Hybrid hot flow as the source of optical-to-X-ray emission of black hole binaries

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Poutanen & Veledina, 2014, SSRv, 183, 61

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Plan:

• Introduction: transient black hole X-ray binaries; spectral states and truncated disc model

• Spectral properties of optical/IR emission and flares

• A (hybrid) hot flow scenario

• Other properties explained
Black hole binaries: transients

Done, Gierliński & Kubota 2007

XTE J1550–564  m=10  d=5.3

GX 339–4  m=6  d=8

GRO 1655–40  m=6.3  d=3.2

ASM (1.3-12 keV)
Spectral states – moving truncation radius

\[ \frac{L_h}{L_s} \]

- hard state
- soft state

Graph showing energy vs. flux with two states:
- Soft state
- Hard state

Energy (keV)
Broad-band spectrum of LMXB

Jet? Accretion disc?
Inner hot flow?

X-rays: Corona
Hot inner flow

Radio
Optical
X-ray

Swift J1753.5−0127

Cadolle Bel et al. 2007,
Durant et al. 2009
XTE J1550−564 in 2000 in OIR

Flare in the OIR starts with alpha=+0.7. This contradicts the jet models (Russell et al. 2010, 2011).
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Broad-band spectrum of XTE J1550–564 in 2000
GX 339-4 in 2009-2010

[Graph showing data points and trends over time.]
GX 339-4 in 2009-2010

![Graphs showing data points with MJD axes and V(V-H) vs. (V-H) scatter plot.](image)
GX 339–4 in 2009-2010
XTE J1550−564 in 2000 in X-rays

Poutanen+ 2014
Radio vs X-rays: the jet and QPO line

Belloni (2009)
Hot inner flow in the hard state

We consider first pure synchrotron self-Compton models.

Synchrotron photons
Inhomogeneous accretion flow

\[ F_\nu \propto \nu^\alpha \]

\[ \log \nu F_\nu, \log \nu \]

10 \( R_S \)
Inhomogeneous accretion flow

\[ F_\nu \propto \nu^\alpha \log \nu \]
Inhomogeneous accretion flow

\[ F_\nu \propto \nu^\alpha \]

\[
\log \nu F_\nu \quad F_\nu \propto \nu^\alpha
\]
Inhomogeneous accretion flow

\[ B \propto R^{-\beta} \]
\[ \tau \propto R^{-\theta} \]
\[ \tau(\gamma) \propto \gamma^{-p} \]
\[ \nu_t \propto R^{[\beta(p+2)+2\theta]/(p+4)} \]

\[ \alpha = \frac{5\theta + \beta(2p+3) - 2p - 8}{\beta(p+2) + 2\theta} \]
Broad-band spectrum from a hybrid hot accretion flow
Optical/X-ray cross-correlation

Veledina et al. 2011
QPO: X-ray vs. optical

X-ray and optical QPOs coming in phase are observed

Swift J1753.5−0127
Veledina et al. 2015
The X-rays are produced in the inner part of the precessing hot flow. The flow precesses as a solid body if $H/R > \alpha$ (Fragile et al. 2007). Optical, IR emission is produced in the outer part of the hot flow and the QPOs can be produced by the same precessing flow (Veledina et al. 2013).
Conclusions

- Power-law-like OIR spectrum of LMXBs in the hard state can be produced by an extended hot flow.
- In the soft state, OIR emission is thermal and the irradiated disc is the likely source.
- OIR flares are consistent with the synchrotron emission from the hybrid hot flow. The “hot flow line” seems to coincide with the “radio jet line” and the “QPO line”.
- The hot flow paradigm can also explain: optical-X-ray CCF, QPOs, hard X-ray time lags.