



Explosive Events in the Transient Radio Sky

*Gamma-ray Counterparts & Accretion/Ejection
Study in X-ray Binaries*

Alan Loh

2nd year PhD student under the supervision of **Stéphane Corbel**

*Laboratoire d'Étude des Phénomènes Cosmiques de Haute Énergie
Service d'Astrophysique CEA-Saclay, Université Paris Diderot*

2015, July 1st
Journées des Thésards – CEA IRFU

Studies

2008-2012

Magistère in Fundamental Physics, Univ. Paris Diderot

3 Astronomy-related Internships, APC & LESIA laboratories

2012-2013

M2 Astronomy & Astrophysics, Paris Observatory

Internship at CEA/SAp with Stéphane Corbel

2013-2016

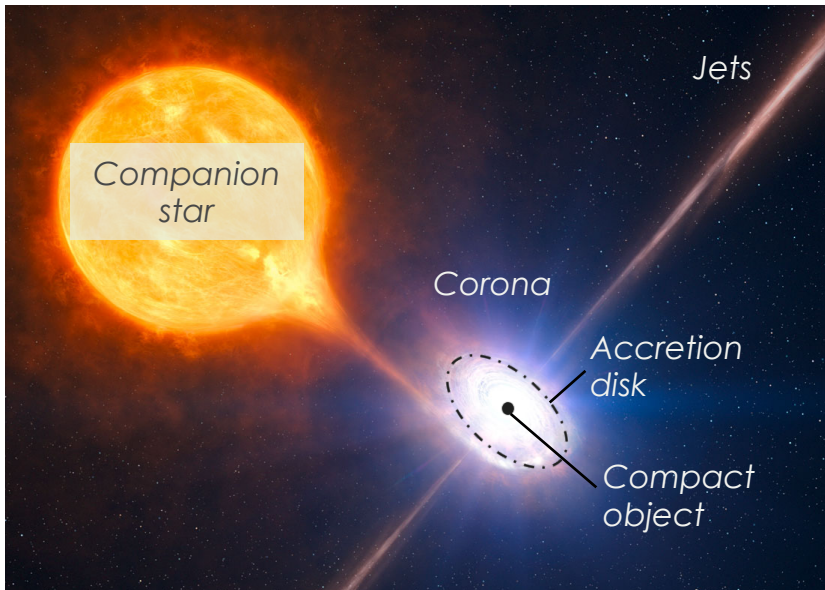
PhD Thesis, supervised by S. Corbel

Introduction – PhD Project

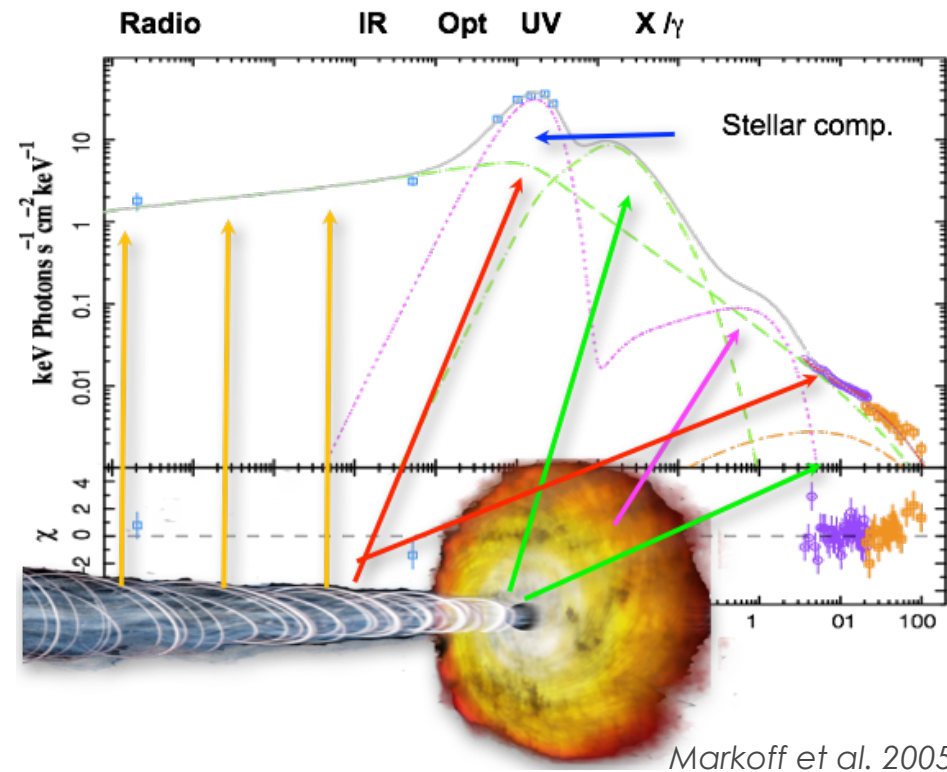
Title: 'Explosive Events in the Transient Radio Sky'

X-ray Binaries / Galactic Sources

Variability from ms to years
Multi-Wavelength emission



Example of Spectral Energy Distribution



Introduction – PhD Project

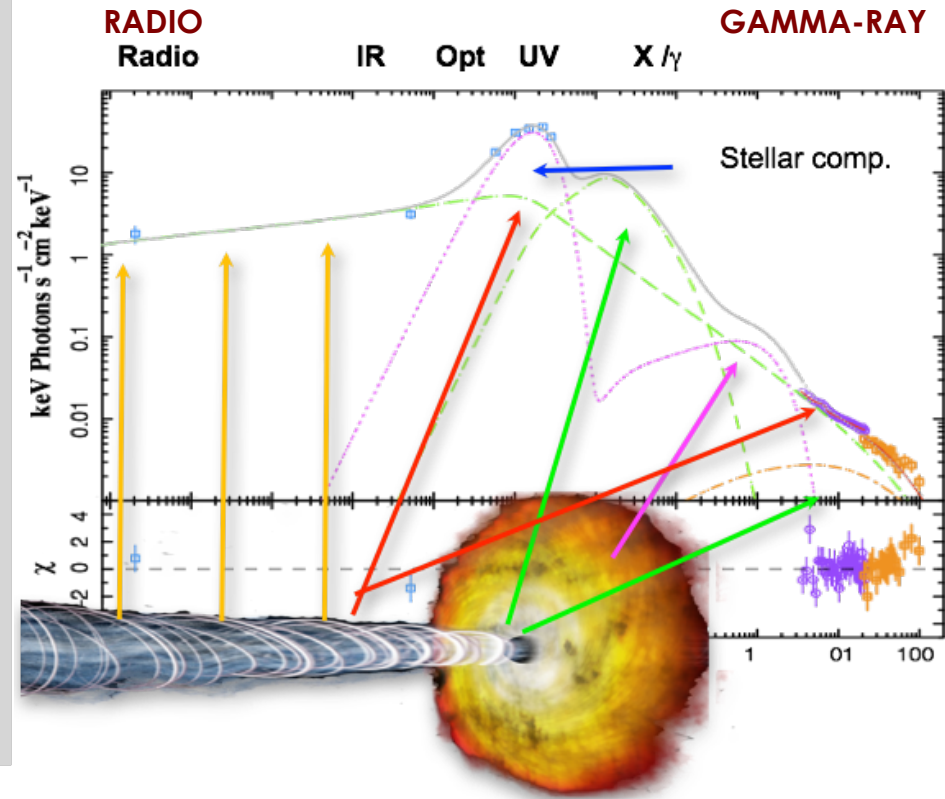
Title: ‘Explosive Events in the Transient Radio Sky’

Gamma-ray: physics of new sources (new gamma-ray classes)

Radio – Gamma-ray: common mechanisms \rightarrow particles acceleration, interaction with radiation fields

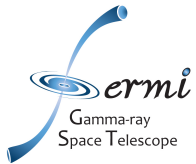
Radio – X-ray: link between accretion & ejection

Radio: jet properties/interaction with interstellar medium



Introduction – PhD Project

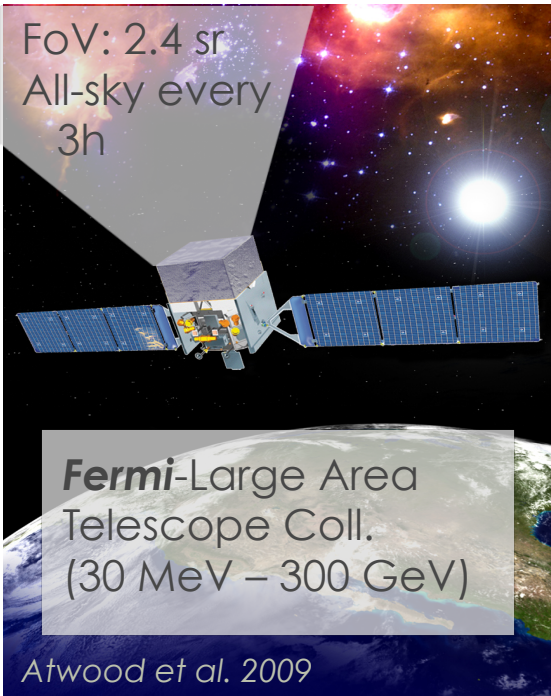
Title: ‘Explosive Events in the Transient Radio Sky’



Gamma-ray & Radio Observations



FoV: 2.4 sr
All-sky every
3h



Fermi-Large Area
Telescope Coll.
(30 MeV – 300 GeV)

Atwood et al. 2009

From the Academy Award-Winning Director of ‘Forrest Gump’ and Pulitzer Prize-Winning Author of ‘Contact’

JODIE FOSTER
MATTHEW McCONAUGHEY

**Very Large
Array**
27 x 25m-
antennas

A journey to the heart of the universe.

CONTACT

Perley et al. 2011



International LOFAR Telescope (ILT)



Chilbolton
Dutch stations
LOFAR Core (NL)
Jülich
Effelsberg
Tautenburg
Unterweilenbach
Nancay
Onsala
Norderstedt
Potsdam
Baldy
Borówiec
Lazy

**LOFAR (10 – 250 GHz)
International array**



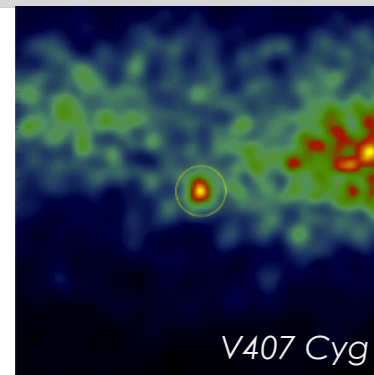
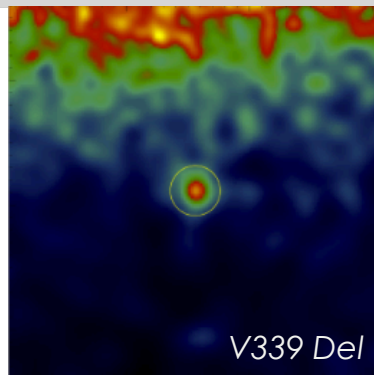
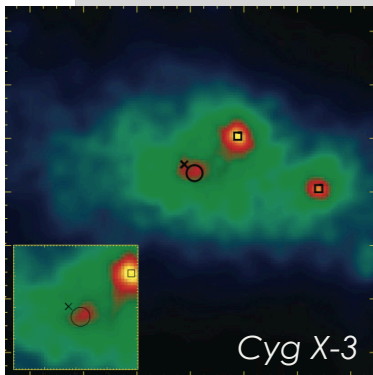
van Haarlem et al. 2013

Detection of Transient Sources

in Gamma-ray with *Fermi*-LAT

Transient Detection with *Fermi*

Large field of view (20% of the sky)
All-sky monitor (every 3h)



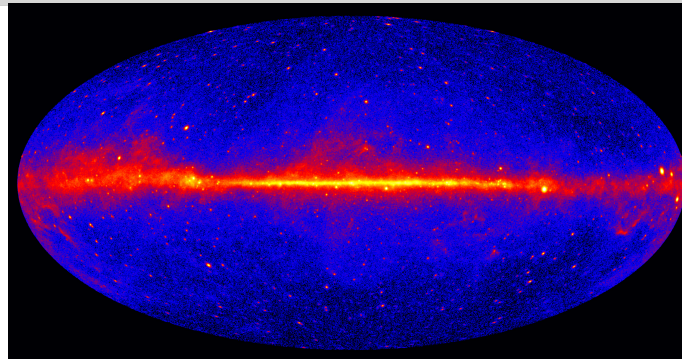
**Microquasar
Novae...**

The Fermi-LAT Coll. (2009)
The Fermi-LAT Coll. (2014)

Poor spatial resolution (at low energy)
High background 'pollution' from the Galactic plane

5-year sky map

(Credits: NASA/
DOE/Fermi LAT
Collaboration)



SS Cyg, Cataclysmic Variable

Red-dwarf + white dwarf

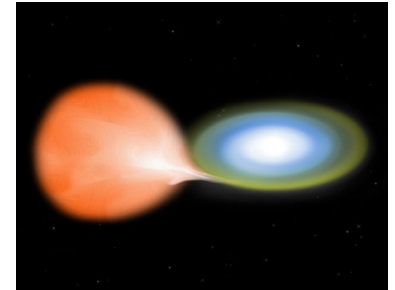
Recurrent outbursts

Proximity (114 pc ~ 370 light years)

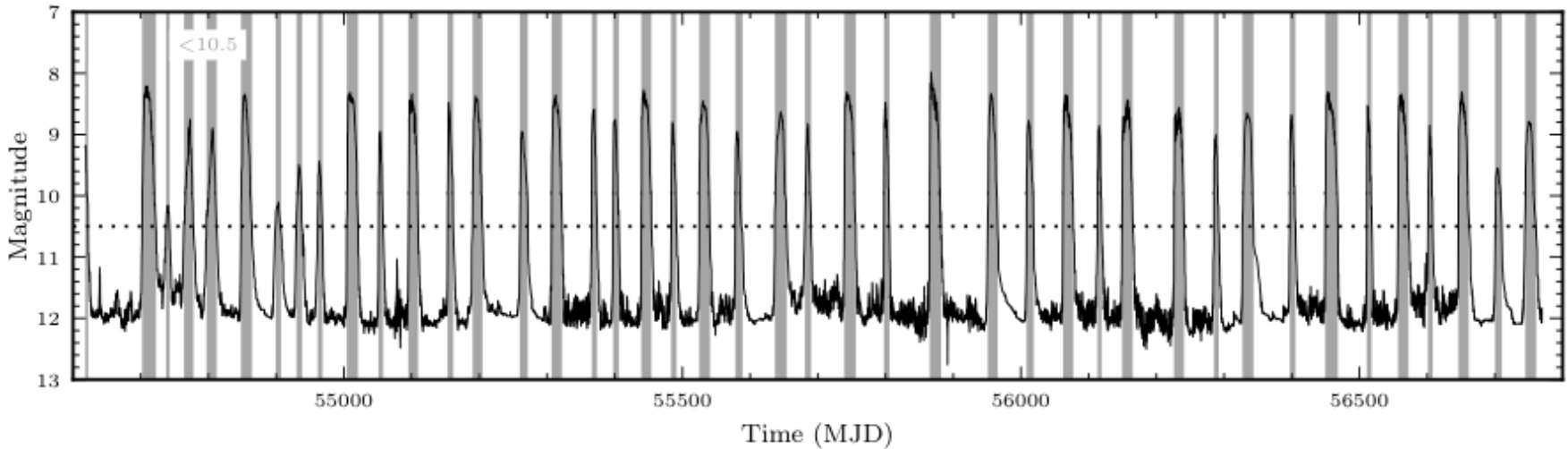
Non thermal emission during outbursts

Miller-Jones et al. (2013)

Körding et al. (2008)

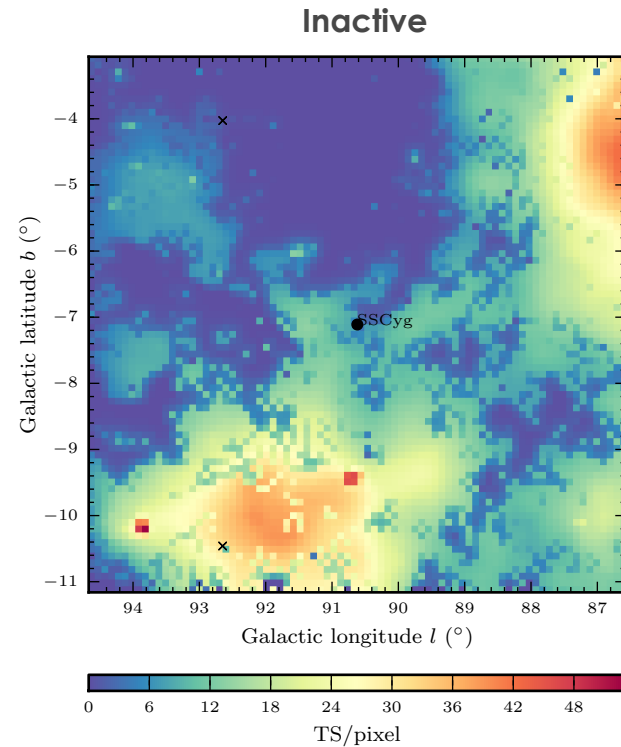
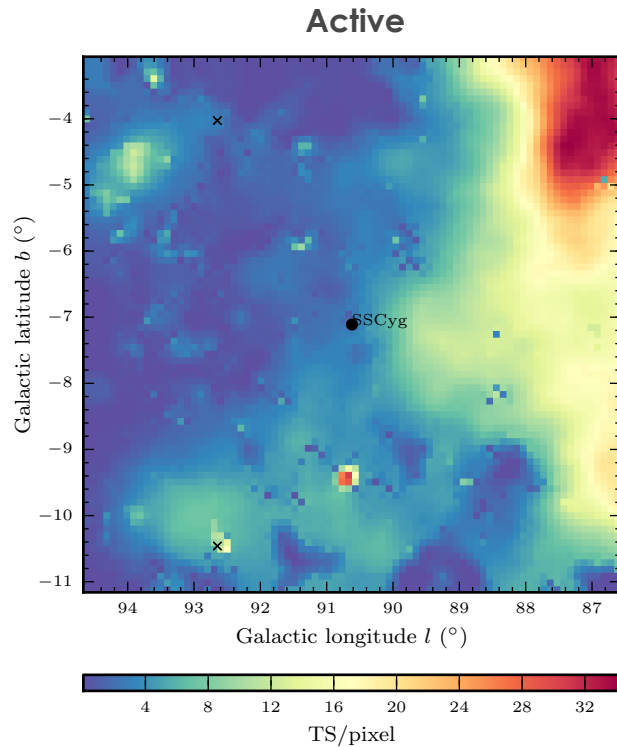


Optical light-curve of SS Cygni



Time-selection for gamma-ray analysis → **active** or **inactive** states

SS Cyg, No detection...



→ Upper-limits on the gamma-ray flux
Constraints on the **magnetic field intensity**
Limits on the **system extension**

Loh, Corbel, Dubus (in prep)

DG CVn, an active binary star

Two 'Red dwarfs' $\sim M_{\text{Sol}}/3$, separated by 3.6 au
(\rightarrow no compact object!)

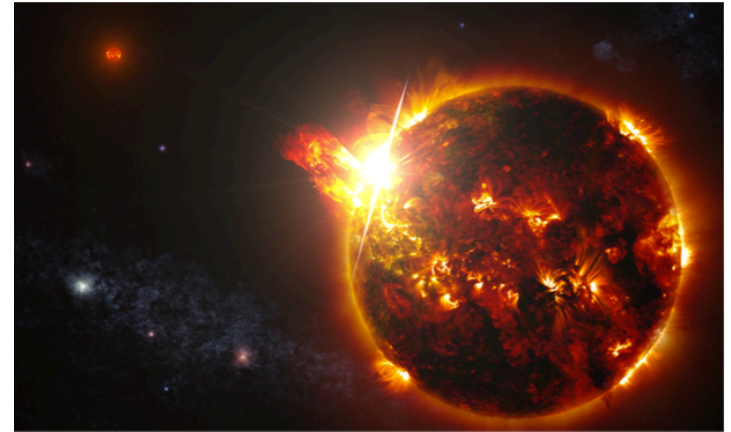
Far away from the Galactic plane ($b \sim 81^\circ$)

Nearby system (18 pc \sim 60 light years)

Very young (< 30 Myr)

Rapid spin ($v \sin i \sim 50$ km/s)

Riedel et al. (2014); Mohanty & Basri (2003); Mason et al. (2001)



(Credits: NASA's Goddard Space Flight Center)

\rightarrow characteristics of an active system

DG CVn, an active binary star

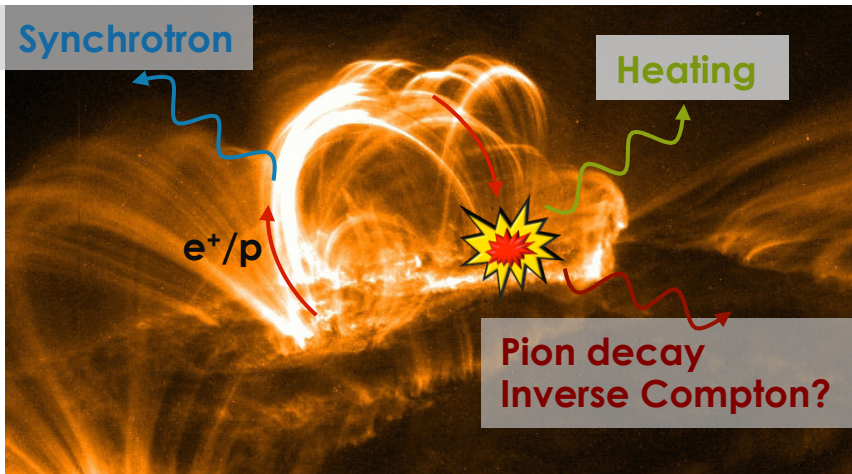
Swift-BAT (X-ray)

Detection of a **'superflare'** (2014 April 23) *Drake et al. (2014)*

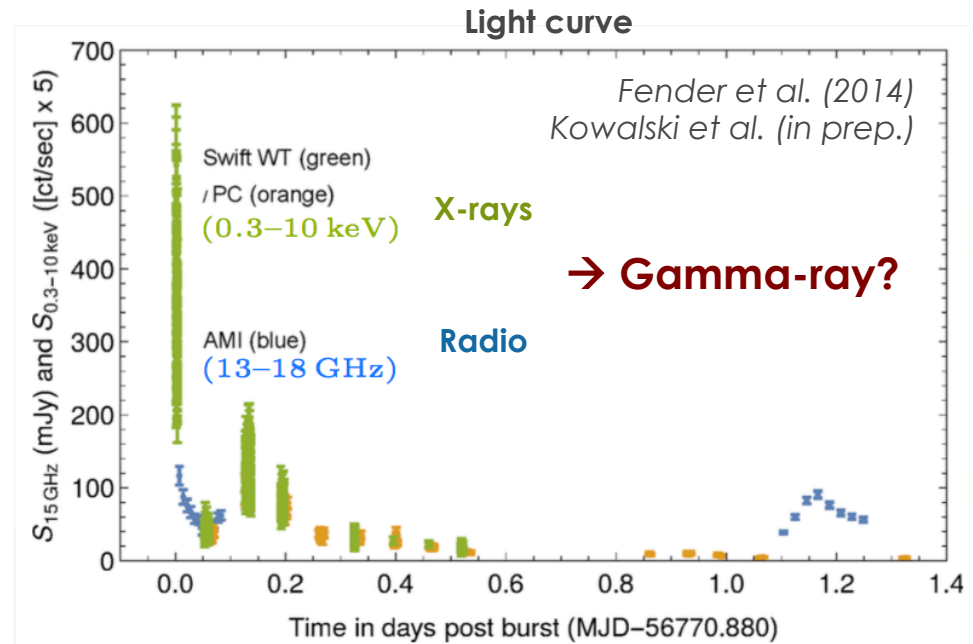
Class **X10⁵** (X45 max. for the Sun)!

Radio follow-up

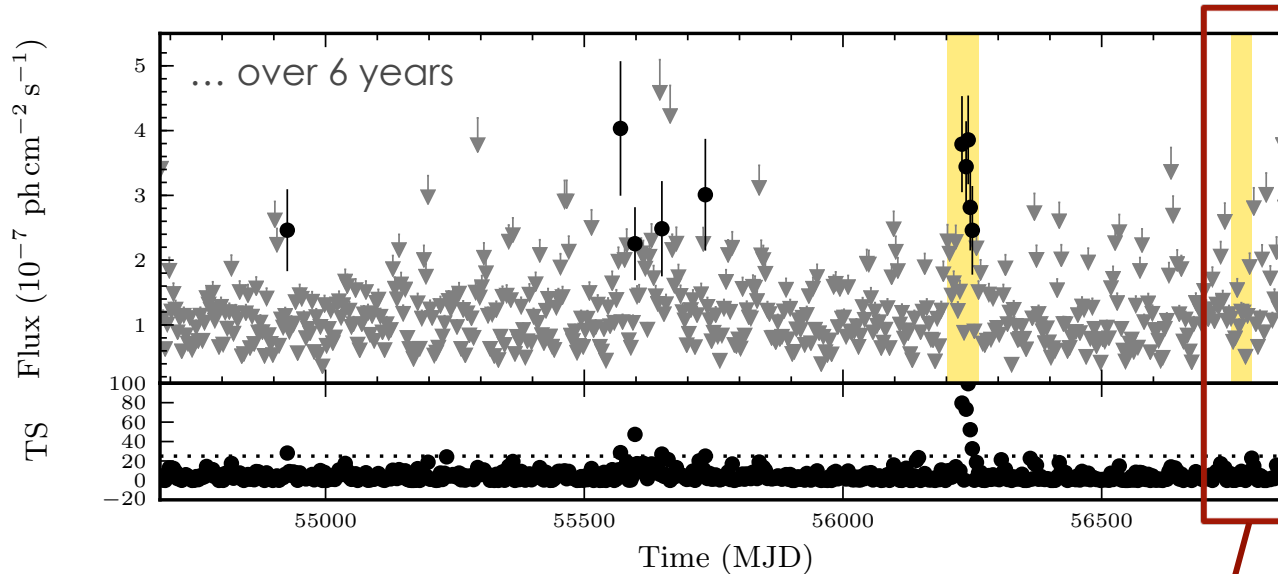
Synchrotron radiation from particles trapped in magnetic coronal loops



Neupert (1968)



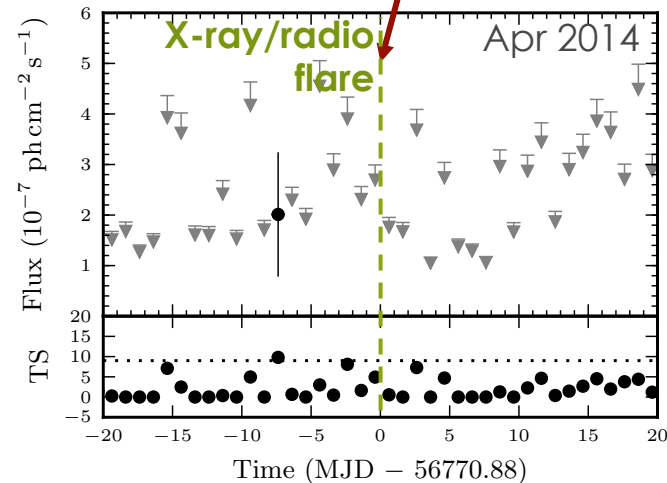
DG CVn, Long-term Variability



2 periods of interest

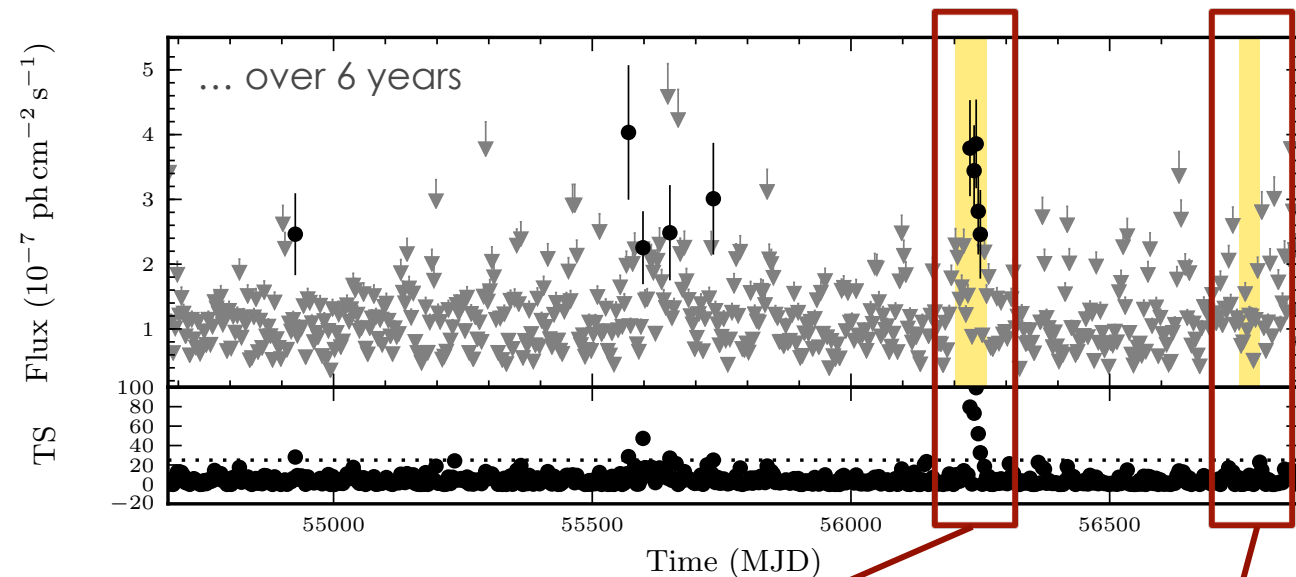
Apr 2014

During the 'superflare' → no detection

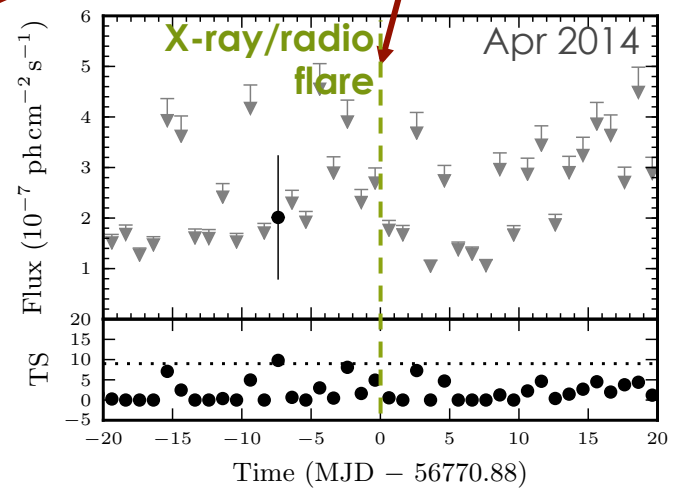
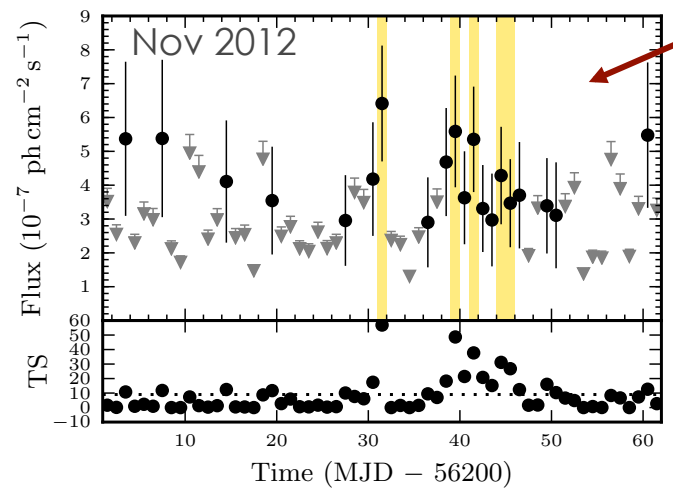


Loh, Corbel, Dubus
(2015, in prep)

DG CVn, Long-term Variability



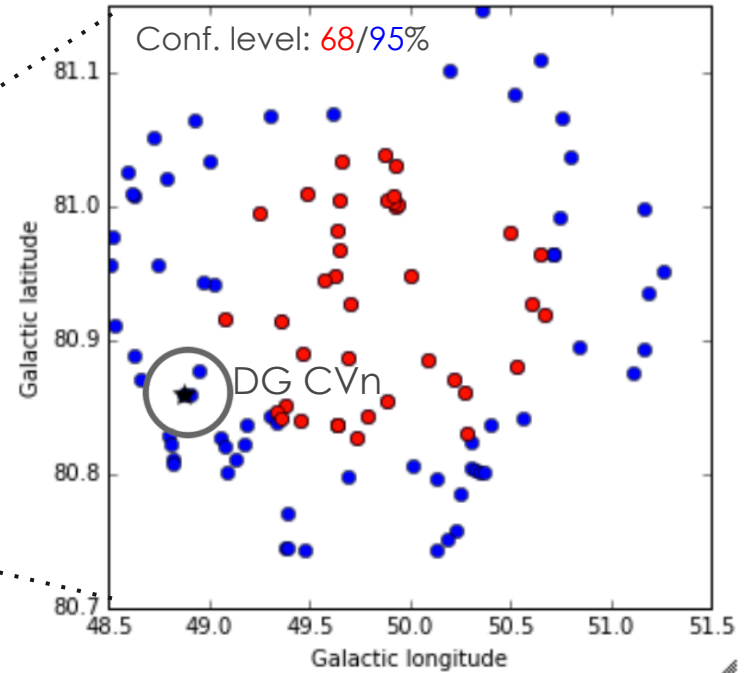
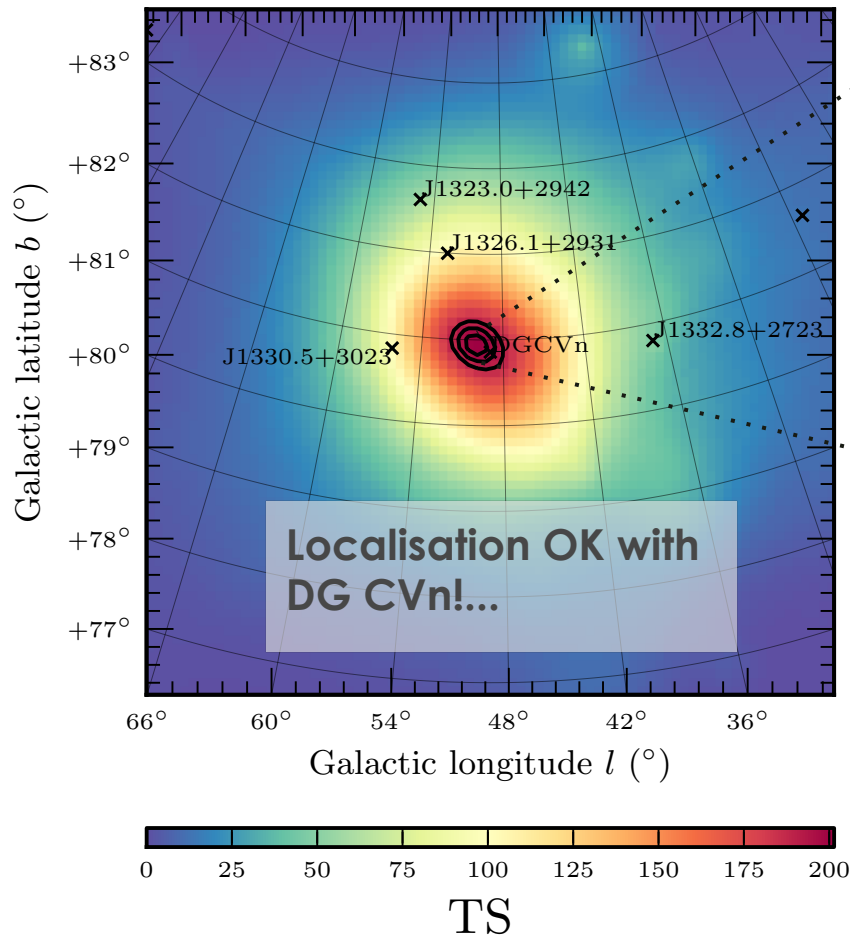
2 periods of interest
Nov 2012
Significant gamma-ray excess!
Apr 2014
During the 'superflare'
→ no detection



Loh, Corbel, Dubus
(2015, in prep)

DG CVn, a new class?

Nov 2012 – Significance map



...but **many sources** within the localisation uncertainties

Could also be a background **Active Galactic Nucleus**

Loh, Corbel, Dubus (2015, in prep)

Detection of Transient Sources

in radio with the Very Large Array

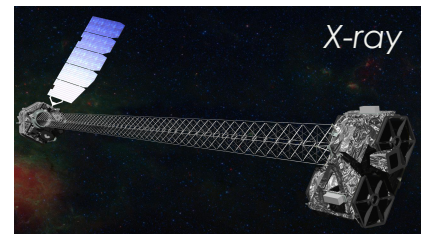
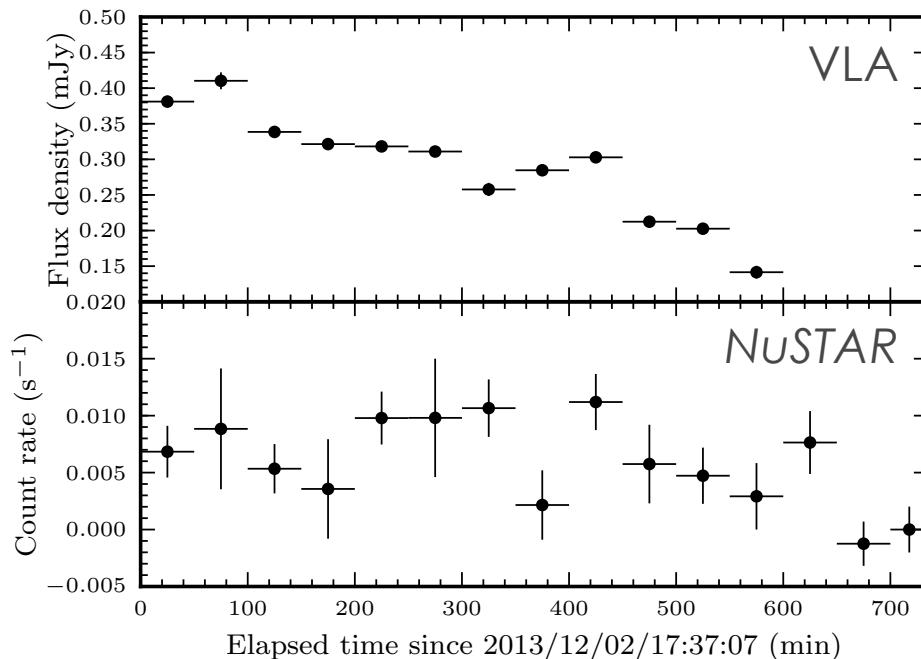
V404 Cyg, the sleeping BH

Low-mass X-ray Binary (black hole + star $< 1 M_{\text{Sol}}$)

Mostly in **quiescent state**: only 3 outbursts (in 1938, 1956, 1989)

Most luminous quiescent BH.

Simultaneous 9h observations: **VLA + NuSTAR**

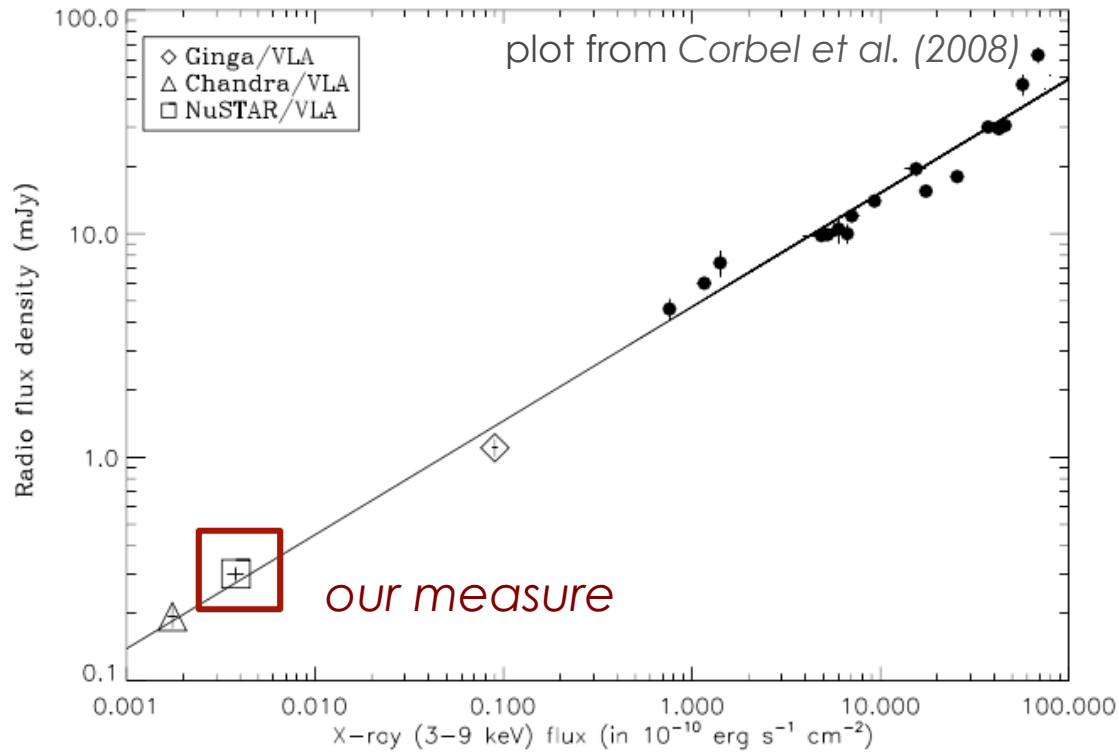


No clear correlation at short time scales

Rana, **Loh**, Corbel, Tomsick (2015, in prep)

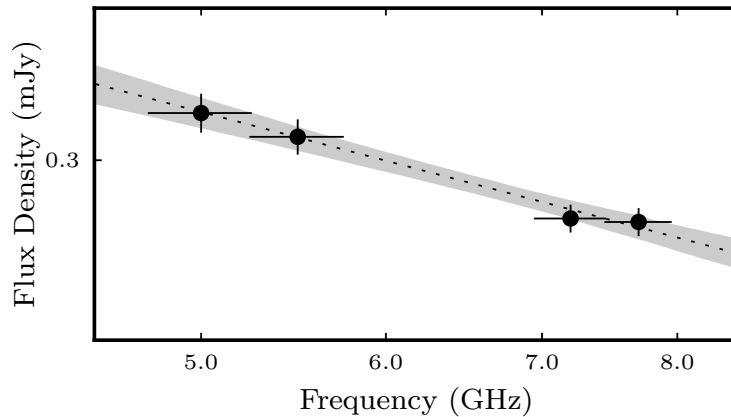
V404 Cyg, the sleeping BH

...but **perfect X-ray/Radio correlation** at longer time scale.

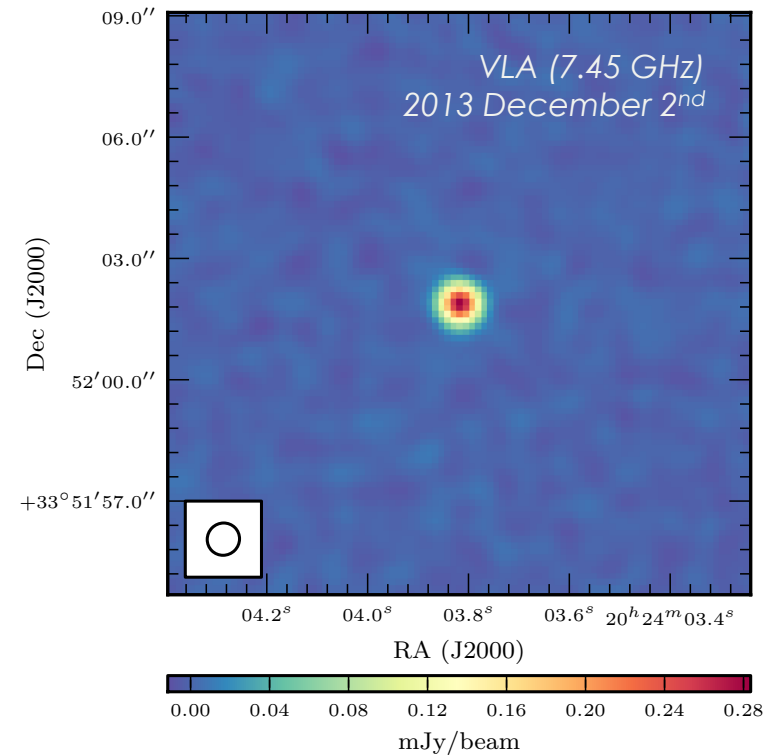


Rana, Loh, Corbel, Tomsick (2015, in prep)

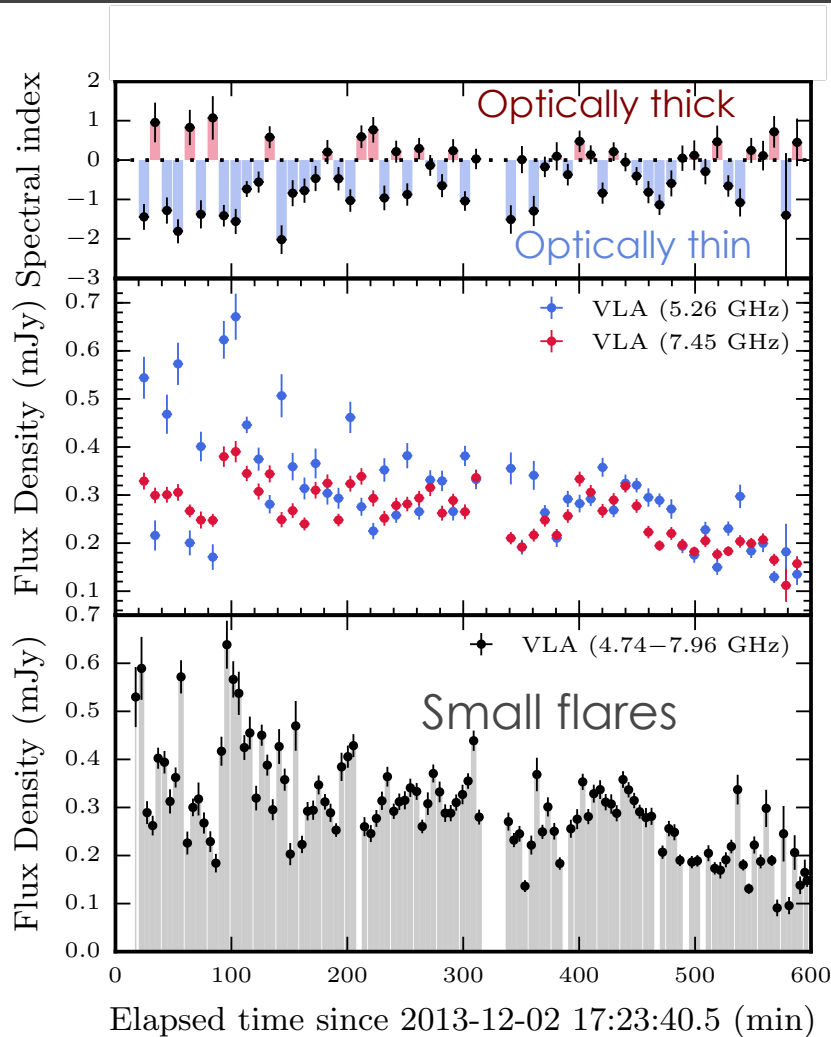
V404 Cyg, detailed radio study



Averaged radio spectrum consistent **with synchrotron emission from a compact jet**



V404 Cyg, detailed radio study



High radio variability on short time scales!

Compact jet instabilities (low density/inefficient particles acceleration)

Stochastic accretion flow instabilities (turnover frequency shift to low frequencies as accretion rate decreases)

Physical conditions changes (B, size of acceleration zone...)

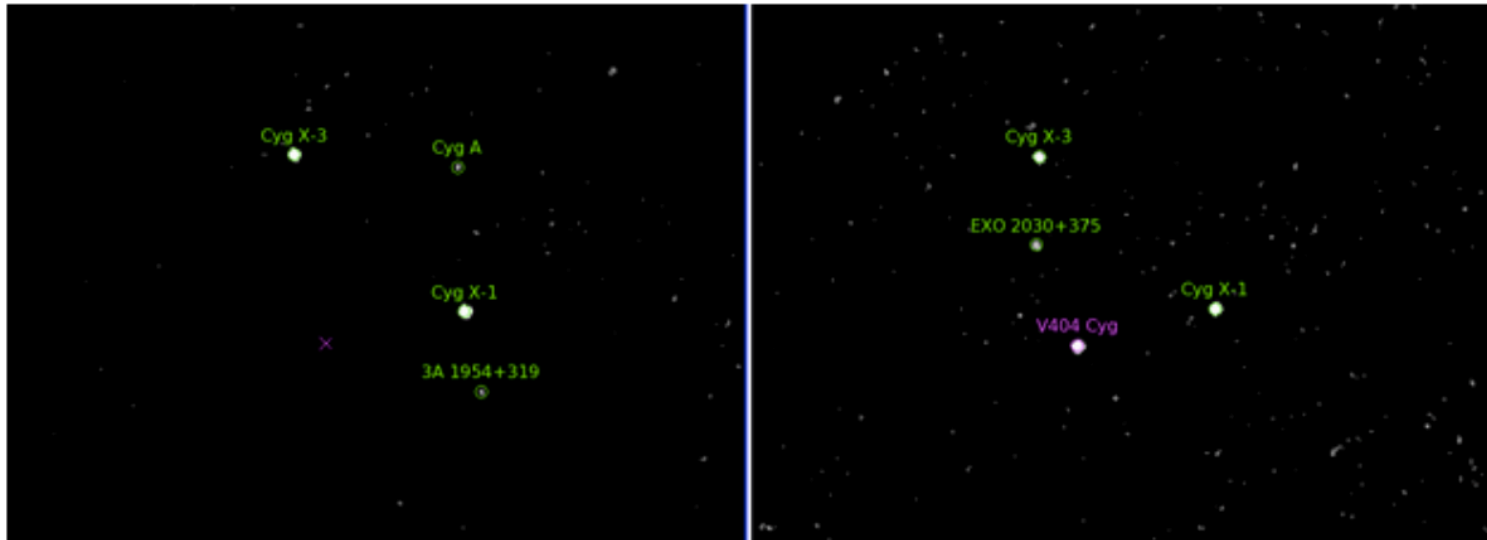
Bonus!

Live from yesterday/today

V404 Cyg, explosive awakening

Since 2015 June, 15th: **extremely bright flares from V404 Cyg**
Seen at all wavelengths, from radio to hard X-rays, **not yet in gamma-rays!**

INTEGRAL IMAGE BEFORE AND AFTER THE OUTBURST OF V404 CYGNI

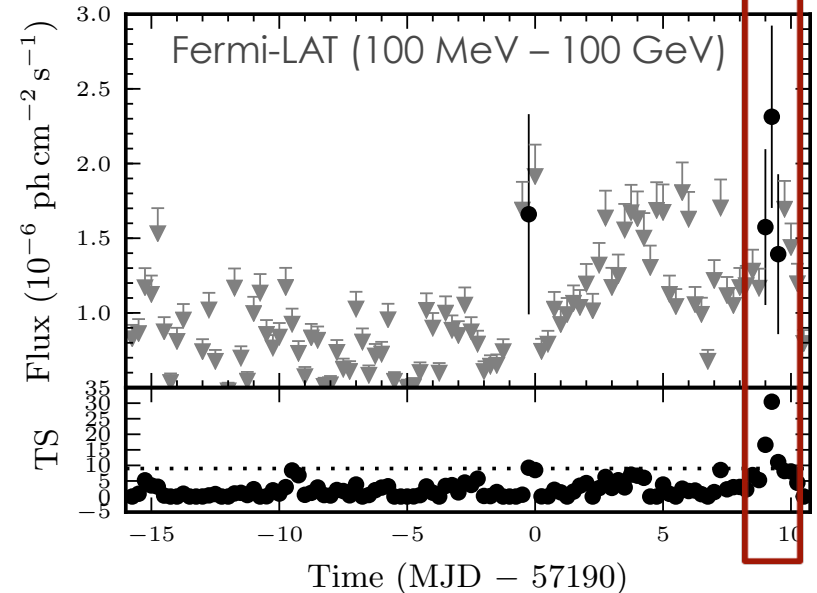
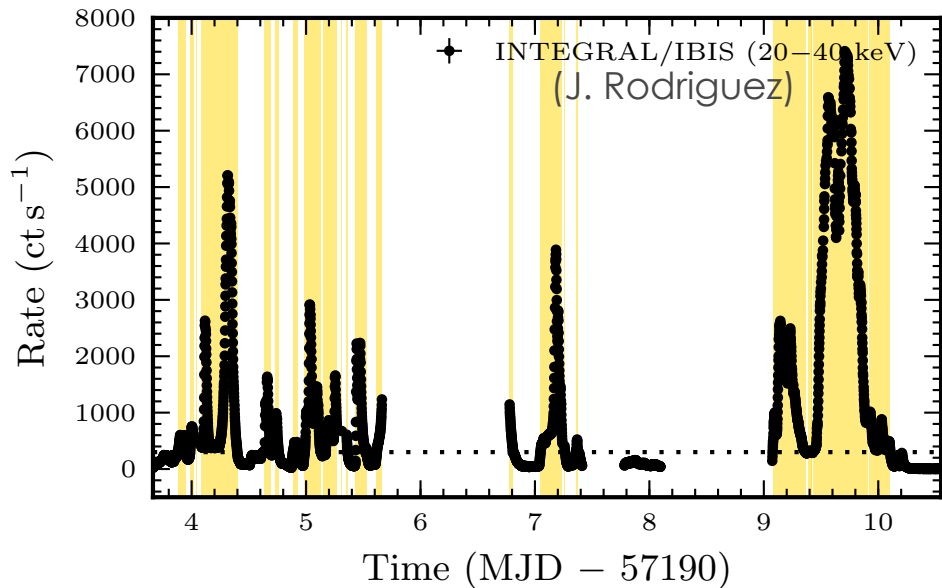


(Credits: ESA/INTEGRAL/IBIS/ISDC)

up to **50 times brighter than the Crab system!** (one of the brightest X-ray source) in hard X-rays (20 – 60 keV)

V404 Cyg, explosive awakening

Detection with Fermi-LAT!



Second microquasar firmly detected at high-energy gamma-rays!
First one in the LMXB category!

- Astronomer Telegram to be published in the coming days
- A paper will follow

Perspectives

Many different studies on a broad range of Galactic systems (radio – gamma-ray)

Rapid responses to flaring activity from binaries

X-ray/radio accepted program

Fermi-LAT

Detailed radio study of Cyg X-3 with LOFAR

Compact jet + ISM interaction

Thank you!

GRS 1739-278, response to a transient

'Target of Opportunity' program (PI: John Tomsick)

→ **X-ray / radio correlation** (Swift-XRT / Very Large Array)
black hole transient in the *hard state* (at the rise & decay of an outburst, **steady compact jet**)

