AGN PHYSICS
Corona (temperature)
and
Disk (density)

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with help from many collaborators including

Anne Lohfink, Jiachen Jiang, Javier Garcia, Michael Parker, John Tomsi '

European Research Council

Established by the European Commission

WHAT DETERMINES CORONAL TEMPERATURE?

Coronal properties

- Corona in AGN is responsible for all X-ray flux >1 keV

- 15<kT<150 keV, most 50-150 keV (Fabian+15,17; Ricci+17; Tortosa+17; Lanzuisi+19)
- R<10 r_g for much of the power (Kara+16; Chartas+17)
- Some could be outflowing (Beloborodov99, Malzac+01, Wilkins+14), probably not static!
- Lower part dominates reflection, upper part dominates observed power-law

CORONA IS RADIATIVELY COMPACT

Dimensionless compactness parameter, GuilbertFabianRees83

$$\ell = \frac{L}{R}\frac{\sigma_T}{m_e c^3}.$$

$$l = \left(\frac{m_\mathrm{p}}{m_\mathrm{e}}\right)\left(\frac{R}{R_\mathrm{S}}\right)^{-1}\left(\frac{L}{L_\mathrm{Edd}}\right)$$

For AGN ℓ typically 10-1000

Compton cooling time < light crossing time

Photon Column Density = Density x Size

$$N_\gamma = \frac{L}{4\pi R^2 c E_\gamma} R$$

$$N_\gamma = 2 \times 10^{26} \left(\frac{L}{L_{\rm Edd}} \right) \left(\frac{R_{\rm S}}{R} \right) \left(\frac{E_\gamma \, {\rm MeV}}{E_\gamma} \right)$$

$$\tau = 200 \left(\frac{\sigma}{\sigma_{\rm T}} \right) \left(\frac{L}{L_{\rm Edd}} \right) \left(\frac{R_{\rm S}}{R} \right) \left(\frac{E_\gamma \, {\rm MeV}}{E_\gamma} \right)$$

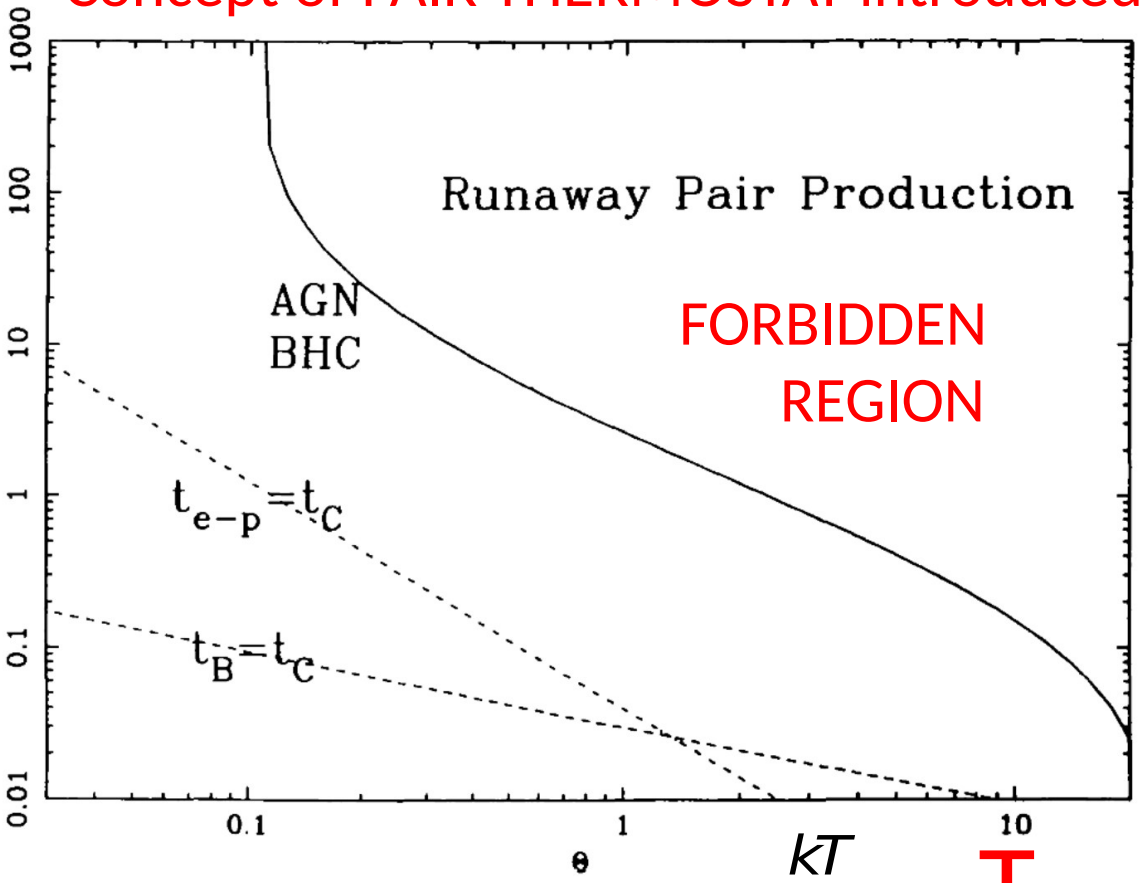
PAIR PRODUCTION: electron-positron pairs form when photons and/or particles collide at energies $> m_e c^2 = 511 keV$

photon-photon collisions: $\gamma + \gamma \rightarrow e^{\pm}$ requires $\frac{\epsilon_1}{m_e c^2} \frac{\epsilon_2}{m_e c^2} > 2$

Svensson, 82,84, Zdziarski 85, many other papers and workers 80s + 90s

Concept of PAIR THERMOSTAT introduced

L/R



ℓ

$\frac{kT}{m_e c^2}$ T

Schematic from Fabian94

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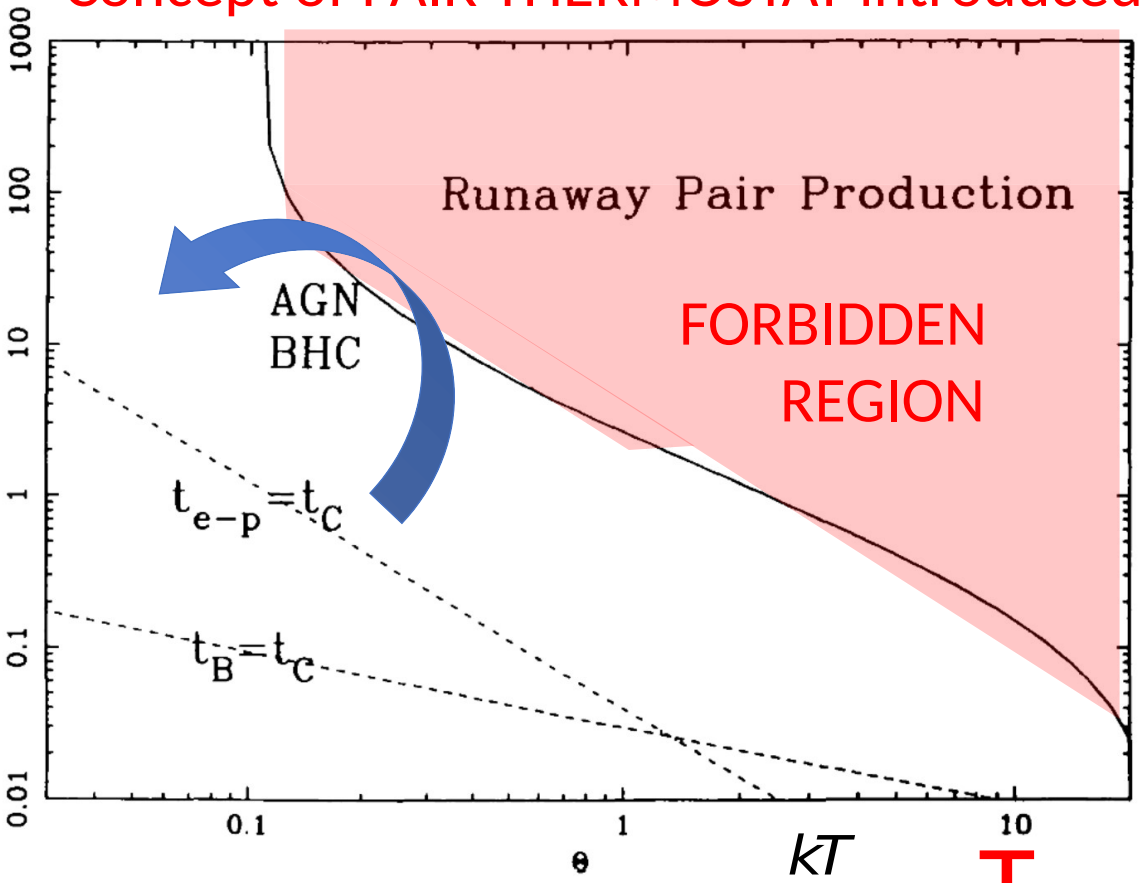
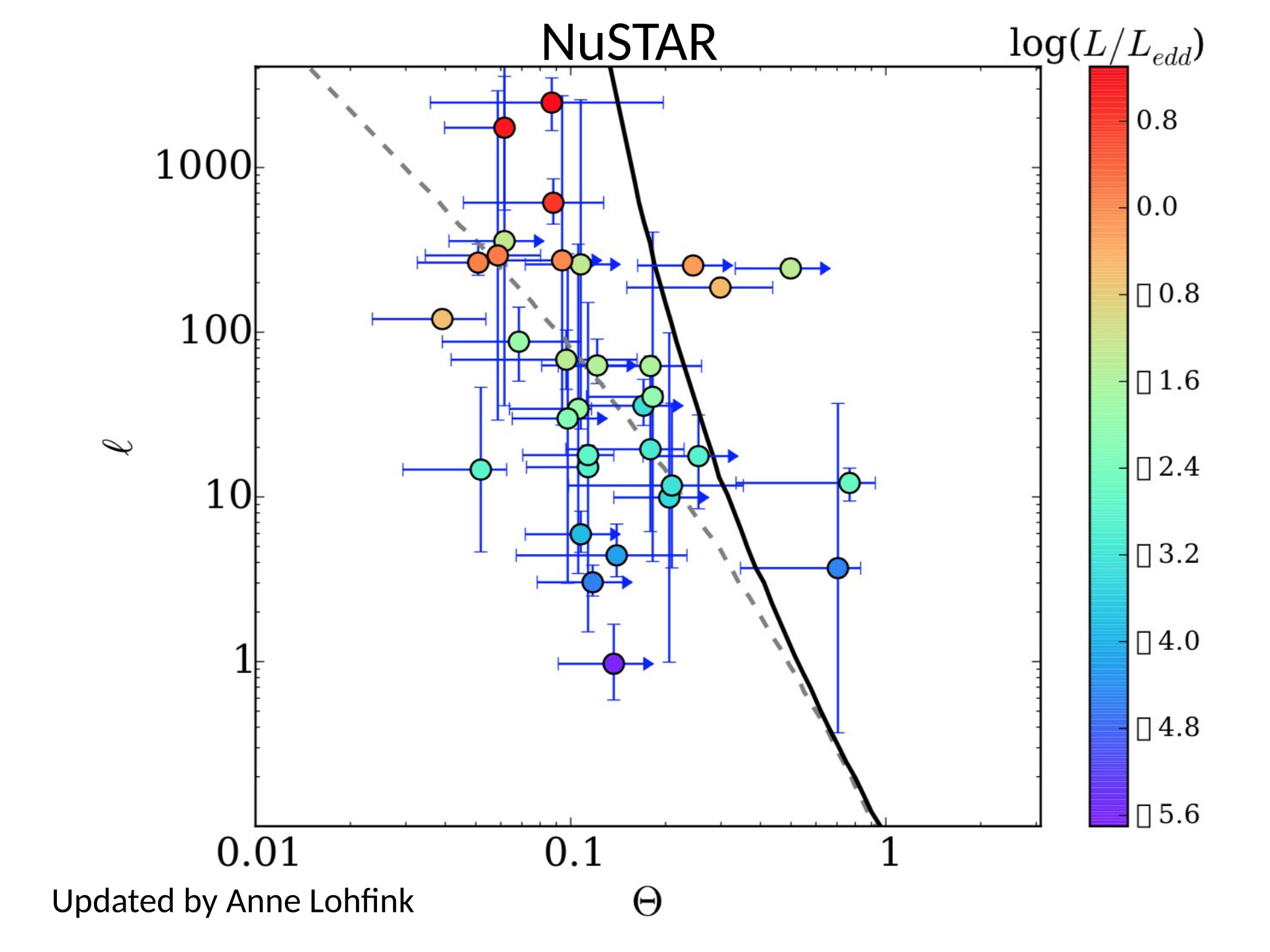


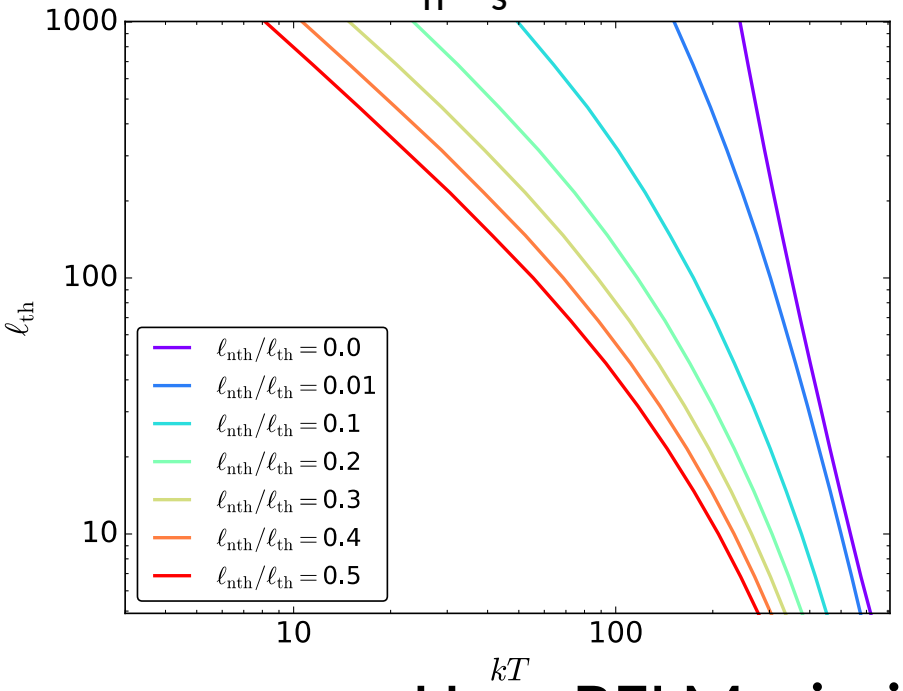
Schematic from Fabian94



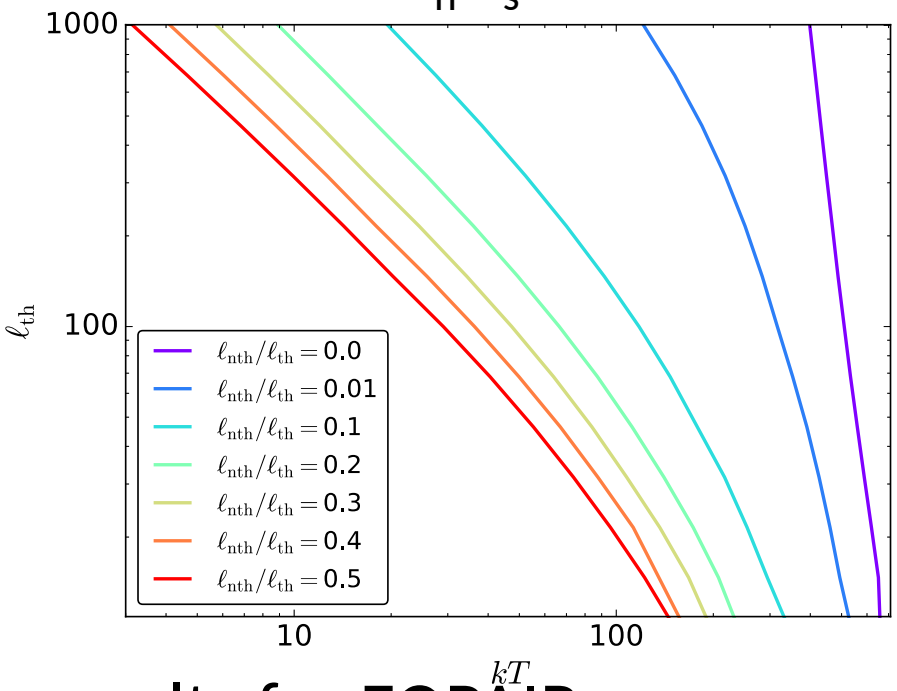
Updated by Anne Lohfink

Effect of addition of nonthermal particles - Hybrid Plasma

l_h/l_s=1



l_h/l_s=0.1

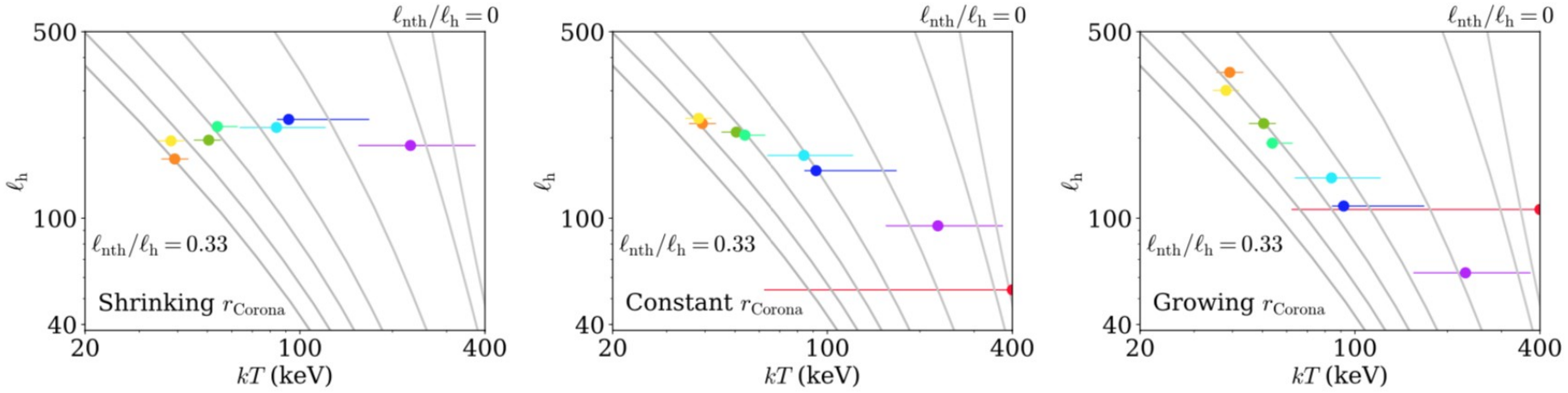


Uses BELM, similar results for EQPAIR

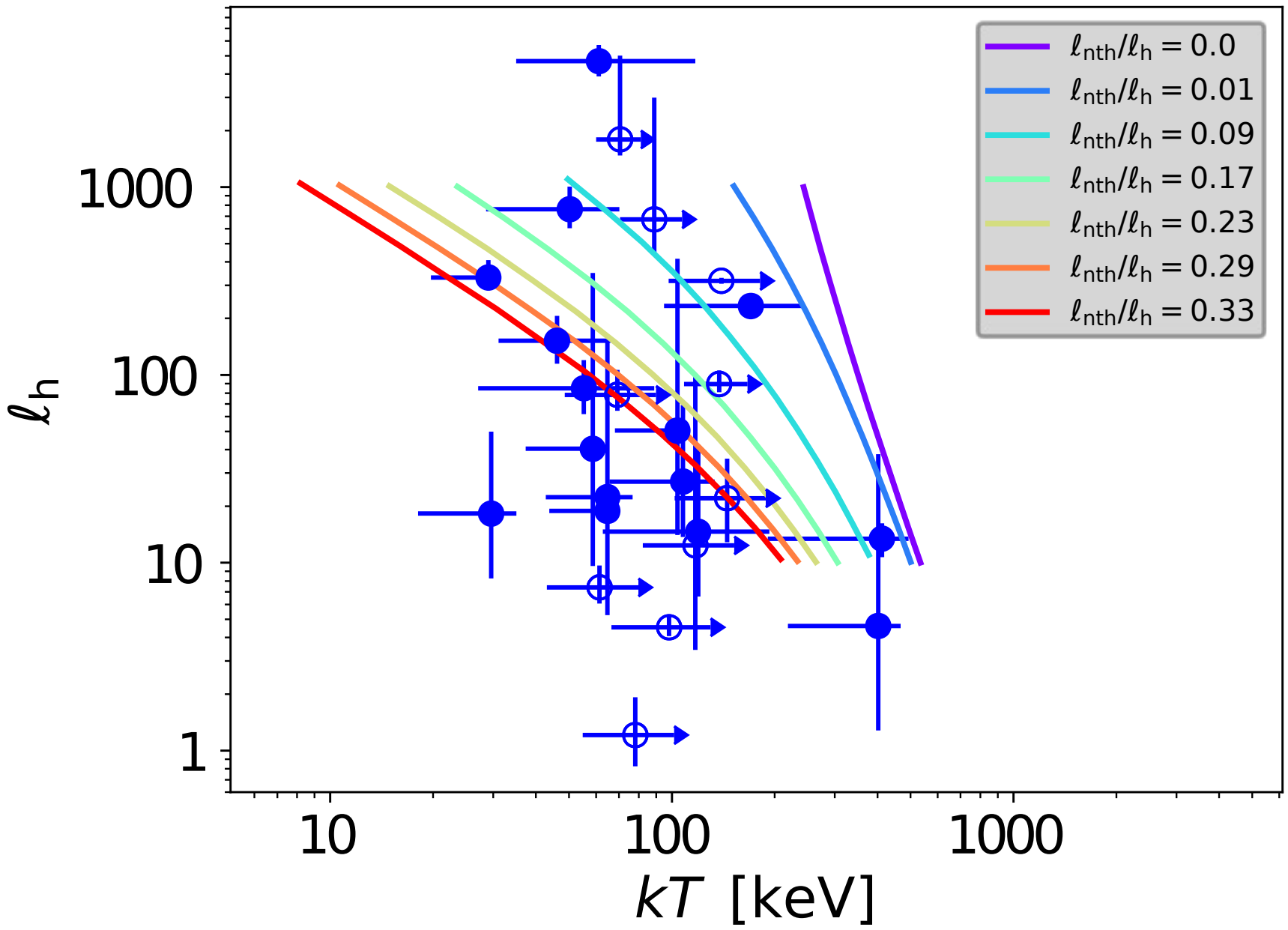
Fabian, Lohfink, Belmont, Malzac, Coppi 17

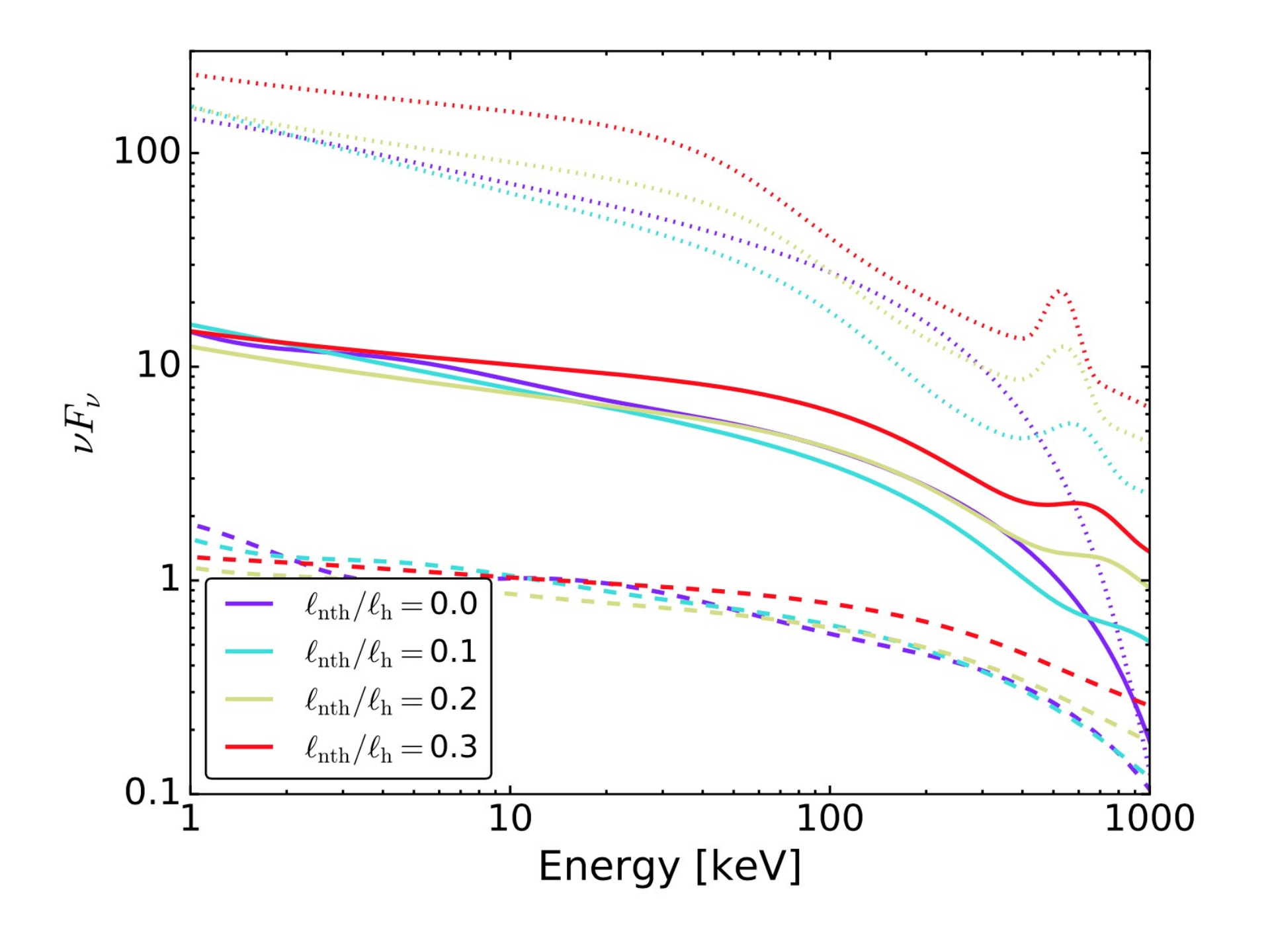
See Zdziarski+93, Ghisellini+93, Coppi99…

MAXI J1820+070



With GR corrections

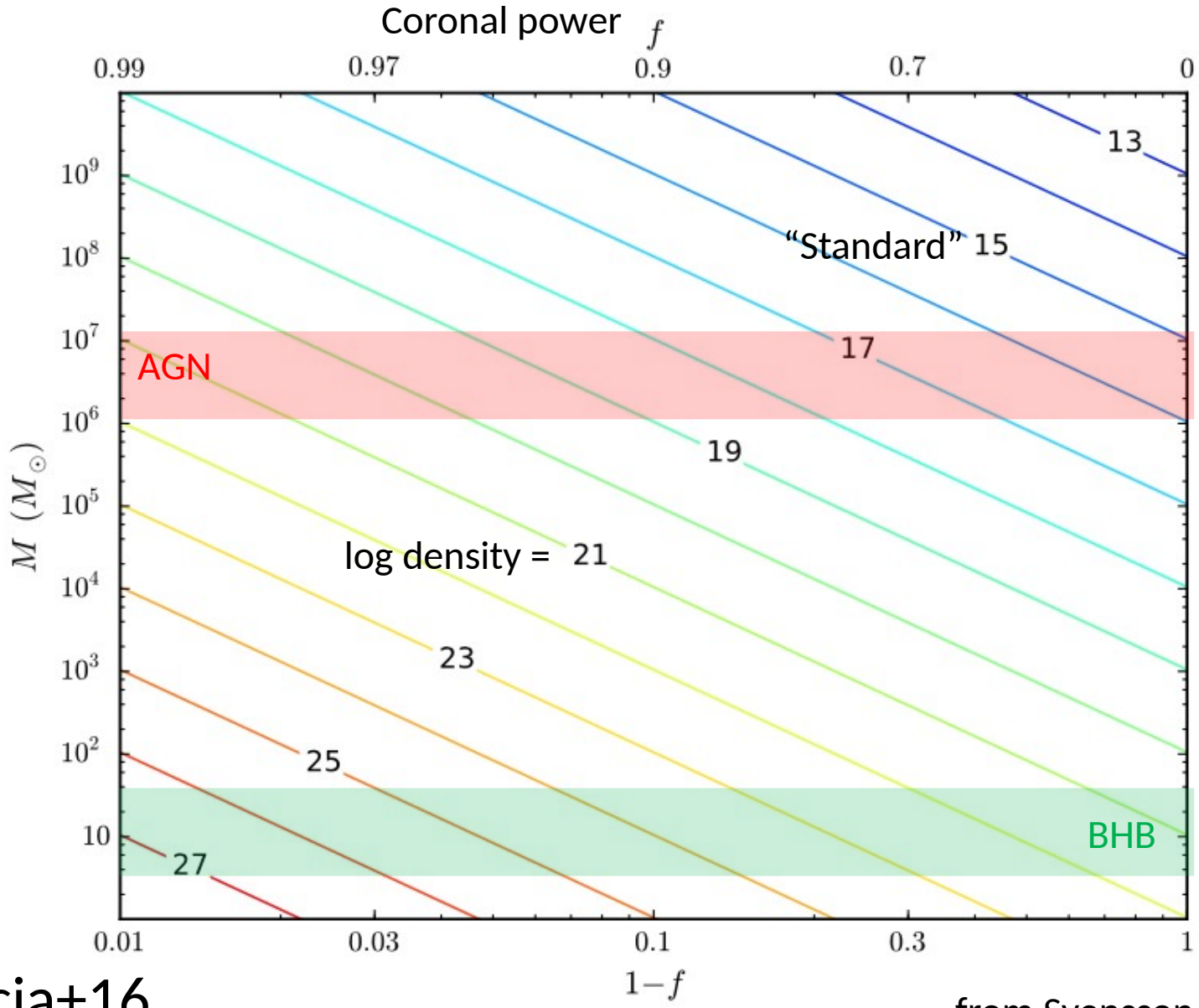



100
10
1
0.1
νF_ν
1
10
100
1000
Energy [keV]
$\ell_{\rm nth}/\ell_{\rm h} = 0.0$
$\ell_{\rm nth}/\ell_{\rm h} = 0.1$
$\ell_{\rm nth}/\ell_{\rm h} = 0.2$
$\ell_{\rm nth}/\ell_{\rm h} = 0.3$

High Density Reflection

Measuring the density of the reflecting surface

HIGH Density Reflection Models appropriate



10^8

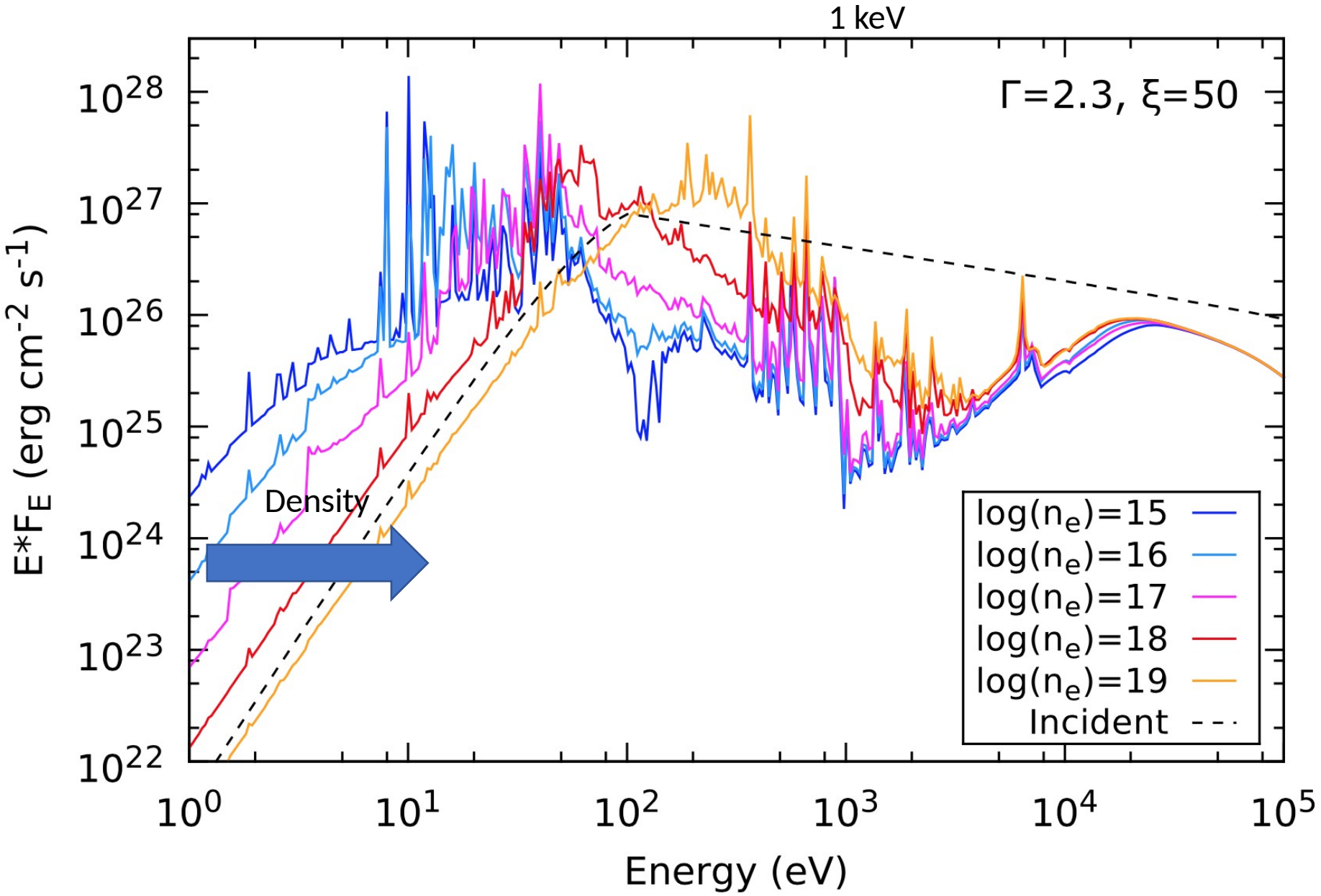
10^7

10^6

10 M_{sun}

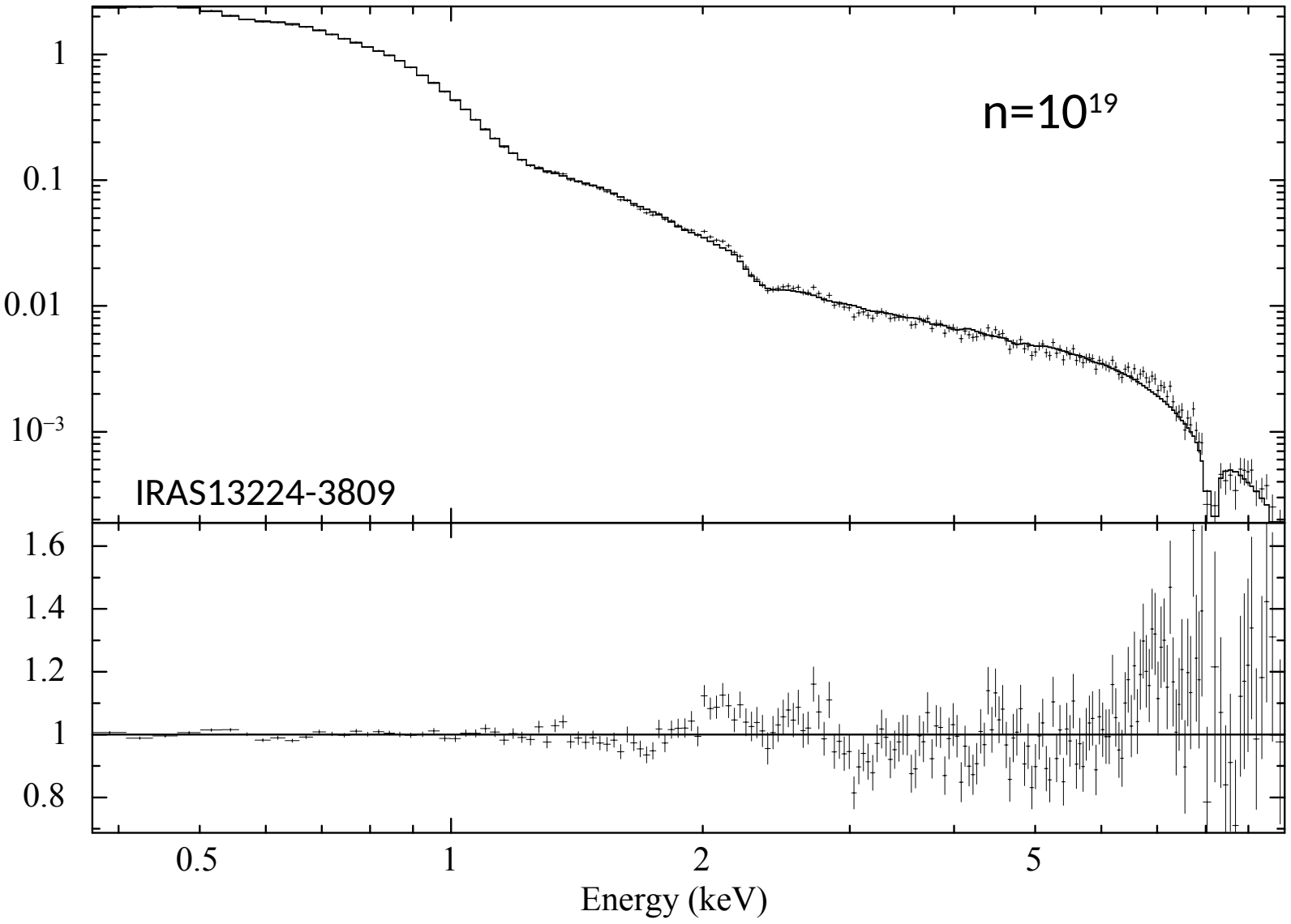
Garcia+16

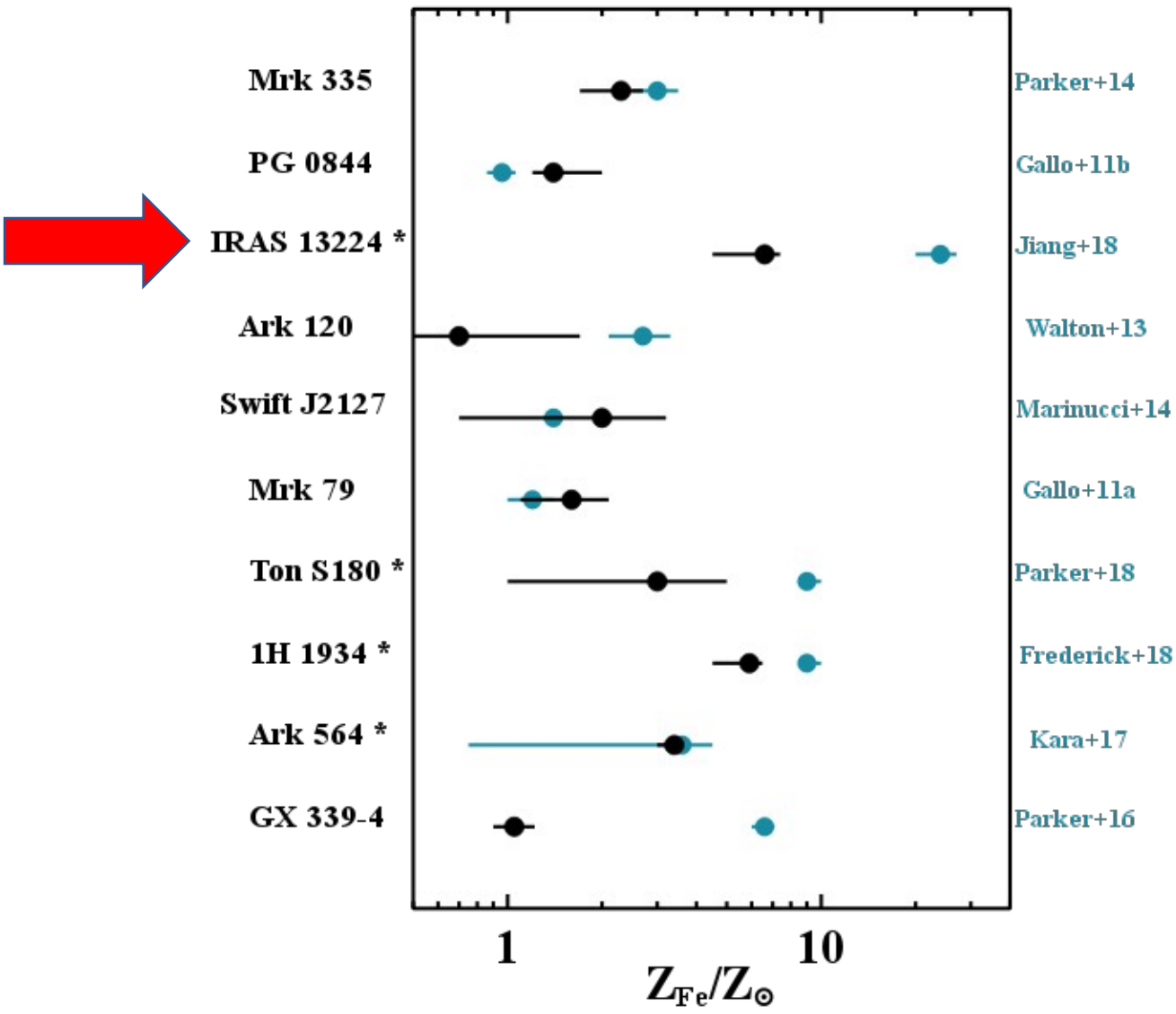
from Svensson & Zdziarski94


1 keV
Γ=2.3, ξ=50
Density
log(ne)=15
log(ne)=16
log(ne)=17
log(ne)=18
log(ne)=19
Incident
E*FE (erg cm-2 s-1)
Energy (eV)
10^28
10^27
10^26
10^25
10^24
10^23
10^22
10^0
10^1
10^2
10^3
10^4
10^5

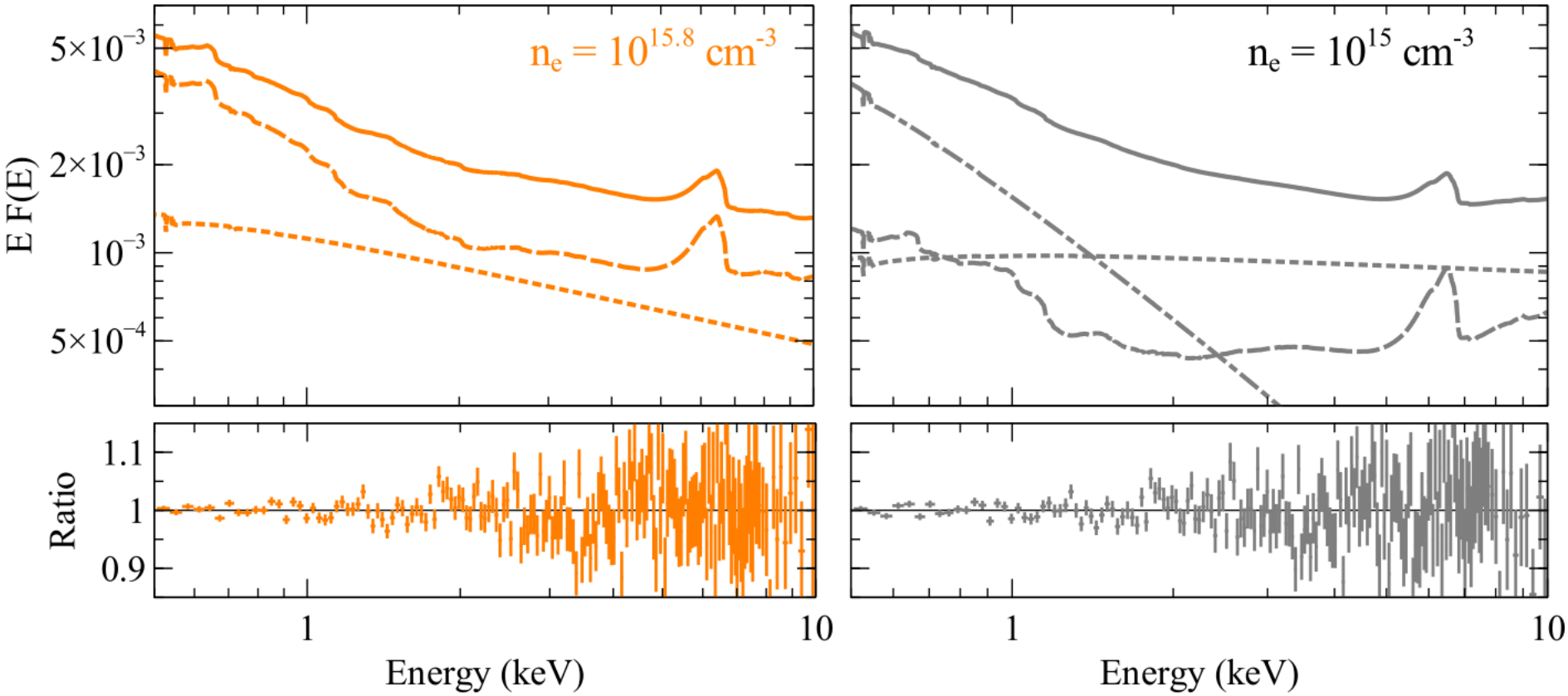
Garcia+16

High Density Fit to low state




Mrk 335
PG 0844
IRAS 13224 *
Ark 120
Swift J2127
Mrk 79
Ton S180 *
1H 1934 *
Ark 564 *
GX 339-4
Parker+14
Gallo+11b
Jiang+18
Walton+13
Marinucci+14
Gallo+11a
Parker+18
Frederick+18
Kara+17
Parker+16
1
10
$Z_{Fe}/Z_{\odot}$

Ton S180

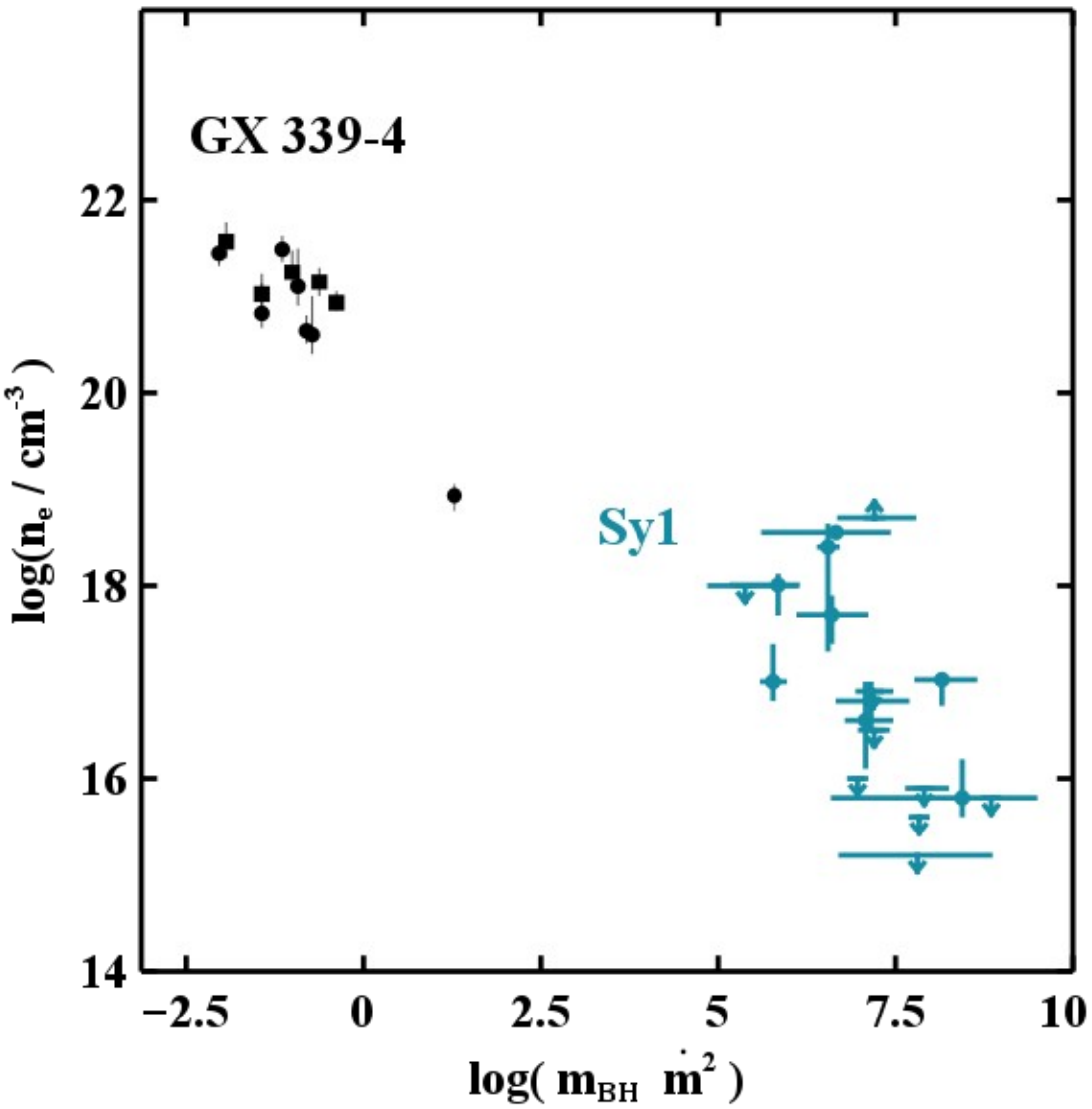


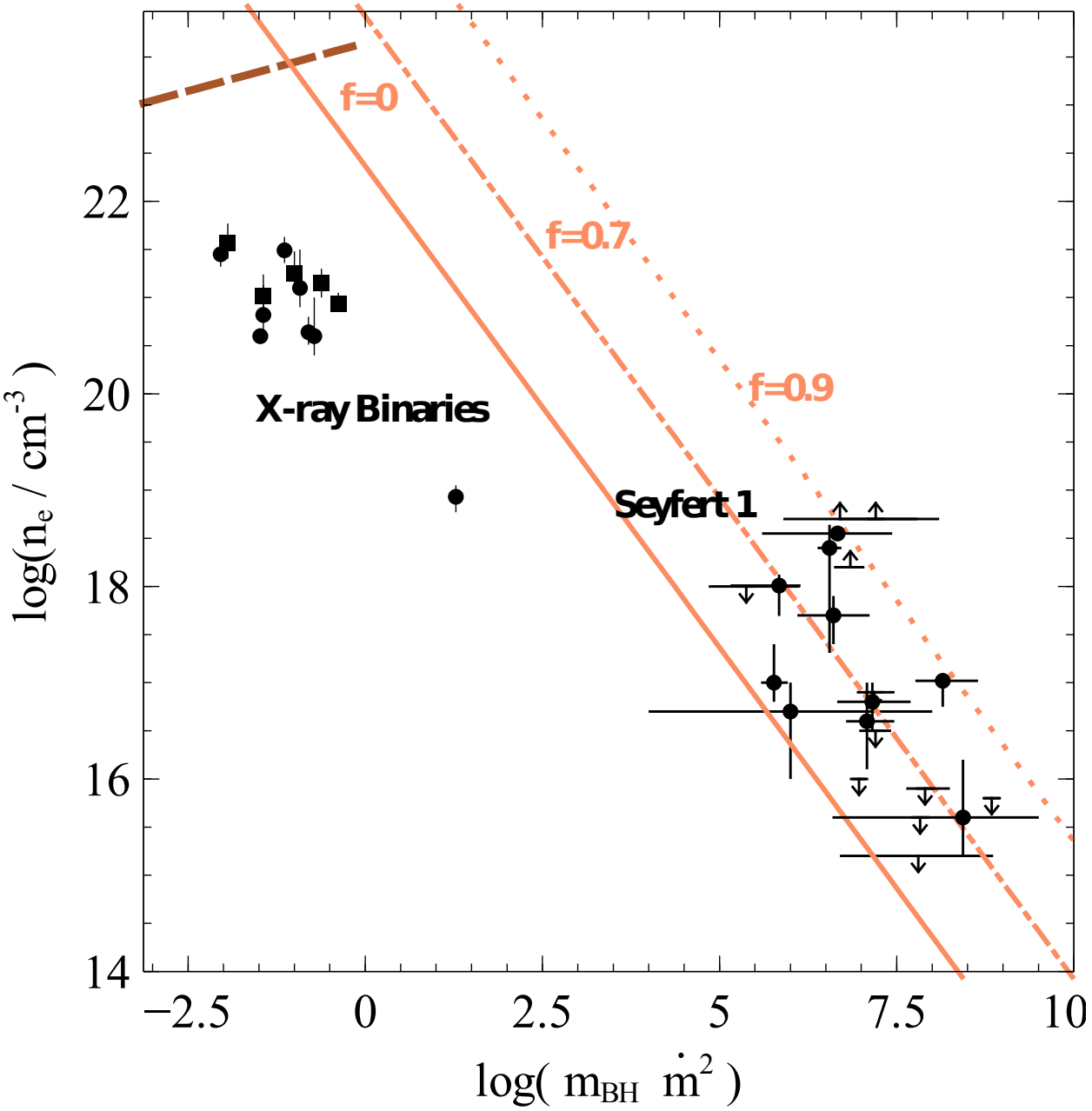
Z=3

Z=8

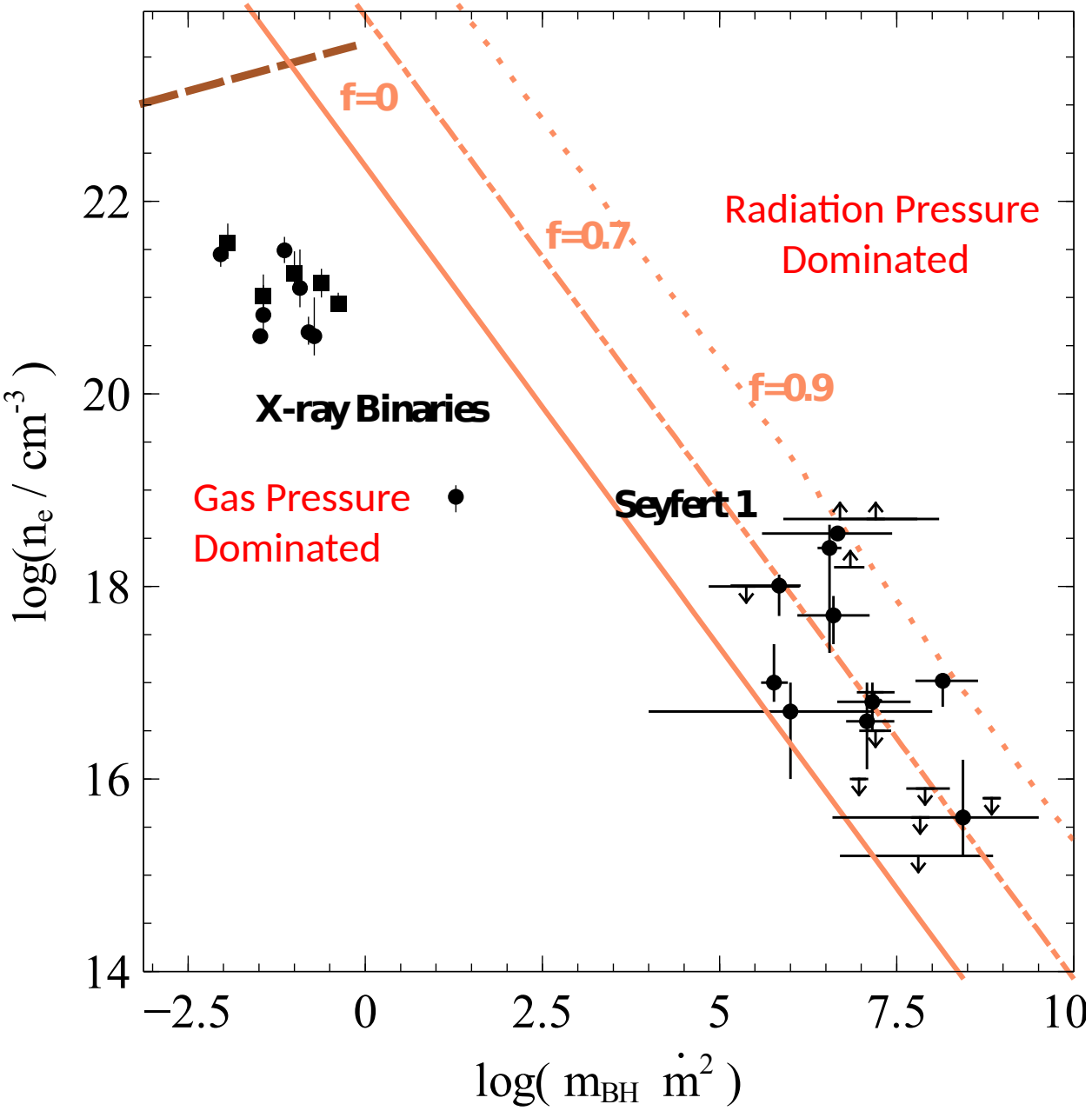
Densities $>10^{19}$ cm^{-3}

- Suite of models built by Michael Parker and Jiachen Jiang using the late Randy Ross' code REFLIONX_HD (see Fabian&Ross07).
- "There are shifts of ionization potential and K-threshold energies, albeit very minor (<<eV). The shift grows with effective charge (Zeff=Z-N+1). Meanwhile, there are virtually no shifts in the energy/wavelength of lines (Deprince et al. 2018, 2019).
- Dielectronic Recombination (DR) suppression affects heating/cooling and ionization balance. Current tests indicate enhancement of soft flux and Fe K emission, but this effect might depend on ionization (still under investigation, Garcia et al. in prep.)"
- REFLIONX_HD models applied to Cyg X-1 (Tomsick+18) and GX339-4 (Jiang+19a); RELXILLD used for low mass AGN (Jiang+19b).

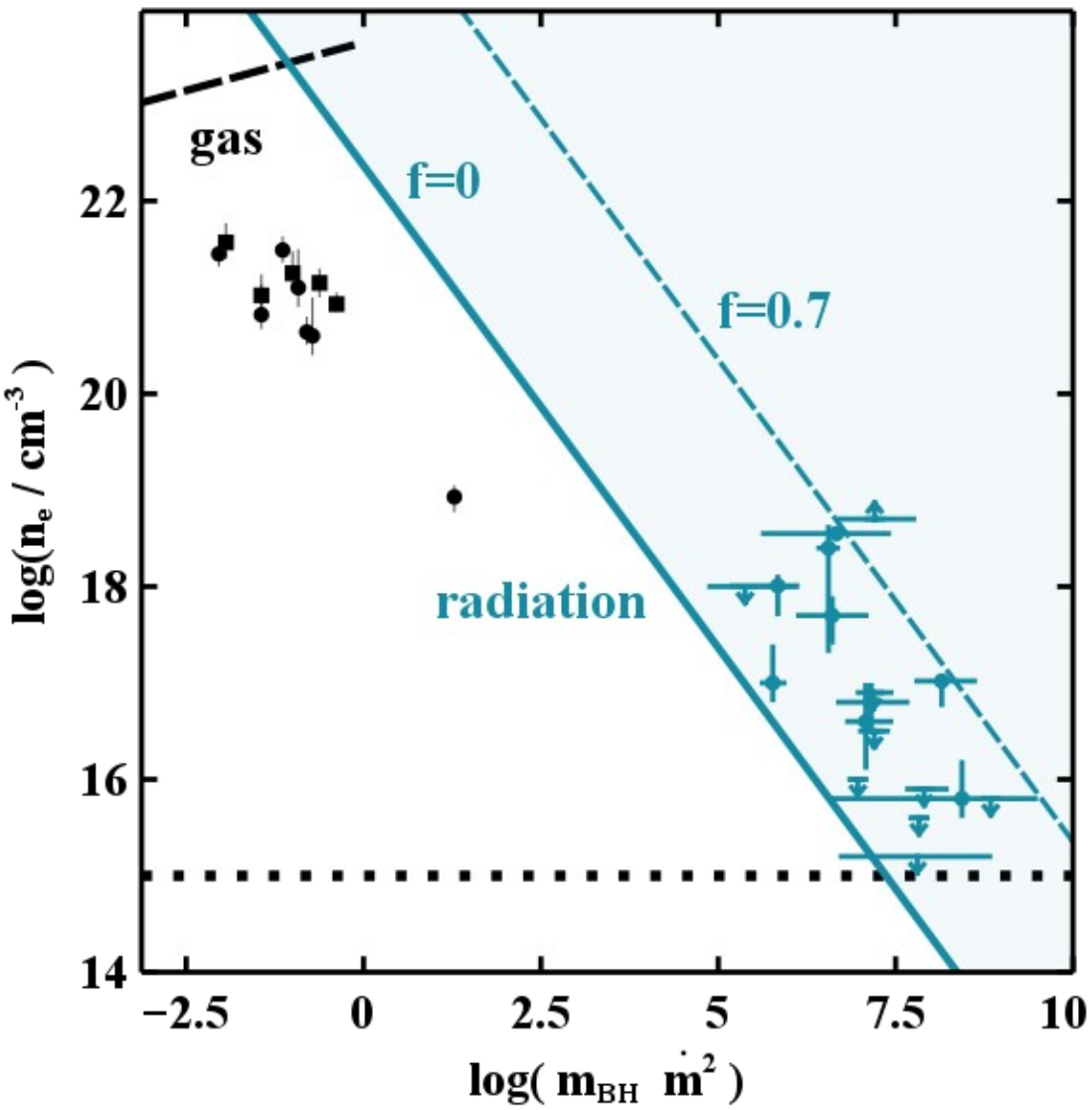

GX 339-4
Sy1
22
20
18
16
14
−2.5
0
2.5
5
7.5
10
log(n_e / cm^-3)
log(m_BH ṁ^2)

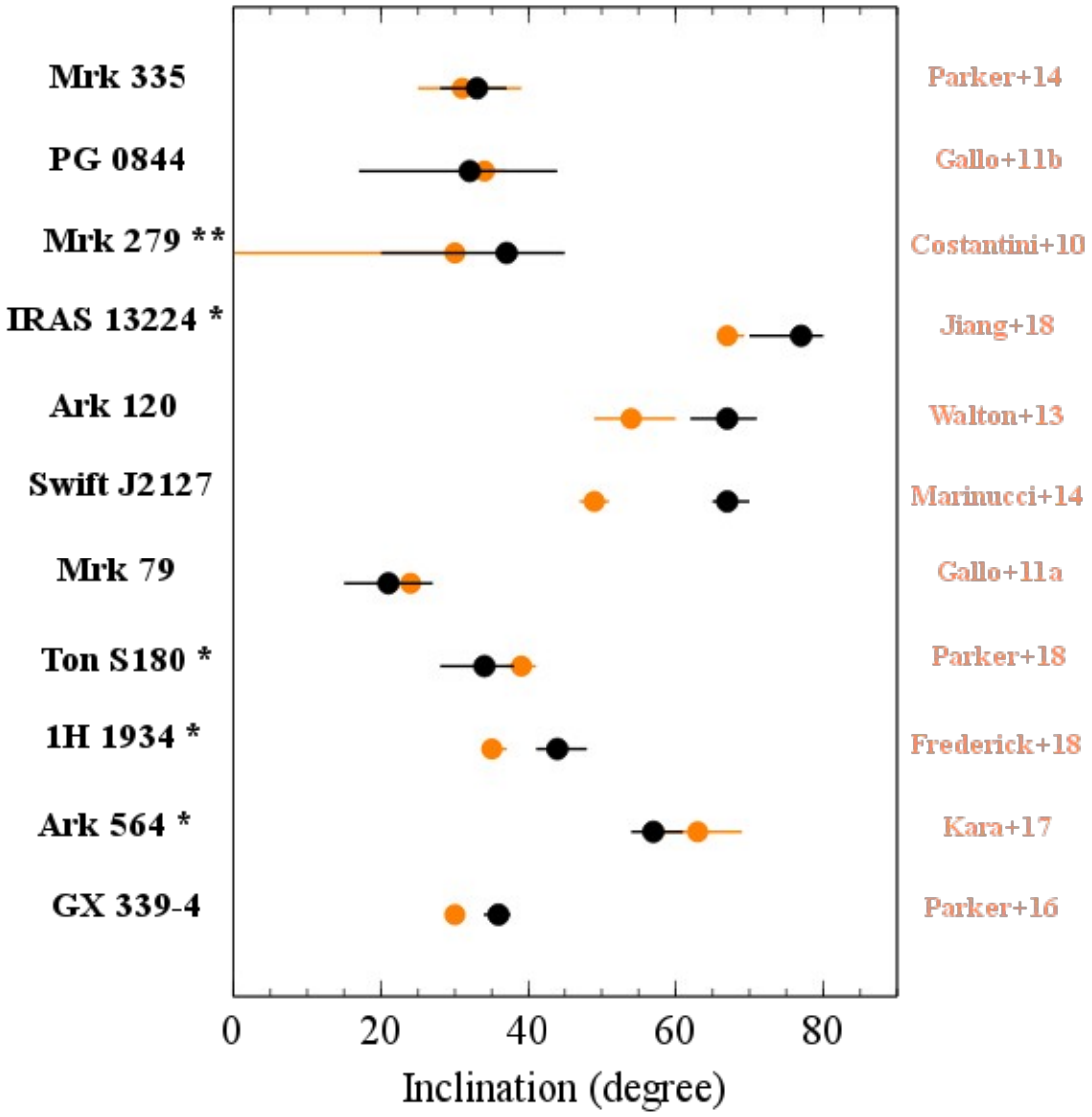

f=0
f=0.7
f=0.9
X-ray Binaries
Seyfert 1
log(n_e / cm^-3)
log(m_BH ṁ^2)
22
20
18
16
14
−2.5
0
2.5
5
7.5
10

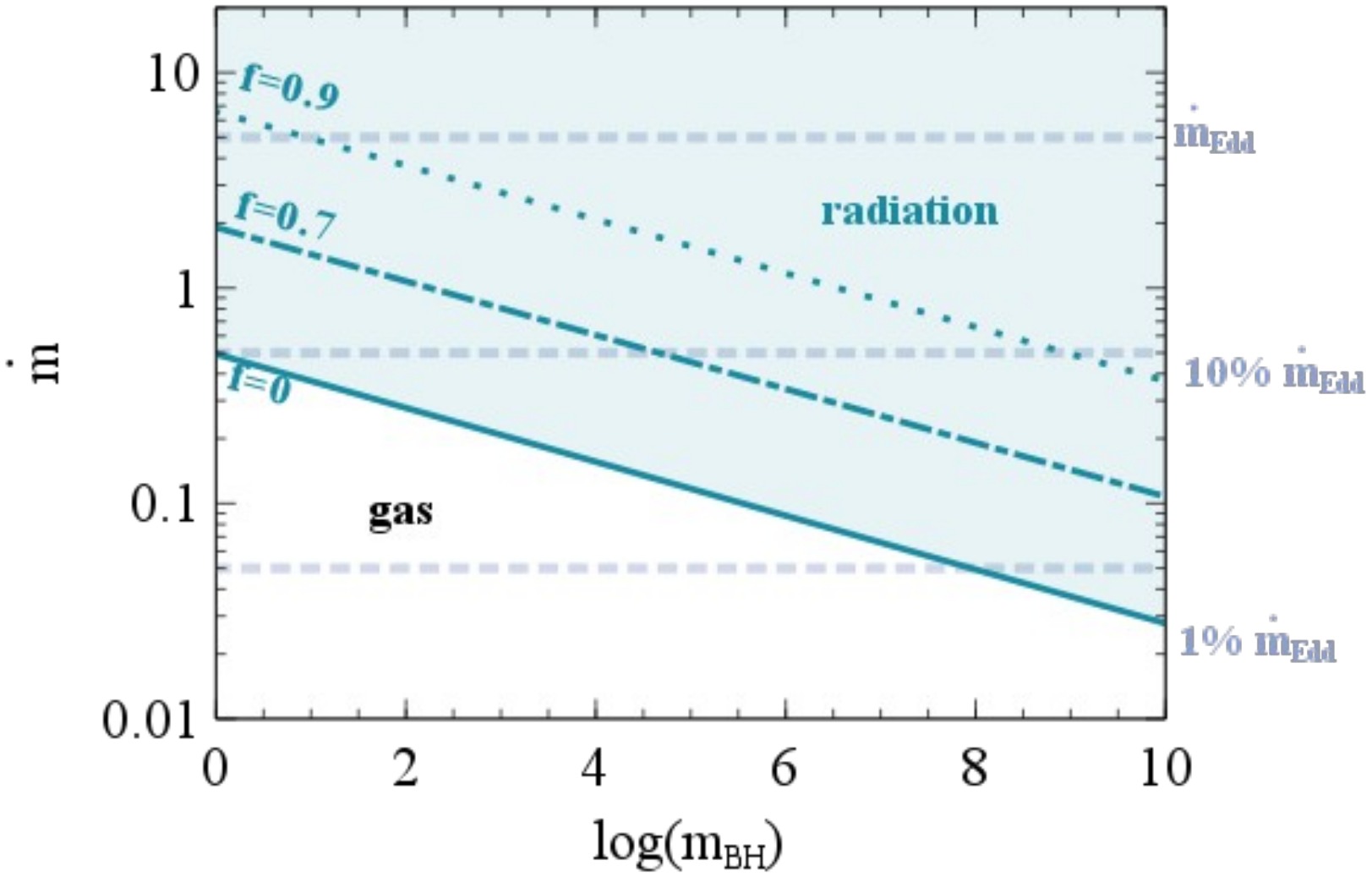
Jiang+19a,b

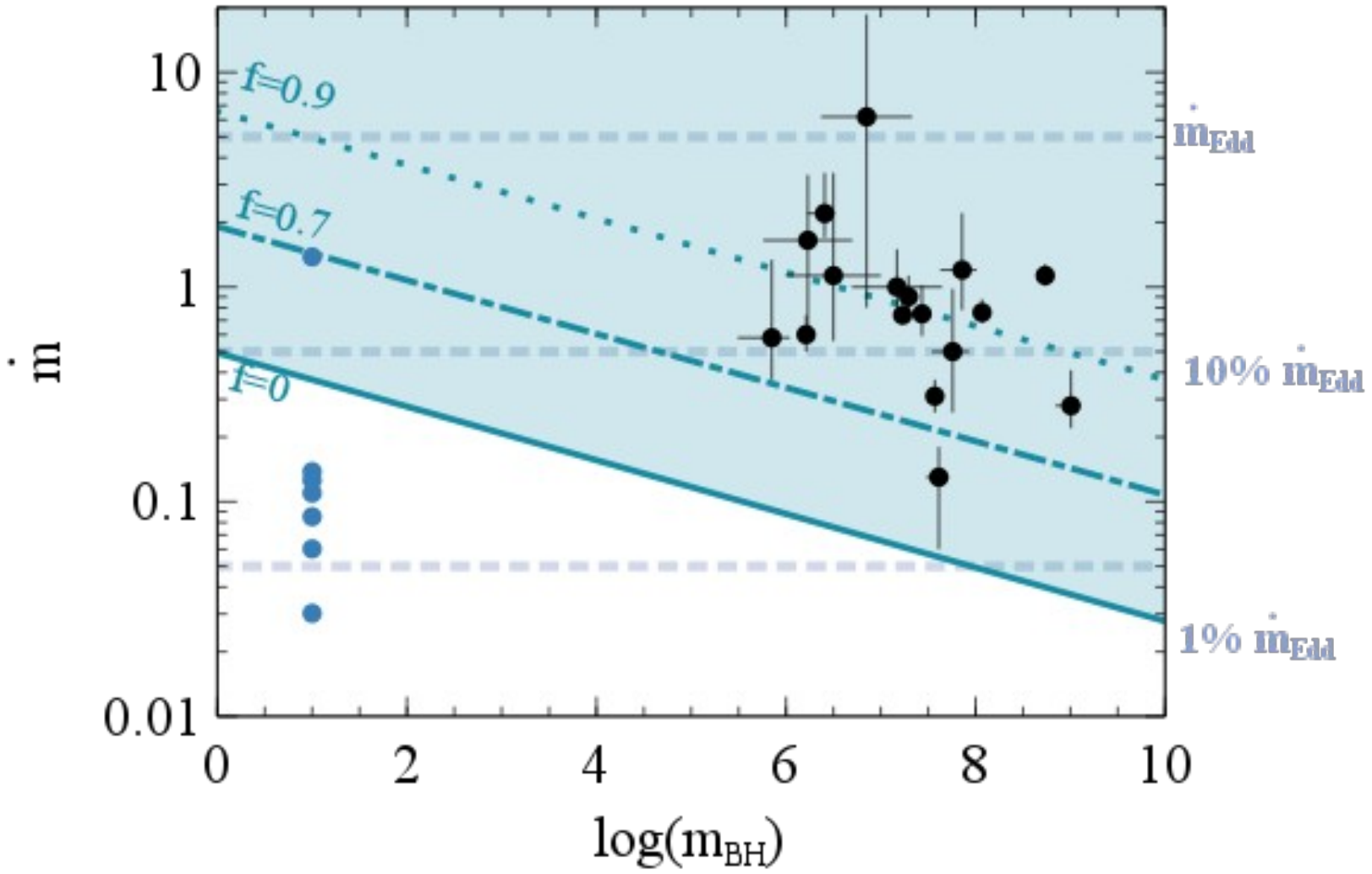

f=0
f=0.7
f=0.9
Radiation Pressure
Dominated
X-ray Binaries
Gas Pressure
Dominated
Seyfert 1
log(n_e / cm^-3)
log(m_BH ṁ^2)
22
20
18
16
14
−2.5
0
2.5
5
7.5
10

Jiang+19


gas
f=0
f=0.7
radiation
22
20
18
16
14
log(n_e / cm^-3)
−2.5
0
2.5
5
7.5
10
log(m_BH ṁ^2)


Mrk 335
PG 0844
Mrk 279 **
IRAS 13224 *
Ark 120
Swift J2127
Mrk 79
Ton S180 *
1H 1934 *
Ark 564 *
GX 339-4
Parker+14
Gallo+11b
Costantini+10
Jiang+18
Walton+13
Marinucci+14
Gallo+11a
Parker+18
Frederick+18
Kara+17
Parker+16
0
20
40
60
80
Inclination (degree)


10
1
0.1
0.01
0
2
4
6
8
10
log(m_BH)
ṁ
f=0.9
f=0.7
f=0
radiation
gas
ṁ_Edd
10% ṁ_Edd
1% ṁ_Edd

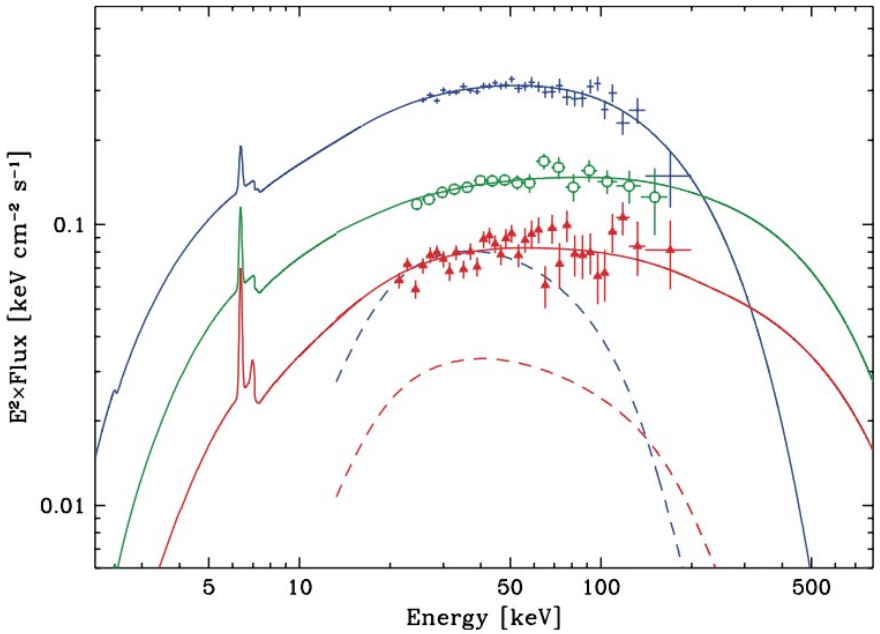

10
1
0.1
0.01
0
2
4
6
8
10
ṁ
log(m_BH)
f=0.9
f=0.7
f=0
ṁ_Edd
10% ṁ_Edd
1% ṁ_Edd

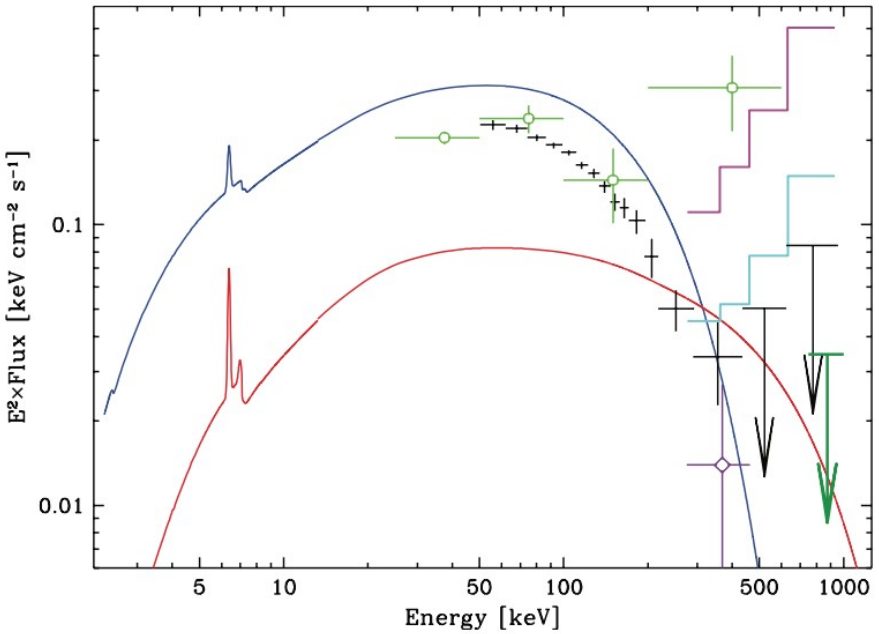
- High density reflection is important for BHB and AGN with $M_{BH} < 5 \times 10^7 M_{sun}$.

- Extraction of energy from disc to corona plays an important role.

- Discs in luminous AGN are radiation-pressure supported and discs in BHB gas-pressure supported following results from SZ94 (i.e. modified SS73).

NGC4151



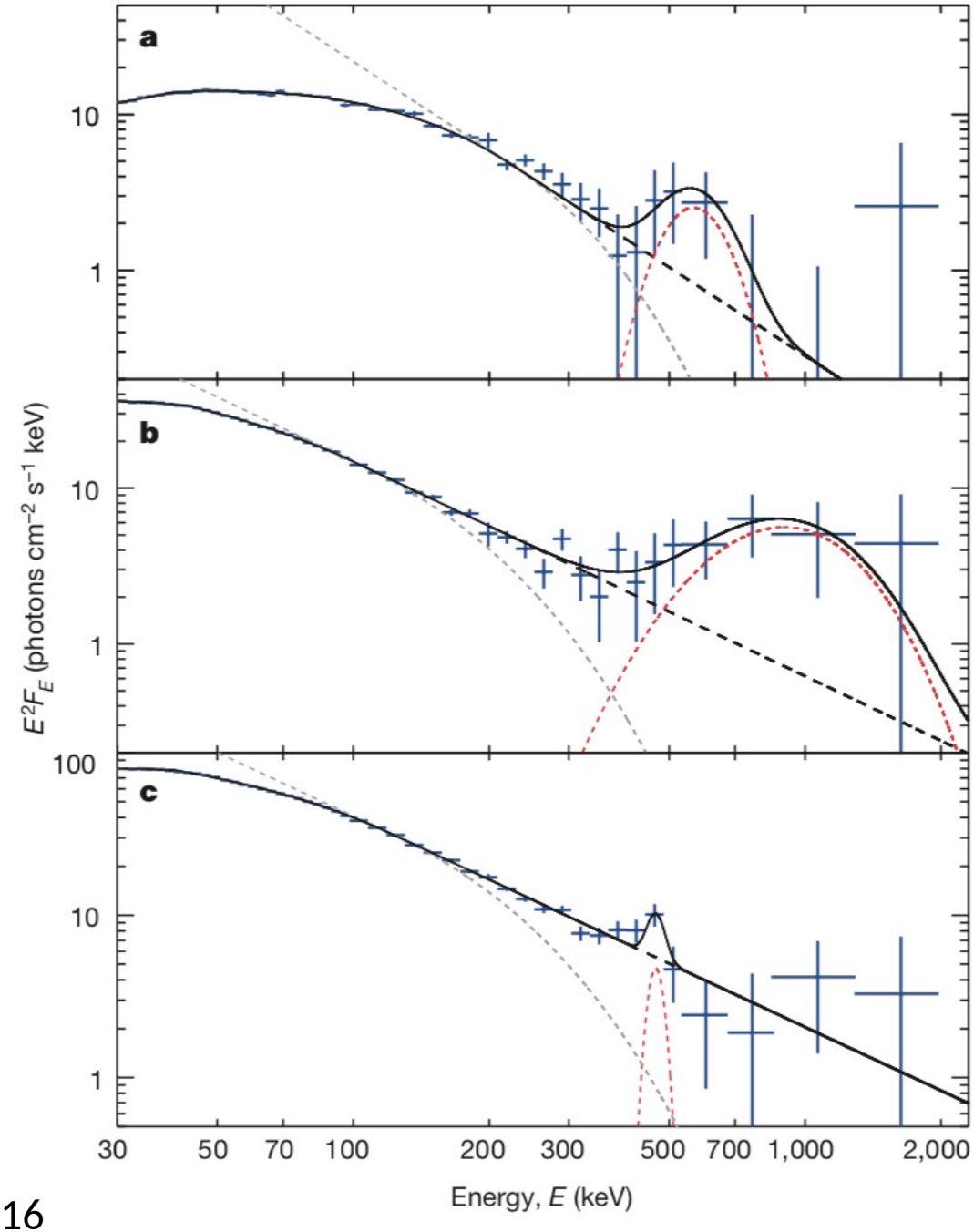


INTEGRAL

OSSE, Comptel

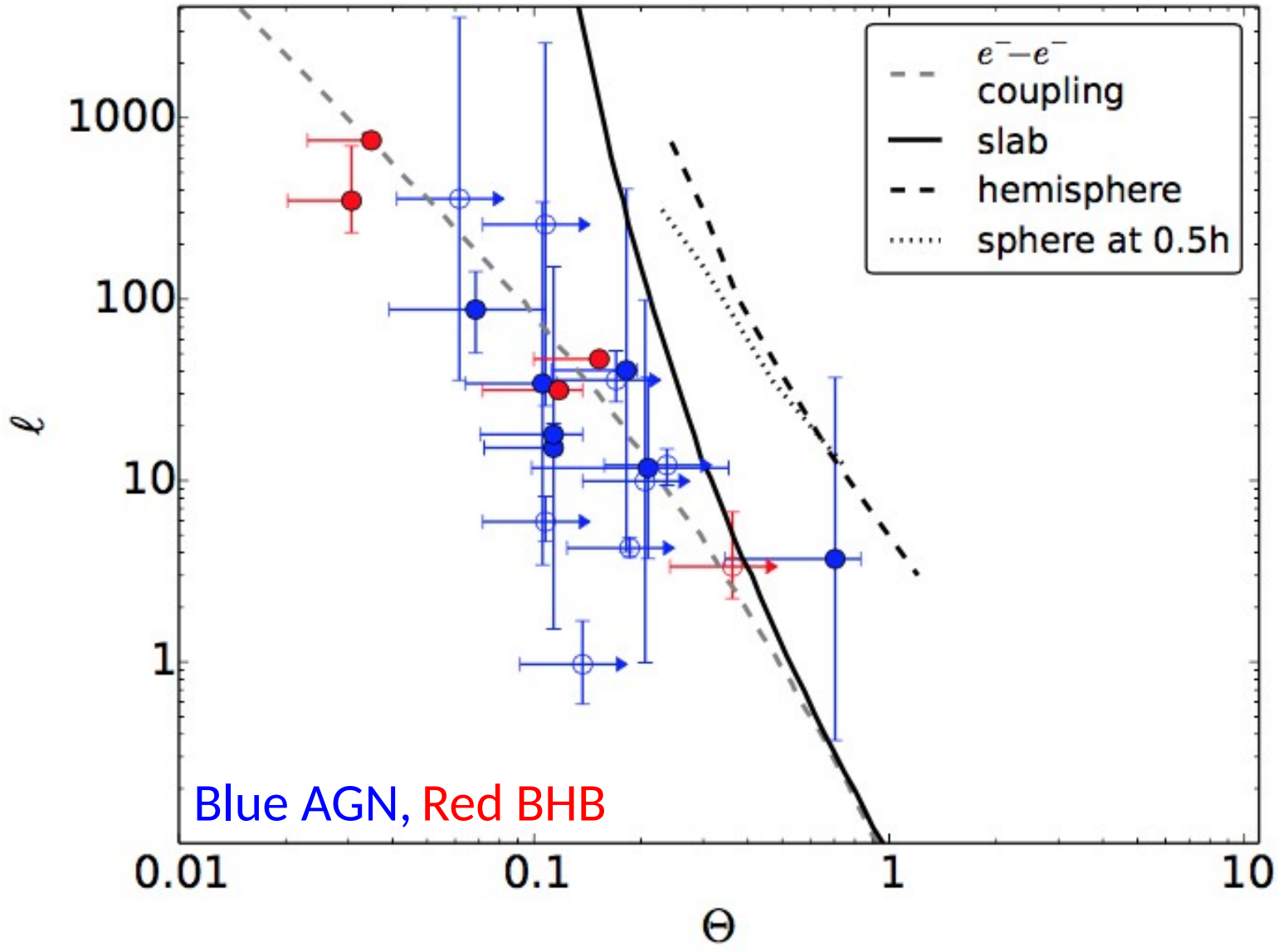
INTEGRAL/PICsIT SPI

Lubinski+10 see alsoKeck+15, Beuchert+17



INTEGRAL Siegert+16

NuSTAR results



R=10r_g unless indications otherwise Fabian+15