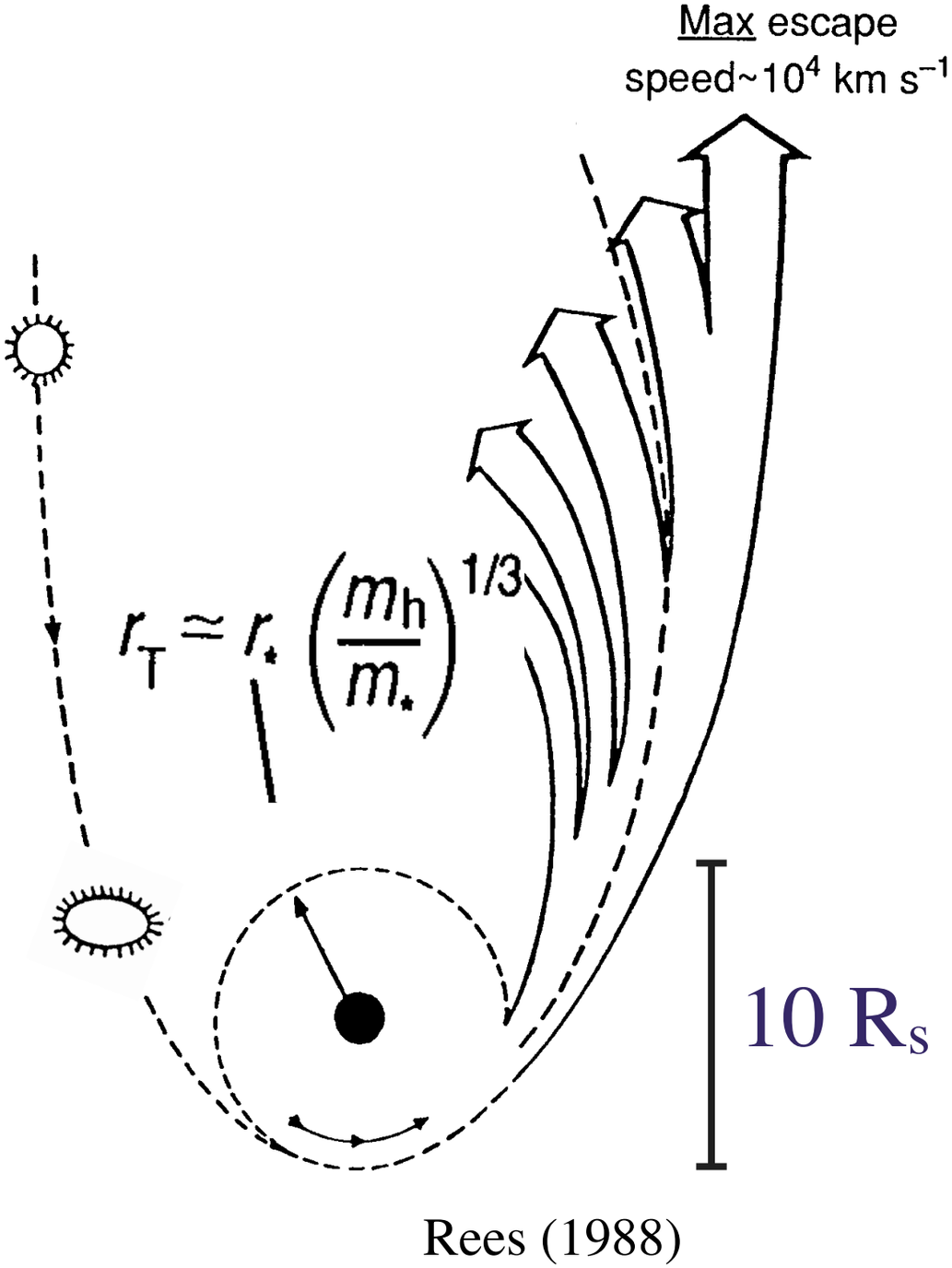
Sjoert van Velzen (NYU, UMD)

X-ray Astronomy 2019, Bologna
Sep 9, 2019

Multi-wavelength observations of stellar tidal disruption flares

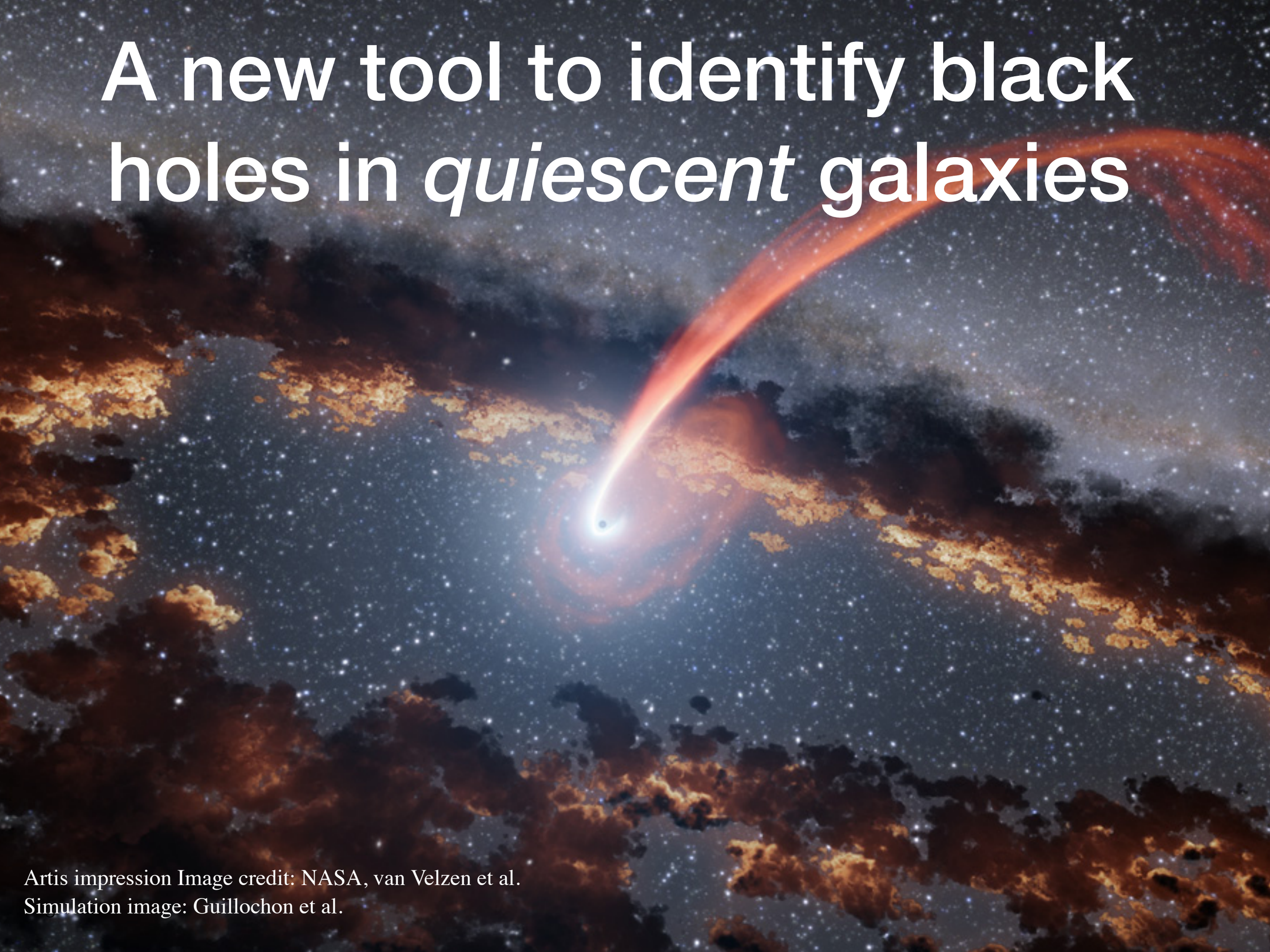
Stellar tidal disruptions

- Star passes within Roche radius (r_T)
- Half of the debris remains bound
- Steep fallback rate: $t^{-5/3}$
- Rare events: ~10^4 yr wait time per galaxy
- M>10^8 $M_\odot$, Roche radius inside black hole horizon



Rees (1988)

A new tool to identify black holes in *quiescent* galaxies



Artis impression Image credit: NASA, van Velzen et al.
Simulation image: Guillochon et al.

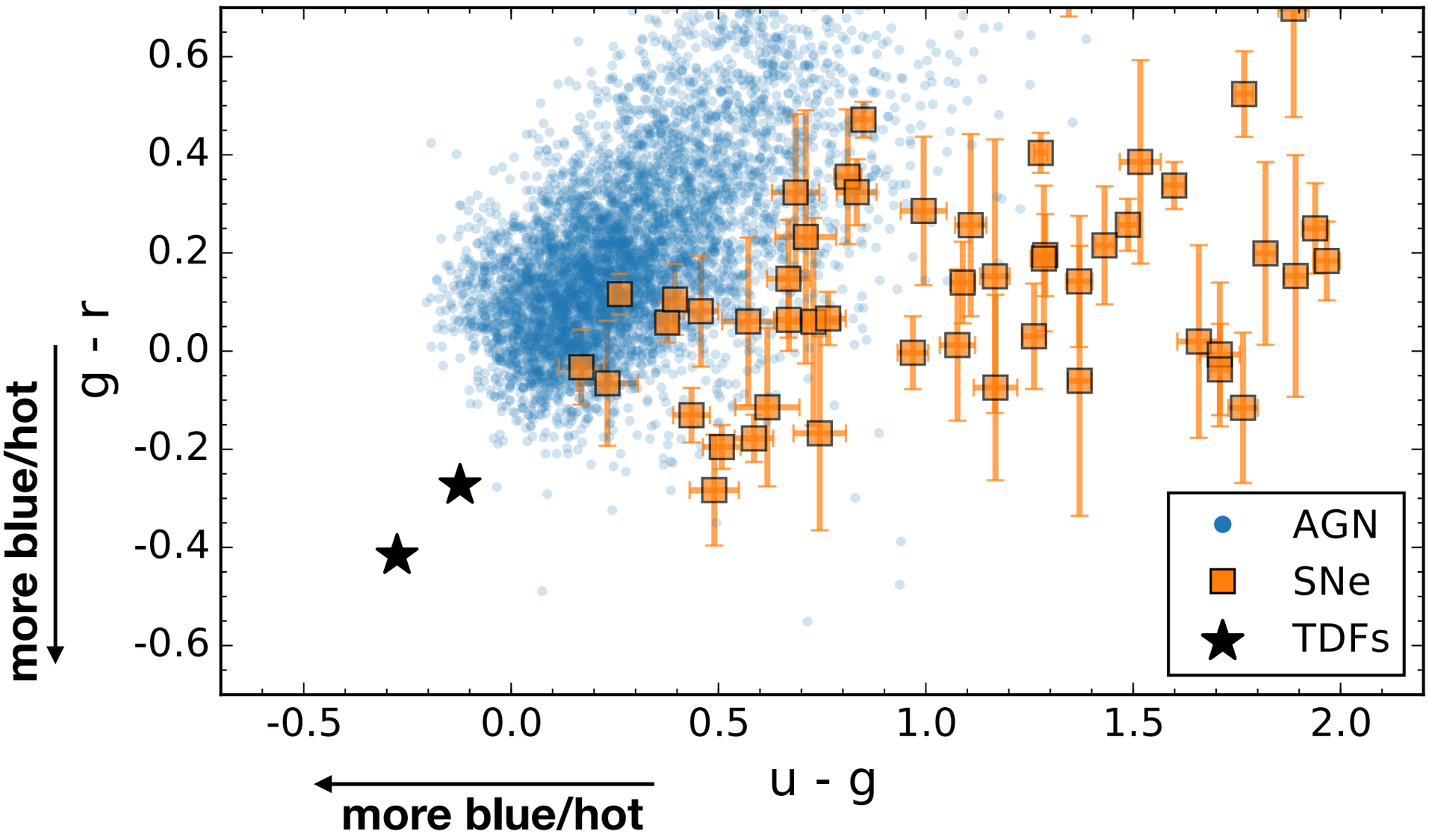
Big Questions

Do all galaxies host massive black holes in their nuclei? (LISA)

Is accretion/jet physics scale invariant? (Athena)

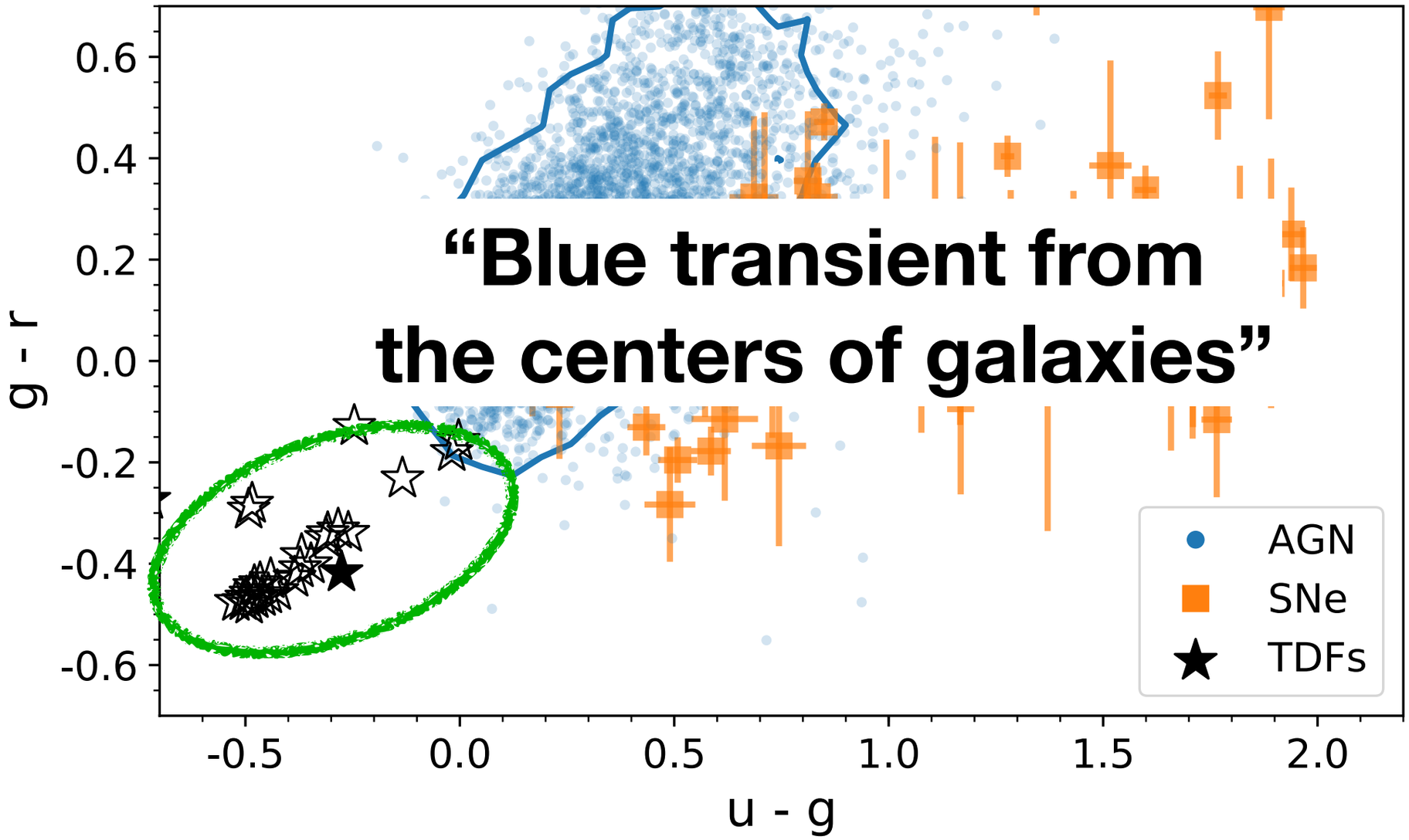
credit: Wikimedia

TDE locus in optical surveys (2011)



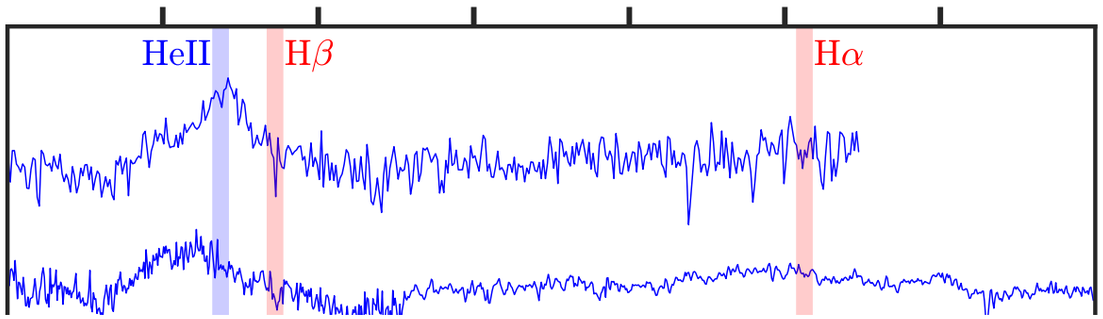
adapted from van Velzen et al. (2011)

TDE locus in optical surveys (2019)

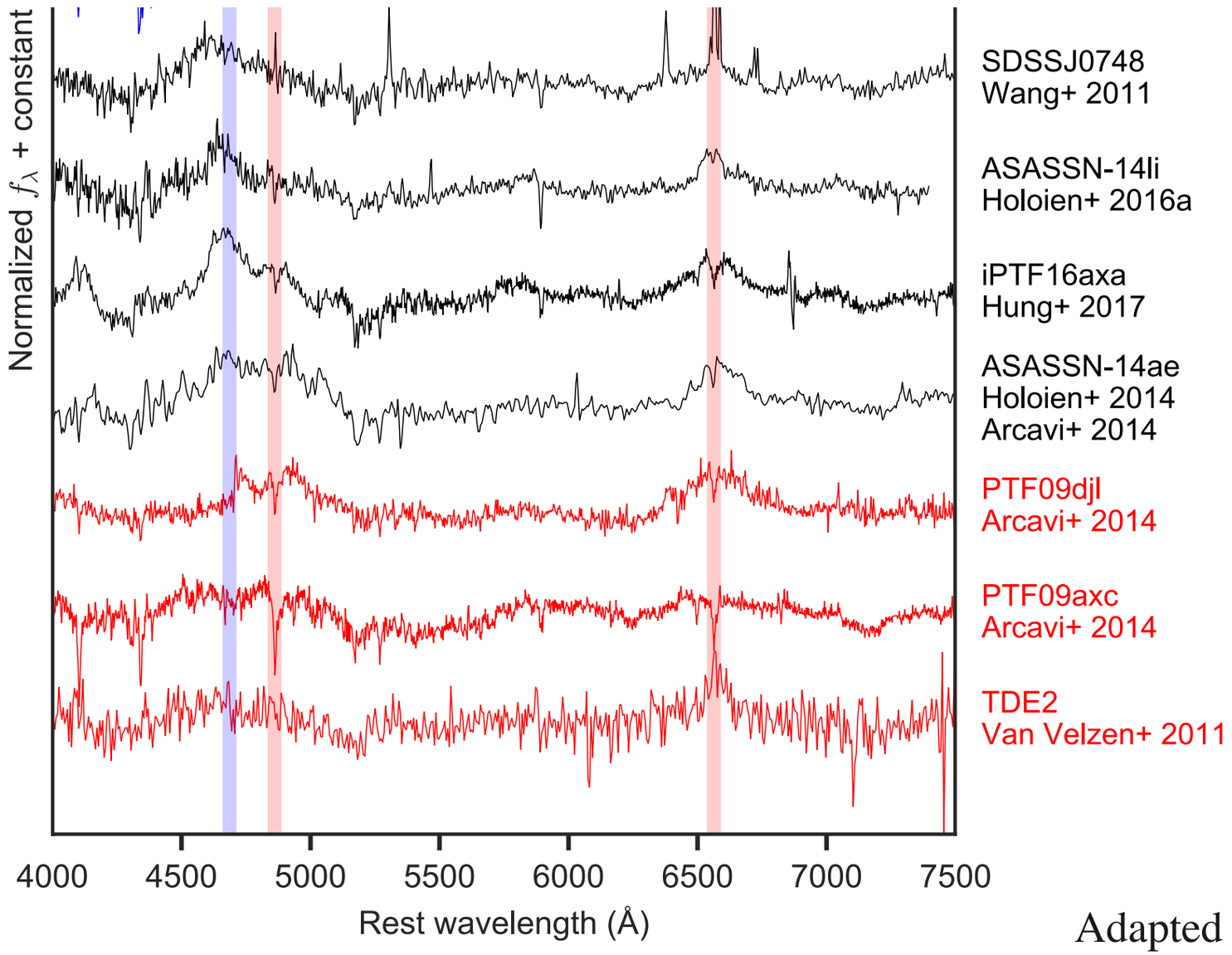


adapted from van Velzen et al. (2011)

Optical spectroscopic sequence

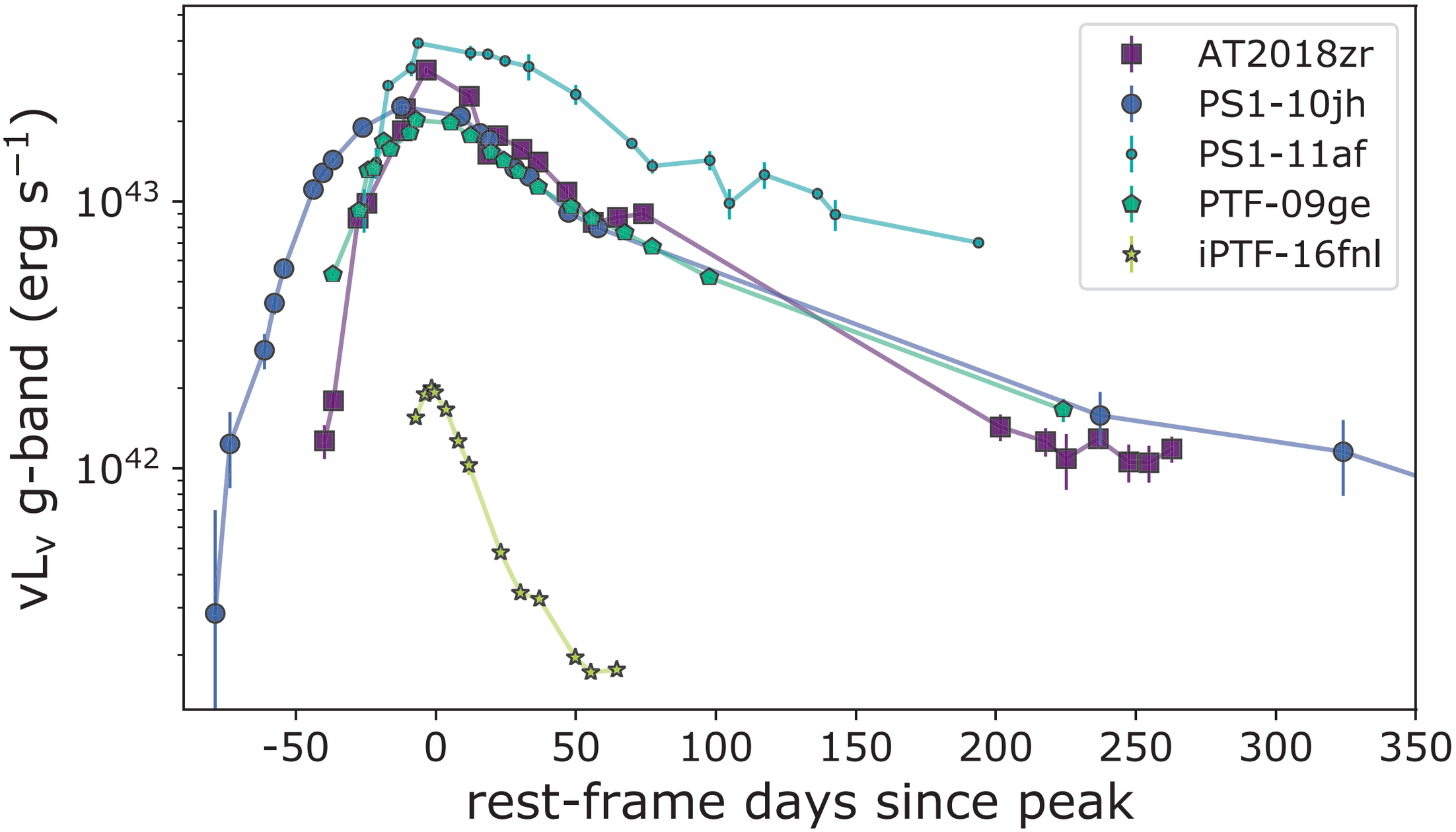


"Blue spectra with broad H/He"



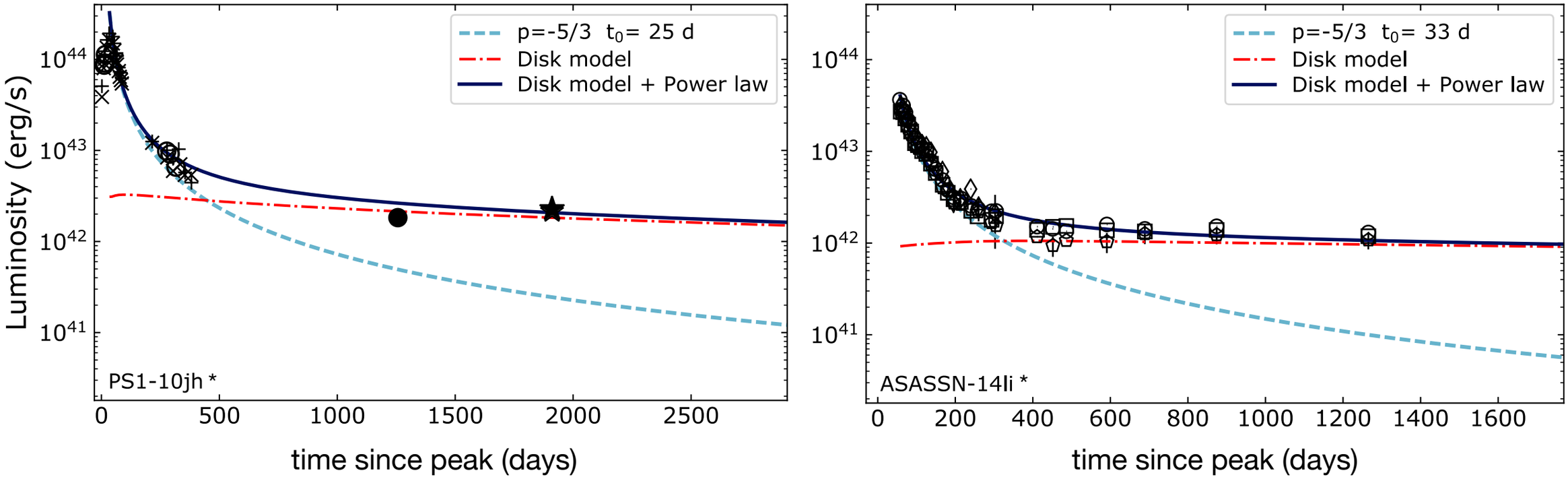
Adapted from Arcavi et al. (2014)

Early-time optical light curves: steep power-law decay



van Velzen et al. (2019b)

Late-time light curves: an accretion disk emerges



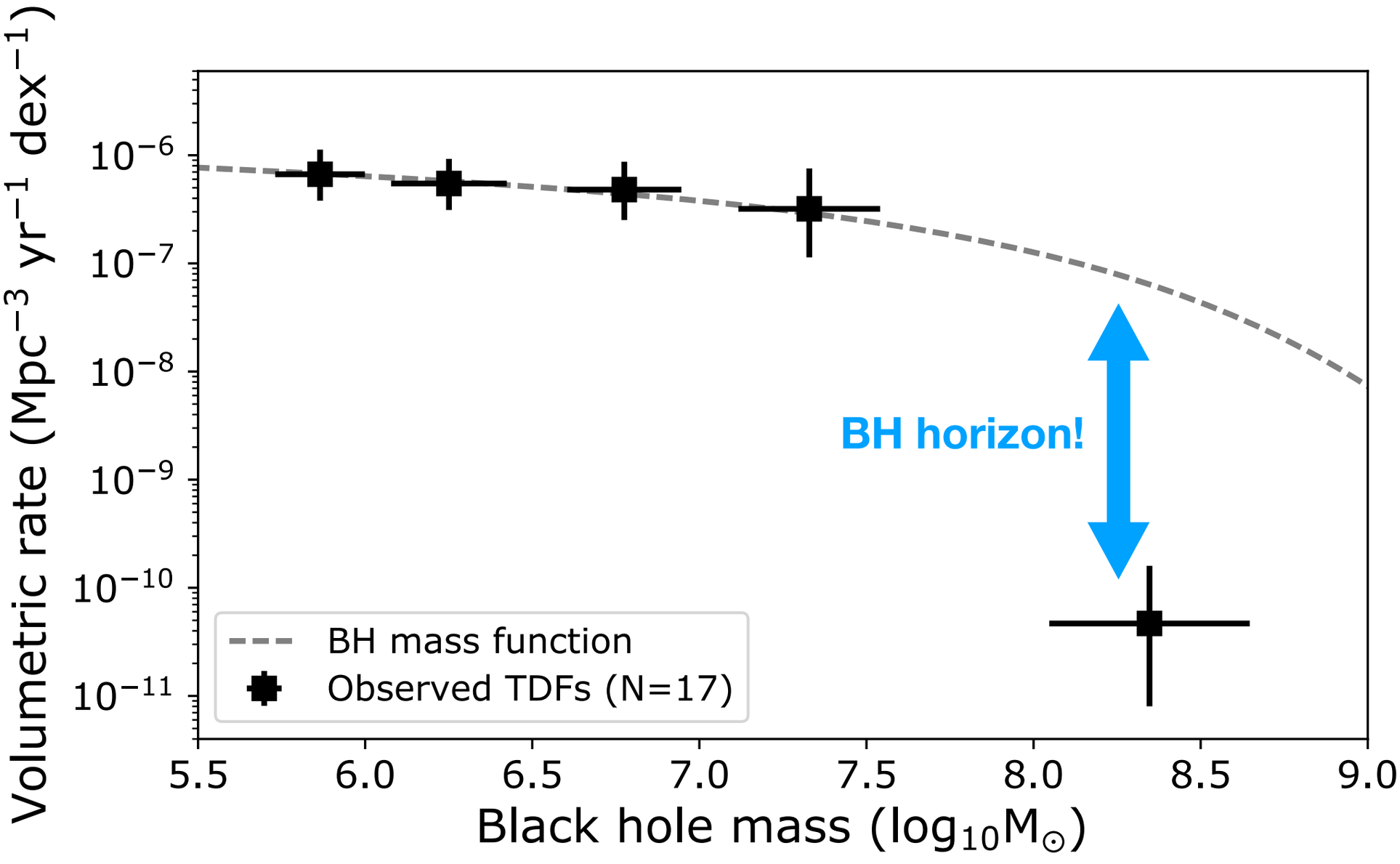
- *HST* and *Swift* UV follow-up

  (van Velzen et al. 2019a)
- UV detections; light curve flattens
- Late-time X-ray detections

  (Jonker et al. 2019)

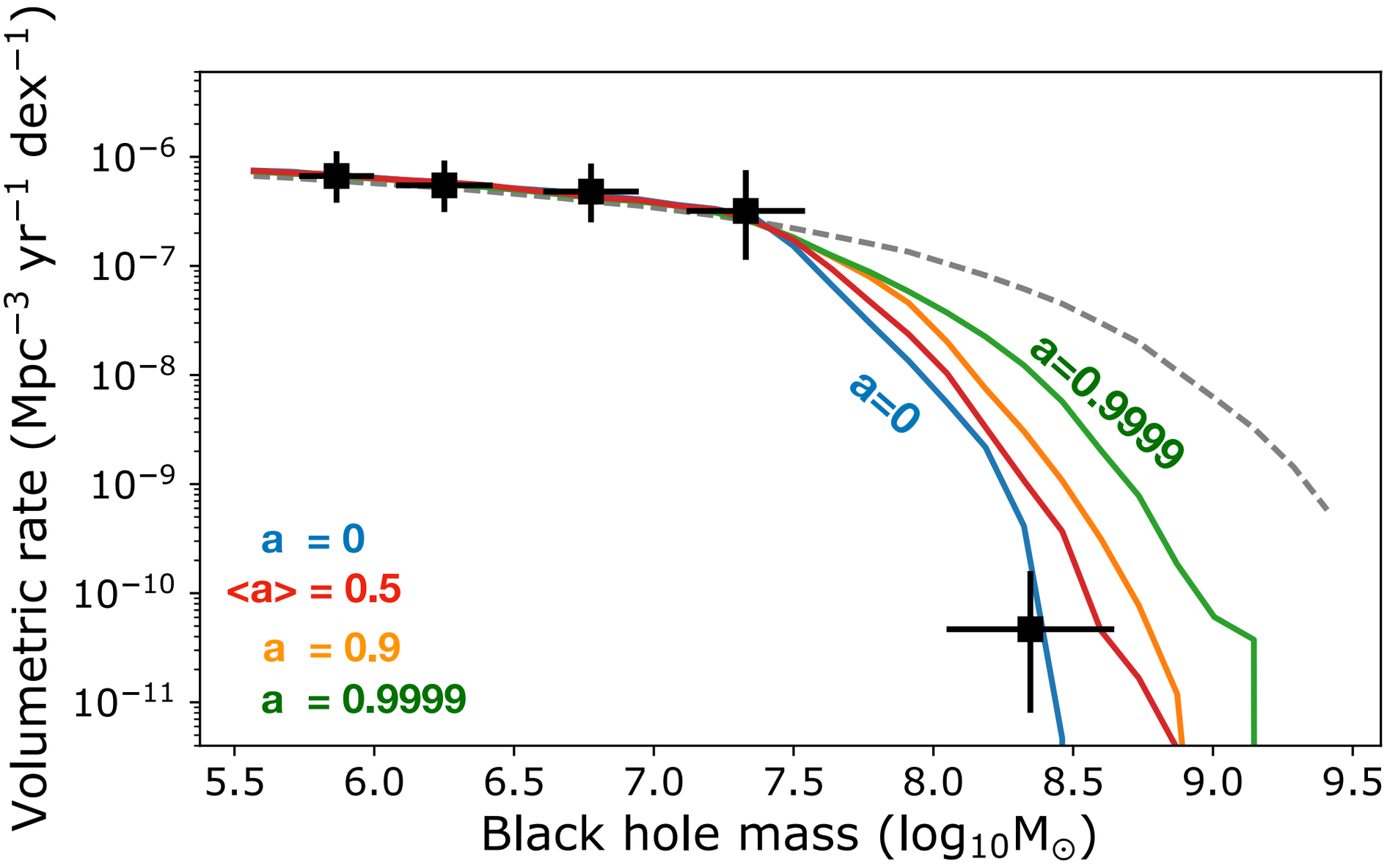
*data from:
Gezari et al. (2012, 2015)
Holoien et al. (2014)
van Velzen et al. (2019a)

Disruption rate as a function of black hole mass



Based on method in van Velzen (2018);
data from Wevers et al. (2017, 2019)

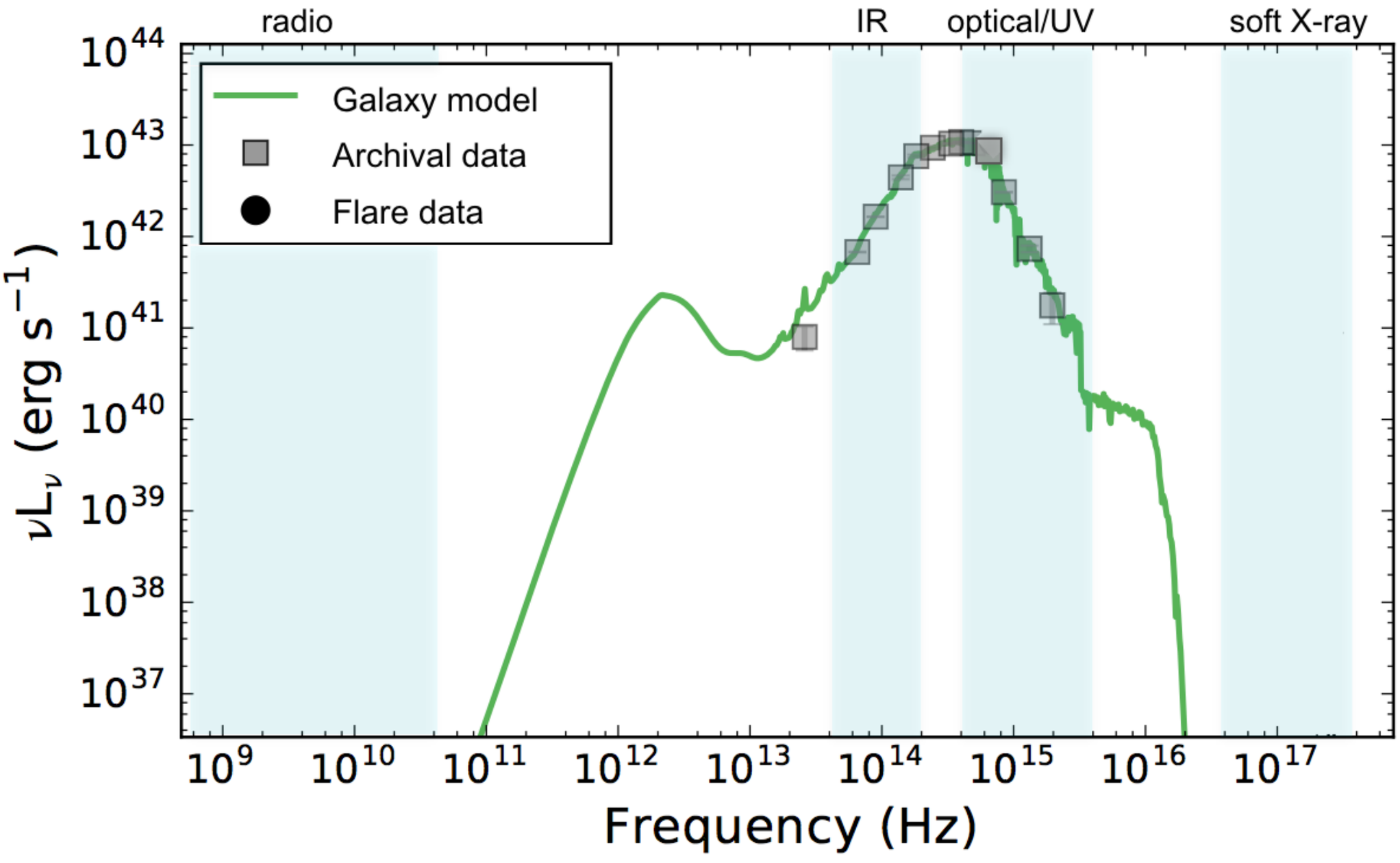
Measuring the average spin of quiescent black holes



ASASSN-15lh: Leloudas et al. (2016)

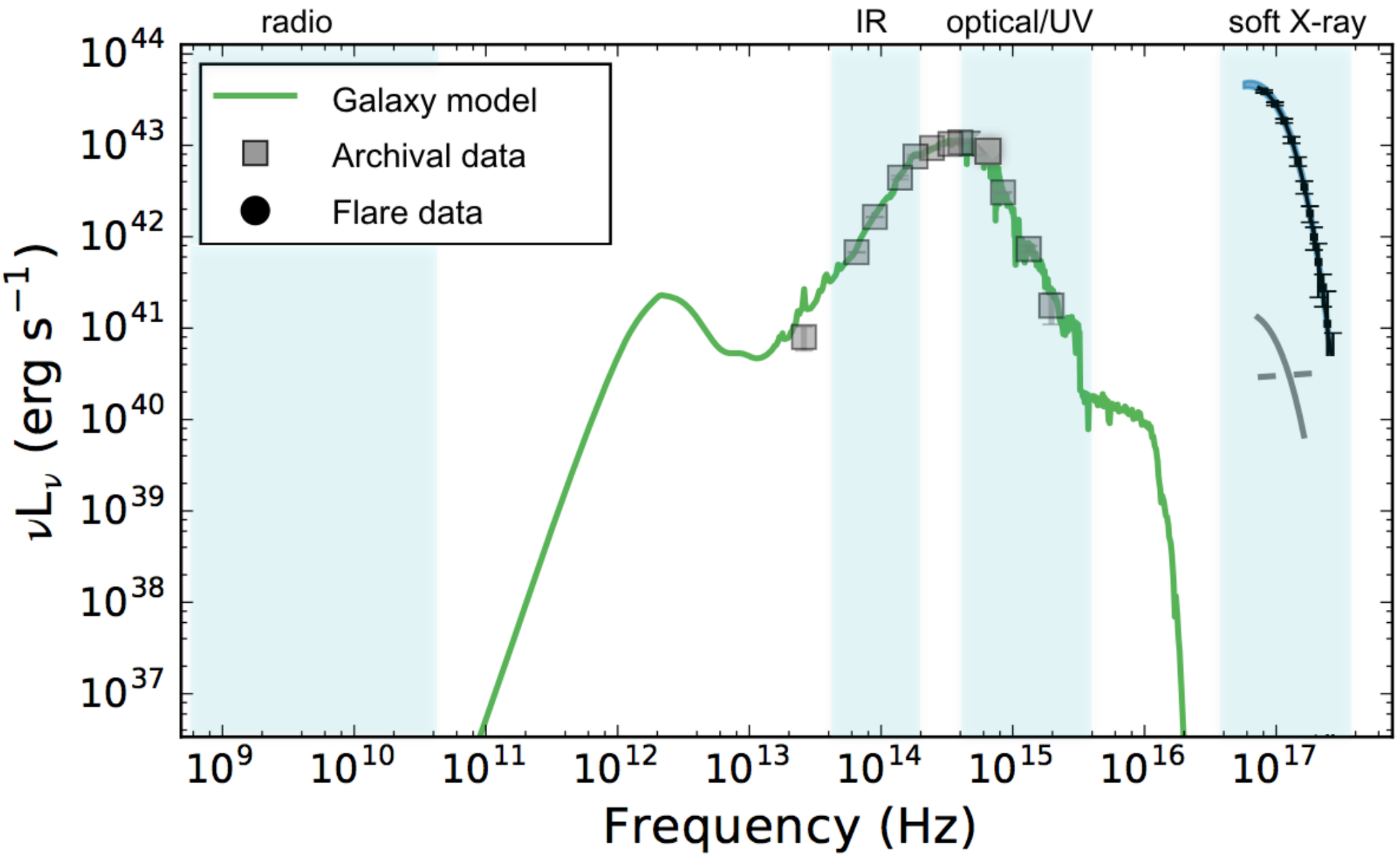
Figure: Stone & van Velzen (2019, in prep)

Spectrum of a tidal disruption flare



Velzen et al. (Science, 2016)

Spectrum of a tidal disruption flare



Velzen et al. (Science, 2016);
ASASSN-14li (Holoien et al. 2016)

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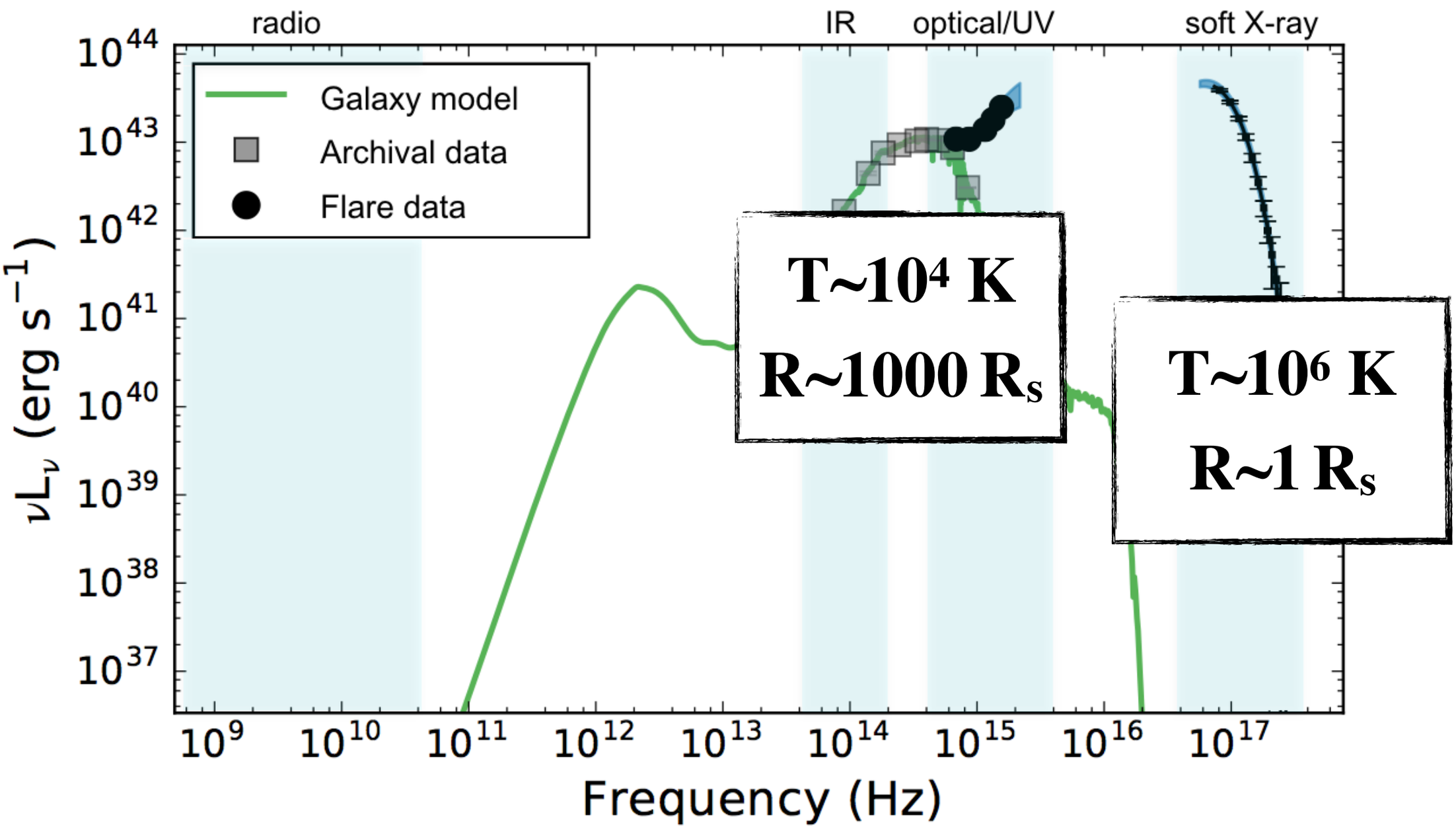

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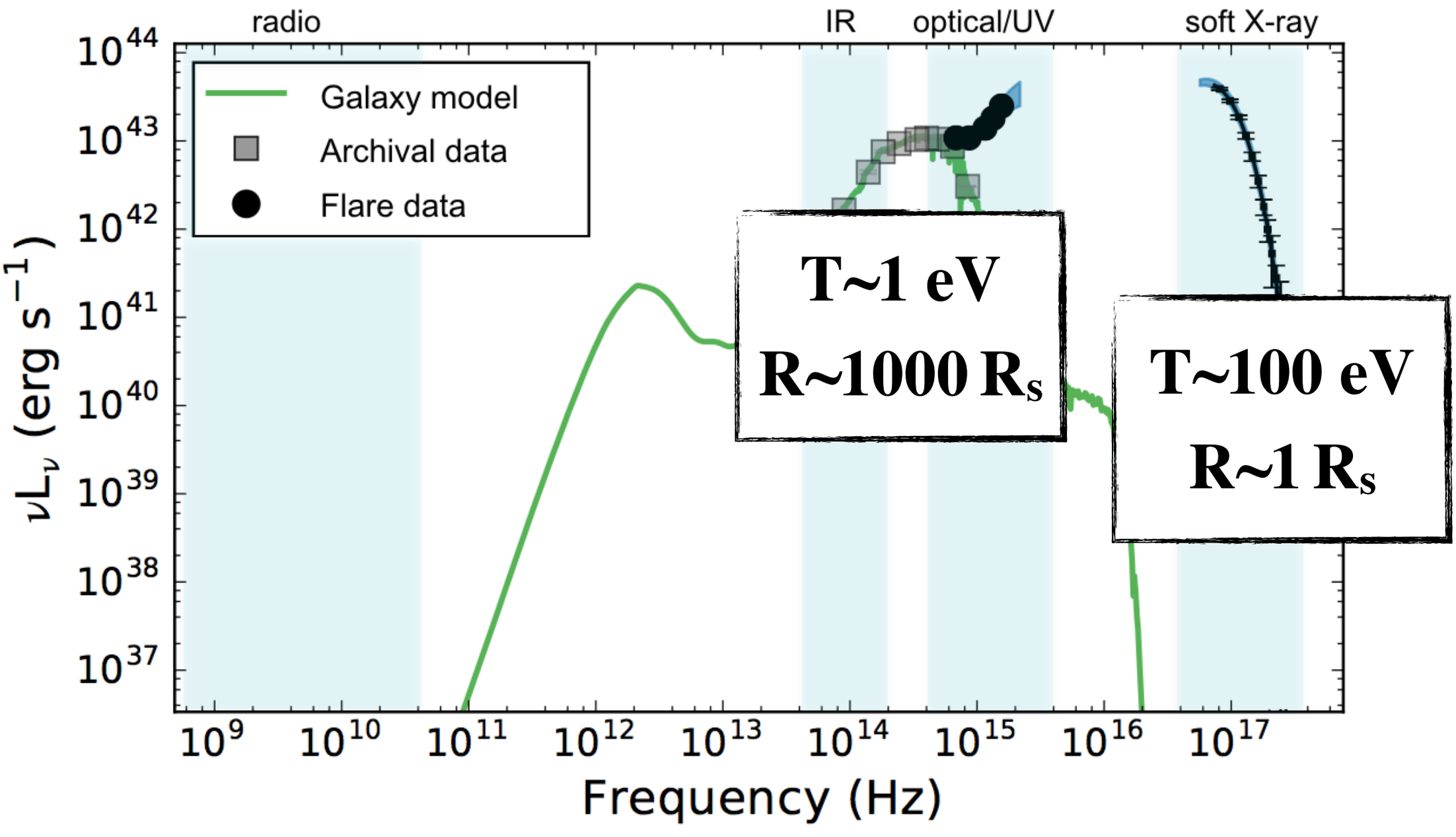
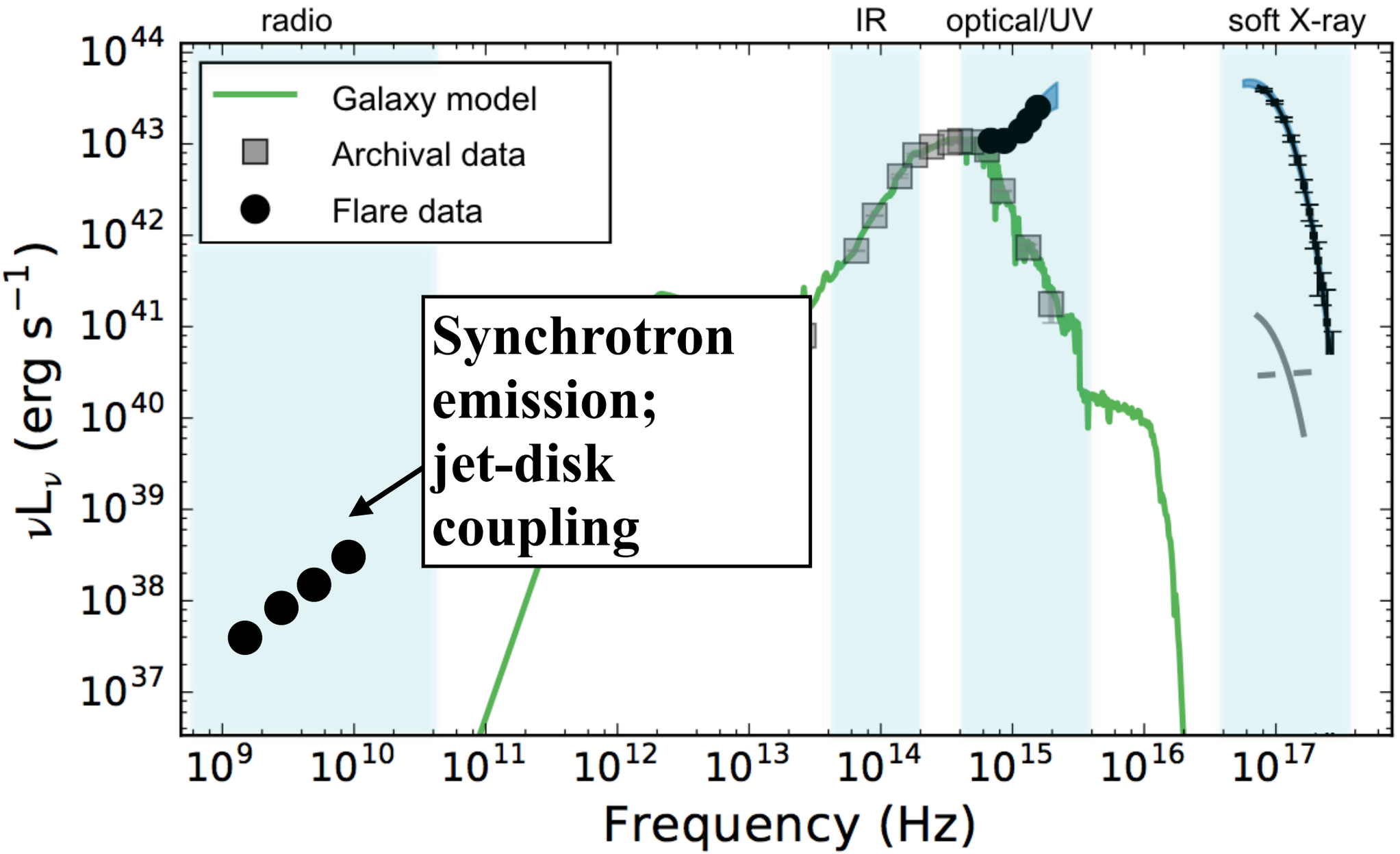


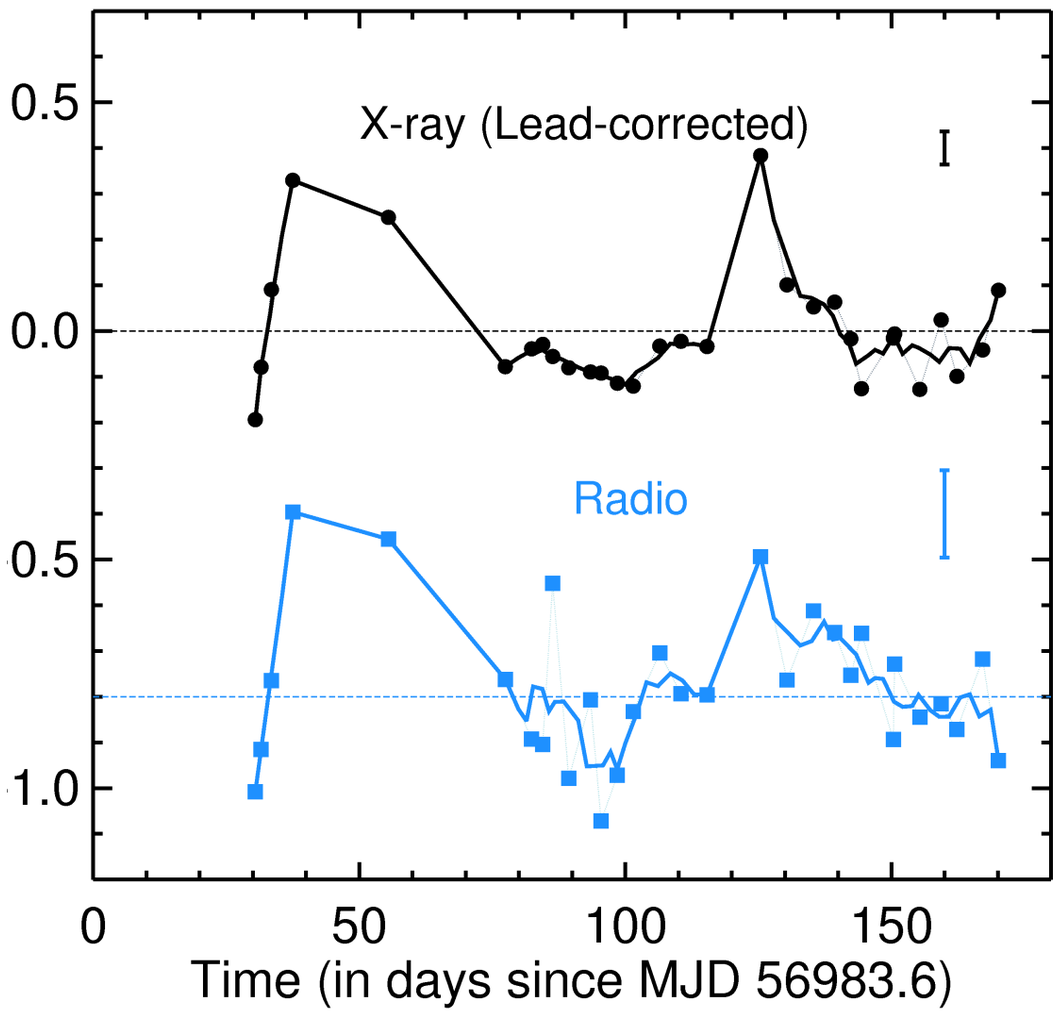
Velzen et al. (Science, 2016);
ASASSN-14li (Holoien et al. 2016)

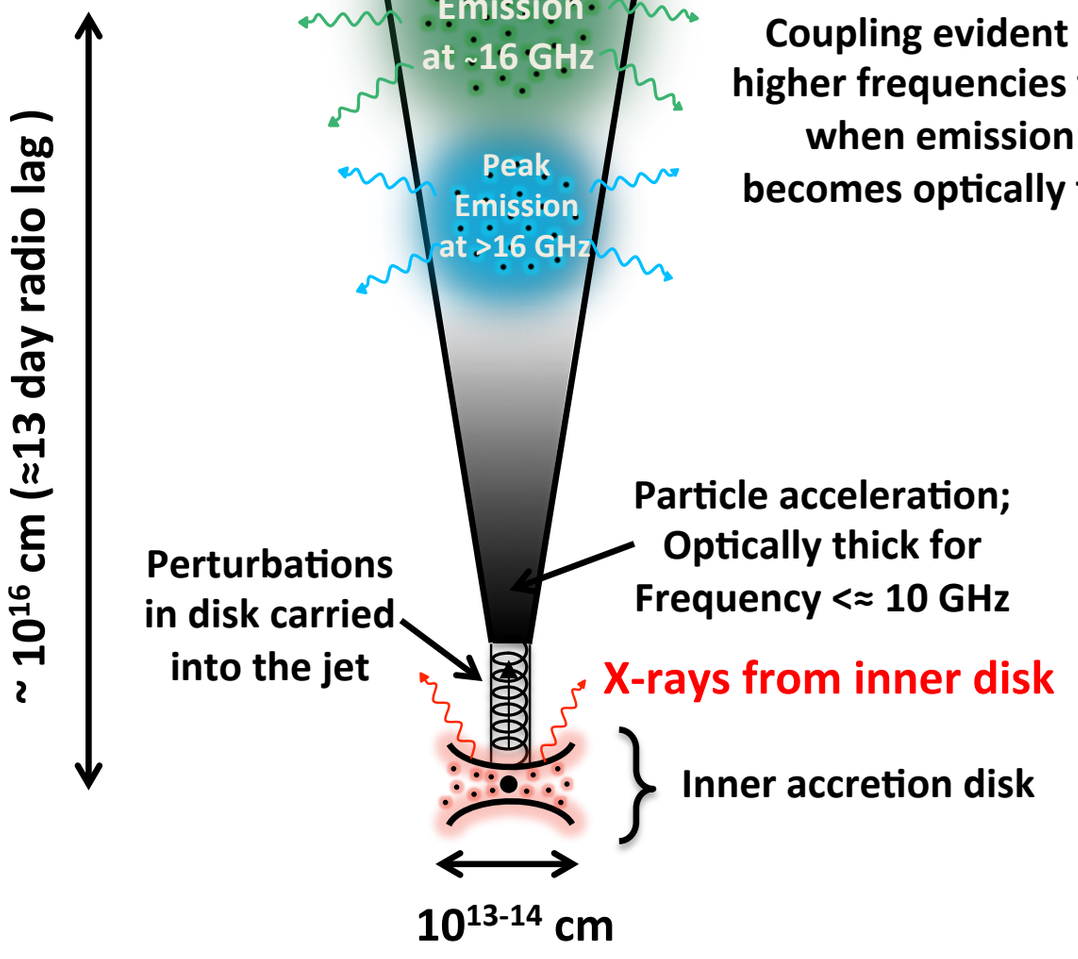
Multi-wavelength tour: radio emission



Radio data: Velzen et al. (2016); Alexander et al. (2016)

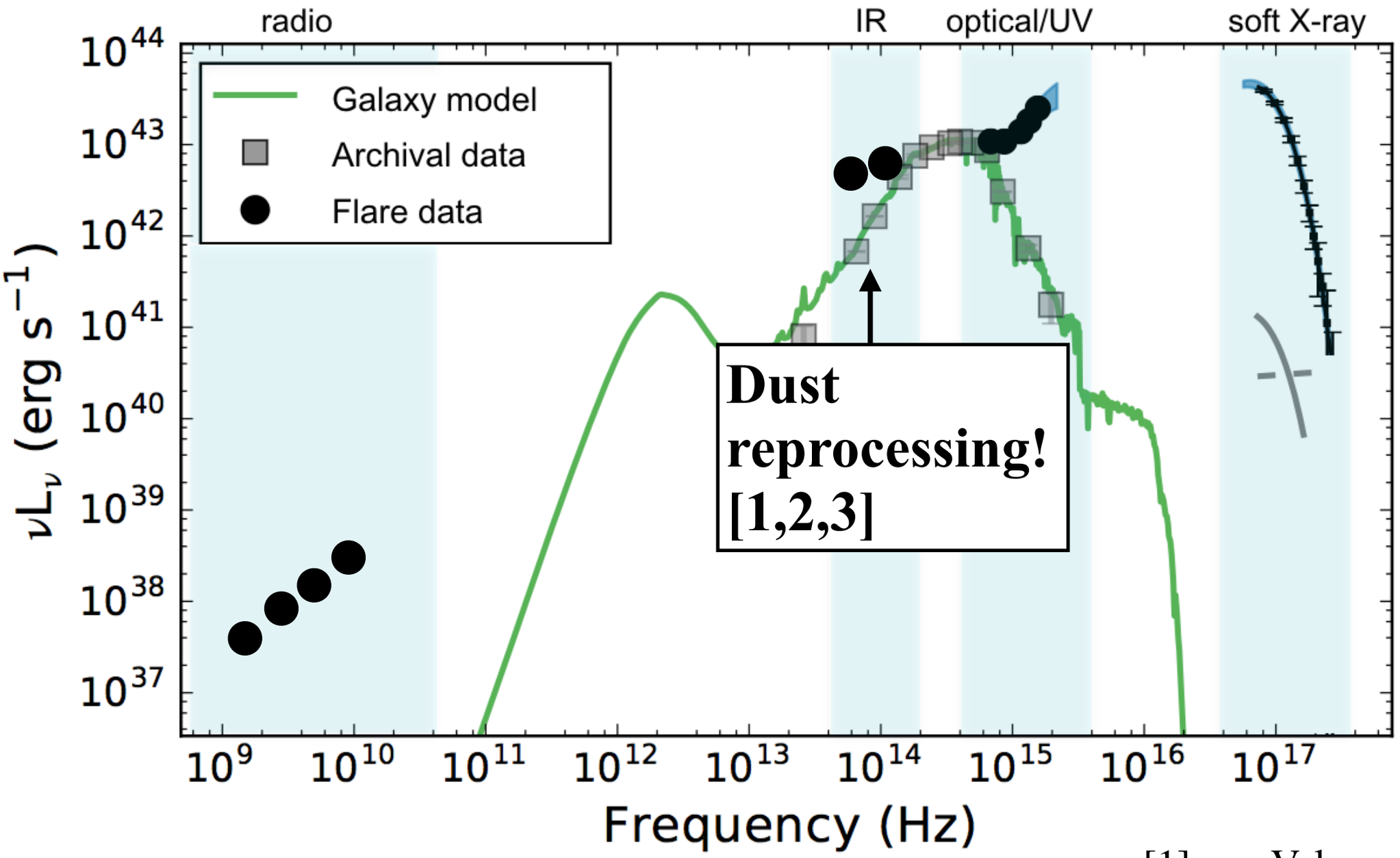
Radio / X-ray crosscorrelation





Pasham & van Velzen (2017)

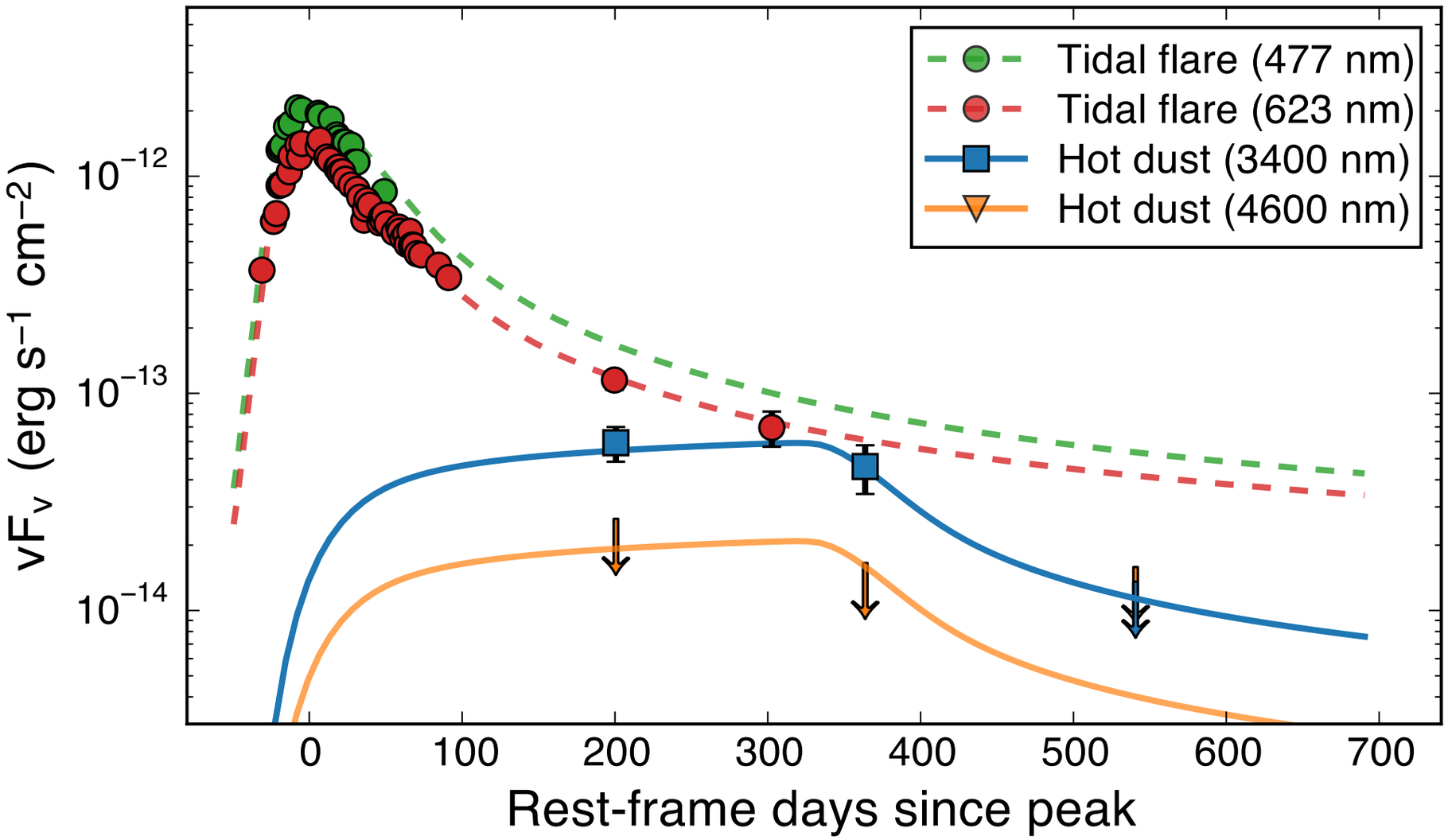
Multi-wavelength tour: infrared emission



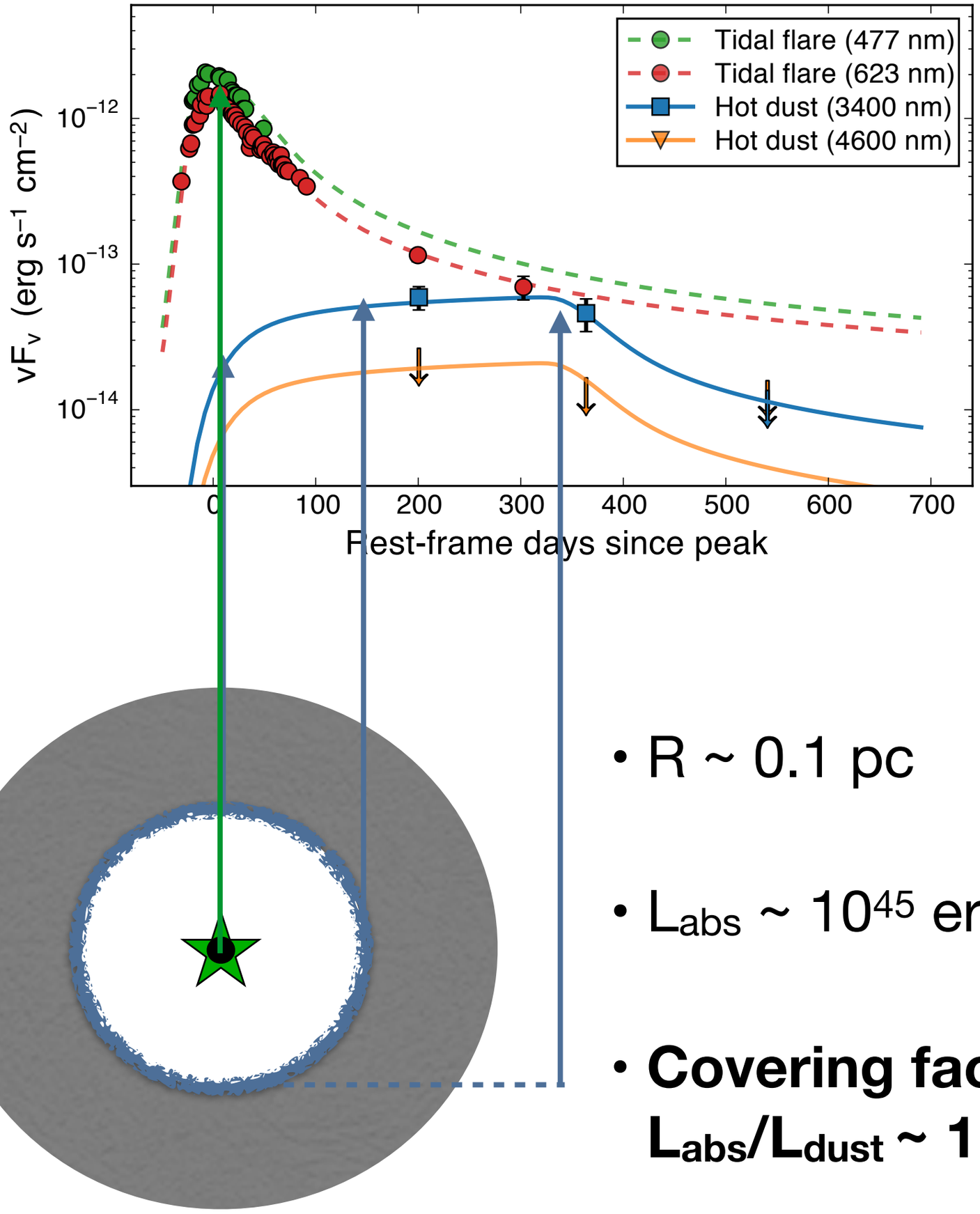
[1] van Velzen et al. (2016)
[2] Jiang et al. (2016)
[3] Wang et al. (2018)

Artis impression Image credit: NASA, van Velzen et al.
Simulation image: Guillochon et al.

We detected a “dust echo”



van Velzen et al. (2016b)



- R ~ 0.1 pc
- L_{abs} ~ 10^{45} erg/s
- **Covering factor: L_{abs}/L_{dust} ~ 1%**

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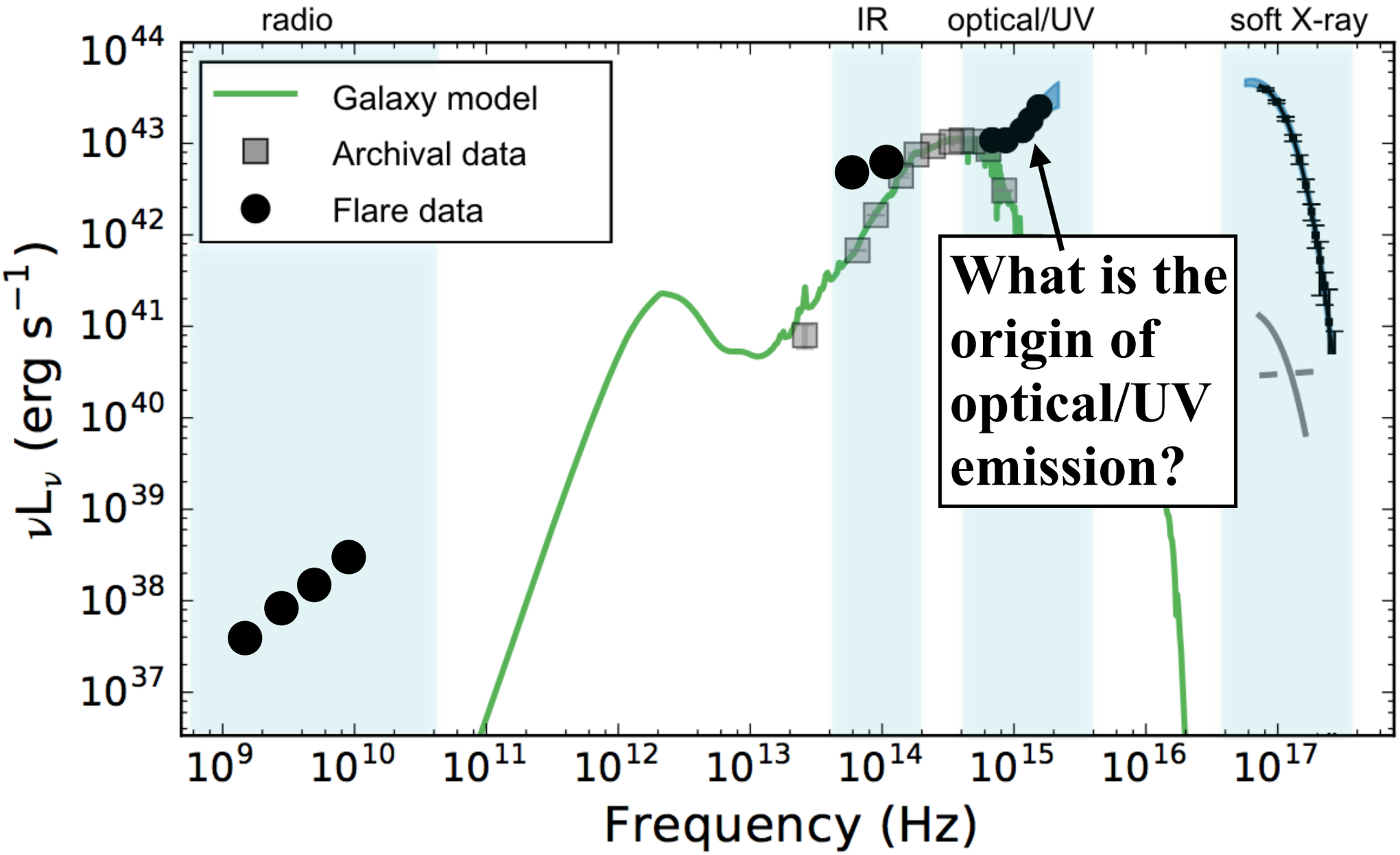
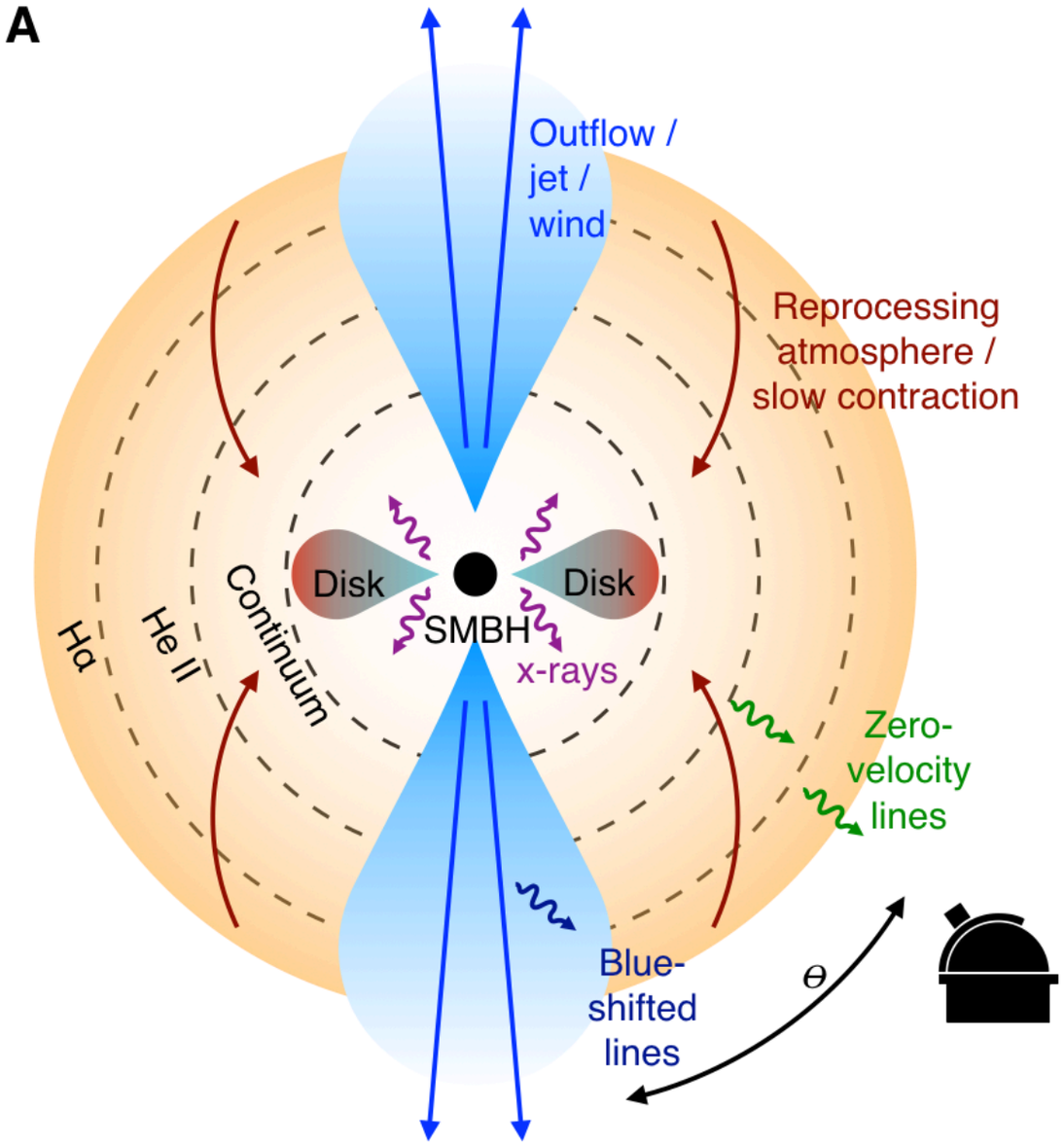
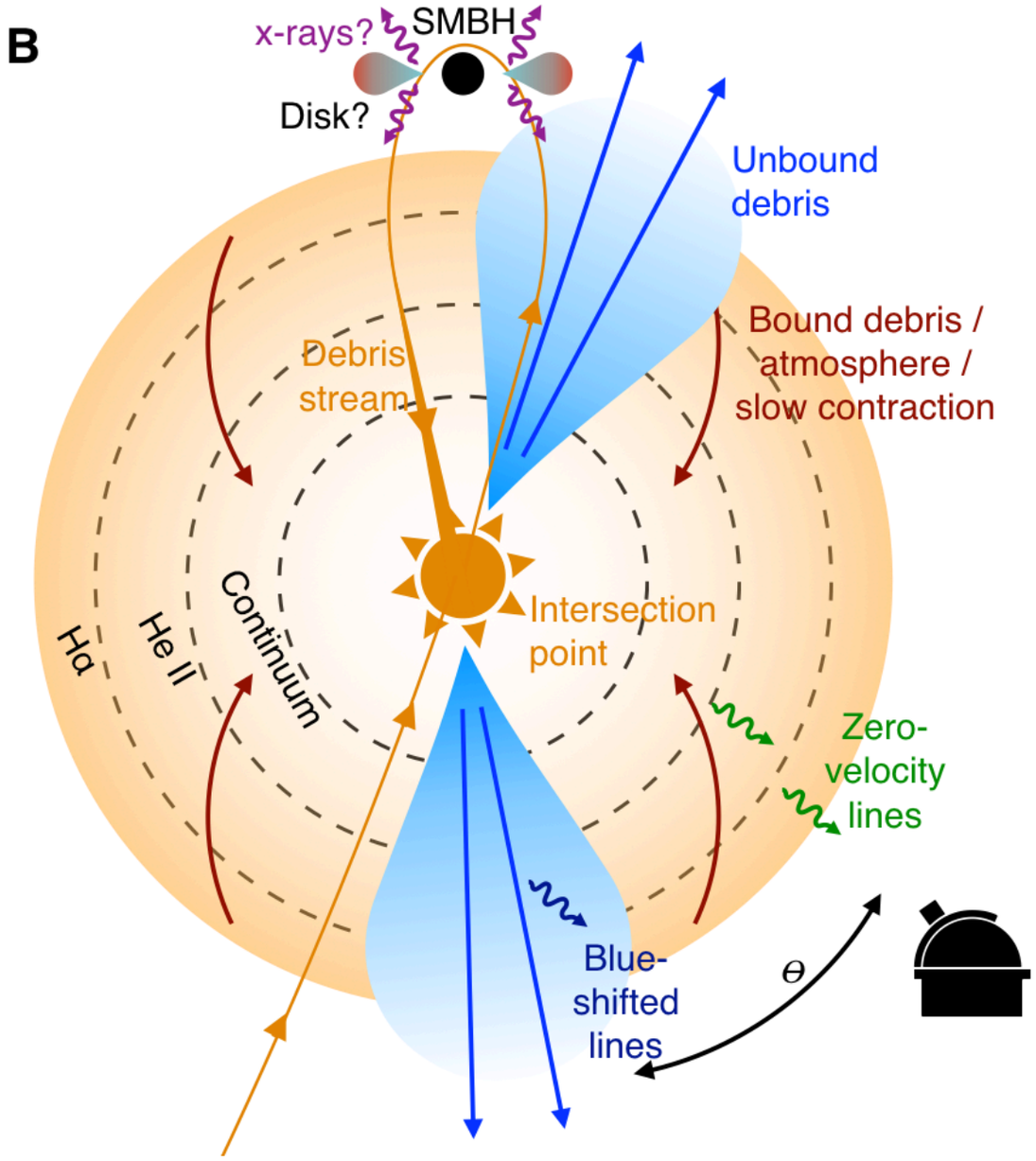
Multi-wavelength tour: optical emission



“Disk powered”

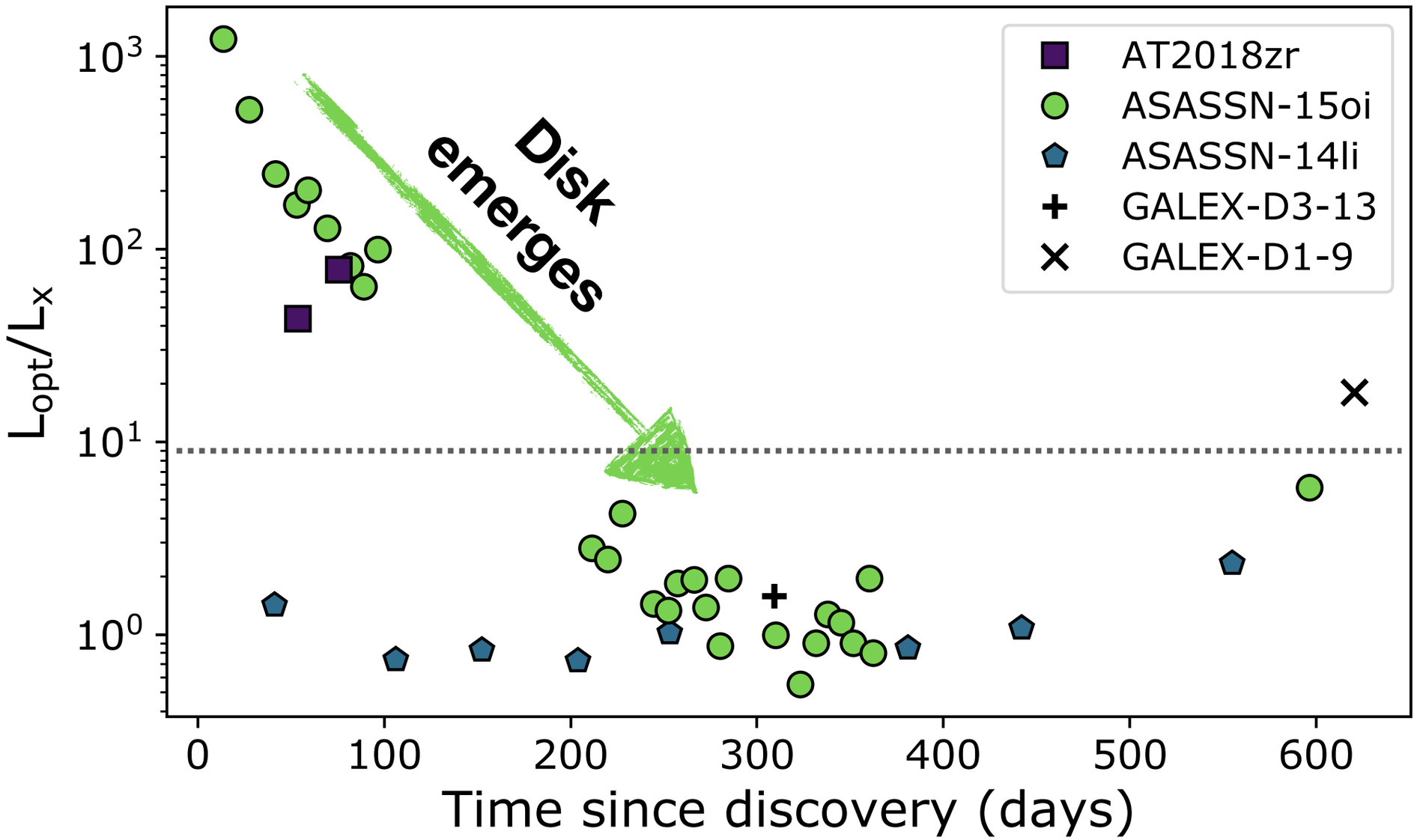
“Stream powered”





Nicholl et al. (2019)

X-ray photons to the rescue

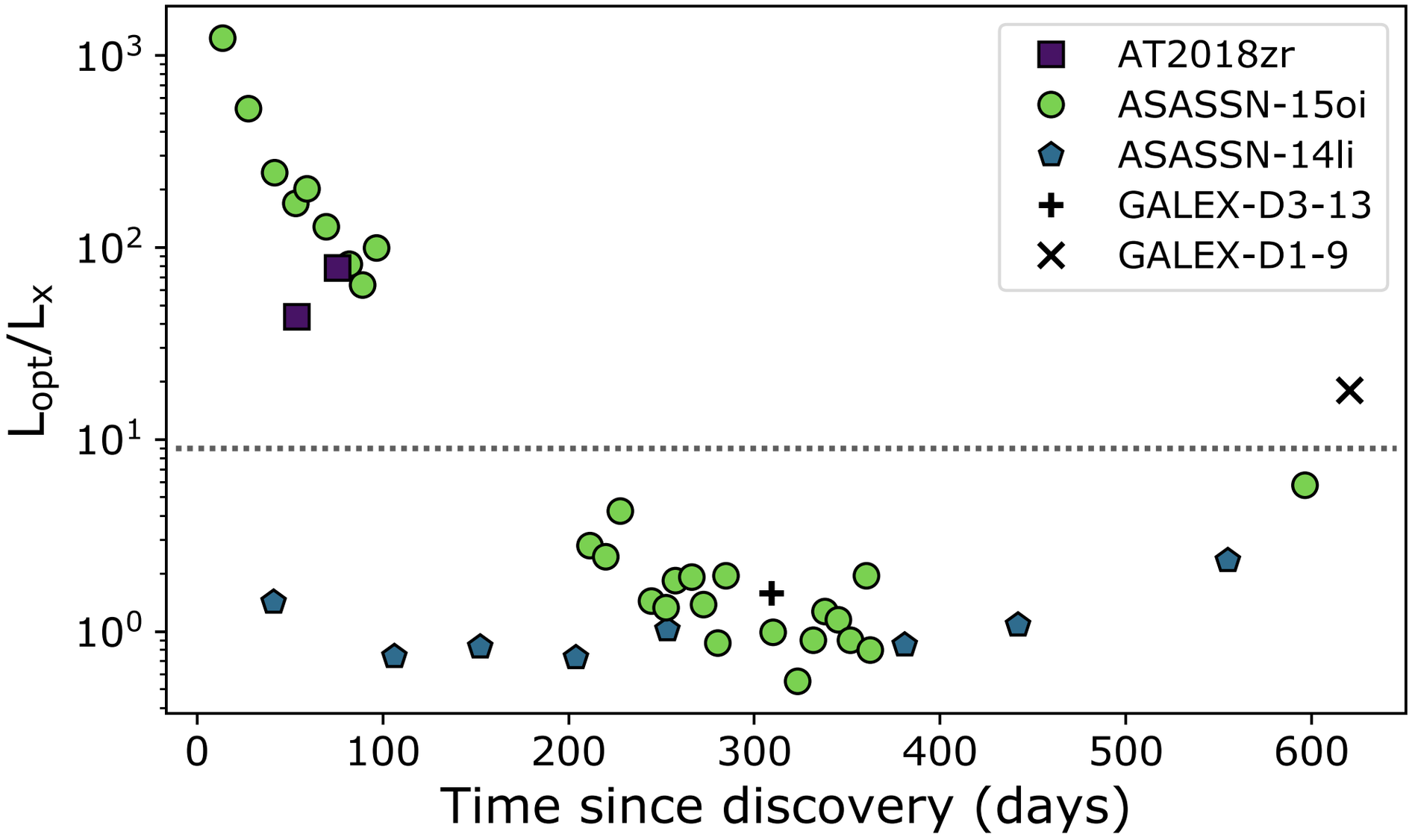


“X-ray weak”

“X-ray bright”

Gezari et al. 2017;
van Velzen et al. 2019b

X-ray photons to the rescue

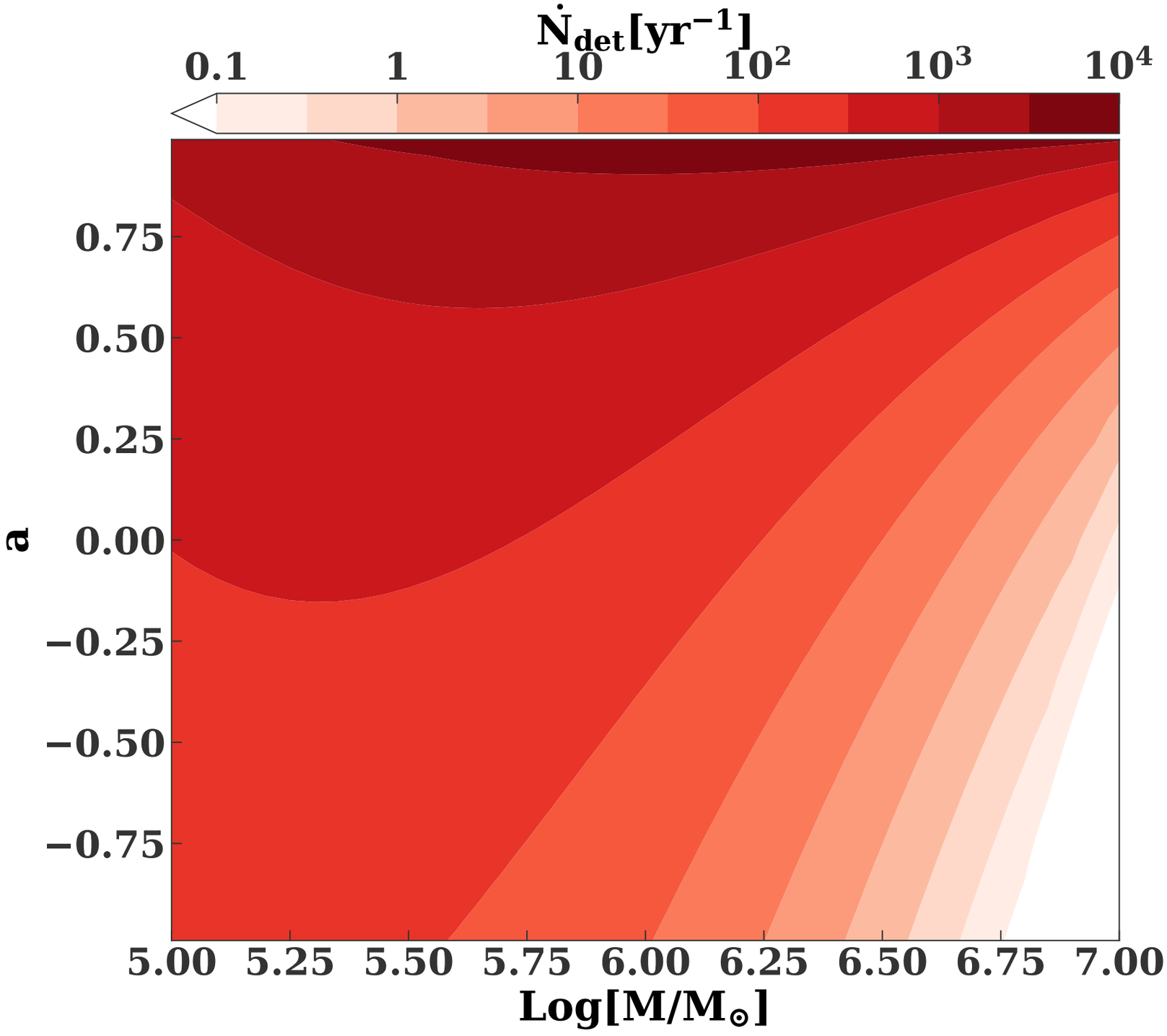


“X-ray weak”

“X-ray bright”

Gezari et al. 2017;
van Velzen et al. 2019b

eROSITA detection rate



Jonker et al.
(arXiv:1906.12236)

Conclusions

- Tidal disruption events are multi-wavelength transients
- Discovery rate keeps increasing (eg, ZTF, XMM, eROSITA, LSST)
- We started to use TDEs as tool to measure:
  - Nuclear dust on **sub-pc** scales (eg, van Velzen et al. 2016, Lu et al. 2016)
  - Accretion **disk formation** (van Velzen et al. 2019a, Jonker et al. 2019, Wevers et al. 2019)
  - **Jet-disk** coupling (Pasham & van Velzen 2018, Mattila et al. 2018)
  - SMBH **spin** (Leloudas et al. 2016, Stone & van Velzen 2019)

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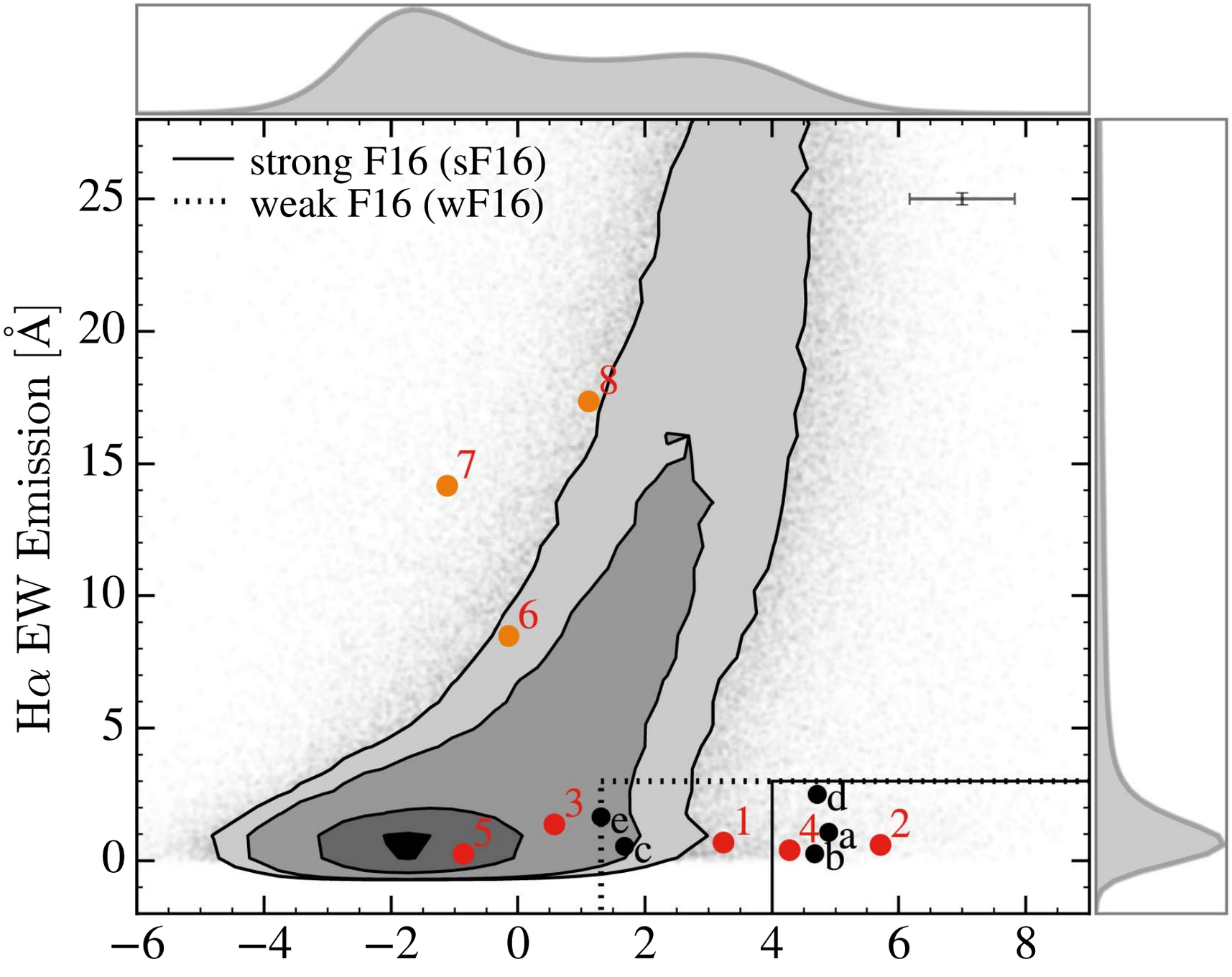
Post-starburst host galaxies



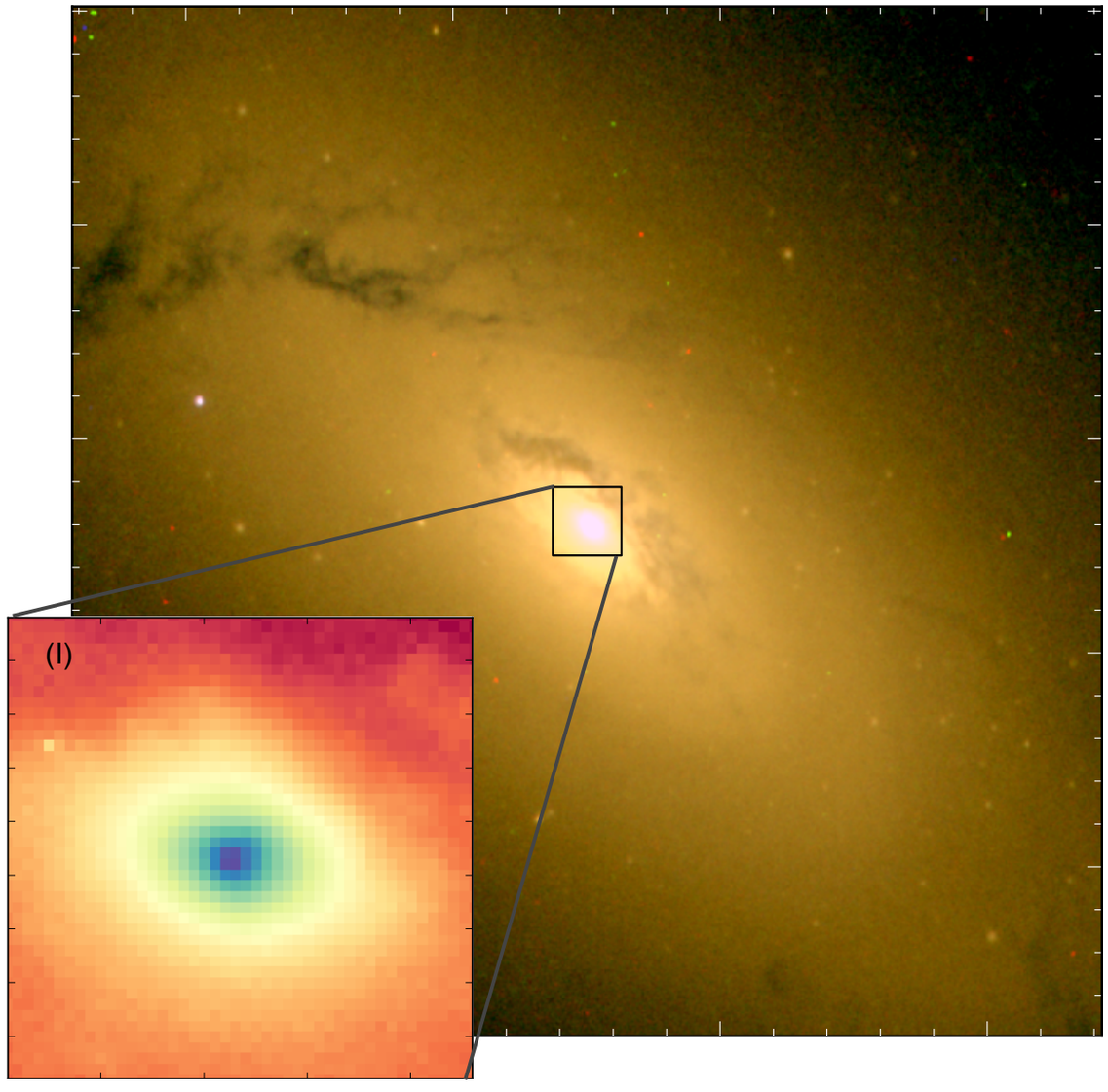
French et al. (2016);
Law-Smith et al. (2017)

Calibrate loss cone filling

- Tidal flares often found in post-starburst galaxies (Arcavi+14; French+16)

- This preference can be explained by high stellar concentration

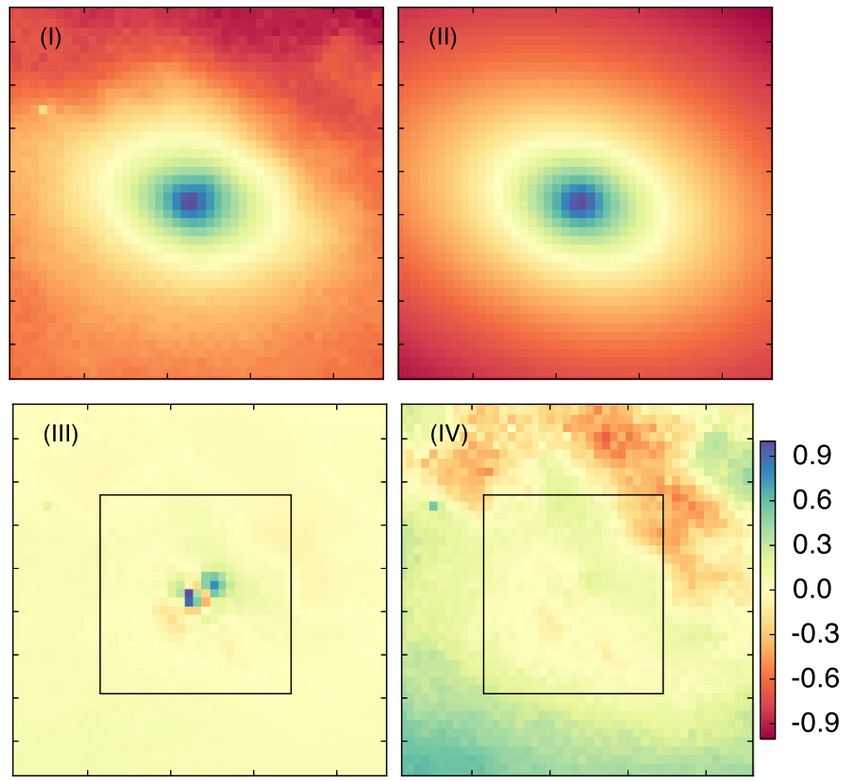
- Can be tested using *Hubble Space Telescope* (HST) observations



NGC 3156 (z=0.0044); Stone & van Velzen (2016)

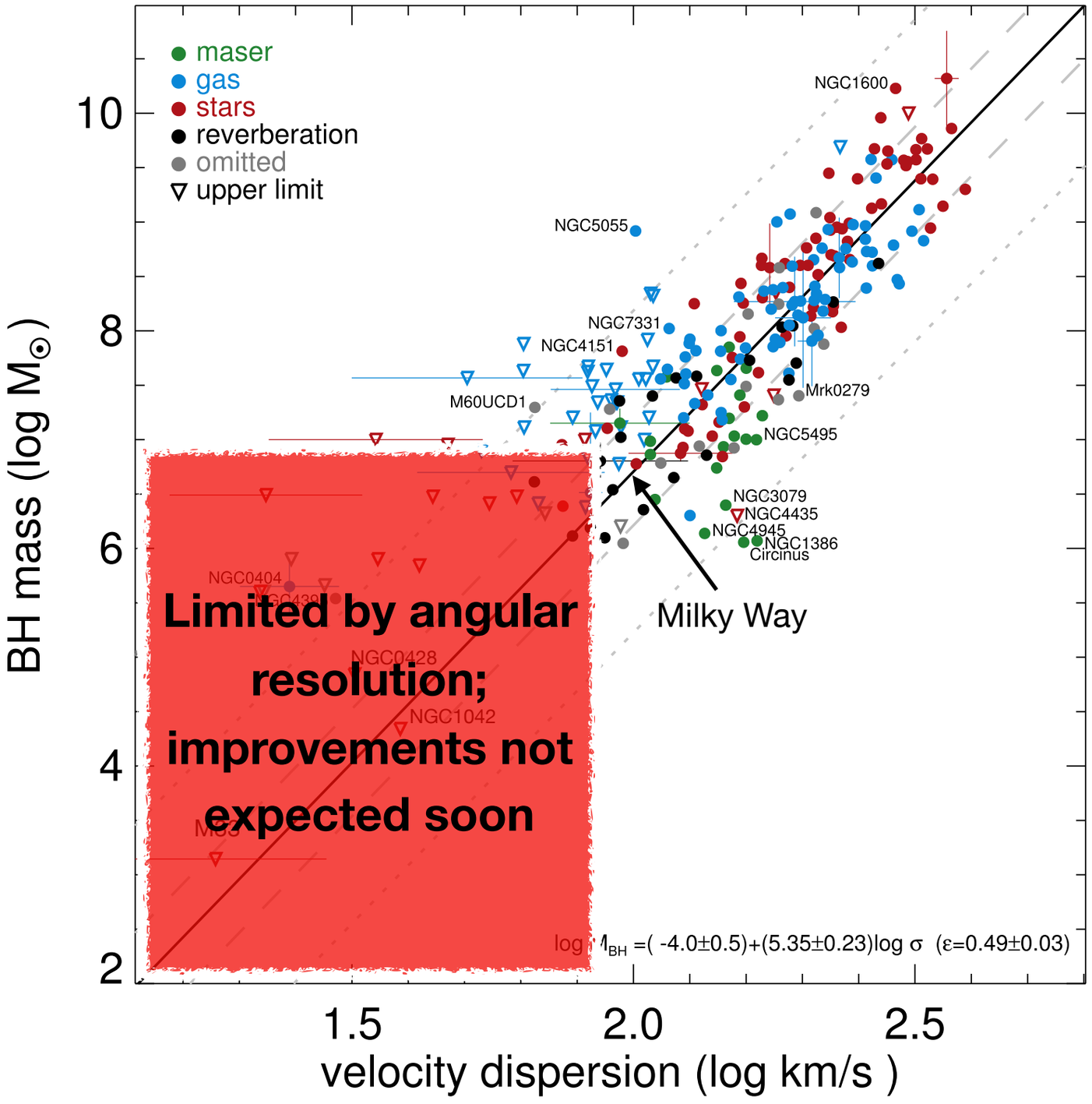
Calibrate loss cone filling

- NGC 3156:
  - Careful surface brightness measurements
  - Detected very steep inner slope
  - Factor ~10 enhanced to stellar disruption rate
- In the near-future:
  - Approved HST observations



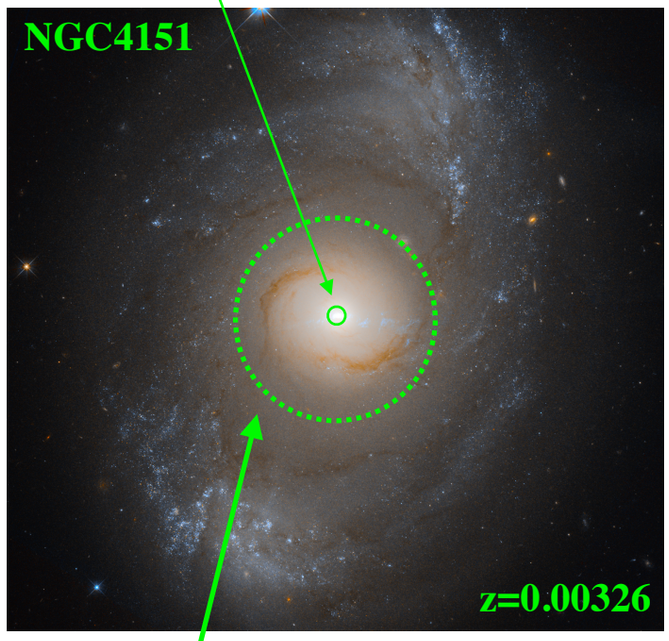
Stone & van Velzen (2016)

The M-σ relation and its limitations



van den Bosch (2016)

BH sphere of influence ~ pc



Effective radius ~ kpc