Vela X-1 and sgHMXB: hydro driven hard X-rays

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Motivation

- Variability
- off states
- pseudo-period of \(~7000\) sec
- log normal flux distribution

Can this be understood?
Stellar Winds + X-ray source

\[ L_X \sim 4 \times 10^{36} \text{ erg s}^{-1} \]

Castor, Abbot and Klein (1975): CAK

\[ \left( \frac{L_X}{L_\odot} \right)^{1/2} \ll 1 \]

\[ L_X \ll 4 \times 10^{36} \text{ erg s}^{-1} \]

\[ \dot{M}_w \sim 4 \times 10^{-6} \text{ M}_\odot \text{ yr}^{-1} \]

\[ \nu = \nu_\infty \left( 1 - \frac{R_*}{r} \right)^\beta \]

\[ v_* = 1750 \text{ km/s} ; \beta = 0.8 \]
Use of VH1
(developed by J. Blondin at NCSU)
Radiatively driven stellar winds (CAK)
Photoionization
Tested on Vela X-1 and IGR J17252-3616

Parameters
$L^*$, $R^*$, $M^*$, $T^*$ Derived from optical/IR
$\alpha$ Orbital solution
$\rho_0$, CAK-$\alpha$, CAK-$k$ Fixed from $v_\infty$ and $M_w$
$\xi_{crit}$ Photoionisation model
$L_X$ IGR/BAT/XMM obs.
$M_{NS}$ 1.88 $M_\odot$

Resolution @ NS: $\sim 10^9$ cm
Stellar Winds + X-ray source
Stellar Winds + X-ray source

Hydro Driven Accretion

Geneva, Dec. 14th, 2015 - 28th Texas Symposium

A. Manousakis - CAMK-PAN
Off-states: cavities in the bow shock

Off states as a consequence of hydrodynamics
Bow shock oscillations

\[ t_{ff}(r_A) \approx 0.1 \, \text{s} \]
\[ t_{ff}(r_{acc}) \approx 60 \, \text{s} \]
\[ t_{ff}(R_{BS}) \approx 6000 \, \text{s} \]
Bow shock oscillations

$t_{ff}(r_A) \sim 0.1 \text{ s}$
$t_{ff}(r_{\text{acc}}) \sim 60 \text{ s}$
$t_{ff}(R_{BS}) \sim 6000 \text{ s}$

Stellar Wind

Back funneled wind

Hydro Driven Accretion

Variability: self-organized criticality

Log-normal distributions:

- income in Switzerland
- GRB peak fluence (Li, 1996)
- Coronal Mass Ejection (Aoki, 2004)
- X-ray flux of IRAS 13244 (Gaskell, 2004)
- X-ray flux of Cyg X-1 (Uttley, 2005)
- X-ray flux of BL Lac (Marsher, 2008)
- X-ray flux of Vela X-1 (Fuerst, 2010)
- airborne bacteria density
- size of crystals in ice creams
- age of marriage of Danish women
- duration of phone conversation
- farm size in England
- age of Alzheimer onset

wind heating/cooling
3D hydro simulation

Clumps
propeller
Inner stellar wind velocity field
Inner stellar wind velocity field

\[ \alpha = 1.77 \, R^* \]

\[ v = 1400 \text{ km s}^{-1} \]

\[ \beta = 0.5 \]

\[ \alpha = 1.77 \, R^* \]
Conclusions

- Hydro simulations work well:
  - Variability
  - Log-normal distribution of the accretion rates
  - Off-states & flares
- Variability amplitude matches the observations
- Bow-shock variability time scales matches the observed oscillations
- A steep inner stellar wind velocity field is favored
- Future (work) realistic (physics) simulations (CPU time) are needed and coming out soon!!
Future Perspectives

Realistic Stellar Wind with NS/BH

Gating mechanisms

Sundqvist & Owocki 2013; Dessart & Owocki 2003; Owocki et al. 1988

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Gating mechanisms
Thank you for your attention

Questions?