Flaring Episodes of Cyg X-3 with KVN (Korean) & VERA (Japanese) VLBI Facilities

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“microquasars” (late 1980s): X-ray binaries (BH/NS) with relativistic jets (> 0.9c)

micro-scale to quasars/AGN: but, jet production is as efficient as those in SMBH

MQs in our Galaxy (a dozen known): flares/ jets once a few-tens of yrs (but, with irregular recurrences); hard to catch a radio flare, even with ToO, esp. in the rise of a day or two.
Flaring Activities in Cygnus X-3

Cyg X-3: multi-wavelength light curves

- Exceptions: GRS 1915+105 & Cyg X-3 – restless flaring activities ~ mins-yrs in the radio; no real quiescence.
- GRS 1915+105: extensively observed for last decades with VLBI – leaving more homework than understanding
- Cyg X-3: much poorly explored; BHC, massive but tight ($P_{\text{orb}} \approx 4.8$ hr) XRB with an unusual companion, WR.
Two VLBI Observations during Large Flares

- Only a few detailed jet image has been explored for main, large flares, with **missing rise** phases, < 2 days.
- Catching an initiation of jet event in a rise with VLBI (ToO) is extremely challenging! (whether large or small flares)
- Initial rise & initiation of jet ejection are crucial/important to understand why/how jet forms & accelerated.
- Feedback to AGNs

### 1997 (VLBA @15 GHz)
- Ryle & GBI
- 2 days
- Bean size (mas): (a) 3.98x3, (b) 4.66x4.13, (c) 4.29x3.81

### 2001 (VLBA@22 GHz)
- VLA
- 2001 Sep 18
- 8.59x3.48 mas
- 2001 Sep 19
- 8.30x4.00 mas
- 2001 Sep 20
- Beam size: 5.88x3.77 mas

[Miller-Jones et al. 2004]

[Mioduszewski et al. 2001]
X-rays: (1) In **hard state** (before a major flare), strong correlation of the radio to soft X-rays; (2) In **flaring state**, correlation of the radio to HXs; anti-correlation of the radio & HXs to SXs;
(3) In between, **ultra-soft (transition) state**:  

- Soon as it entered the US state [Beckman et al. ATel],
- VERA: in the **early rise** during a state transition from US toward harder states *for the first time* (red vertical arrow).
2007 Major Flare with VERA during State Transition [2]

- ~3 hr-long flare (or “mini-flare”) in the course of rise in 2007 large flare
- model fits: expansion of the major axis → Jet ejection (~0.3c) - proves rise in the major flare is not simple; a series of repetitive flaring activity (i.e. X-rays)

• on-going KVN @22-43-86 GHz (2014-15); VERA proposal for 2015, in prep.
Polarization in MQs: only a handful of linear polarization in the radio

- **GRO J1655-40**: 1994 large flare, peak to decay (1.38-9.2 GHz) with ATCA → 0-12% [Hannikainen et al. 2000]
- **V404 Cyg**: 1989 large flare (1.49-14.9 GHz) with VLA → 0-6% [Han & Hjellming 1992]
- **GRS 1915+105**: 1997 large flare (4.994 GHz), MERLIN → 3-14% [Fender et al. 1999]
- **SS 433**

- **Cyg X-3**:  
  (1) **large flares**: extensively in 1972, 1974 & 1975  
  - 1972, from rise to decay (2.7, 8 & 10.5 → 0-14% [Dent et al. 1972 (SD), Aller 1972 (SD), Gregory et al. 1972 (SD), Seaquist et al. 1972 (NRAO 4-element interferometer)]  
  - 1974, from mid-rise to decay (4.2 GHz) with a SD → 5-9% [Kawano & Kawajiri 1975]  
  - 1975, peak to decay (8 & 14.5 GHz) with a single-dish → 5-25% [Ledden et al. 1976]

(2) **small flares**: covering peak to decay only once at 43 GHz  
- 2002, peak to decay (15/43 GHz) with VLA → 0-4% @43 GHz [Miller-Jones et al. 2009]
- 1971, only 2 epochs in decay of a small flare? (1.415 GHz) with Westerbork synthesis telescope → marginal detection [Braes & Miley 1972]

Polarization during 2013 small flare at **22 GHz**, for the first time, with KVN.
2013 Small Flare at 22 GHz: [1] Polarization

In their VLA@15 & 43 GHz during 2002 small flare, Miller-Jones et al. (2009) claimed:

1. Opacity effect:
   - Large flare: large-scale, optically thin (~peak) → diffusion
   - Small flare: compact, optically thick (~peak) → thin → diffusion

2. No detection (lower degree) of pol. at 15 GHz due to greater optical depth: only for > 43 GHz?

2013 small flare at 22 GHz:
1) ~3% at 22 GHz, comparable to 43 GHz,
2) Similar enhancement of pol. in the course of decay is confirmed, plausibly due to a transition of jet from opt. thick to thin, and
3) VLBI ob. (~ peak?) in analysis ...

- on-going 2014-2015 KVN @22-43 GHz
THANK YOU
감사합니다