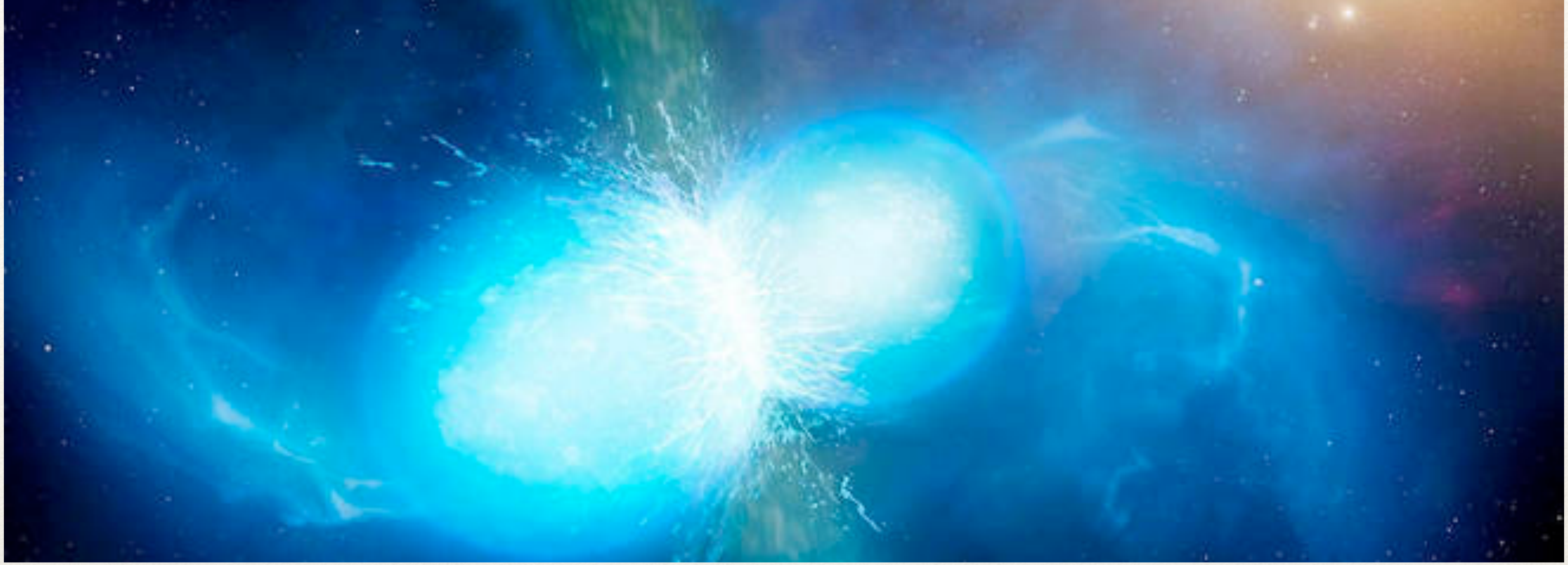

Radio and HE transients

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Terre - Planète - Univers
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l'Observatoire de Paris

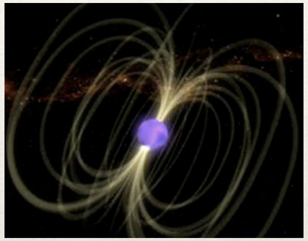
Outline

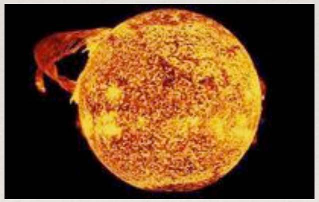
- Radio and HE transients
- Alerts in radio = jets most of the time !
- Example of the XRBs highlighting their broadband emission.
- What do we need to collect and how ?
- Conclusions

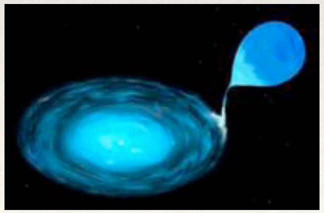
A variety of h.e.transients

Source	Timescale
TGF	ms
GRB	ms - weeks
SGR	ms - sec
TDE	days - yrs
Solar flare	min
SN/Nova	min - yrs
X-ray bin.	sec - yrs
AGNs	hr - centuries

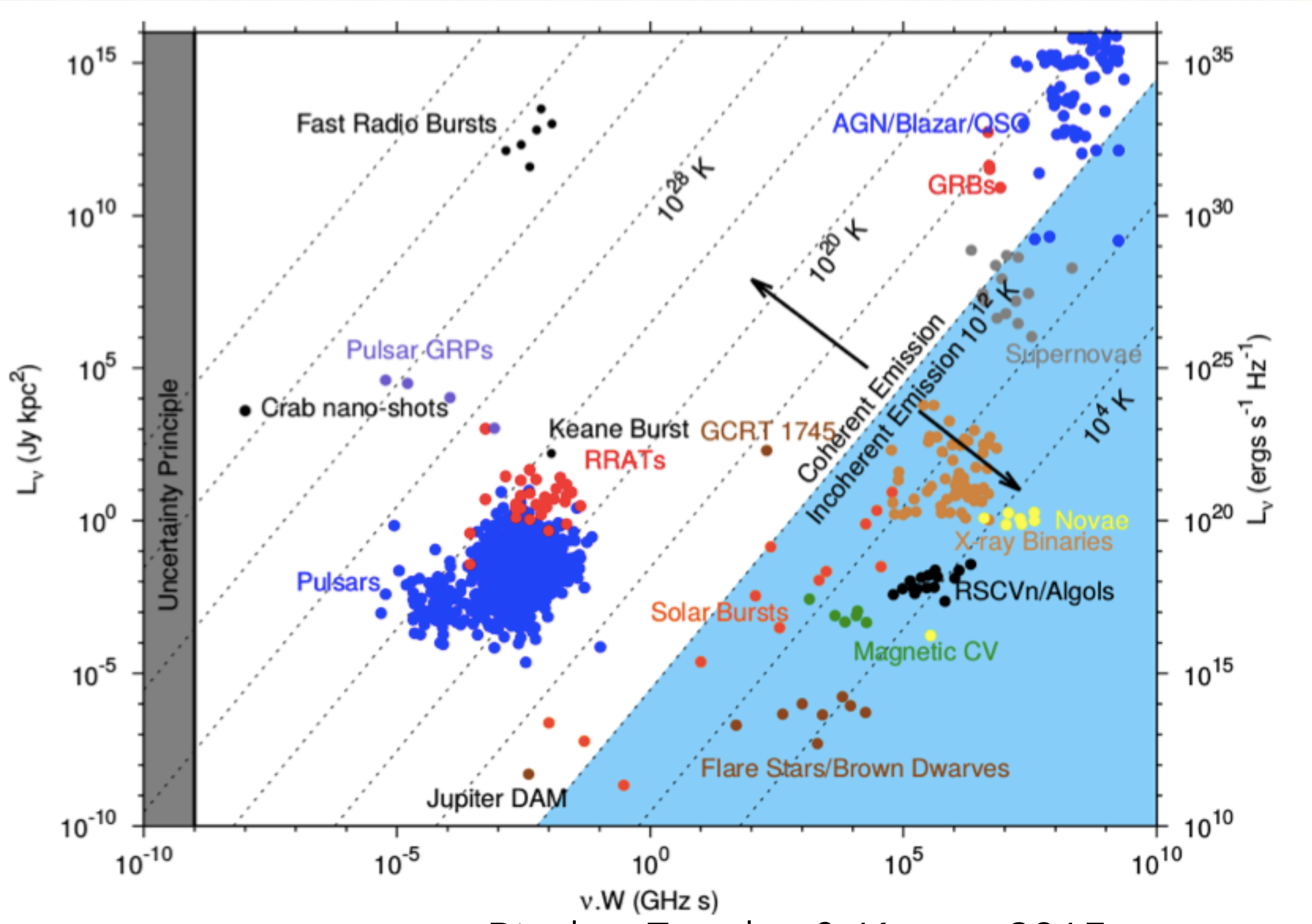









Radio Transients



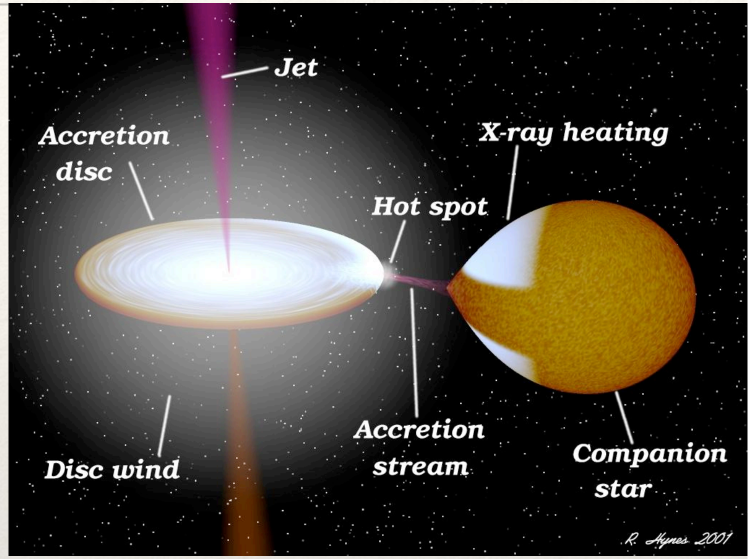
Pietka, Fender & Keane 2015

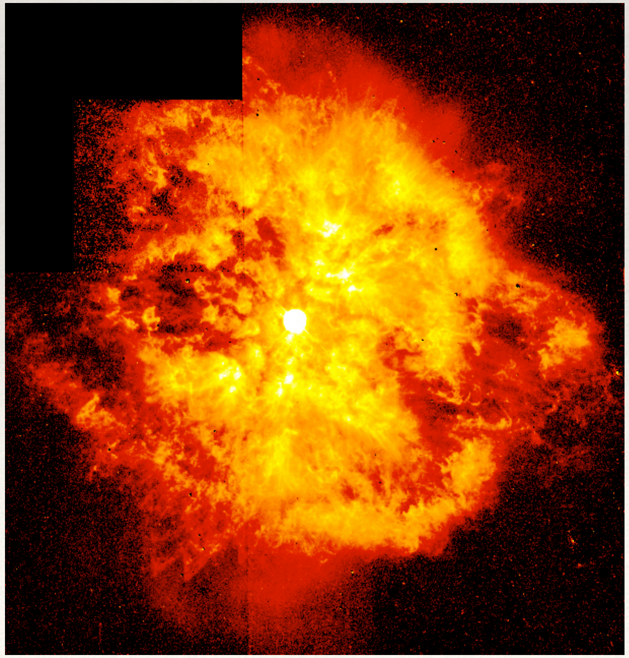
Limit ~1 sec

Imaging vs. Time series

Synchrotron transients

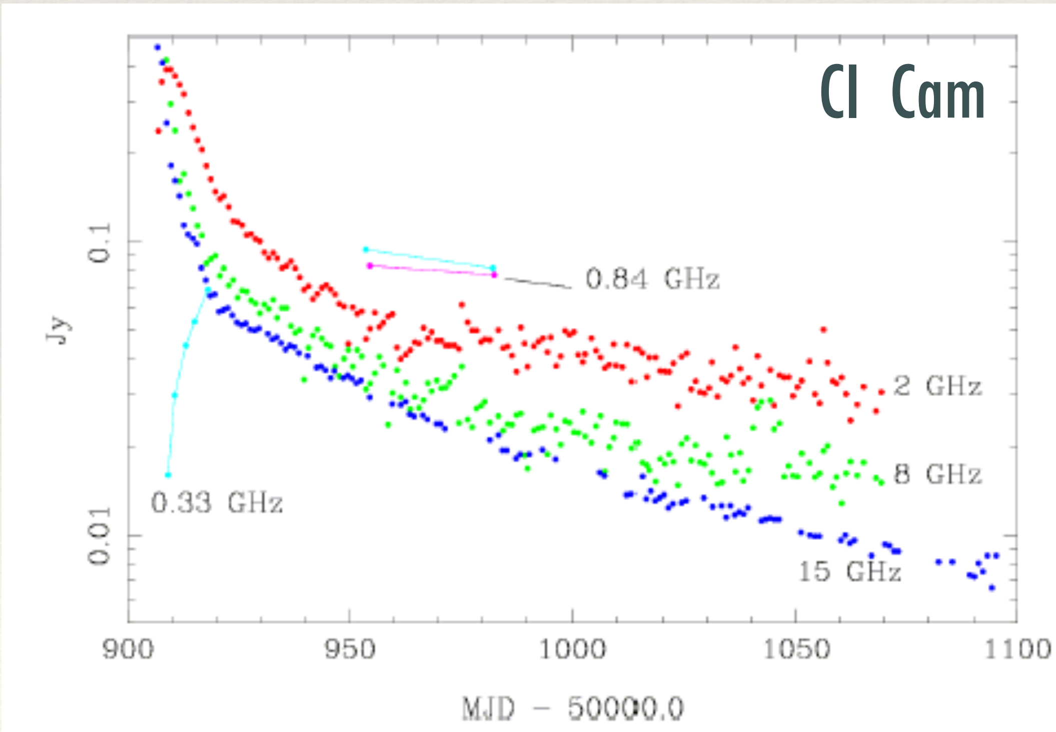
- Primarily explosive events or outflows
- Known source classes:
  - X-ray Binaries (BH, NS, WD)
  - Ultra Luminous X-ray sources (ULX)
  - Isolated black holes and IMBH
  - Magnetar outbursts, gamma-ray binaries
  - Supernovae (SNe) ➥ Rigault
  - Active Galactic Nuclei (AGN)
  - Tidal disruption events (TDEs)
  - Gamma-ray bursts (GRBs) ➥ Götz
  - Some **novae** (usually thermal)

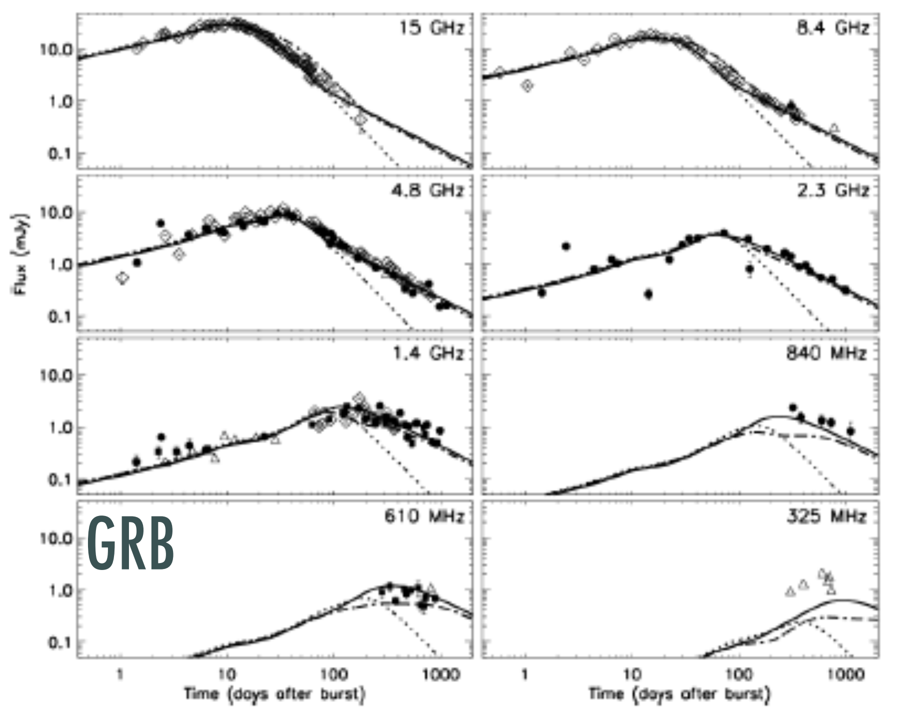




Incoherent synchrotron processes

- Shock-accelerated electrons and magnetic fields
- Important frequency evolution. Become optically thin later at lower frequencies (+lower flux also).



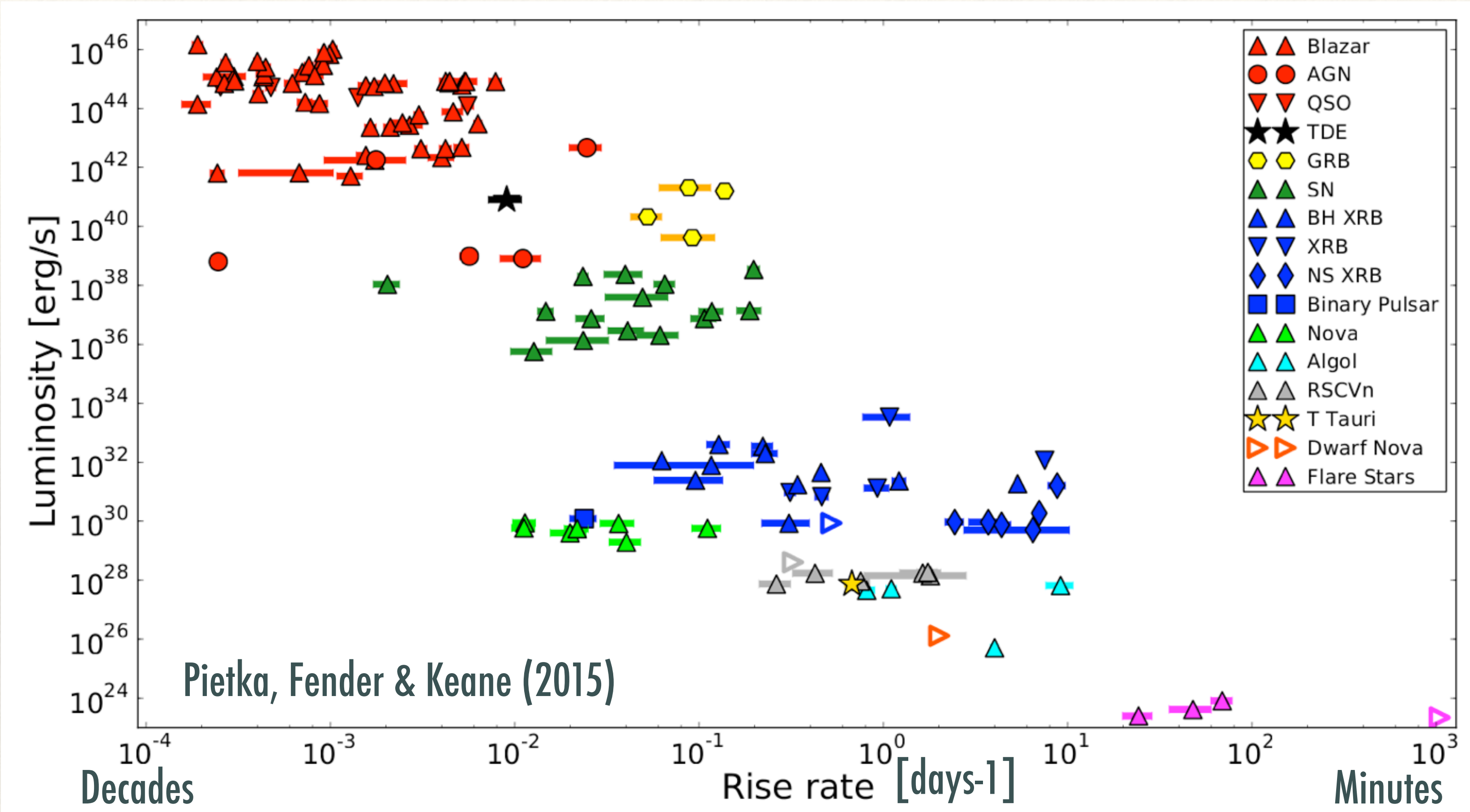


van der Horst et al. (2008)

Motivations

- **Accretion**: the most powerful source of energy in the Universe !
- Whenever you have accretion, you always see **ejection** !! Nature of the existing **fundamental coupling** ? Is it universal along the mass scale ?
- **Synchrotron flares** from stellar mass compact objects : a **unique laboratory** with associated variabilities accessible with our lifetime.
- Astrophysics in **extreme** environments : density, temperature, gravity, velocity, ... !
- **Jets**: Composition? Formation ? Energetics ? Feedback on their environment ?
- Existence of **intermediate mass** black holes ? Seeds of supermassive BHs ? EOR ?

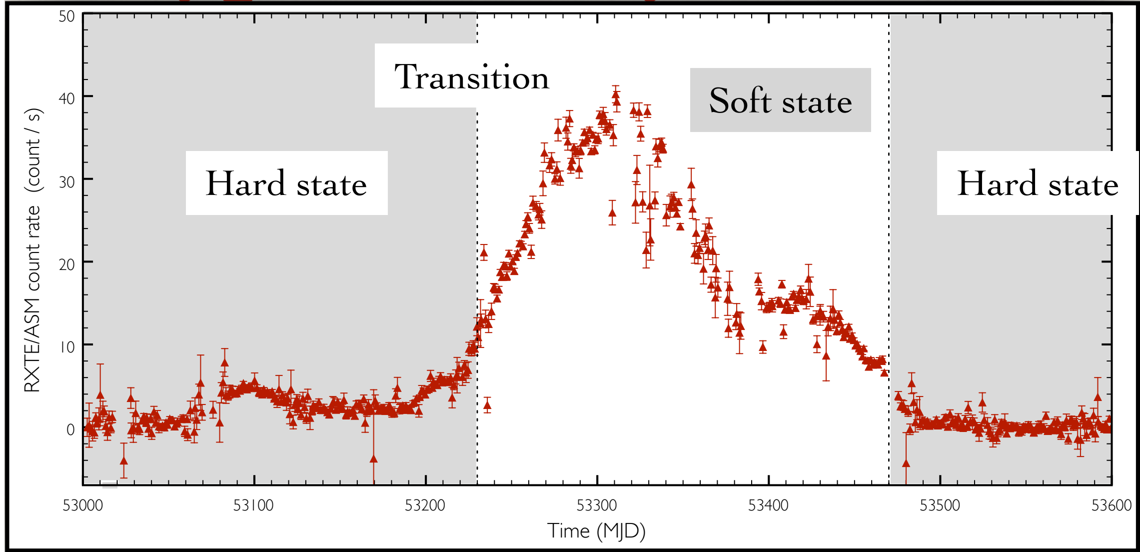
Similar physics across the entire mass scale?

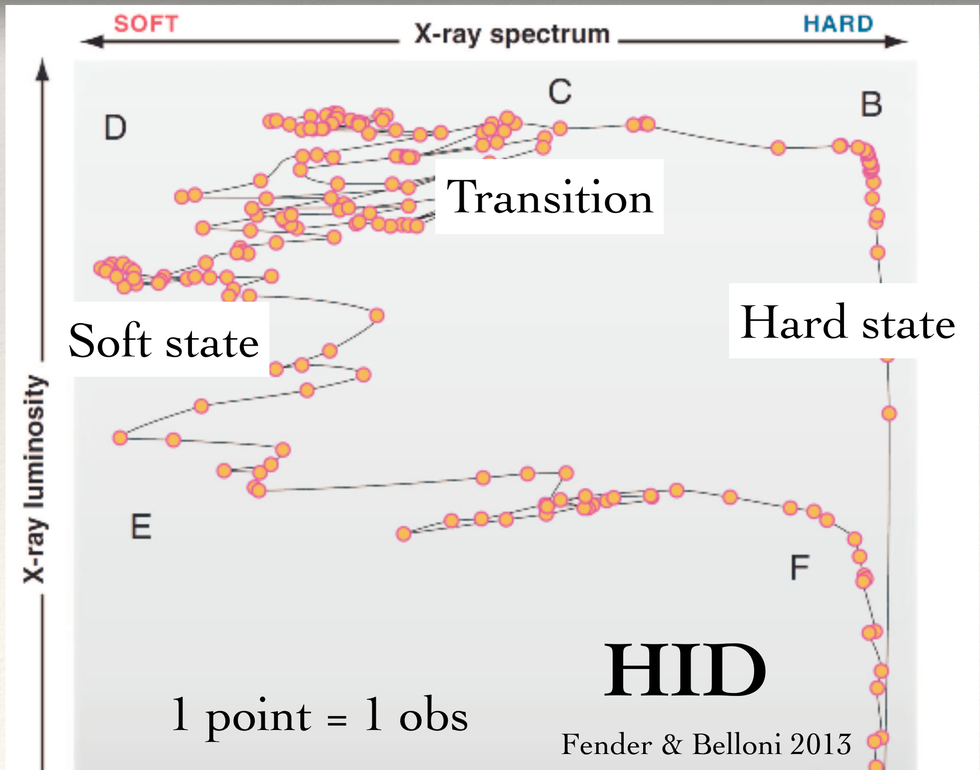


Despite **very different classes of objects**, they will share **similar requirements** in term of specificities

Example of jets in XRB transients

Typical x-ray evolution of a bht in outburst

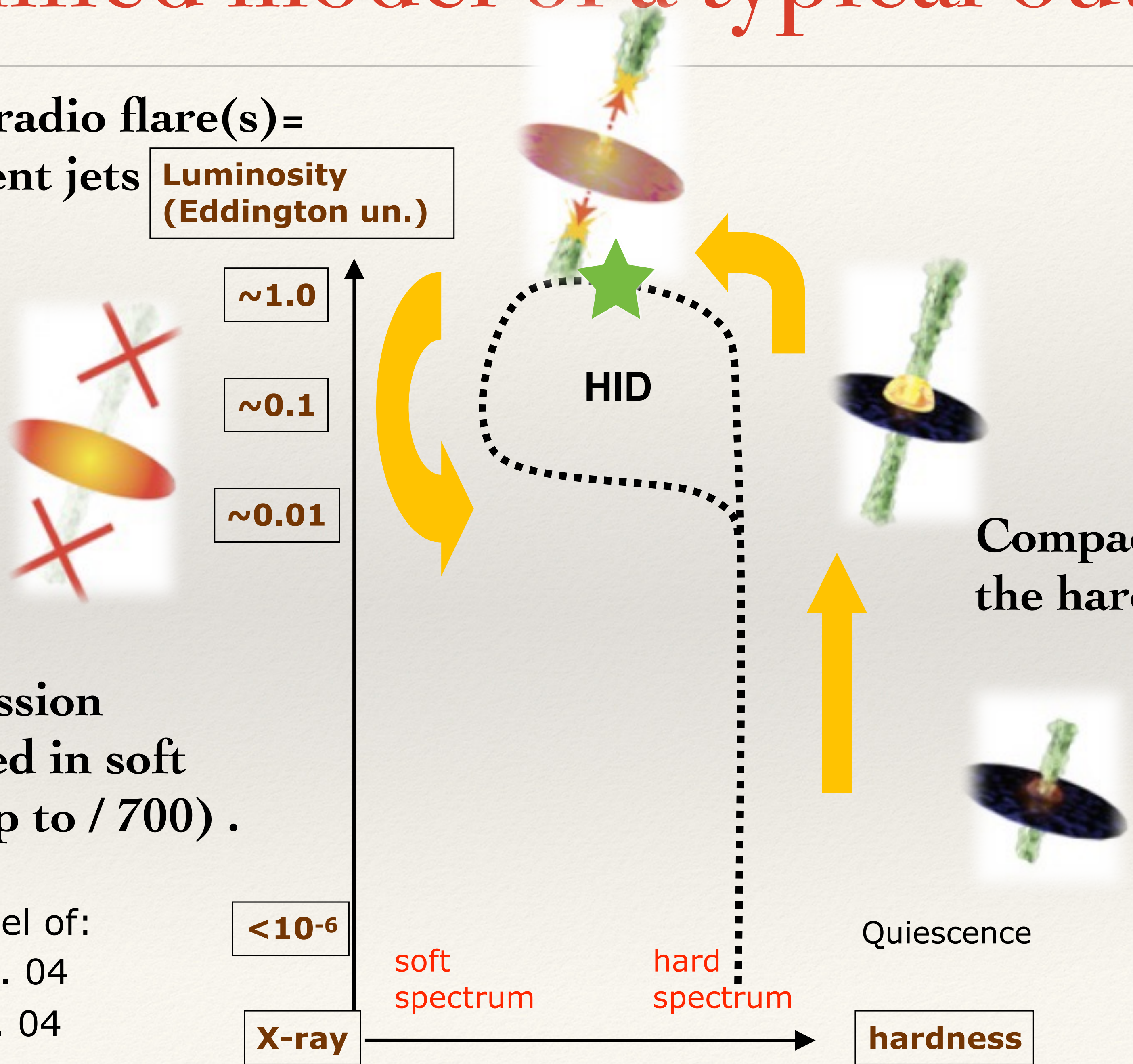




- X-ray **evolution** (energy spectrum + power spectrum): different states
- **Hardness Intensity Diagram** (HID): hardness = ratio of counts in 2 different bands (model independent)
- **Disc Fraction Luminosity Diagram** (DFLD) : hardness = non thermal power-law / total flux. Allows comparison between different populations.

Unified model of a typical outburst

Major radio flare(s)= Transient jets

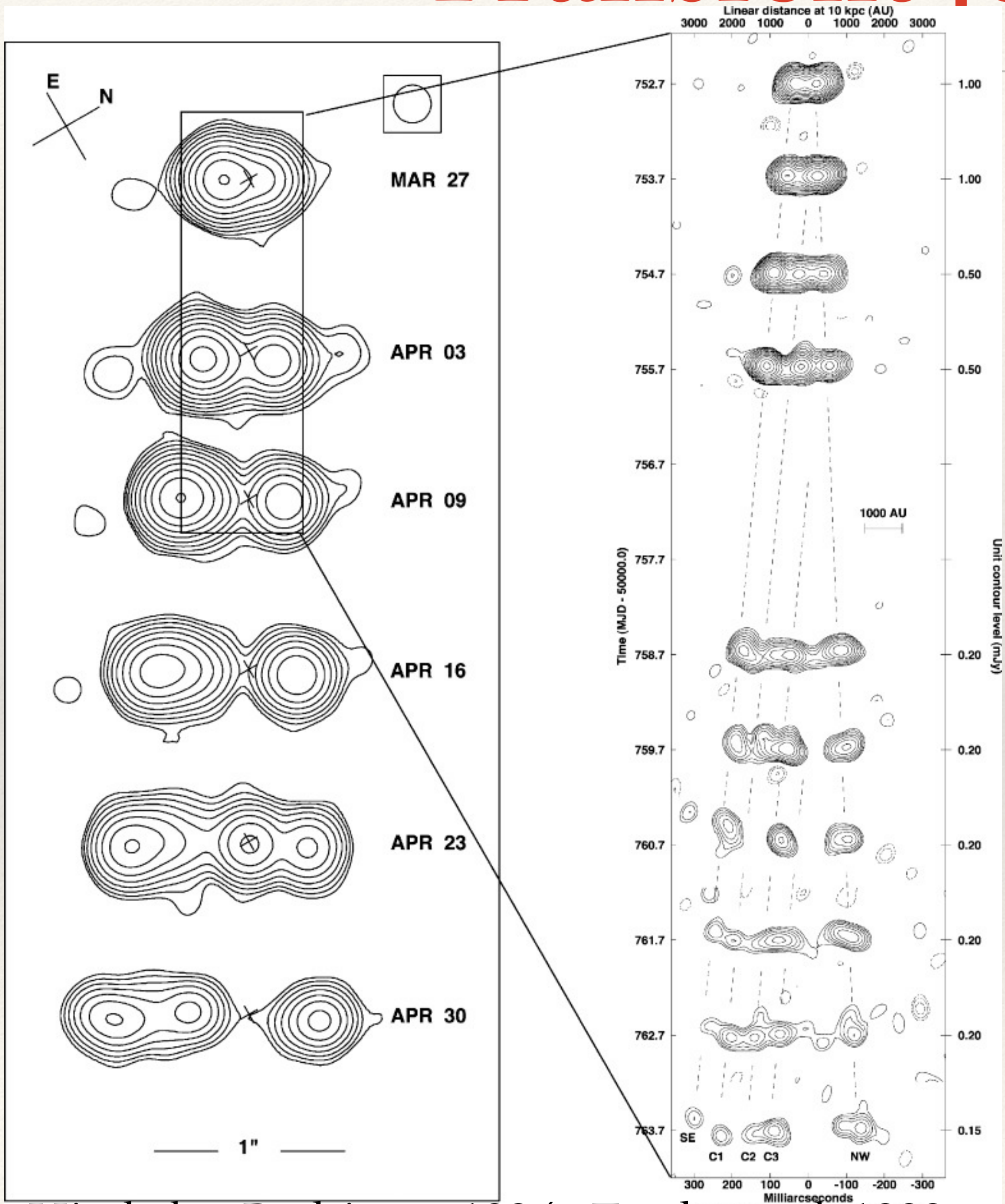


Compact jets in the hard state

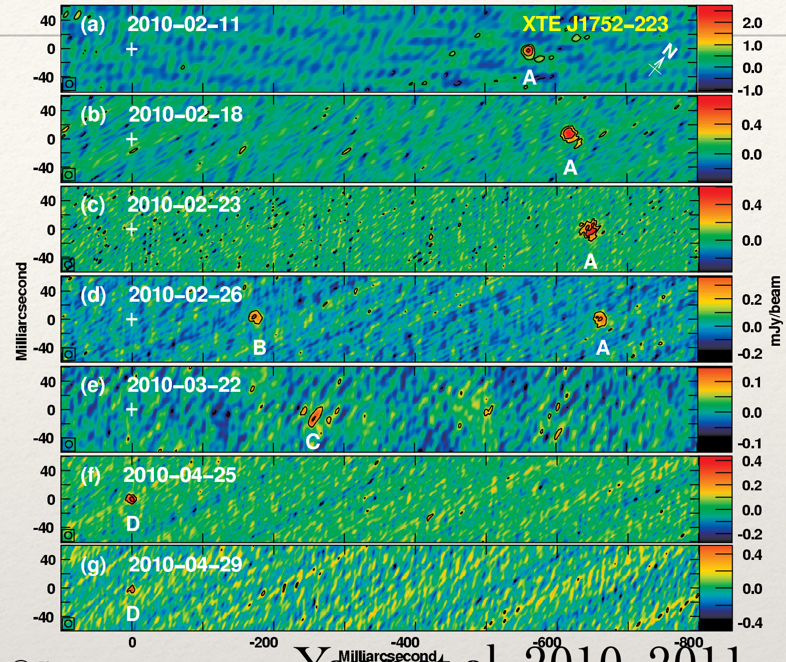
Jet emission quenched in soft state (up to / 700) .

Unified model of:
Fender et al. 04
Corbel et al. 04

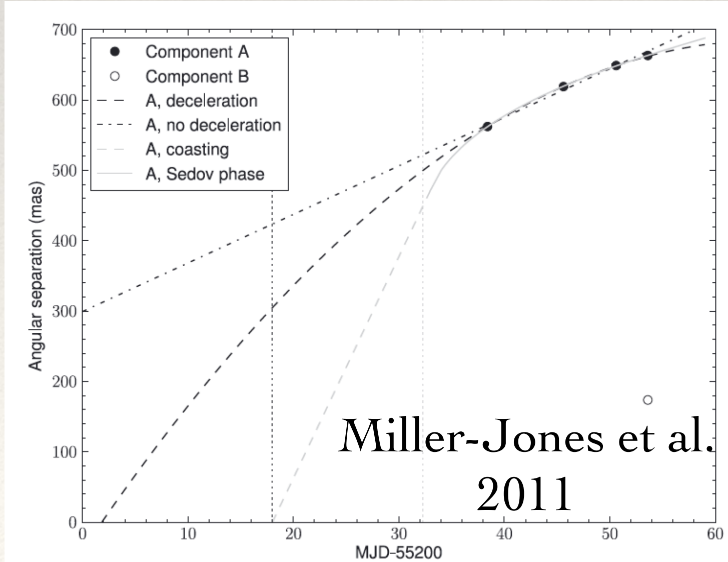
Transient jets in BHT



Mirabel & Rodriguez 1994 ; Fender et al. 1999



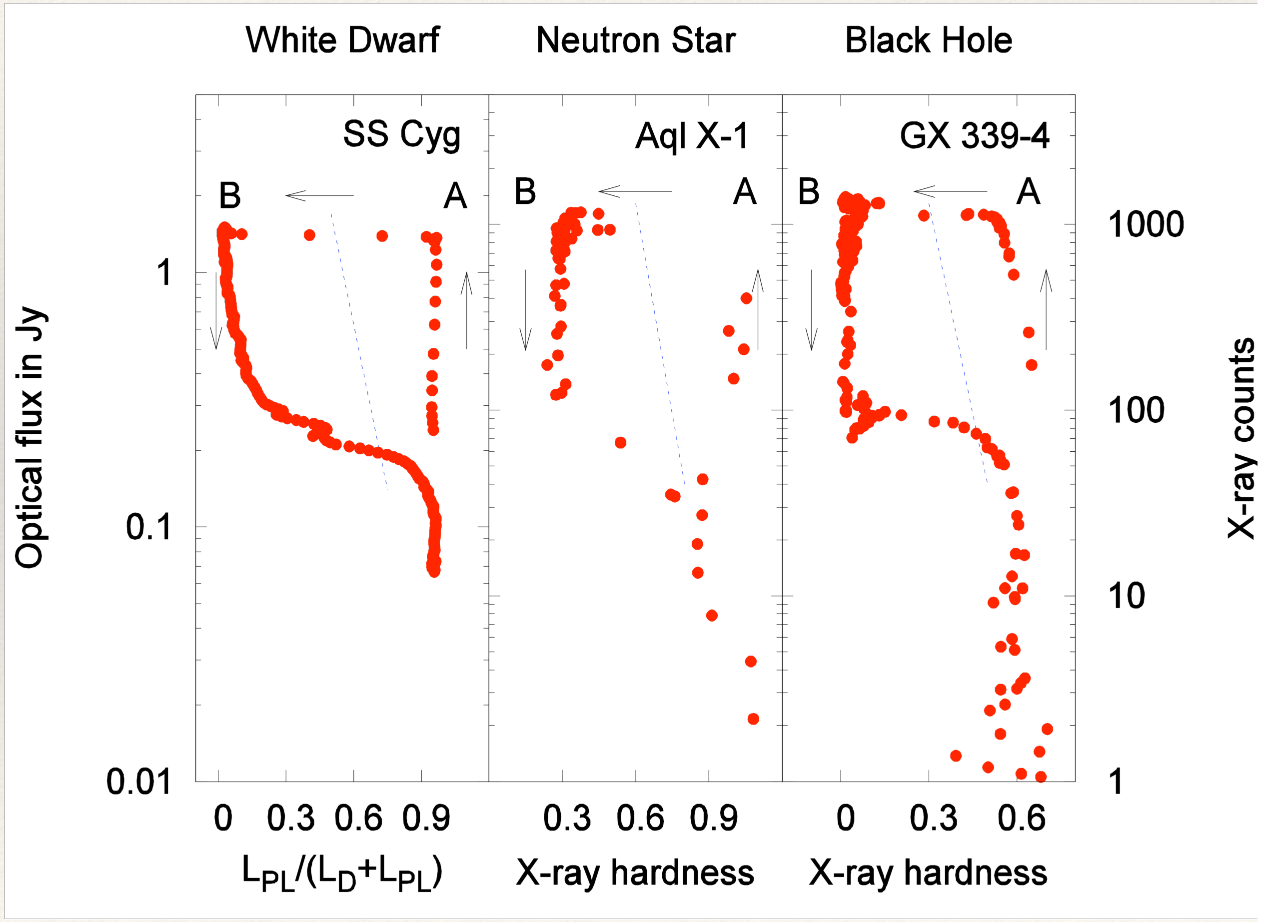
Yang et al. 2010, 2011



Miller-Jones et al. 2011

Unification in galactic compact objects

Koerding et al. 2008



Coppejans et al. 2016

Koerding et al. 2008

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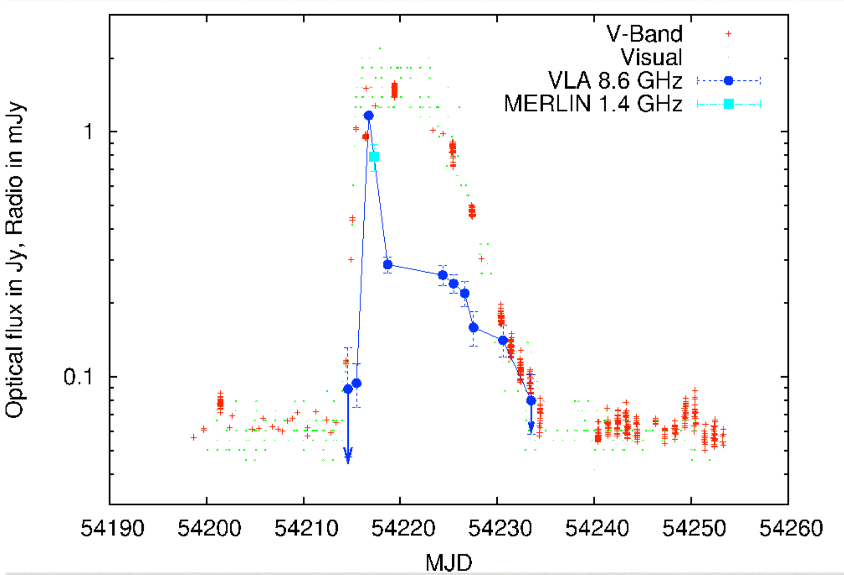

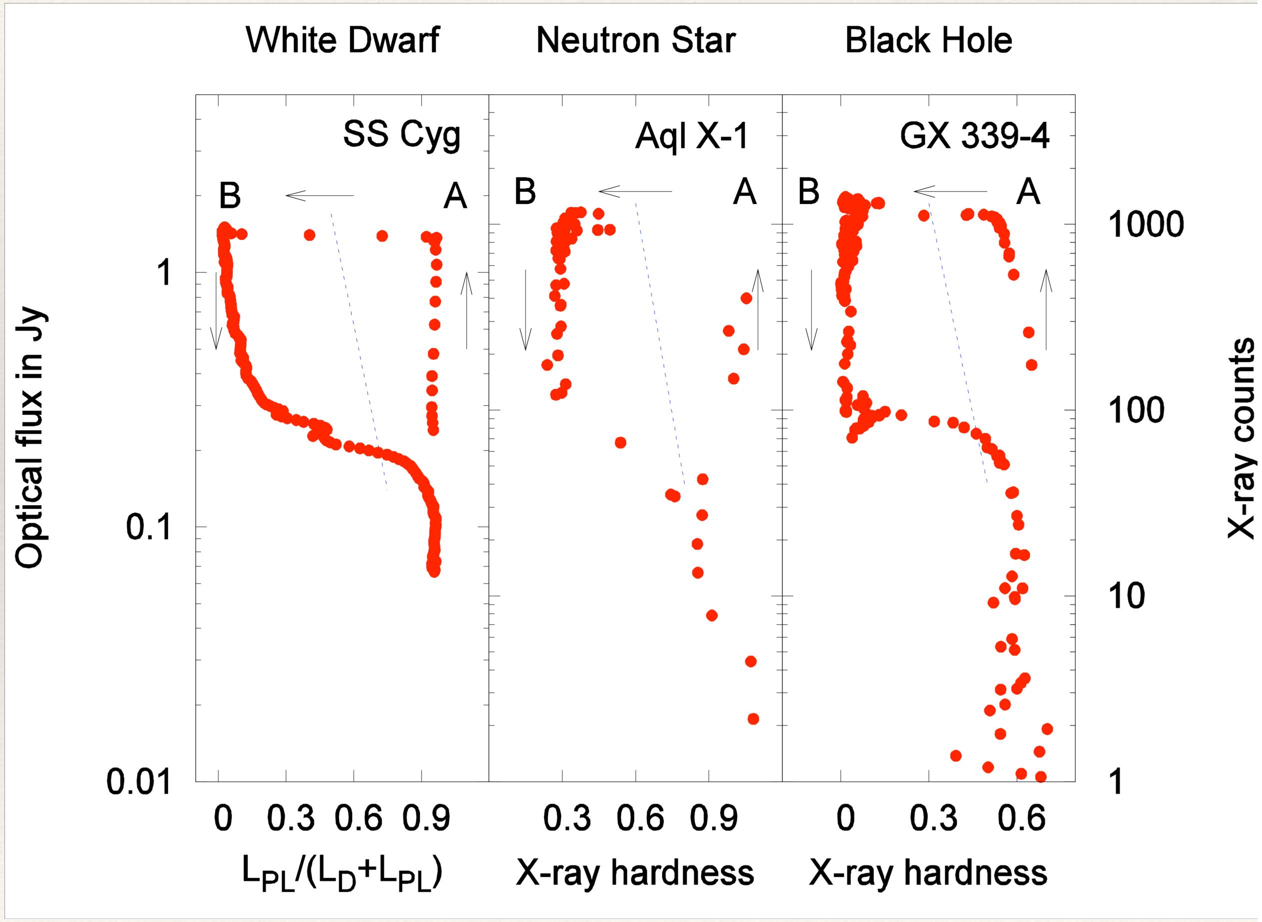

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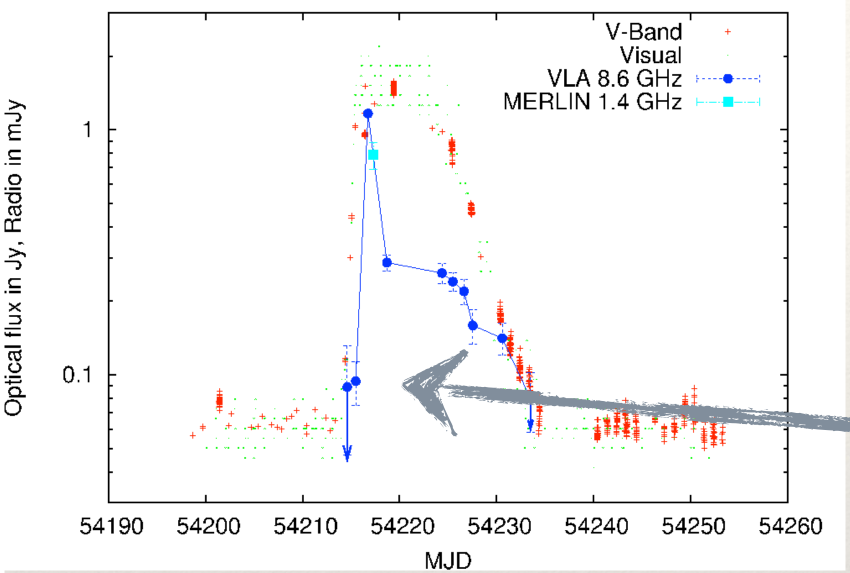

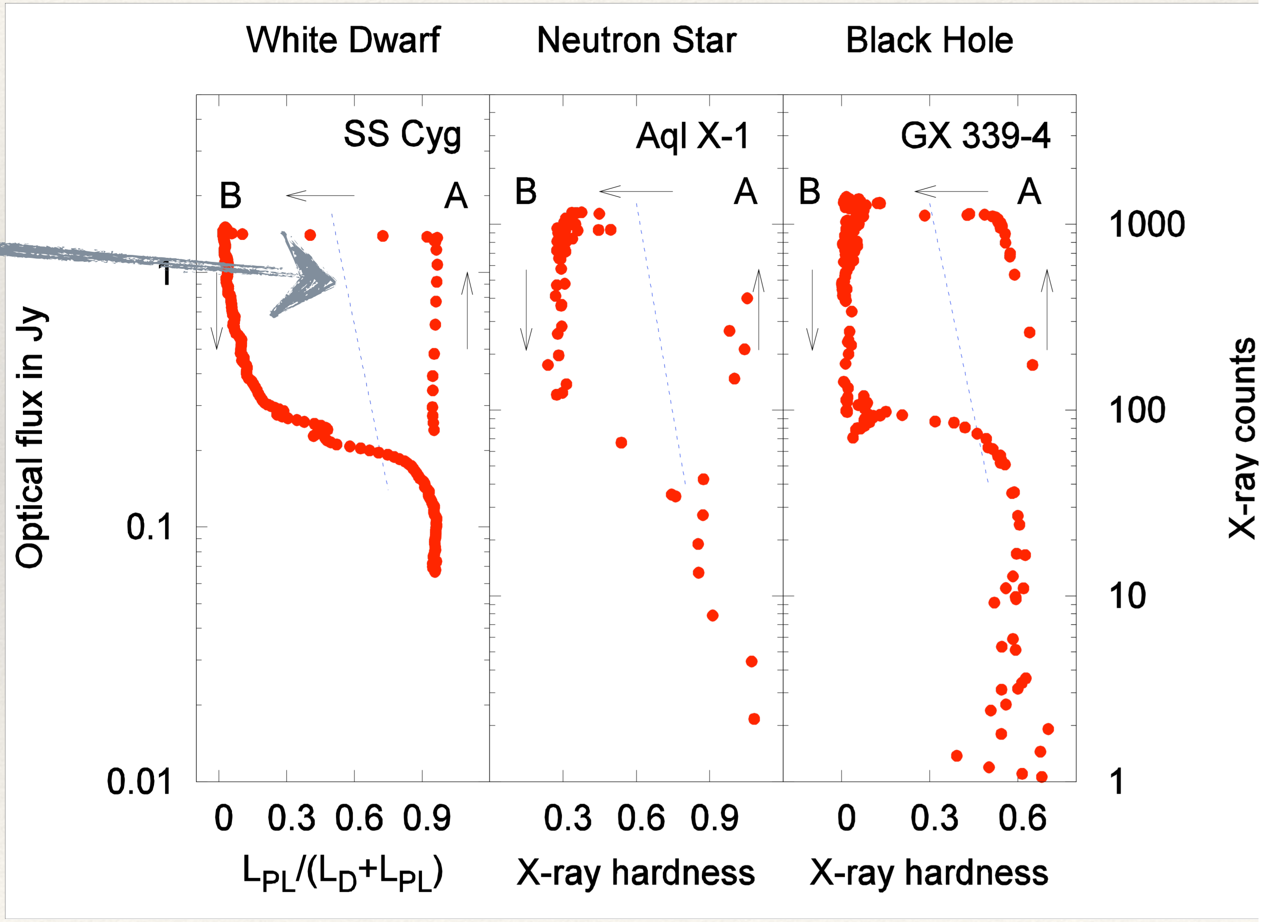

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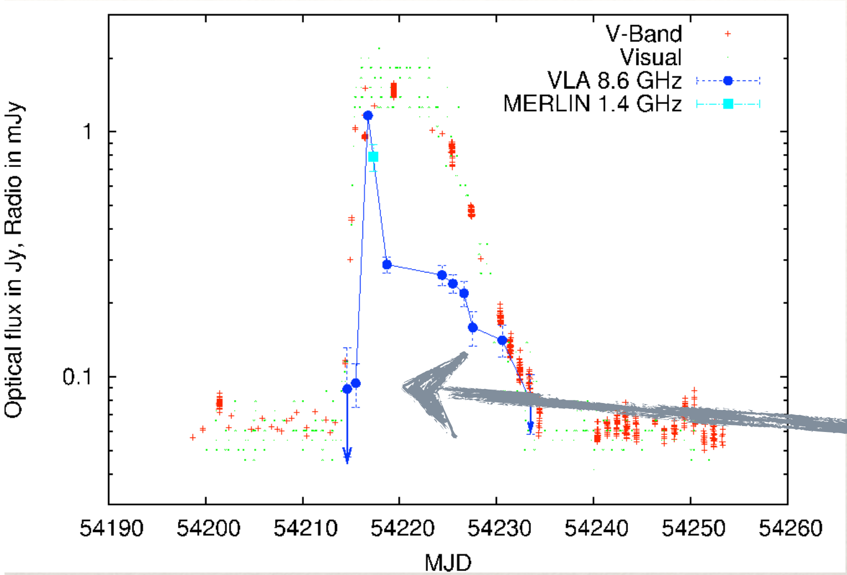

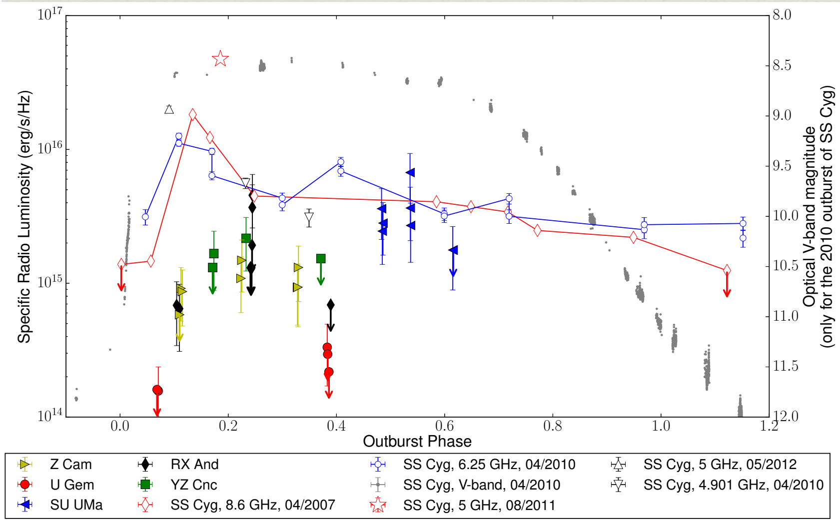

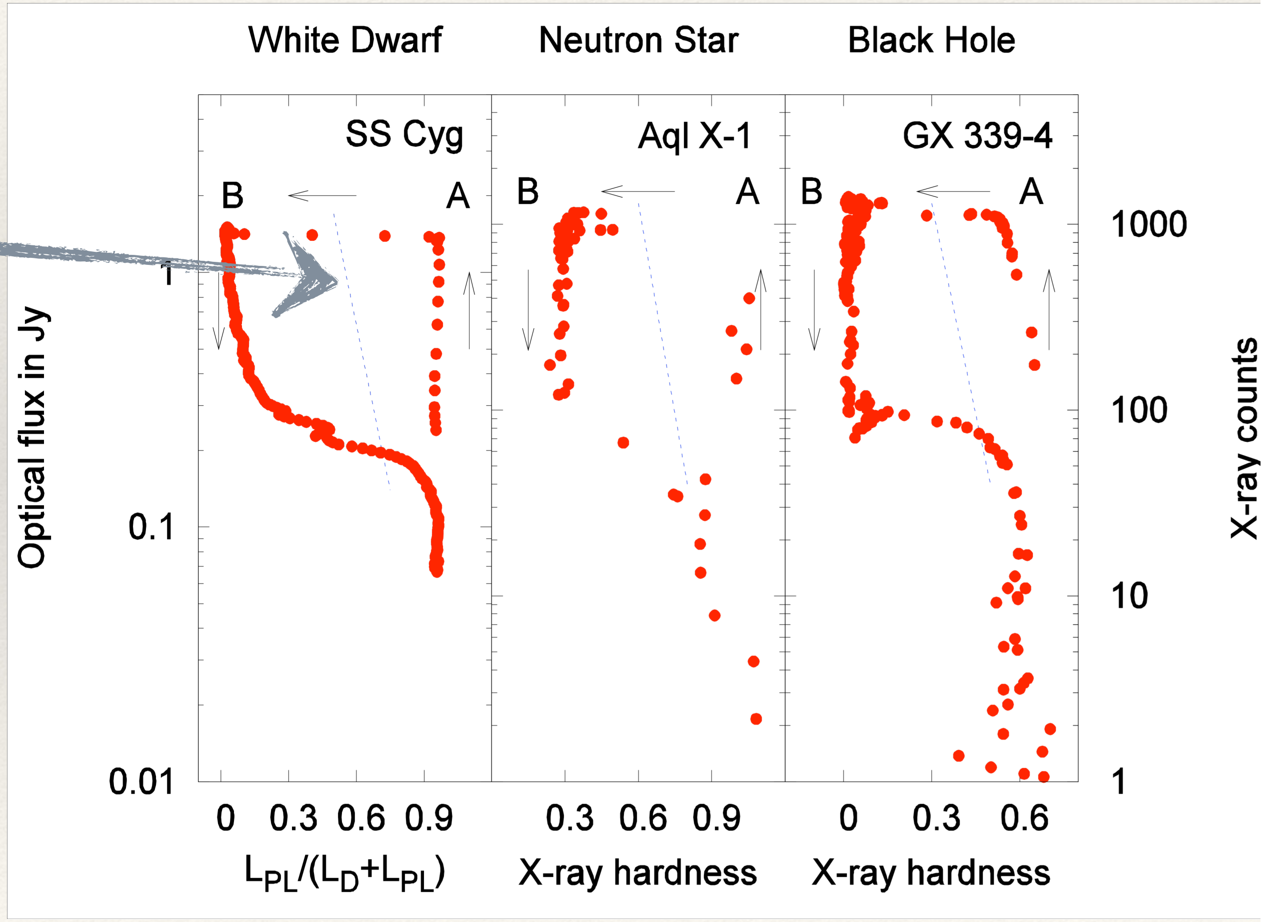

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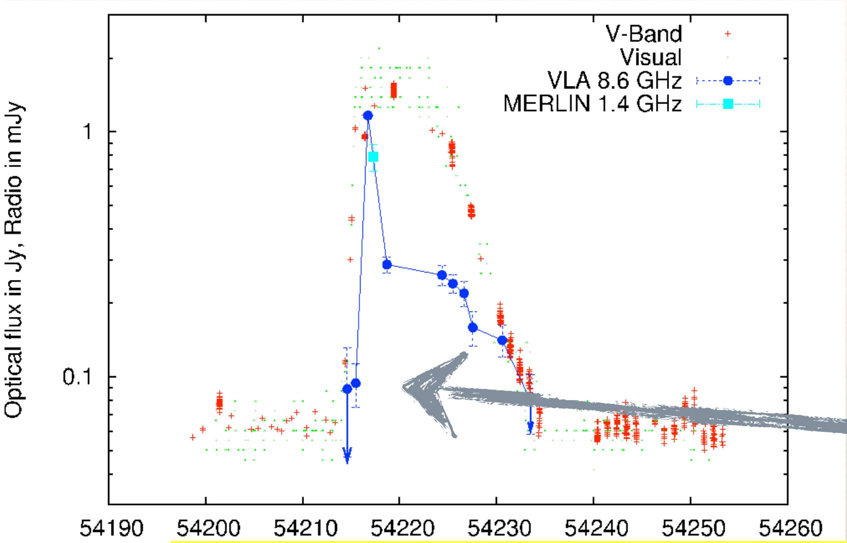
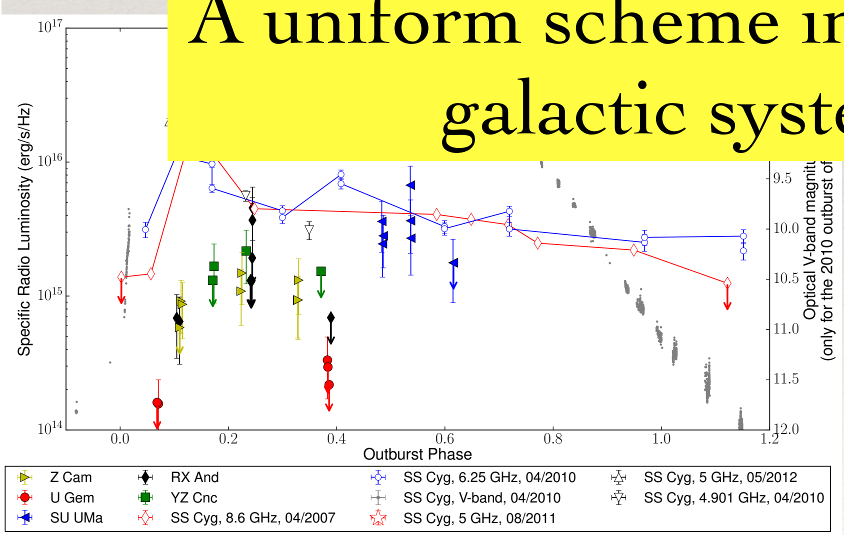
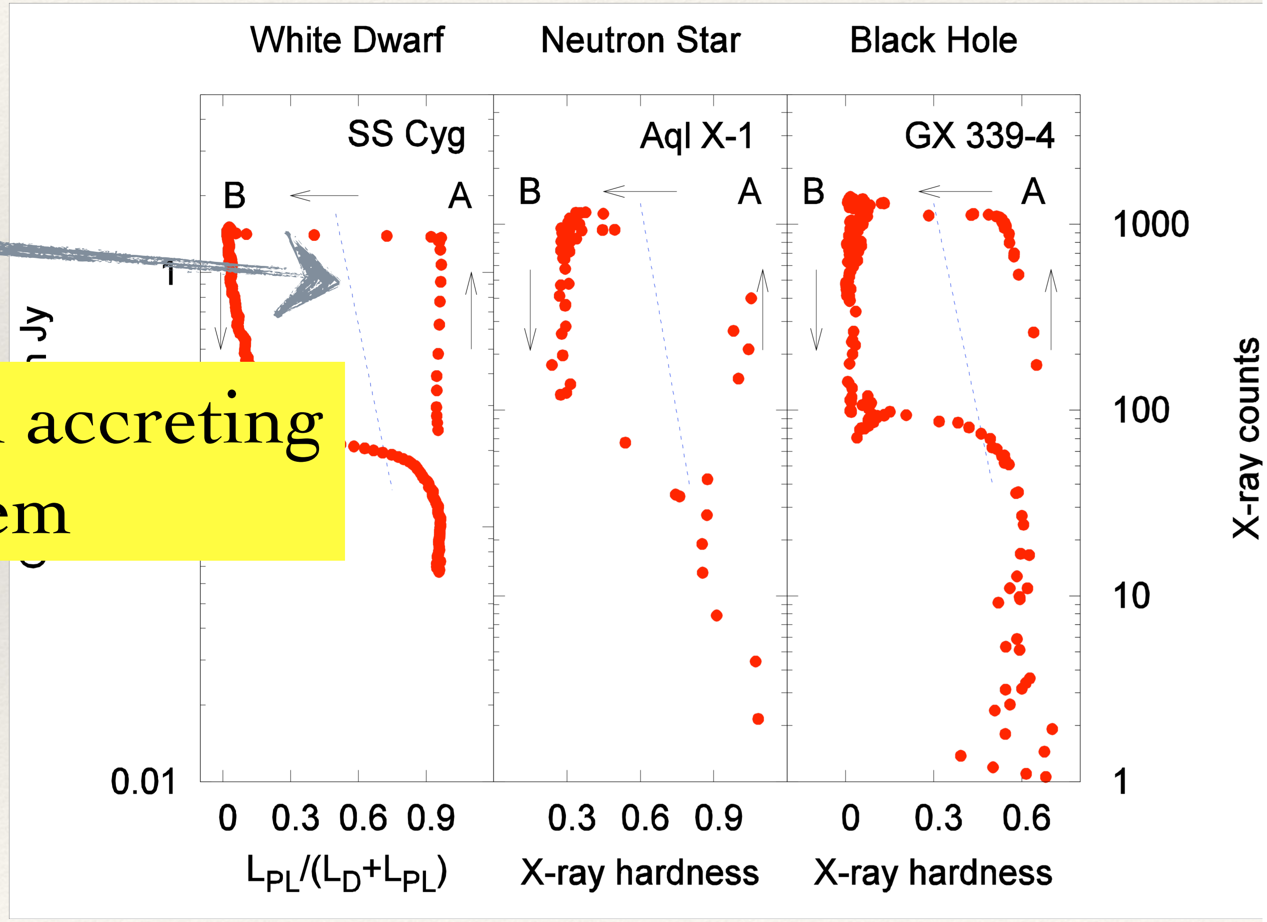






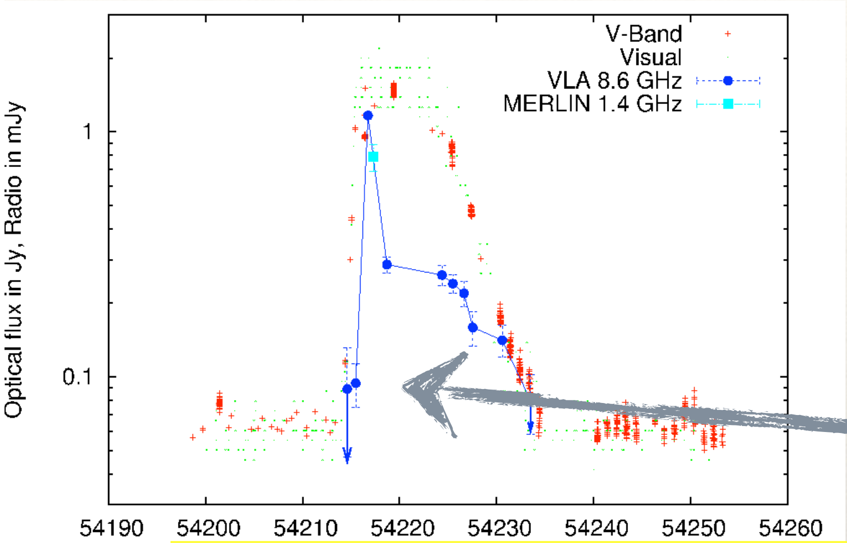
A uniform scheme in accreting galactic system

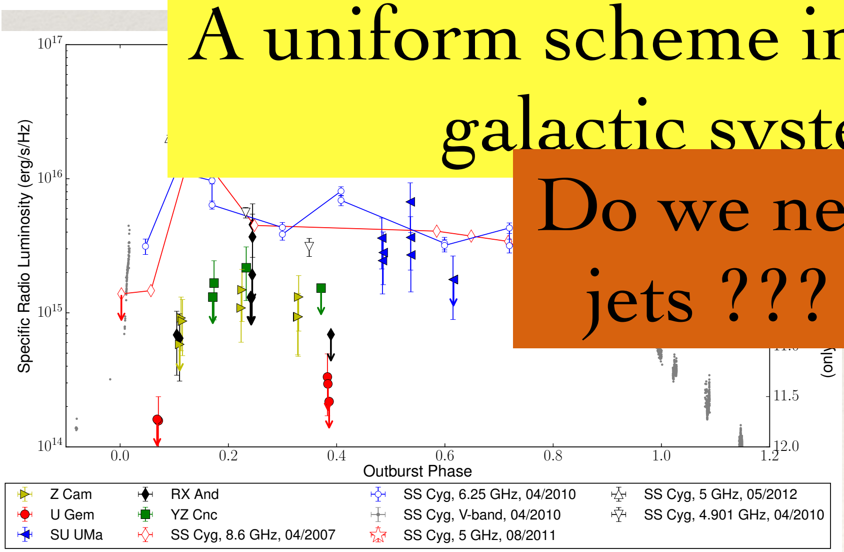
Coppejans et al. 2016

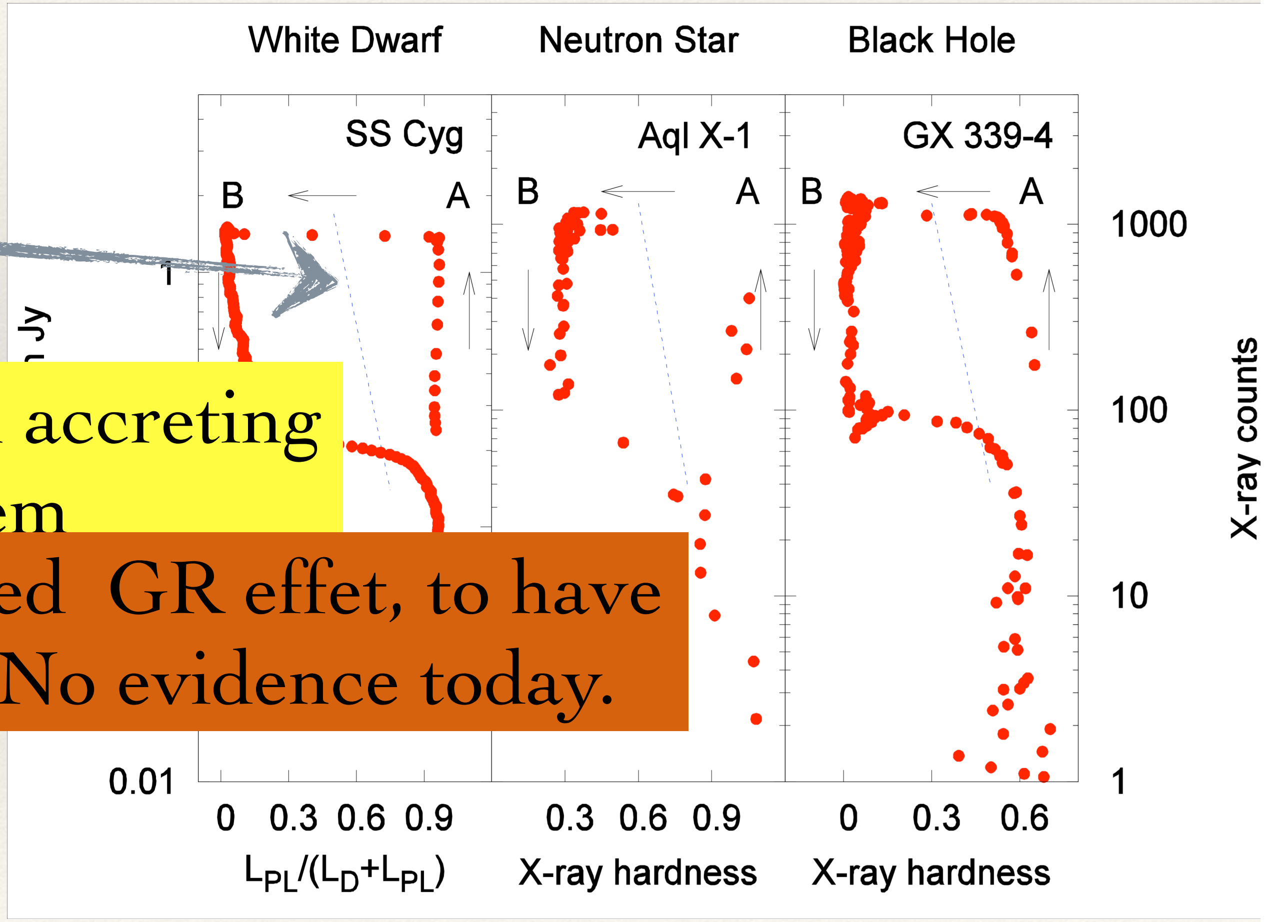
Koerding et al. 2008

Unification in galactic compact objects

Koerding et al. 2008







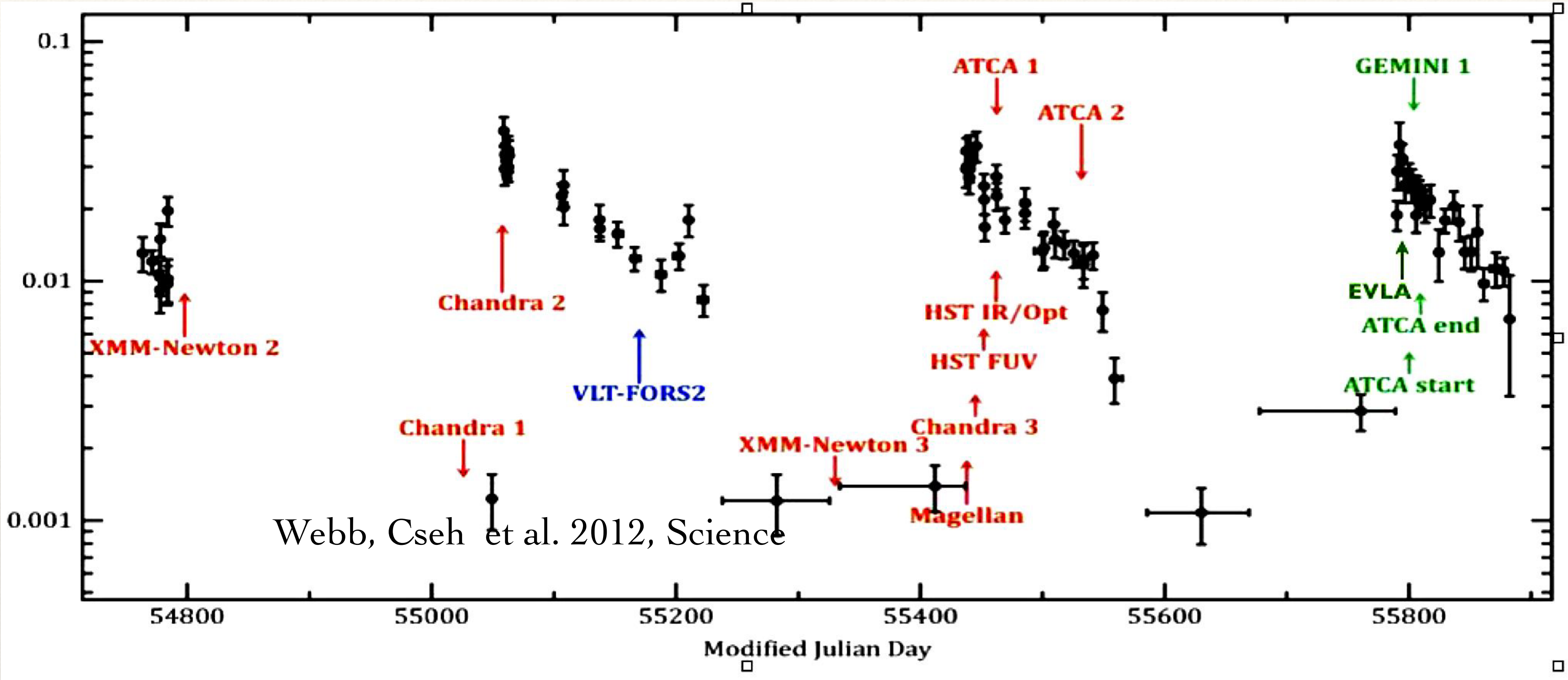
A uniform scheme in accreting galactic system

Do we need GR effet, to have jets ??? No evidence today.

Coppejans et al. 2016

Koerding et al. 2008

What about ULX ? An IMBH in ESO 243-49 ?



Webb, Cseh et al. 2012, Science

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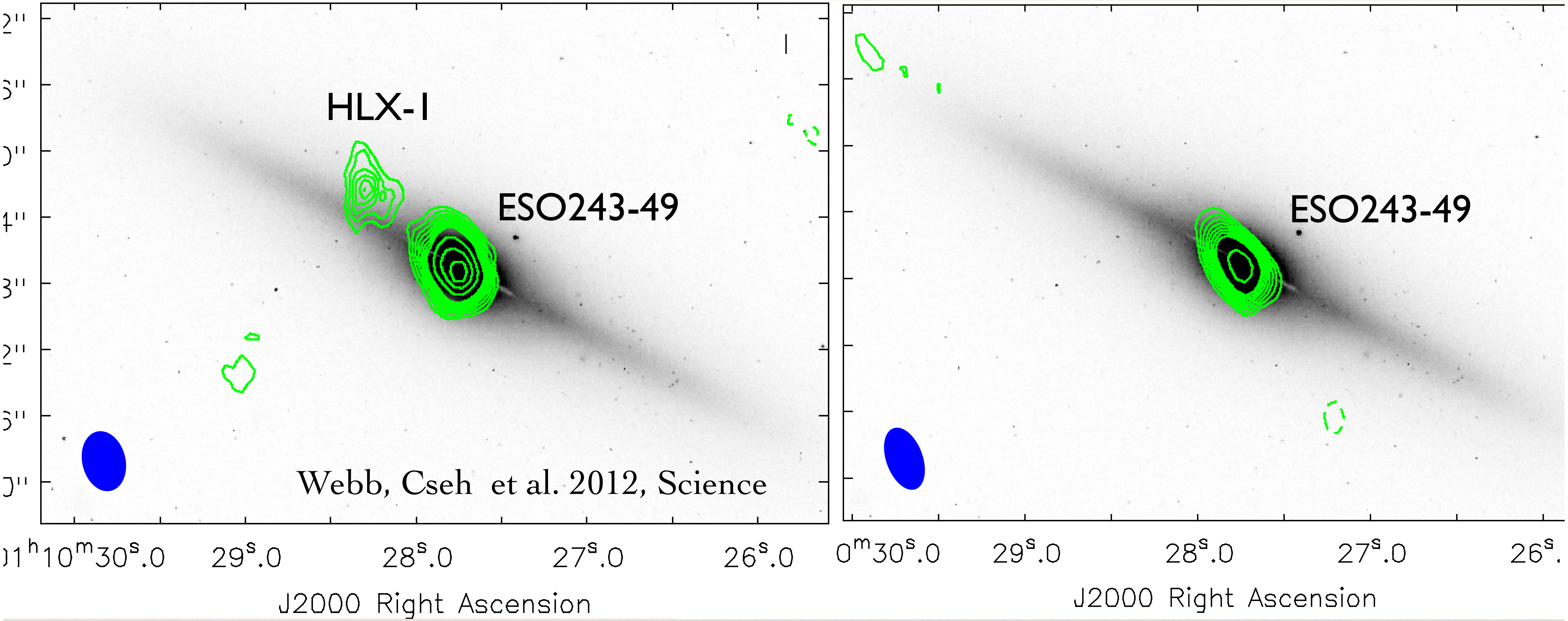

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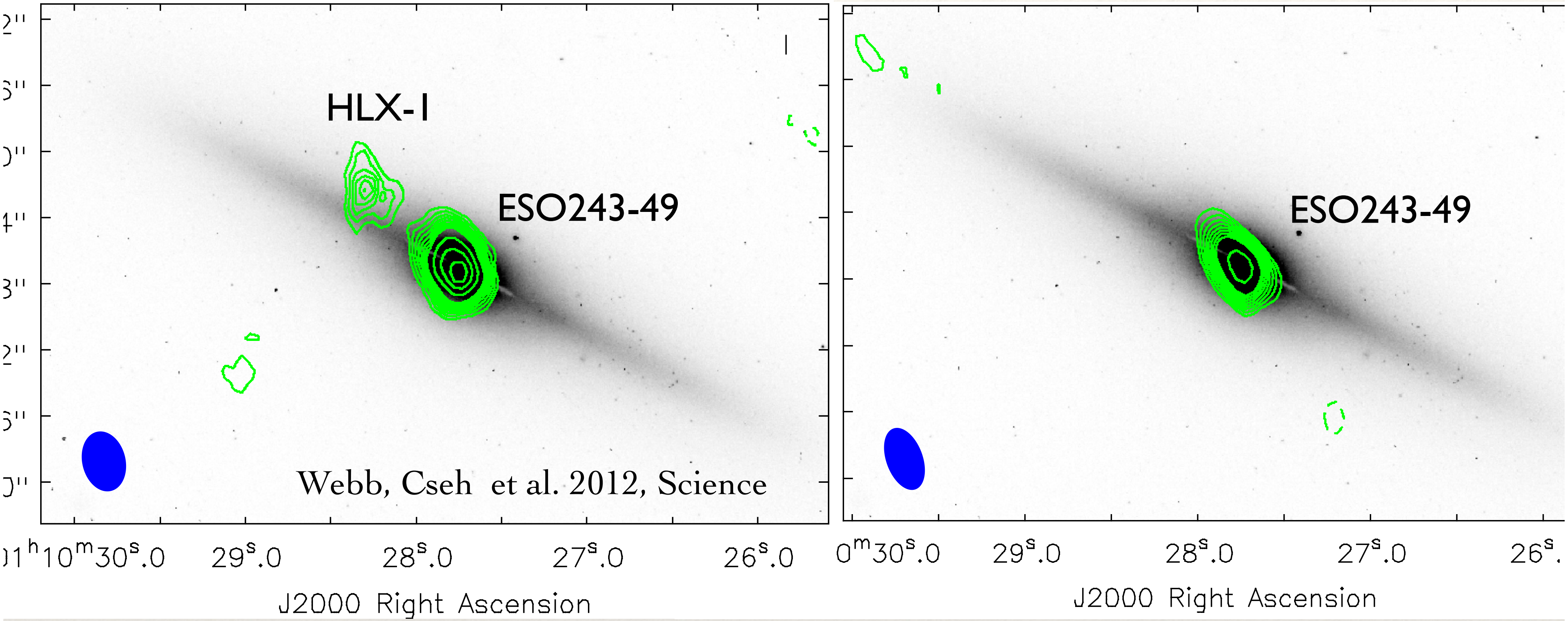

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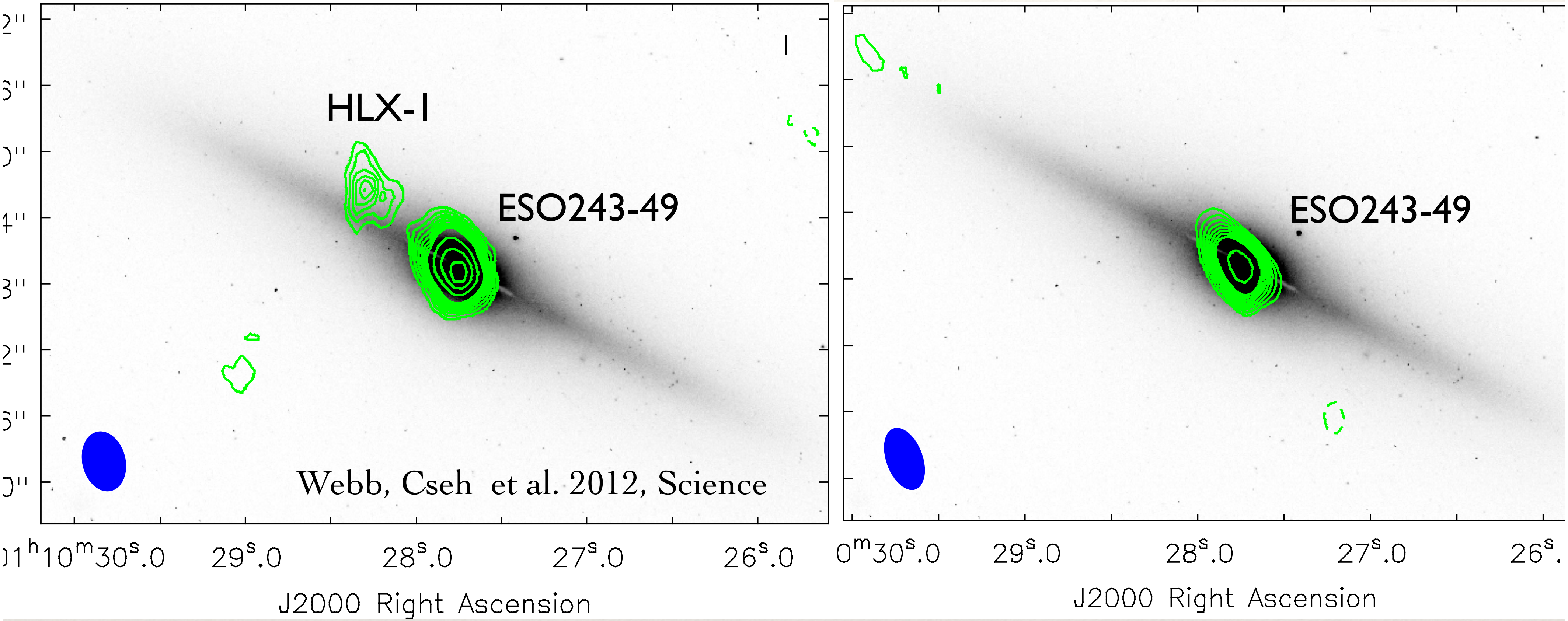

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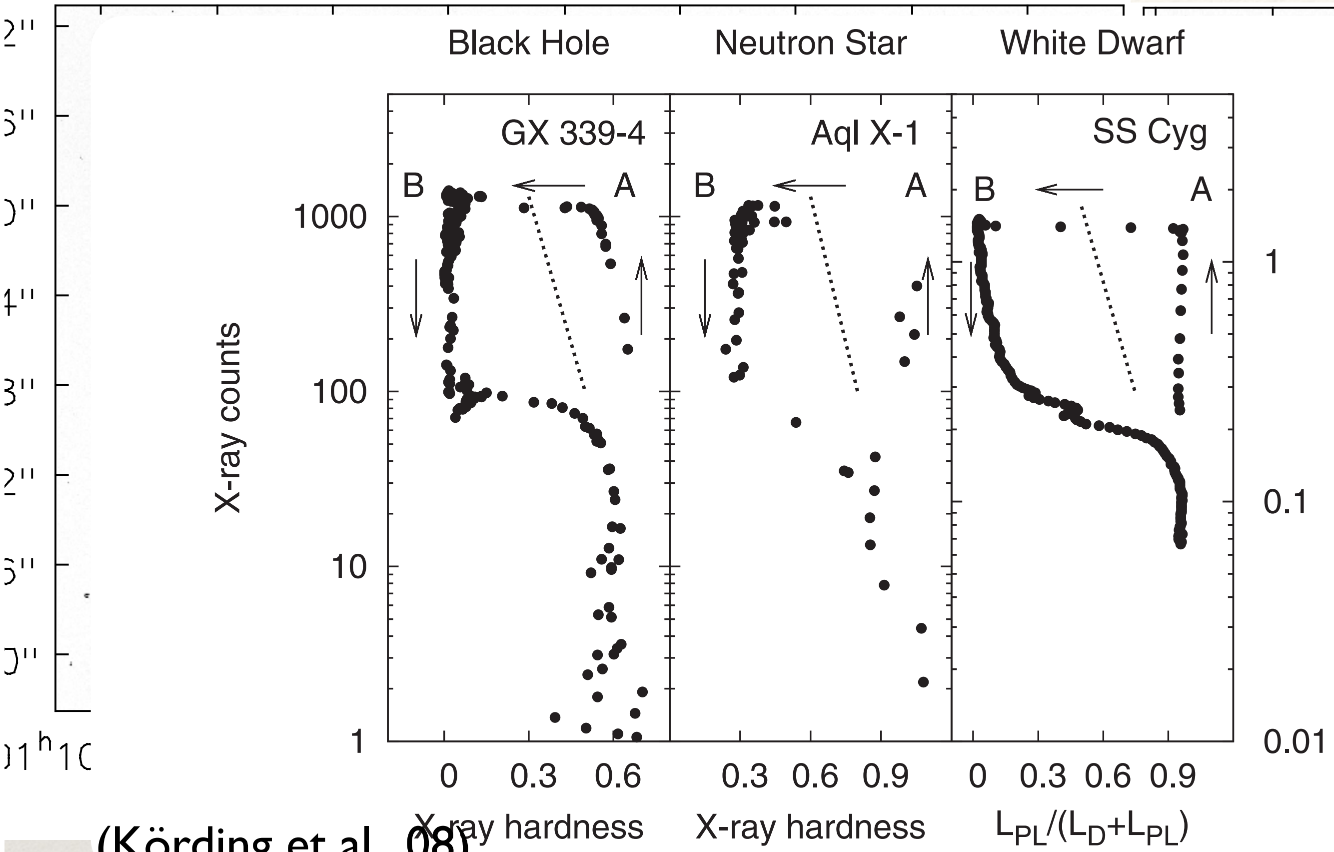
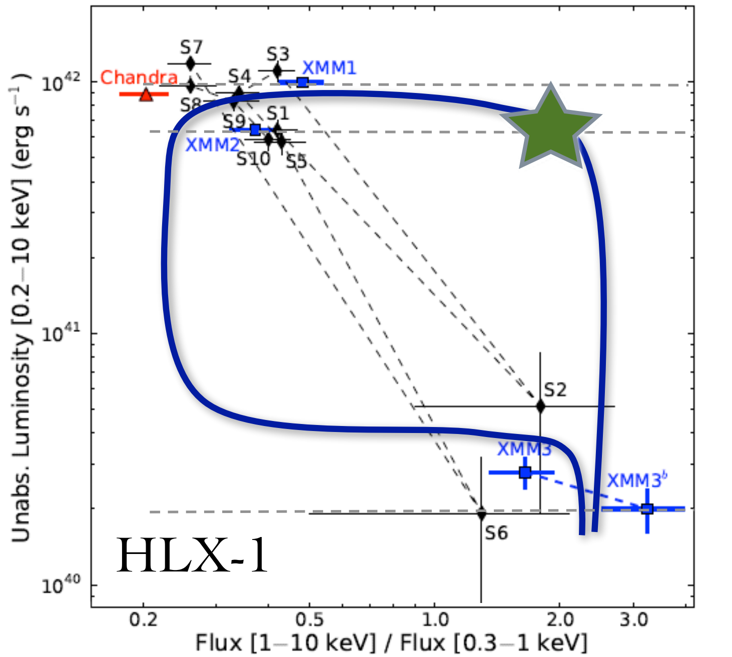


(Körding et al. 08)



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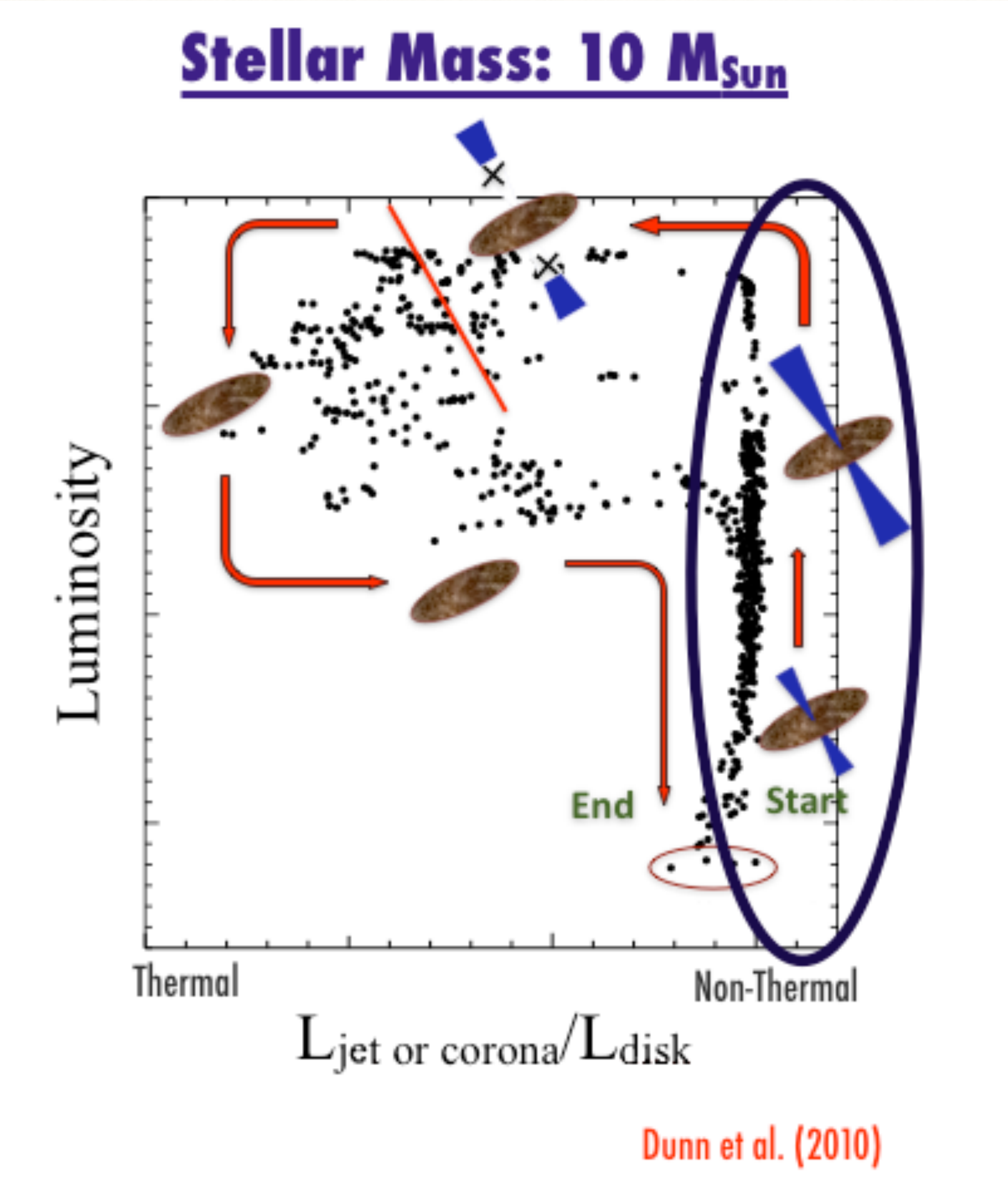
What about AGN? Unification?



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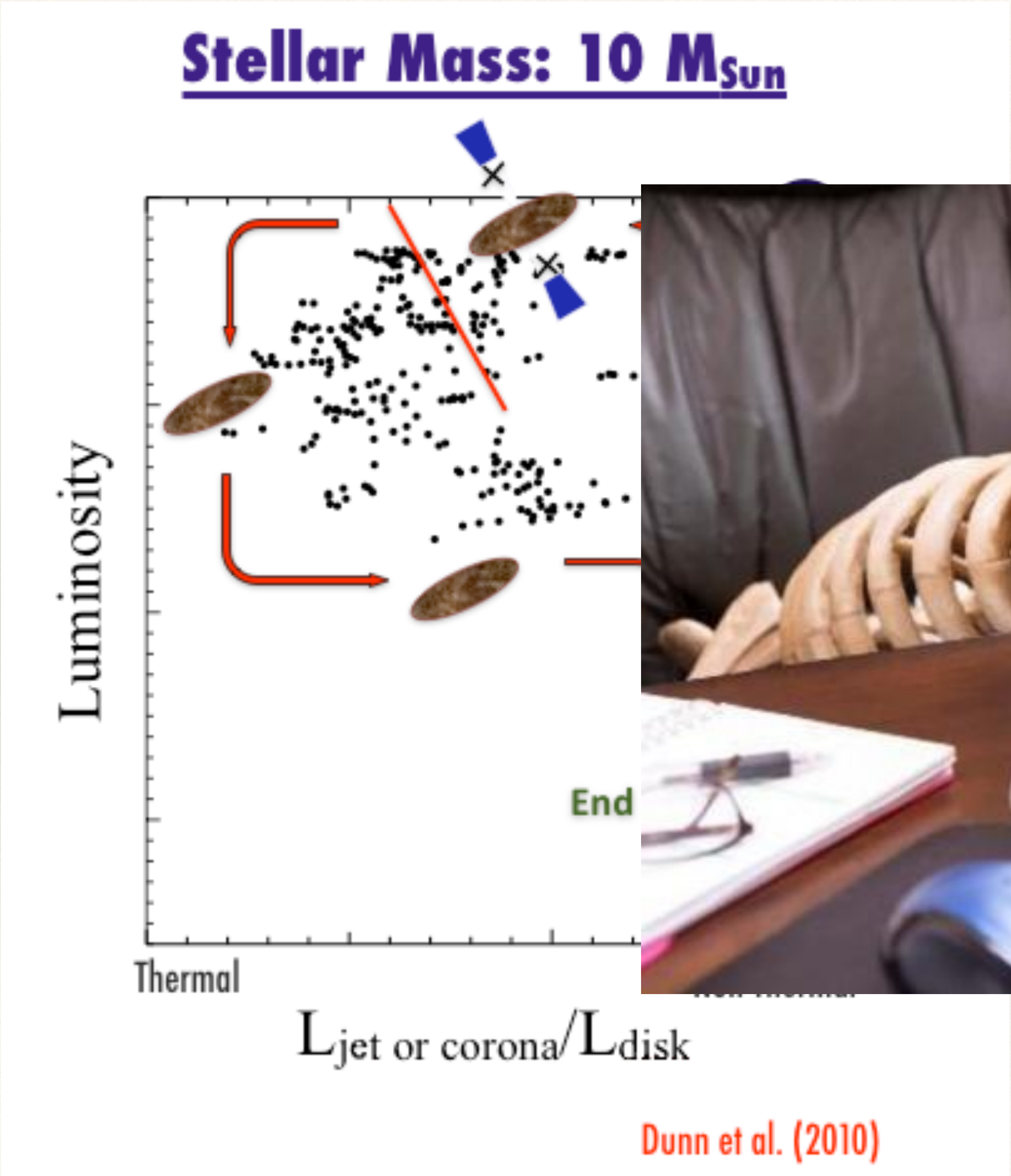

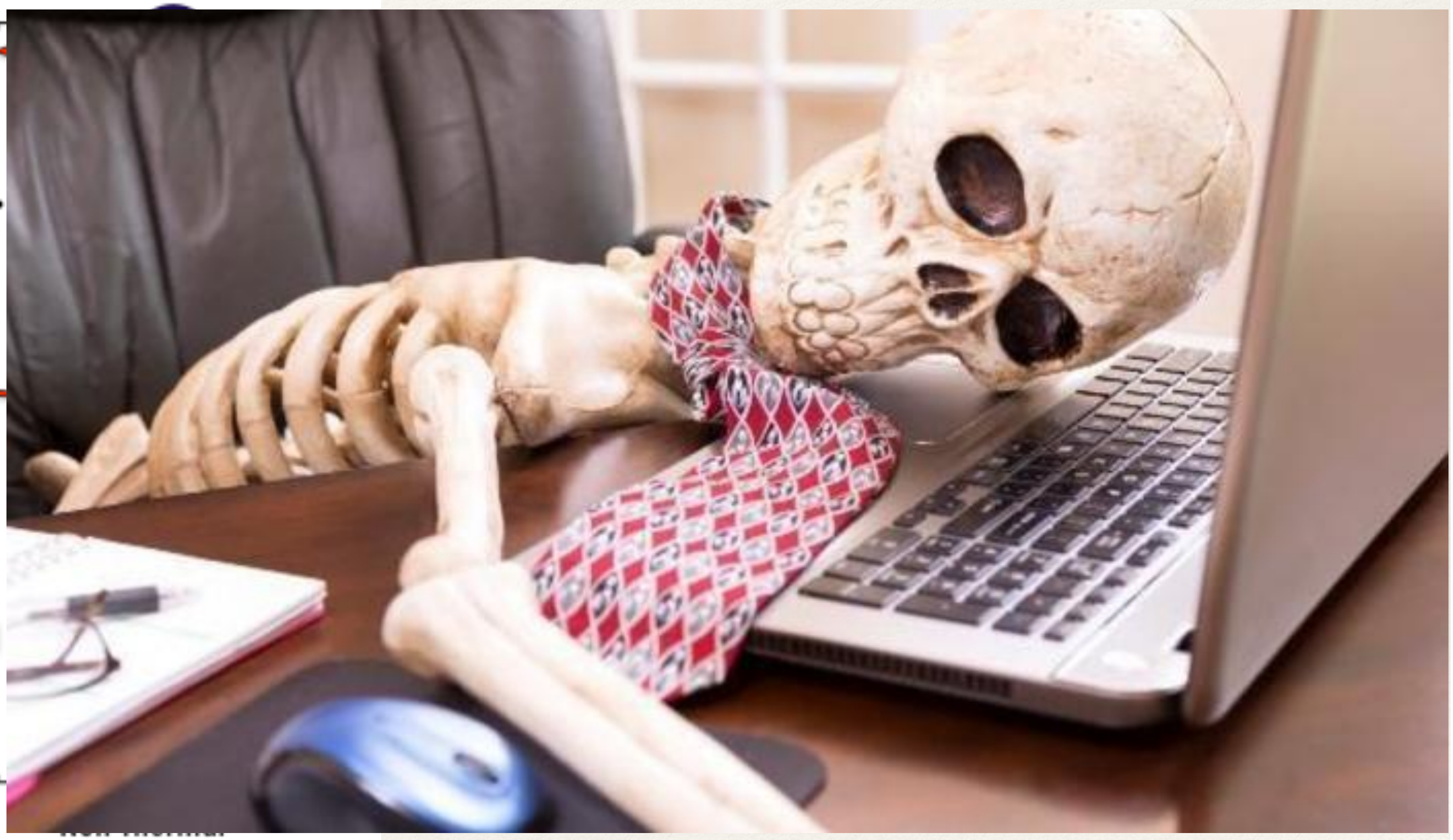

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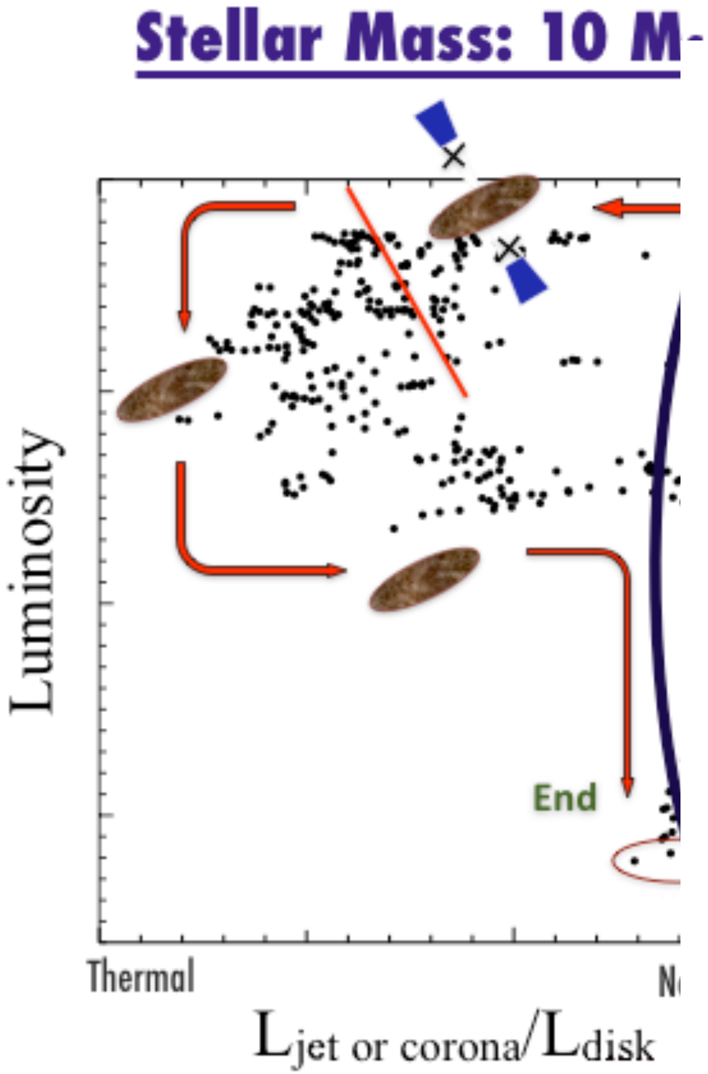
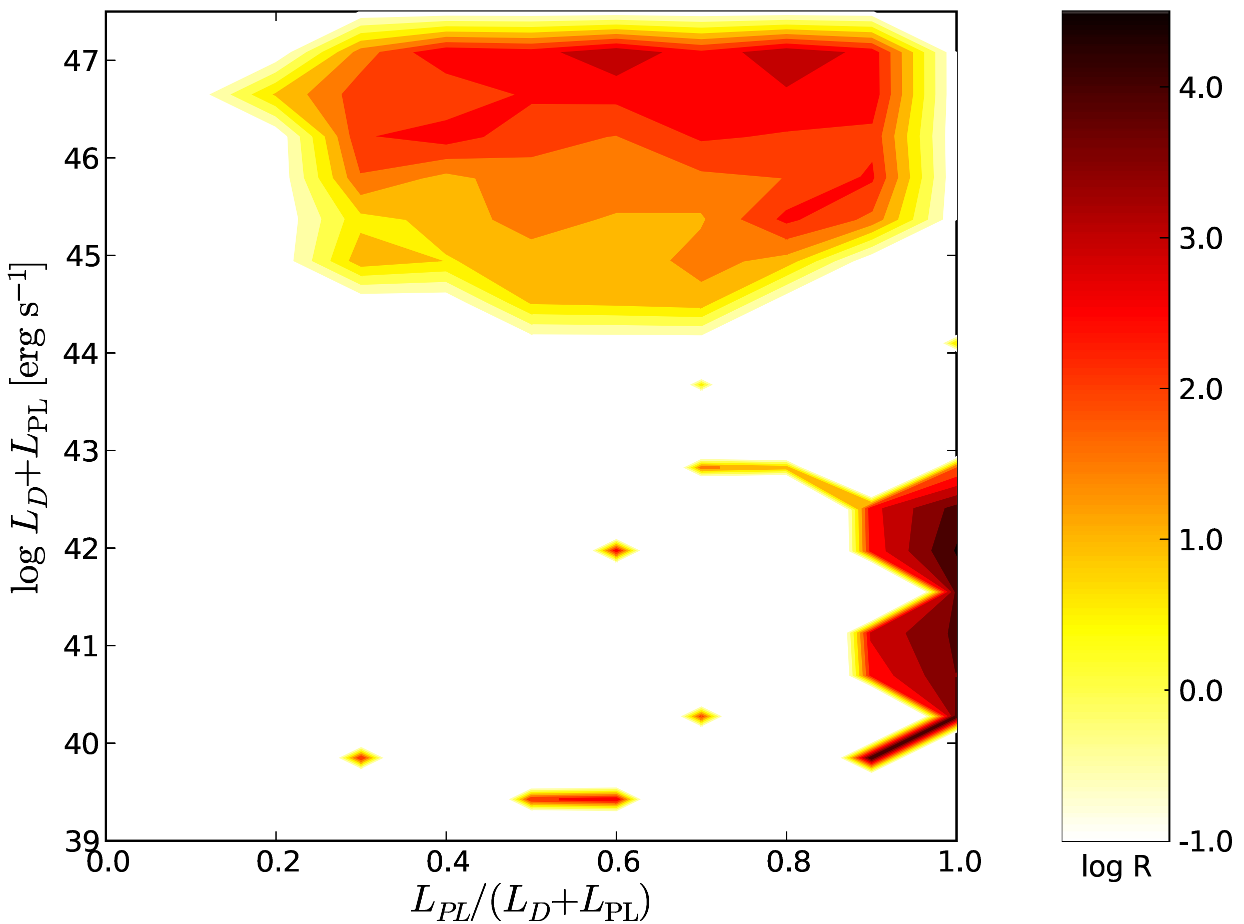


Dunn et al. (2010)



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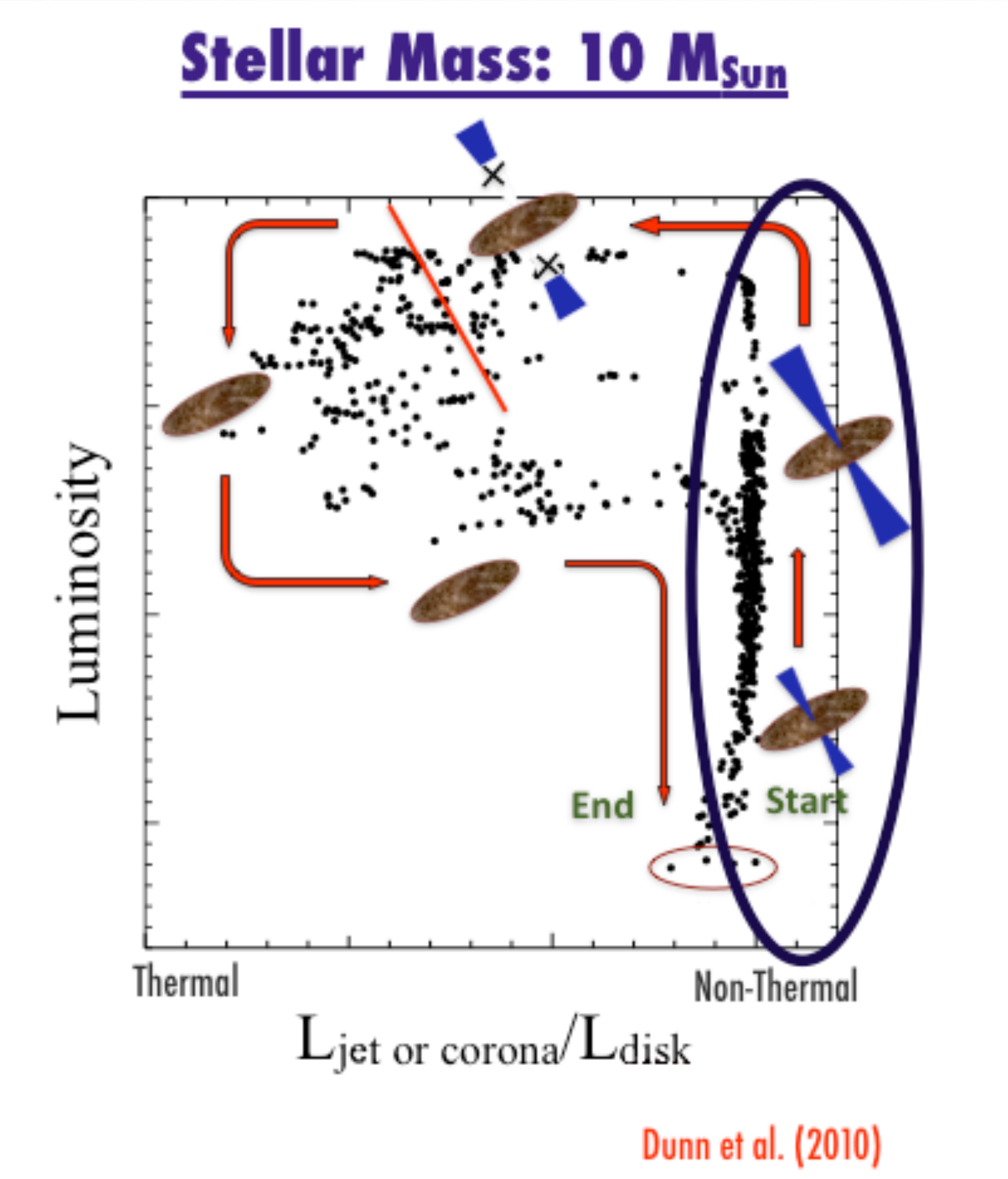
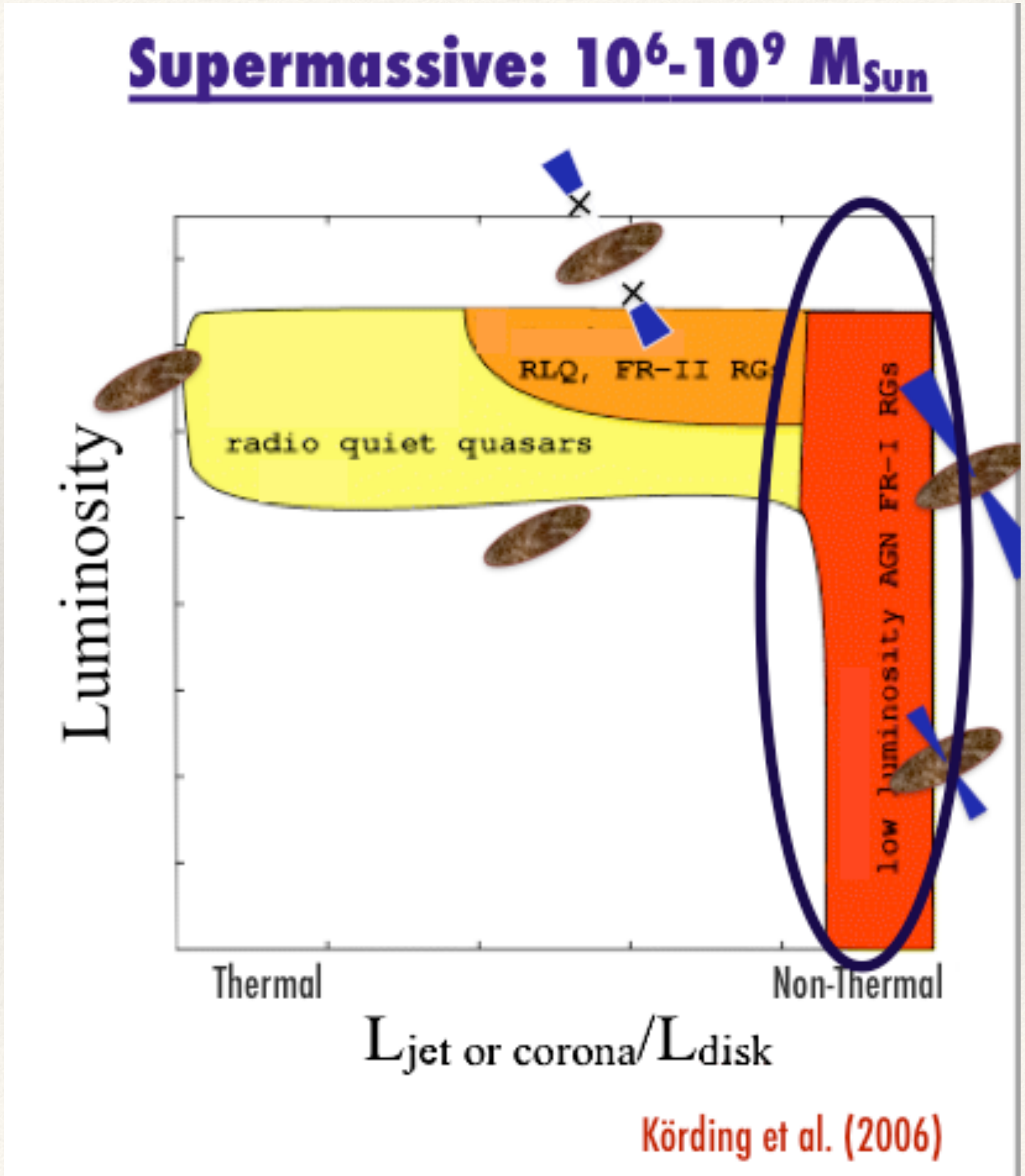
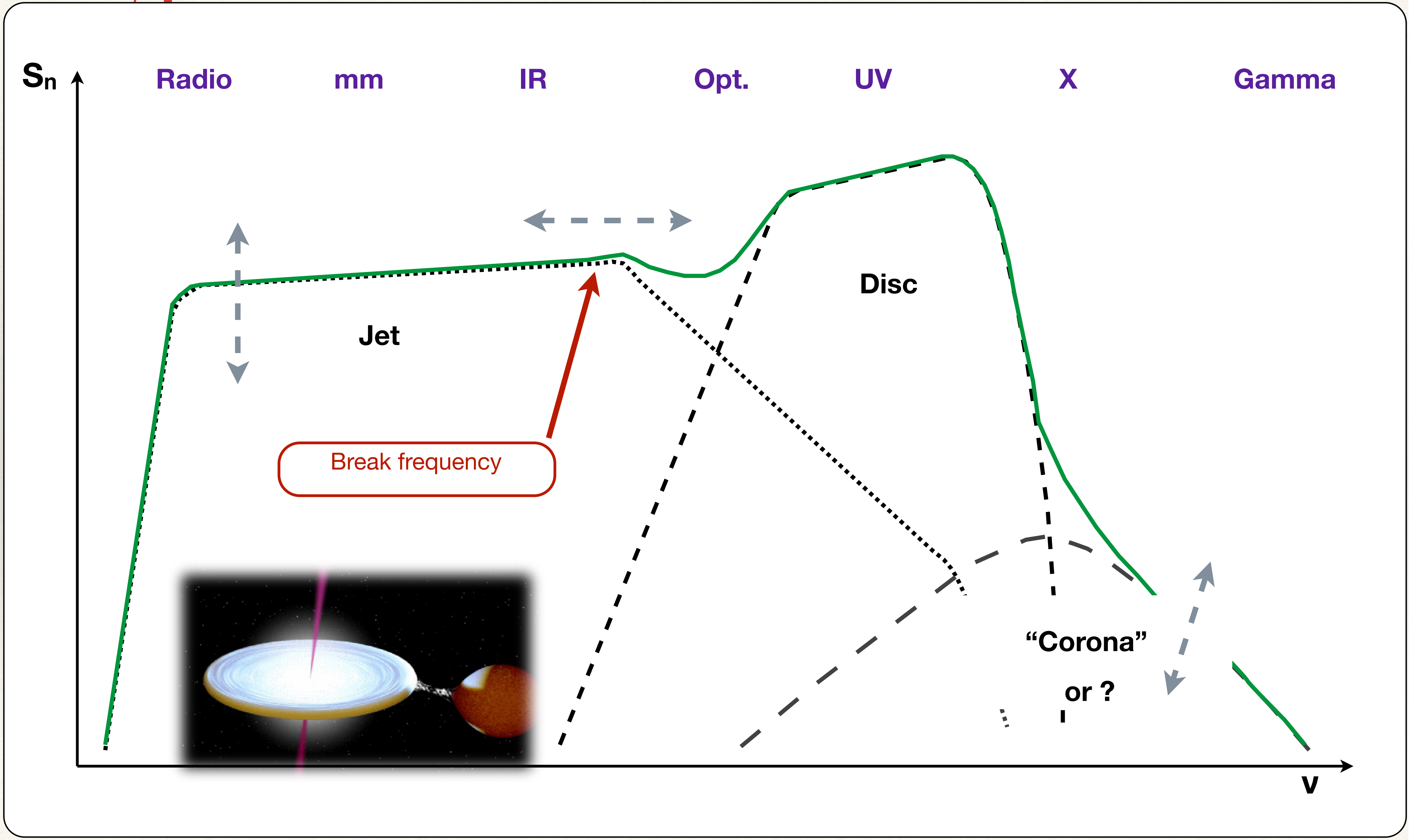




Typical SED of BH in the hard state



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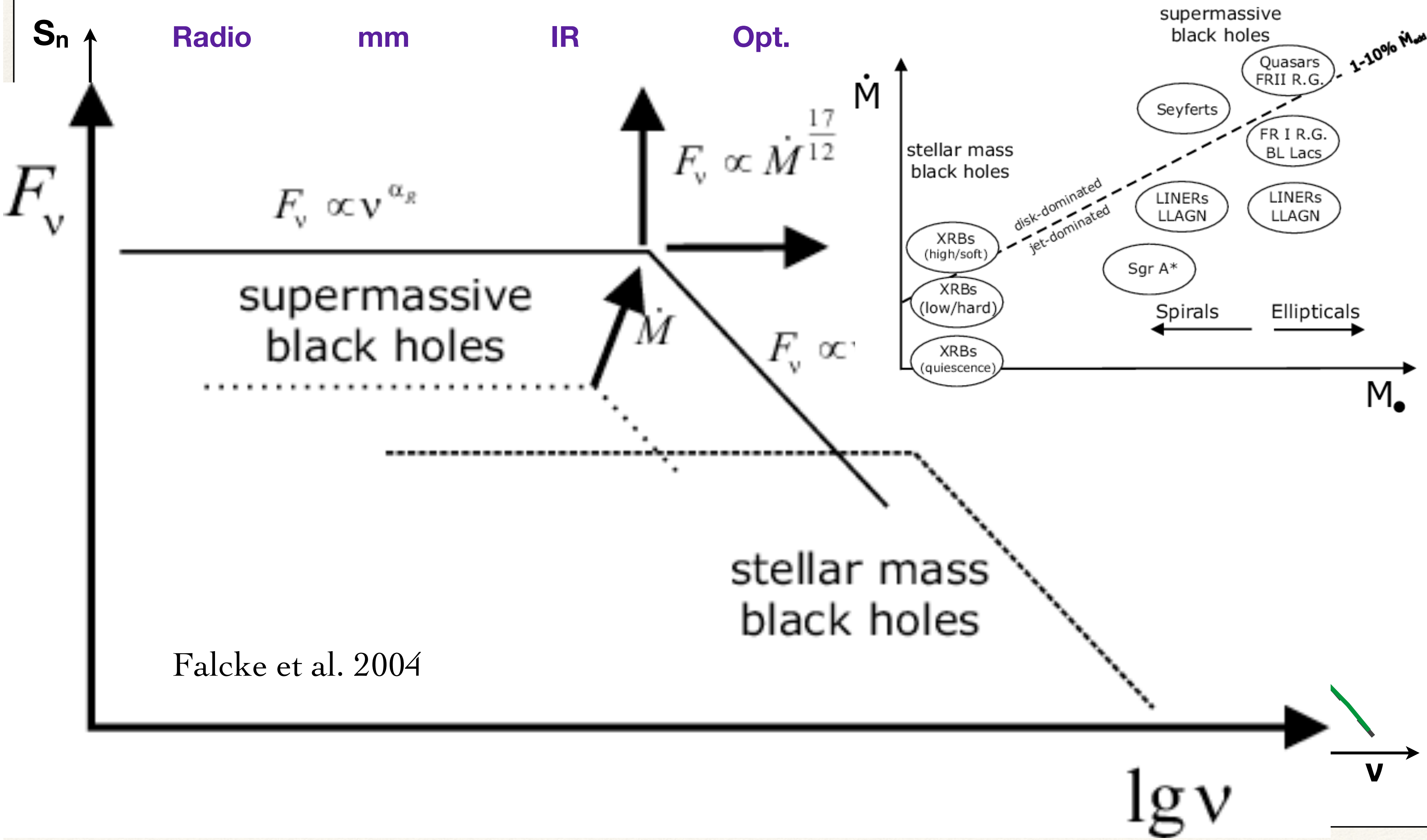
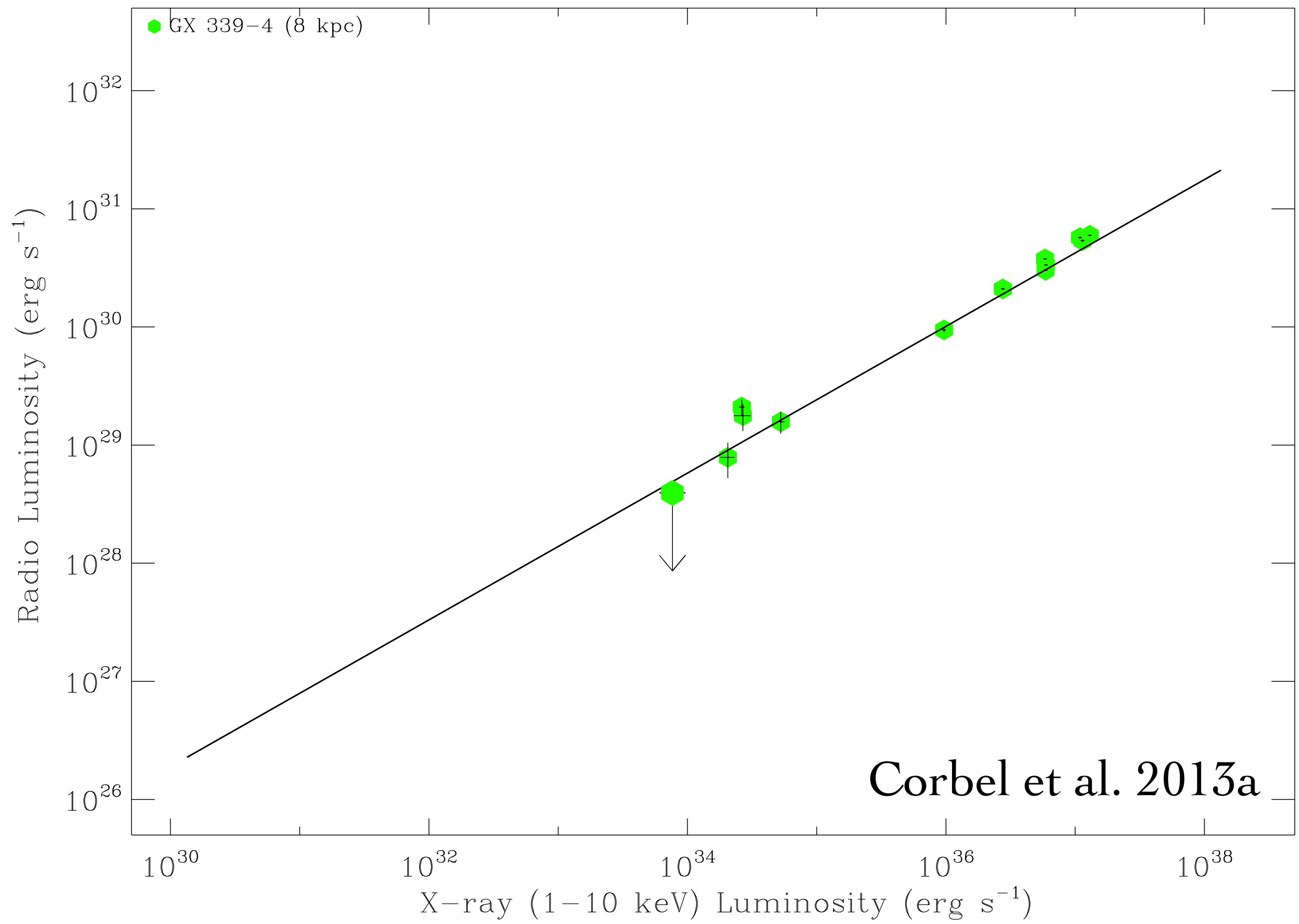


Falcke et al. 2004

Radio/X-ray correl. state of the art



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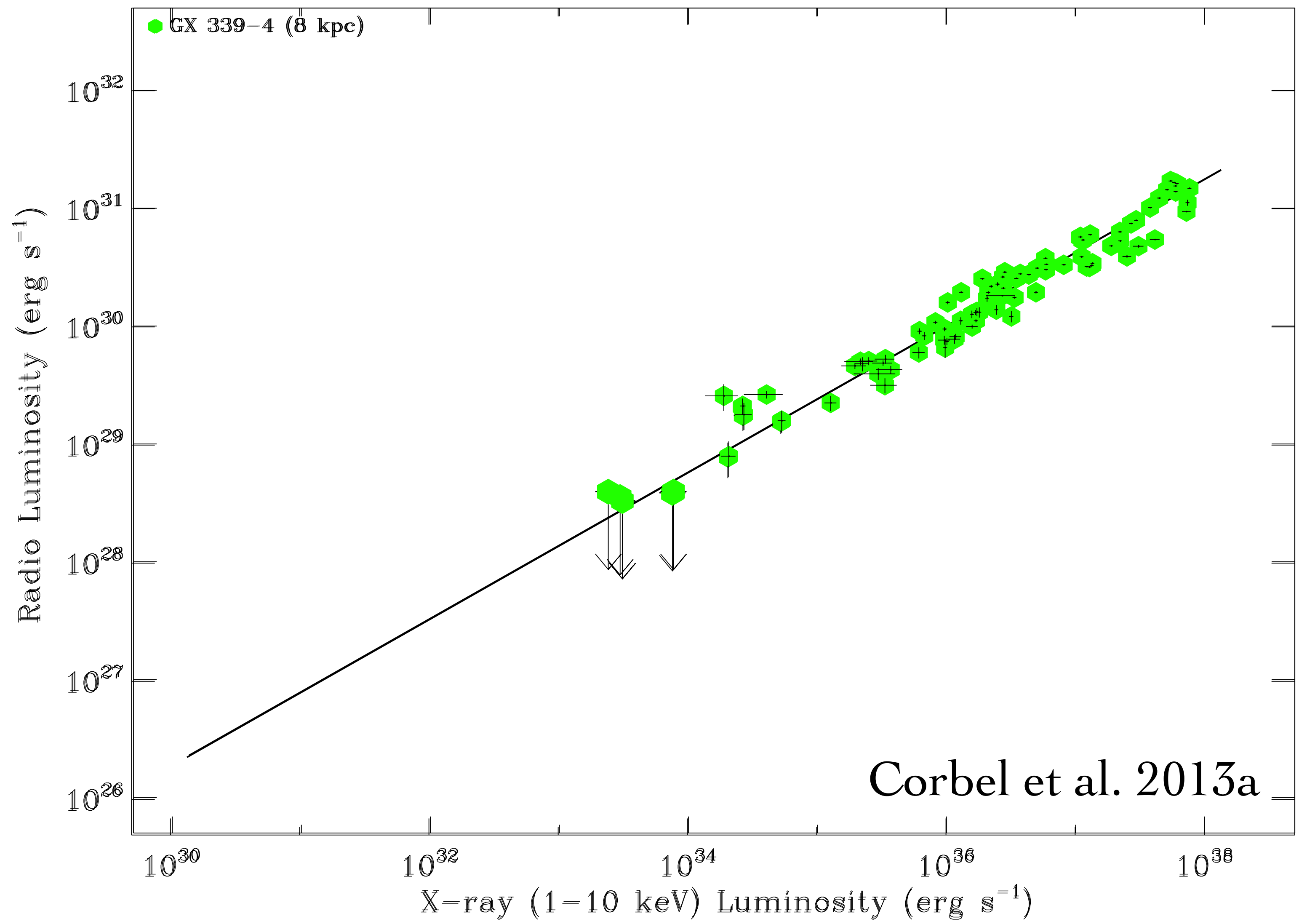

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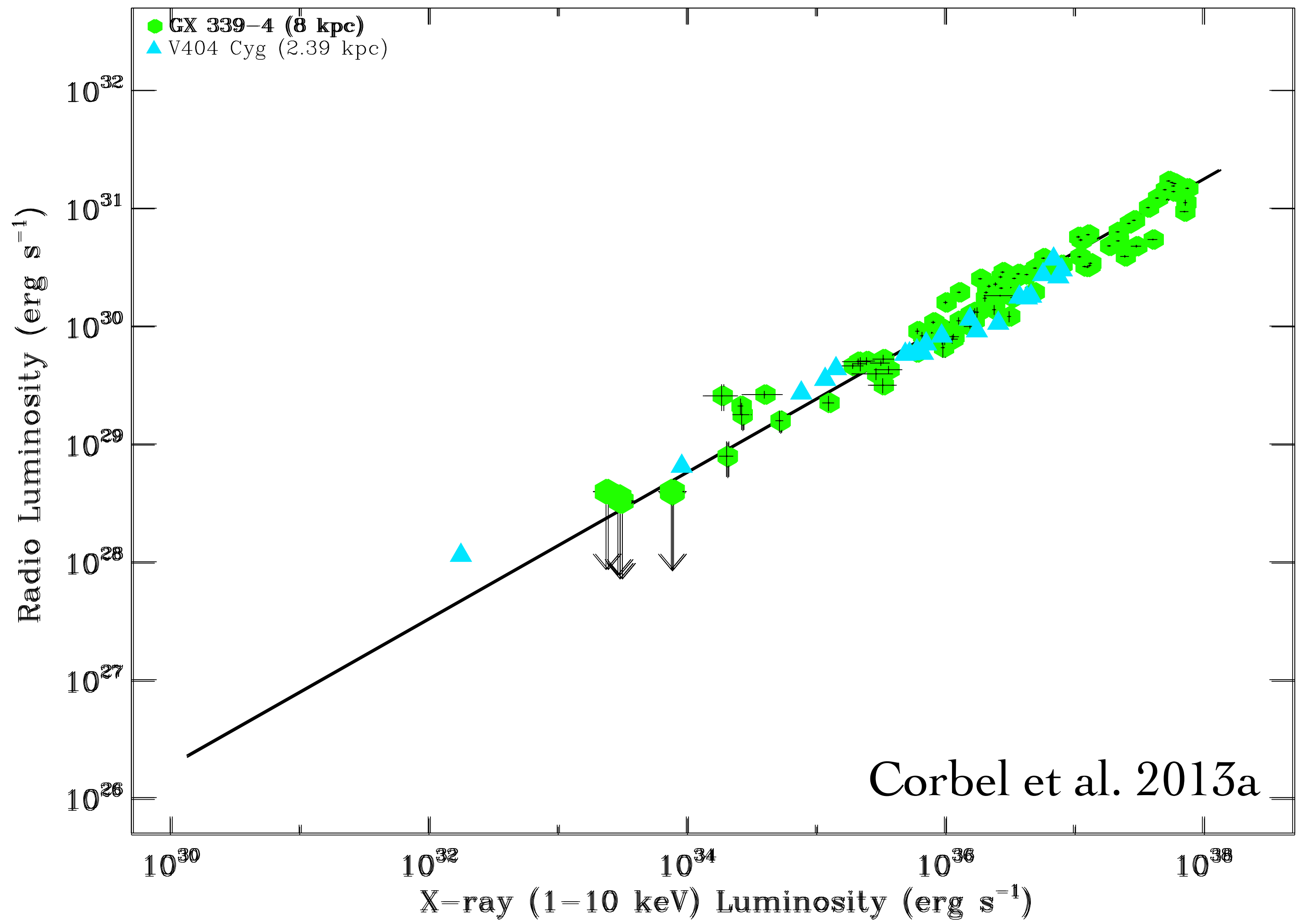

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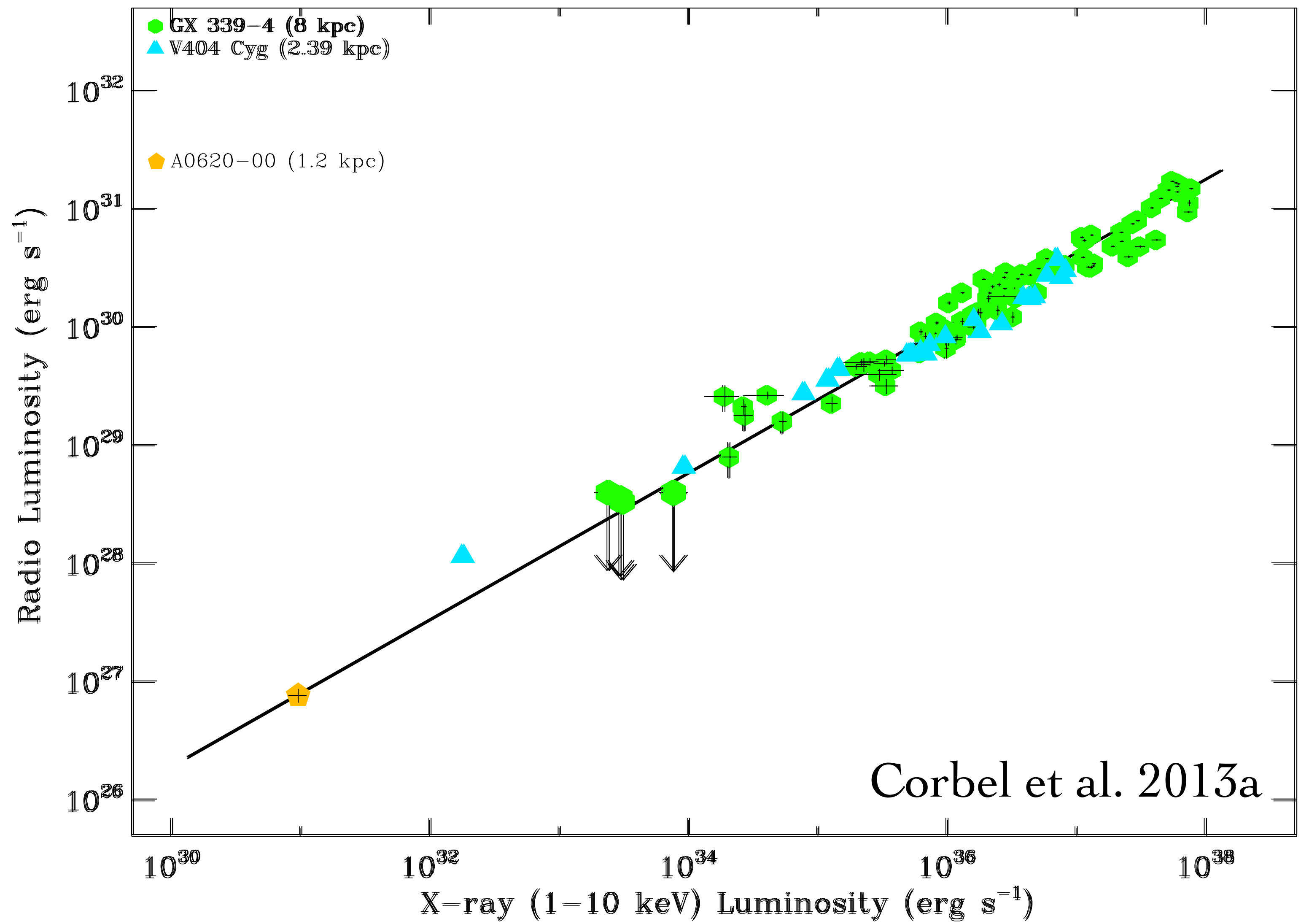

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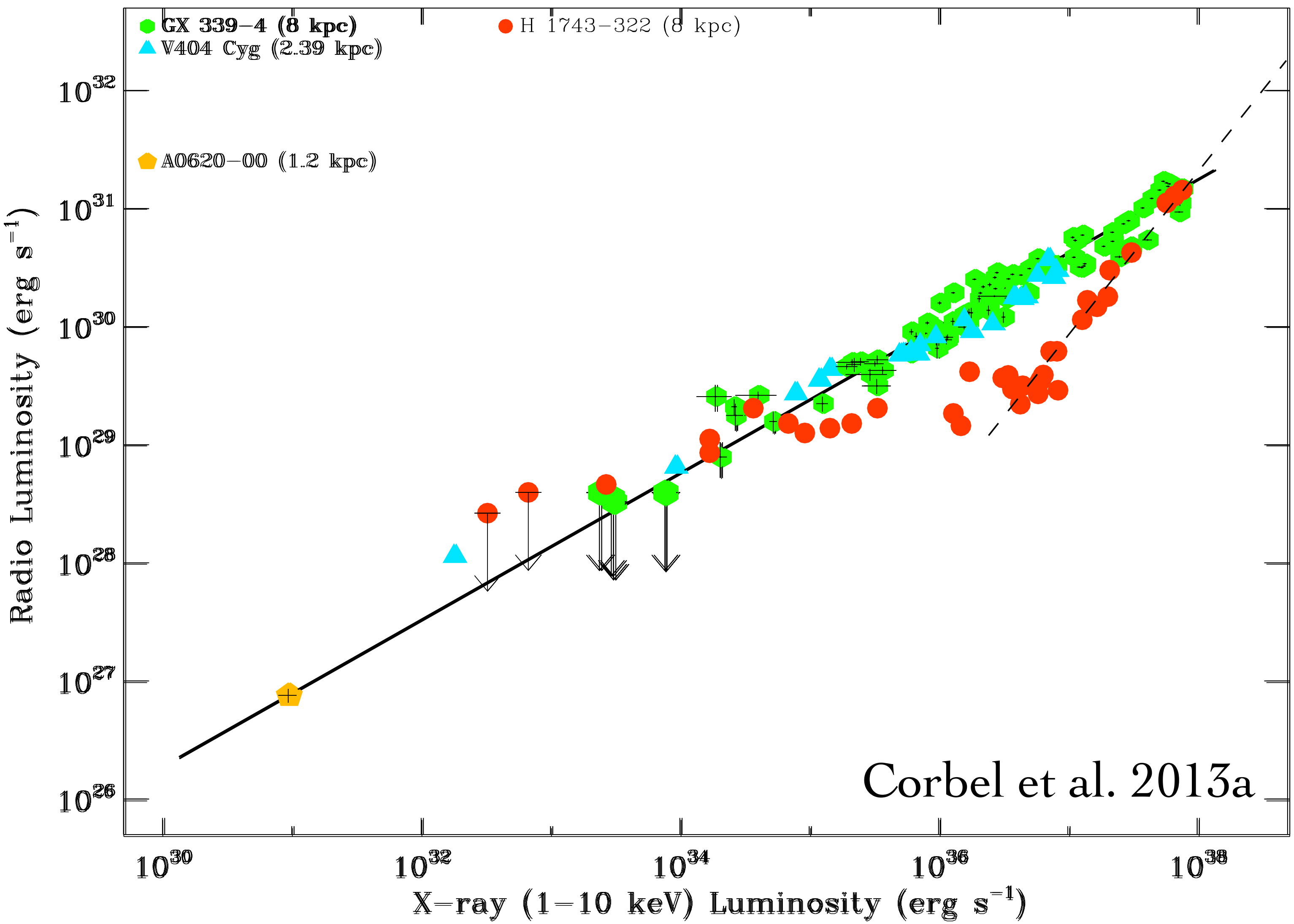

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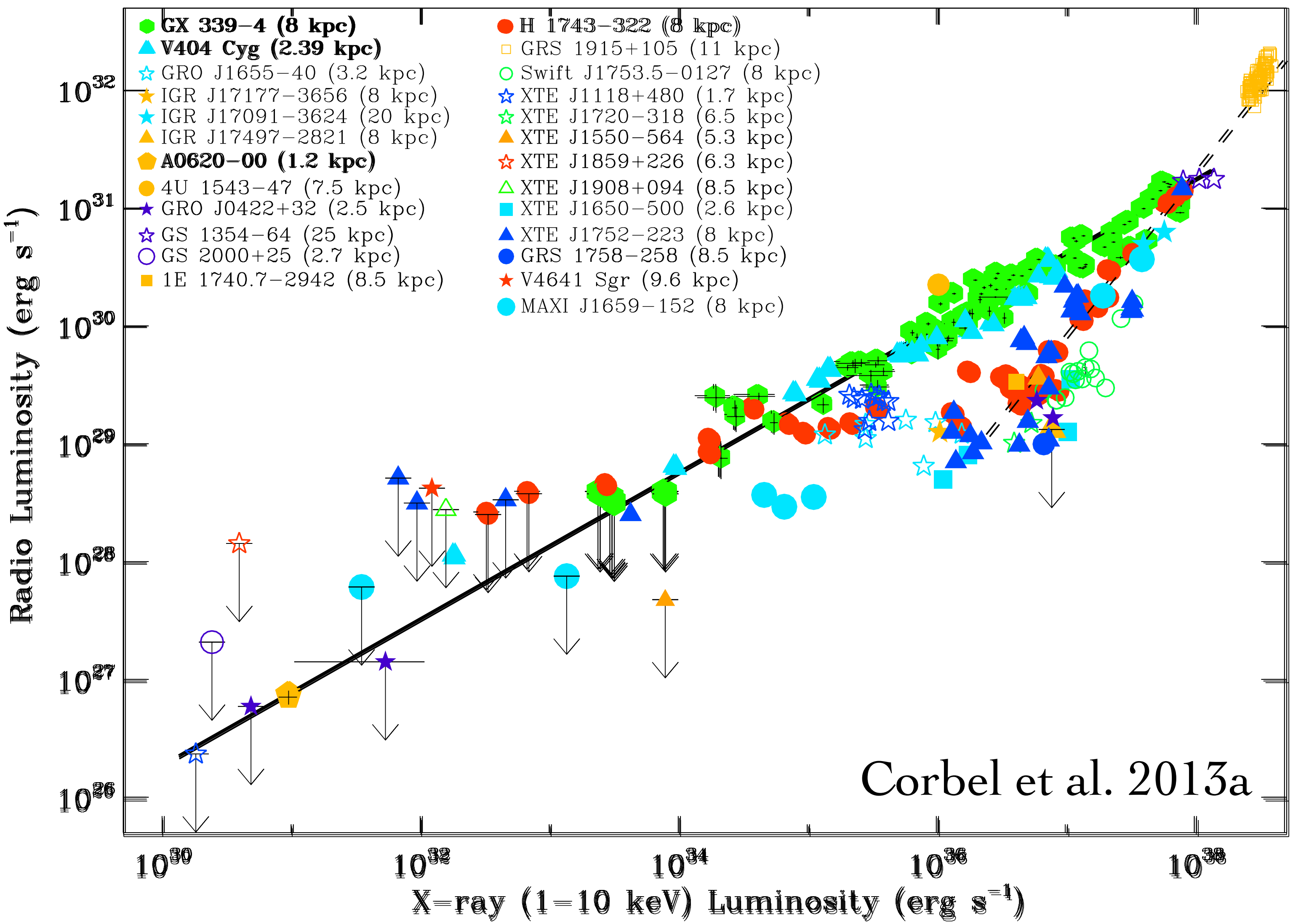

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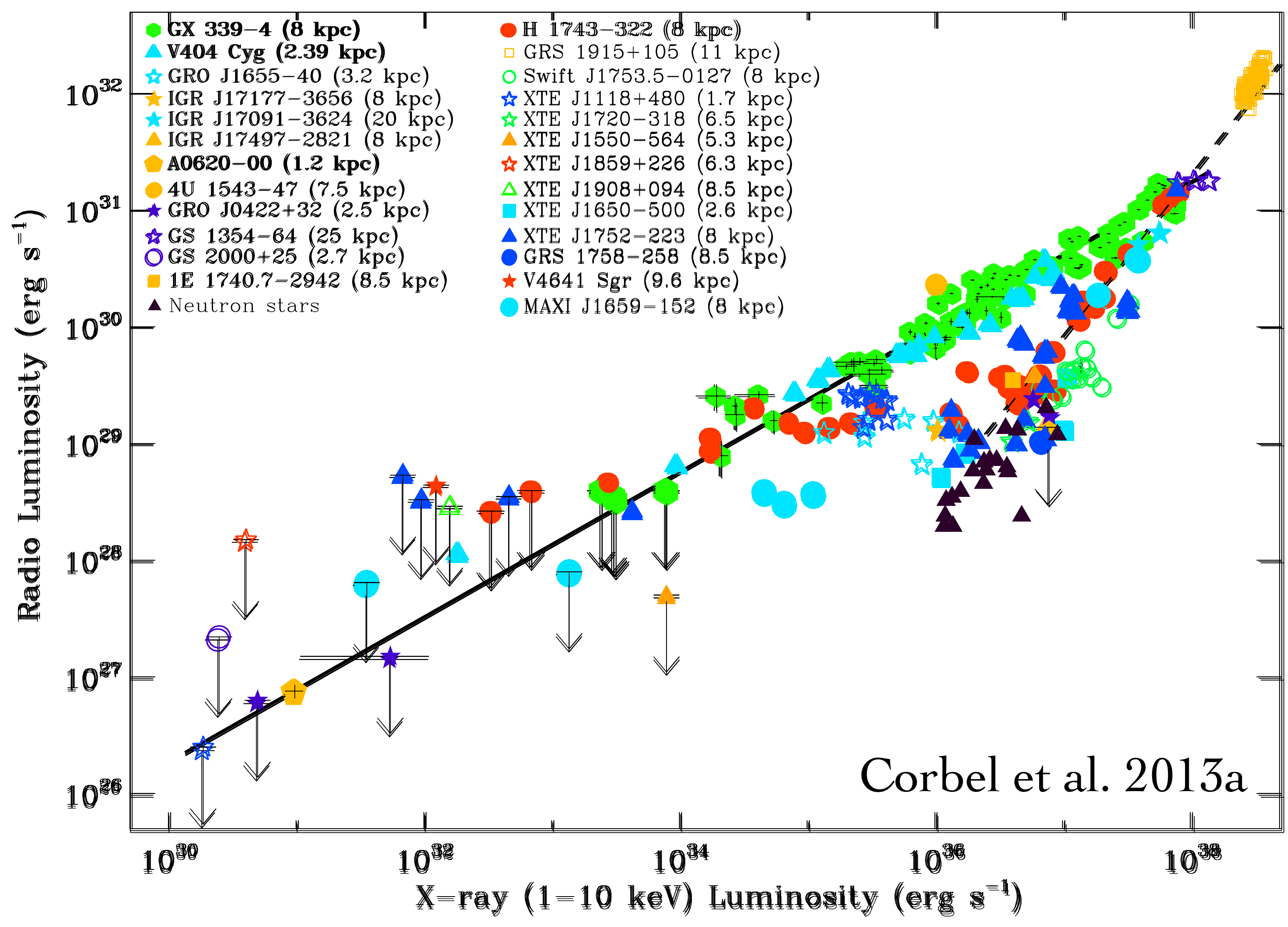
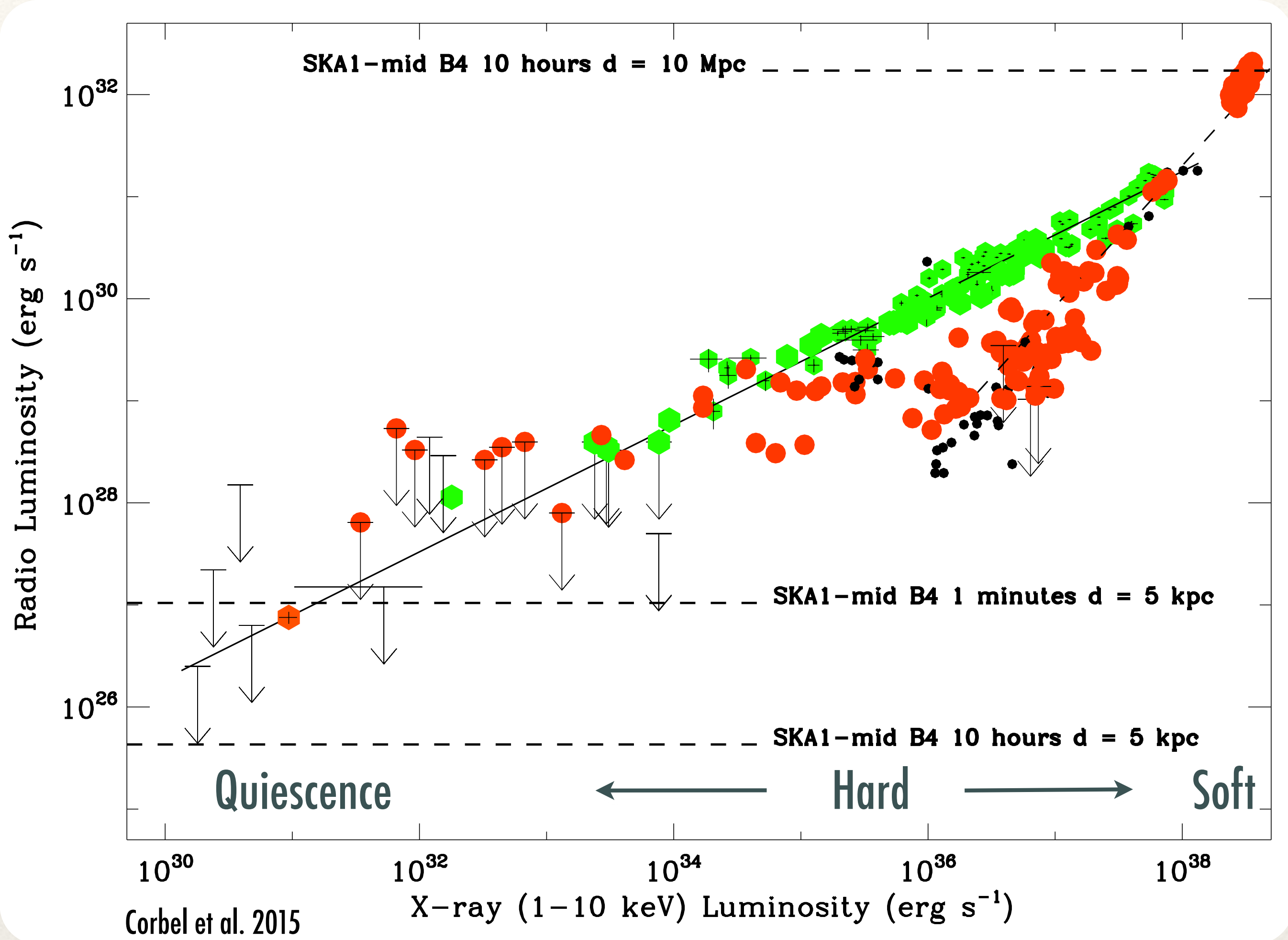
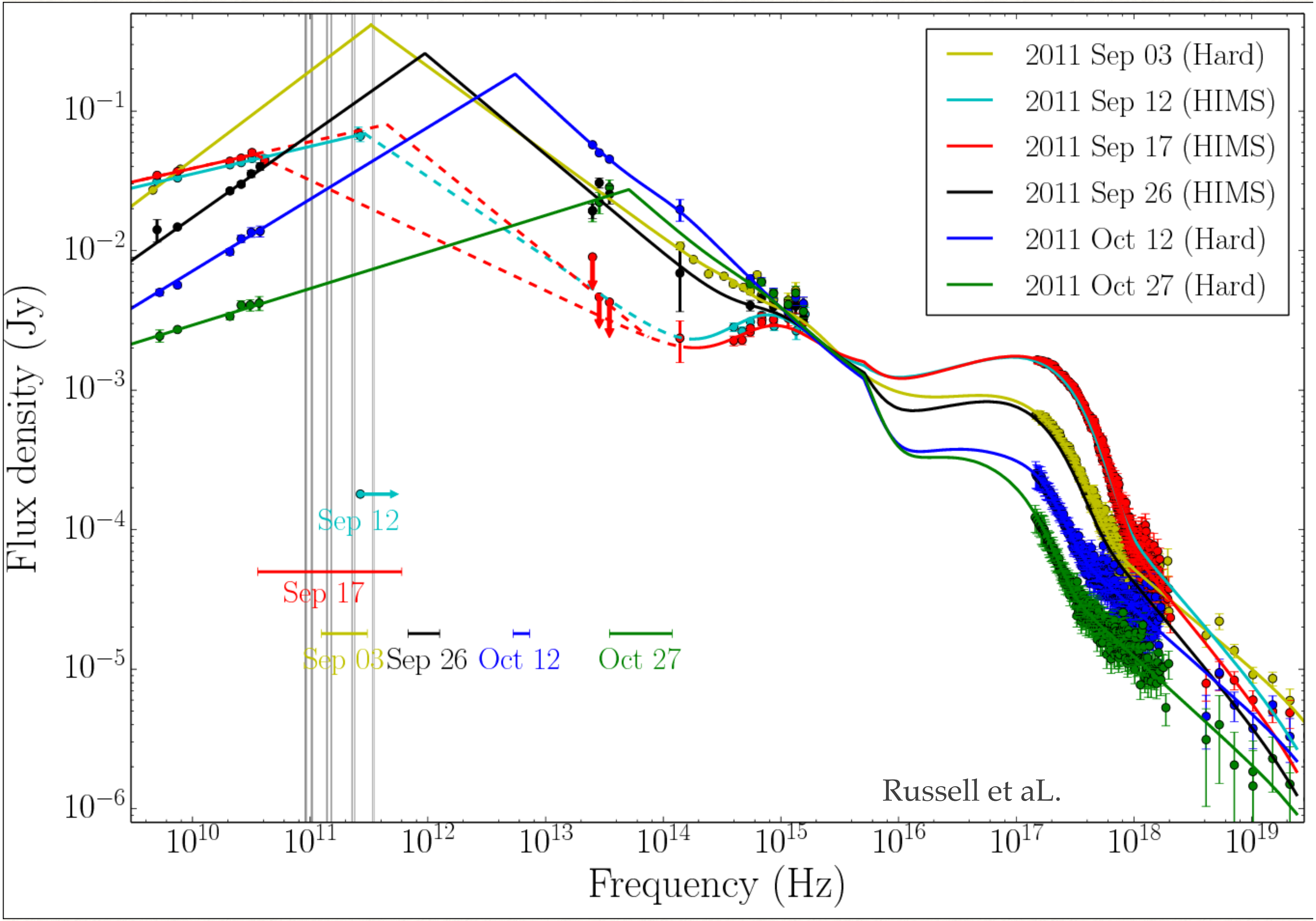


prospect with the ska



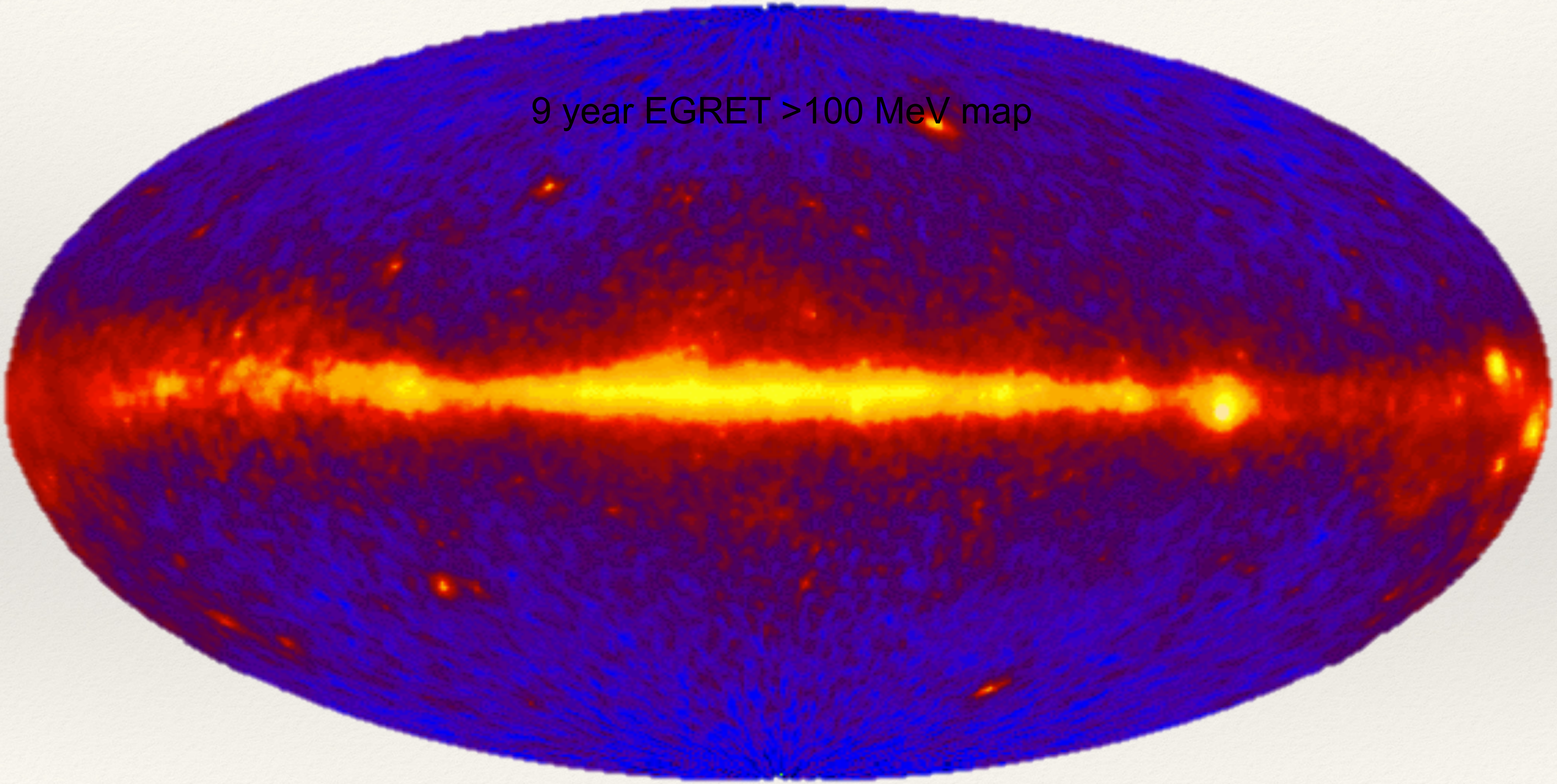
SKA: probing **a significant fraction of the whole outburst** duration for almost all BHs in our Galaxy

All **flaring transient** BHs accessible in the **local Universe** (possibly also up to Virgo @ 15 Mpc)



2011 Sep 03 (Hard)
2011 Sep 12 (HIMS)
2011 Sep 17 (HIMS)
2011 Sep 26 (HIMS)
2011 Oct 12 (Hard)
2011 Oct 27 (Hard)
Sep 12
Sep 17
Sep 03
Sep 26
Oct 12
Oct 27
Russell et aL.
Flux density (Jy)
Frequency (Hz)

The GEV sky



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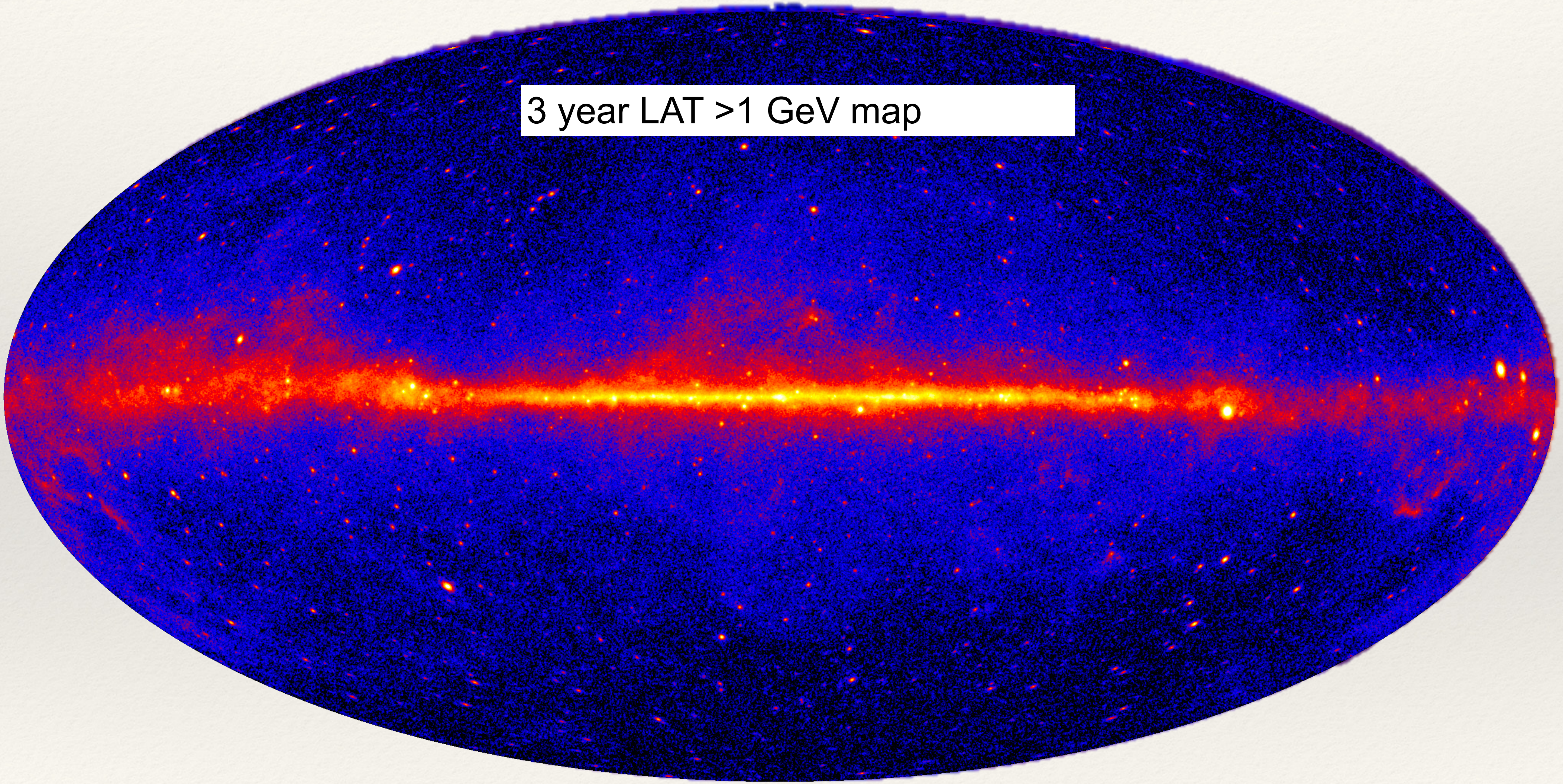
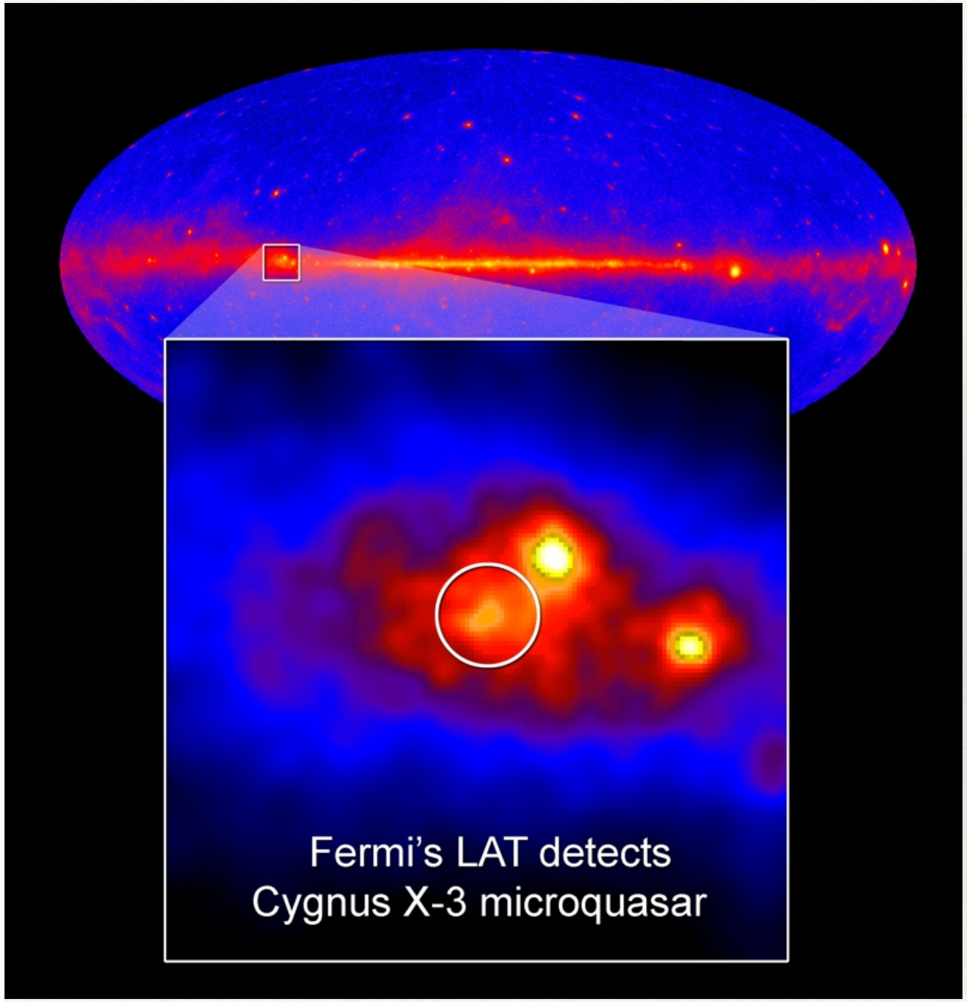


2FGL catalogue 1873 sources; Nolan et al., 2012, ApJS, 199, 31

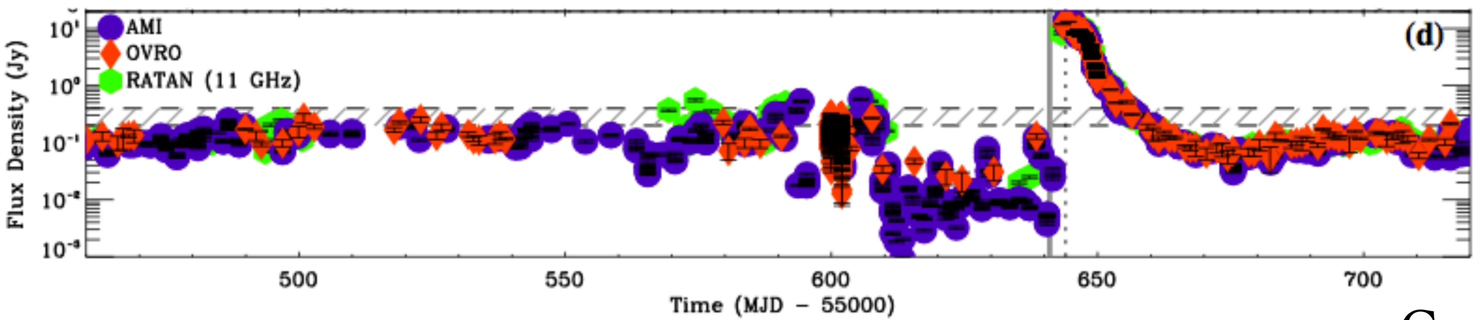
High energy emission from microquasar



Abdo et al. 2009; Tavani et al. 2009

- **Cyg X-3**: Black hole (?) with a WR companion star, short orbital period (4.8 hr)
- Brightest transient radio source
- Frequent radio outbursts associated with powerful relativistic jets (pointing «towards» the observers)
- Until now, **Cyg X-3 is the only microquasar observed in γ-rays** (repeatably). Detect. of orb. modul.
- Origin: inverse Compton scattering of UV star photons on jets e-

Multi-wavelength monitoring
21 September, 2010 - 8 June 2011

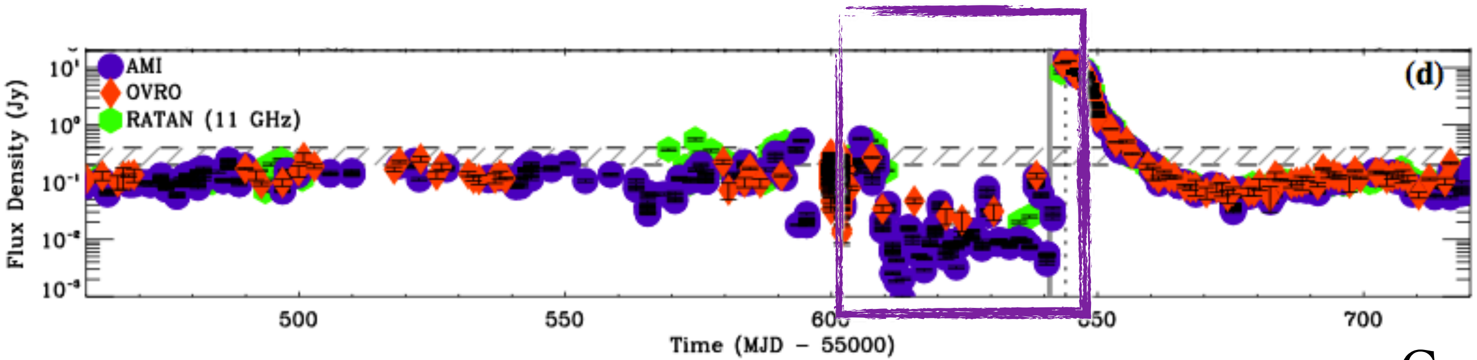


radio
11 & 15 GHz

Corbel et al. 2012

Multi-wavelength monitoring
21 September, 2010 - 8 June 2011

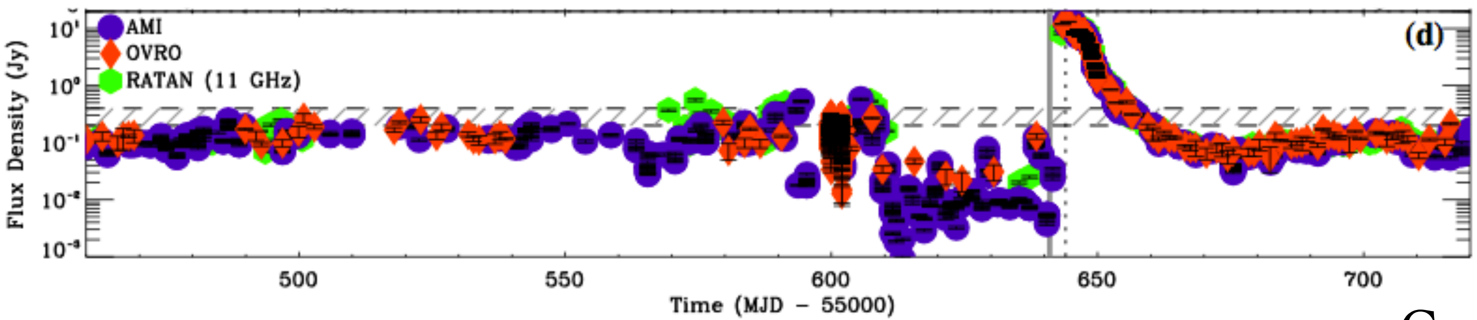
quenched state



radio
11 & 15 GHz

Corbel et al. 2012

Multi-wavelength monitoring
21 September, 2010 - 8 June 2011



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Multi-wavelength monitoring
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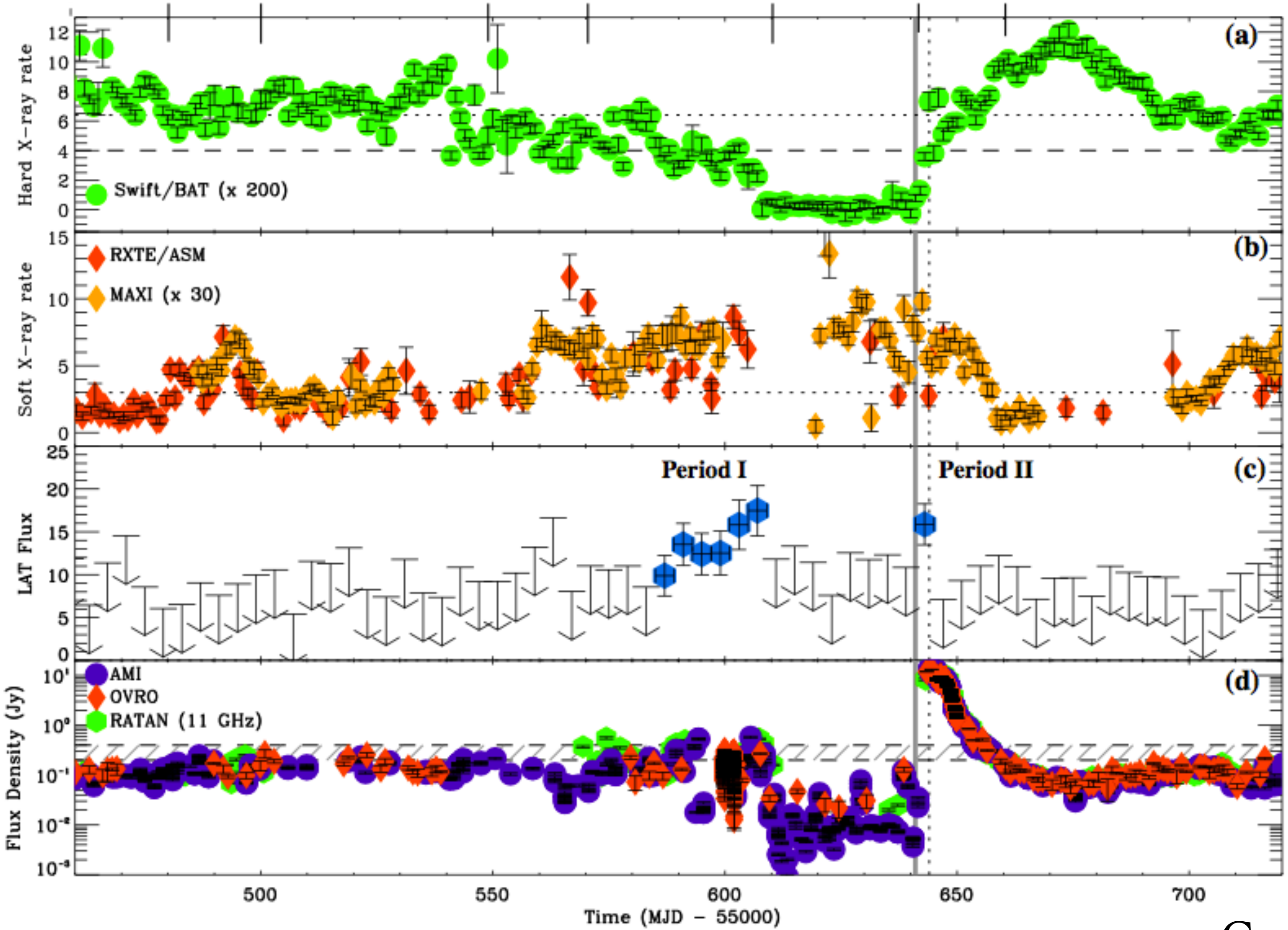


X-ray
15-50 keV

X-ray
3-5 keV

gamma-ray
>100 MeV

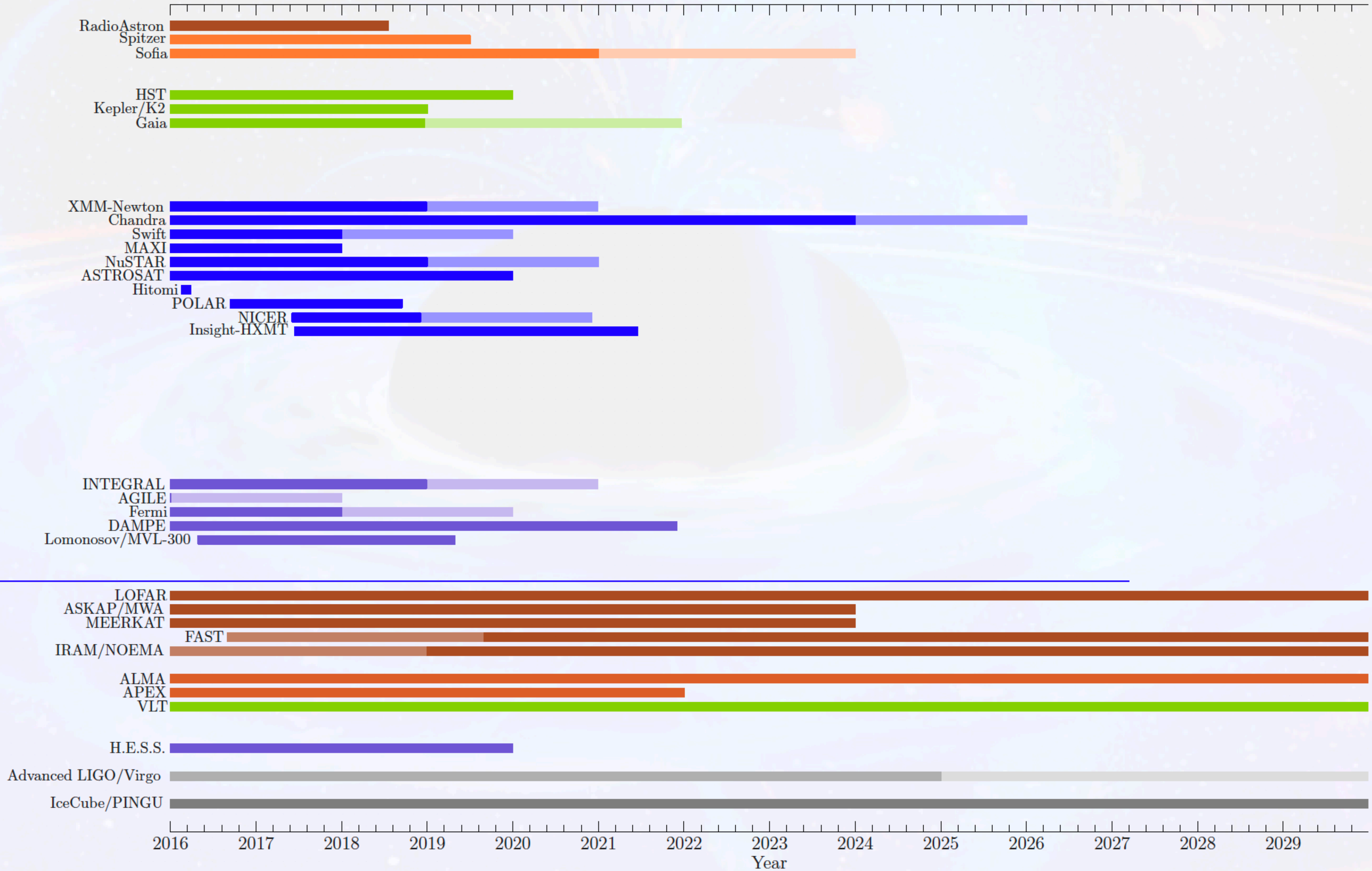
radio
11 & 15 GHz

Corbel et al. 2012

What do we need ?

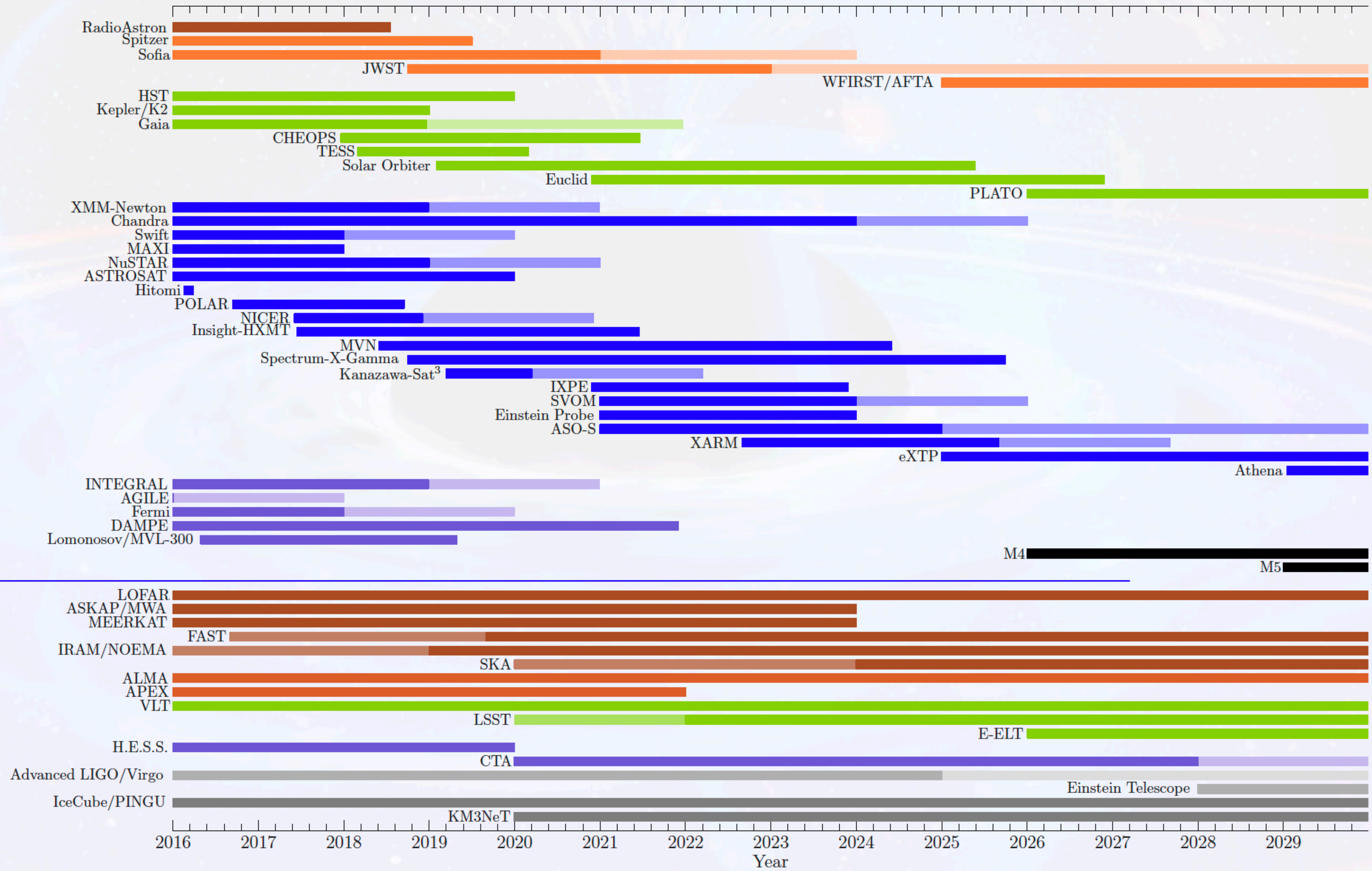
- From all λ, a rapid diffusion of location of new transients and/or an interesting phase of an evolving outburst.
- Timescale range from ms to days. Basically, we need to be on source ASAP when something happens
- Need to disseminate the location (with error box) ASAP. VO Event.
- Need to coordinate the MW campaign in order to collect SEDs as broad as possible. Necessary to have proposals (incl. follow-up) in place. Time commuting in organisation !
- Need to develop a publicly available database with SEDs (but with spectra and response files, not flux units)

Current Facilities



Slide: J. Wilms

Approved Facilities



Reaction time

- Should be on source after alert asap in extreme case : timescale of seconds/minutes (detection in ~1 minute with AMI).
- **X-ray**: Human interactions
    - All Sky Monitor: information almost available immediately : position +crude spectrum. Today: Swift/BAT + MAXI; Tomorrow: SVOM, eXTP. Quick on board analysis —> dissemination. Usually publicly available.
    - Pointed observations : Reaction time much slower, may take up to few days or even more. Deep observations usually (meaning less frequent). However, excellent example with the reactivity of RXTE.
- **γ-rays:** e.g. *Fermi* a significant fraction of the sky is always visible (but limited sensitivity), different from Cherenkov experiments (small FOV)
- **Radio**: Larger FOV, limited multifrequencies capabilities (use of sub-arrays ?), commensal observing —> serendipity. High resolution maps if possible. See talk by Julien Girard for more details on the alert itself. React to VO in future.

Conclusions

- HE and Radio transients are usually connected (cf same population of electrons radiating at different energies).
- Flaring sources on varying timescales implies that we need to collect observations as frequent as possible in order to sample their SED (where the physics hide).
- Radio is well organised for that purpose (see J. Girard's talk). Radio information will likely be available in coming years for all transients.
- Question about available X-ray ASM in the next years.