Technion - Israel Institute of Technology

# What sets the covering factor of the BLR and the innermost torus?

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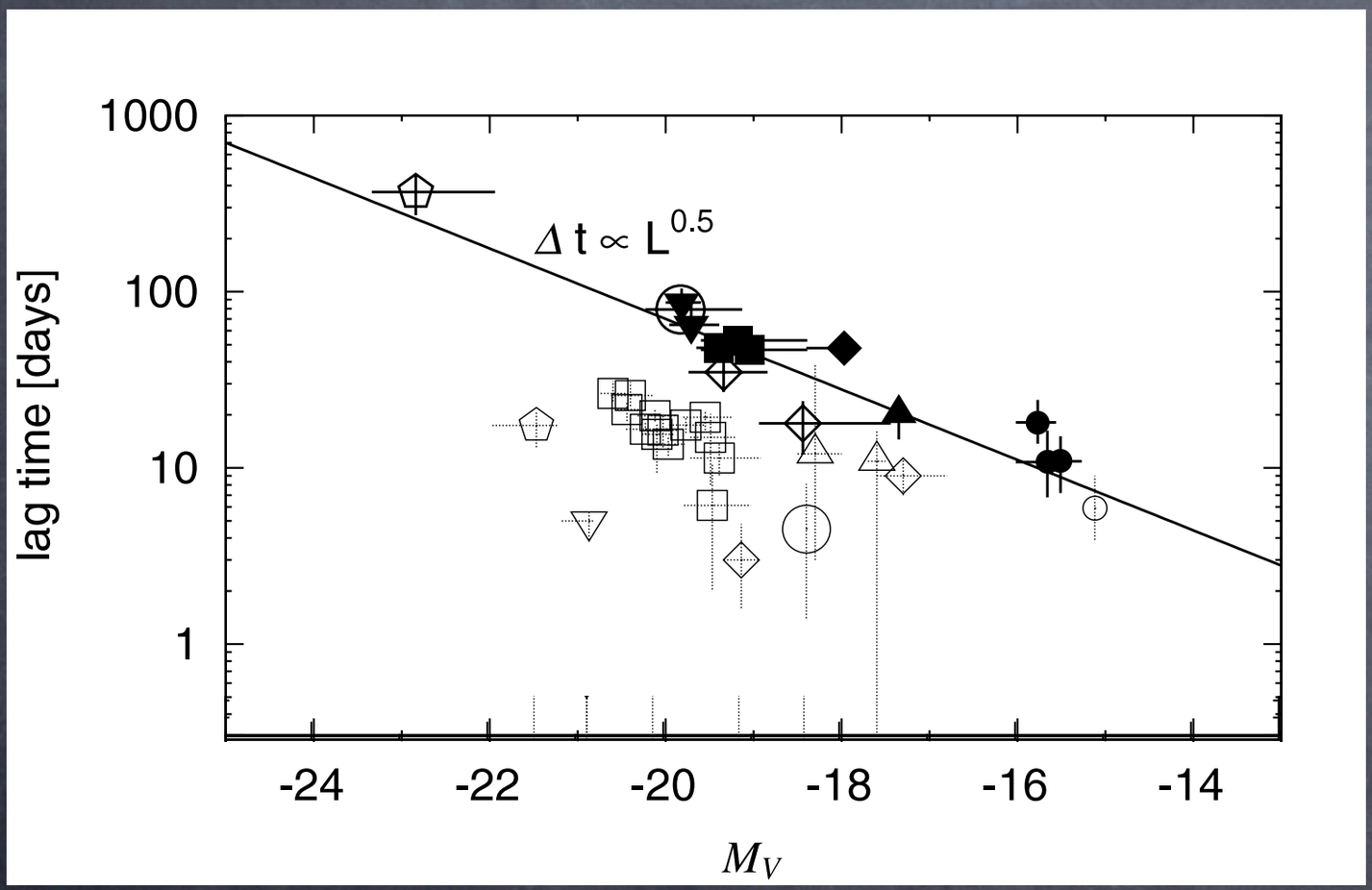
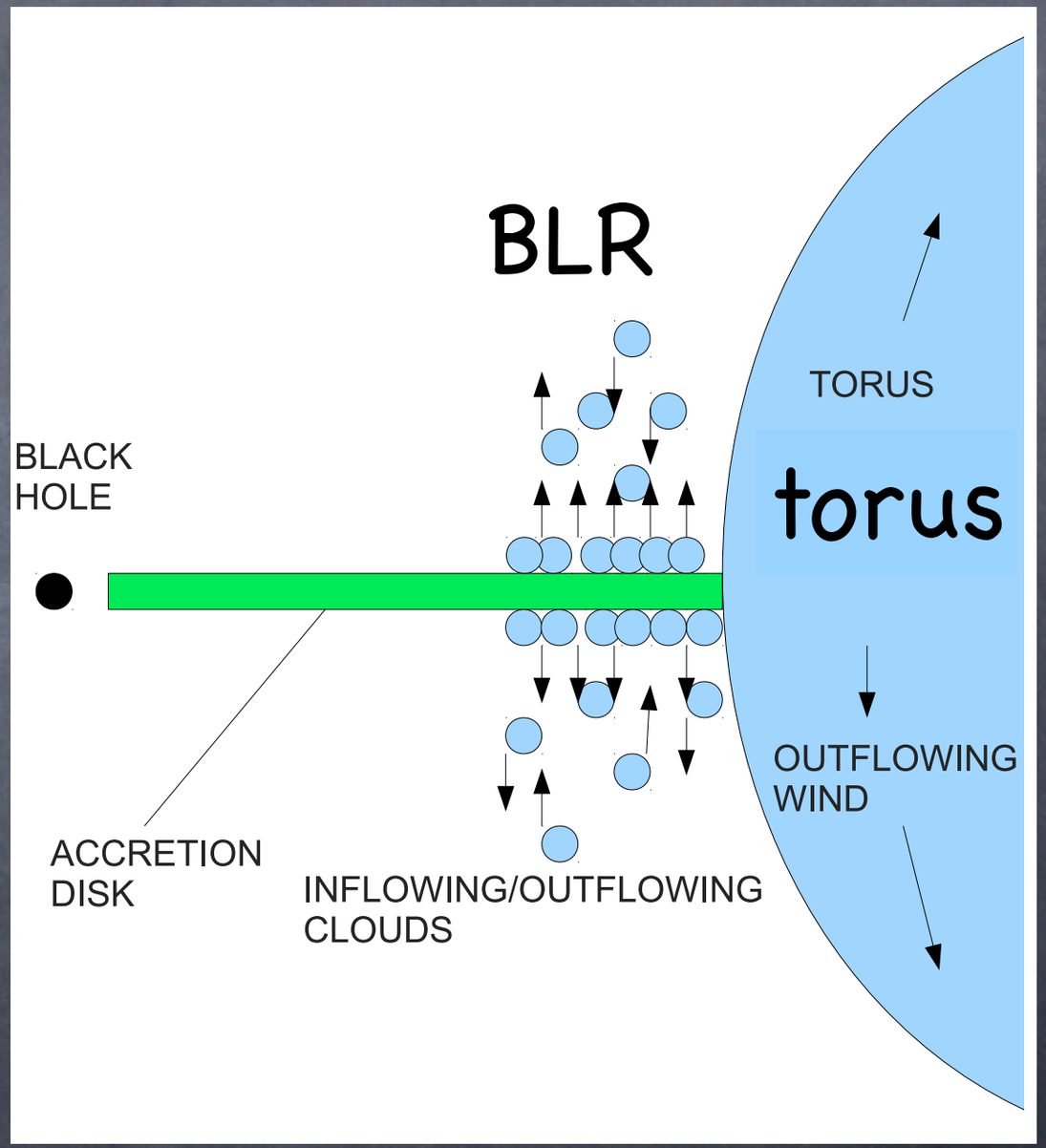
Work in progress
Preliminary results

TORUS 2015, Winchester, UK, September 2015

# The BLR is located just inward to the torus

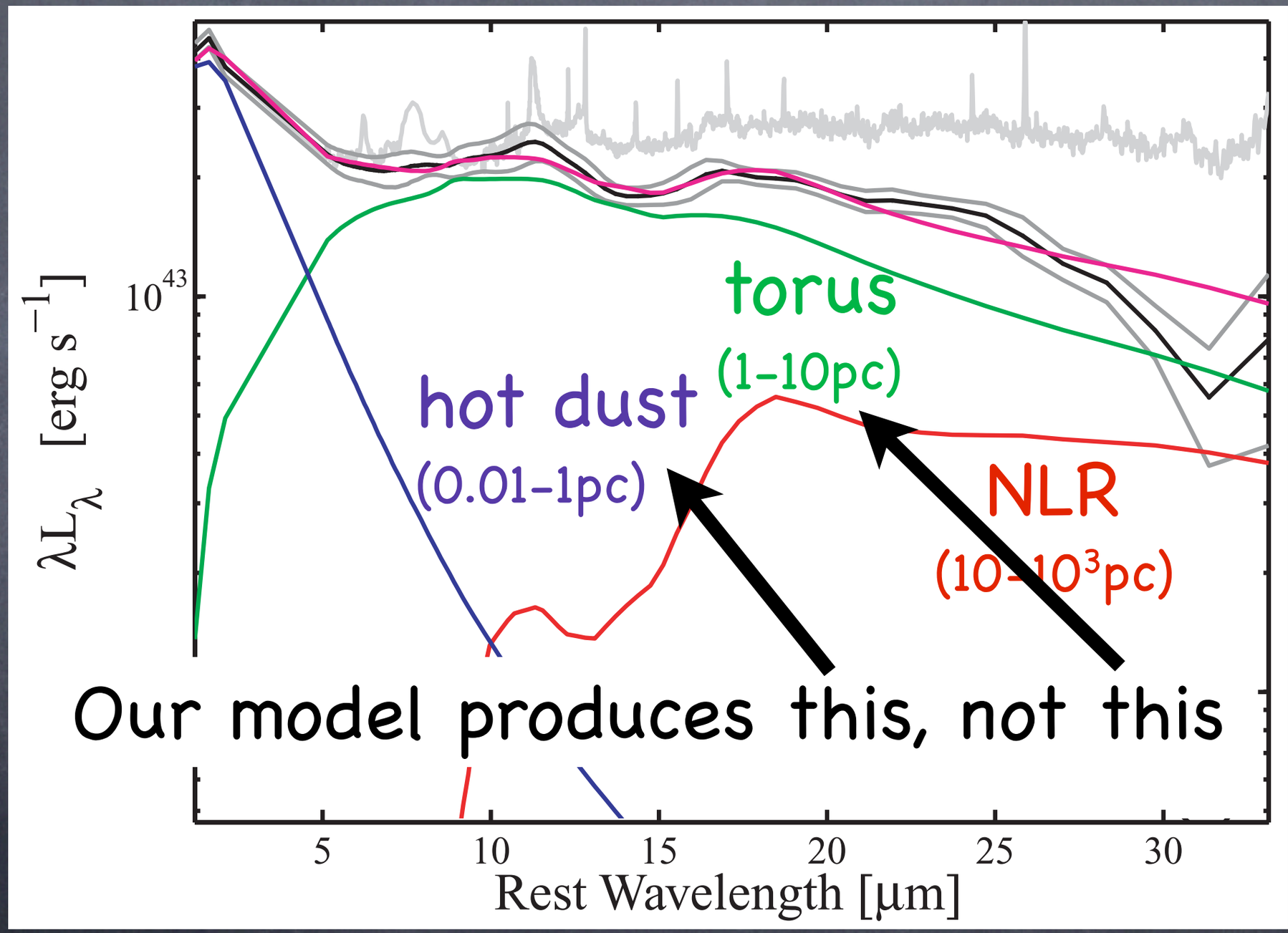



Suganuma+06
(see also Koshida+14)




Czerny & Hryniewicz (2011)

# What torus are we talking about?




Mor & Netzer (2012)

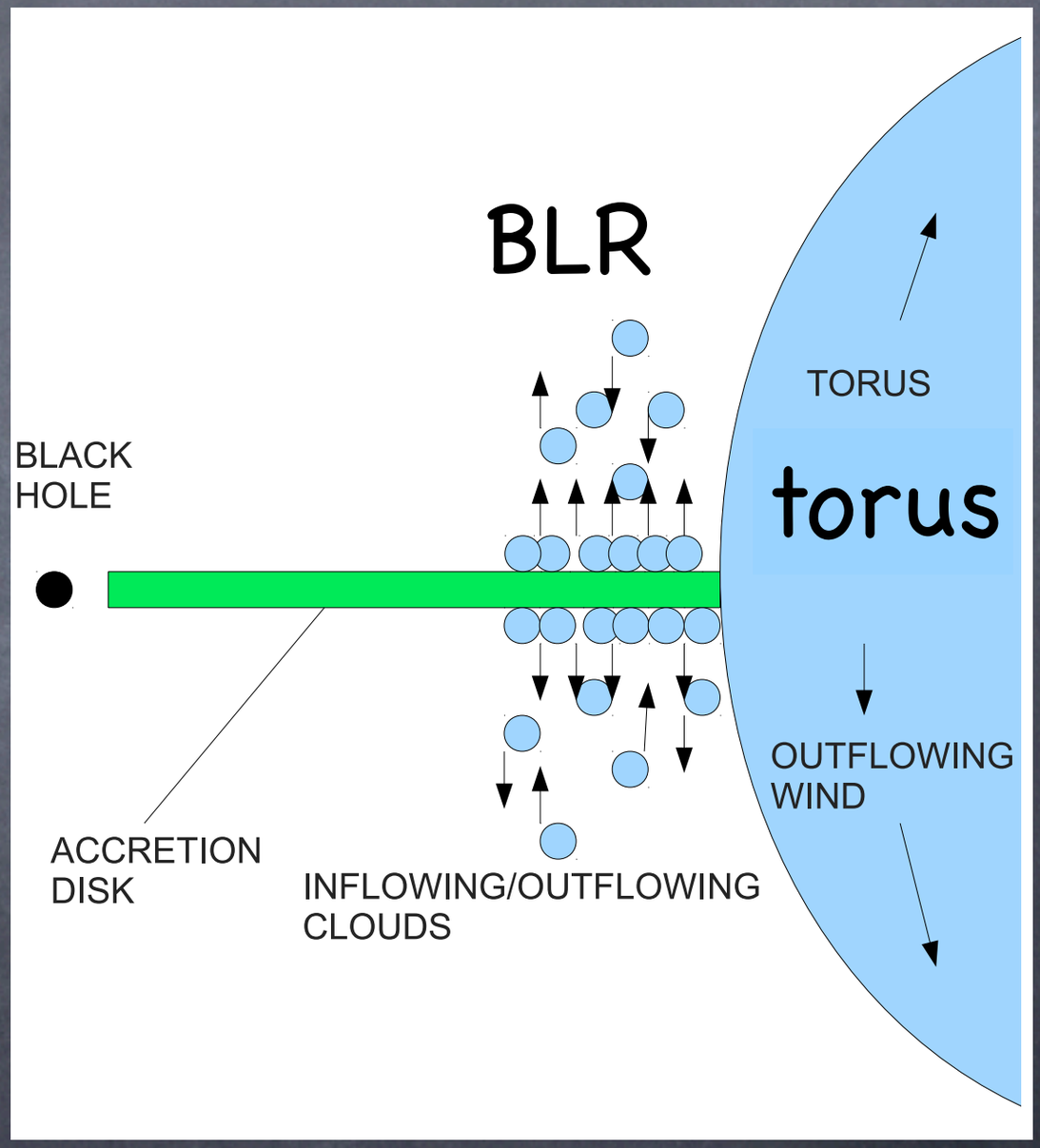
# Lifting the BLR gas by disc radiation pressure on dust

- The driving force: Flux

$$f_{\rm rad} = \frac{\kappa_{\rm dust}}{c} \frac{3}{8\pi} \frac{GM_{\rm BH}}{R^3} \dot{M}$$

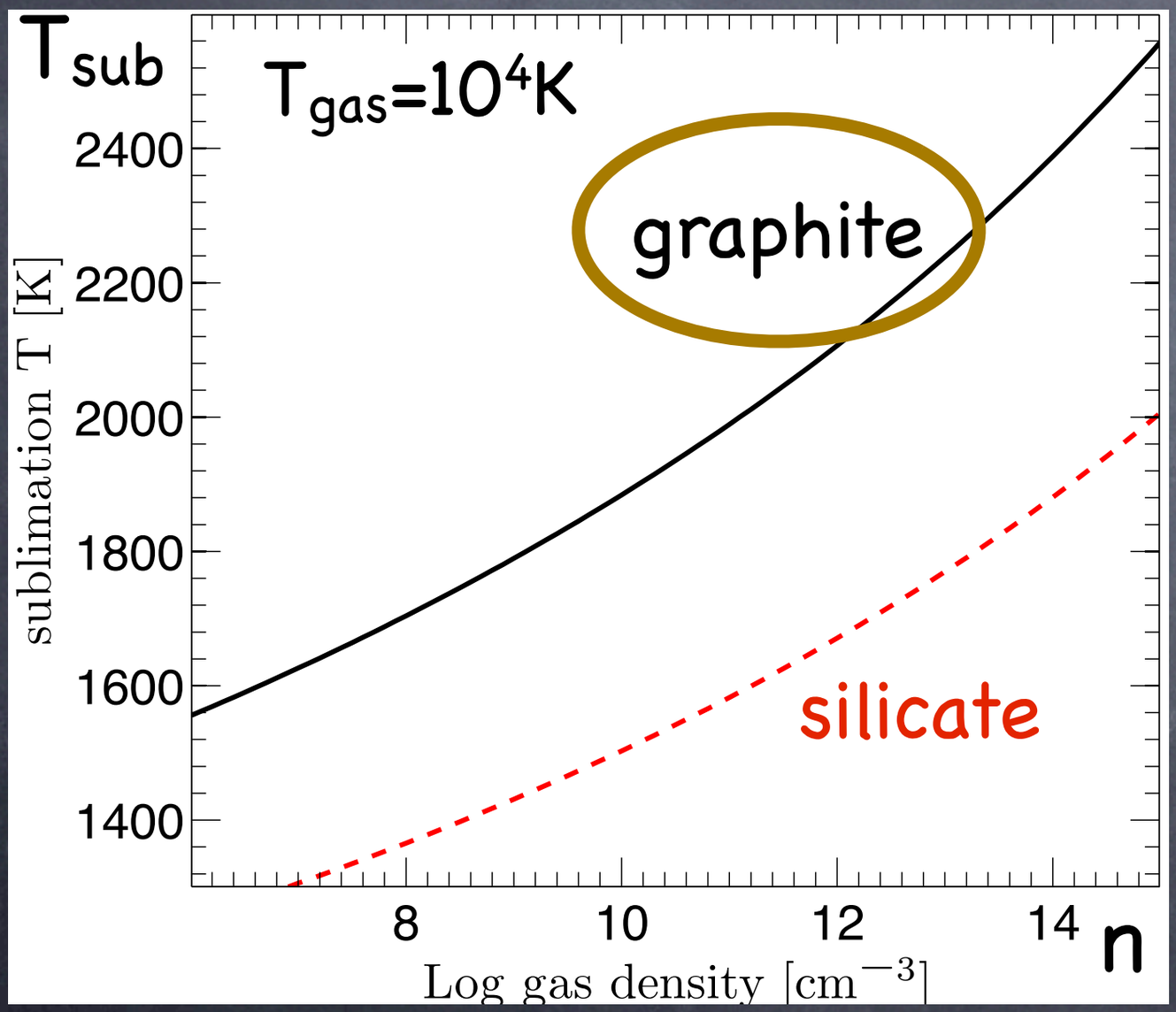
- $\kappa_{\rm dust}(a_{\rm min}, a_{\rm max}, \beta, Z, {\rm comp'})$

- gas+dust elevated ==> dust exposed to AGN ==> dust sublimates ==> BLR line emission




Czerny & Hryniewicz (2011)

# The dust sublimation T vs. the gas density




$P_{sat} \approx 6 \times 10^{11} T^{0.5} \exp[-T_0/T]$

$T_0$=81,200K for graphite,
$T_0$=68,100K for silicate
(Guhathakurta & Draine, 1989)

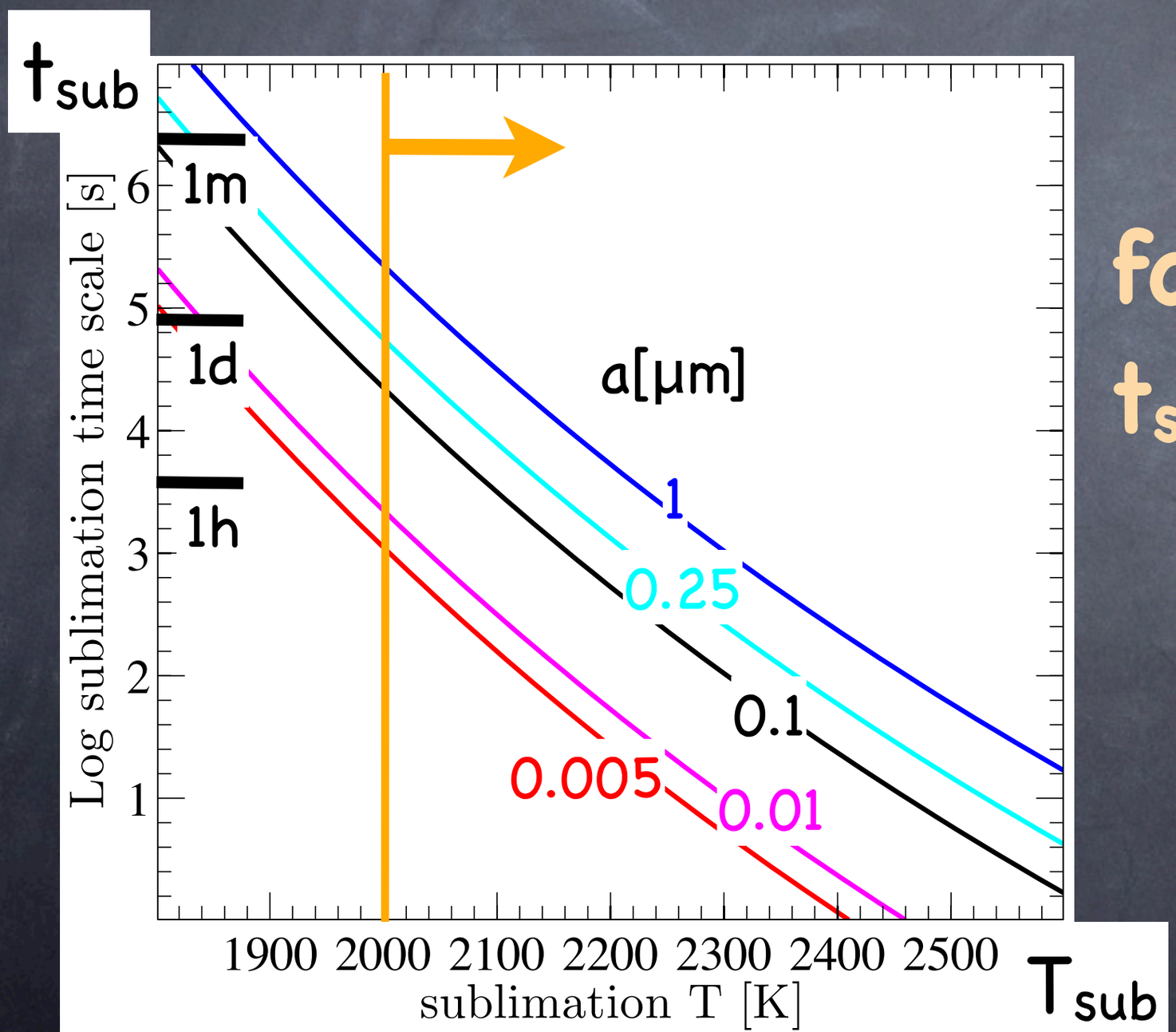
**the innermost hottest dust is graphite**

for $n \sim 10^{14}$, $T_{sub} \sim$ 2400K
for $n \sim 10^{11}$, $T_{sub} \sim$ 2000K

# The sublimation timescale for graphite

$t_{sub} = N / [dN/dt] \approx [4\pi/3\ a^3\ \rho/m_C] / [n_{C,sat}\ v_C\ 4\pi a^2]$

$v_C = (2kT_{gas}/m_C)^{0.5}$




for T≳2000K,
$t_{sub}$ < a few days

# $T_{grain}$ vs. grain size

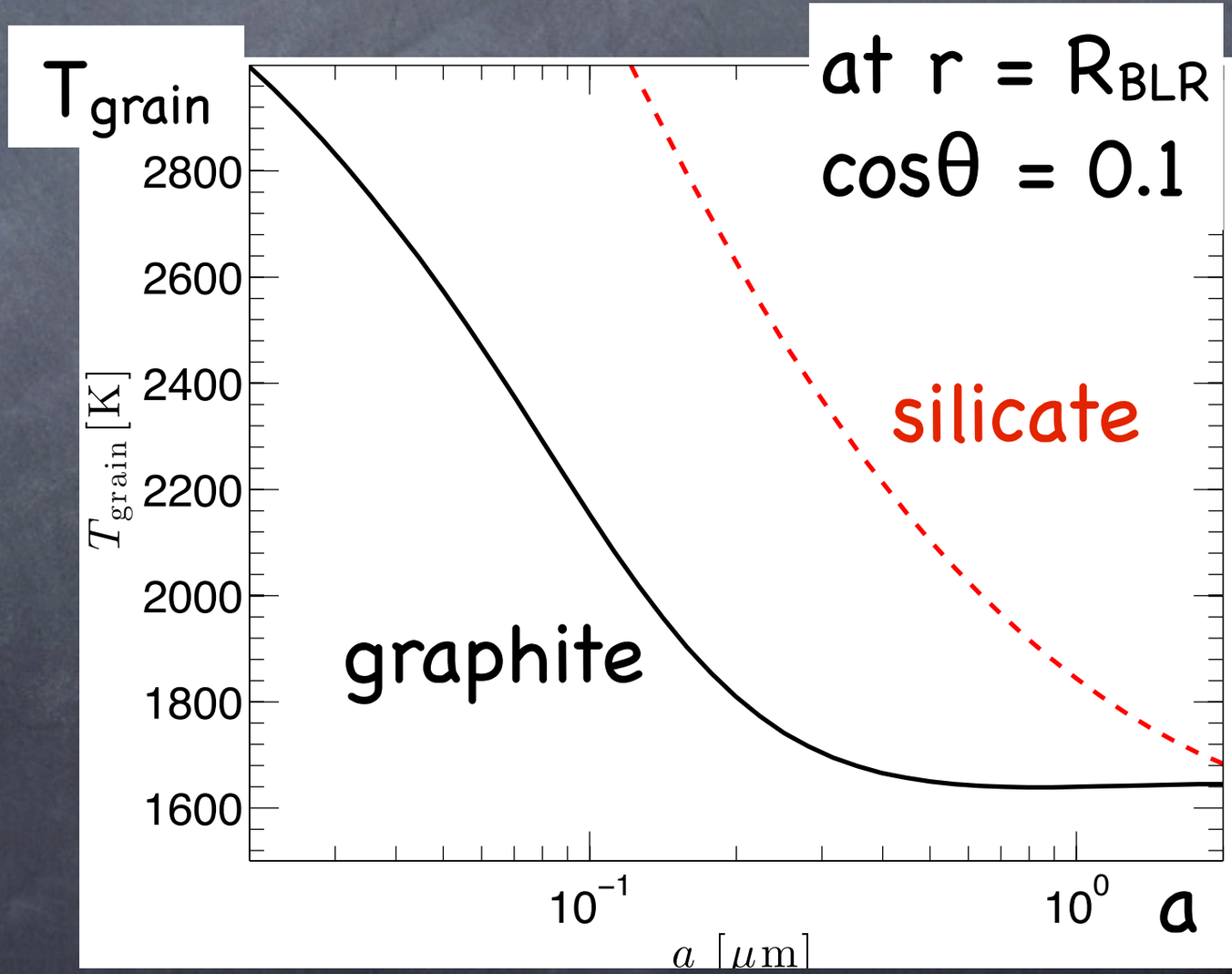
cooling = heating

$$\mathrm{cooling} = 4\pi a^2 \times \int \pi B_\nu(T_{\mathrm{grain}}) Q_{\mathrm{abs}}(a,\nu)\mathrm{d}\nu$$

$$\mathrm{heating} = \pi a^2 \times \int \frac{2L_\nu \cos\theta}{4\pi r^2} Q_{\mathrm{abs}}(a,\nu)\mathrm{d}\nu$$

disc emission

At given r and a, graphite grains are cooler



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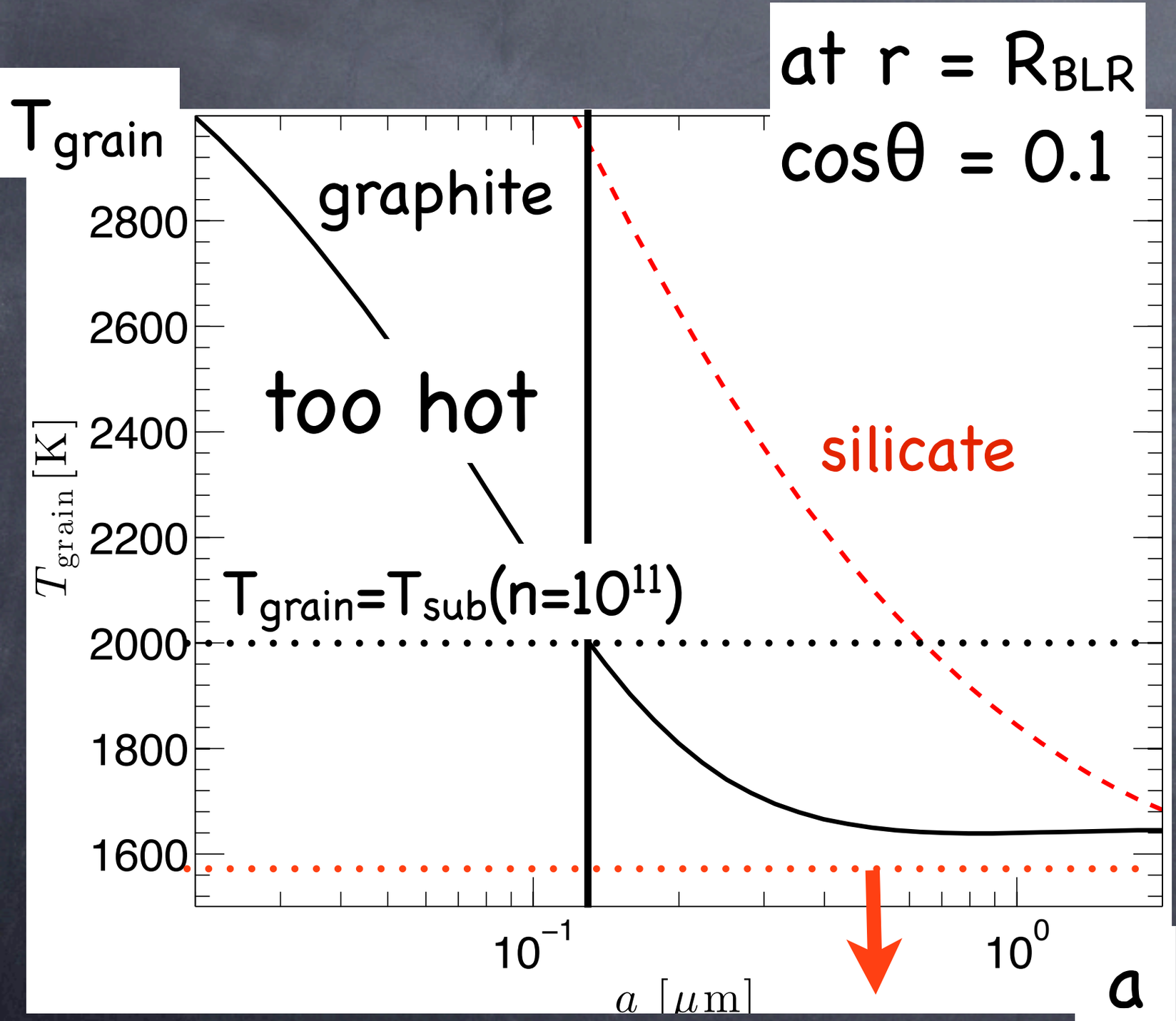
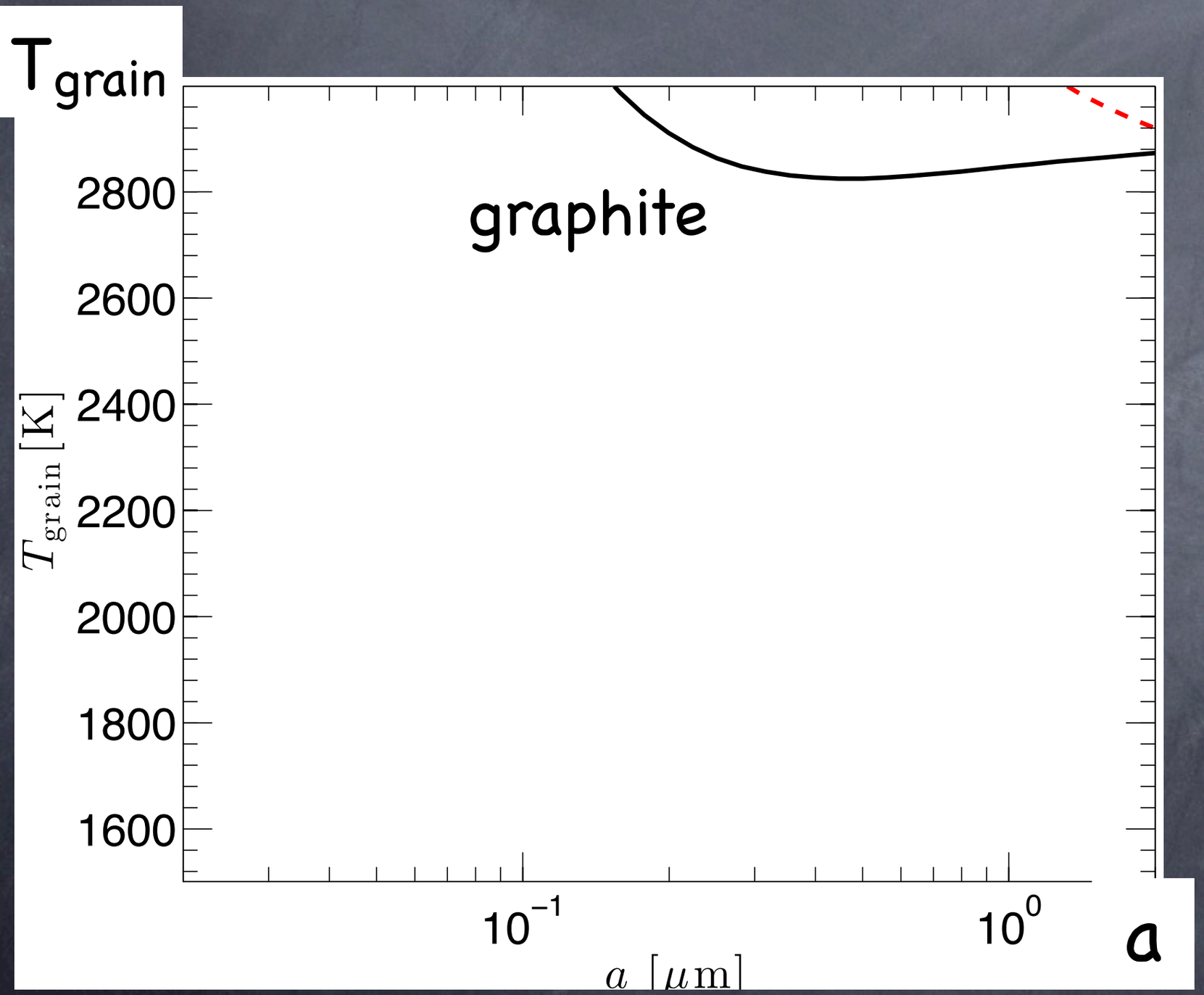



The driving is by large ($a \gtrsim 0.1$) graphite grains

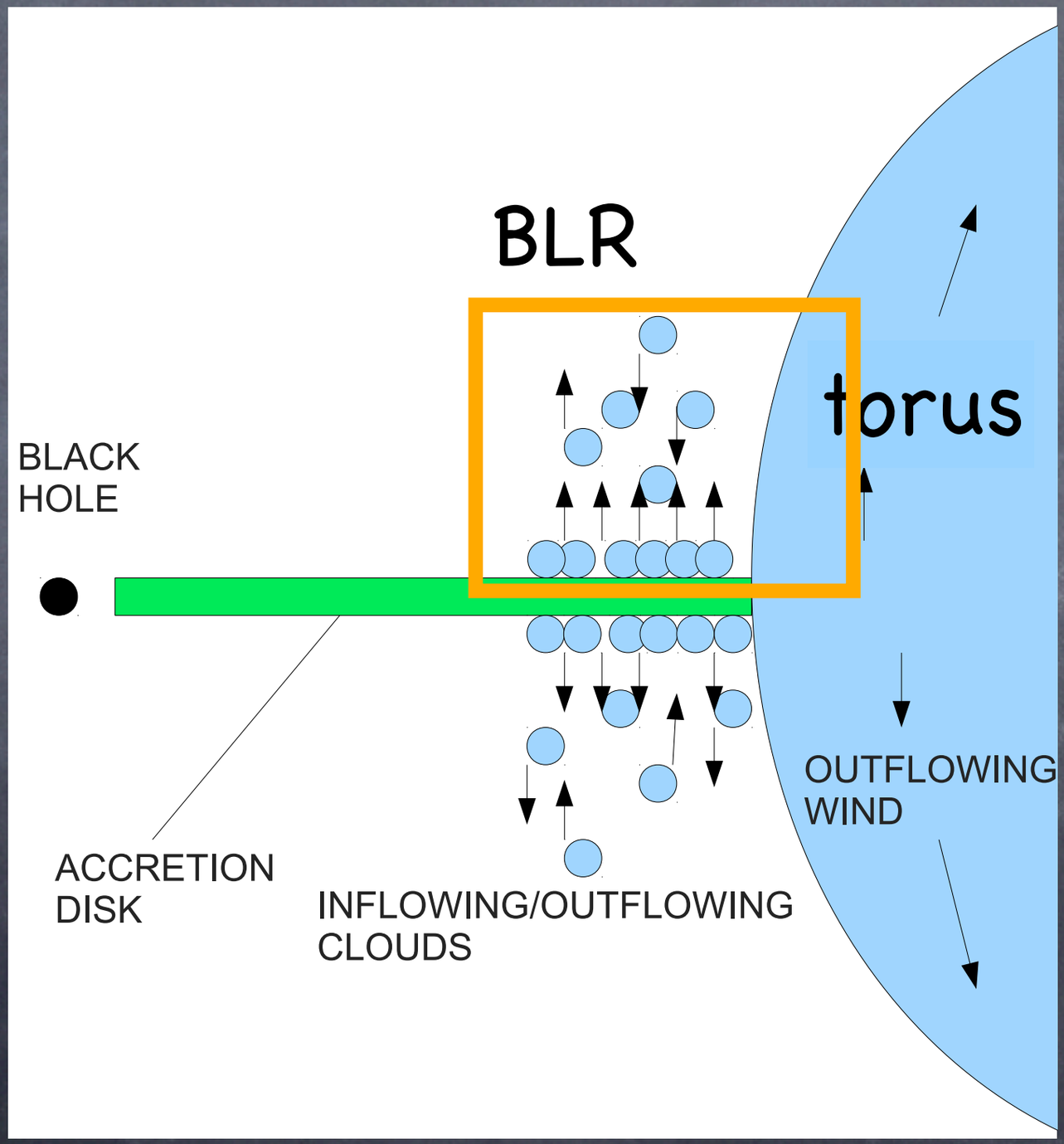
# $T_{grain}$ vs. grain size




at $r = R_{BLR}$

$\cos\theta = 1$

# The disc hight - static solution



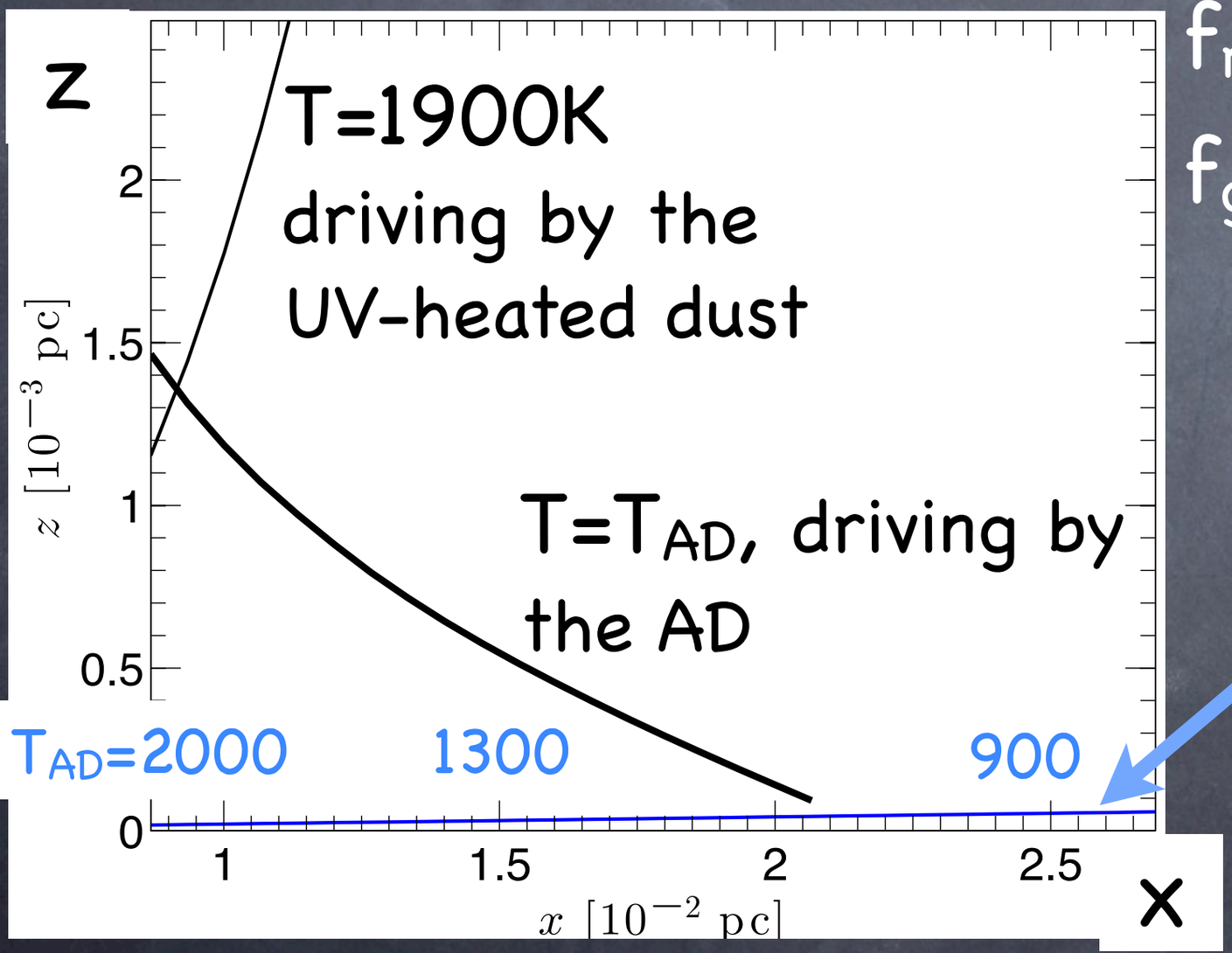

Czerny & Hryniewicz (2011)

# The disc hight - static solution

$f_{rad} = f_{grav}$

$f_{rad} = \sigma T^4 \kappa_{dust}(T)/c$

$f_{grav} = GM_{BH}z/x^3 + 2\pi G\Sigma_{AD}$




AD dominated by gas opacity

graphite dust: $a_{min}$ = 0.005, $a_{max}$=0.25, $\beta$=-3.5, dust/gas = 0.01.

$L_{bol}=10^{45}$, $M_{BH}=10^8 M_\odot$, $Z=Z_\odot$

# The sublimation sphere

**dusty gas**

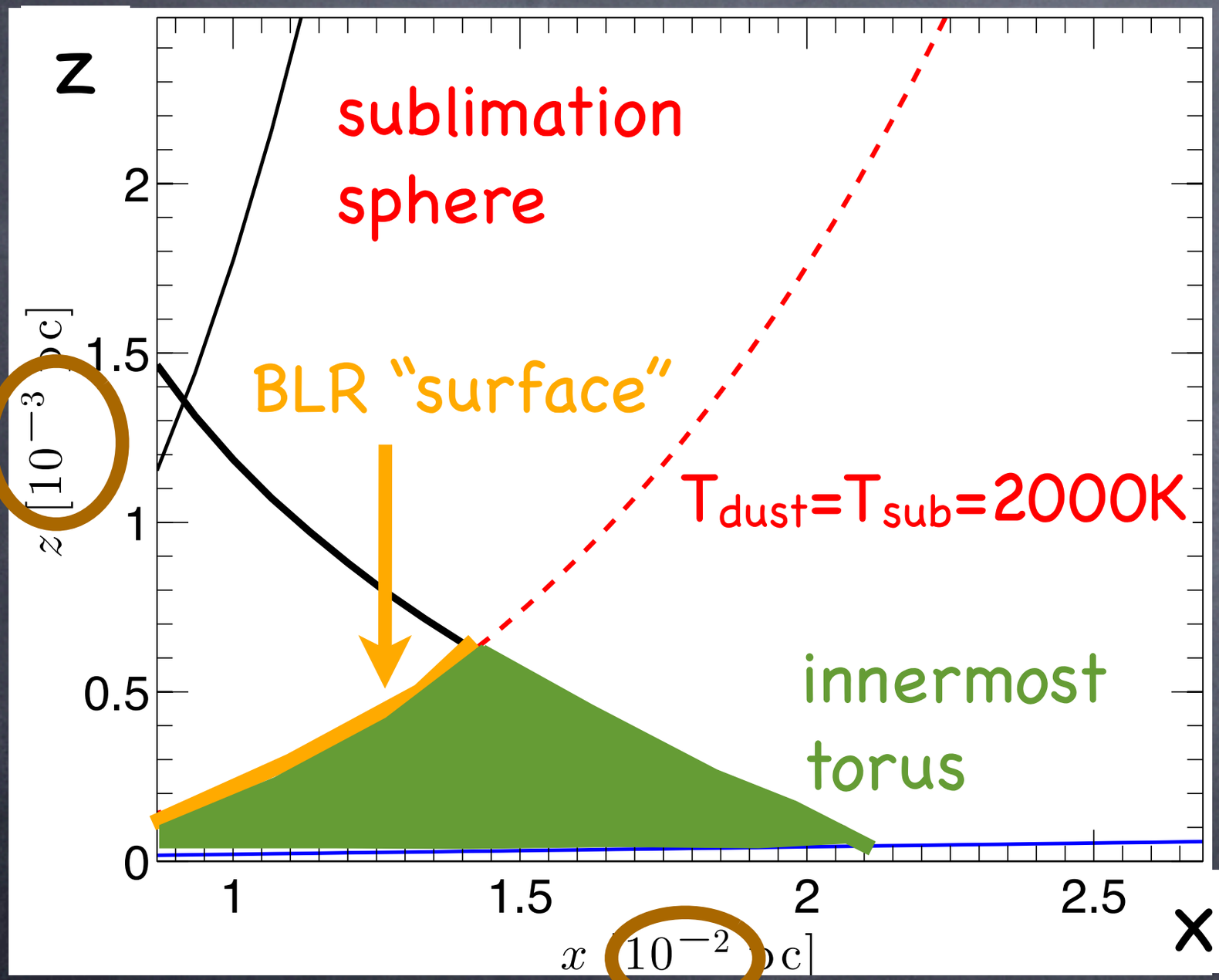
$$\frac{2L_{\rm bol}\cos\theta}{4\pi r^2} = 4\sigma T_{\rm sub}^4$$

sublimation sphere

r

θ

# The disc hight - static solution

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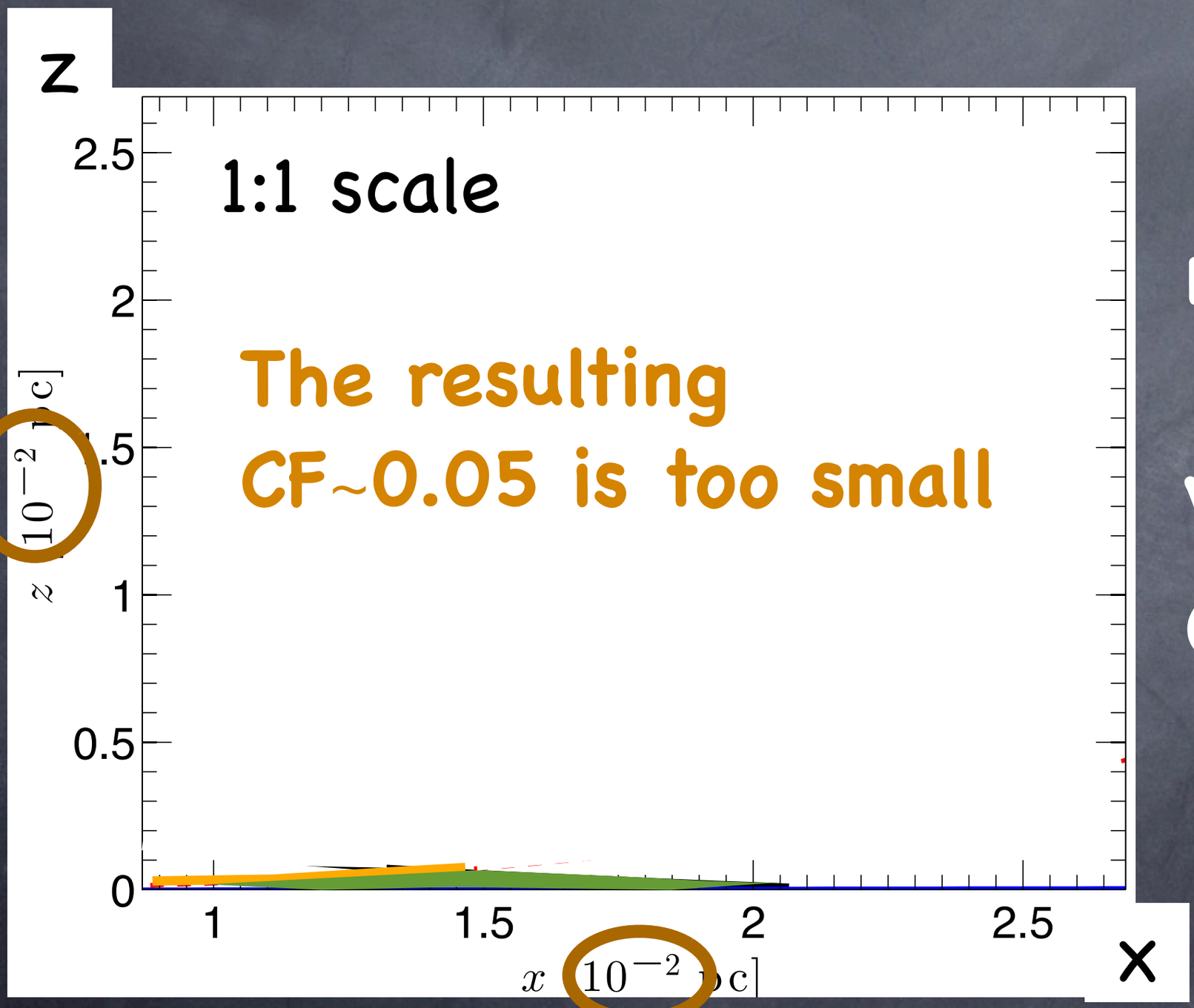
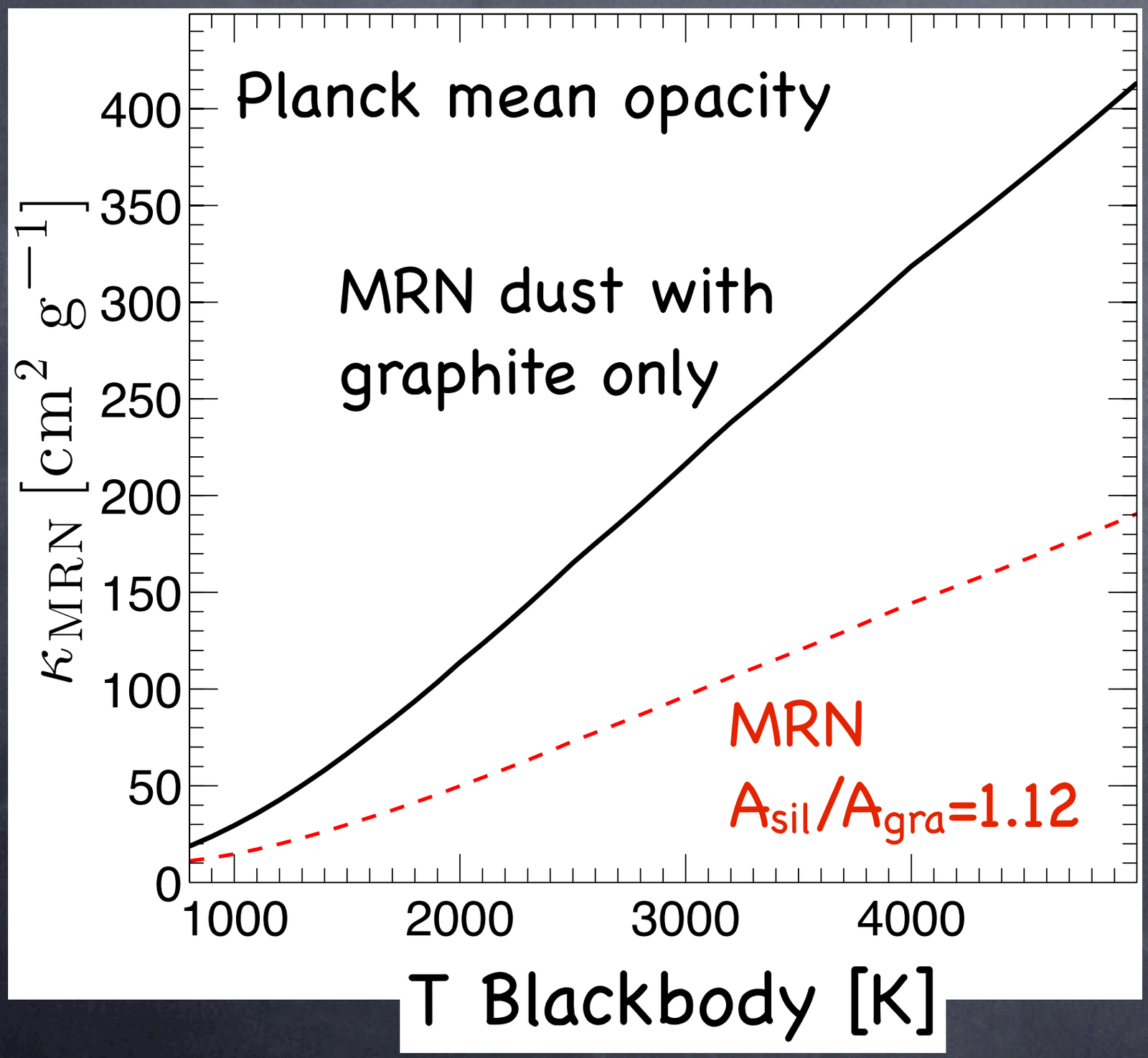



need CF~0.3

What can make CF larger?

graphite dust: $a_{min}$ = 0.005, $a_{max}$=0.25, β=-3.5, dust/gas = 0.01.
$L_{bol}=10^{45}$, $M_{BH}=10^{8}M_{\odot}$, $Z=Z_{\odot}$

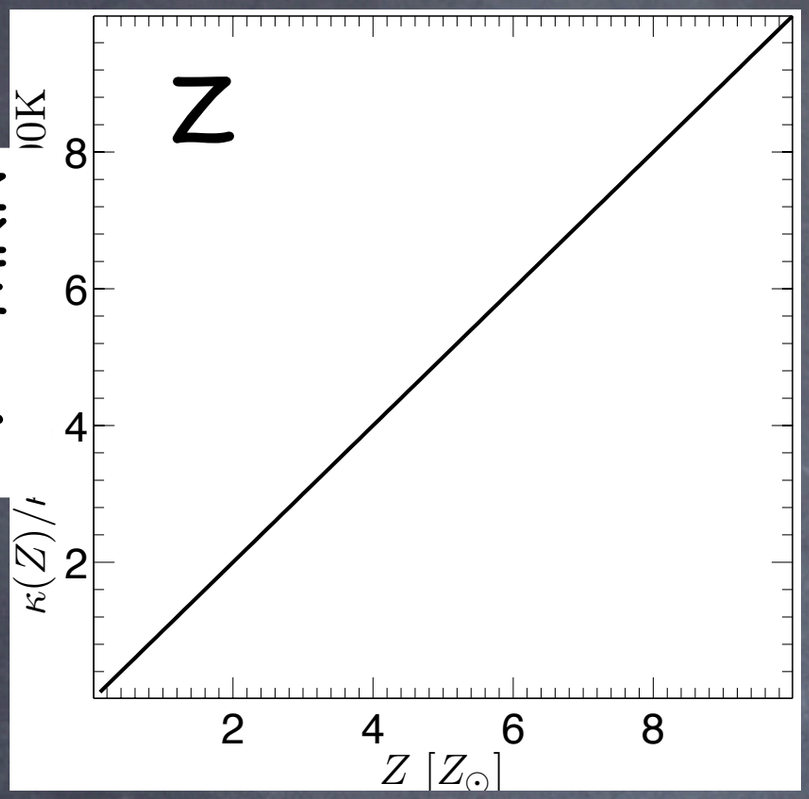
# $\kappa_{dust}$ vs. T for MRN dust

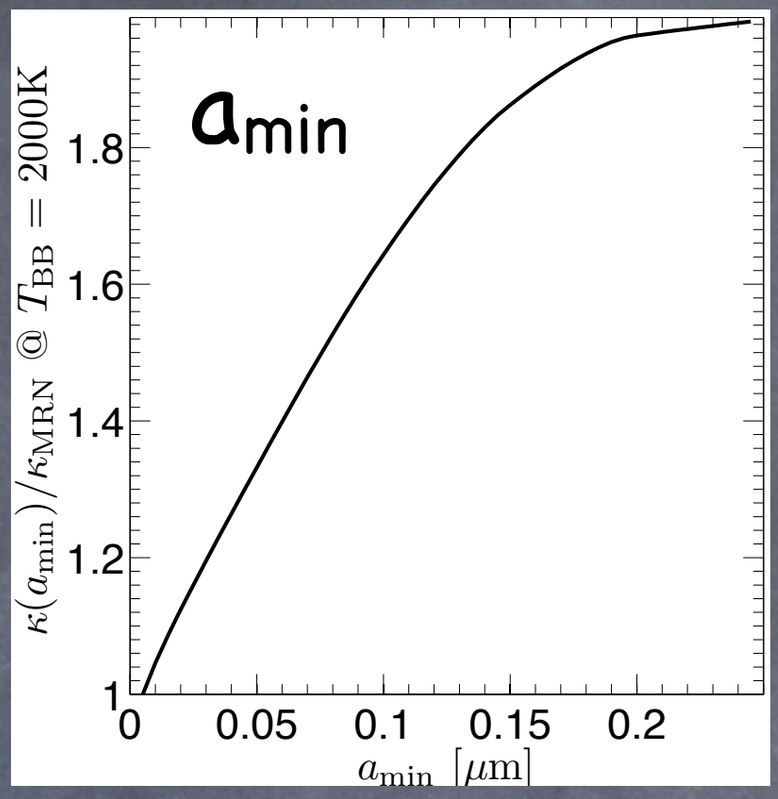


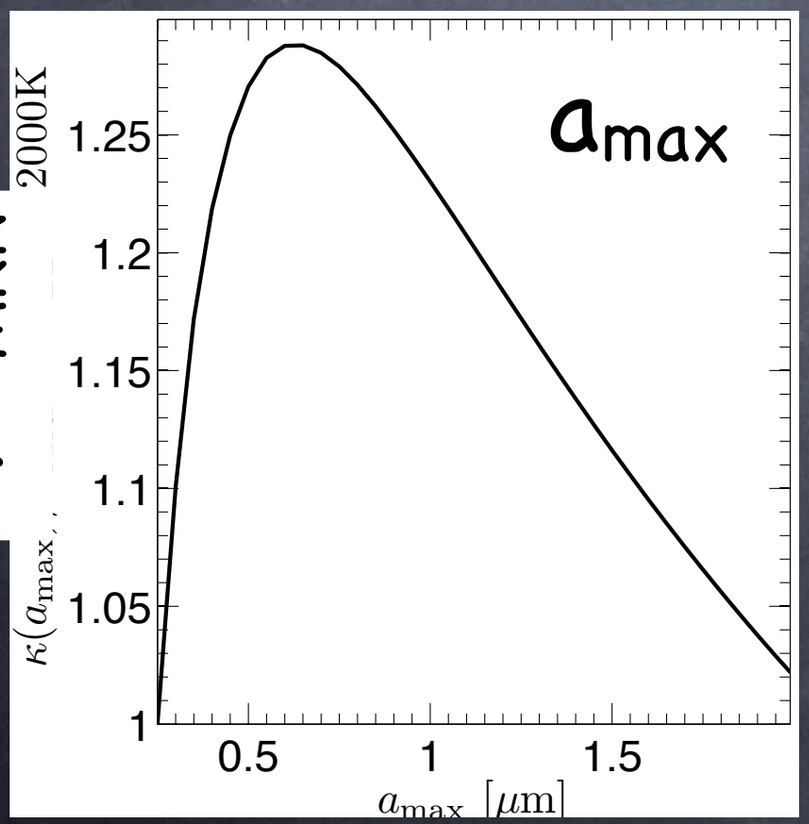

$dn_i(a) = A_i\ n_H\ a^\beta\ da$
$(a_{min} \le a \le a_{max})$

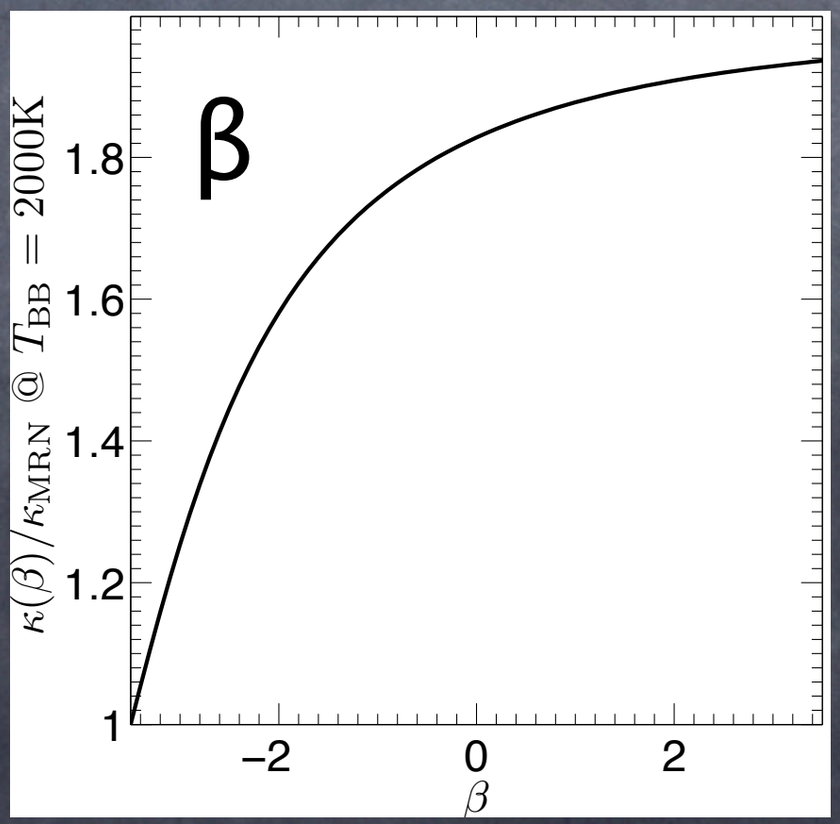
MRN dust:
$a_{min}$ = 0.005,
$a_{max}$ = 0.25,
$\beta$ = -3.5
$Z = Z_\odot$

# $\kappa_{dust}$ vs. Z and dust properties




for a larger CF:

- somewhat larger grains help
- Z is the dominant factor

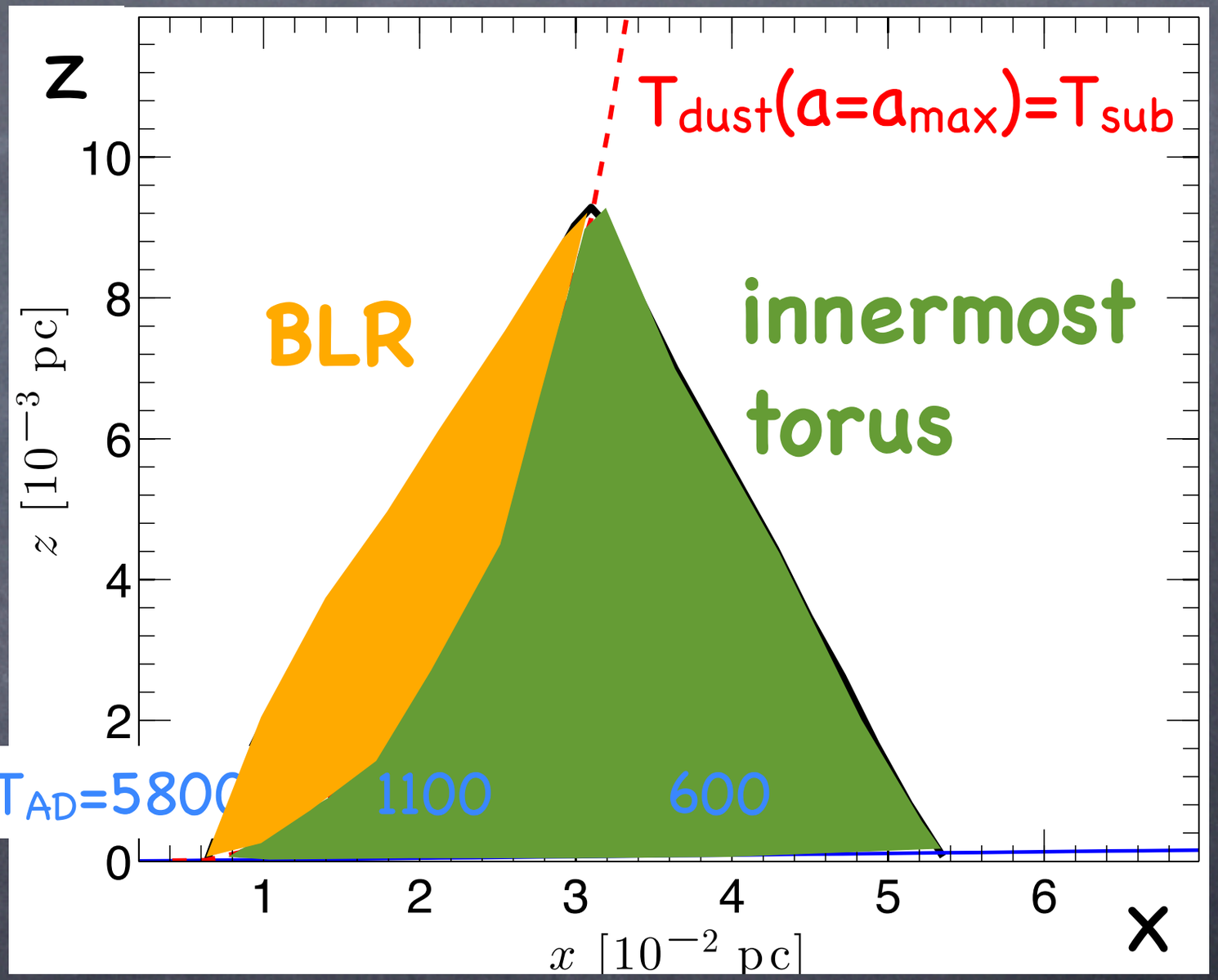
# The BLR hight - dynamic estimate

$E_{grav} + E_{rad} = 0$

$E_{grav} \approx GM_{BH}/x^3\ z^2/2$

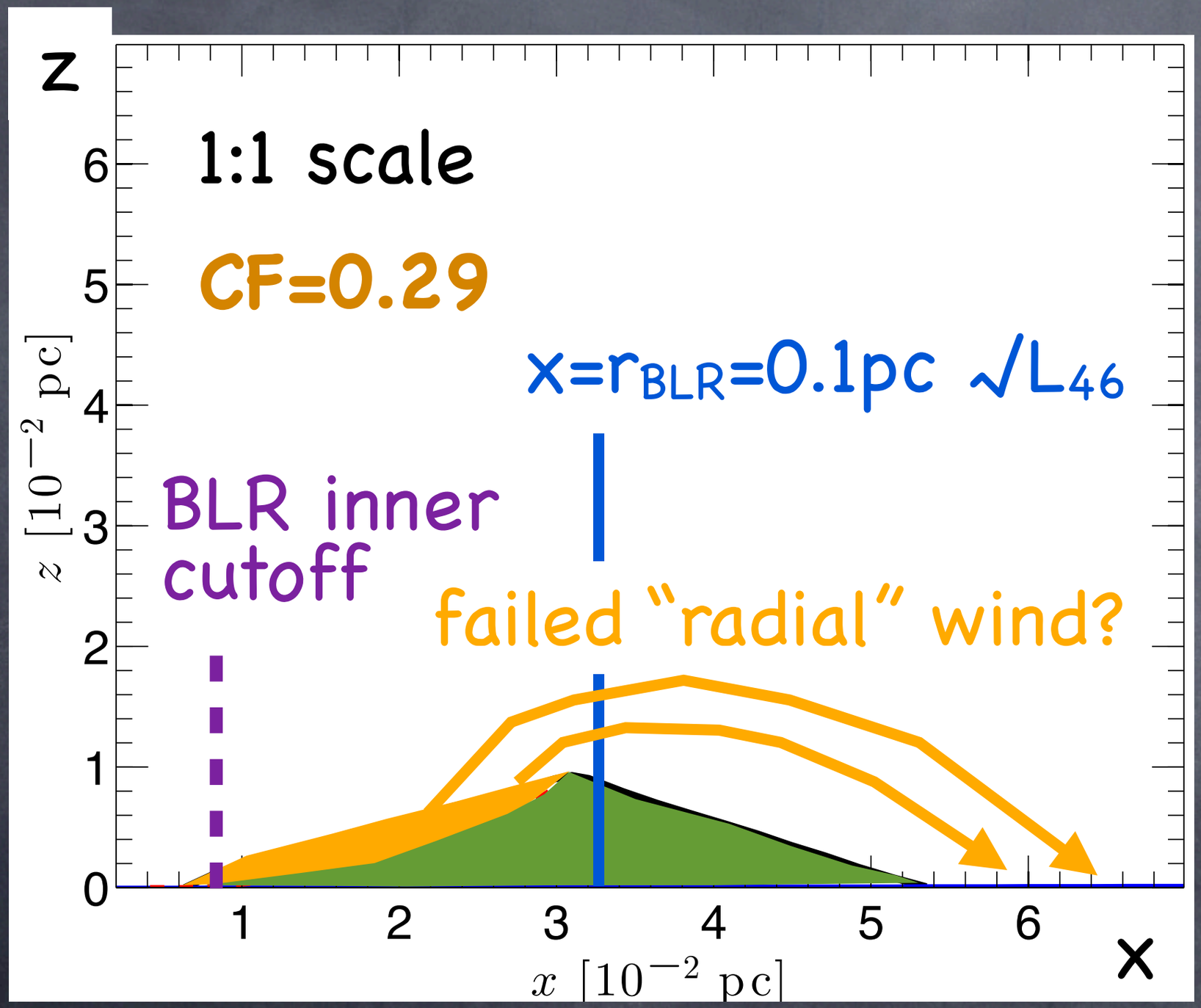
$\Longrightarrow h_{dyn} \sim \sqrt{2}\ h_{stat}$

$E_{rad} = \sigma T^4\ \kappa_{dust}(z)/c\ z$



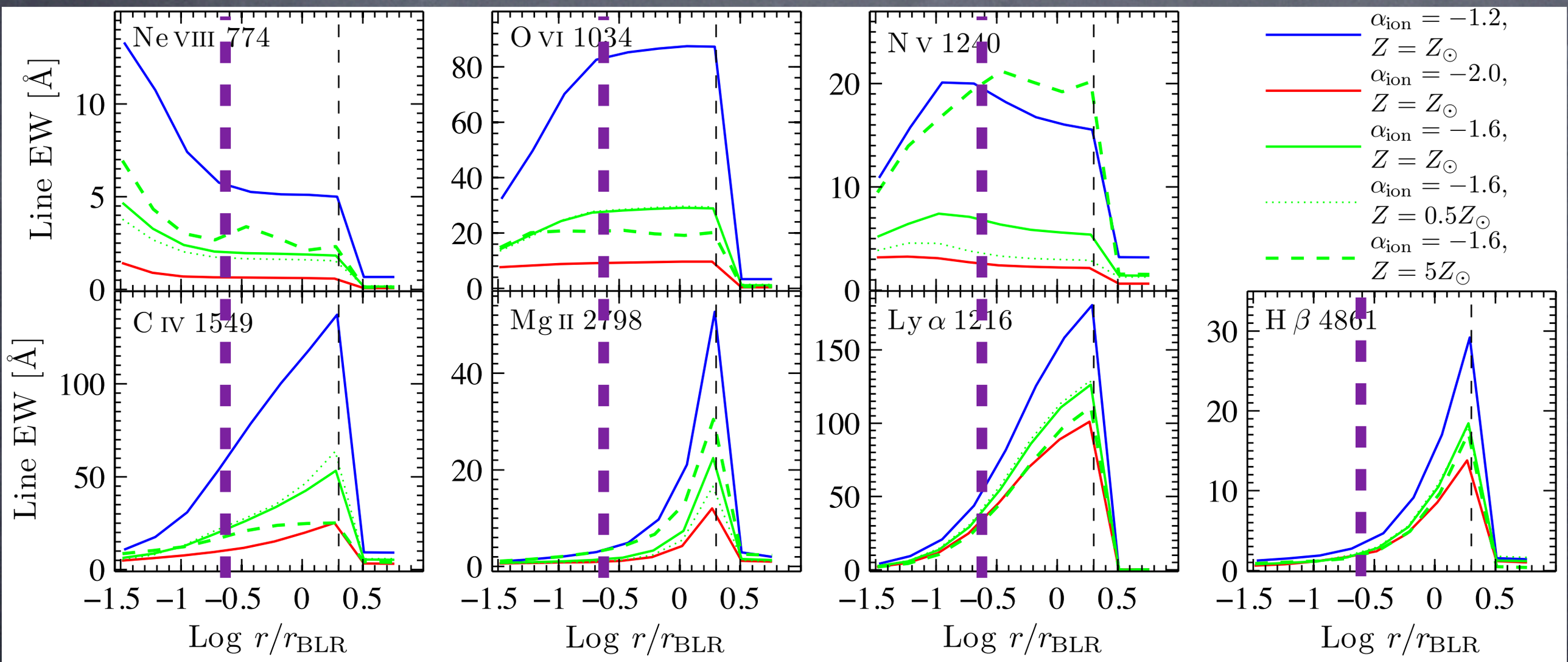

$Z=5Z_\odot$, $a_{min}=0.1$, $a_{max}=1$, $\beta=0$

# The BLR hight - dynamic estimate




Z=5Z⊙, $a_{min}$=0.1, $a_{max}$=1, β=0. $M_{BH}=10^8$, $L_{bol}=10^{45}$

# The effect of the inner cutoff on line emission




AB, Laor & Stern (2014)

$\Omega_{\rm BLR}$=0.3

# Summary

- **The AD naturally produces a bloated region at $r \sim r_{BLR}$ due to disc radiation pressure on dust.**

  The part facing the SMBH is the BLR.

  The outward part is the innermost hottest torus.

- **The CF of the region depends on dust properties.**

  CF~0.1 for MRN dust with graphite only.

  CF~0.3 for dust skewed toward larger graphite grains and $Z \gtrsim 5Z_{\odot}$.

- **Predicted inner cutoff for the BLR.**