Stellar Tidal Disruption

(A theoretical review; observations reported by Stefanie Komossa)

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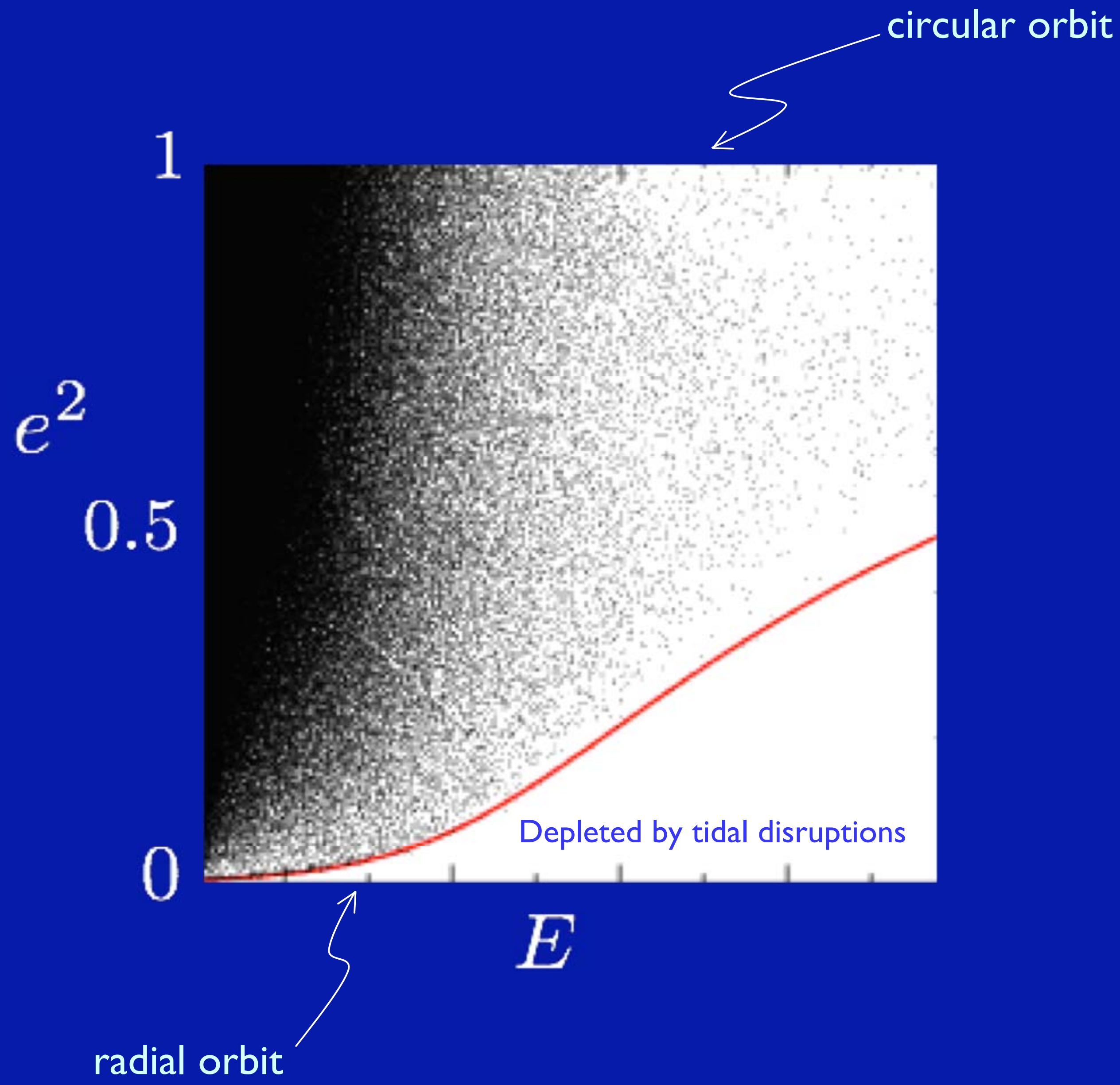
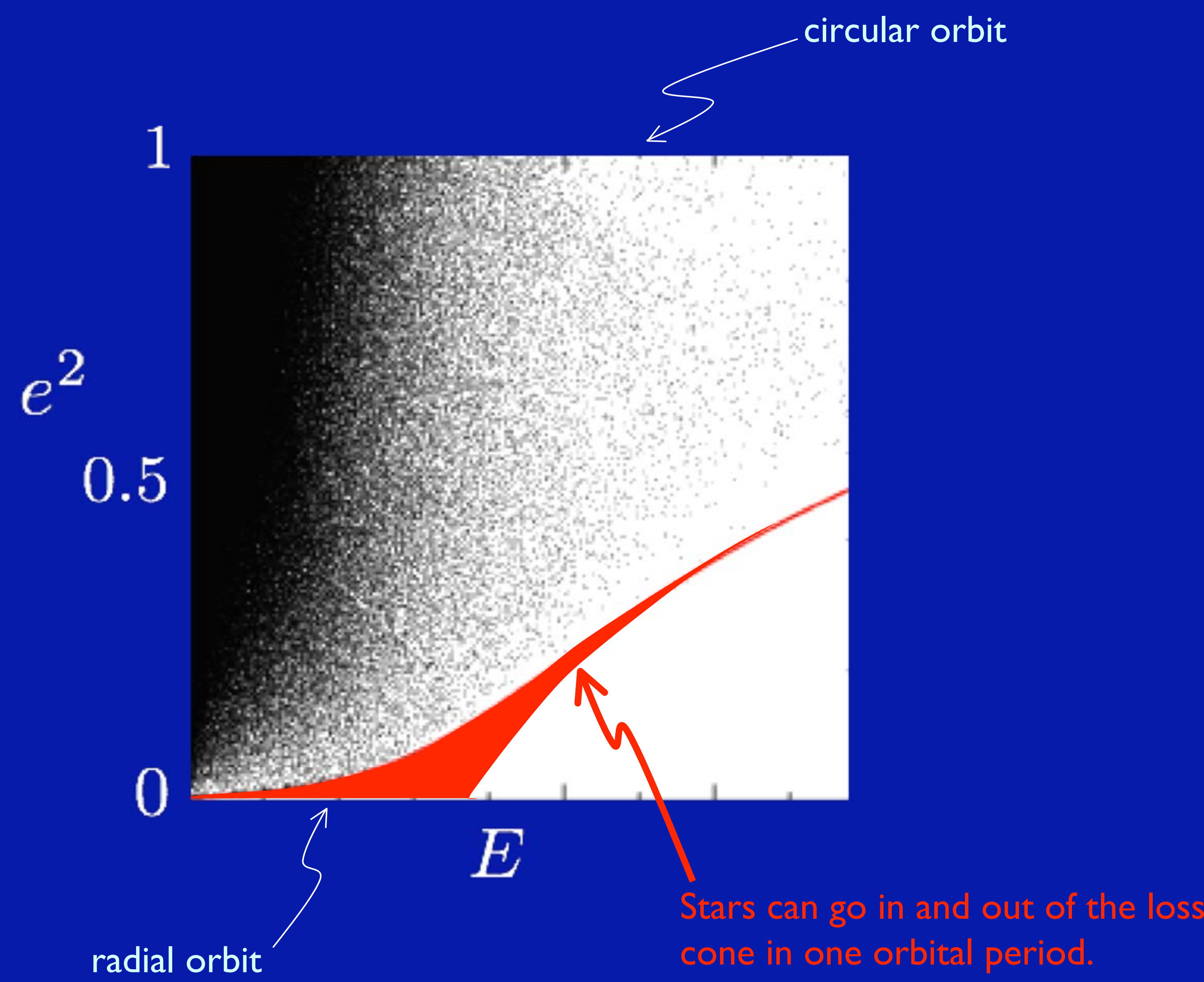
Plan

- Loss cones and tidal disruption rate
- Mechanics of disruption
- Accretion of debris
- Implications for the growth of black holes

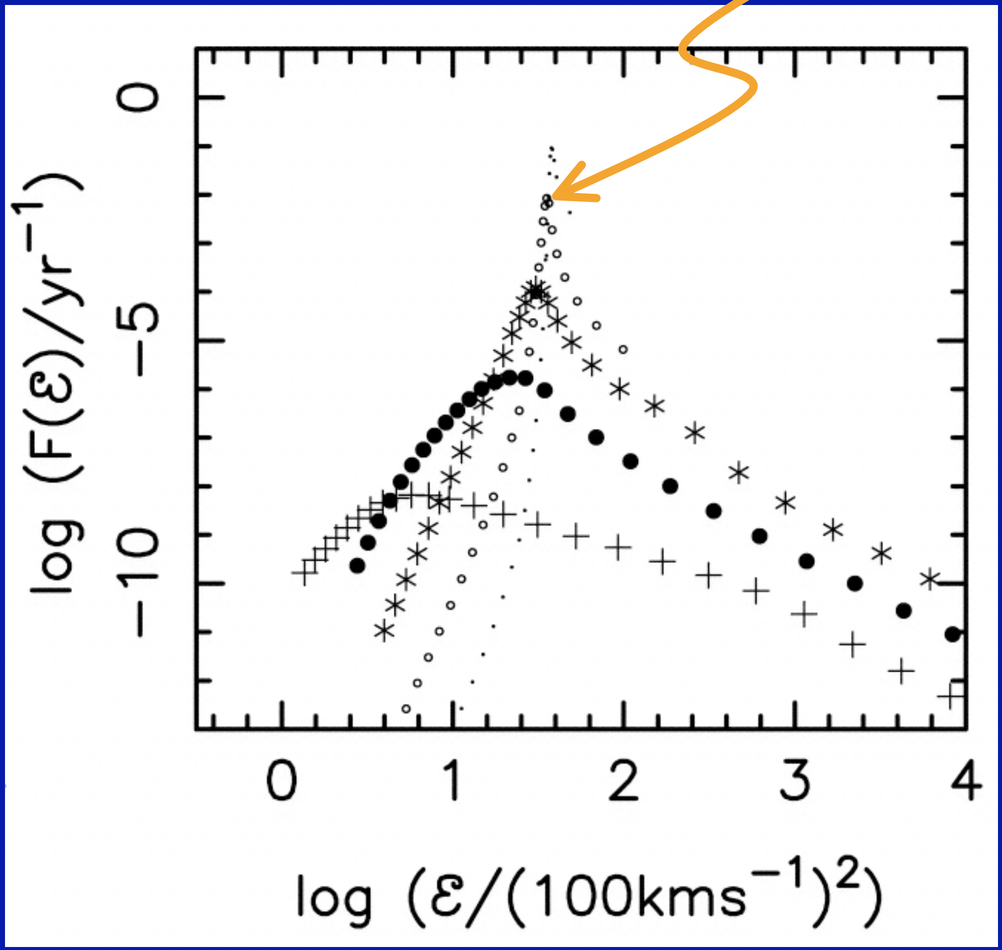

circular orbit
1
e^2
0.5
0
Depleted by tidal disruptions
E
radial orbit



circular orbit
1
e^2
0.5
0
E
radial orbit
Stars can go in and out of the loss cone in one orbital period.

Peaks just inside the radius of influence of the black hole

Number of stars per unit energy per year



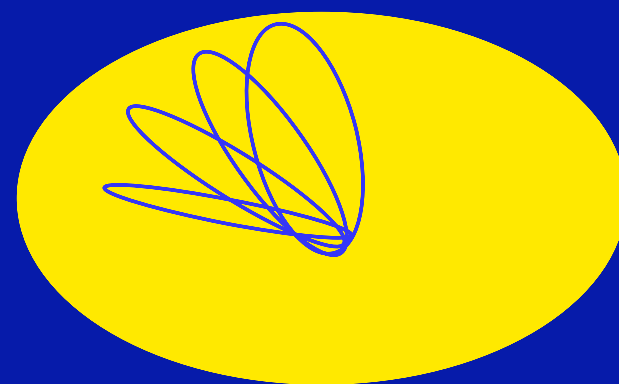
Wang & Merritt 2004

$$\Gamma_{\mathrm{Wang-Merritt}} = 7 \times 10^{-4}\ \mathrm{yr}^{-1} \left(\frac{\sigma}{70\ \mathrm{km\ s}^{-1}}\right)^{7/2} \left(\frac{M_{\mathrm{bh}}}{10^6 M_\odot}\right)^{-1} \times \left(\frac{m_\star}{M_\odot}\right)^{-1/3} \left(\frac{R_\star}{R_\odot}\right)^{1/4}$$

Caveat: very small black hole in large galaxy.

Loss cones in axisymmetric potentials

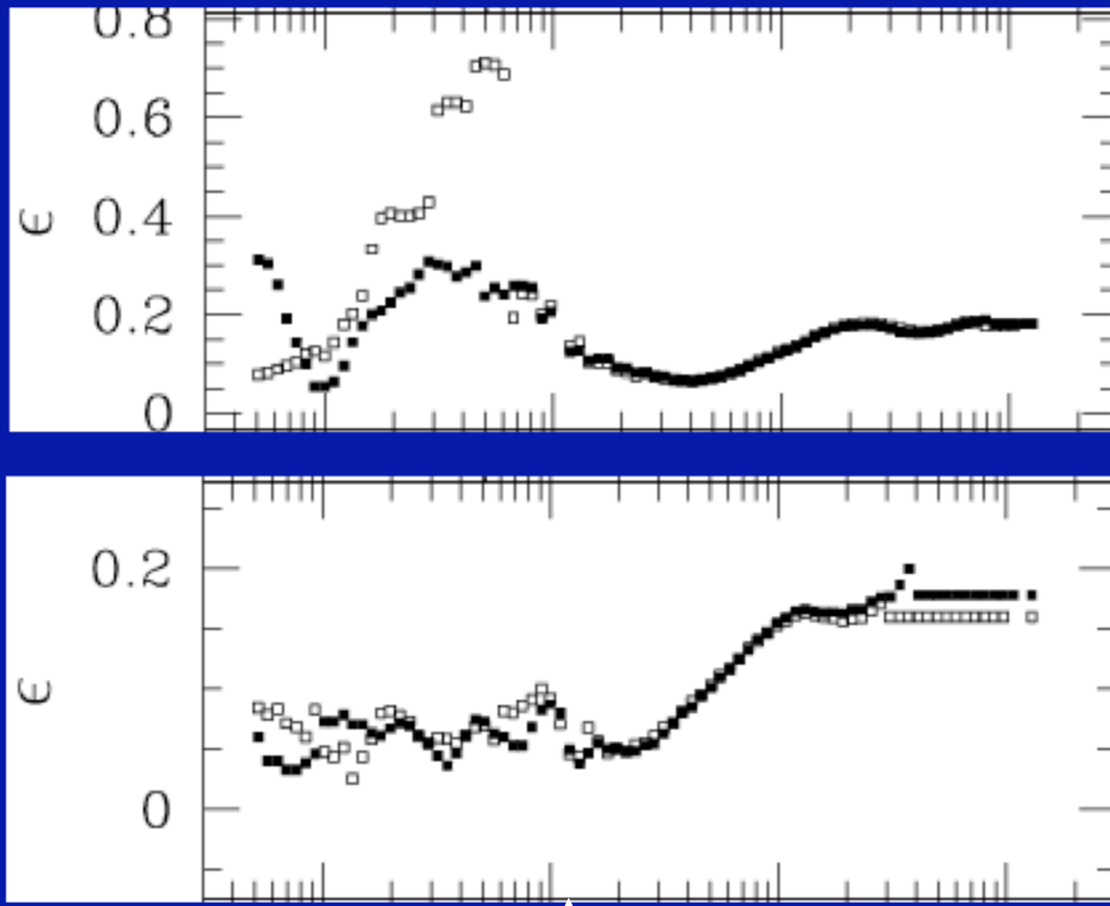
Magorrian & Tremaine 1999



$$(1) \quad \dot{\varpi} < \Gamma_{1-e}$$

$$(2) \quad \dot{\varpi} > \Gamma_{1-e}$$

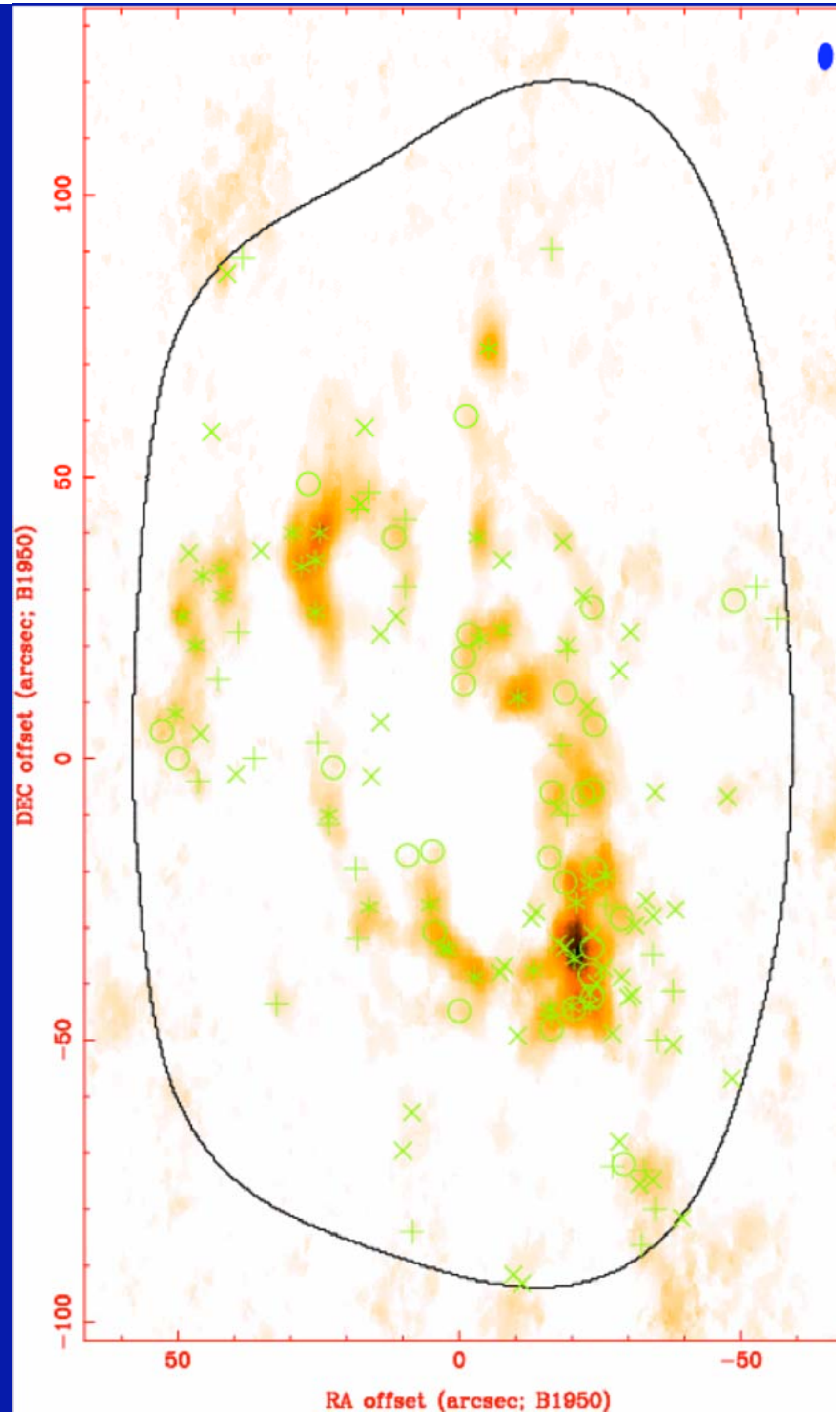
HST/ACS VCS, Ferrarese et al. 2006

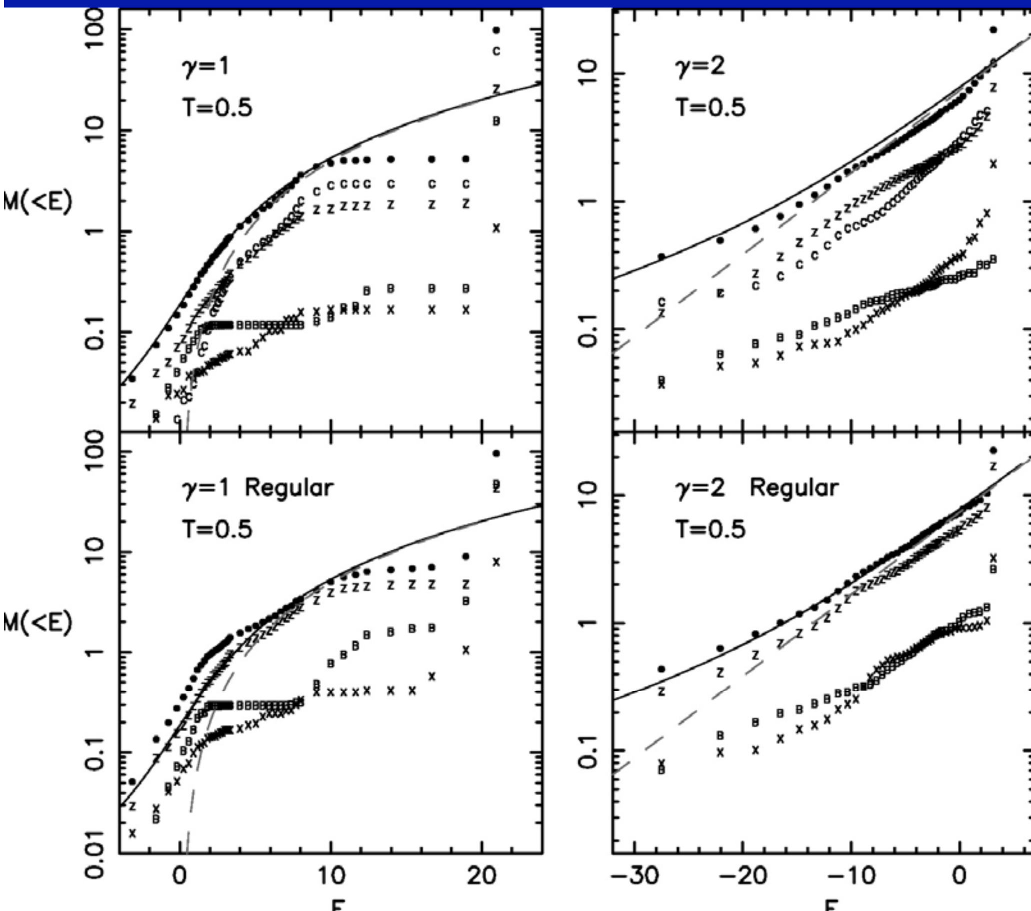


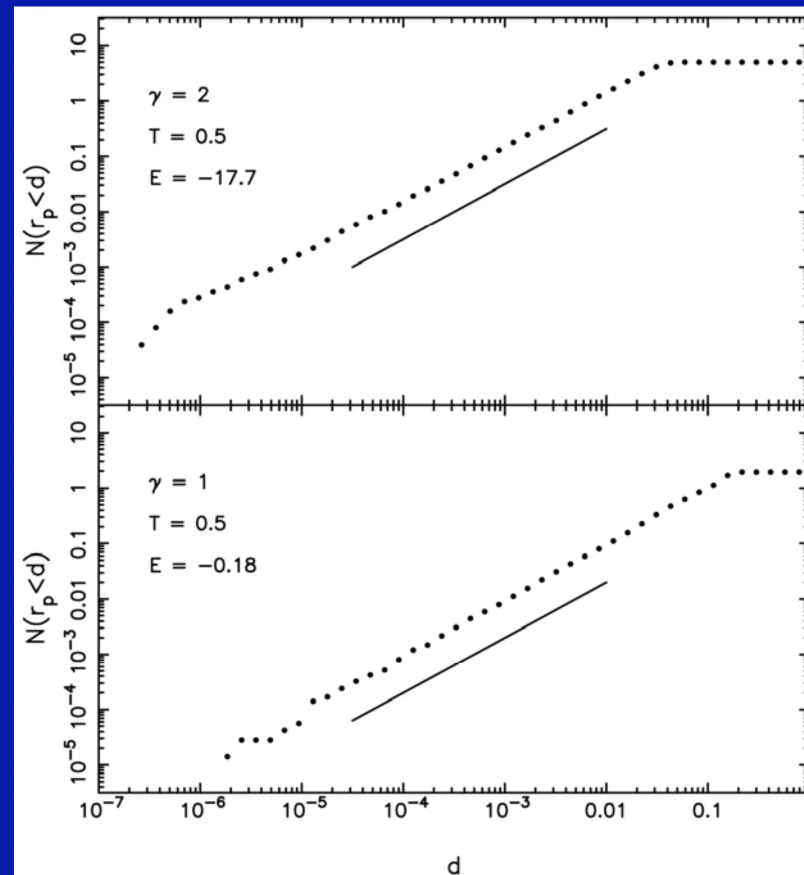
100 pc

Christopher, Scoville, Stolovy & Yun 2004

$$\Gamma_{1-e} \sim \frac{\omega}{\sqrt{1-e^2}} \left(\frac{r_{\rm star}}{r_{\rm pert}}\right)^2 \frac{M_{\rm pert}}{M_{\rm bh}}$$

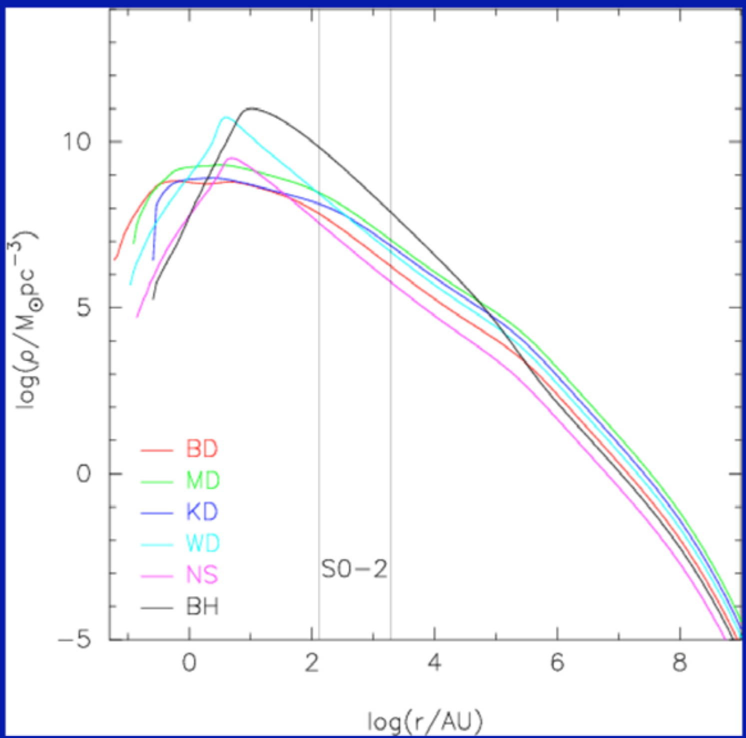




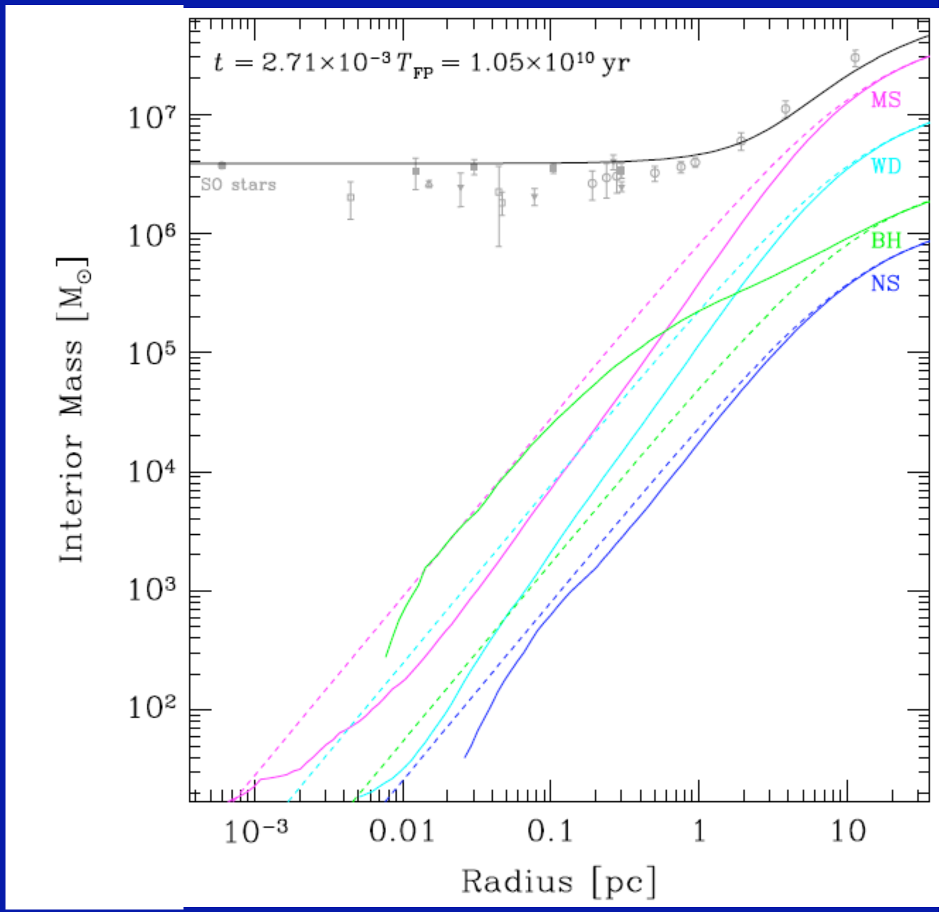


Poon & Merritt 2004

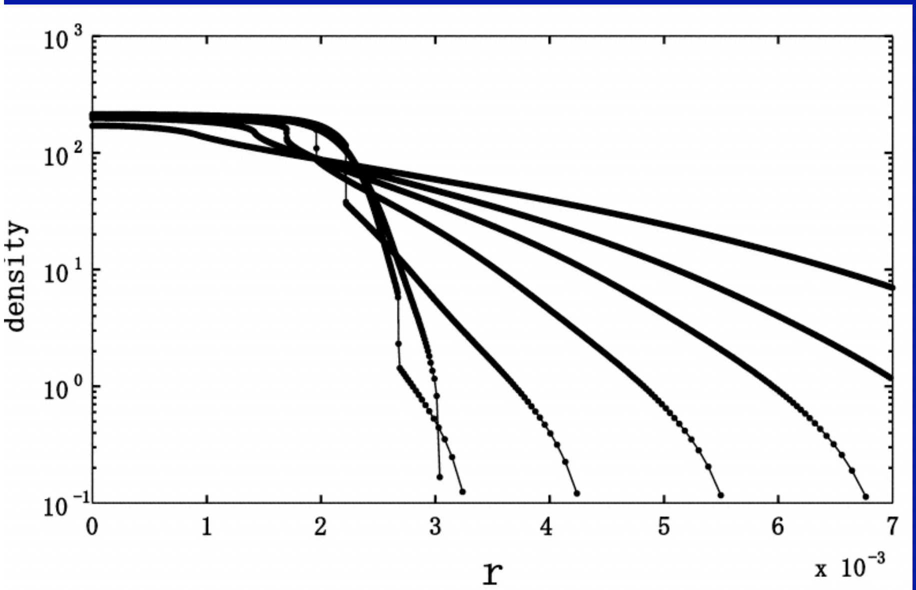
Merritt & Poon 2004

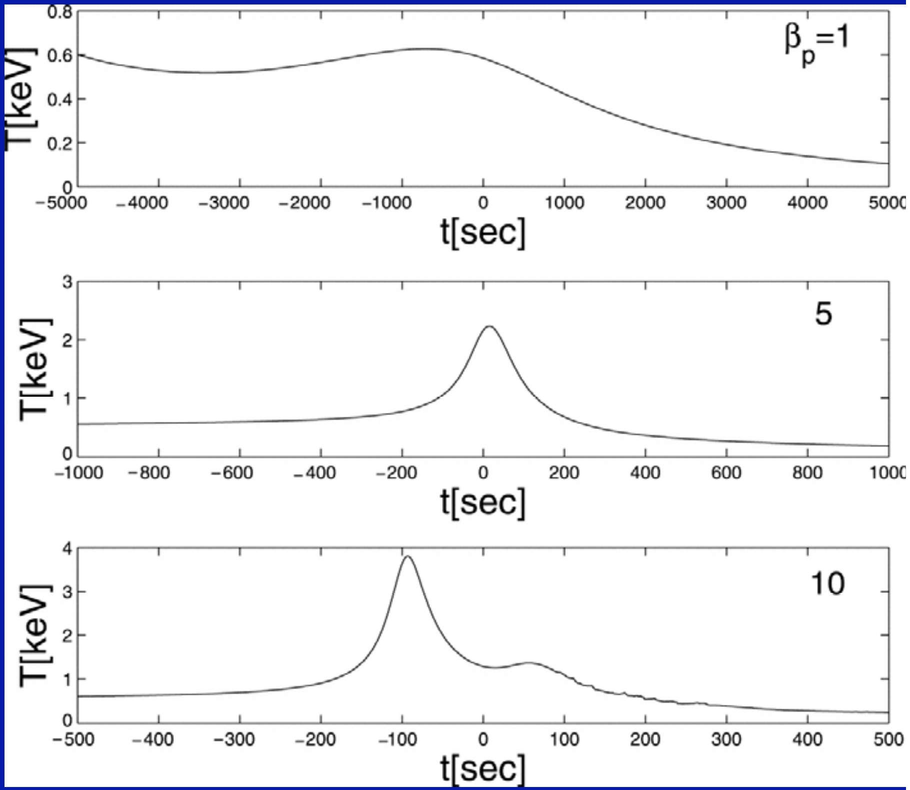


MM 2003

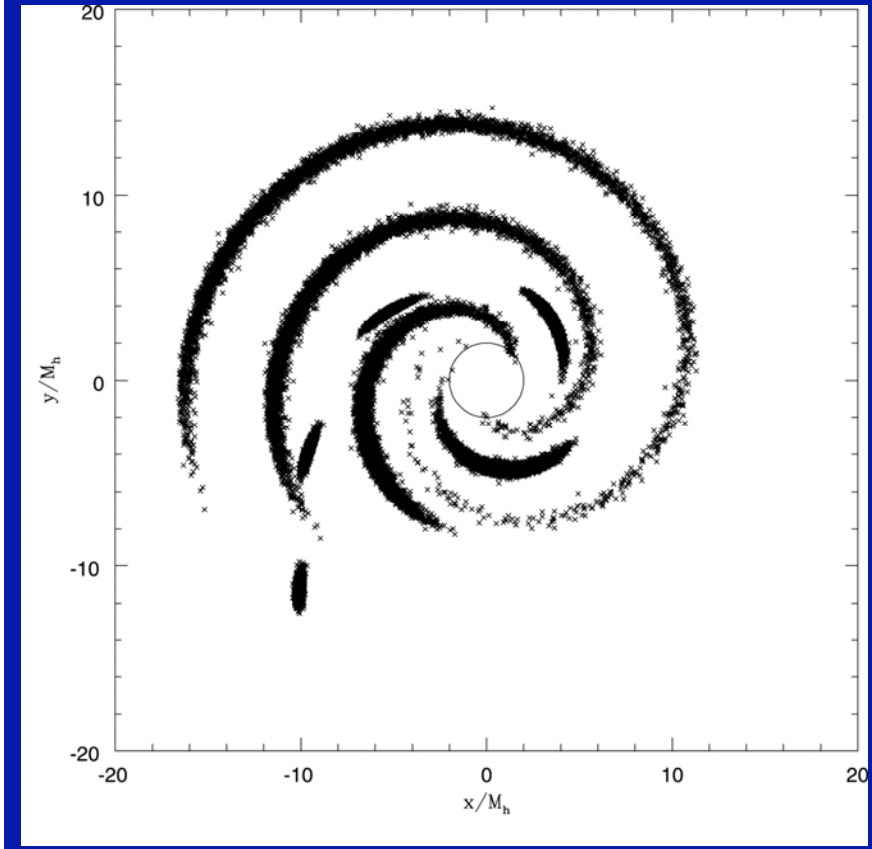


Freitag, Amaro-Seoane, Kalogera 2003

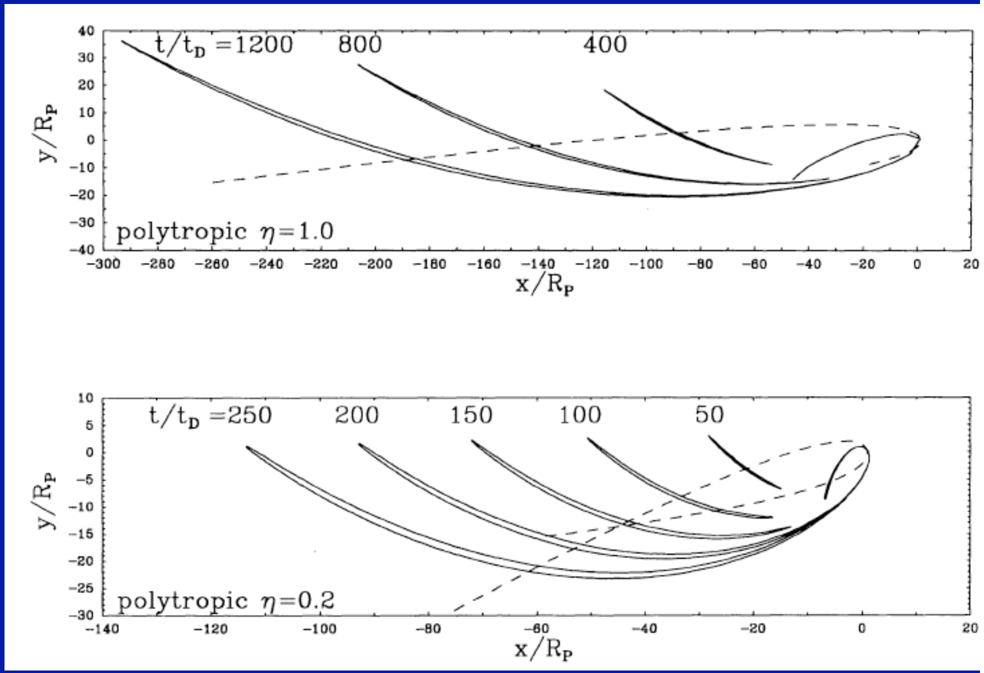




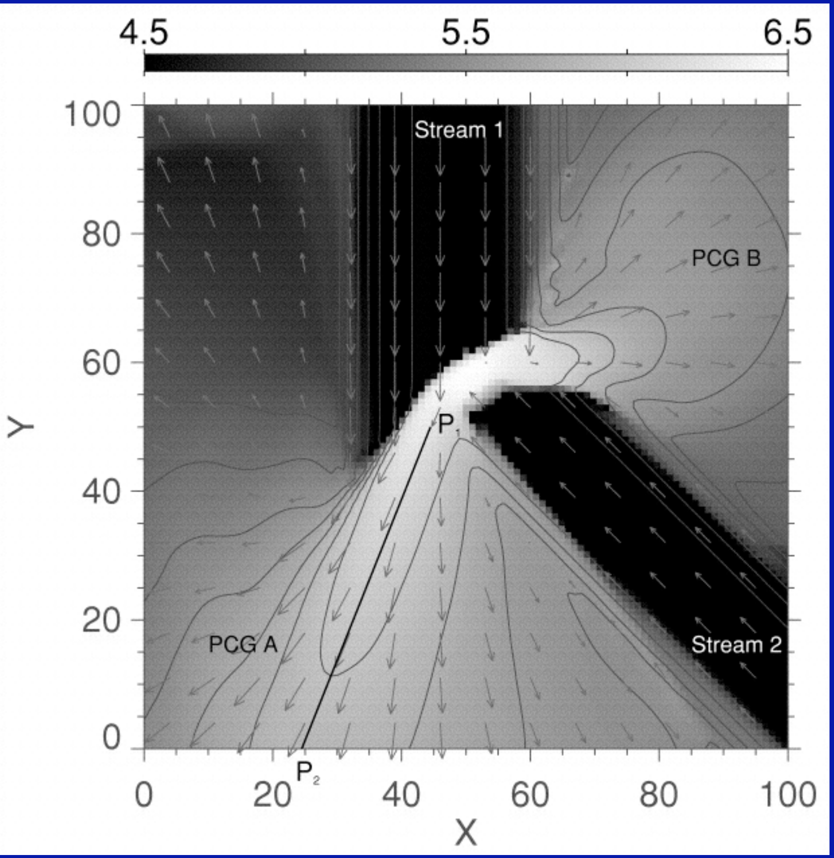
Kobayashi, Laguna, Phinney, Meszaros 2004

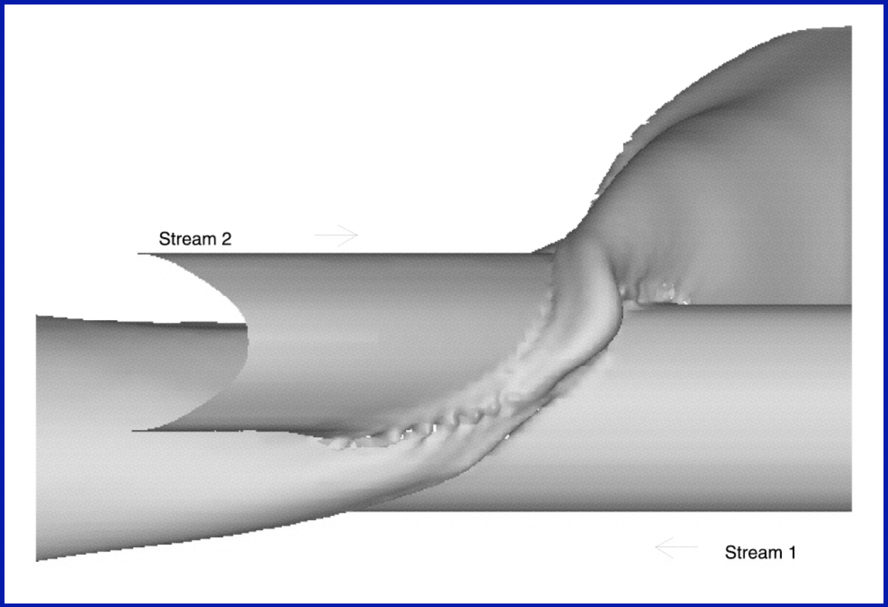


Kobayashi, Laguna, Phinney, Meszaros 2004

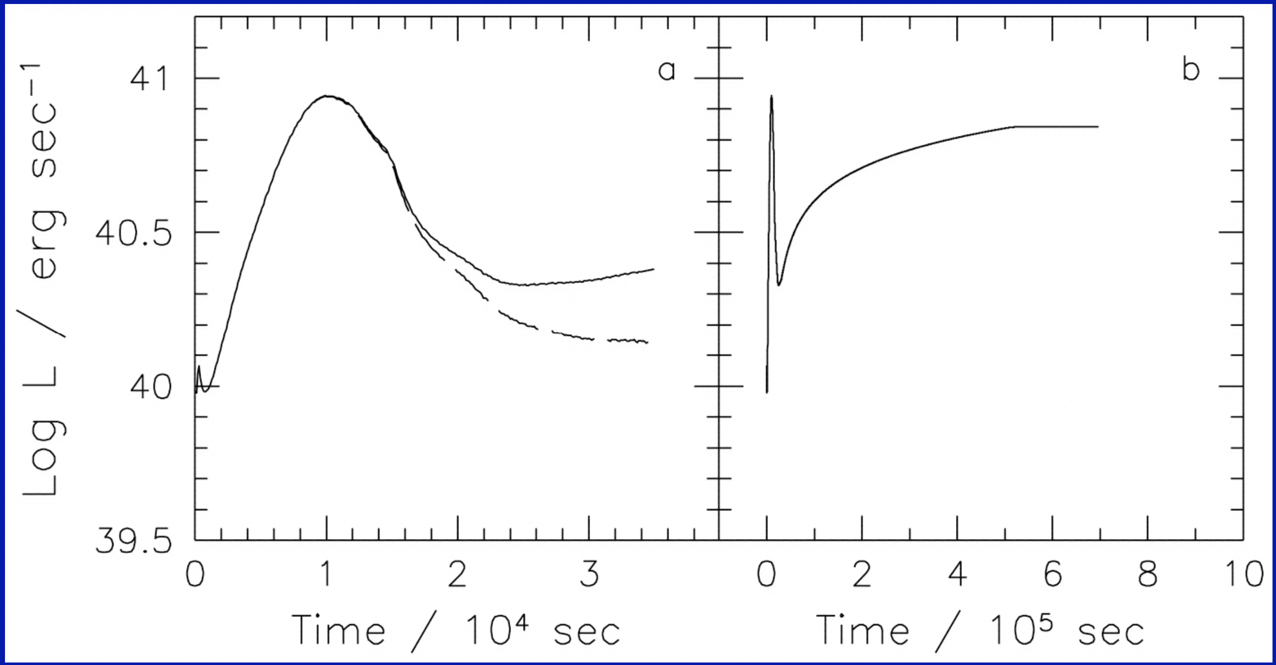


Kochanek 1994



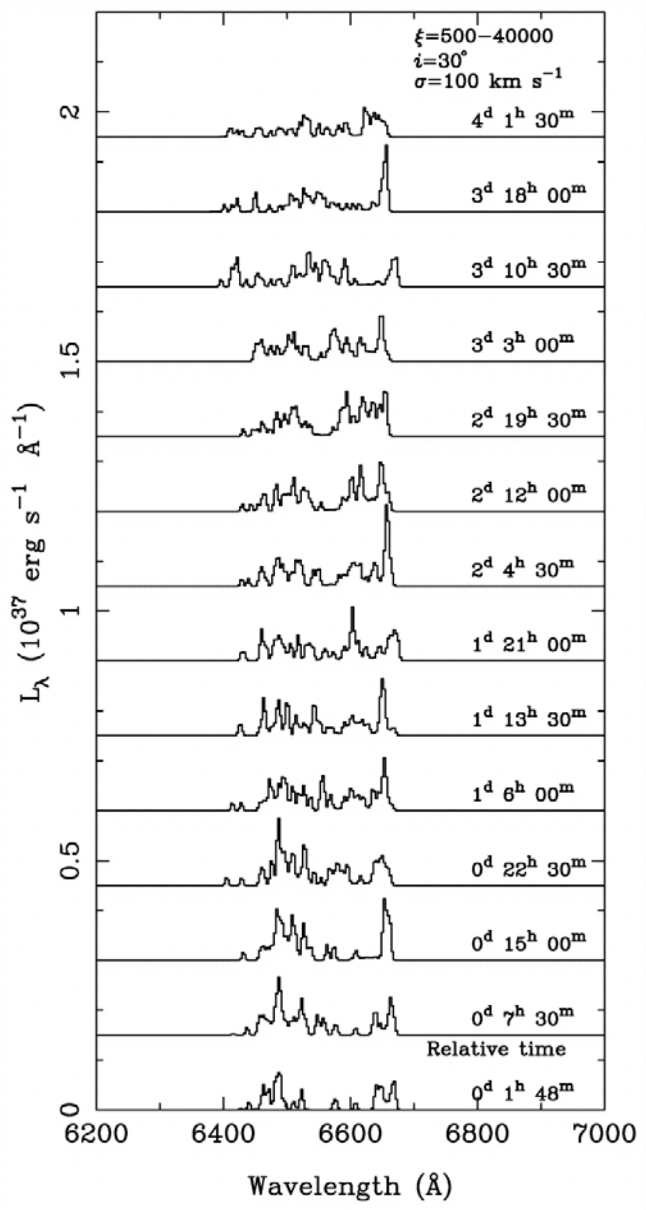


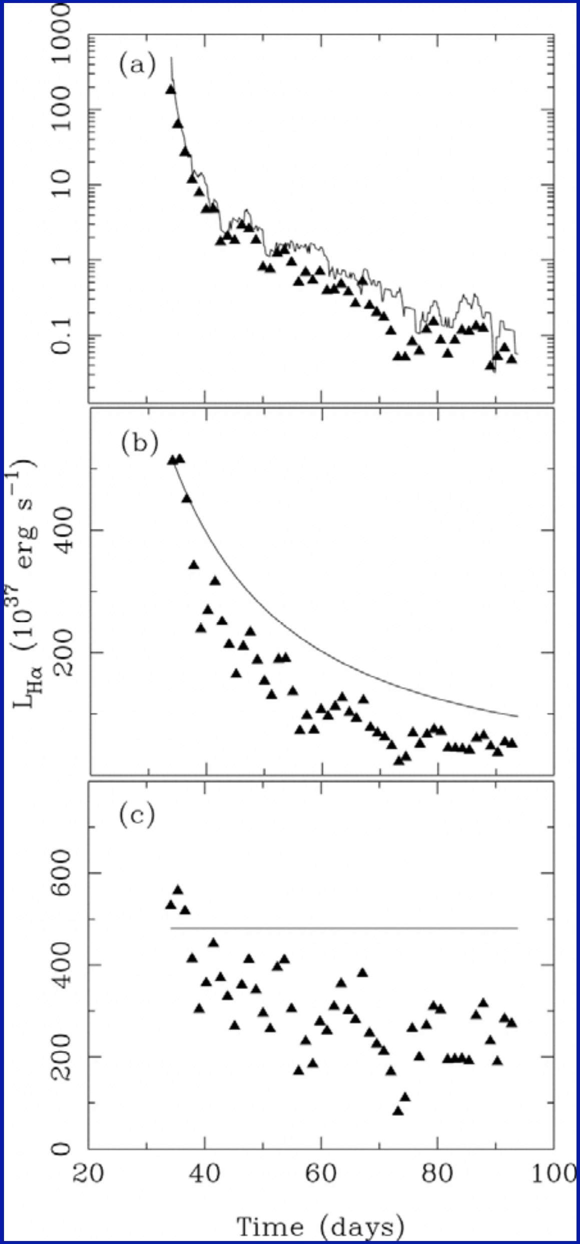
Kim, Park, Lee 1999



Kim, Park, Lee 1999

Bogdanovic et al. 2004





$$\Delta t_1 = 2\pi G M_{\rm BH} (2\,\Delta E)^{-3/2} \approx 0.068\ {\rm yr} \left(\frac{M_{\rm BH}}{10^7\ M_\odot}\right)^{1/2} \left(\frac{M_*}{M_\odot}\right)^{-1} \left(\frac{R_*}{R_\odot}\right)^{3/2}$$

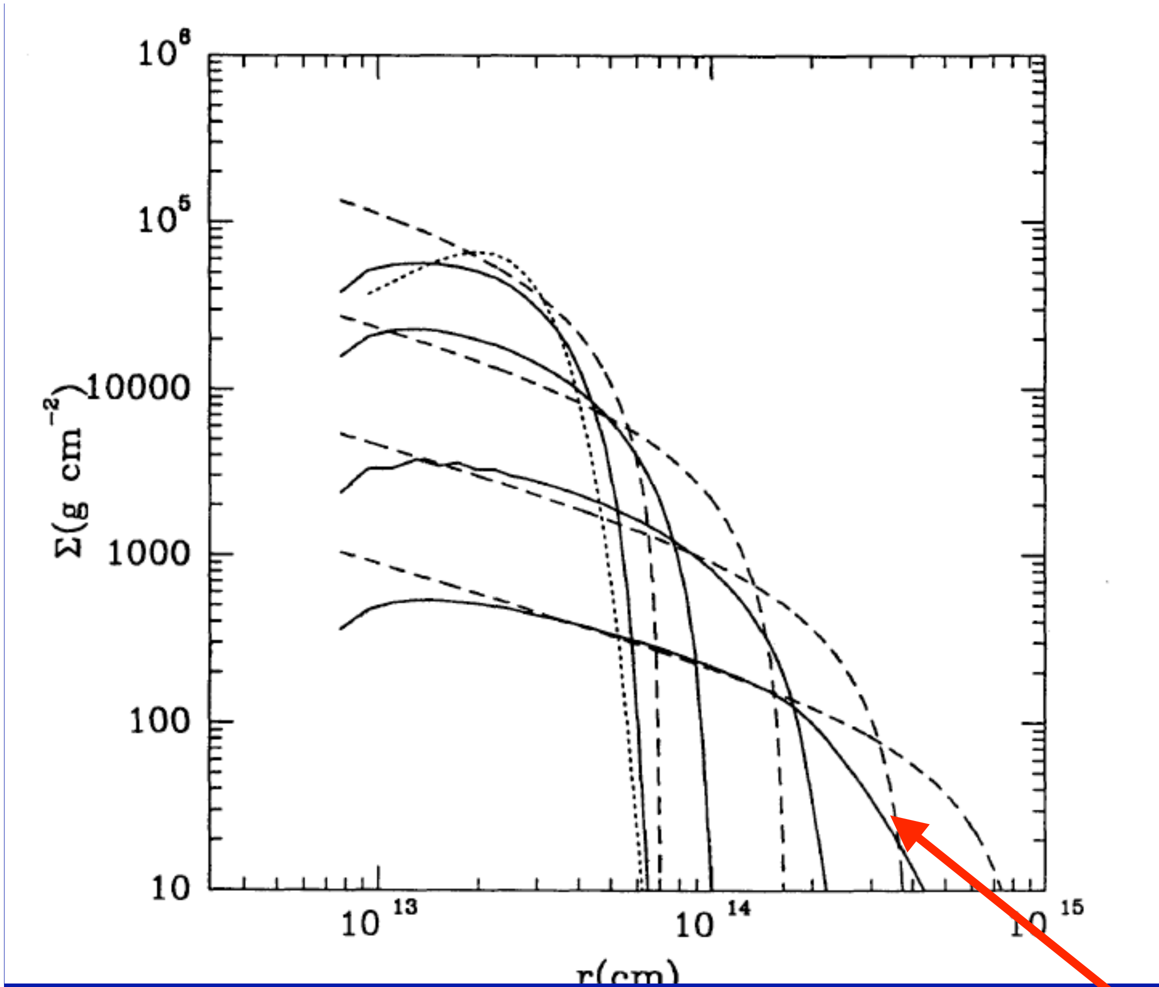
$$L_{\rm peak} \approx 1.36 \times 10^{45}\ {\rm ergs\ s^{-1}} \left(\frac{f}{0.1}\right) \left(\frac{M_{\rm BH}}{10^7\ M_\odot}\right)^{1/6} \times \left(\frac{M_*}{M_\odot}\right)^{7/3} \left(\frac{R_*}{R_\odot}\right)^{-5/2} .$$

$$L = \epsilon \dot{M} c^2 \approx 1.55 \times 10^{43}\ {\rm ergs\ s^{-1}} \left(\frac{f}{0.1}\right) \left(\frac{M_{\rm BH}}{10^7\ M_\odot}\right) \times \left(\frac{M_*}{M_\odot}\right)^{2/3} \left(\frac{t - t_D}{1\ {\rm yr}}\right)^{-5/3} .$$

Li, Narayan, Menou 2002 (Rees 1988, Phinney 1989)

Why X-ray light curve will depart from $\sim t^{-5/3}$

- Frame dragging, delayed circularization: streams miss each other first time around, remain cold beyond t_1
- Creation of an optically-thick atmosphere (debris, wind)
- Interaction of tidal ejecta with ambient medium (Khokhlov & Melia 1996)
- Contribution from a thin accretion disk



Cannizzo, Lee, Goodman 1990

But we have poor handle on how long the material lingers at large radii! (Menou & Quataert 2001)

$$\Psi(M_{\rm bh})dM_{\rm bh} = \Psi_0 \left(\frac{M_{\rm bh}}{M_\star}\right)^{k(\alpha+1)-1} e^{-(M_{\rm bh}/M_\star)^k} \frac{dM_{\rm bh}}{M_\star}$$

$$\Psi(L_X) = \int_{M_{\rm min}}^{M_{\rm max}(m_\star)} dM_{\rm bh} \int_{t_{\rm peak}(M_{\rm bh})}^{\infty} dt \; \Psi(M_{\rm bh}) \, \Gamma(M_{\rm bh}) e^{-\Gamma(M_{\rm bh})t} \times \delta[\omega^{-1} L_{\rm bol}(M_{\rm bh}, t) - L_X],$$

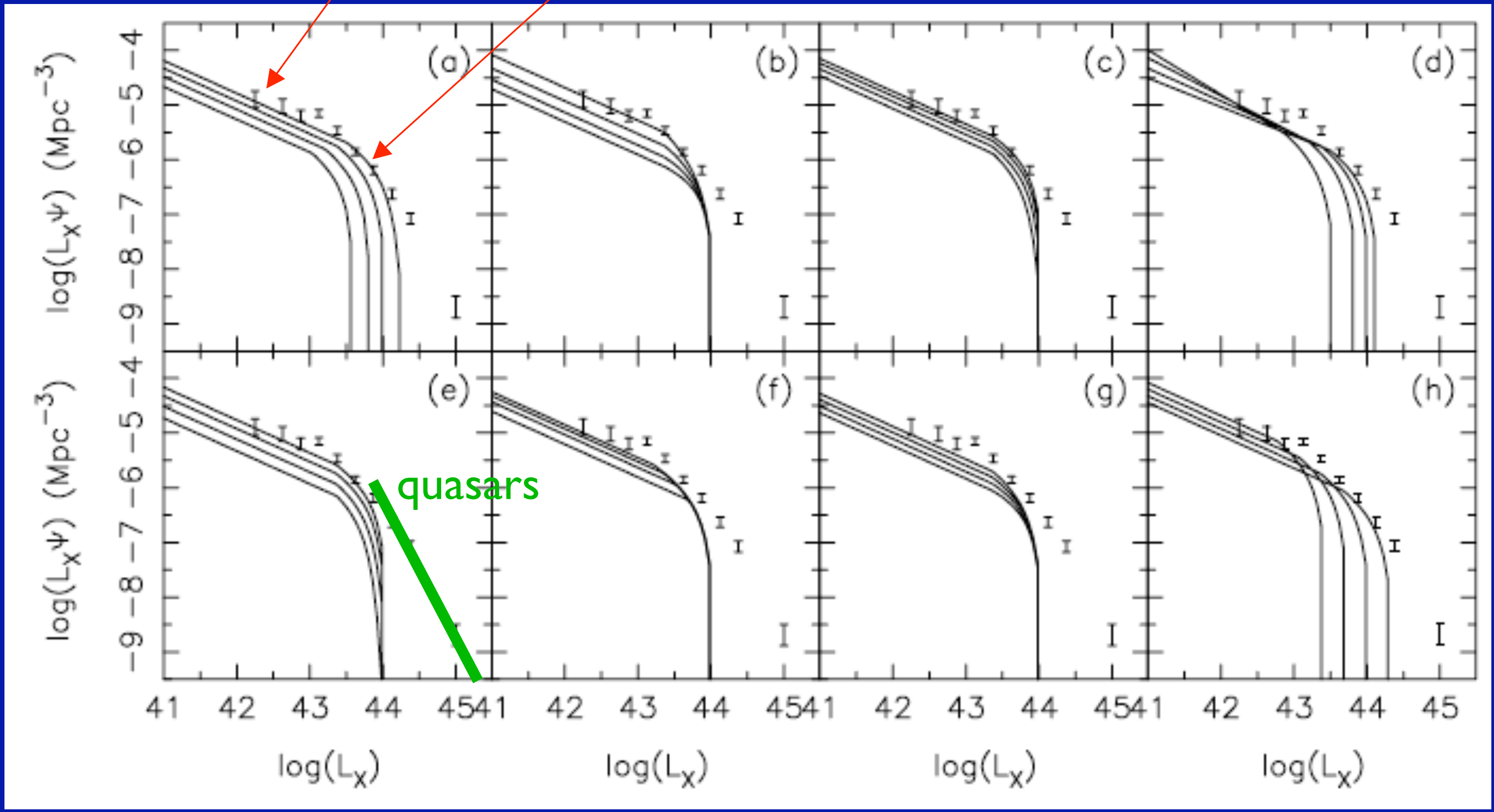
MM, Merritt, Ho 2006

Uncertainties:

- Bulge luminosity function (bulge/disk ratio)
- Incidence of black holes in low-mass spheroids
- Bolometric correction

Slope sensitive to the light curve model (and maybe on the BH MF), amplitude robust.

The knee reflects maximum luminosity in tidal disruption.



MM, Merritt, Ho 2006

Could low-mass massive black holes have grown to their present size by the accretion of tidal debris?