Sjoert van Velzen (NYU, UMD)

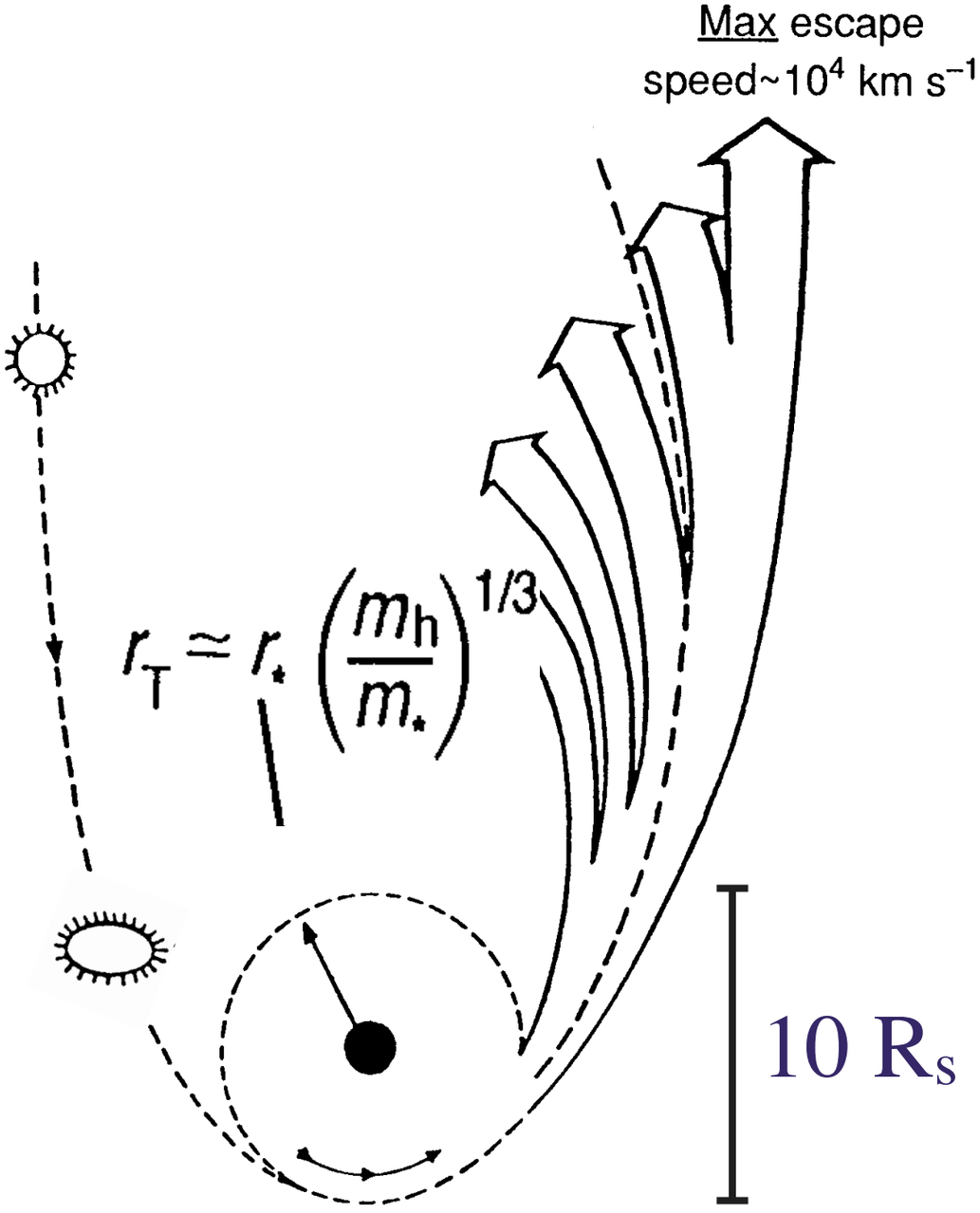
Quasars in Crisis, Edinburgh

August 6, 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
- Above ~10^8 $M_\odot$, Roche radius inside black hole horizon



Rees (1988)

Big Questions

Do all galaxies host massive black holes in their nuclei?

Is accretion/jet physics scale invariant?

credit: Wikimedia

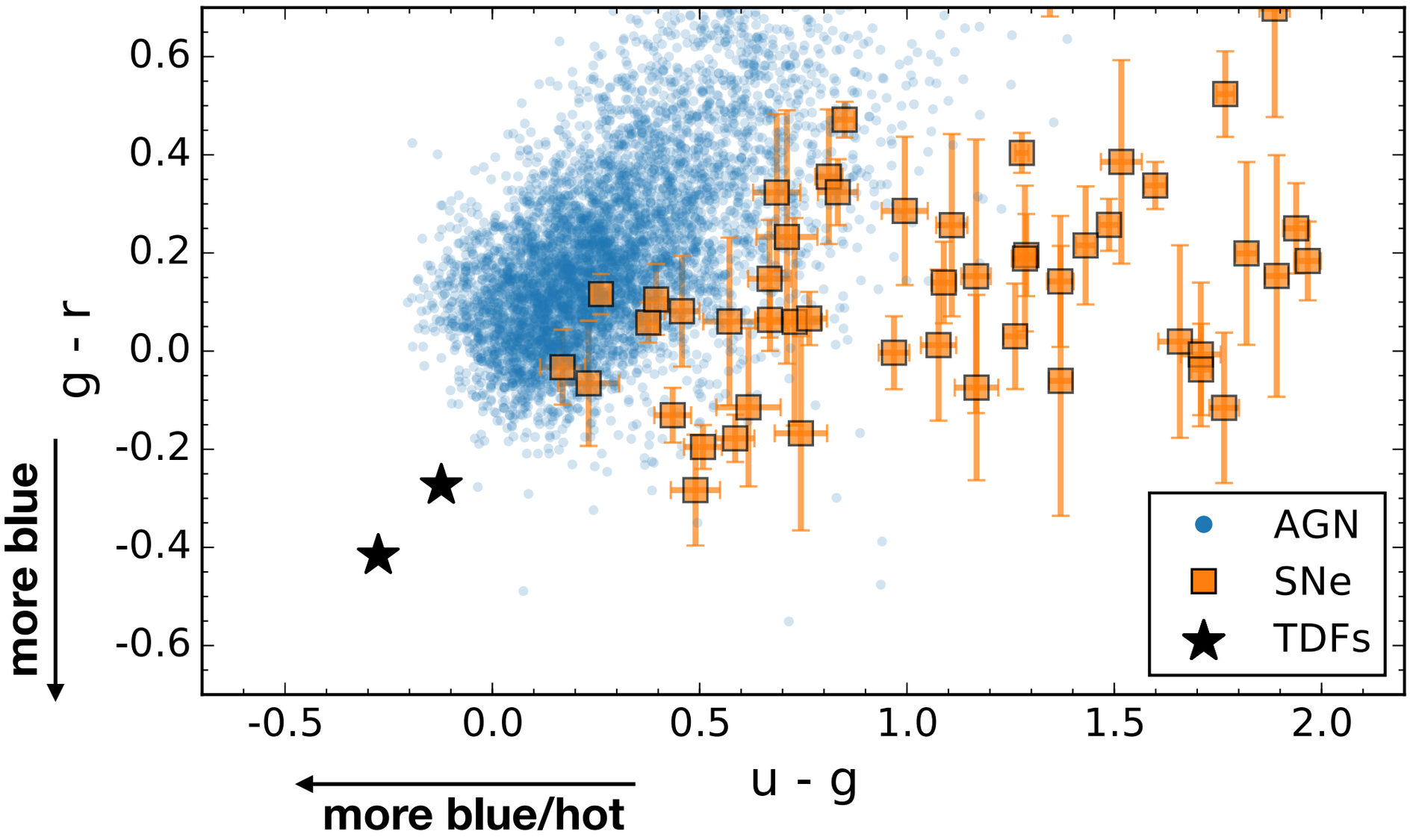
Pertinent Questions

Can we use TDEs to learn about BH accretion?

"Solve the crisis"

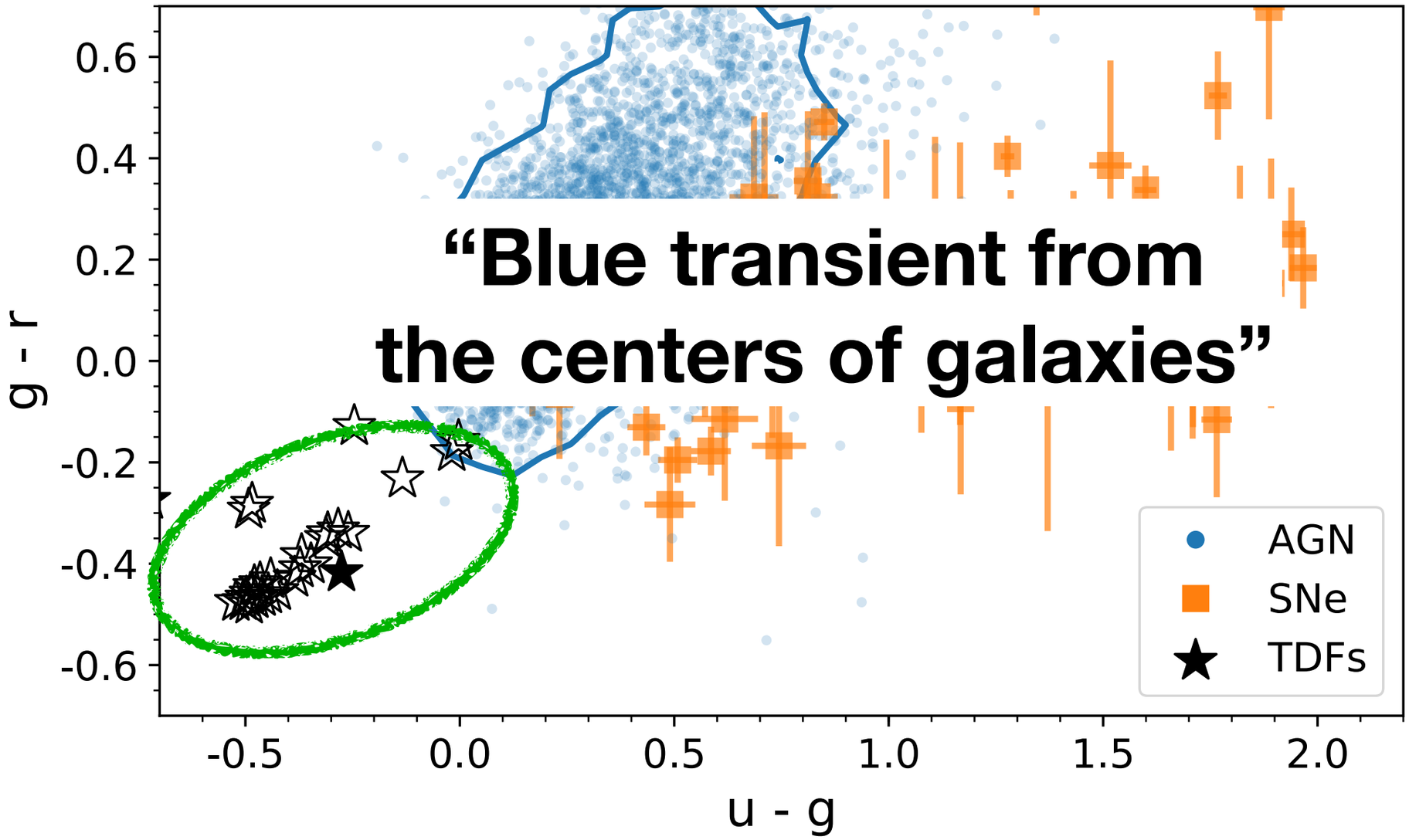
How do we know TDEs are not CL AGN?!

TDE locus in optical surveys (2011)



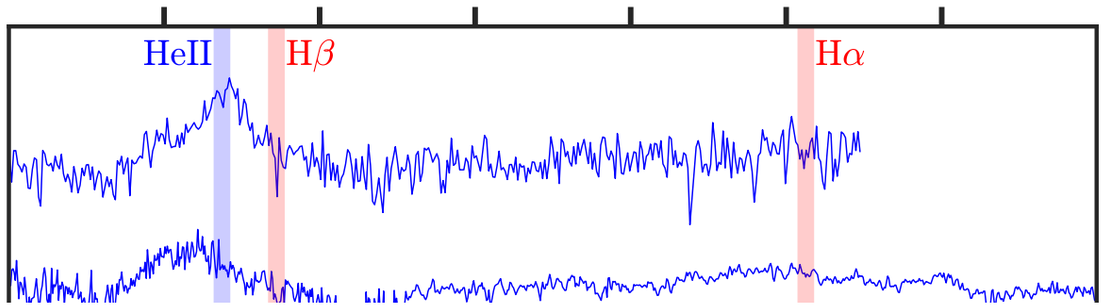
adapted from van Velzen et al. (2011)

TDE locus in optical surveys (2019)



adapted from van Velzen et al. (2011)

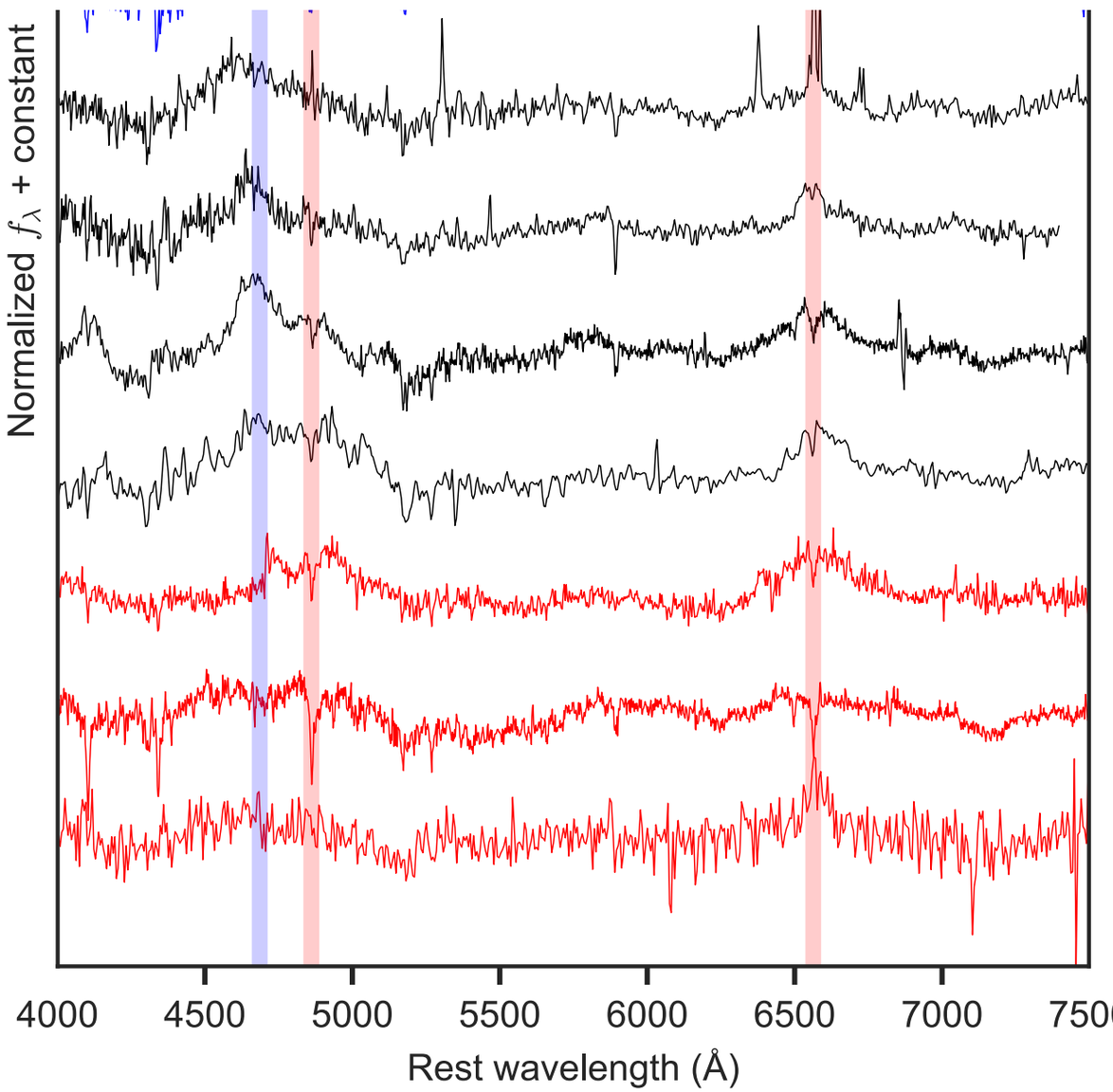
Spectroscopic sequence



PS1-10jh
Gezari+ 2012

PTF09ge
Arcavi+ 2014

"Blue spectra with broad H/He"



SDSSJ0748
Wang+ 2011

ASASSN-14li
Holoien+ 2016a

iPTF16axa
Hung+ 2017

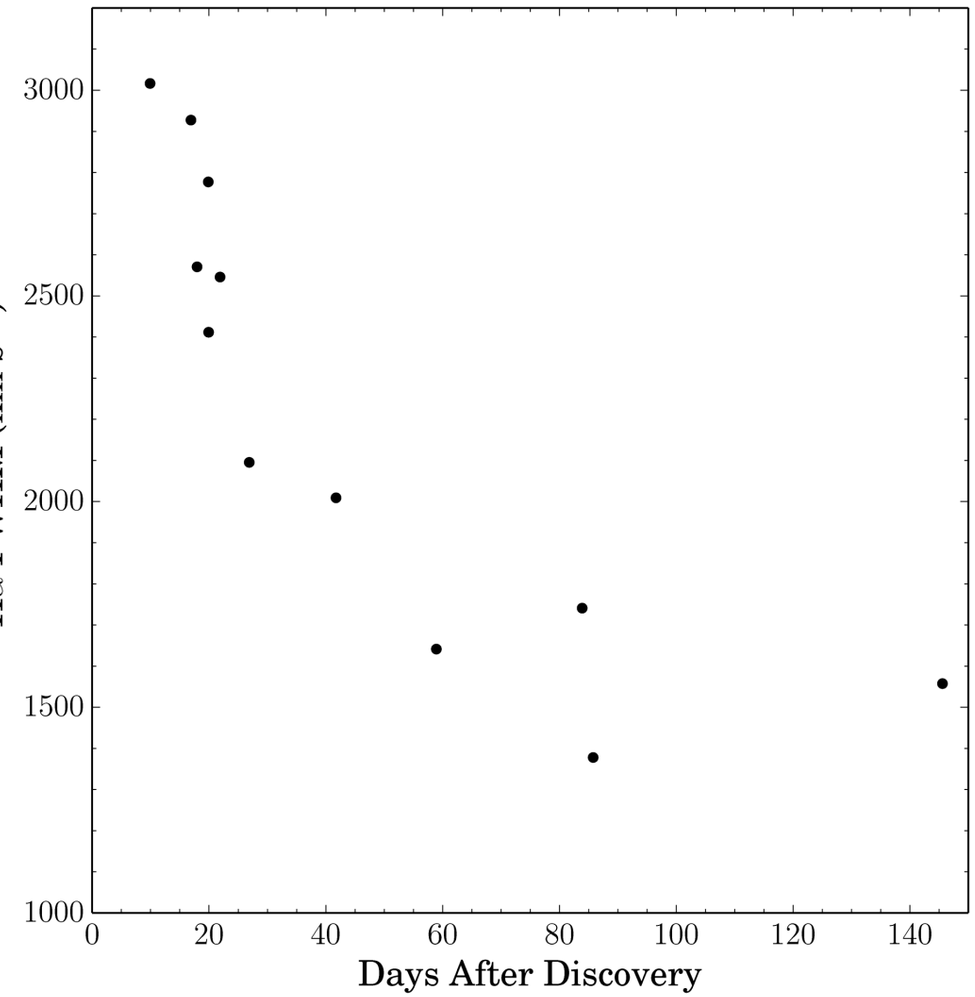
ASASSN-14ae
Holoien+ 2014
Arcavi+ 2014

PTF09djl
Arcavi+ 2014

PTF09axc
Arcavi+ 2014

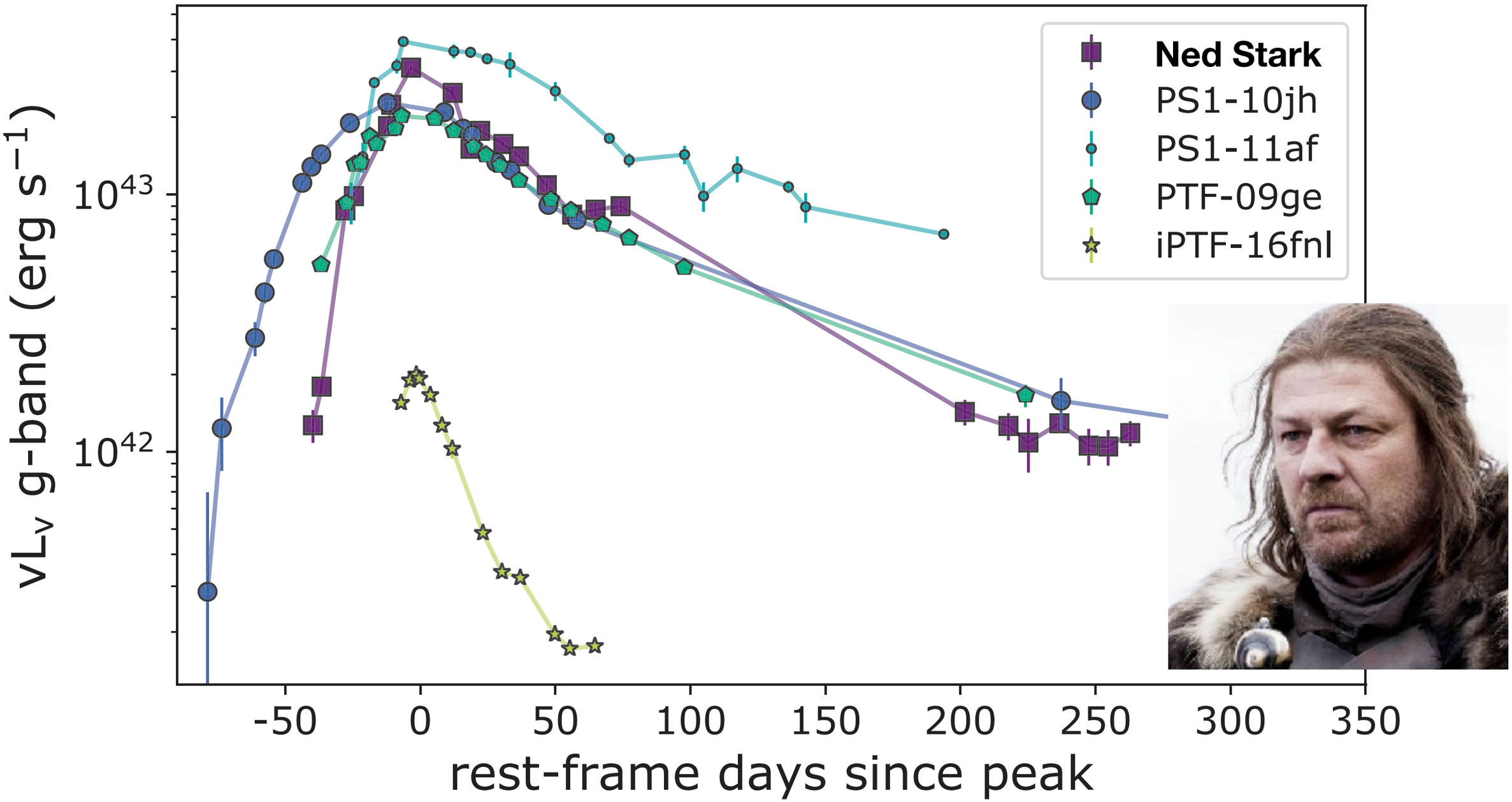
TDE2
Van Velzen+ 2011

Adapted from Arcavi et al. (2014)
updated for ISSI review chapter



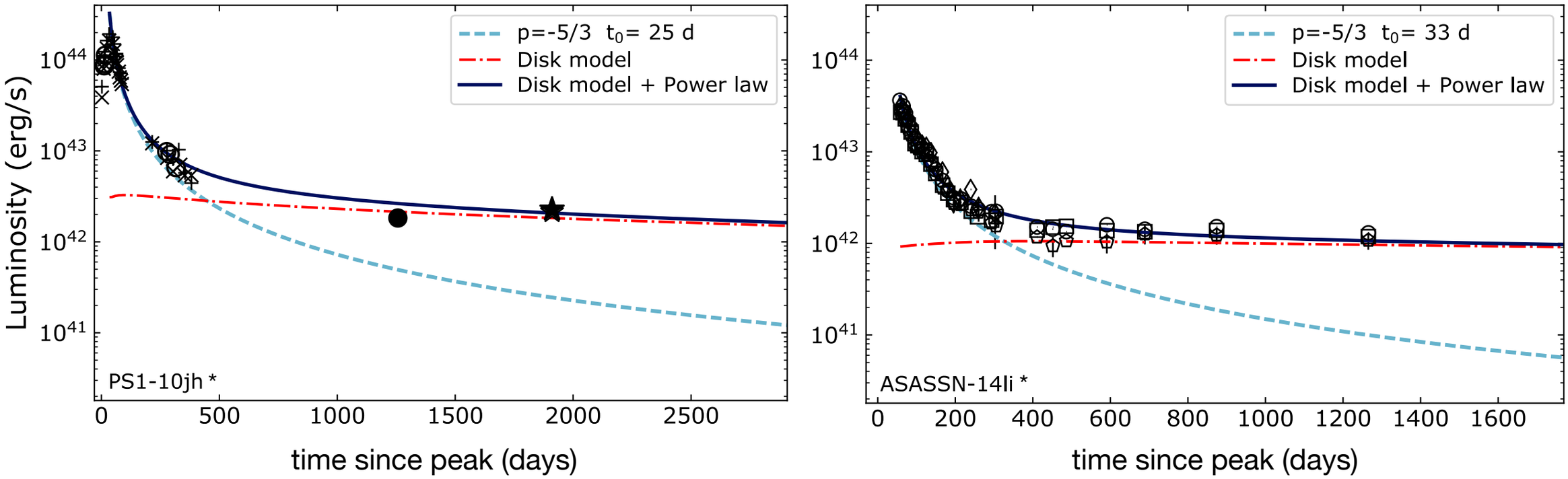
Holoien et al. 2016

Early-time light curves: steep decay



van Velzen et al. (2019)

Late-time light curves: an accretion disk emerges

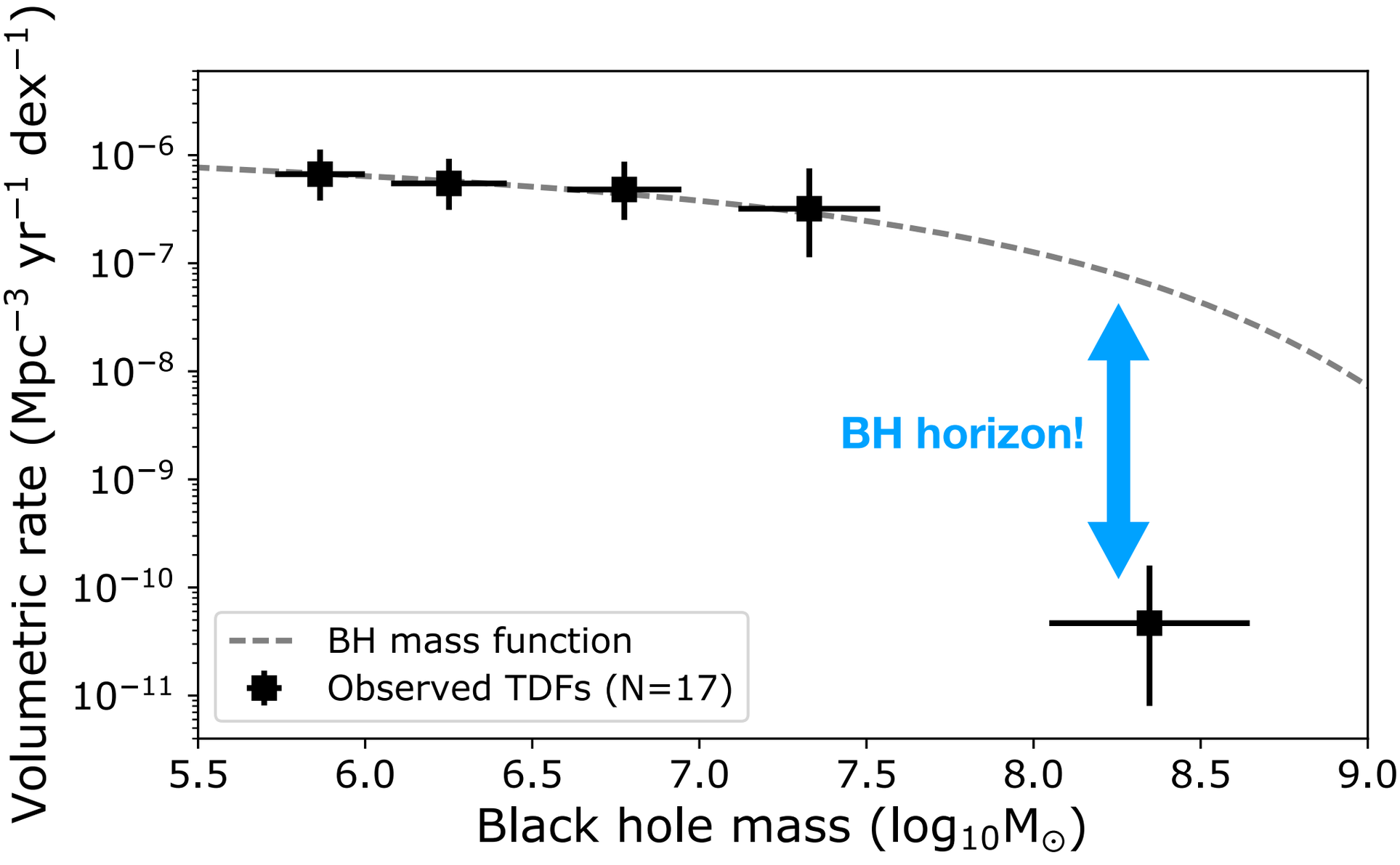


- *HST* and *Swift* UV follow-up
- UV detections; light curve flattens
- Accretion disk required (high α)

(van Velzen et al. 2019)

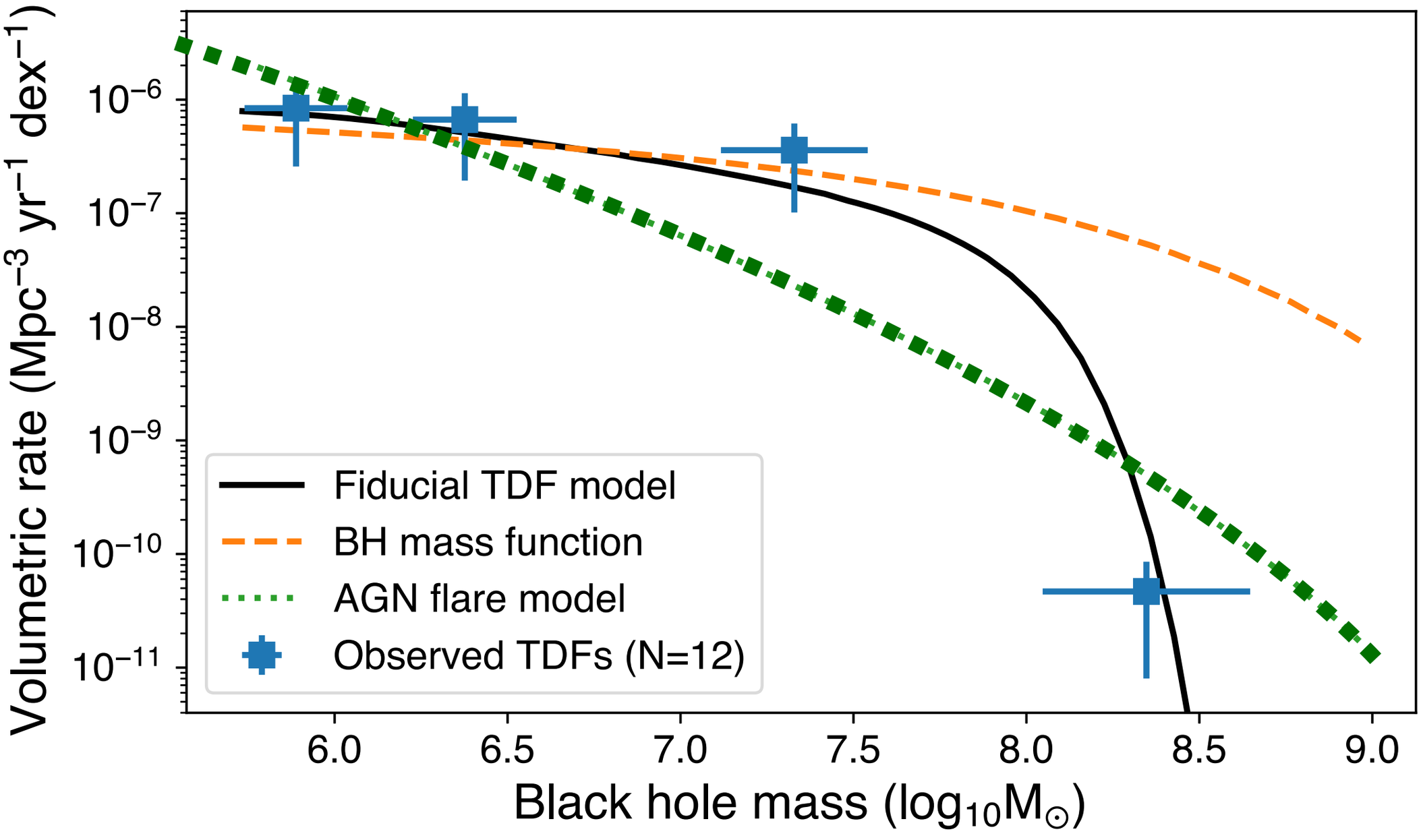
*data from:
Gezari et al. (2012, 2015)
Holoien et al. (2014)
van Velzen et al. (2019)

Disruption rate as a function of black hole mass

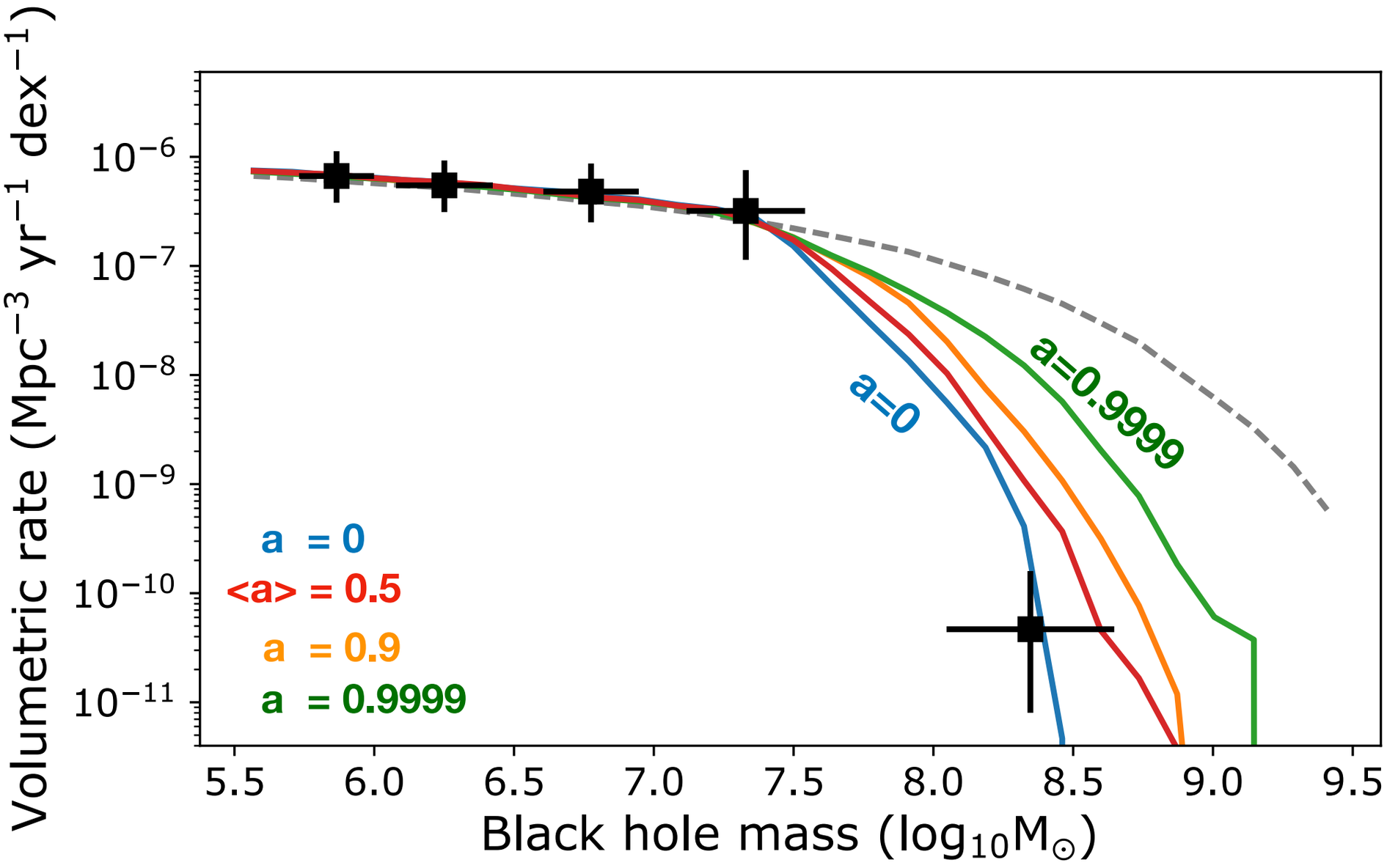


Based on method in van Velzen (2018);
data from Wevers t al. (2017, 2019)

CL AGN should not look like this



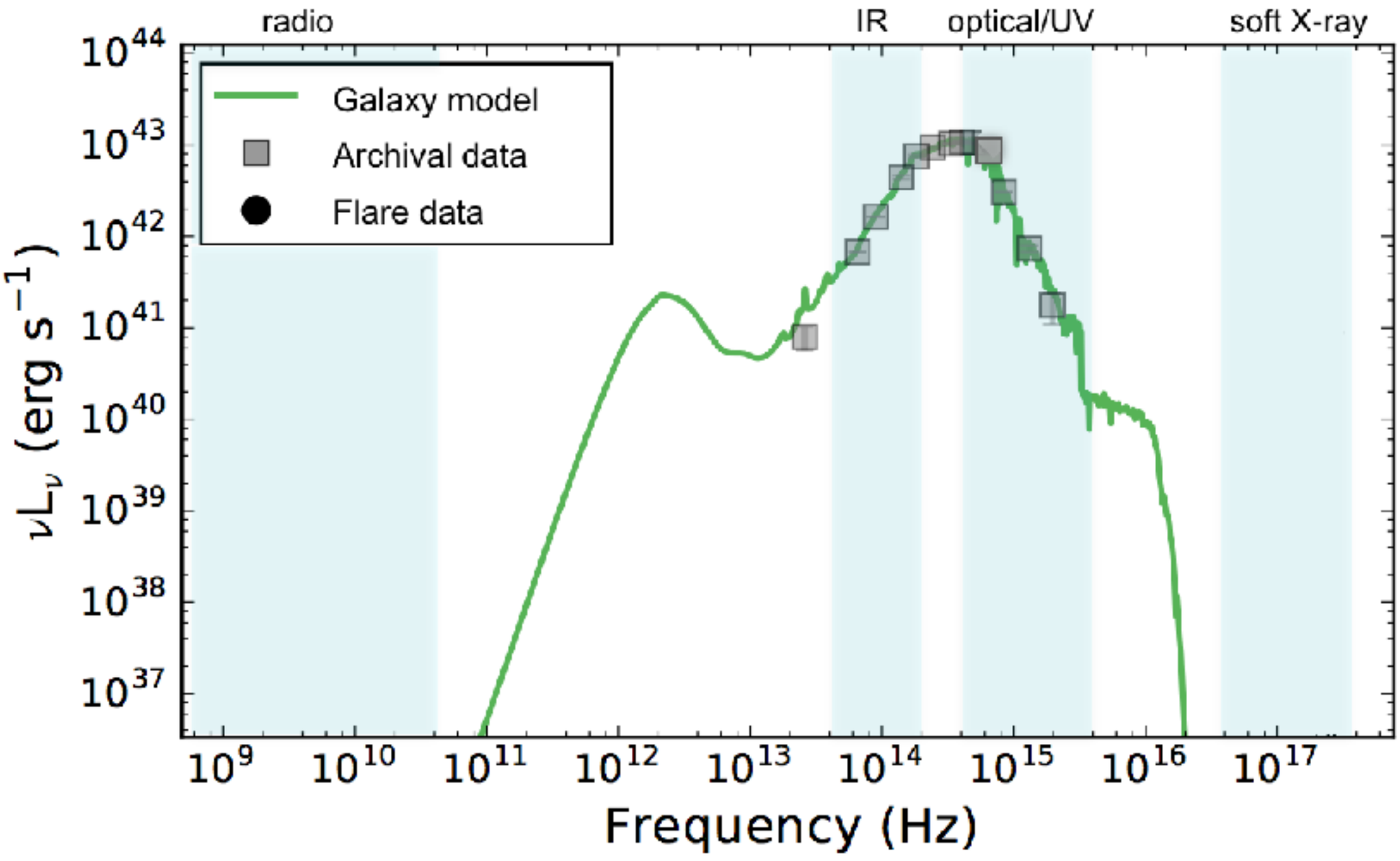
Measuring the average spin of quiescent black holes



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

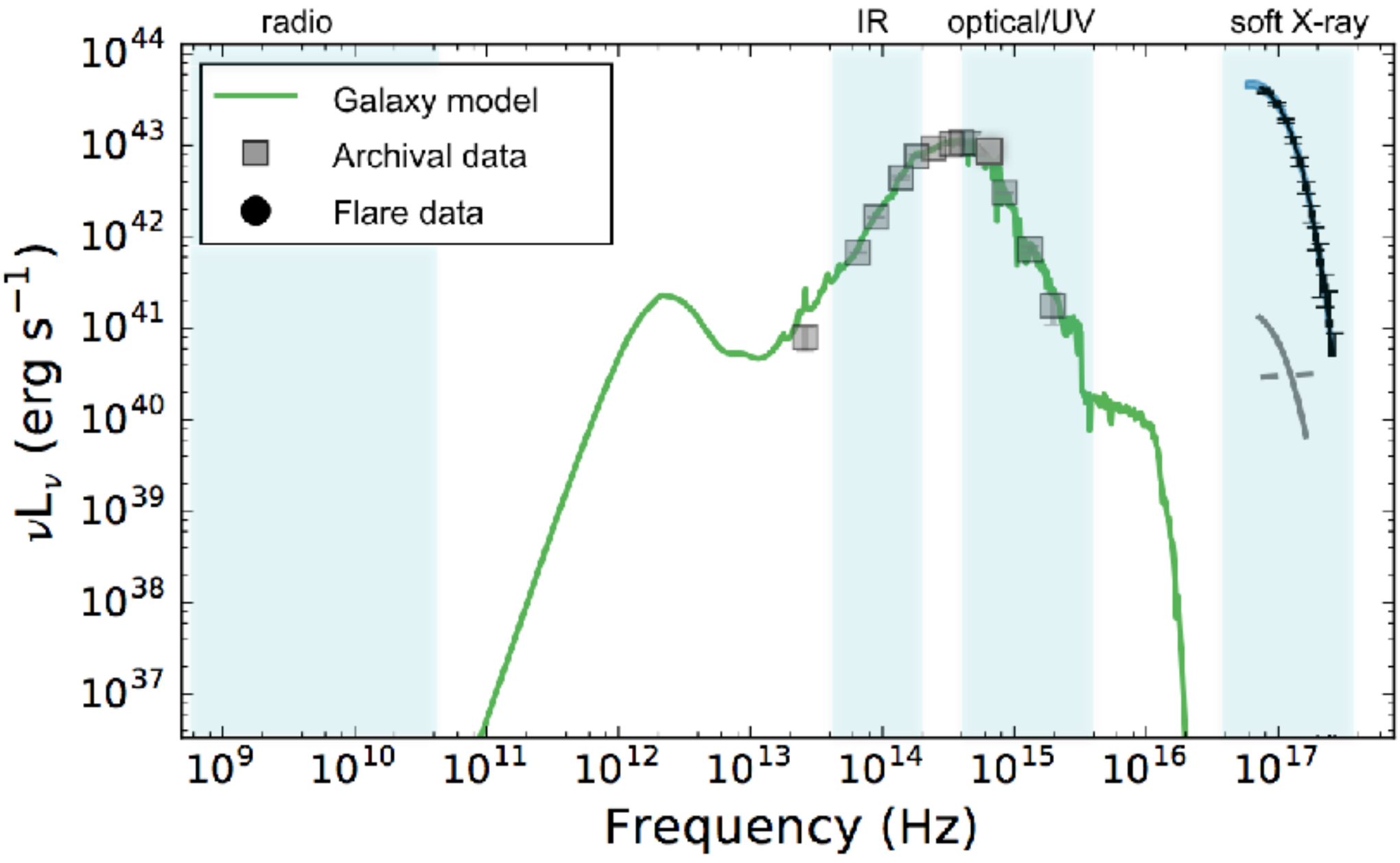
Figure: Stone & van Velzen (2019, in prep)

Spectrum of a tidal disruption flare



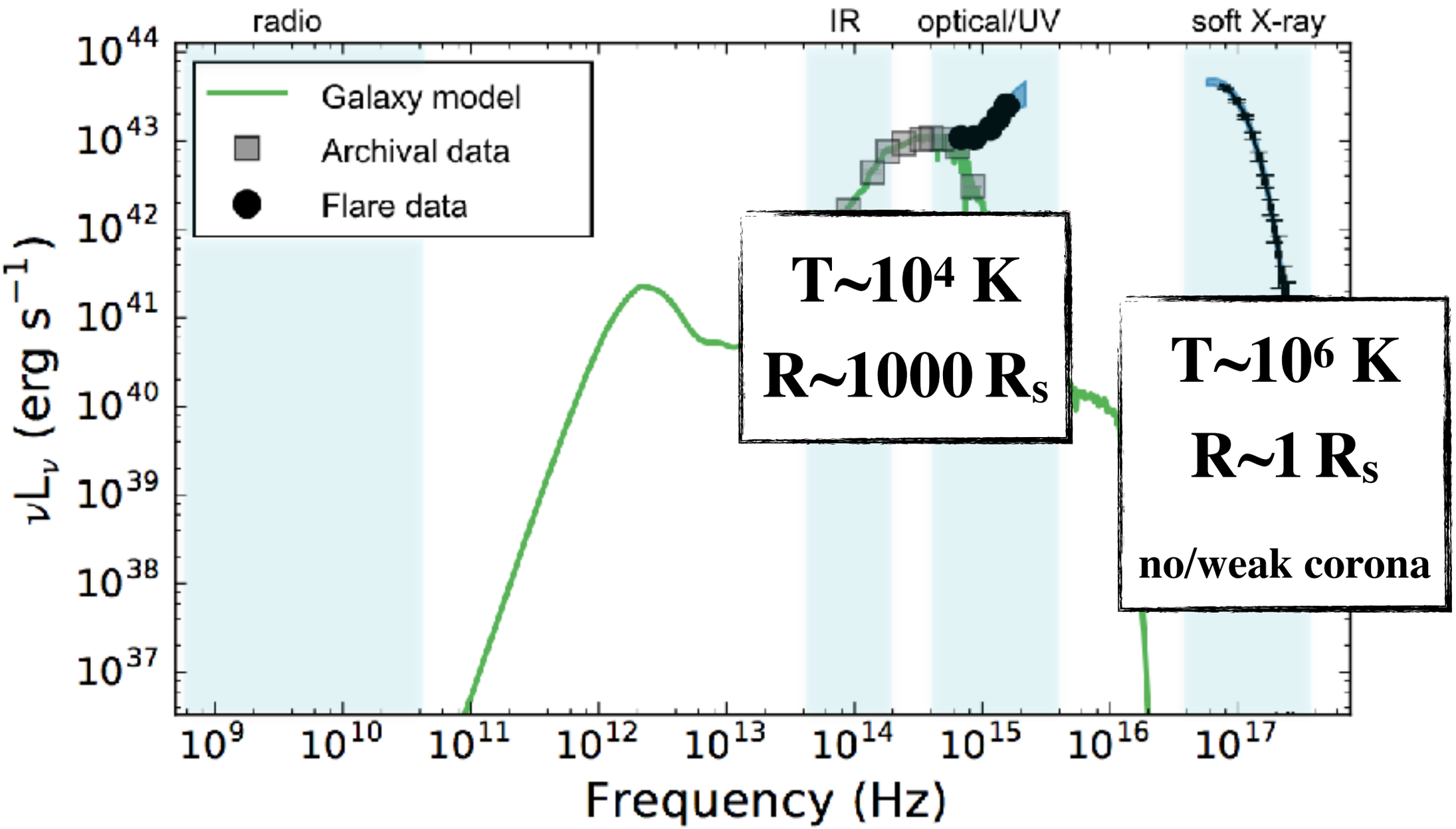
Velzen et al. (Science, 2016)

Spectrum of a tidal disruption flare



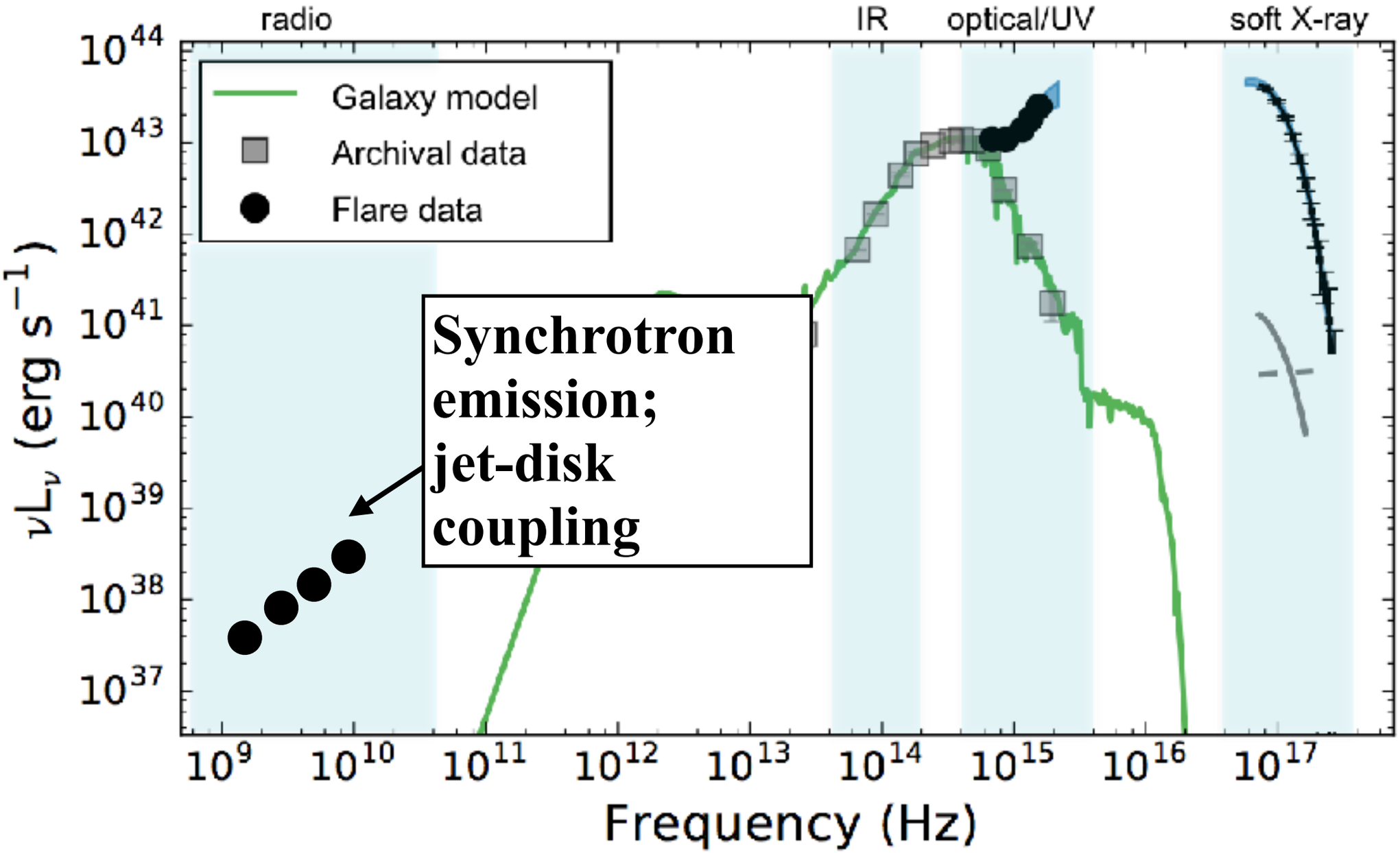
Velzen et al. (Science, 2016);
ASASSN-14li (Holoien et al. 2016)

Spectrum of a tidal disruption flare



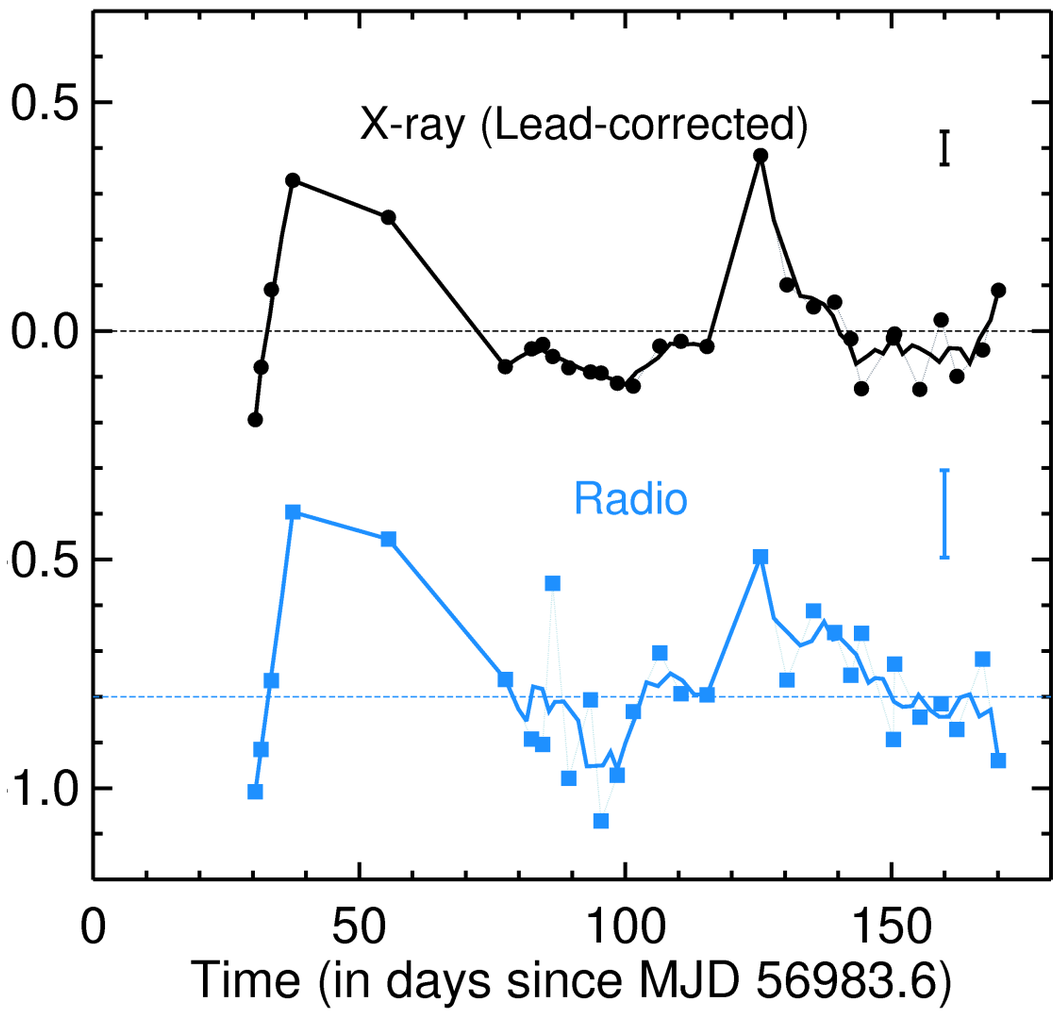
Velzen et al. (Science, 2016);
ASASSN-14li (Holoien et al. 2016)

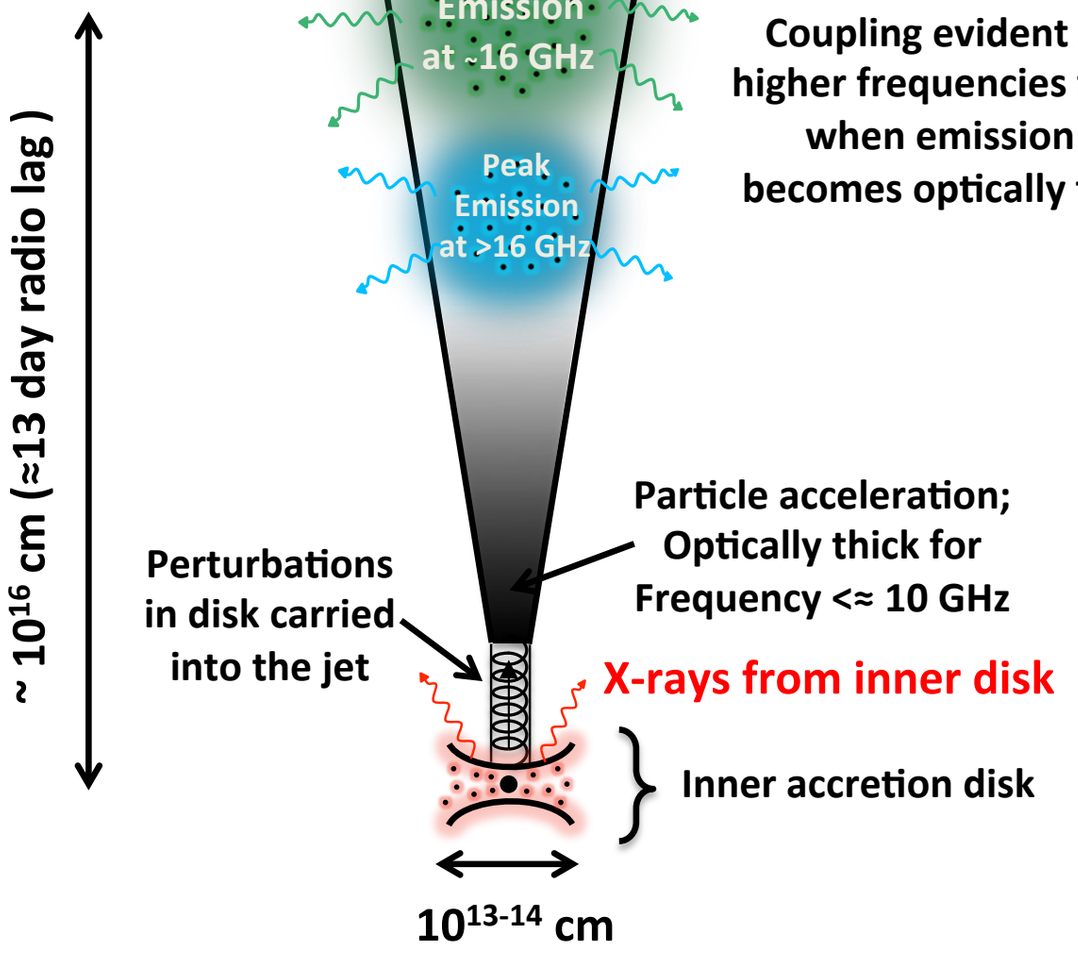
Multi-wavelength tour: radio emission



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

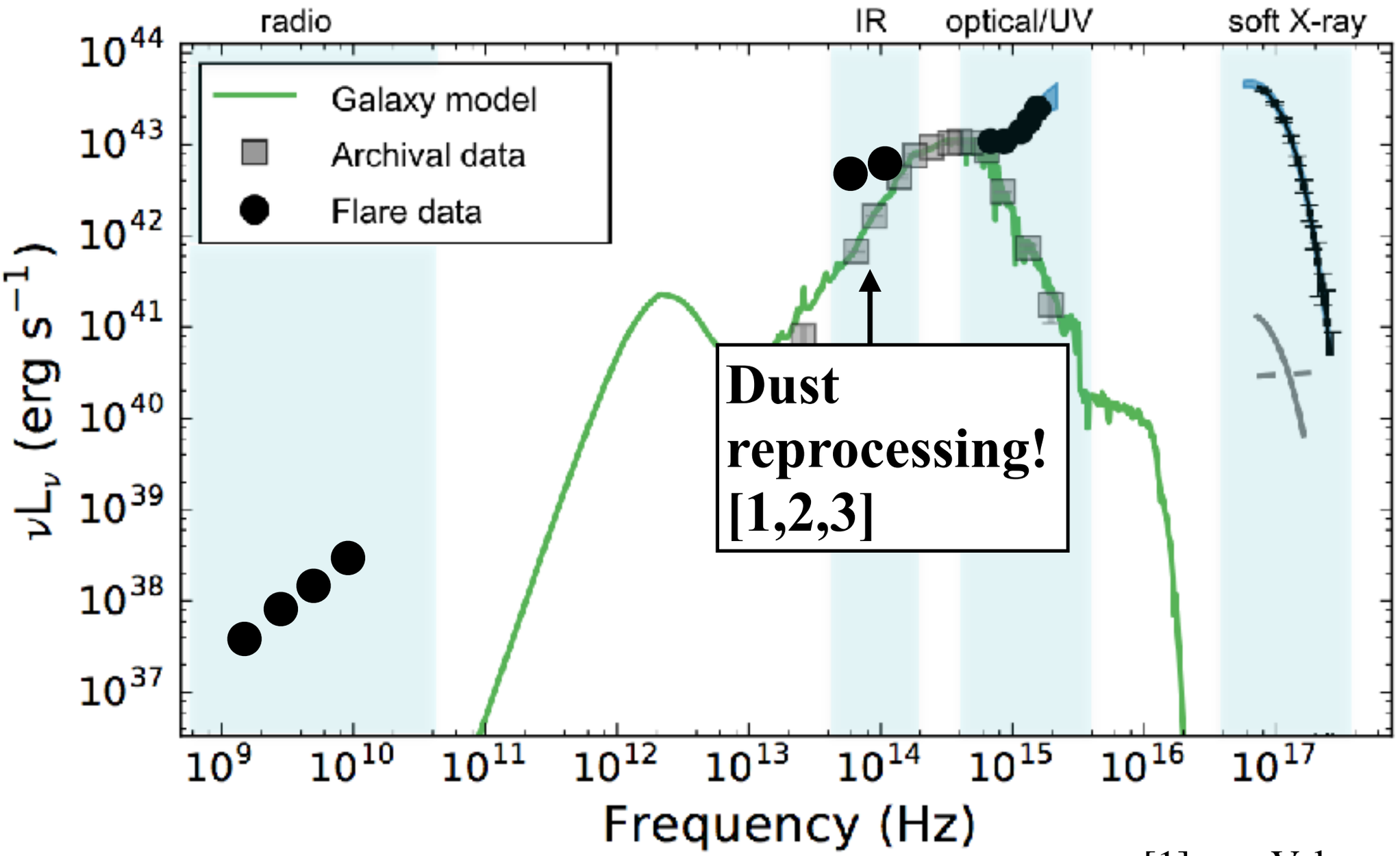
Radio / X-ray crosscorrelation





Pasham & van Velzen (2017)

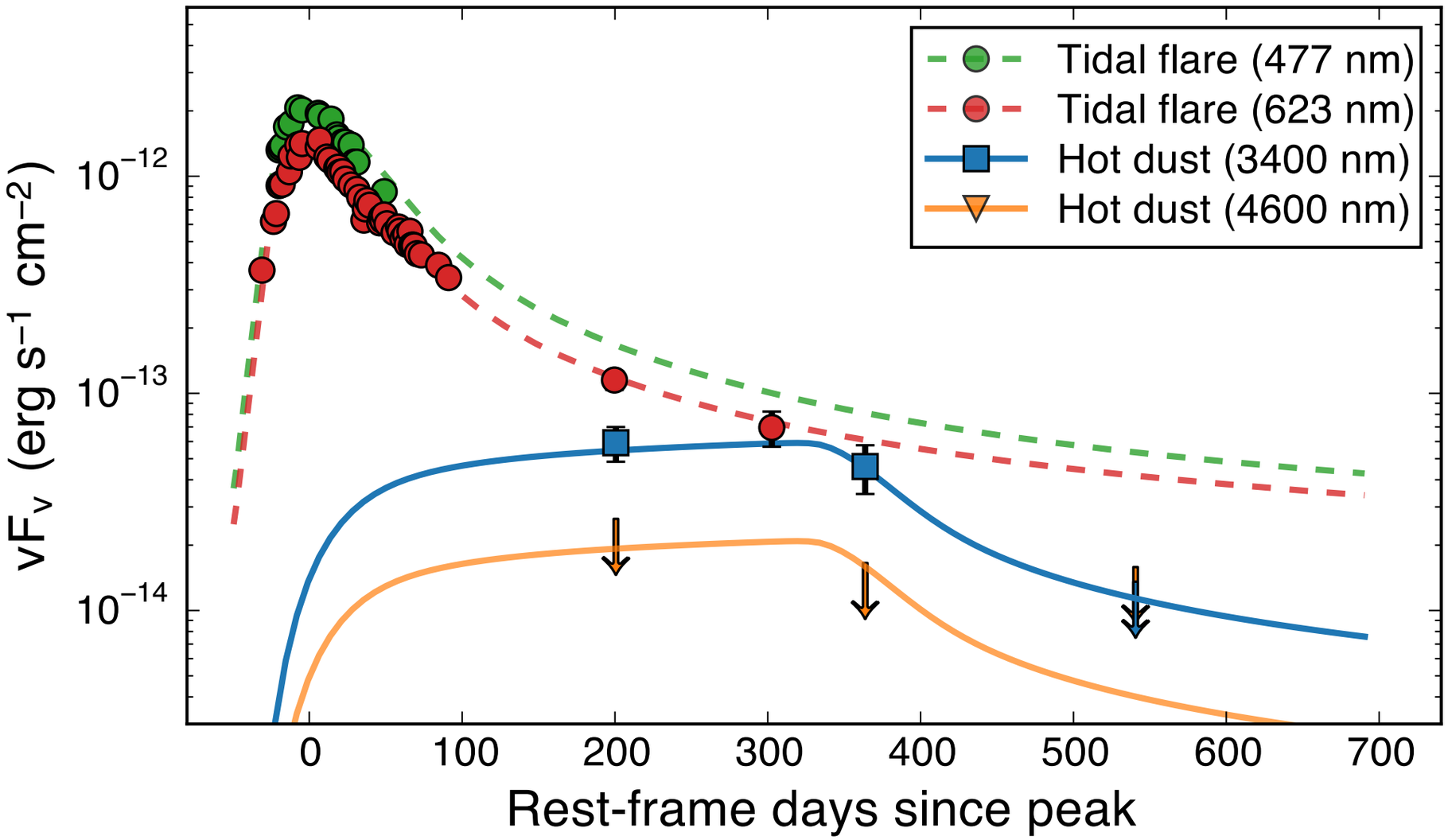
Multi-wavelength tour: infrared emission



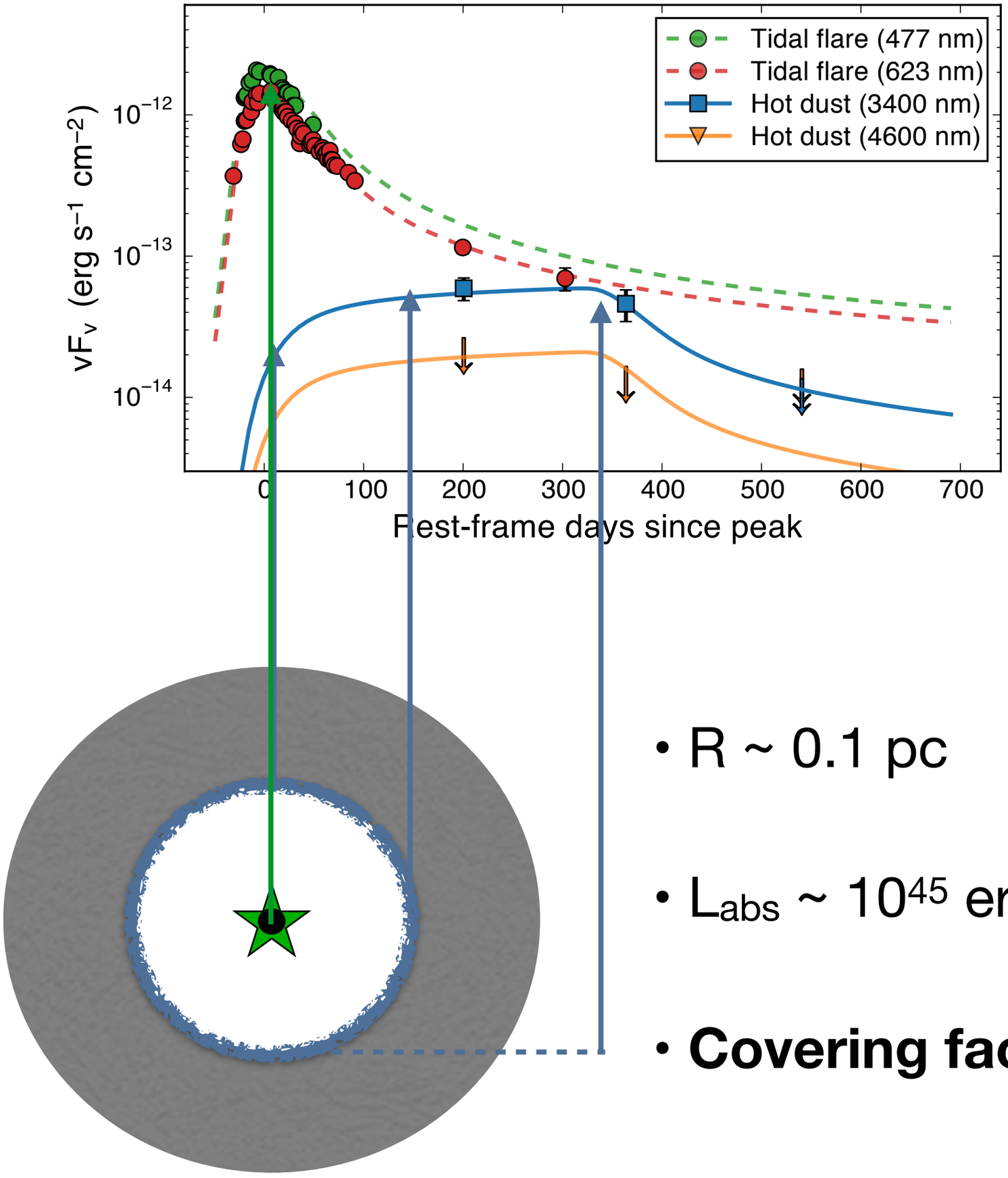
[1] van Velzen et al. (2016)
[2] Jiang et al. (2016)
[3] Wang et al. (2018)

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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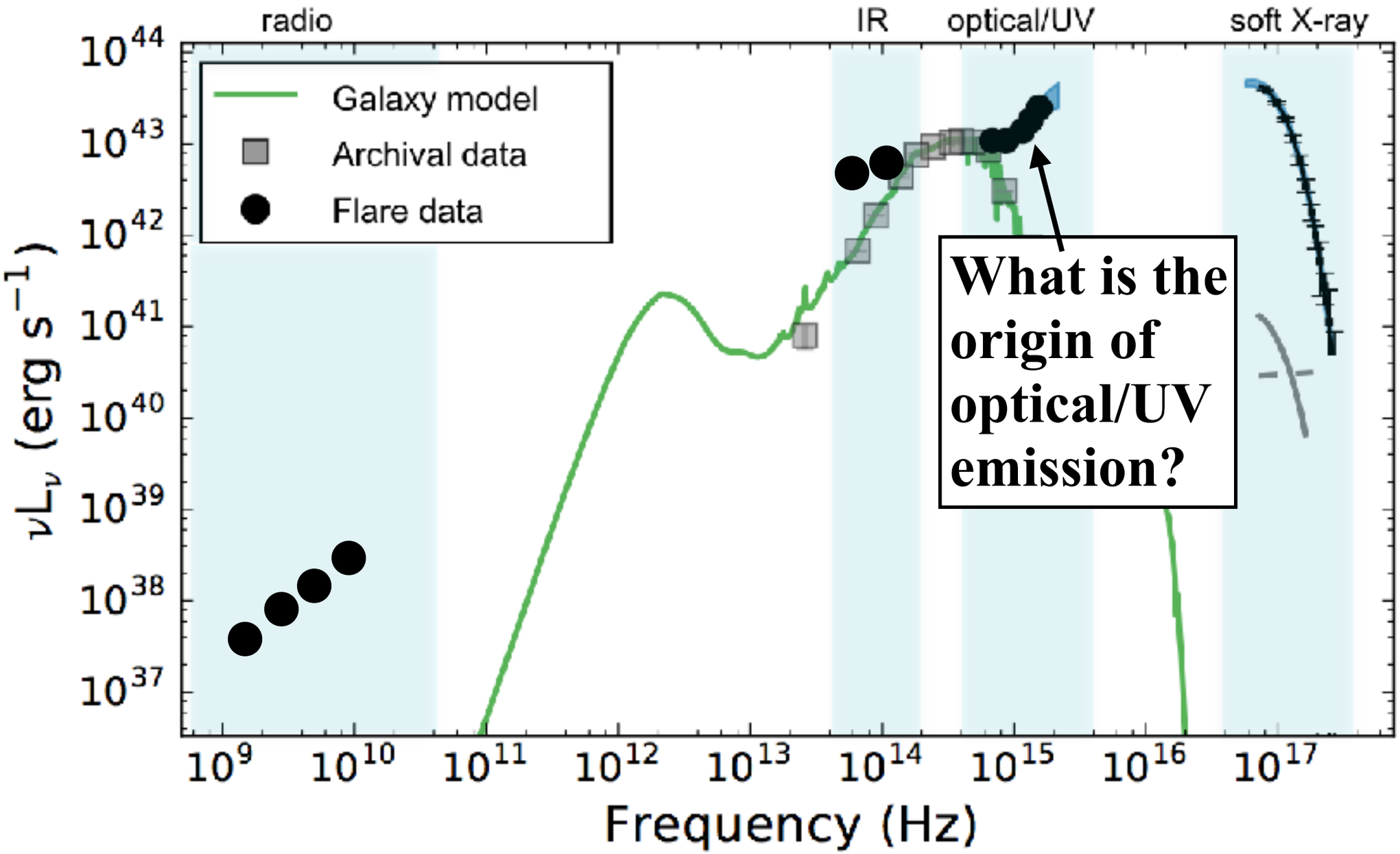
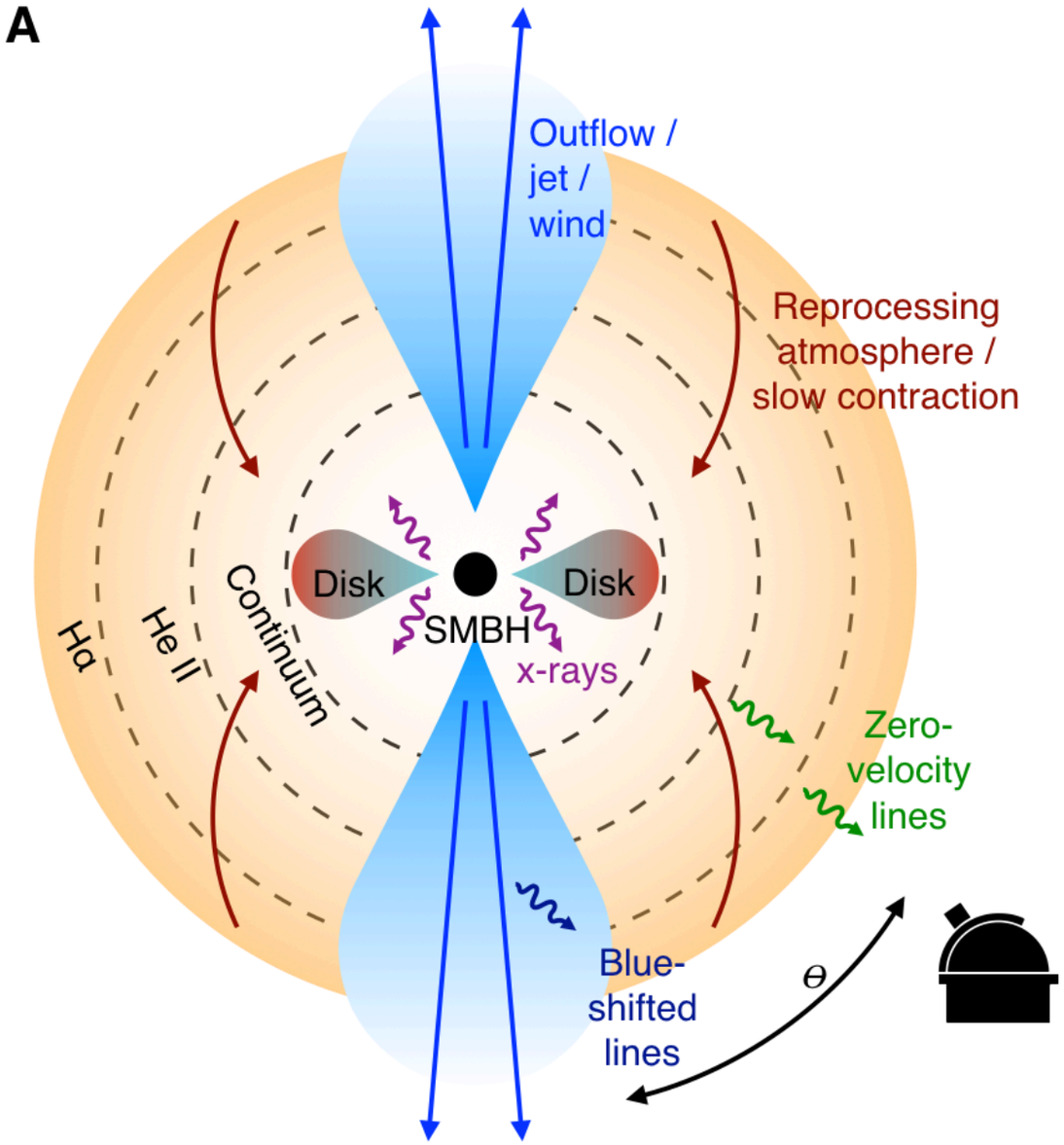
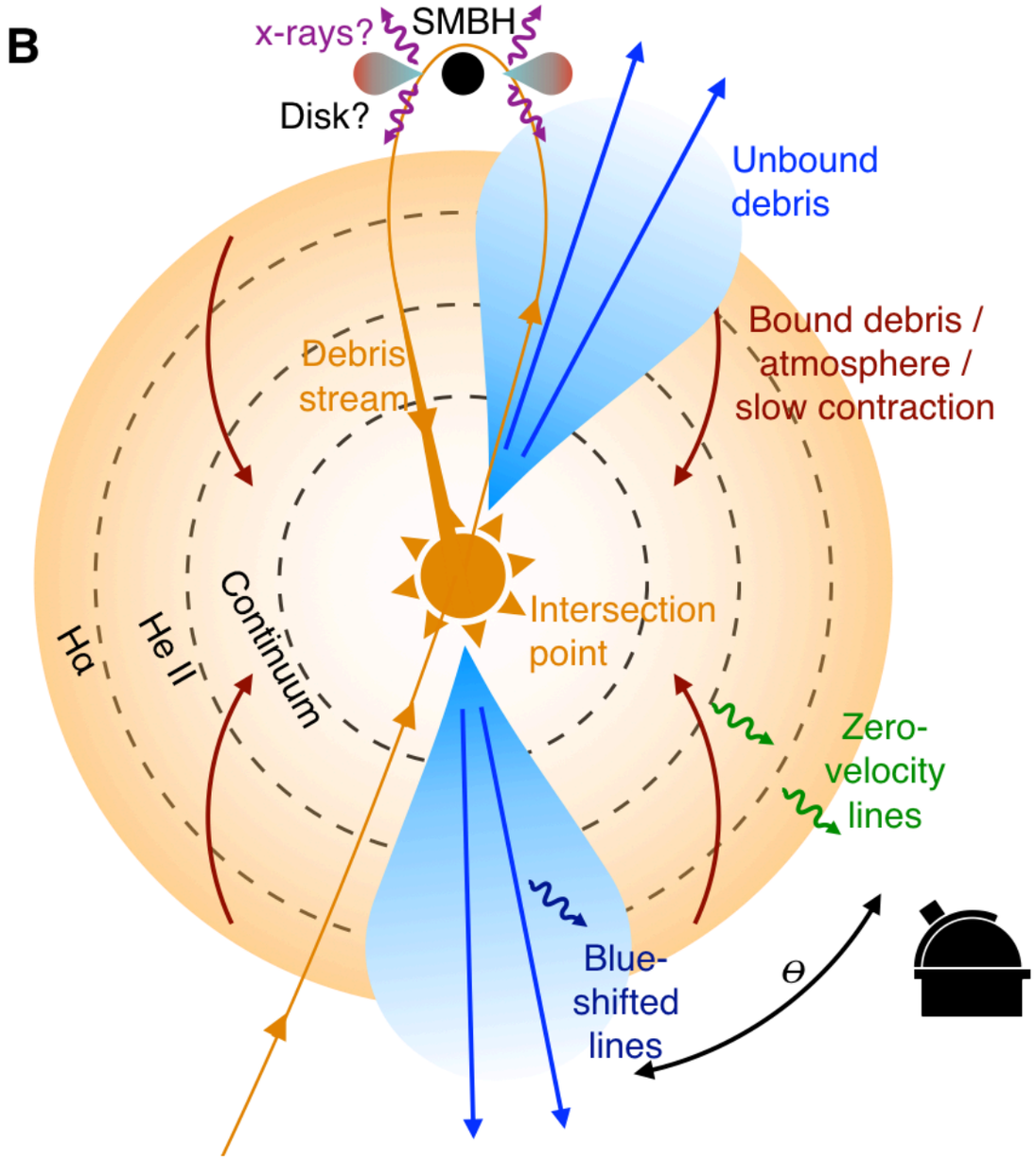
Multi-wavelength tour (final stop): optical emission



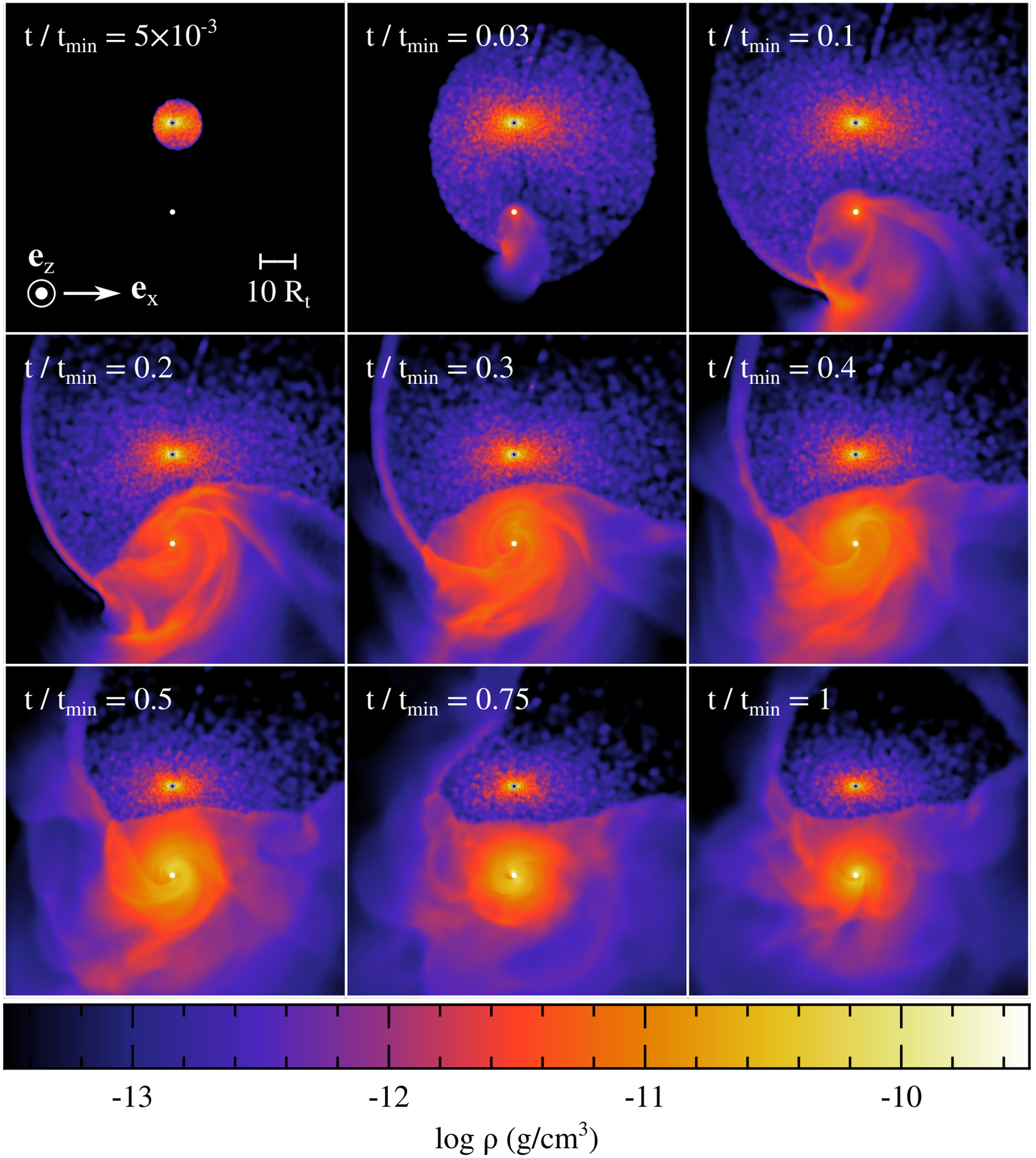
“Disk powered”

“Stream powered”

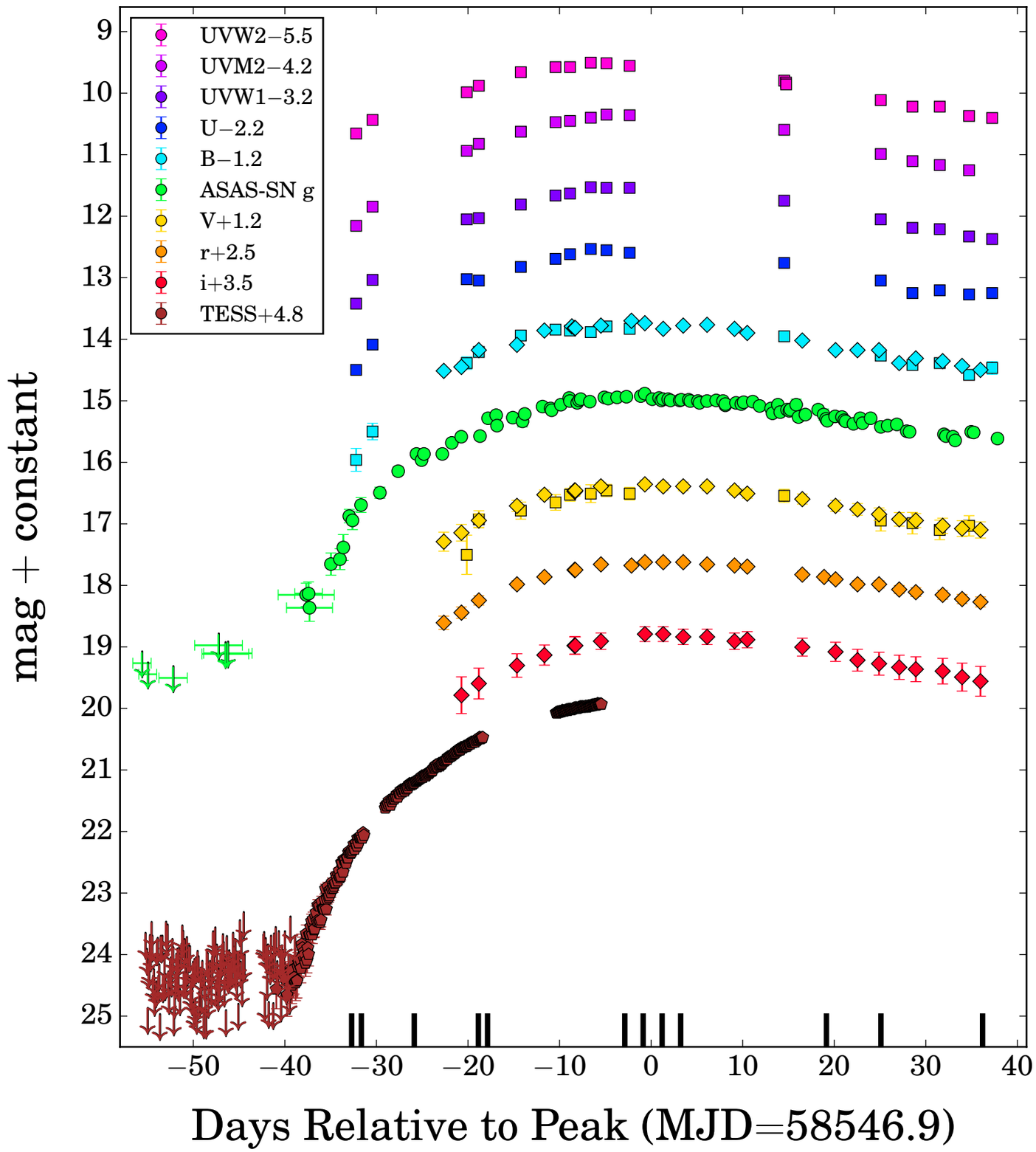




Nicholl et al. (2019)



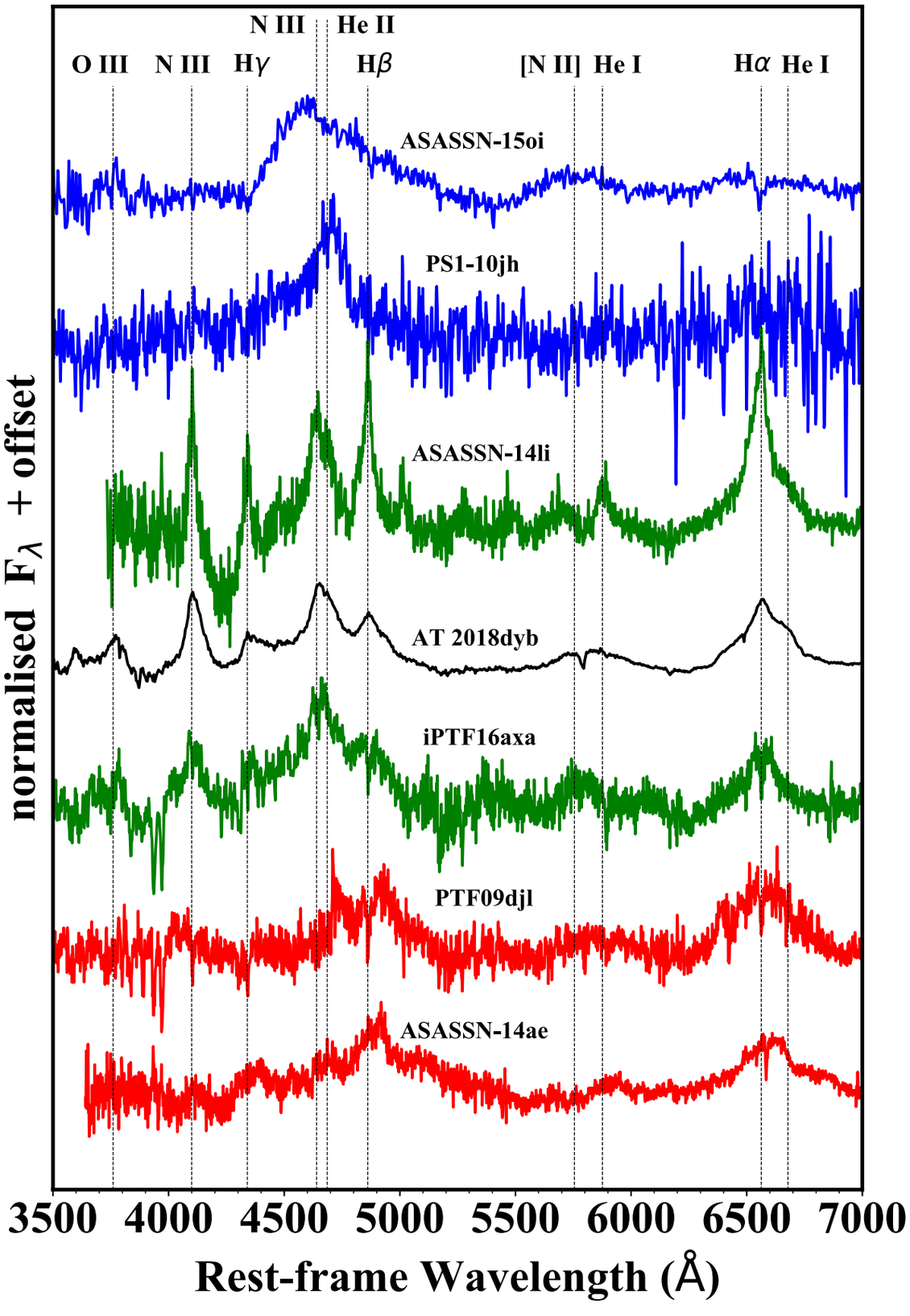
Bonnerot & Lu (2019



ASASSN-19bt; Holoien et al. (2019)

Radius from very early time observations

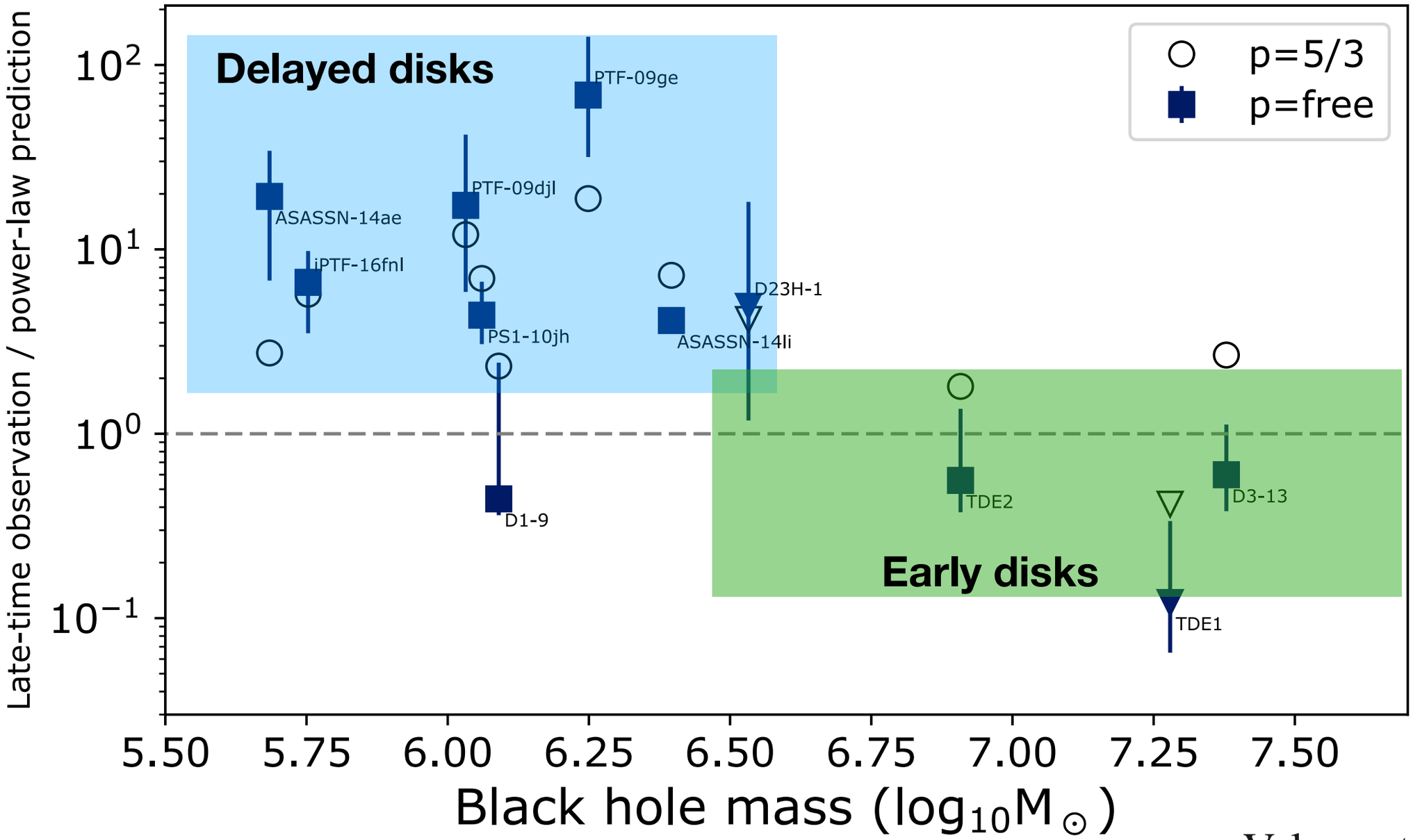
- TESS data
- $L \sim t^2$, homologous expansion?
- Unknown temperature evolution limits R(t=0) measurement



Bowen fluorescence: rapid disk formation?

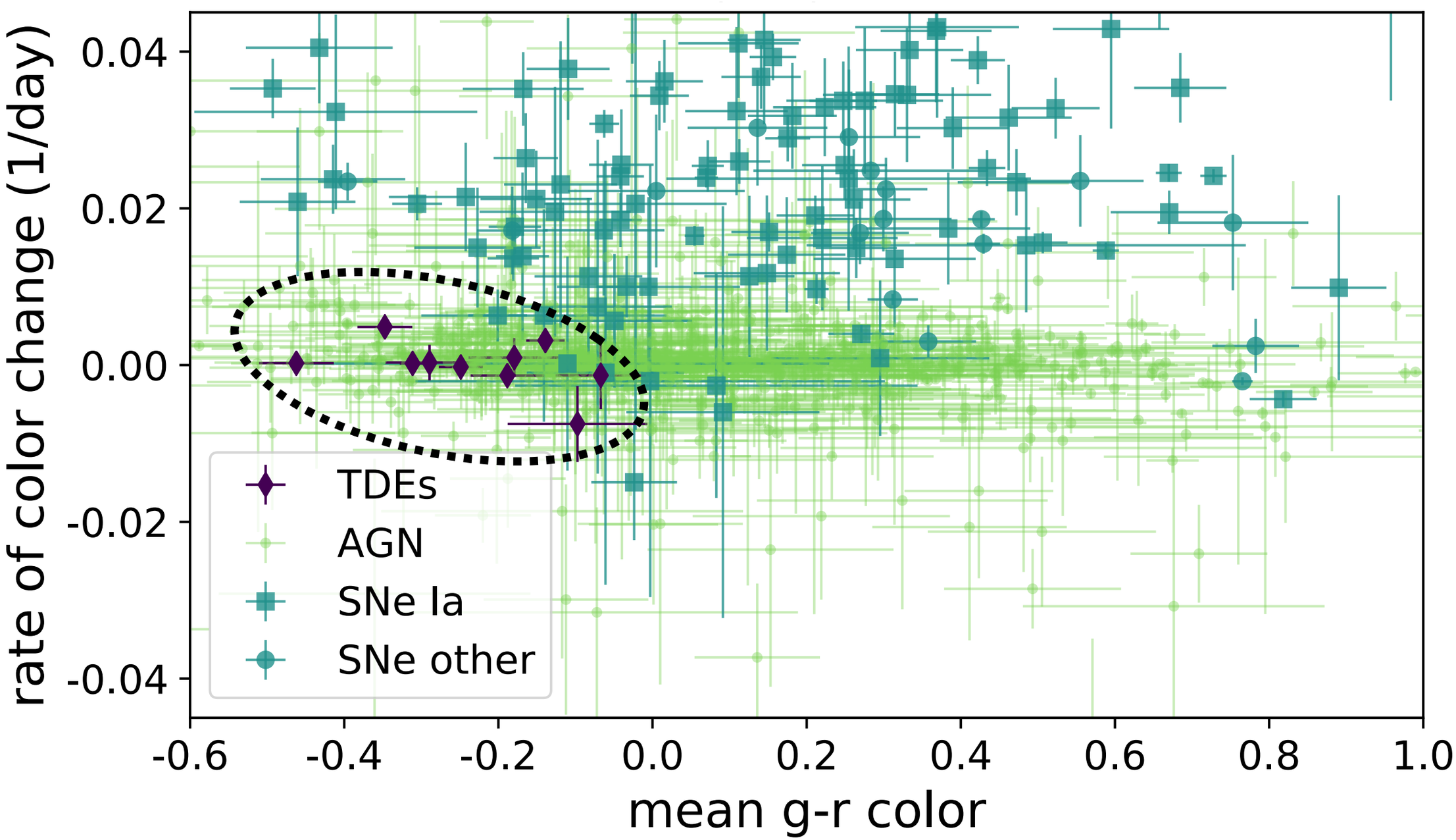
- N III and OIII emission lines (Blagorodnova et al. 2019, Leloudas et al. 2019)
- Implies source of EUV photons (λ<228Å)

Late-time UV excess: delayed disk formation



van Velzen et al. (2019)

What's next? ZTF!



van Velzen, Gezari et al. in prep (2019)

Conclusions

- Optical emission mechanism still unknown; but stay tuned for more discoveries (eg, ZTF)

- We started to use TDEs as tool to measure:

  - SMBH spin (Leloudas et al. 2016, Stone & van Velzen 2019)

  - Accretion disk formation (van Velzen et al. 2019, Wevers et al. 2019)

  - Jet-disk coupling (Pasham & van Velzen 2018, Mattila et al. 2018)

  - Nuclear dust on sub-pc scales (eg, van Velzen et al. 2016, Lu et al. 2016)

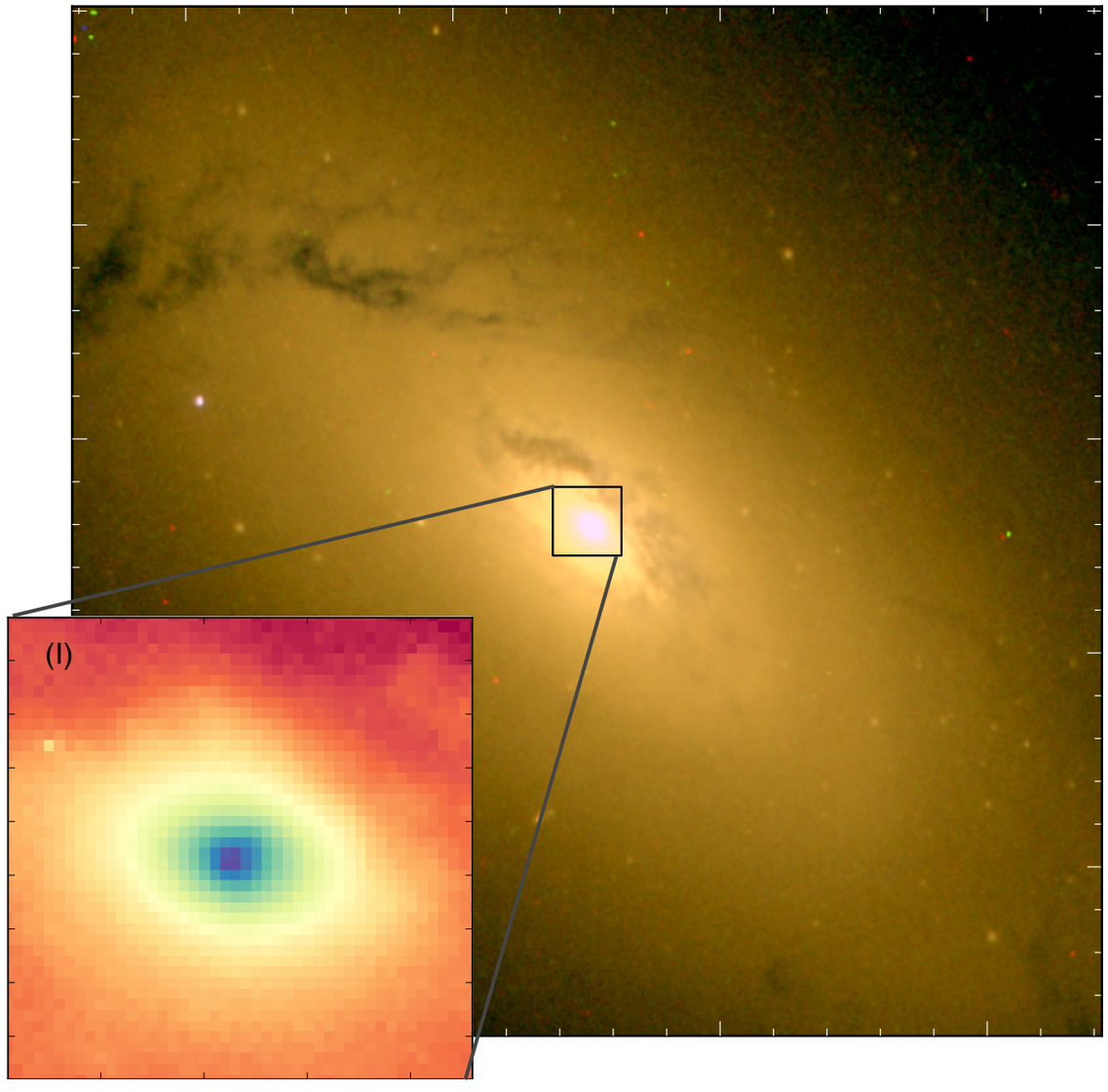

富嶽三十六景
神奈川沖
浪裏

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

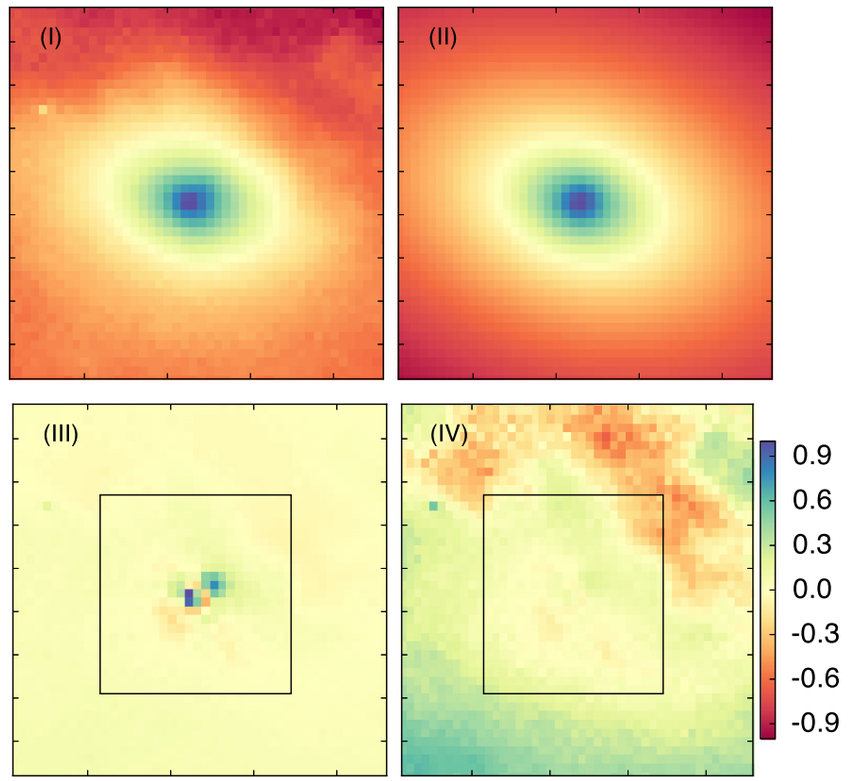
- Can be tested using *Hubble Space Telescope* (HST) observations



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

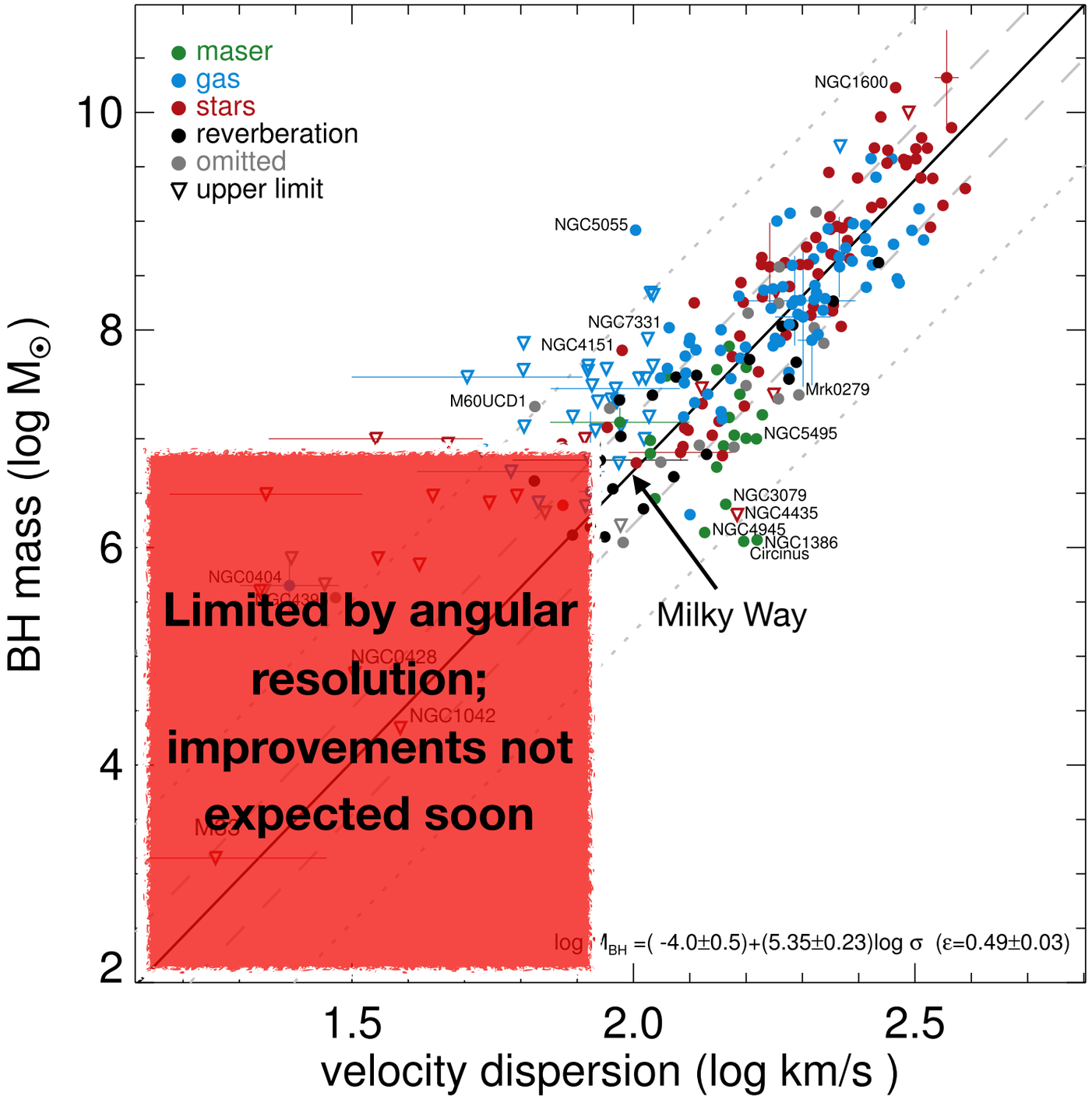
Calibrate loss cone filling

- 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



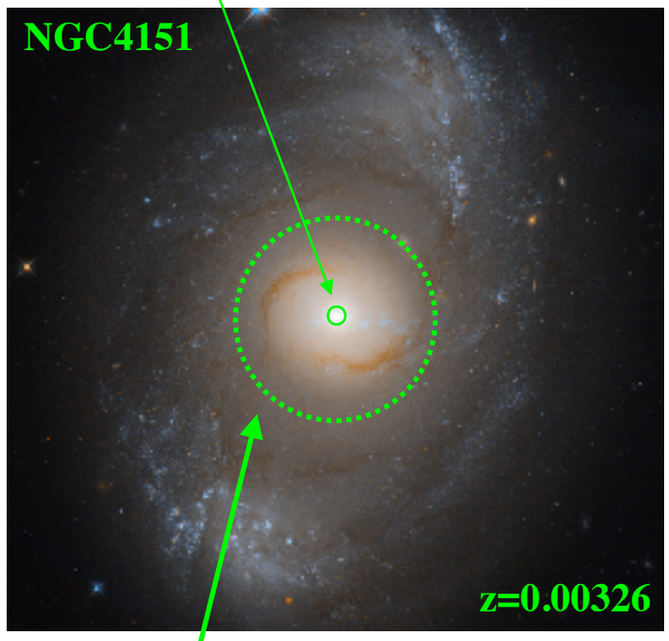
Stone & van Velzen (2016)

The M-σ relation and its limitations



van den Bosch (2016)

BH sphere of influence ~ pc



Effective radius ~ kpc