How multi-wavelength studies help to uncover the nature of

Super-luminous super-soft X-ray sources in external galaxies

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outline

- what are super-soft X-ray sources?
  - white dwarfs w/ steady surface nuclear burning
- what are super-luminous SSSs?
  - near-Chandrasekhar mass white dwarfs or intermediate mass black holes?
- how can multiwavelength studies help?
  - a case study: M81-SSS1

observations of SSS

- a new class of X-ray binaries based on ROSAT PSPC observations of 18 sources in MW and MCs in 90's
- characteristics
  - 15-80 eV
  - 1e35 - 1e38 erg/s
- optical ID: CBSS, Symbiotics, PN, CV

nature of SSS

- White dwarfs with steady nuclear burning on their surface
  - the accretion rates in a narrow range
  - correlation b/w WD mass, temperature and luminosity
- promising progenitors for SN Ia

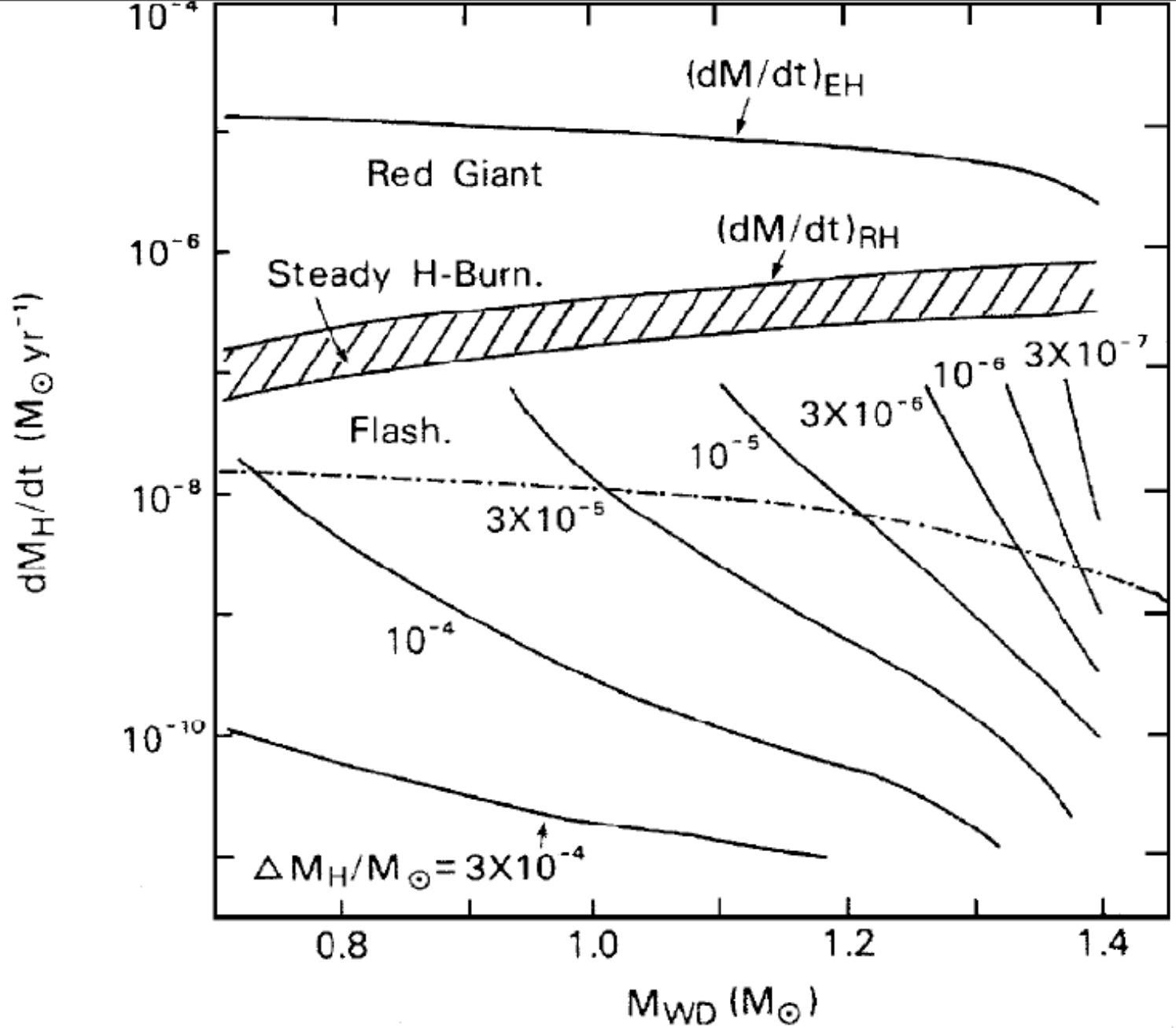

Figure 5 Regimes of steady nuclear burning, weak flashes (cyclic burning), and strong flashes (novae) in the $\dot{M}$–M_{WD} plane (cf Fujimoto 1982a,b, Nomoto 1982, DiStefano & Rappaport 1995). The ΔM_H values indicate envelope masses (for a given accretion rate) at which burning is ignited. Below the *dash-dot line*, flashes produce nova explosions.

(Kahabka & van den Heuvel 1997)

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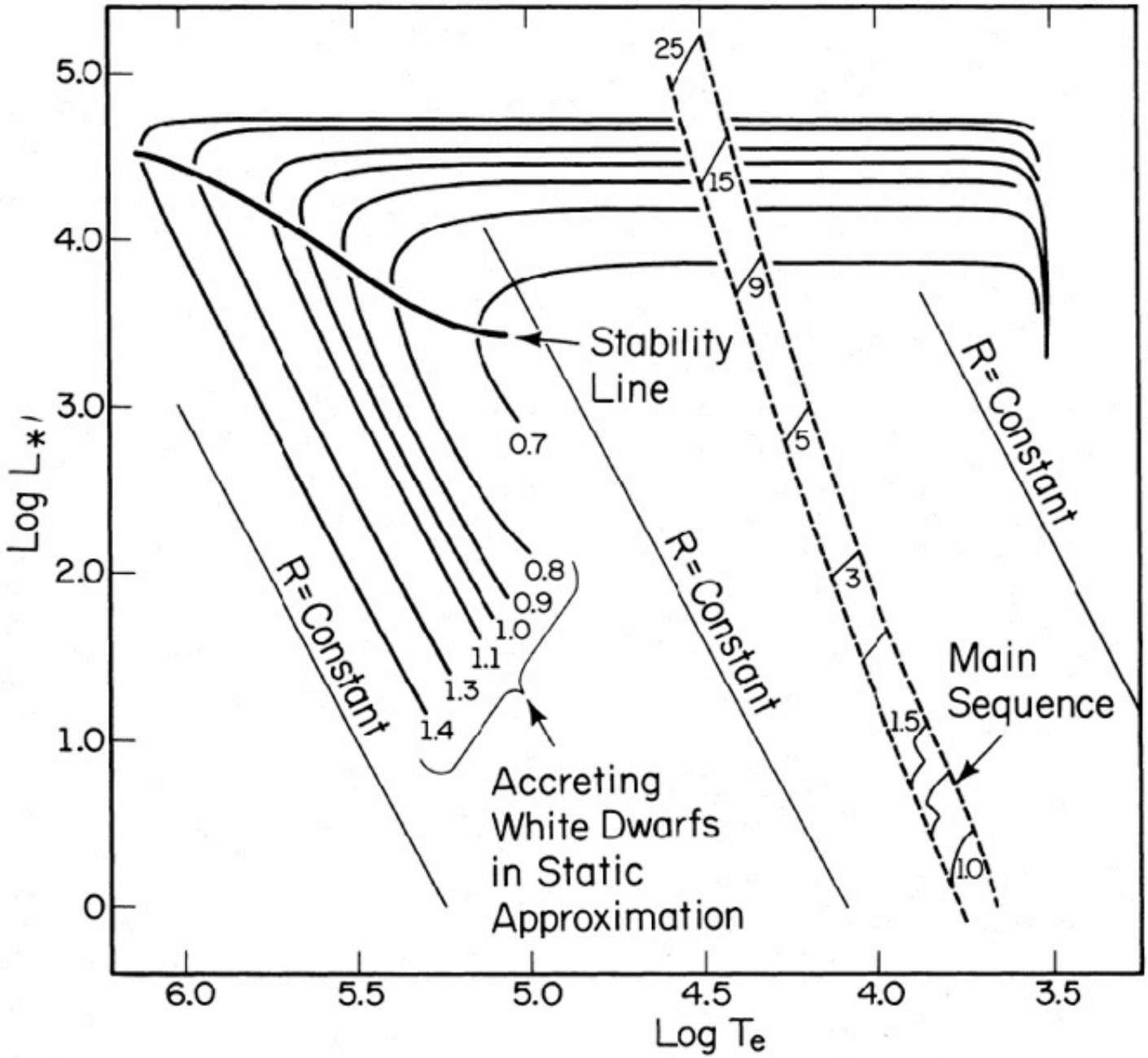

FIG. 2.—Surface luminosity L (in solar units) vs. surface temperature (in K) for accreting stars in the steady-burning approximation. Along each curve, stellar mass is constant at the value given (in solar units) at the low L, high T_e terminus of the curve. Between this terminus and the point at which a curve intersects the stability line (point of maximum T_e), the mass M_e above the hydrogen-burning shell decreases with increasing T_e (and L). Beyond the stability point, M_e increases with decreasing T_e. Envelope mass M_e also increases with decreasing mass (and T_e) along the stability line. The luminosity along the nearly constant L (or plateau) portion of each curve is related to stellar mass by $L_{\text{plateau}} \approx 5.95 \times 10^9(M - 0.5)$. For orientation purposes, rough evolutionary tracks of main-sequence models varying in mass from 1 to 25 are shown, as are several curves of constant radius.

(Iben 1982)

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super-luminous SSS

- super-luminous SSSs revealed in external galaxies by Chandra and XMM
- compared to canonical SSSs, they are typically hotter and more luminous
- some are far above Eddington luminosity
  - WD atmosphere models may reduce the luminosity
  - or intermediate mass black holes (IMBH)?

massive WD or IMBH?

- two possibilities: near-Chandrasekhar mass WDs or IMBHs
- hard to tell w/ X-ray only
- lower energy emission from the accretion disk
  - illuminated flared disk around WD: nu^-1
  - thin multicolor disk around IMBH: nu^1/3


A SSS in M81
17 obs, 230 ksec


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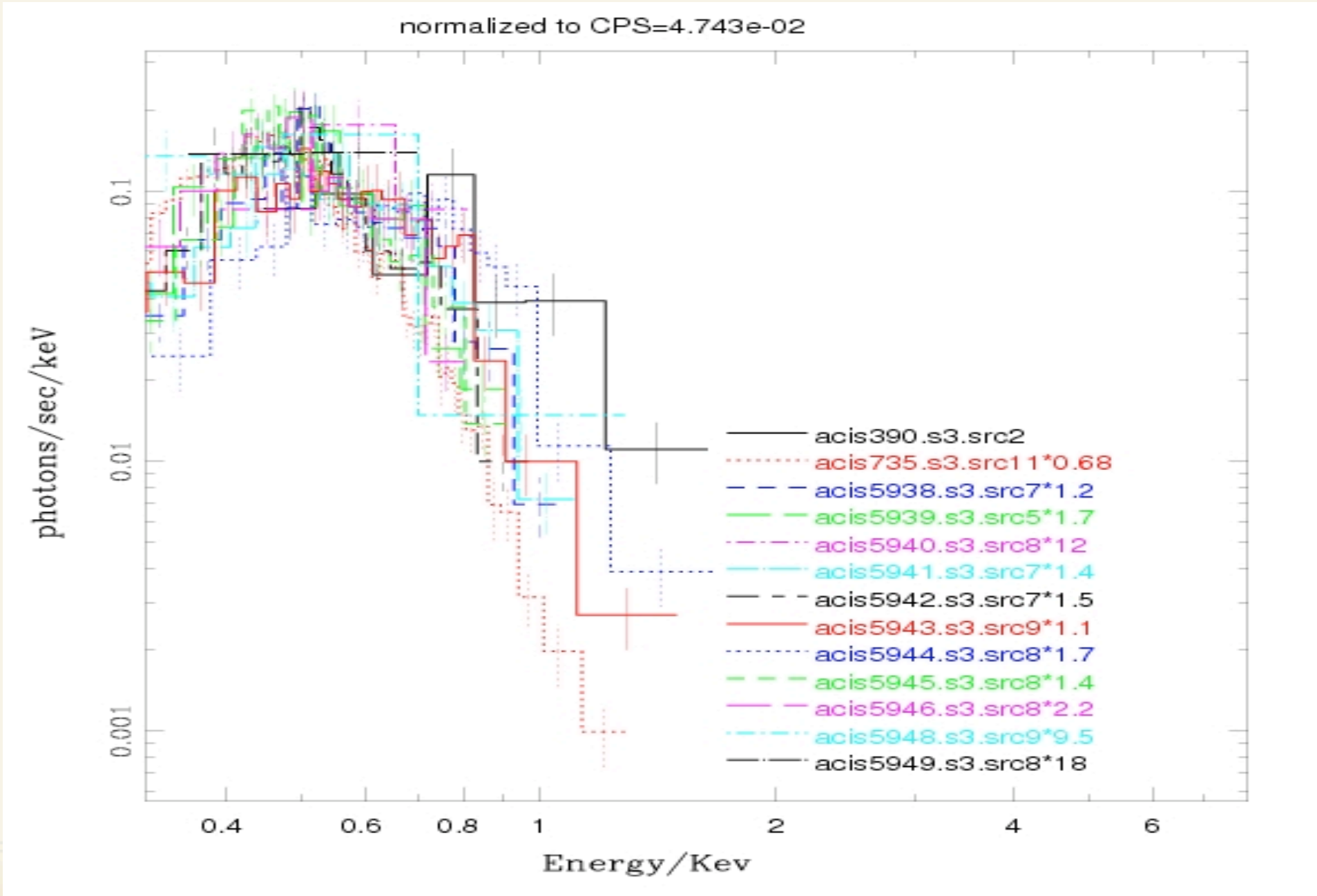
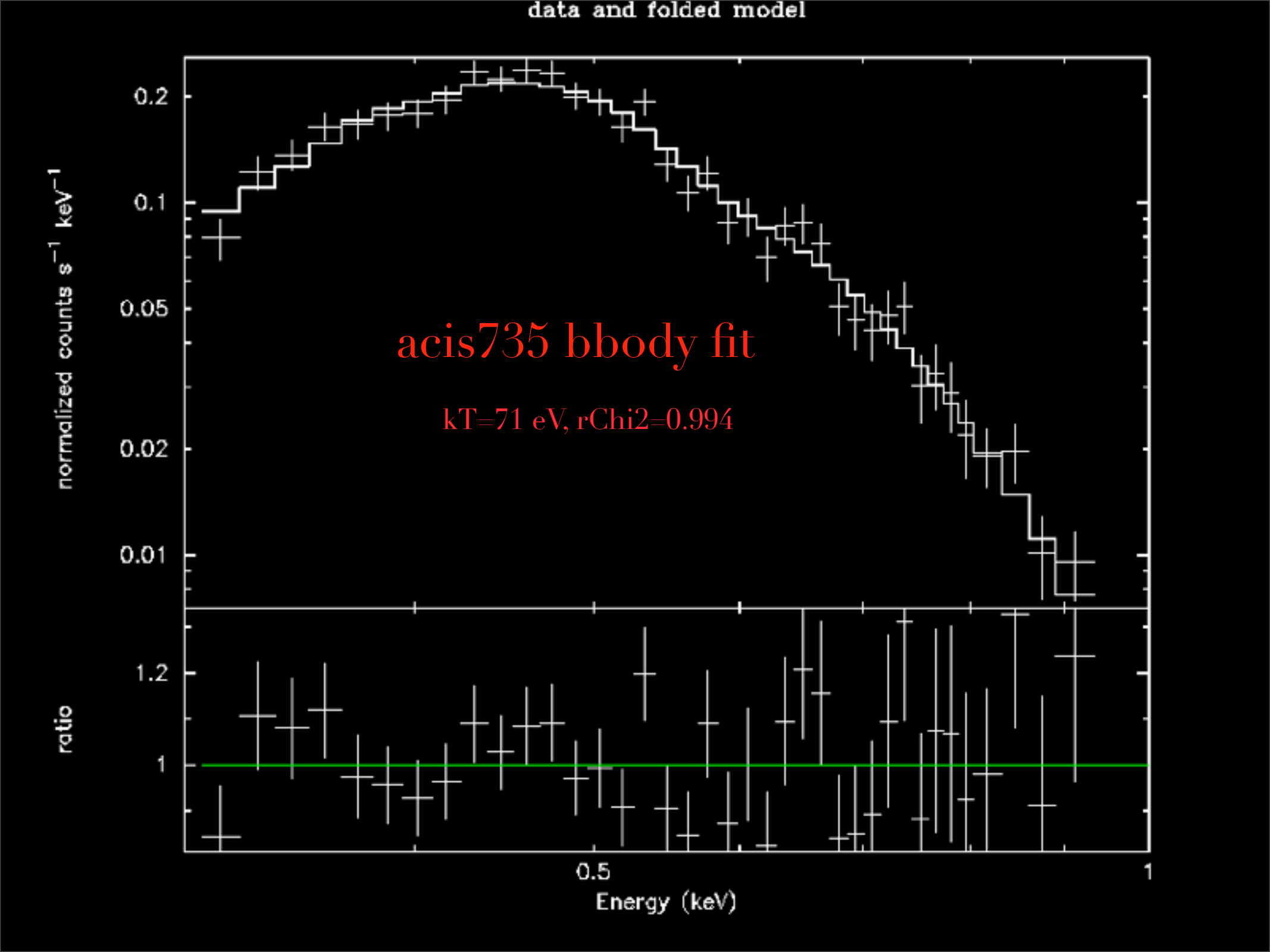
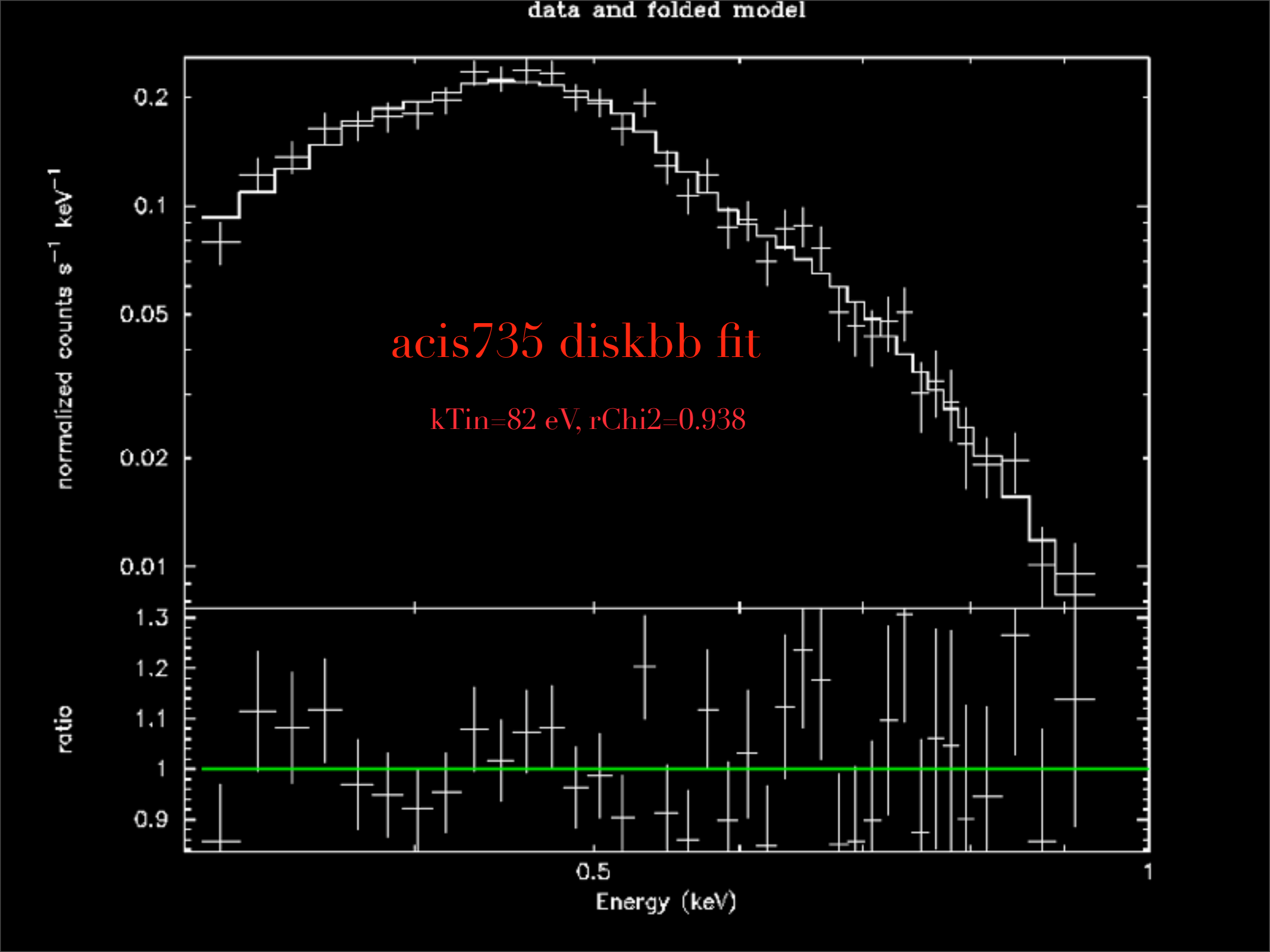
17 obs, 230 ksec

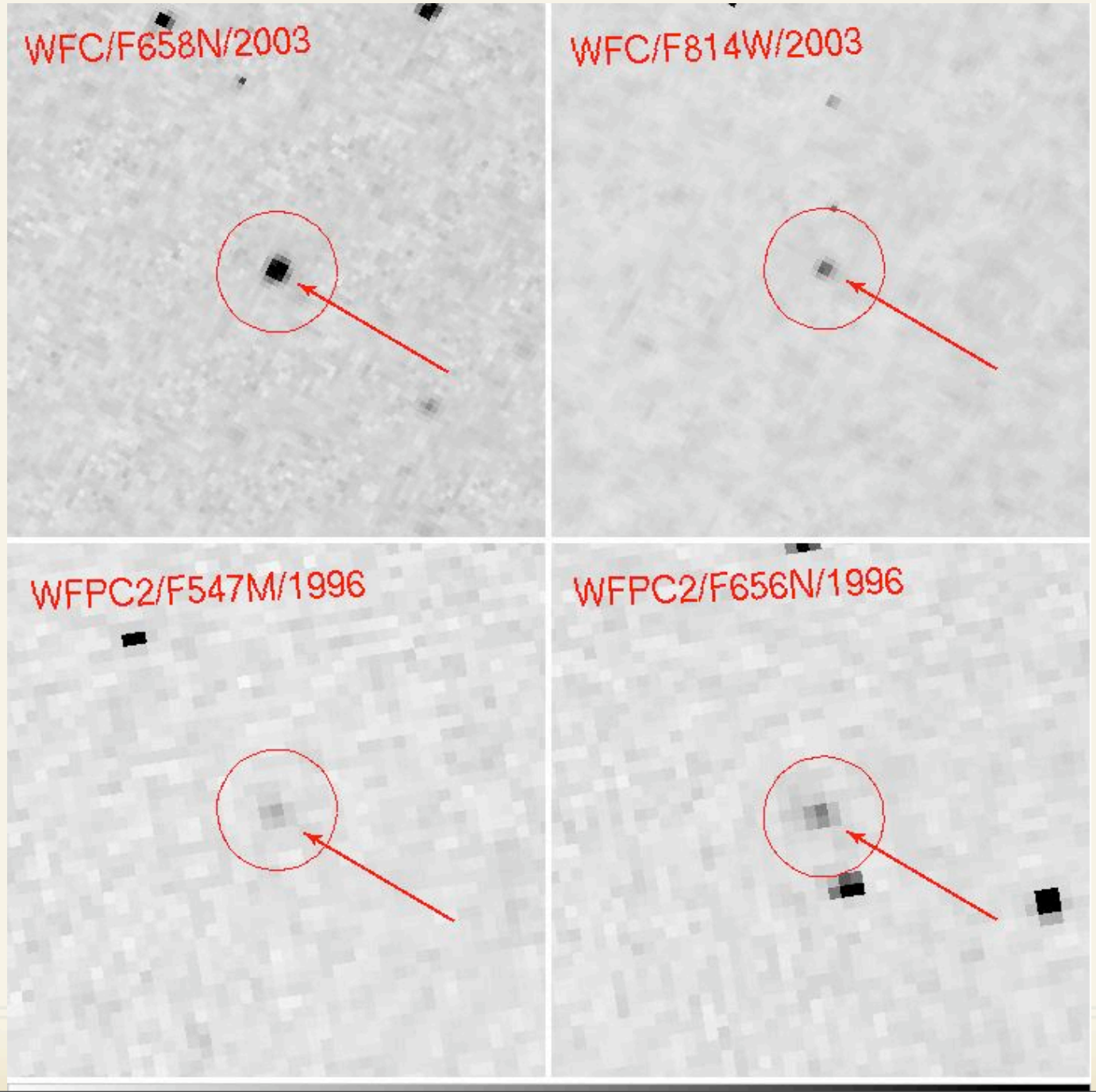
spectra: all black body of ~70 eV




data and folded model
0.2
0.1
0.05
0.02
0.01
normalized counts s^{-1} keV^{-1}
acis735 bbody fit
kT=71 eV, rChi2=0.994
1.2
1
ratio
0.5
1
Energy (keV)


data and folded model
normalized counts s^{-1} keV^{-1}
0.2
0.1
0.05
0.02
0.01
acis735 diskbb fit
kTin=82 eV, rChi2=0.938
ratio
1.3
1.2
1.1
1
0.9
0.5
1
Energy (keV)

optical observations from HST archive



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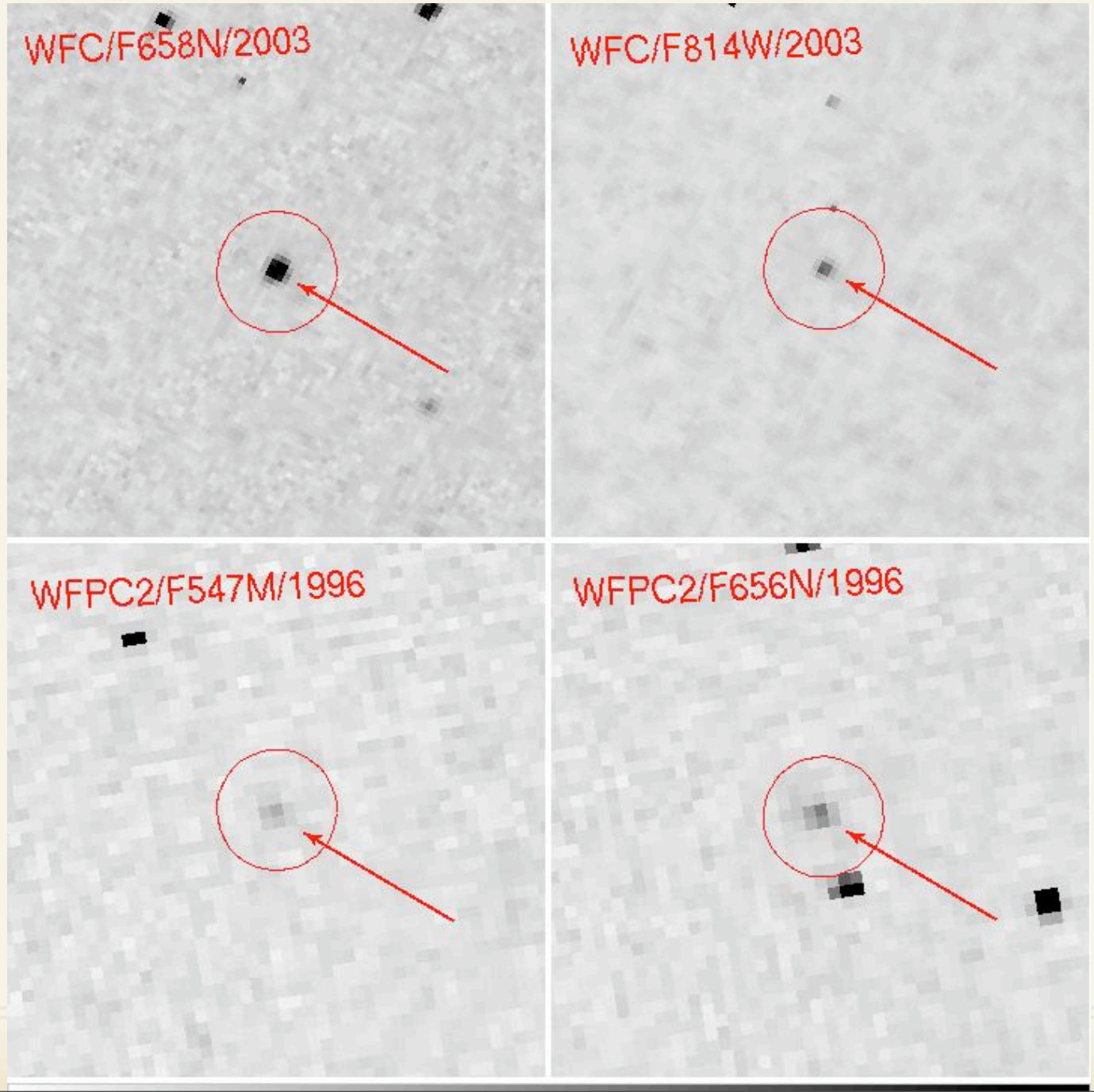
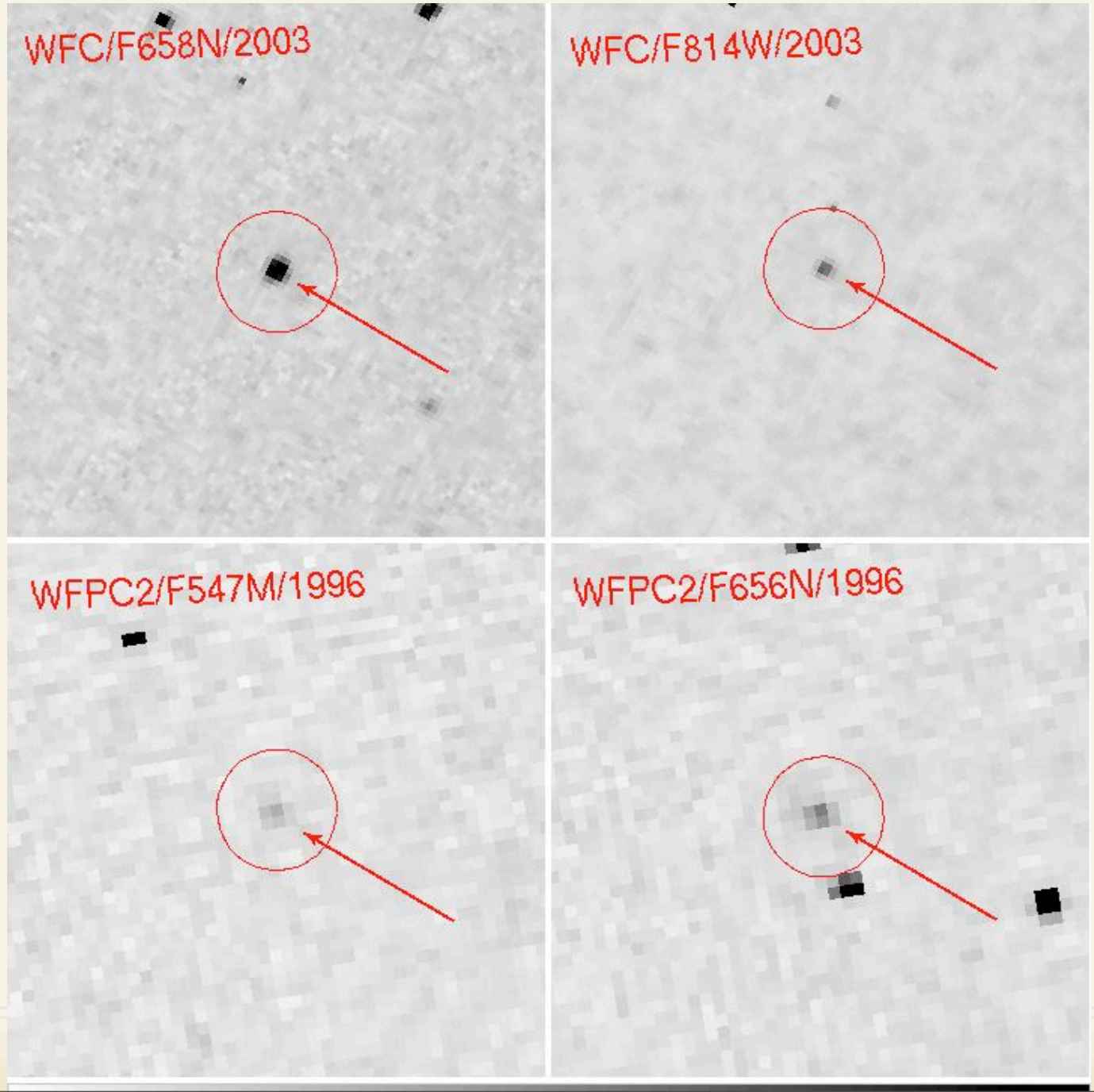


vegamag/2003
F814W: 20.8
F658N: 20.0
vegamag /1996
F547M: 22.1
F656N: 20.2

optical observations from HST archive



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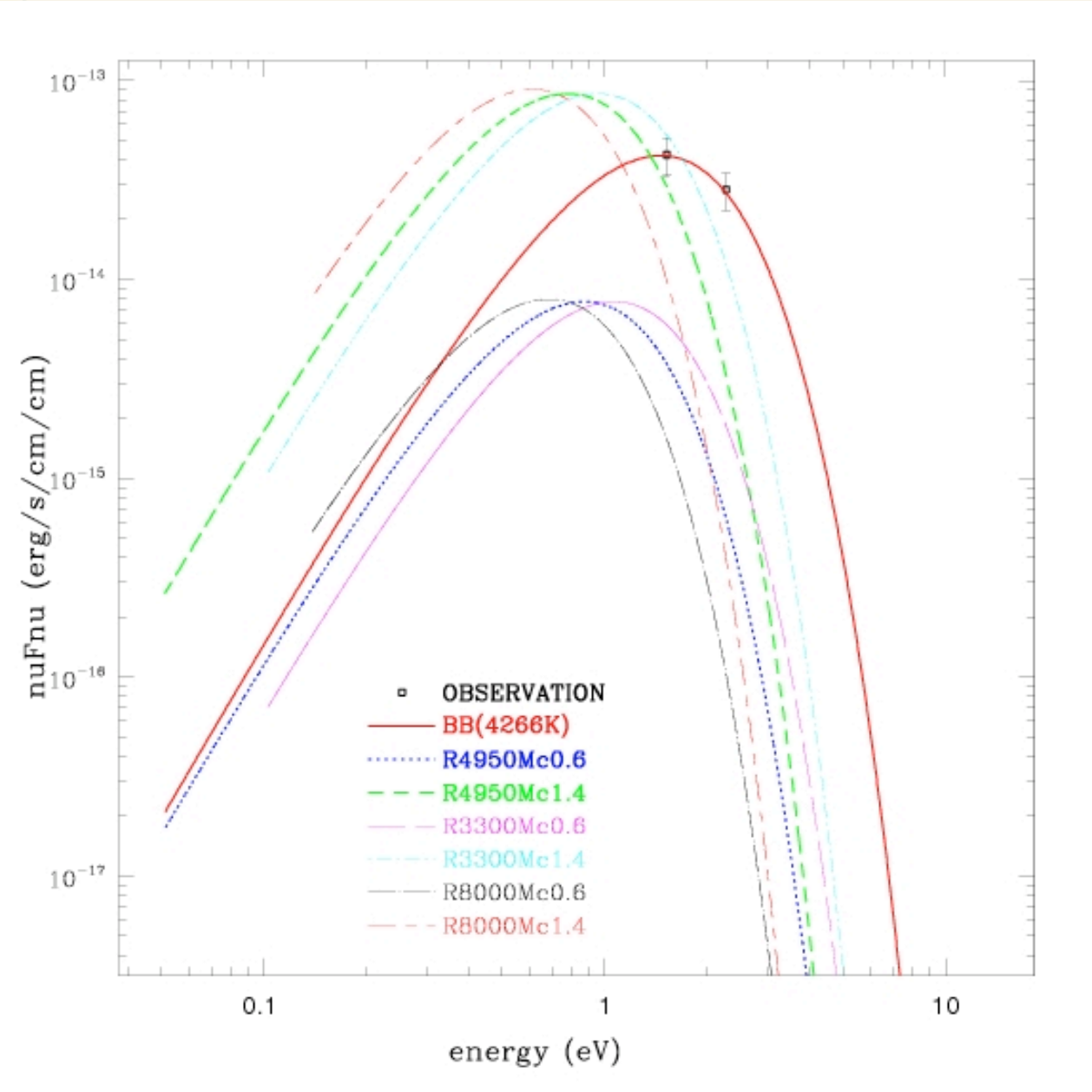
Halpha emision Line
1996: 2e37 erg/s
2003: 8e36 erg/s
X-ray photoionized

AGB secondary?



BB: 4266K

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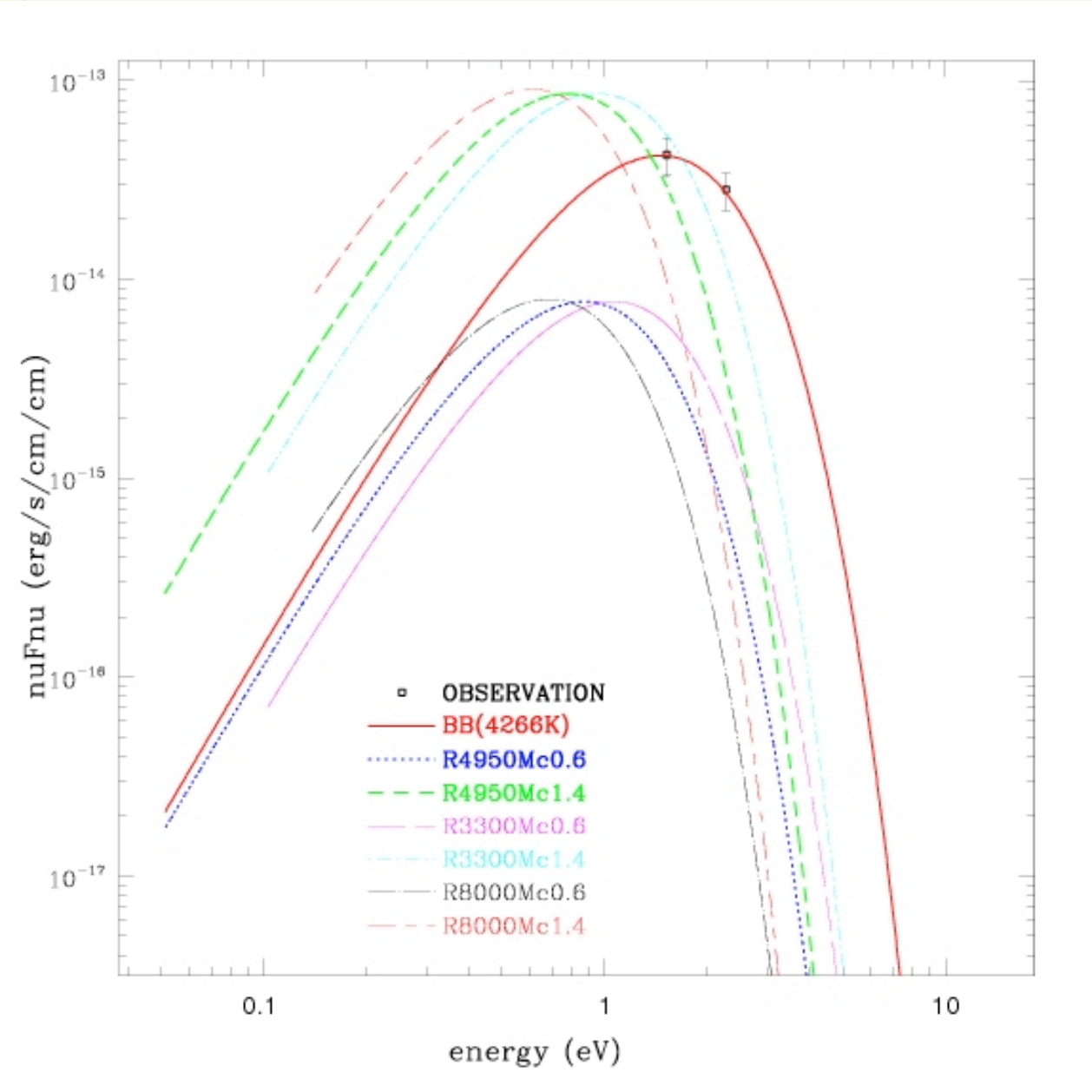

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but for AGB, L/R/T are inter-correlated and determined by core-mass

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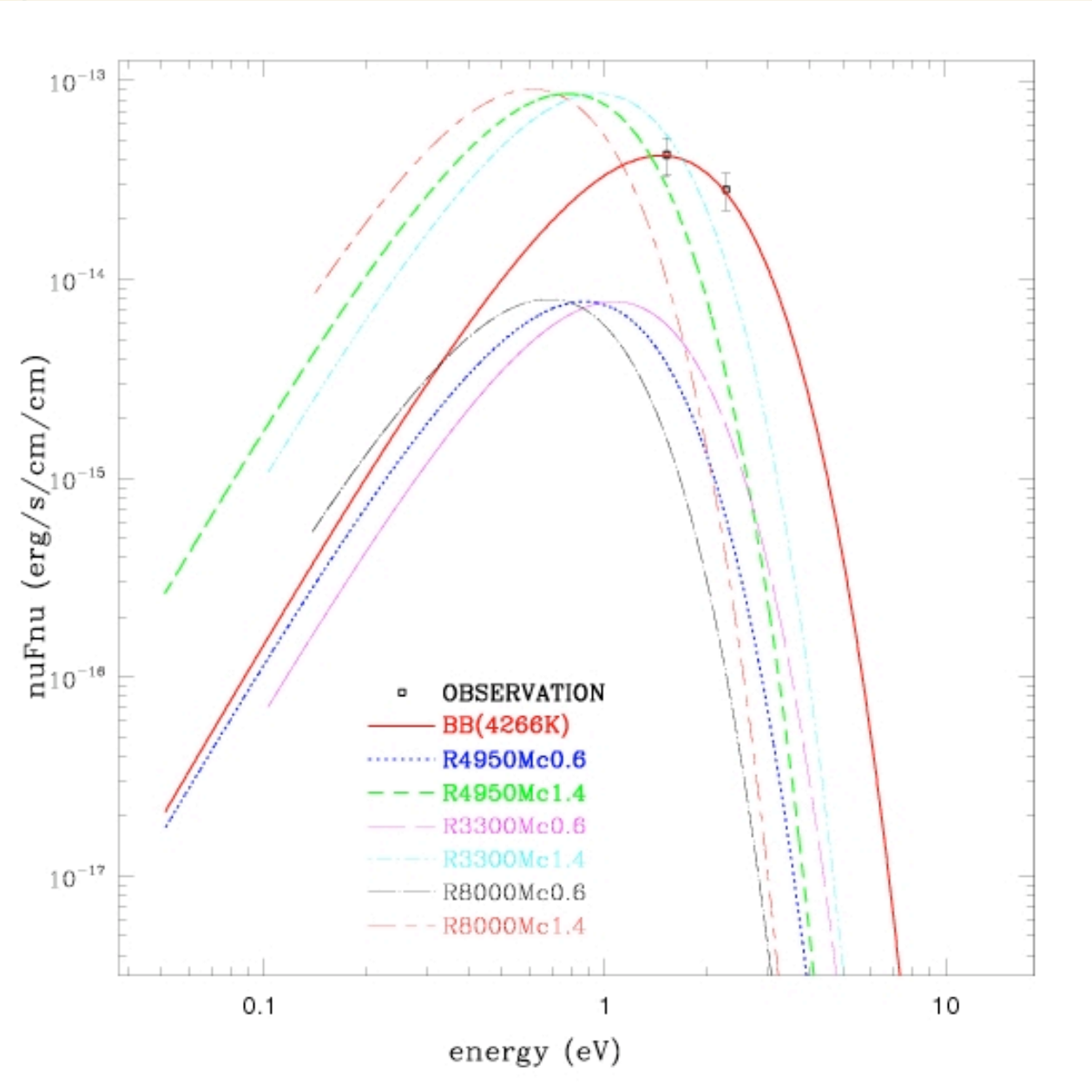
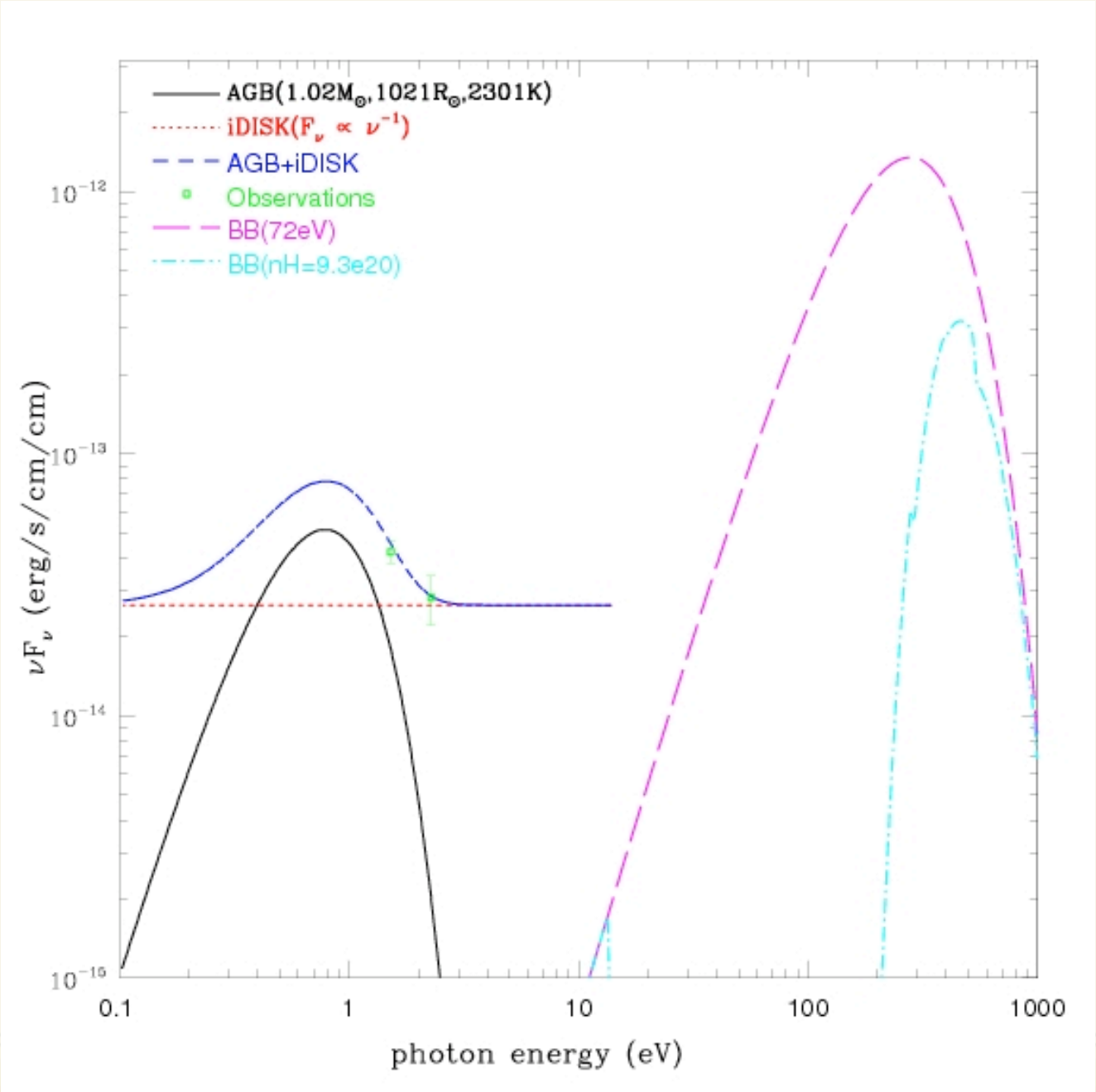


BB: 4266K

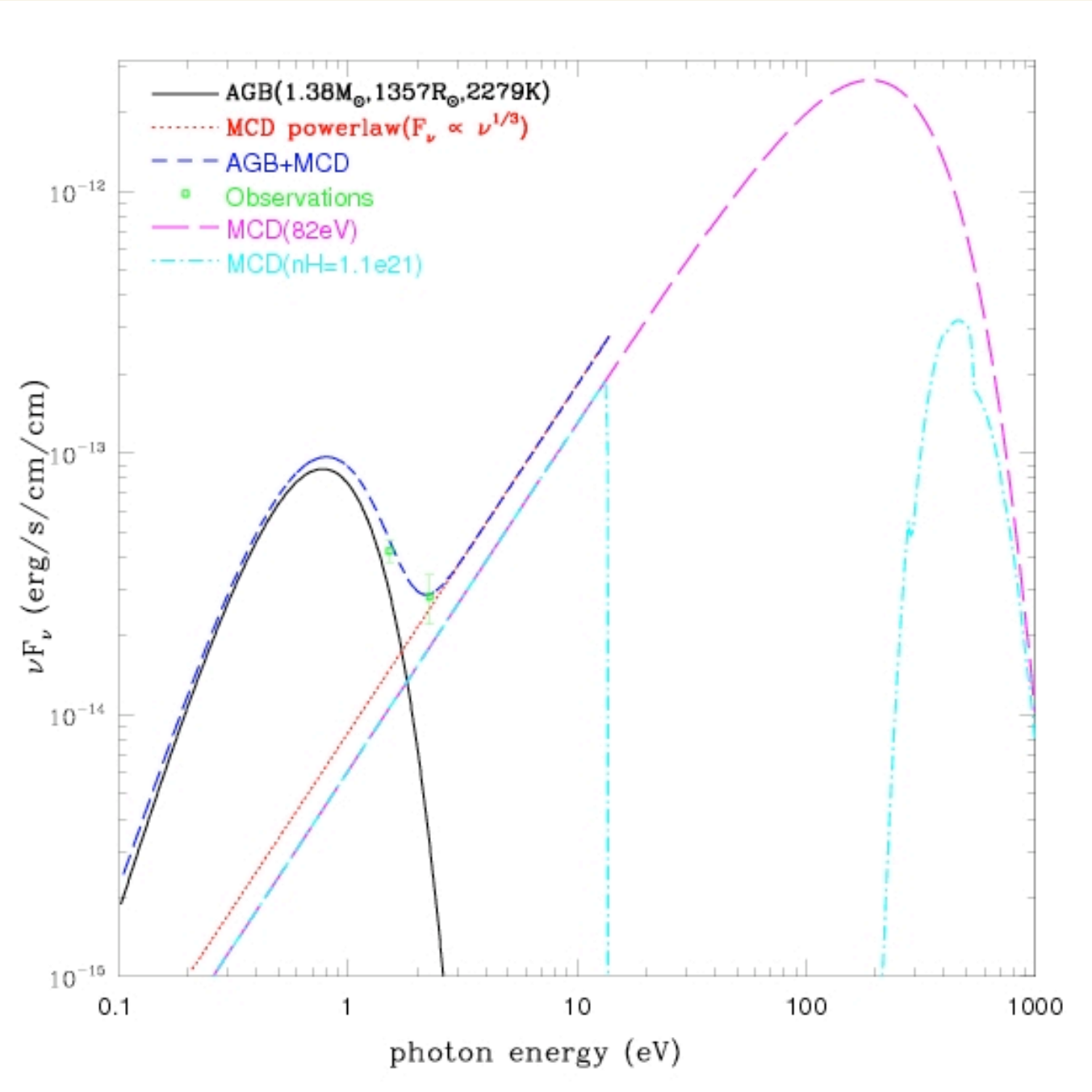
but for AGB, L/R/T are inter-correlated and determined by core-mass

we need an extra bluer component

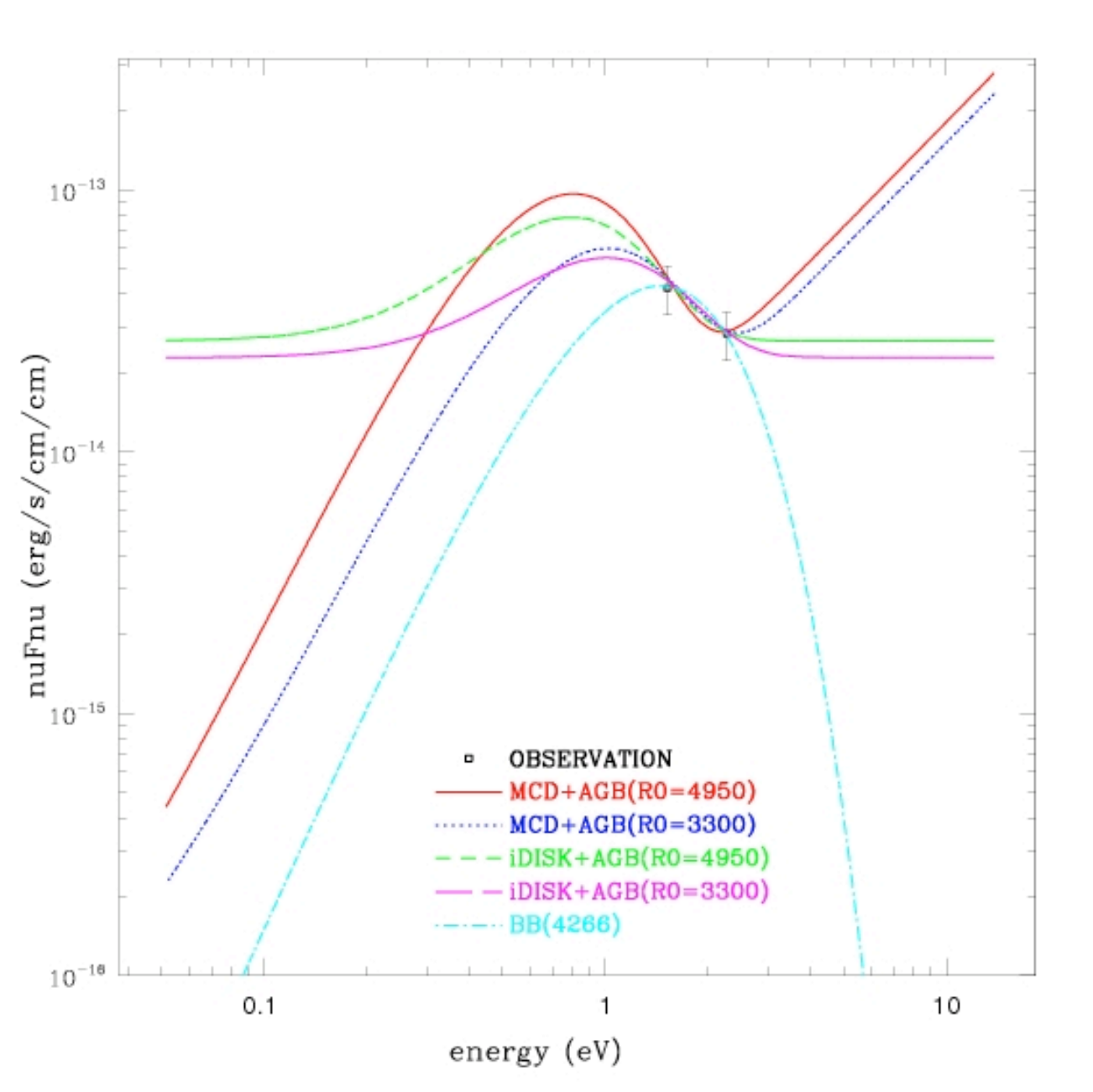
AGB+illuminated disk (nu^-1) around WD



AGB+multi-color disk (nu^1/3) around BH

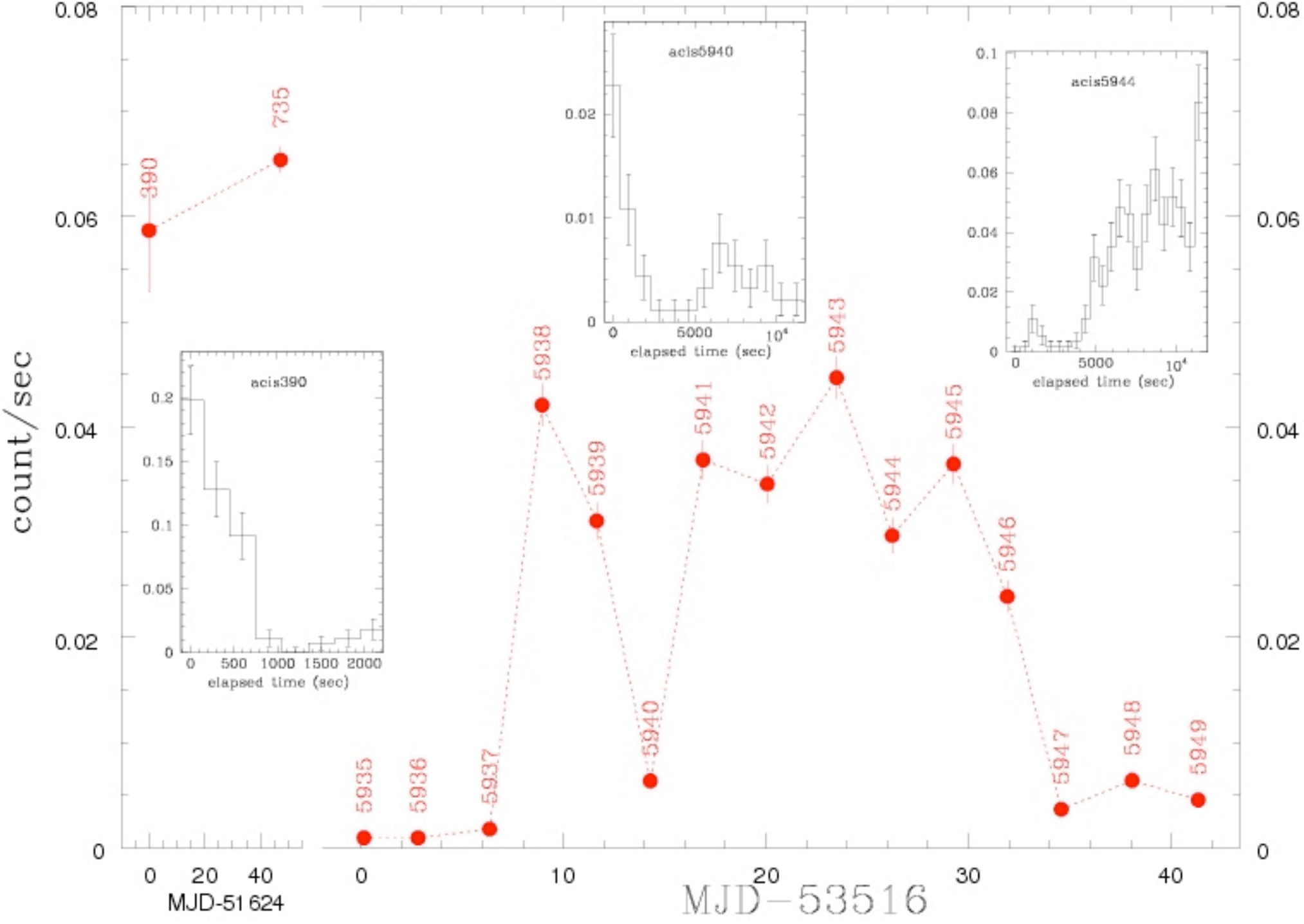


model ambiguity: remove w/ IR and optical observations



summary

- luminous SSSs are massive WDs with steady surface nuclear burning
- super-luminous SSSs in external galaxies present challenges
  - are they near-Chandrasekhar mass WDs?
  - are they intermediate mass black holes?
- multi-wavelength studies may help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MJD-51624
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5935
5936
5937
5938
5939
5940
5941
5942
5943
5944
5945
5946
5947
5948
5949
acis390
elapsed time (sec)
acis5940
elapsed time (sec)
acis5944
elapsed time (sec)