

## Interesting points in

Vela X-1

IGR J07597-3842

Ginga 0836-429

IGR J07565-4139

Vela Pulsar

H 0918-549

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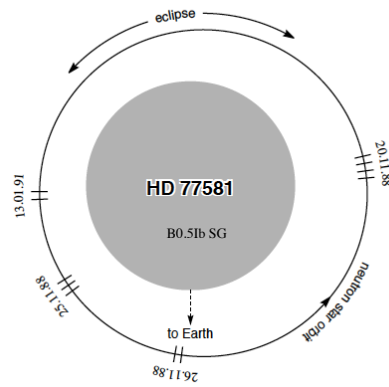
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## Outline

- Vela X-1: the system / characteristics
- Strong variability / off-states / quasi-periods
- Cyclotron lines
- Flux dependence of  $E_{cyc}$
- Long-term decay of  $E_{cyc}$
- Summary

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## Vela X-1 System



**wind-fed accretion**  
(highly structured, clumpy wind)

Kretschmar et al. 1997,  
A&A 325, 623

Ephemeris used:

$$T_{\pi/2} = \text{JD } 2444279.047$$

$$P_{\text{orb}} = 8.96442 \text{ d}$$

$$a_x \sin i = 113.0 \text{ lt-sec}$$

$$\epsilon = 0.089$$

$$\Omega_{\text{peri}} = 150.6 \text{ deg}$$

$$P_{\text{pul}} = 283 \text{ sec}$$

$$L_x = \sim 10^{36} \text{ erg/s}$$

$$E_{\text{cyc}} = \sim 27 \text{ keV and } \sim 54 \text{ keV}$$

## Vela X-1: interesting characteristics

- X-Ray Binary Pulsar (NS + BO 5Ib super giant)

$P_{\text{orb}} = 8.96 \text{ d}$

$P_{\text{pulse}} = 283 \text{ sec}$

binary eclipses

- Sinusoidal double peak pulse profiles (variable !)

- Highly variable flux: strong flares, off-states

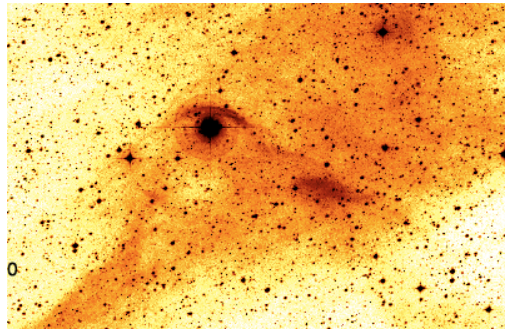
- Quasi-periodicities

- Cyclotron Lines at  $\sim 25 \text{ keV}$ ,  $\sim 50 \text{ keV}$

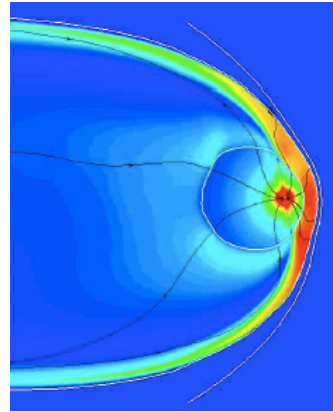
variable: flux- and time dependent !!

## Inter-stellar and stellar-wind environment

Gvaramadze et al. 2018, MNRAS 474, 4421



Inter-stellar environment of Vela X-1  
(H(alpha) + NII)



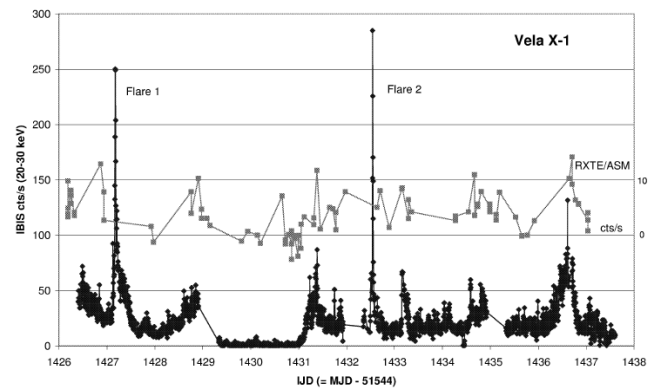
Plasma density simulations

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## Strong Flux Variations

Staubert et al. 2004, Proc. 5th INTEGRAL Workshop (ESA SP-552)

Kreykenbohm et al. 2008, A&A 492, 511



INTEGRAL 2003

resolution: 280 sec

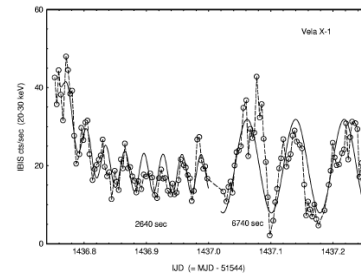
- flares  
(up to 7 Crab)
- off-states

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## Quasi-periodic Variations

Staubert et al. 2004, Proc. 5th INTEGRAL Workshop (ESA SP-552)

Kreykenbohm et al. 2008, A&A 492, 511



INTEGRAL 2003

resolution: 280 sec

- QPOs:

P ~ 2640 sec

P ~ 6740 sec

Figure 7. A special part of the light curve of Vela X-1 of the Nov/Dec 2003 observation. In these data quasi periodic modulations lasting for a few cycles are apparent. The periods are around 2640 s and 6740 s, respectively. The dotted line connects the data points (280 s integration), the solid line is the best fit sine curve (with an additional exponential component for the left train).

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## Discovery of the Cyclotron Line

MPE/Tübingen Mir-HEXE (750 cm<sup>2</sup>)  
two observations in Nov 1988 (total ~ 5 ksec)

Kendziorra et al. 1992, NASA SCP-3137, 217  
Kretschmar et al. 1996, A&A Supl. 120, 175

two cyclotron lines: ~27 keV (fundamental) and ~54 keV

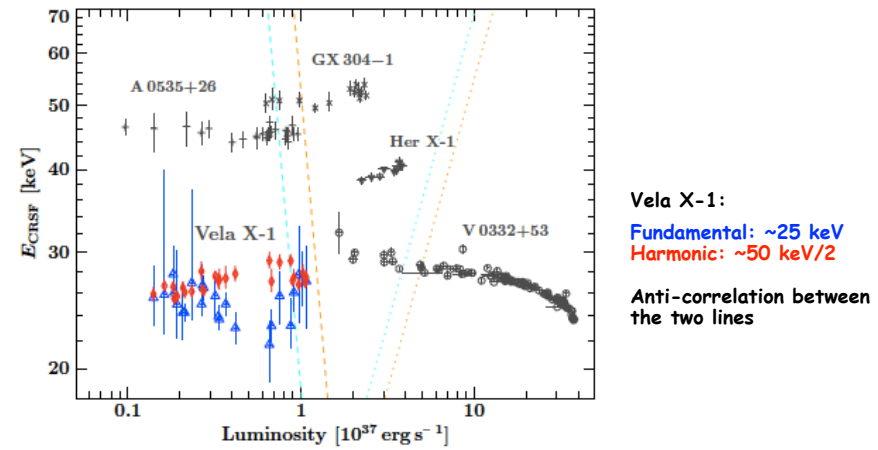
(today we would rather say: ~25 keV and ~50 keV, and  
the fundamental is sometimes not very prominent)



# Discovery of flux dependence

NuSTAR: two observations 53 ks

FÜRST ET AL. 2014 ApJ 780,133

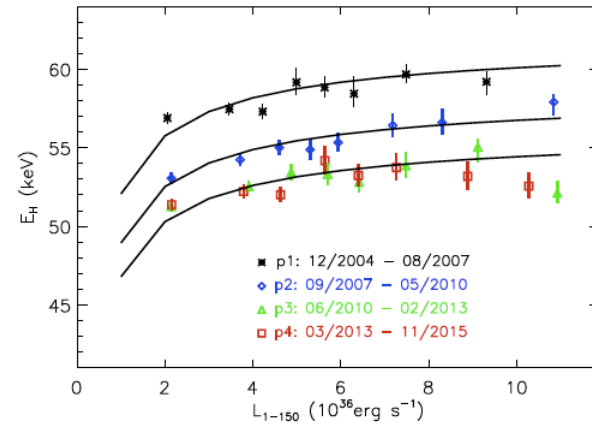


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# Discovery of time dependence

Swift/BAT from 2004 to 2015

LaParola et al. 2016, MNRAS 463, 185



Vela X-1:

Fundamental: not seen  
Harmonic: ~53 -58 keV

- Flux dependence  
(role-off like in GX 304-1)
- Time dependence:  
decay by 0.36 keV/yr  
(similar to Her X-1!)

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## Sources with correlation of $E_{\text{cyc}}$ with $L_x$

negative correlation:  $E_{\text{cyc}} \sim 1/L_x$

V 0332+53	Mihara 1995, PhD thesis Univ. Tokyo first discovery Tsygangov et al. 2006, MNRAS 371, 19 Klochkov et al. 2011, A&A 532, A126 (pulse-to-pulse)
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positive correlation:  $E_{\text{cyc}} \sim L_x$

Her X-1	Staubert et al. 2007, A&A 465, L25 first discovery Klochkov et al. 2011, A&A 532, A126 (pulse-to-pulse)
A 0535+26	Klochkov et al. 2011, A&A 532, A126 (pulse-to-pulse) Müller, D. et al. 2013, A&A 552, A81 (pulse phase resolved) Sartore, N. et al. 2015, ApJ 806, 193
GX 304-1	Yamamoto et al. 2011, PASJ 63, 751 Klochkov et al. 2011, A&A 542, L28
Vela X-1	Fürst et al. 2011, ApJ 780, 133
Cep X-4	Fürst et al. 2015, ApJ 806, 24
V 0332+53	Caballero-Garcia et al. 2016, A&A 589, A9, Doroshenko et al. 2017, MNRAS 466, 2143, Vybornov et al. 2018, A&A, arXiv: 1801.01349
1626.6-5156	DeCear et al. 2013, ApJ 762, 61

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## Sources with time dependence of $E_{cyc}$

long-term **decay** of  $E_{cyc}$

Her X-1	<a href="#">Staubert et al. 2014, A&amp;A 572, A119</a> first discovery <a href="#">Staubert et al. 2017, A&amp;A 606, L13</a> (confirm., end of decay)
Vela X-1	<a href="#">La Parola et al. 2016, MNRAS 463, 2394</a>
V 0332+53	peculiar (decay during burst): <a href="#">Cusumano et al. 2016, MNRAS 460, L99</a> , <a href="#">Doroshenko et al. 2017, MNRAS 466, 2143</a> , <a href="#">Vybornov et al. 2017, (A&amp;A, subm.)</a>

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## Vela X-1 is a very interesting source with two CRSFs

1) confirmed:

Positive correlation of  $E_{cyc}$  with  $L_x$  for fundamental  
Decay of  $E_{cyc}$  with time (0.36 keV/yr, La Parola et al. 2016)

2) future:

Does decay of  $E_{cyc}$  time end some time ??

What can HXMT do?

Participate in further monitoring of  $E_{cyc}$

try to coordinate with NuSTAR, INTEGRAL, Astrosat !?

Thank you for your attention

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