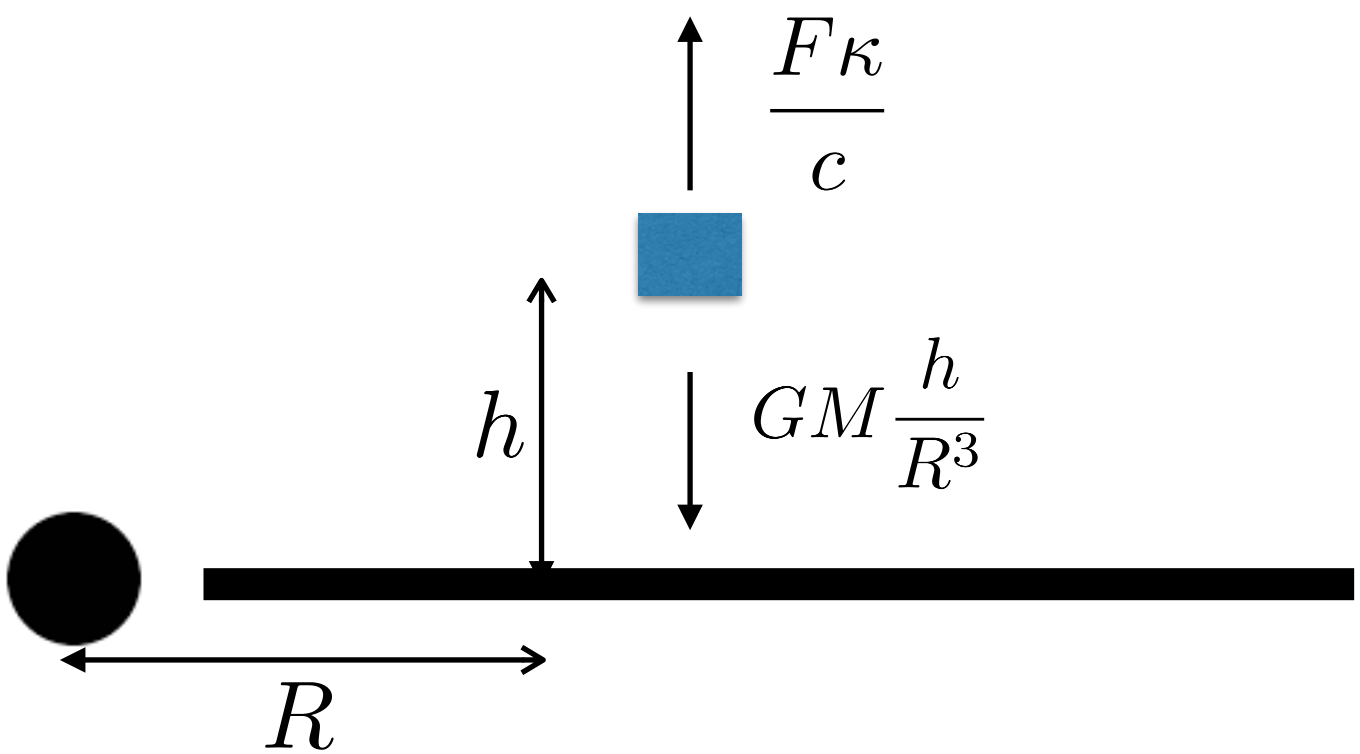
How thick is a thin disk?



$$F = \frac{3}{8\pi}\frac{GM\dot{M}}{R^3}$$

$$\frac{3}{8\pi}\frac{GM\dot{M}}{R^3}\frac{\kappa}{c} = \frac{GMh}{R^3}$$

$$\boxed{h = \frac{3}{8\pi}\frac{\dot{M}\kappa}{c}}$$

For electron scattering, $\kappa_{\mathrm{es}} = 0.4$ —> h is constant

What happens when h/R > 1 ?

$$a_{\rm BH} = \frac{GMh}{R^3} \rightarrow \frac{GMh}{(R^2+h^2)^{3/2}}$$

$$a_{\rm BH} \propto h, \qquad \text{for} \quad h/R \ll 1$$

$$a_{\rm BH} \propto 1/h^2, \quad \text{for} \quad h/R \gg 1$$

So, $a_{\rm BH}$ has a local maximum, $a_{\rm BH,max}$ at $h_{\rm max}$

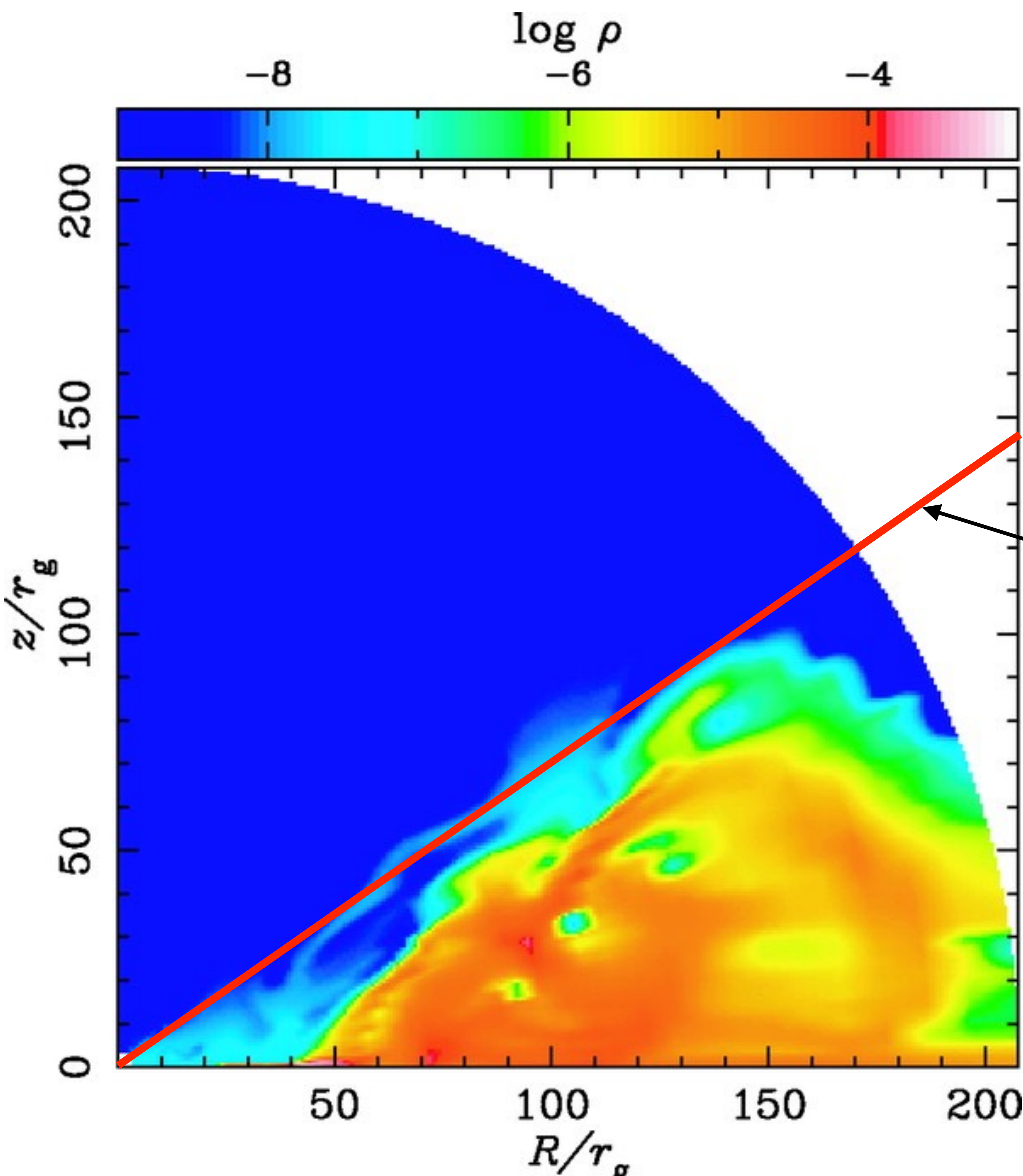
$$\frac{da_{\rm BH}}{dh} = 0 \quad \rightarrow \quad h_{\rm max} = R/\sqrt{2}, \quad a_{\rm BH,max} = \frac{2}{3\sqrt{3}}\frac{GM}{R^2}$$

If $a_{rad} = Fk/c > a_{BH,max}$ —> the gas *escapes!*

A static disk exists only at h/R<0.71

Supercritical Accretion Flows around Black Holes: Two-dimensional, Radiation Pressure–dominated Disks with Photon Trapping

(Ohsuga+05)



$M = 10\ M_{\odot}$

$\dot{m}_{\rm input} = 1000$

$h/R = 1/\sqrt{2}$

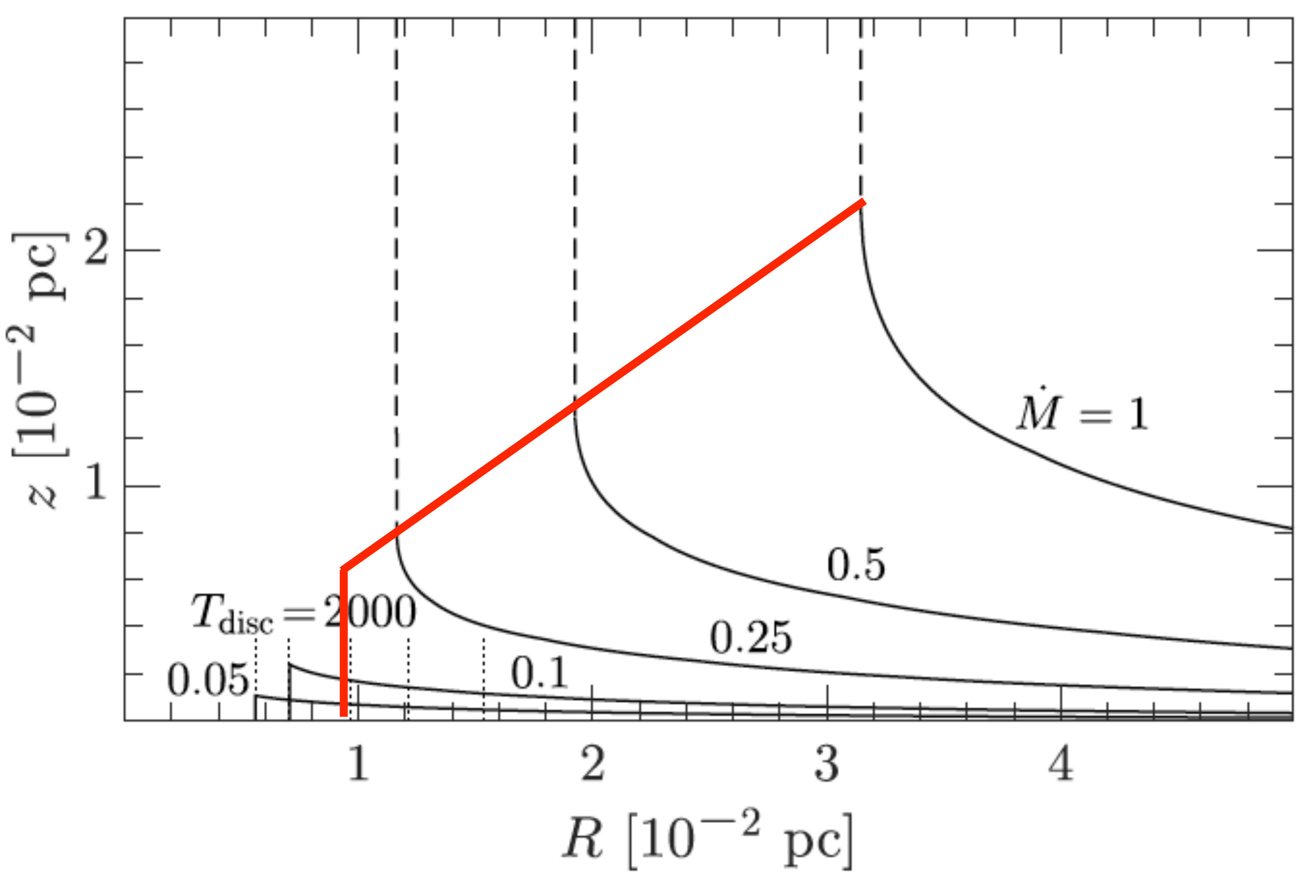
Where does the static solution break?

$$\frac{F\kappa}{c} > \frac{2}{3\sqrt{3}}\frac{GM}{R^2} \quad , \qquad F = \frac{3}{8\pi}\frac{GM\dot{M}}{R^3} \quad \rightarrow \quad R < \frac{9\sqrt{3}}{16\pi}\dot{M}\frac{\kappa}{c}$$

$$\dot{M} = 6.31\times10^{25}\dot{M}_1, \quad \kappa = 0.4\Lambda, \quad R = 1.46\times10^{13}m_8 r_g, \quad \dot{m} = 0.44\dot{M}_1 m_8^{-1}$$

at: $$r_g < 40.3\dot{m}\Lambda$$

(neglecting GR corrections + zero viscosity at $R_{\rm in}$)



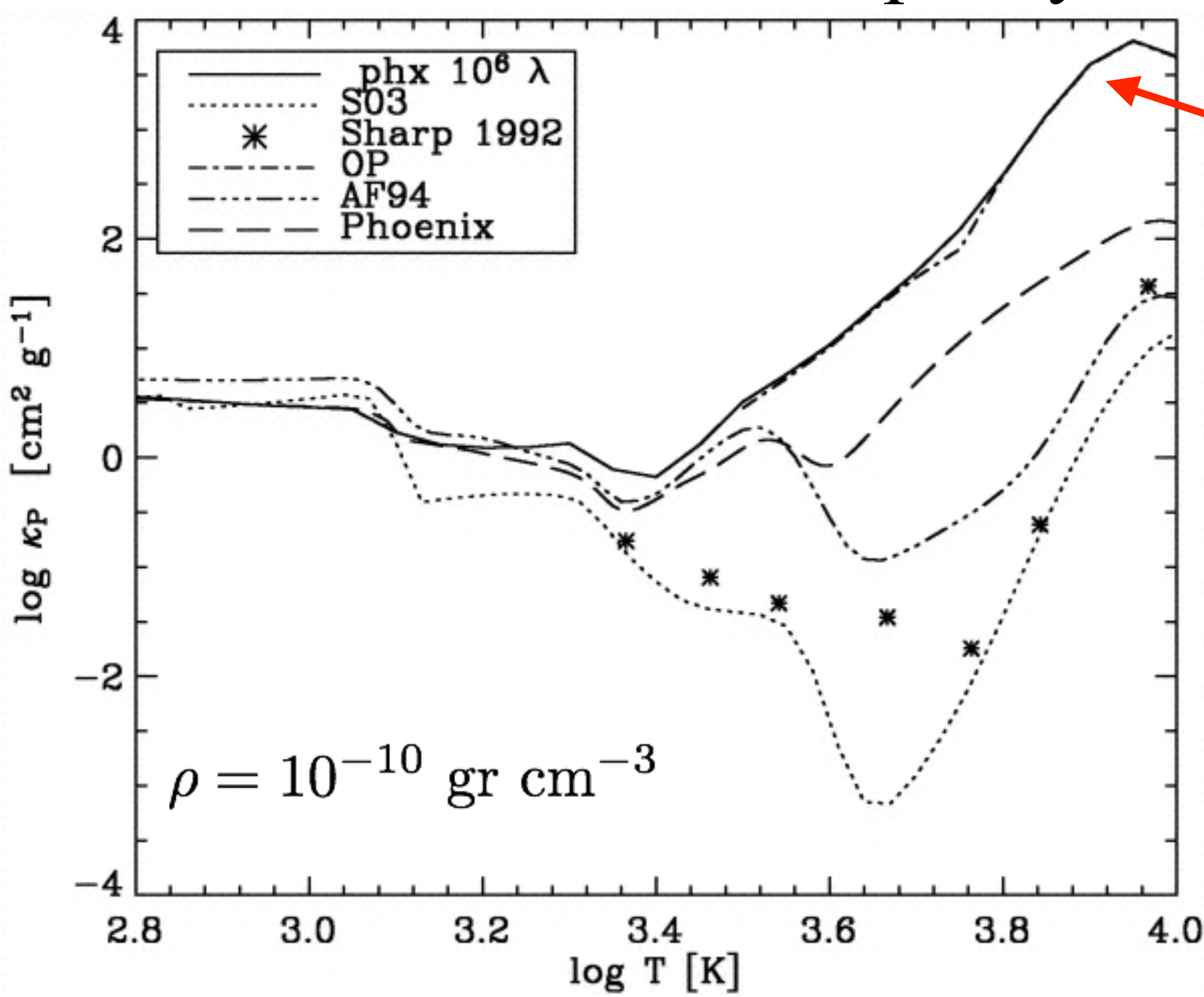
Outer dusty disk solution
Baskin & Laor (2018)

$\Lambda \simeq 350$
$\dot{m} = 0.023–0.45$

what happens inwards?
(where the dust is gone)

What is Λ in the inner accretion disk atmosphere?

The Planck mean opacity



Ferguson+ (2005)

Is Λ really that large?
(depends on density)

If yes, then

$$h = h_{\max} = R/\sqrt{2}$$

in most AGN disks

What does it mean?

Implications

Instead of $F = \frac{3}{8\pi}\frac{GM\dot{M}}{R^3}$ we get $F = \frac{2}{3\sqrt{3}}\frac{GM}{R^2}\frac{c}{\kappa}$

Likely mass loss, as $\dot{M}(R) = 3.22R\frac{c}{\kappa}$

For a constant opacity $T \propto R^{-1/2}$ $(T \propto R^{-3/4})$

(and even flatter for opacity rising inwards)

Which implies **a steep SED** - $L_\nu \propto \nu^{-1}$ $(L_\nu \propto \nu^{1/3})$

(and even steeper for opacity rising inwards)

Are most disks in AGN not thin?

Is it so easy to drive a wind?

Is there an opacity driven variability?