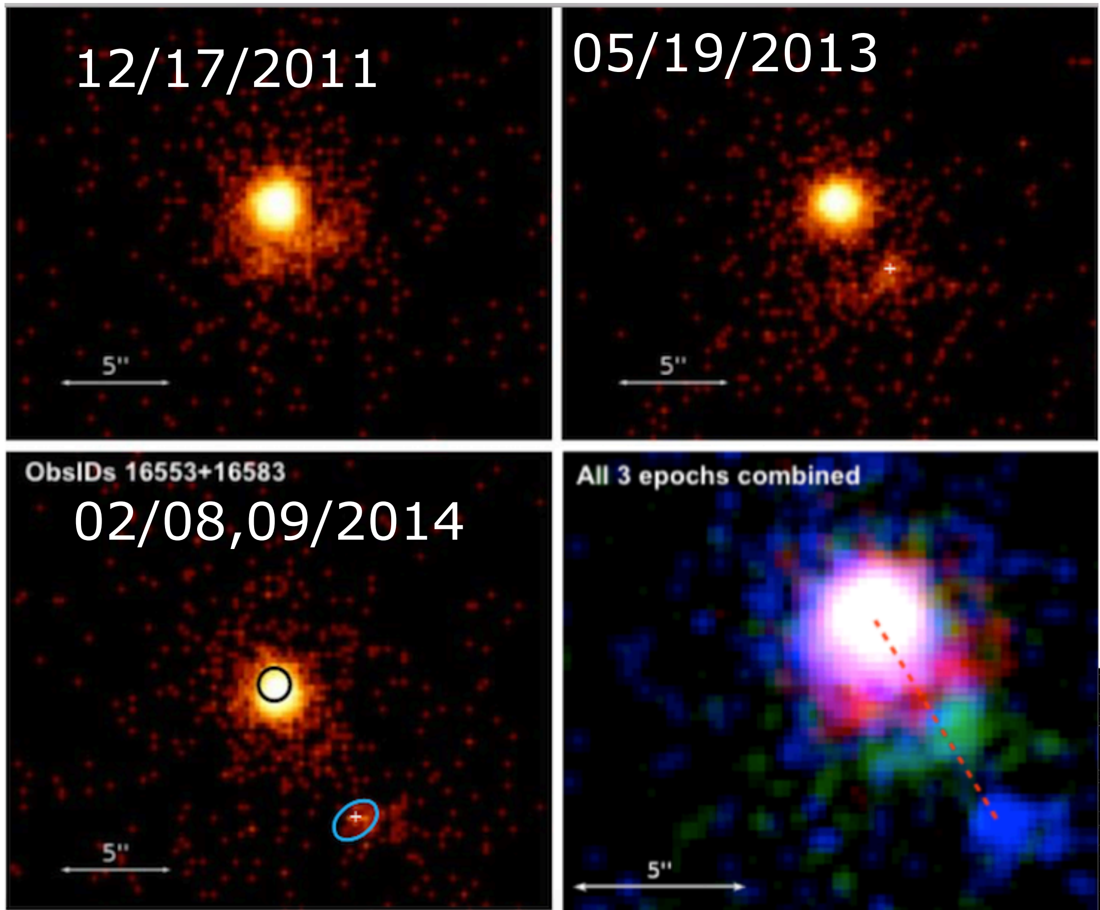
PSR 1259-63 flare

- Accretion unlikely due to propeller effect
- pulsar-stellar wind collision may be responsible
- required clump density/mass comparable to those found in Vela X-1 and Supergiant fast X-ray transients (SFXTs)



Animation of Supergiant Fast X-Ray Transient, IGR J18410-0535 (c) ESA

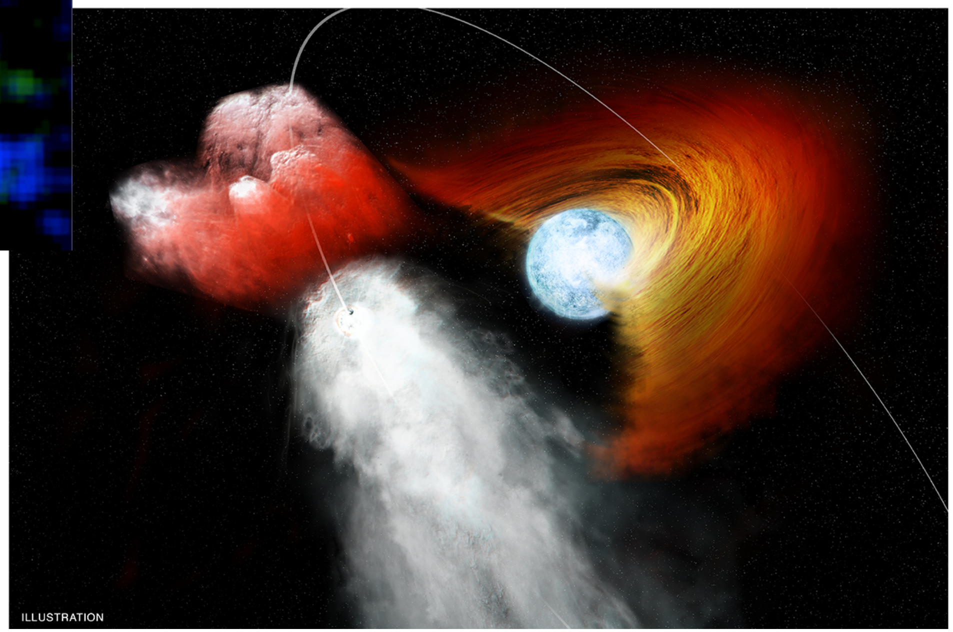
PSR 1259-63 – Chandra observations



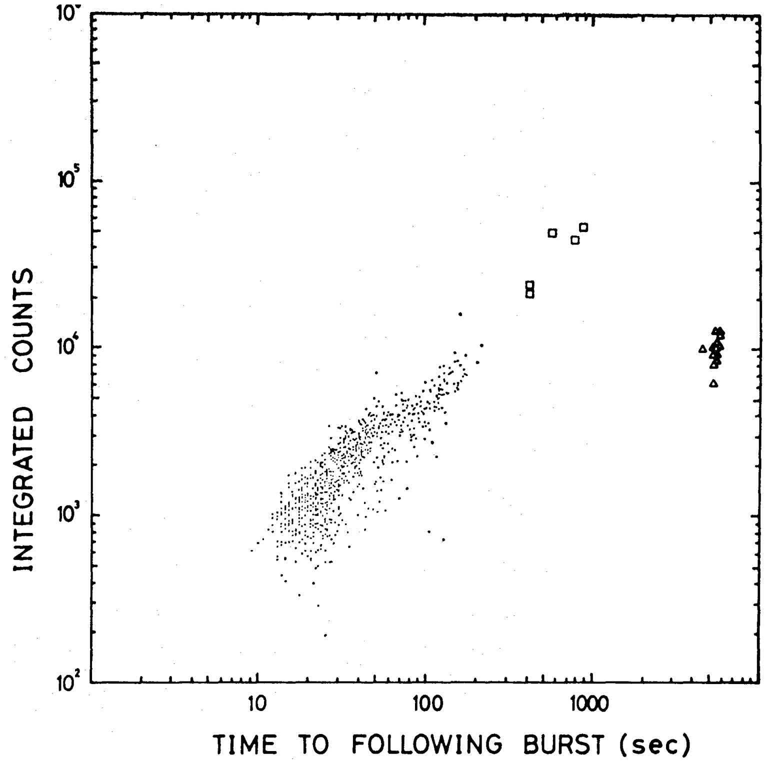
Pavlov et al, 2015

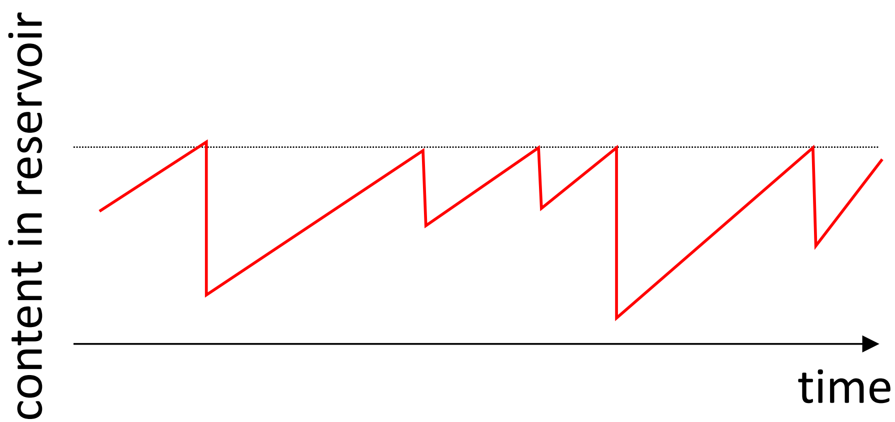
extended source moving at 0.07c

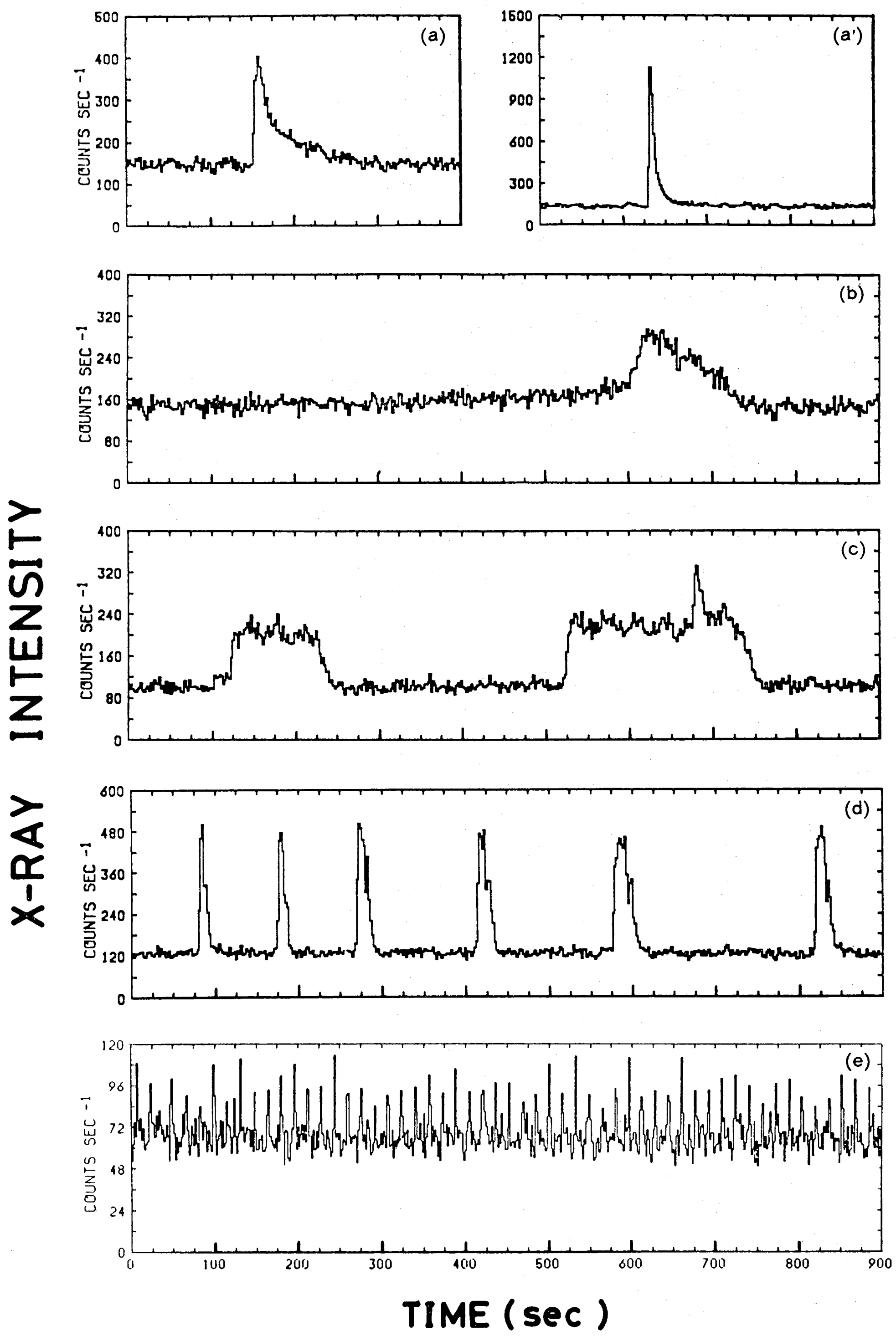
http://chandra.harvard.edu/photo/2015/psrb1259/



Rapid Burster

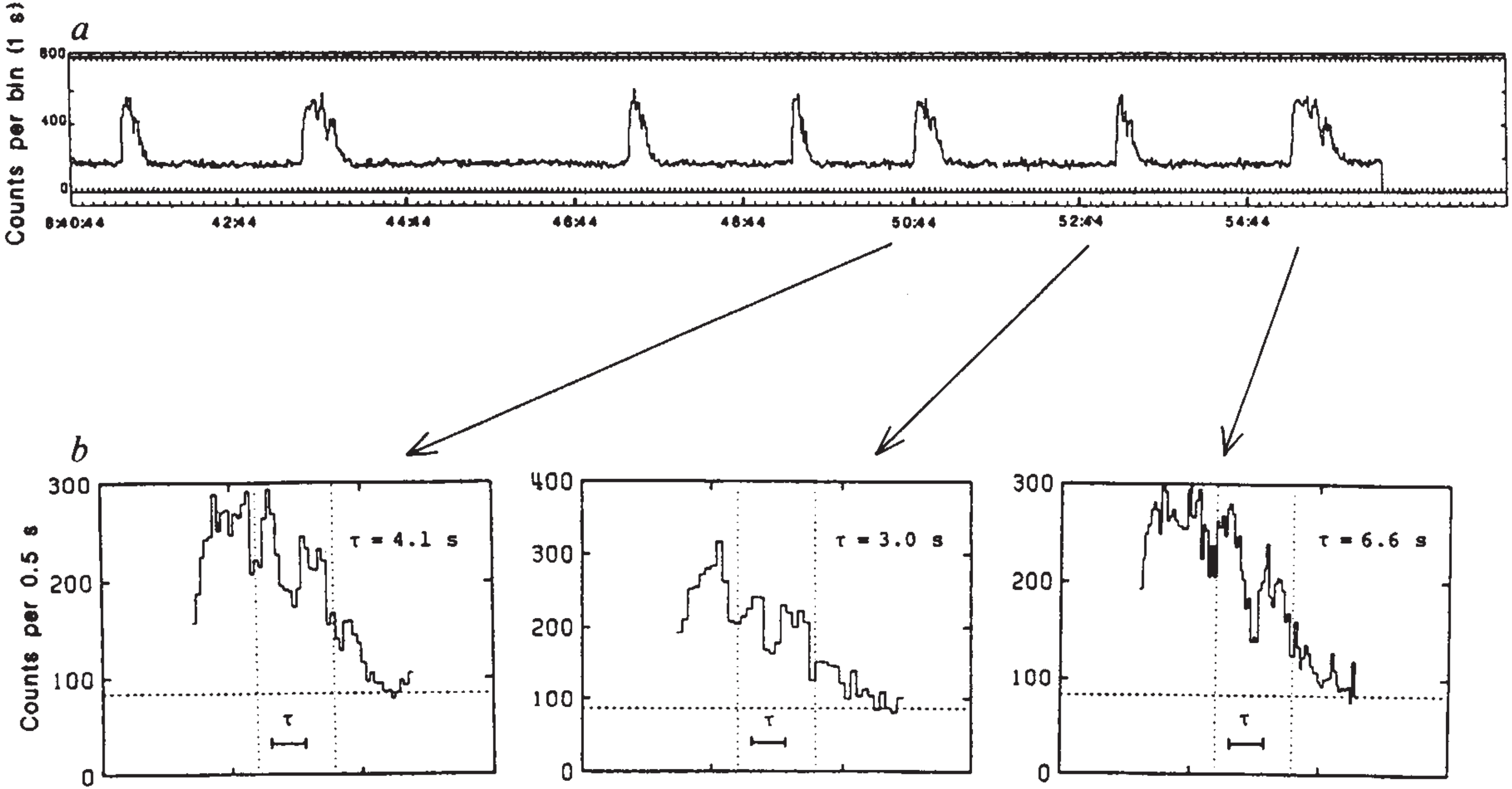




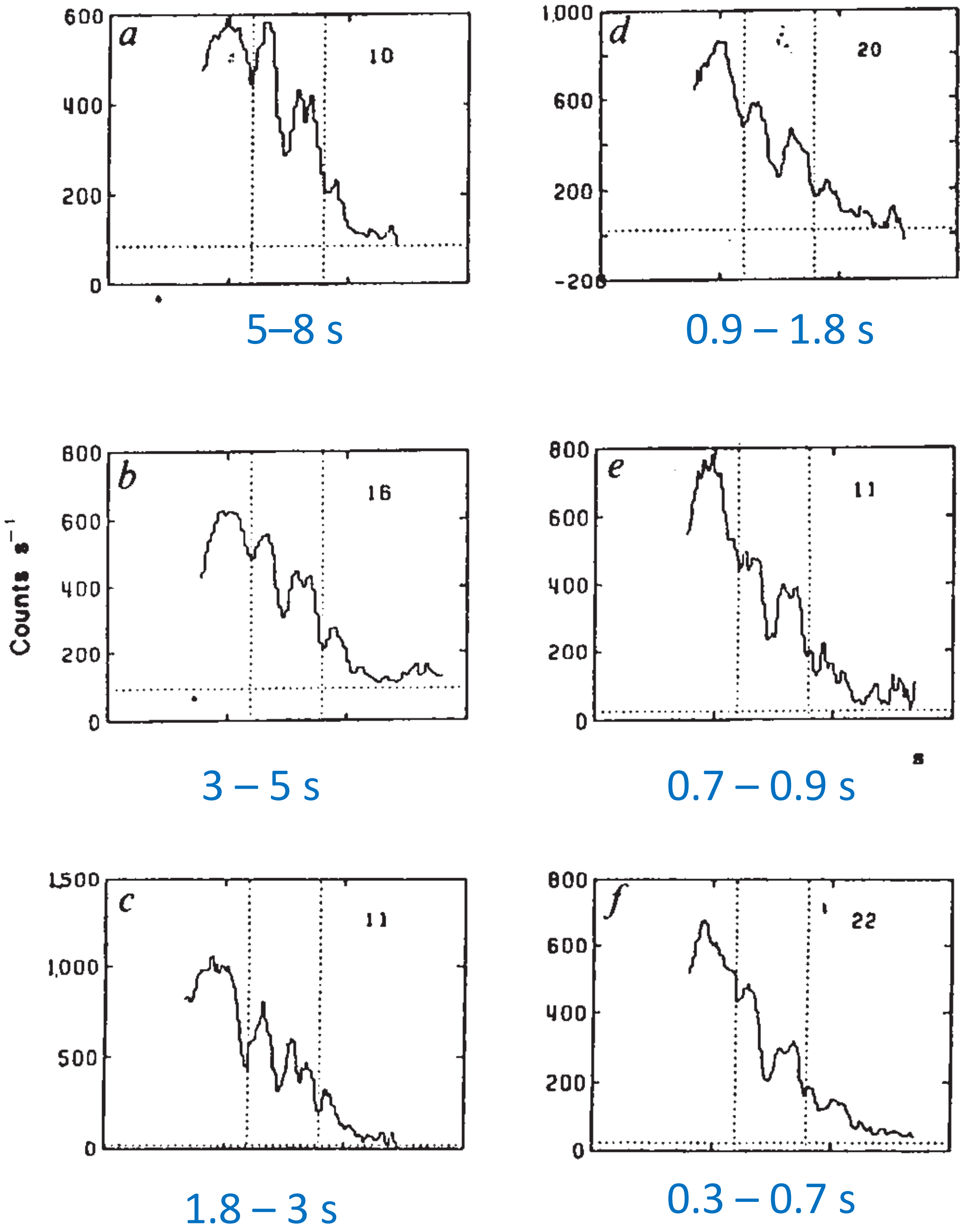


Kunieda et al. 1984

Rapid Burster "Accordion"



Tawara et al. 1984



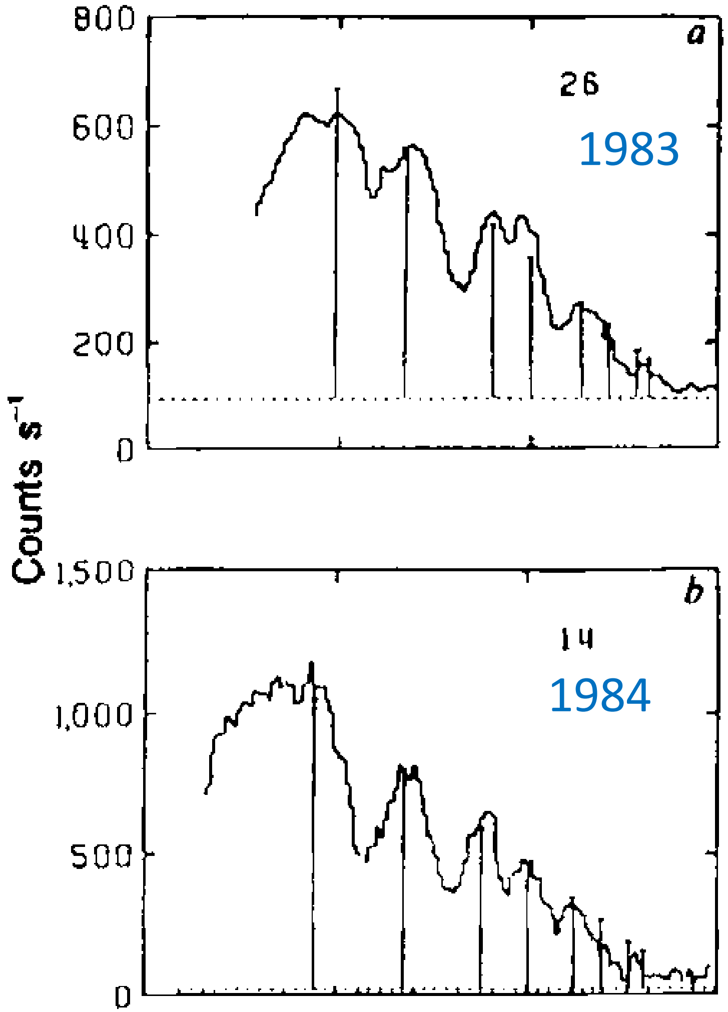
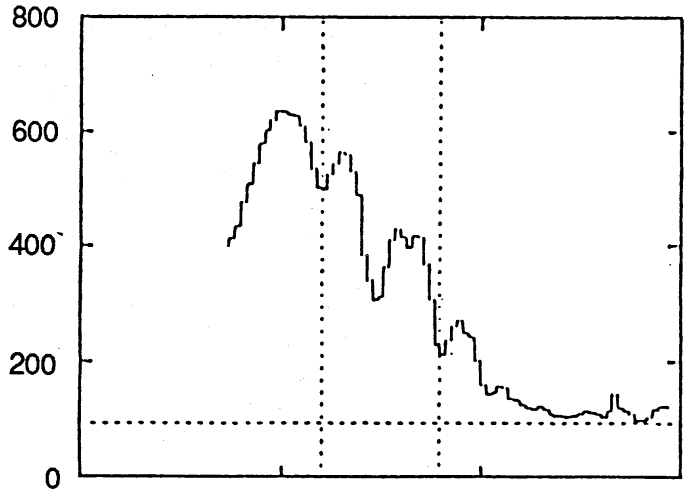


Fig. 3 Composite profile of the type II bursts of 1983 ($2.5 < \tau < 3.5$ s) (*a*) and 1984 ($2.0 < \tau < 3.5$ s) (*b*) activities. Vertical bars indicate the positions and heights of the peaks determined as described in the text.

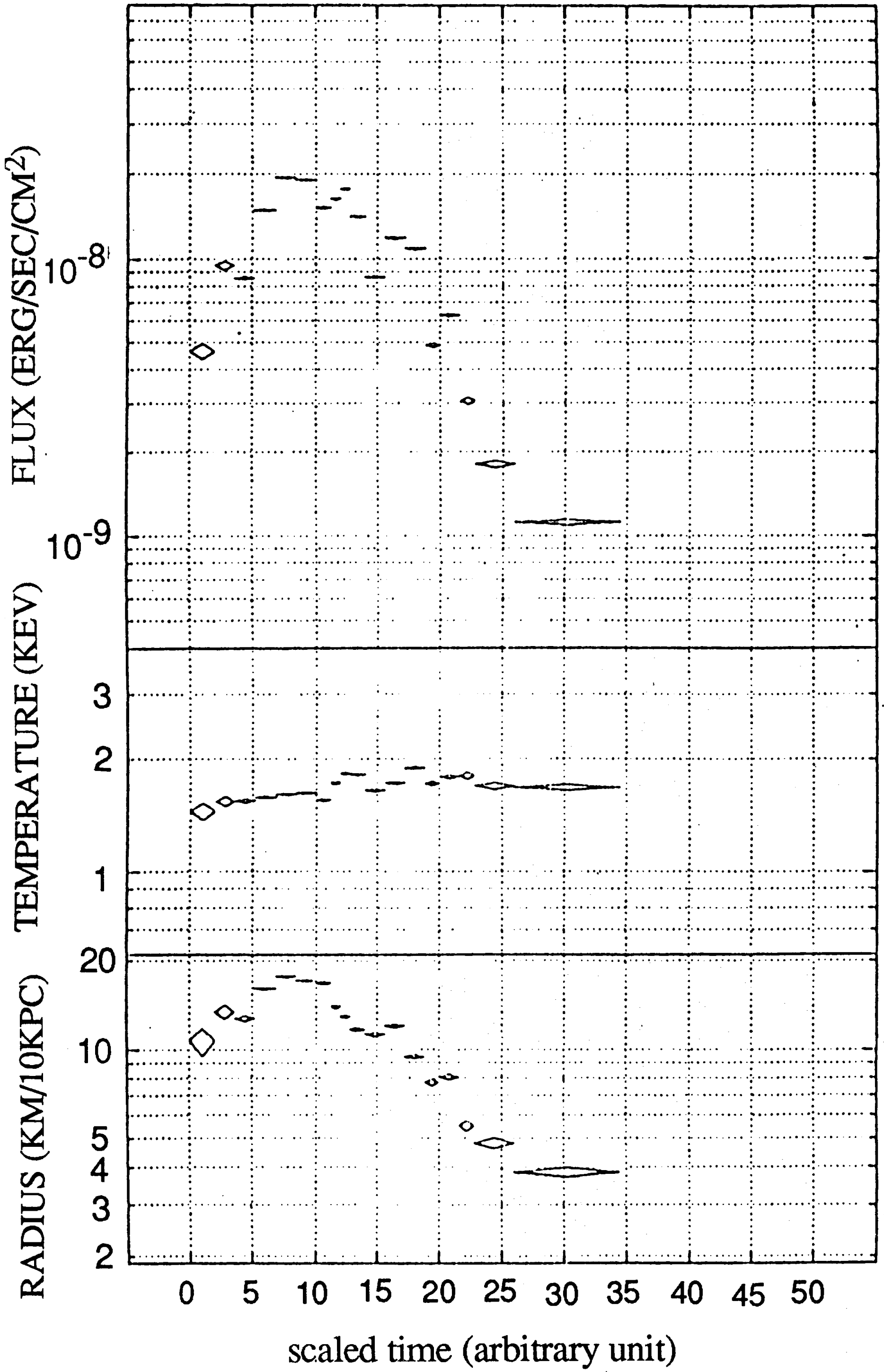
Rapid Burster "Accordion"

Tawara et al. 1984

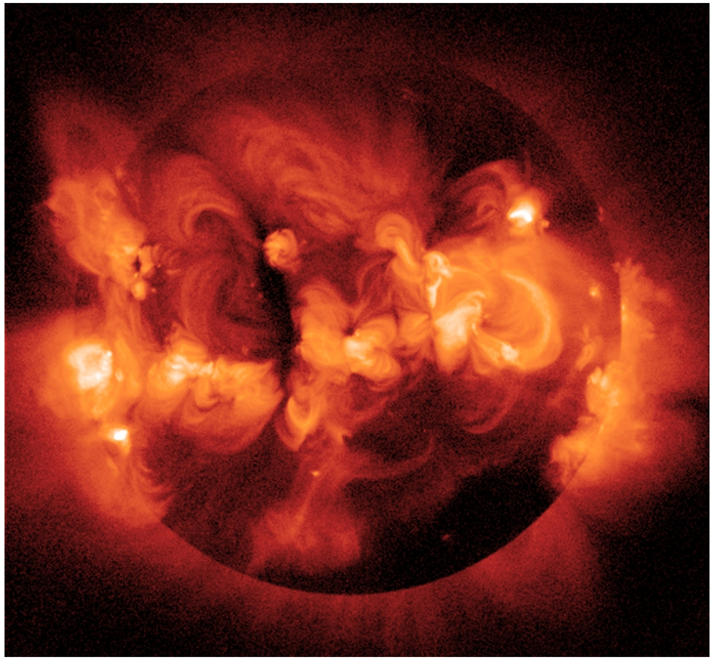
Spectral Evolution



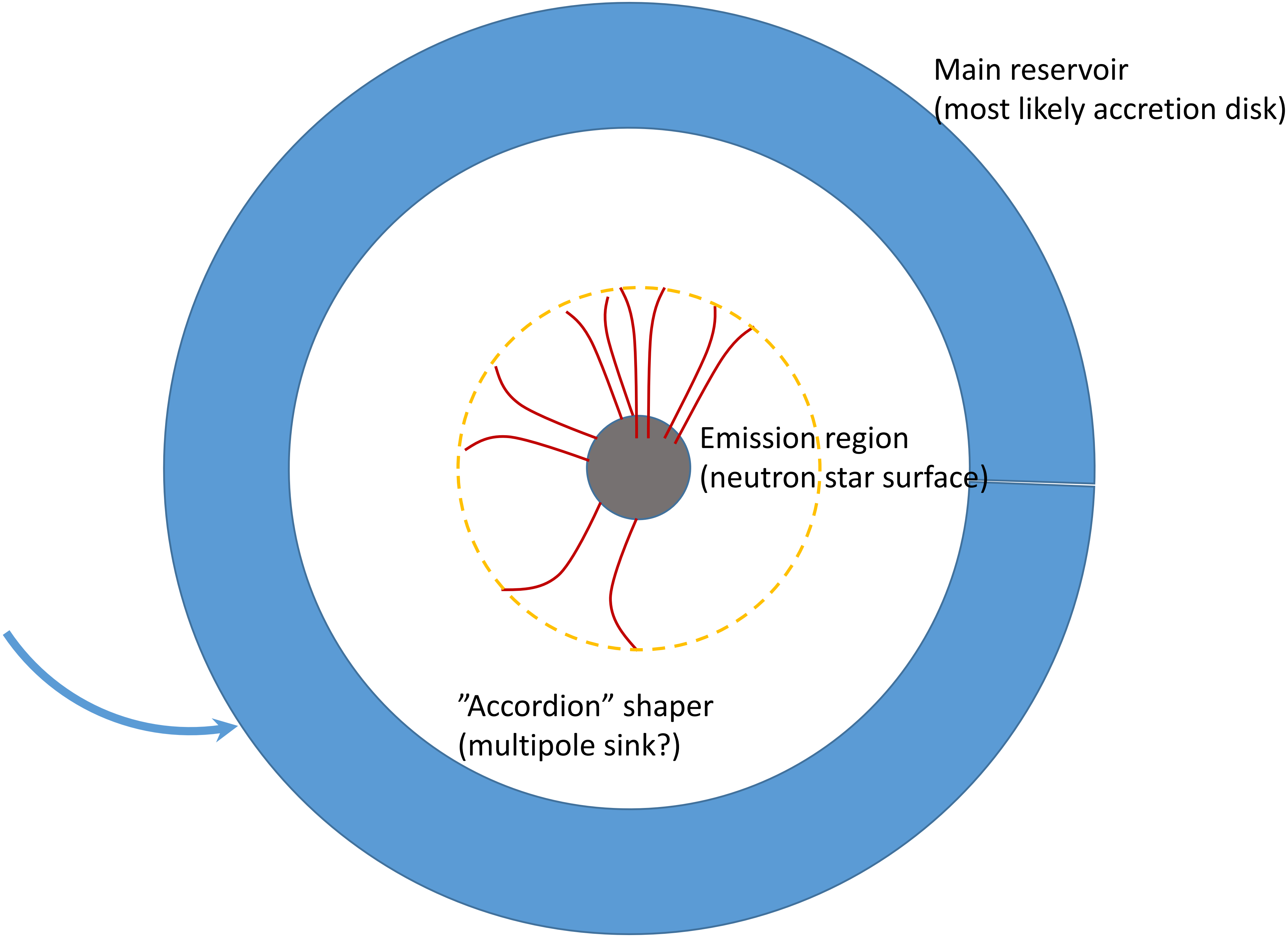
Kawai et al. 1990

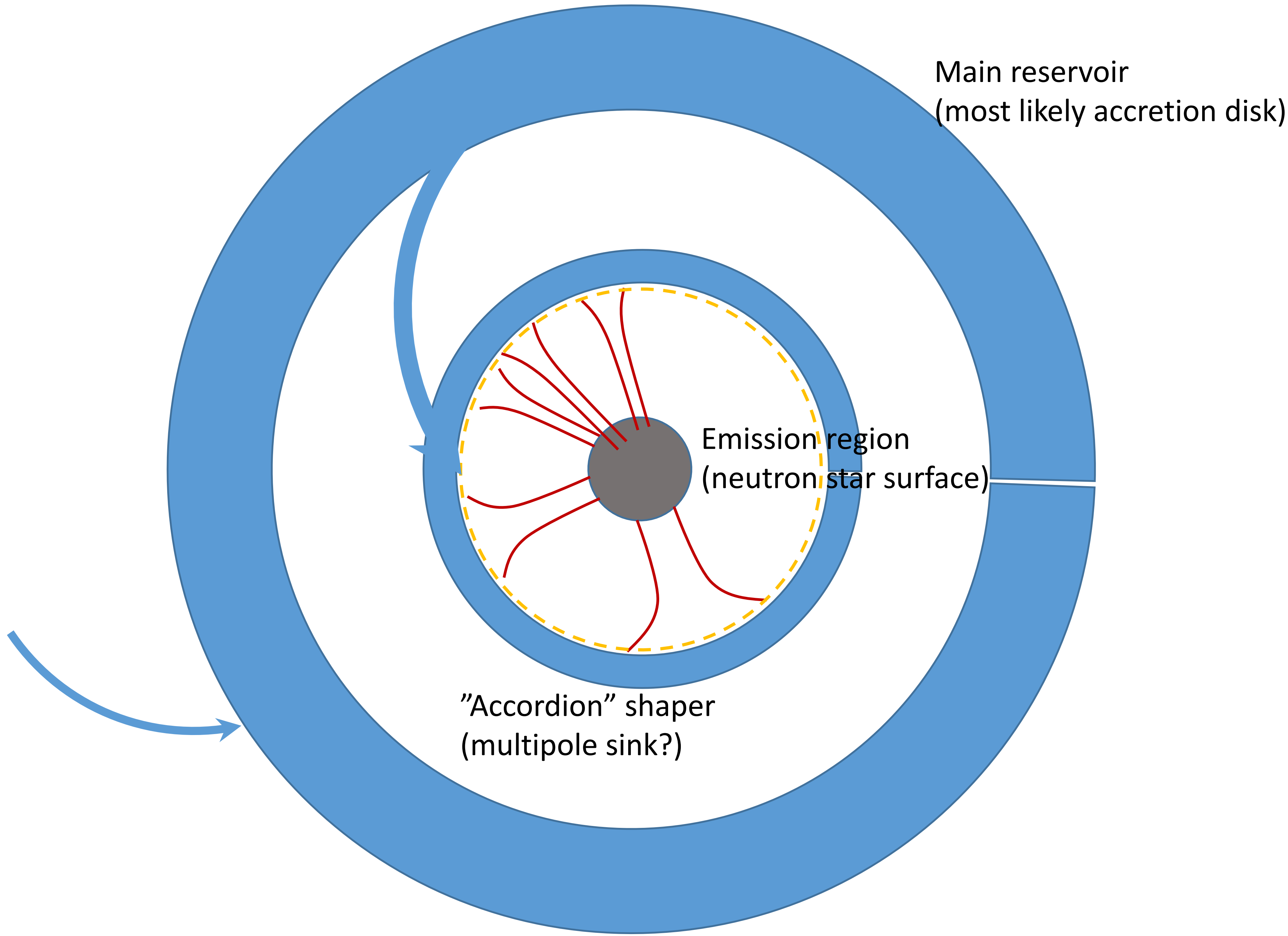


“Accordion”-like burst profile



- Time-scale invariant
- Not self-similar
- Requires three components
  - Main reservoir (E-Δt relation)
  - emission region
  - “accordion” profile shaper
- “shaper” related to “fixed” structure
  - Multi-pole magnetic field of the neutron star?
- Comptonized spectrum
  - bulk-motion Comptonization? (Hirotani et al. 1988)


Main reservoir
(most likely accretion disk)
Emission region
(neutron star surface)
”Accordion” shaper
(multipole sink?)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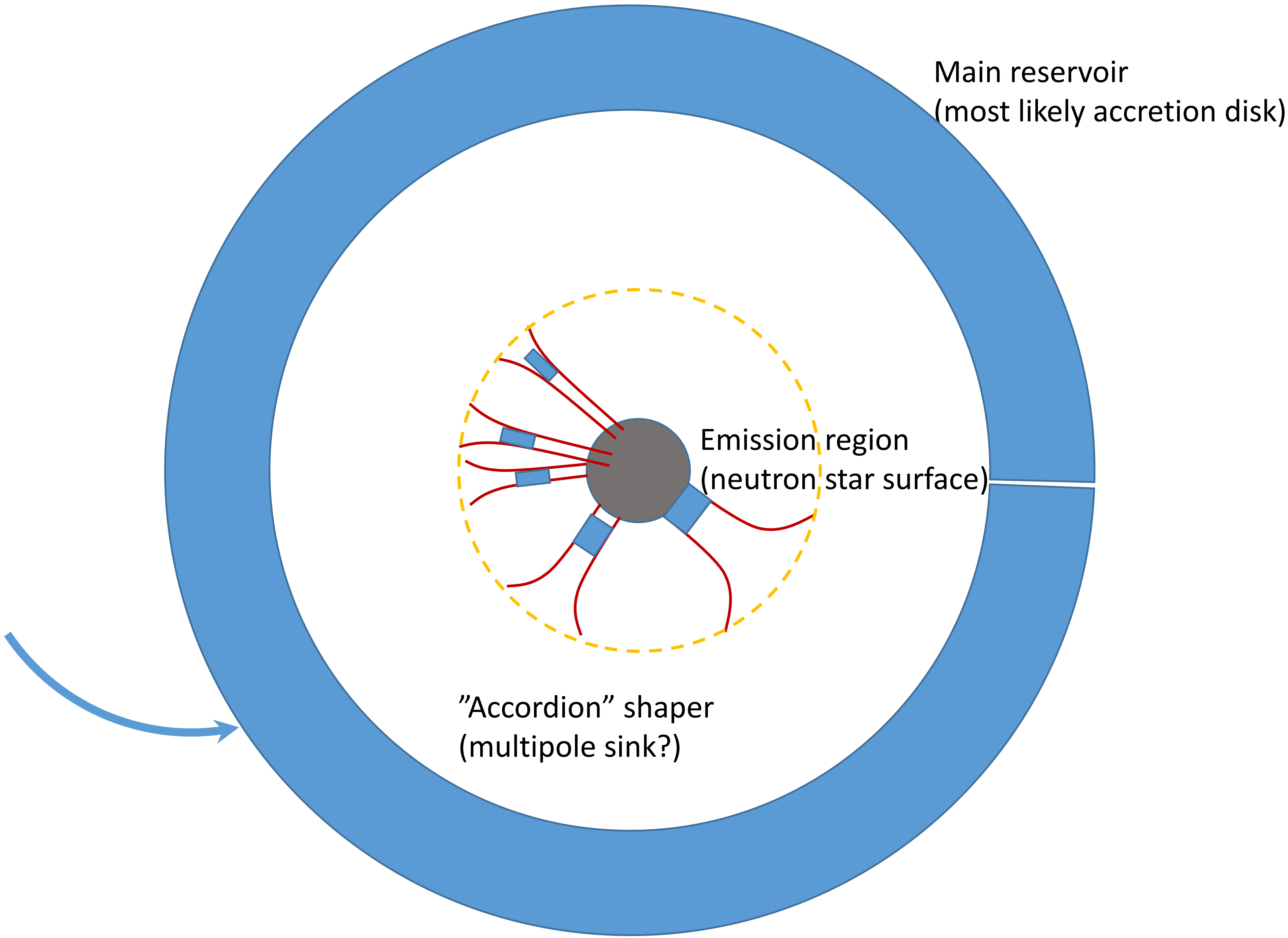

Main reservoir
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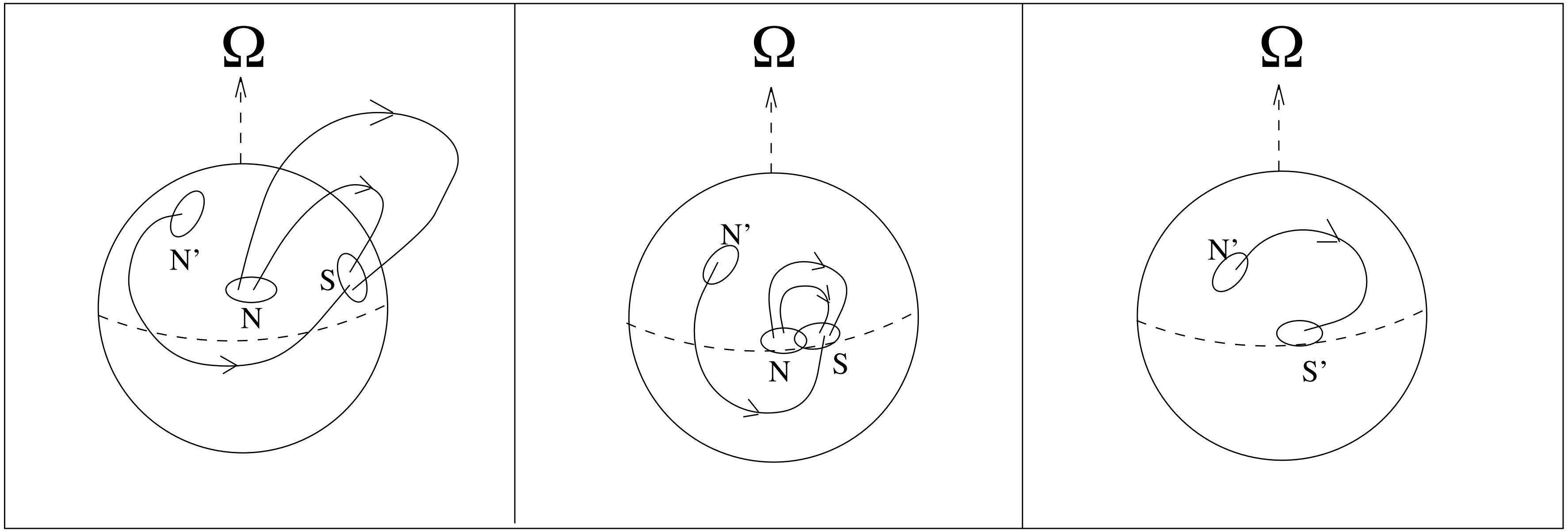
Emission region
(neutron star surface)
"Accordion" shaper
(multipole sink?)

Magnetic poles on neutron stars



Ruderman et al. 1998

(No) Conclusion

- 2FGL J2339.6-0532 – Black widow pulsar
  - mode switch from rotation-powered pulsar to intermittent accretion?
  - Simultaneous radio-X-ray observation needed
- PSR J2022+3842 – Young pulsar
  - gamma-ray flare and anti-glitch, pulse fraction change?
- PSR B1259–63 – Be star – pulsar system
  - transient mass eruption from Be companion?
  - Be disk disruption?
- Rapid Burster (X1730-335) – low-mass binary
  - draining matter to multi-pole sink?