



Remco van den Bosch, MPIA
Schwarzschild Models

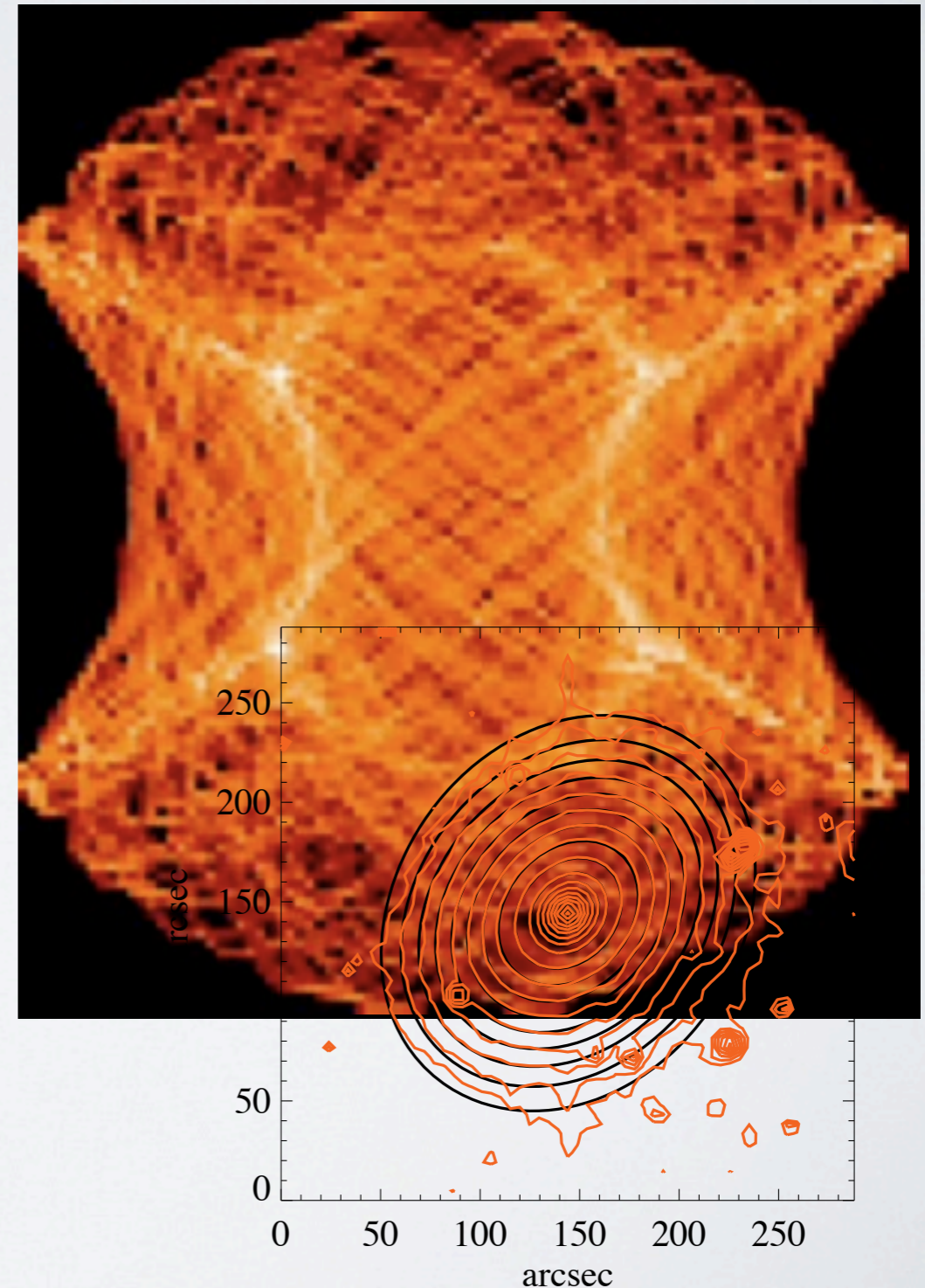
ORBIT-BASED MODELS

- Orbit-based models do not place any assumptions on the anisotropy (orbit configuration) and can use all kinematic information, including higher moments
- Still imposes some assumptions: equilibrium, geometry
- Contain many parts and numerical integrals, but are all well understood.
- Several implementations exist: Spherical (Magorrian, Breddels), axisymmetric (NUKERS, van der Marel, Valluri), Triaxial (van den Bosch)
- When are Schwarzschild models appropriate?



ORBIT-BASED MODELS

- (1) Choose a potential
- (2) Integrate orbit in the potential and store all the observables, including kinematics
- (3) Generate a library of orbits
- (4) Construct a superposition

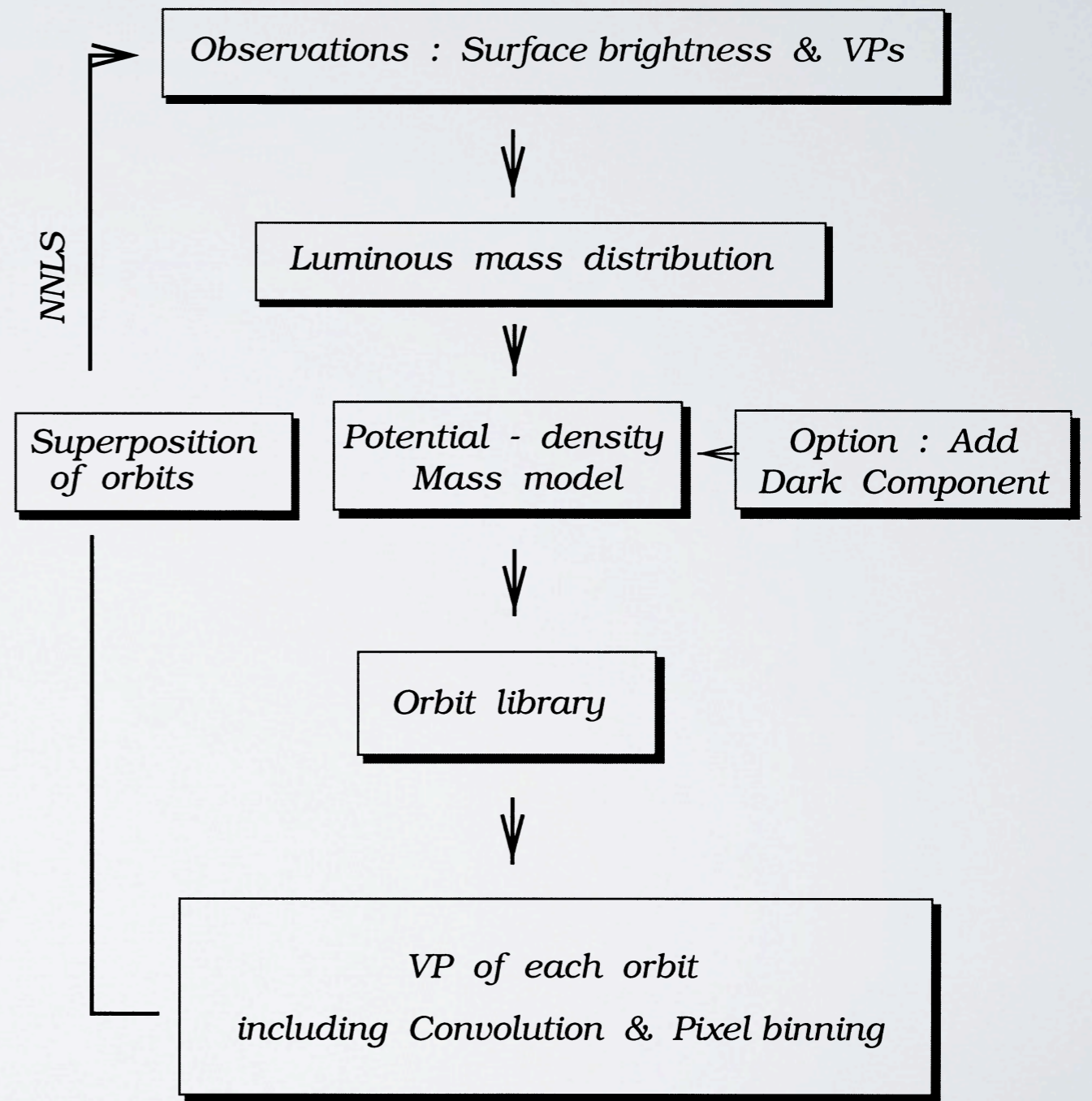


ORBIT-BASED MODELS

Loop over all possible mass distributions:

SMBH, viewing angles, stellar mass-to-light ratio and dark matter

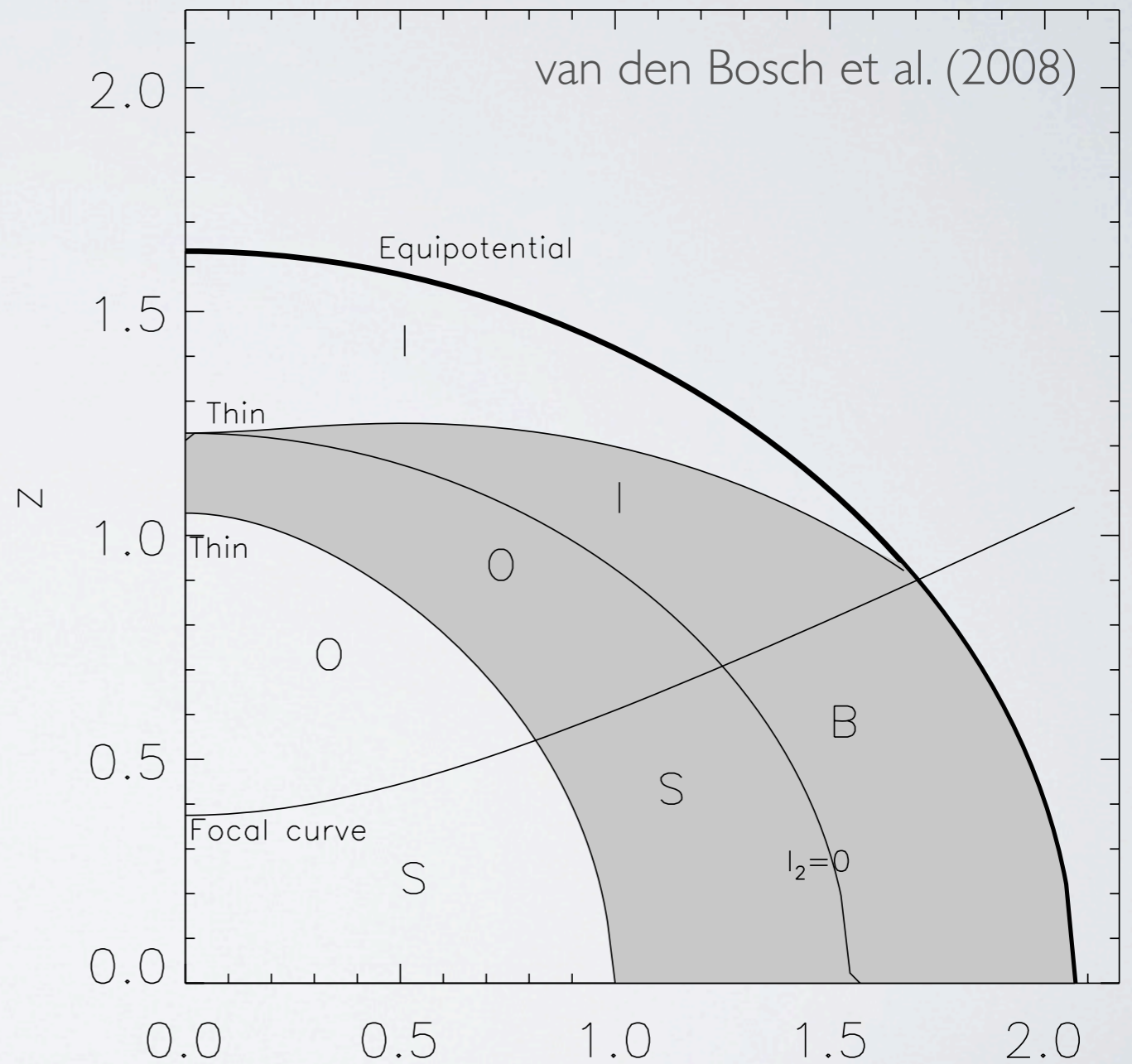
Computationally easy



Cretton et al. 1998

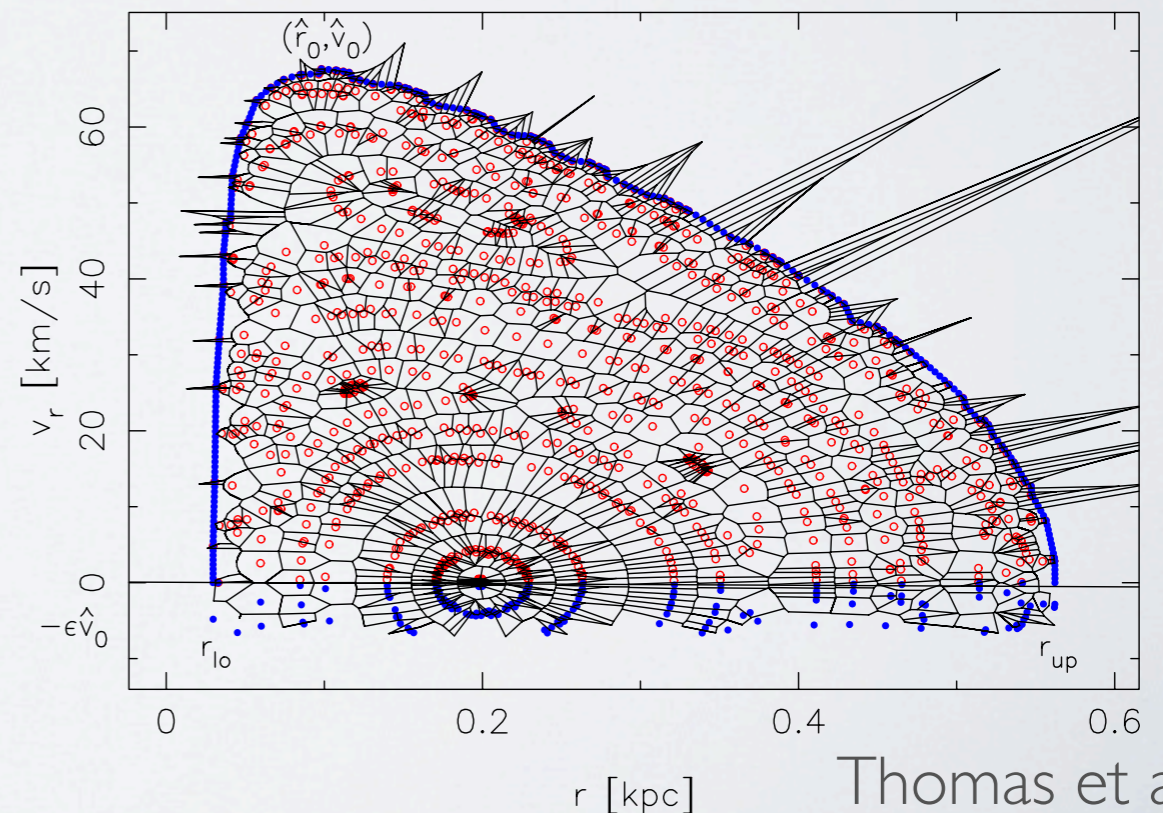
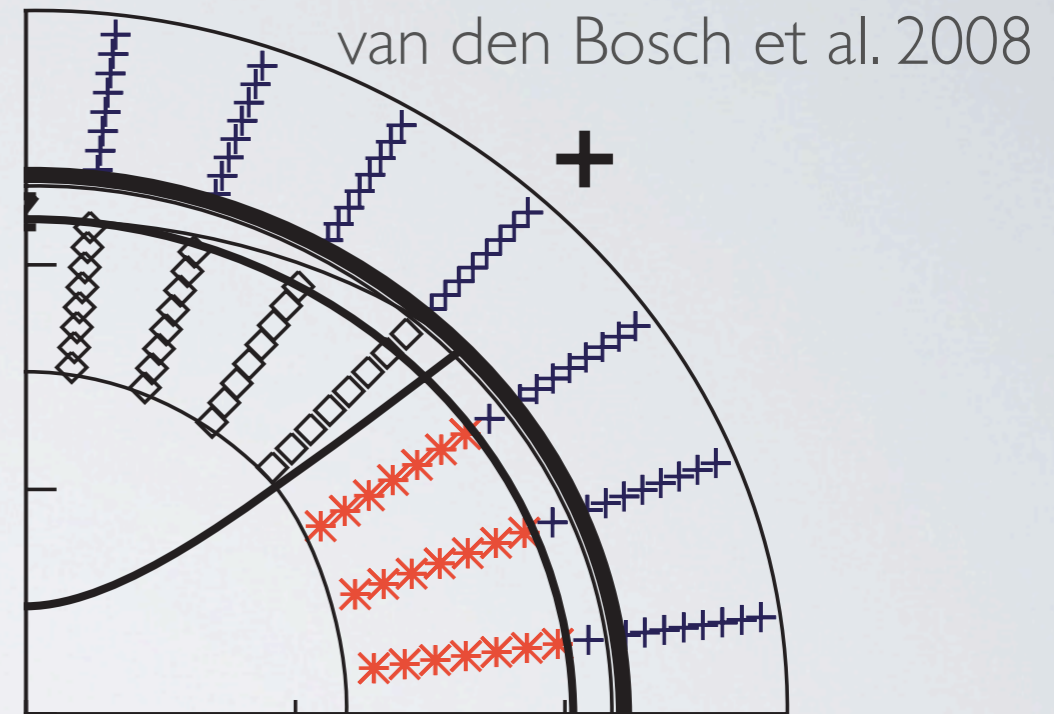
THE SIZE OF AN ORBIT LIBRARY

- How do you know the orbit library is complete?
- Three conserved quantities: Integrals of motions (Energy, Angular momentum and I_3)
- In (non-rotating) potentials all major orbits pass orthogonally through the x-z plane
- Sampling orbits is thus trivial
- Sampling schemes differ, but it is easy to show convergence is reached.

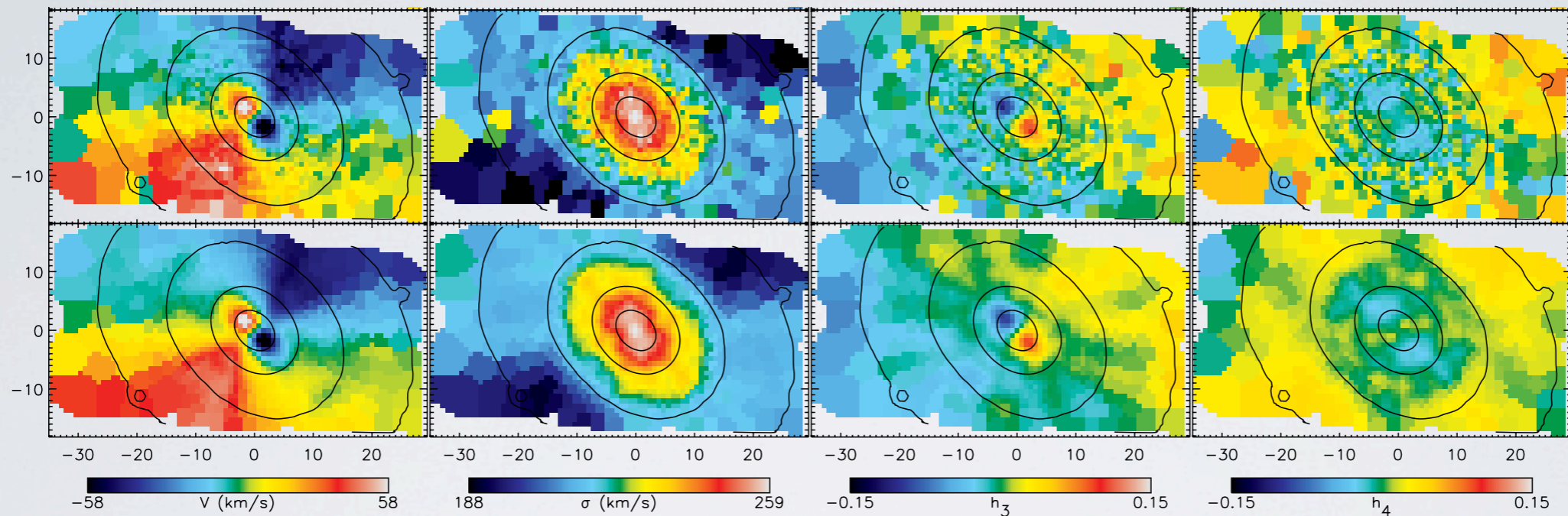


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APPLICATIONS



NGC4365, van den Bosch et al. (2008)

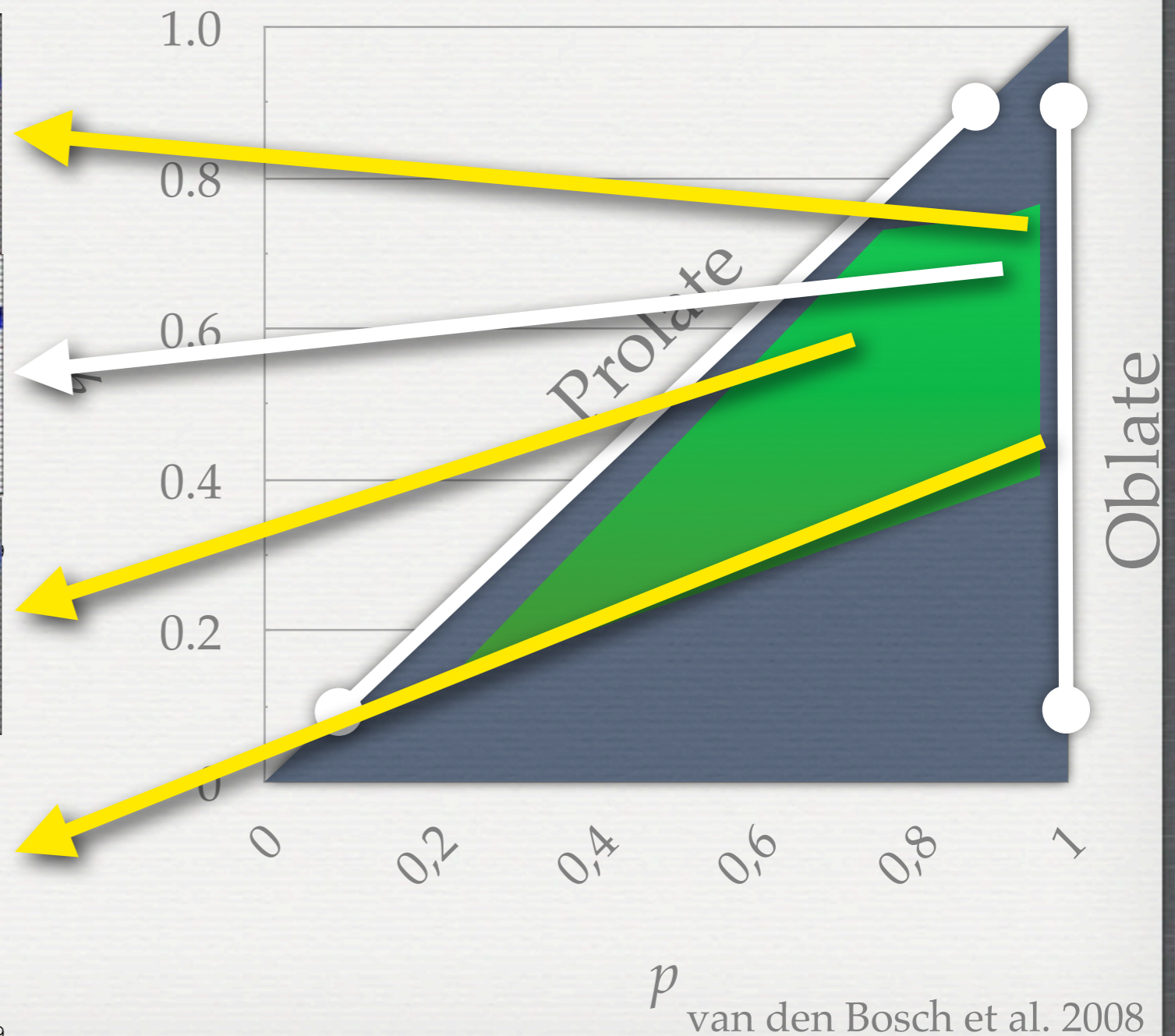
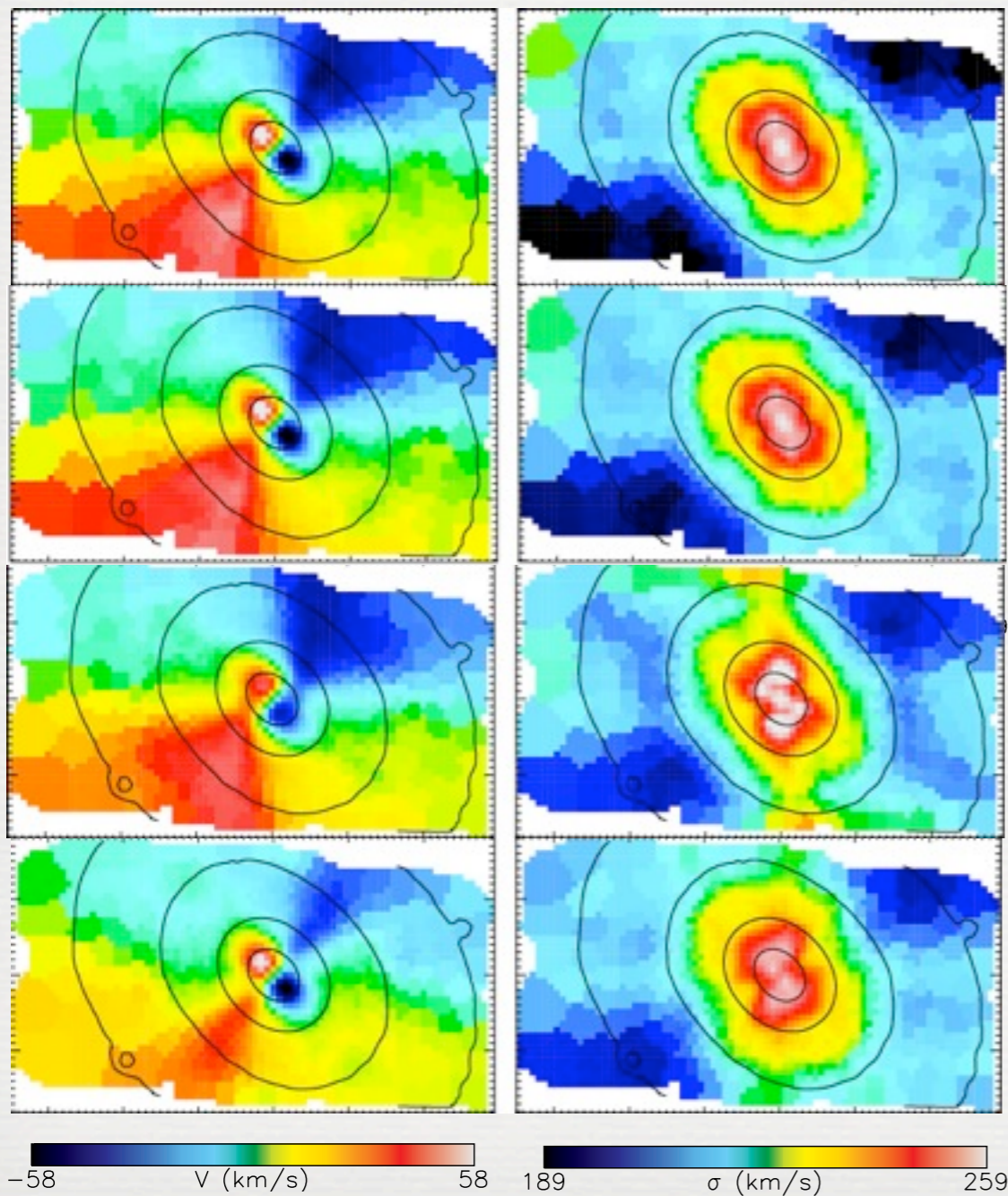
- **Dynamical mass**

- Mass-to-light ratio
- Dark matter
- Super-Massive Black holes

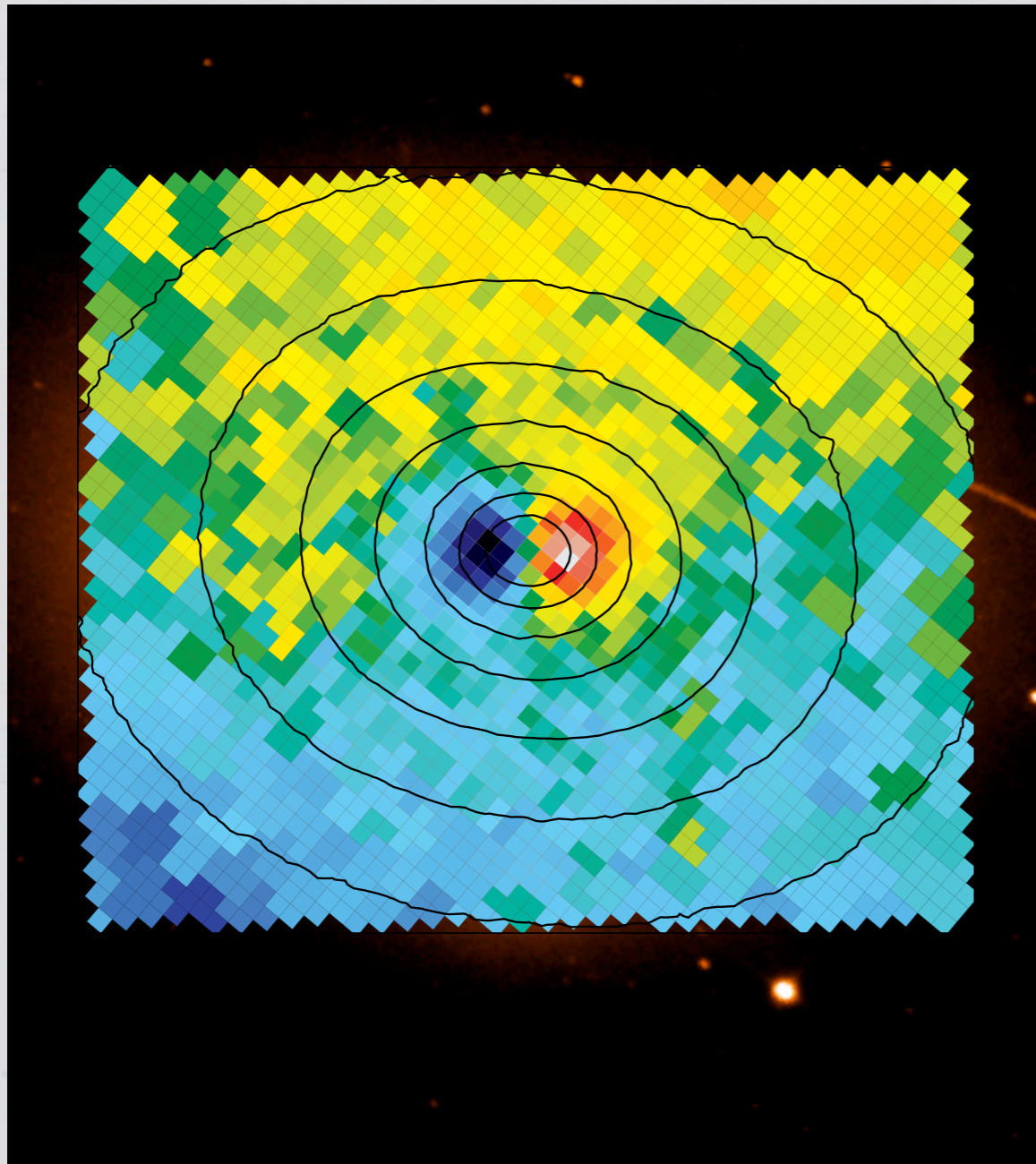
- **Orbital structure**

- Distribution function
- Dynamical decompositions

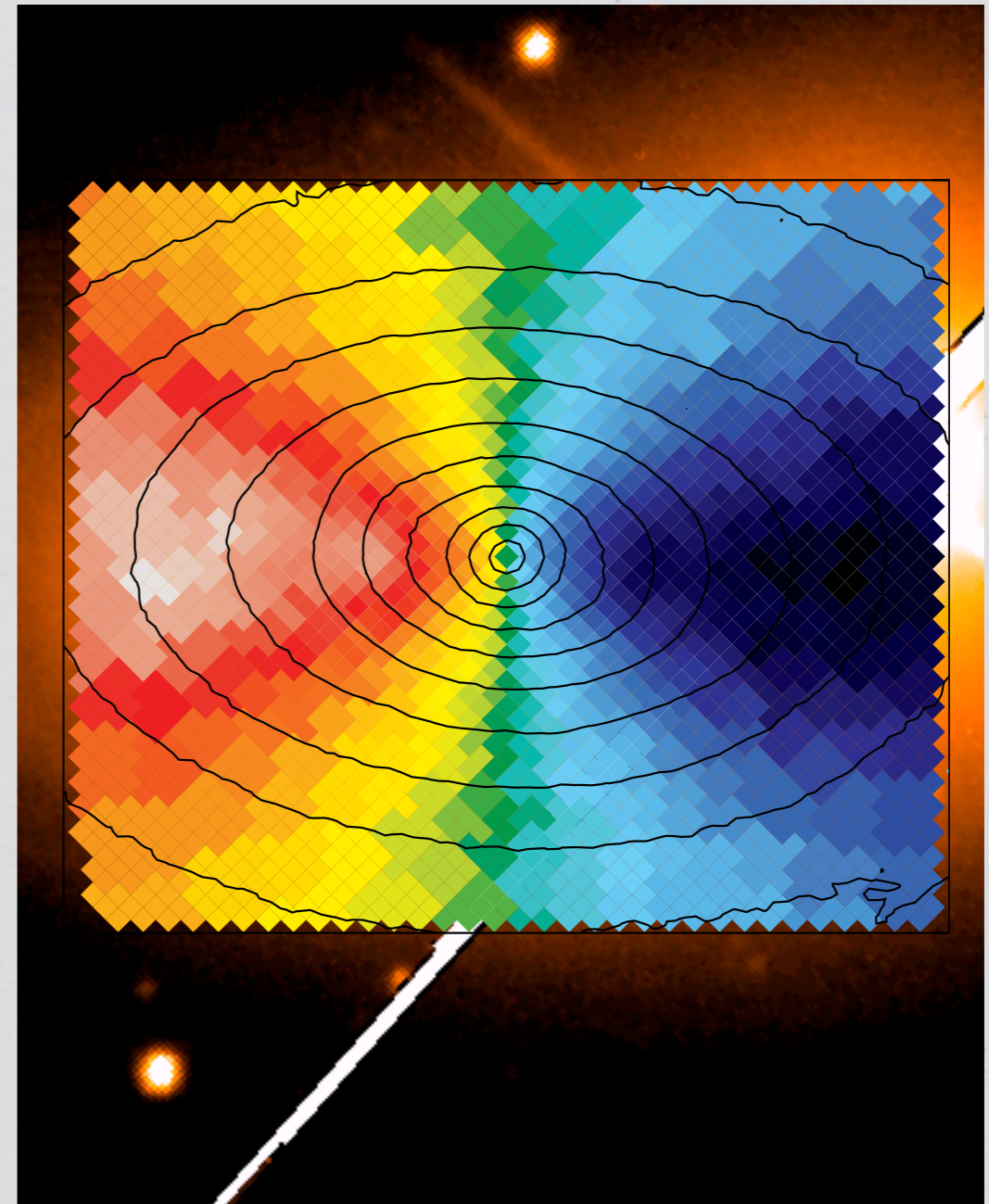
TRIAxIAL SCHWARZSCHILD MODELS



Early Types Galaxies

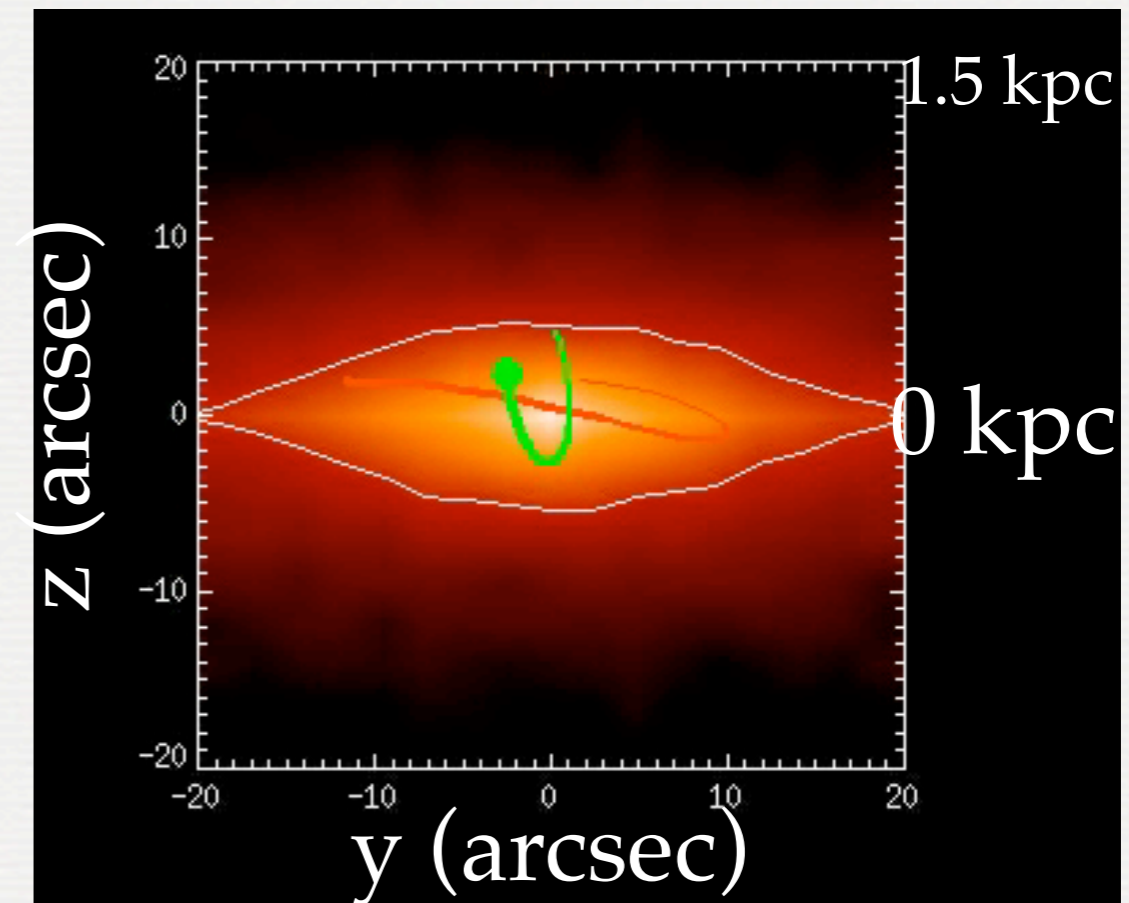
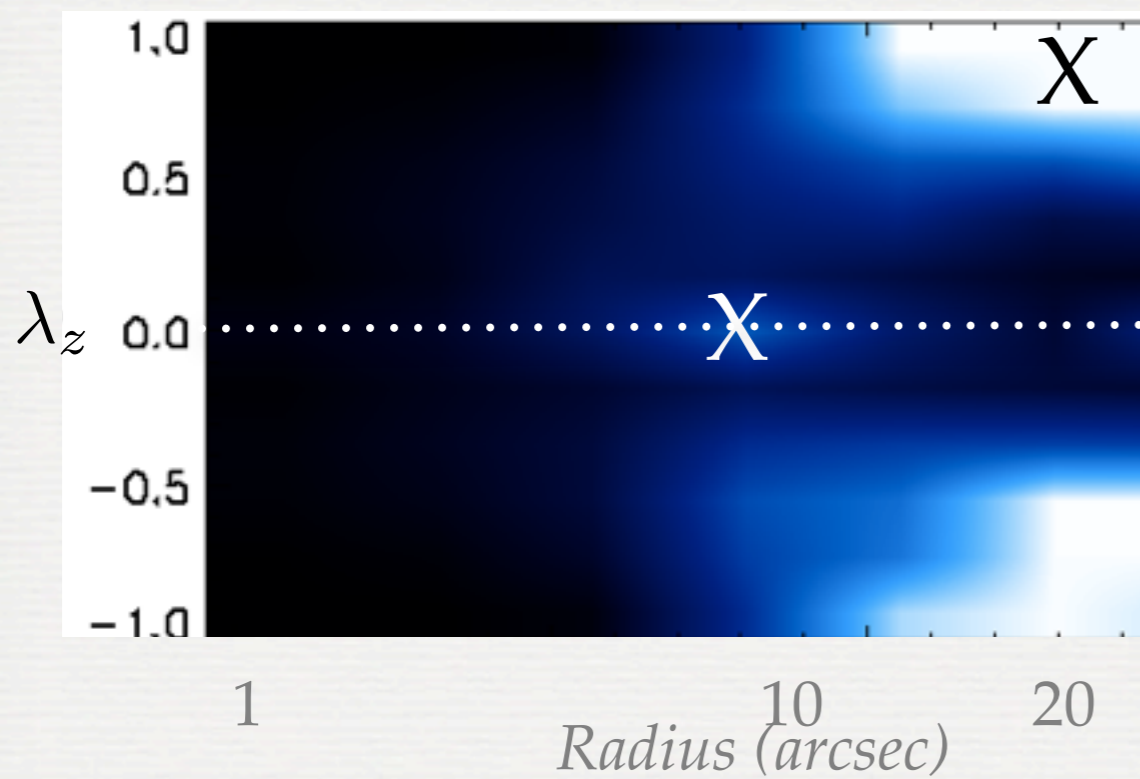


NGC 4406



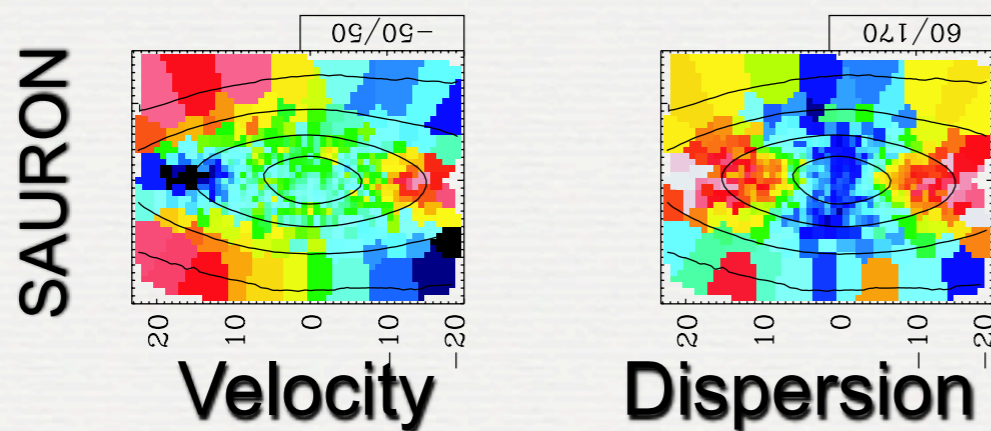
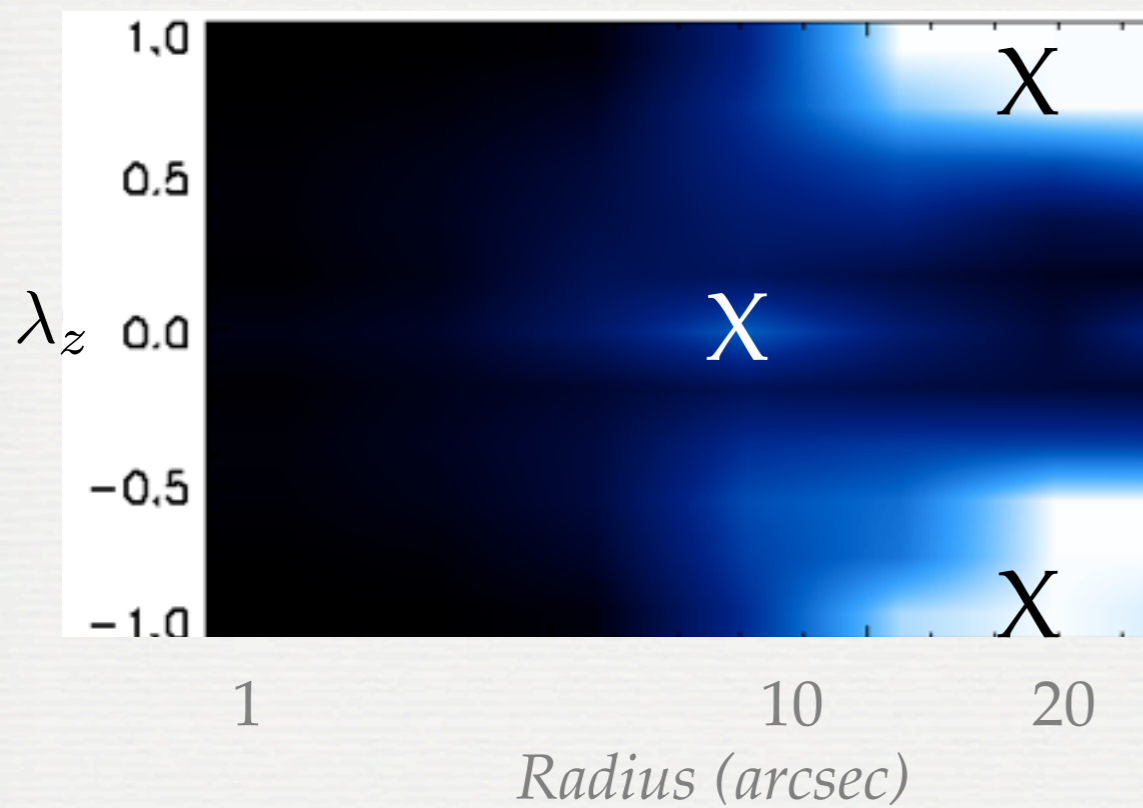
NGC 2974

Disc galaxy



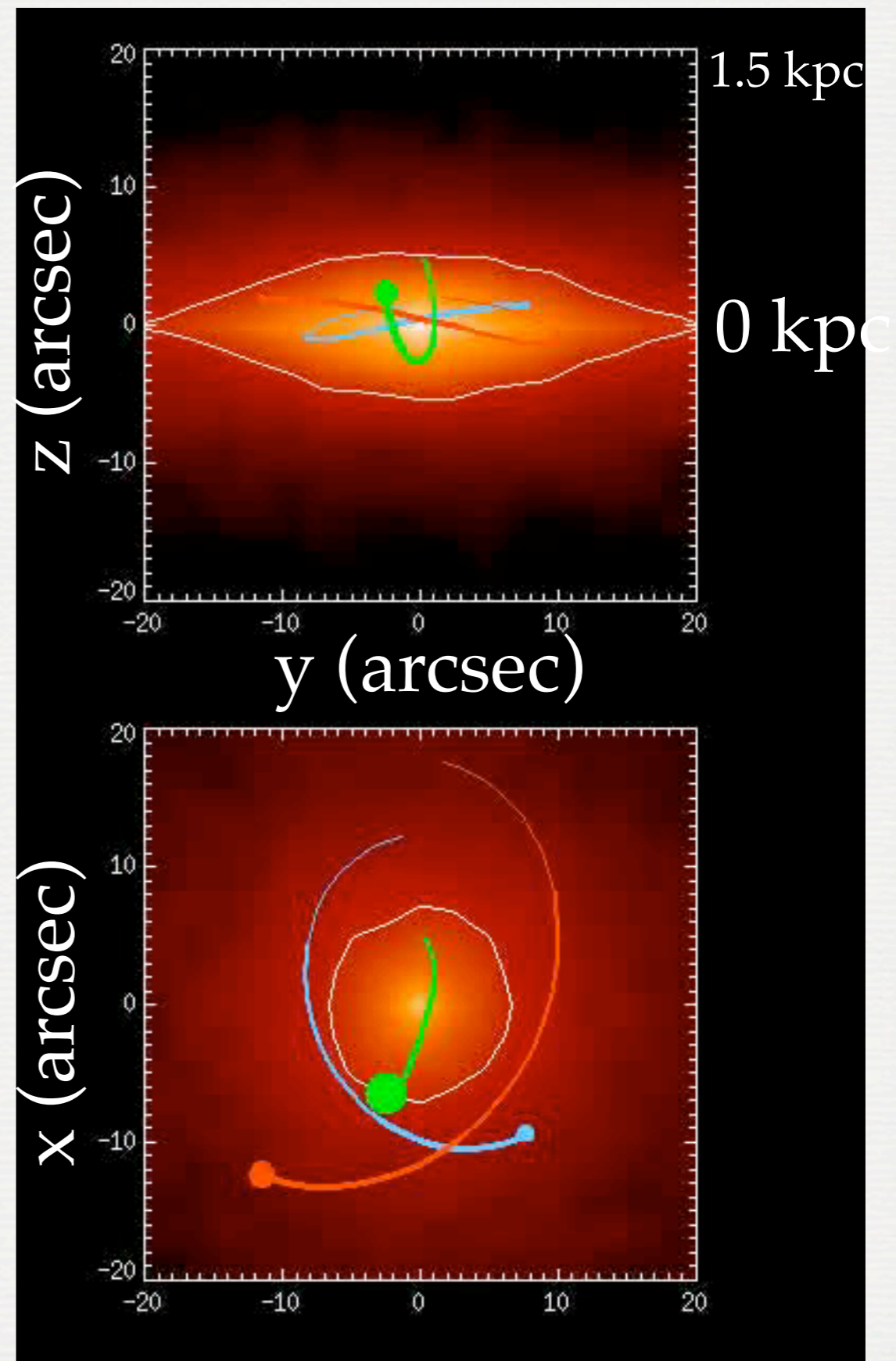
$$\bar{\lambda}_z = \frac{\bar{J}_z}{\bar{R}\bar{\sigma}}$$

Disc galaxy

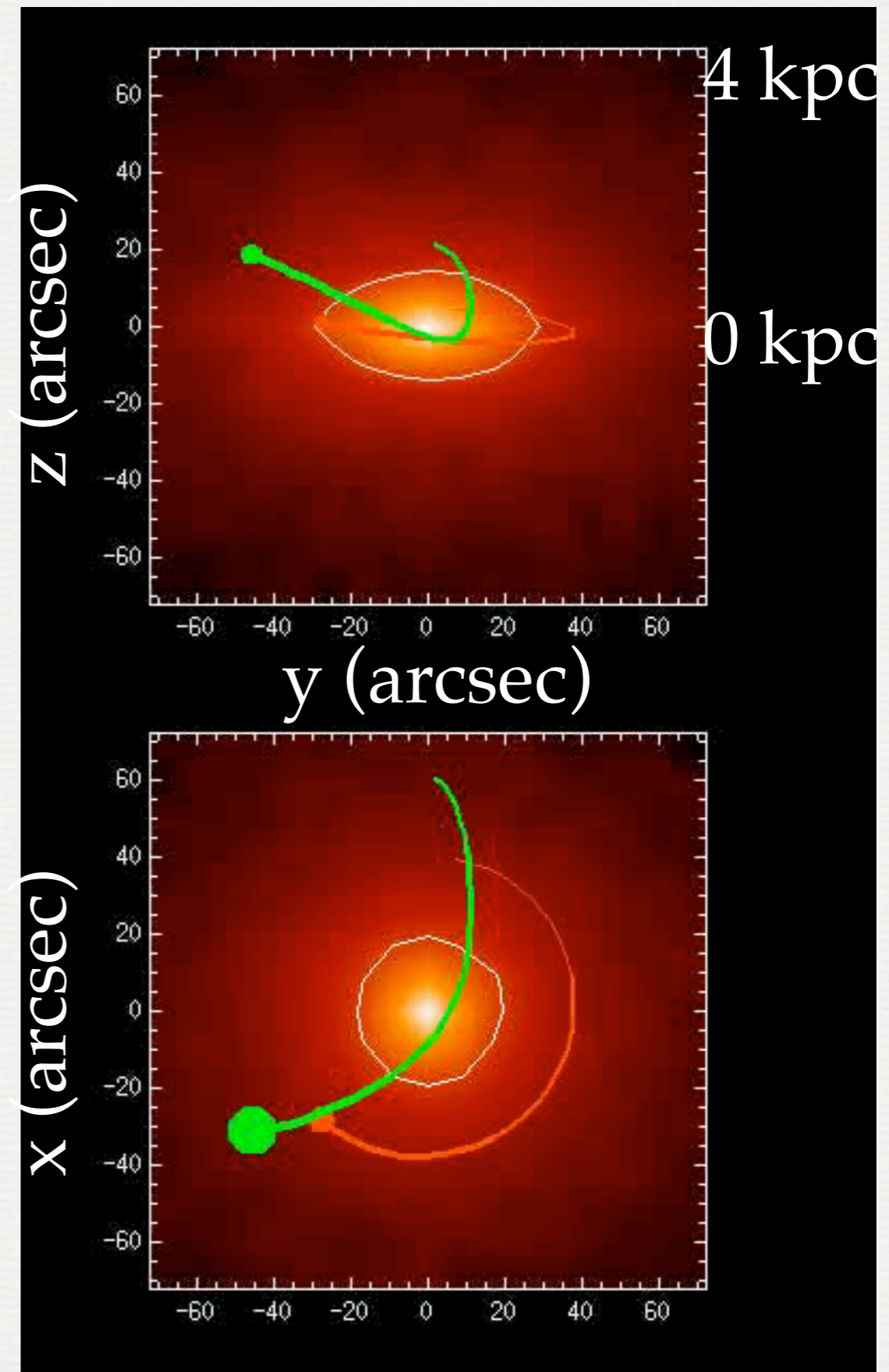
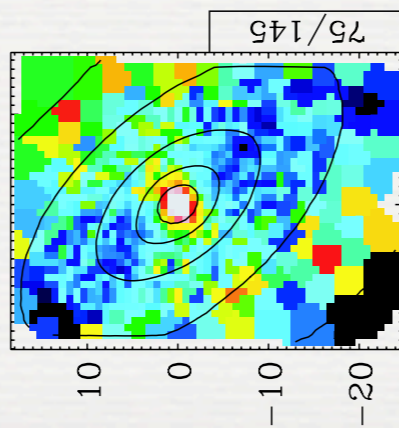
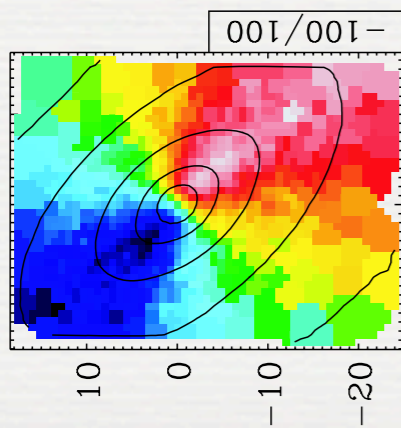
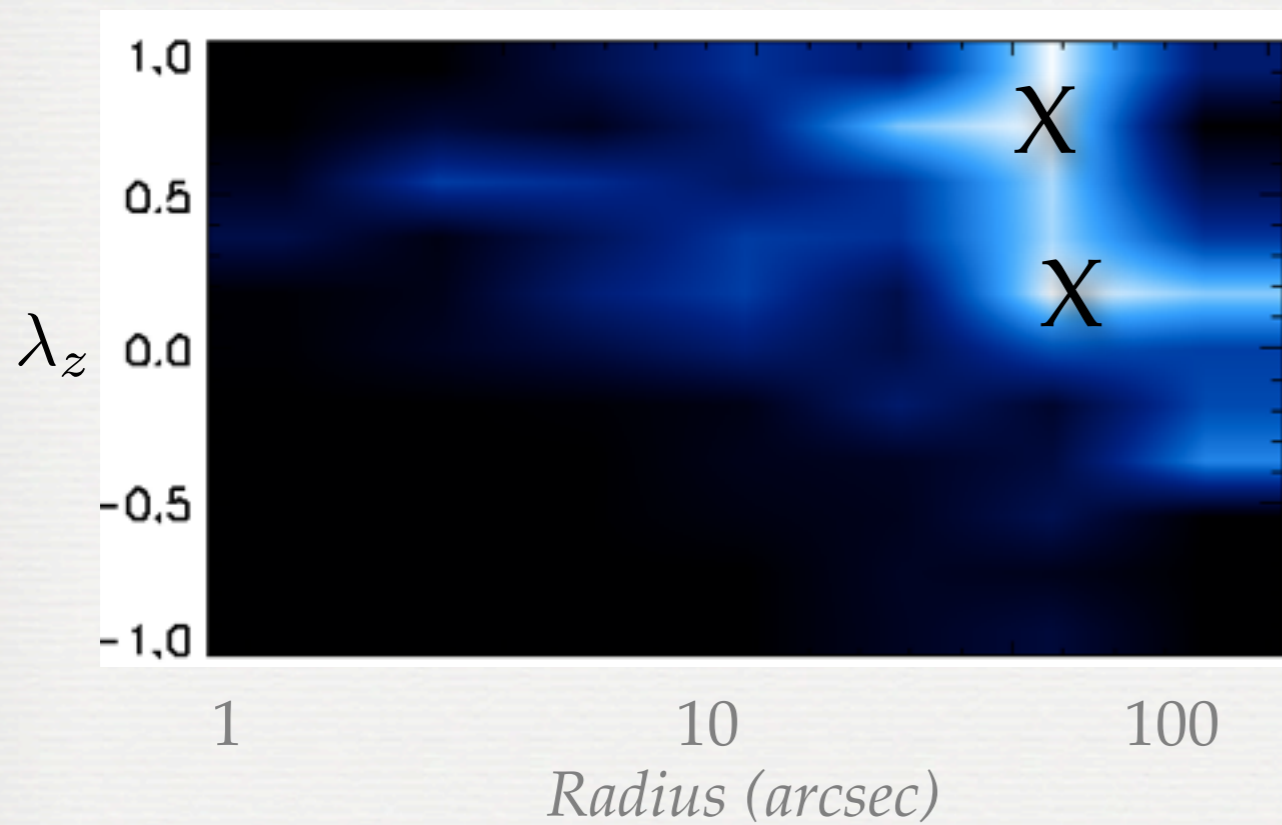


NGC4550

Emsellem et al. (2004)



BULGE DOMINATED NGC3377

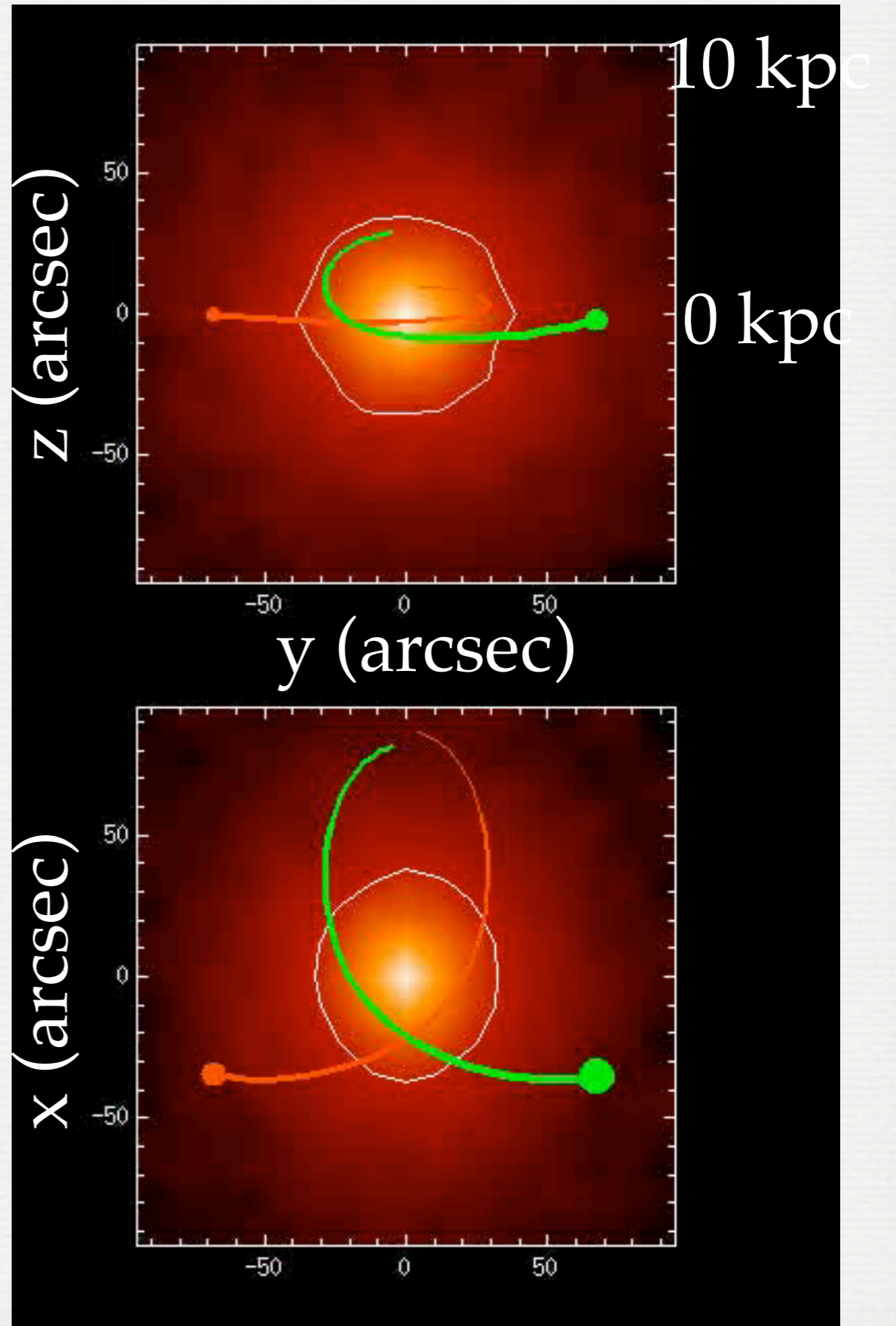
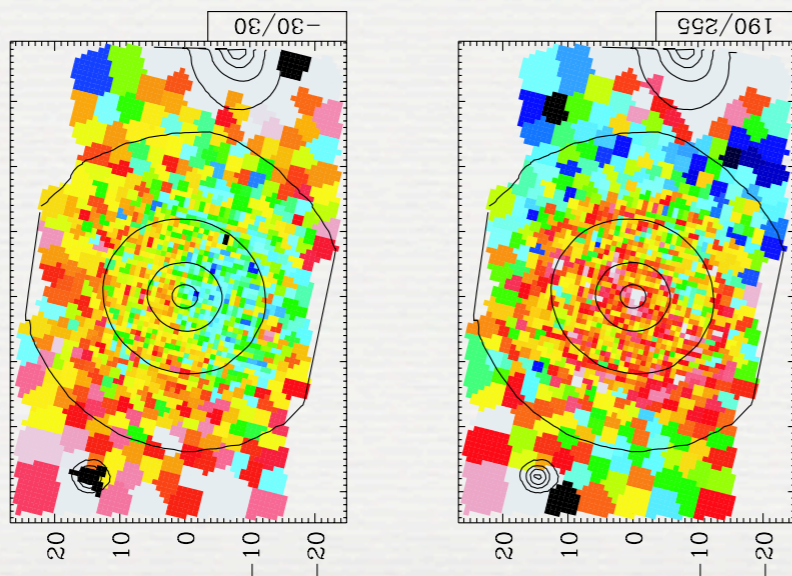


Round

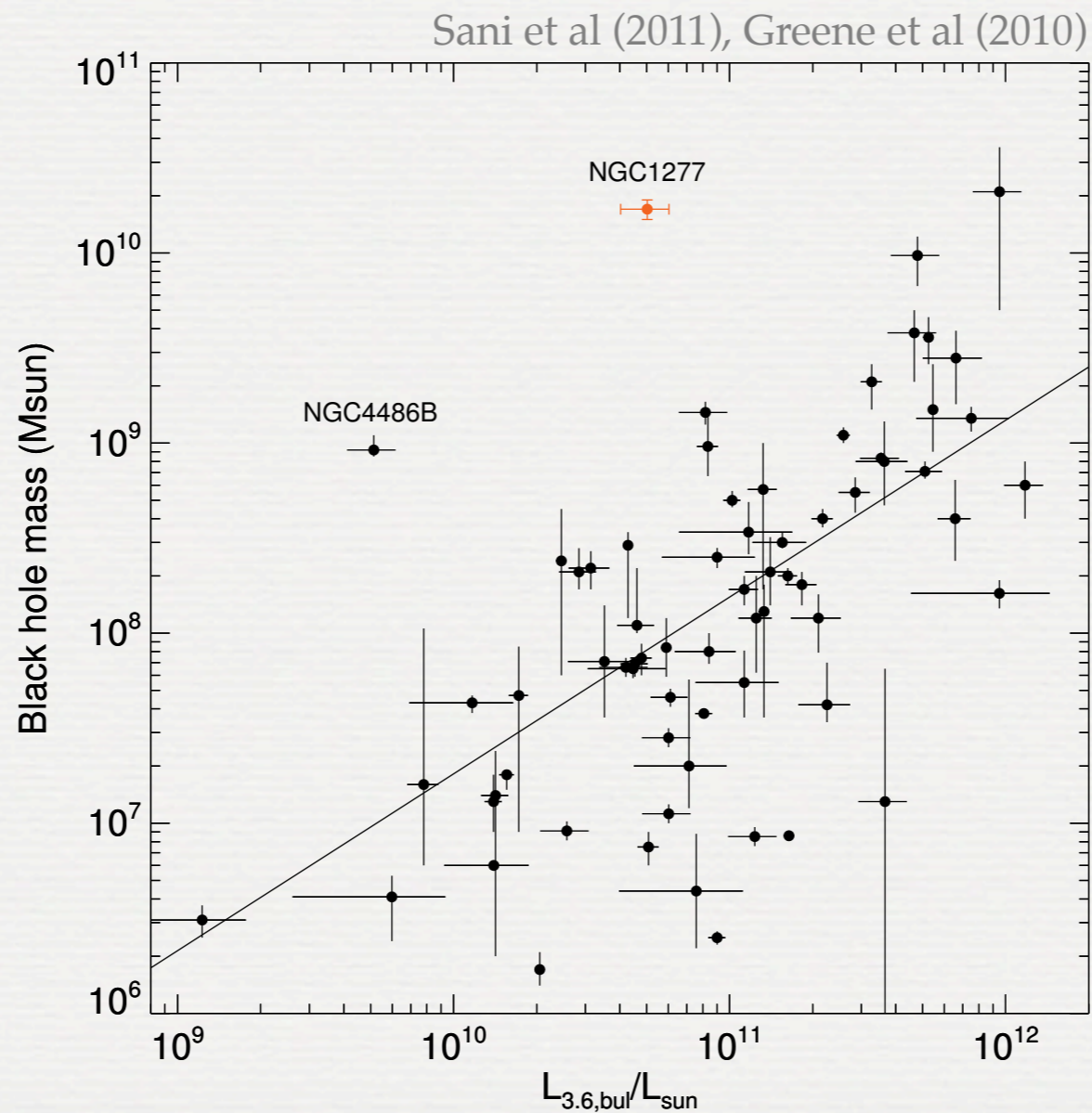
NGC5846



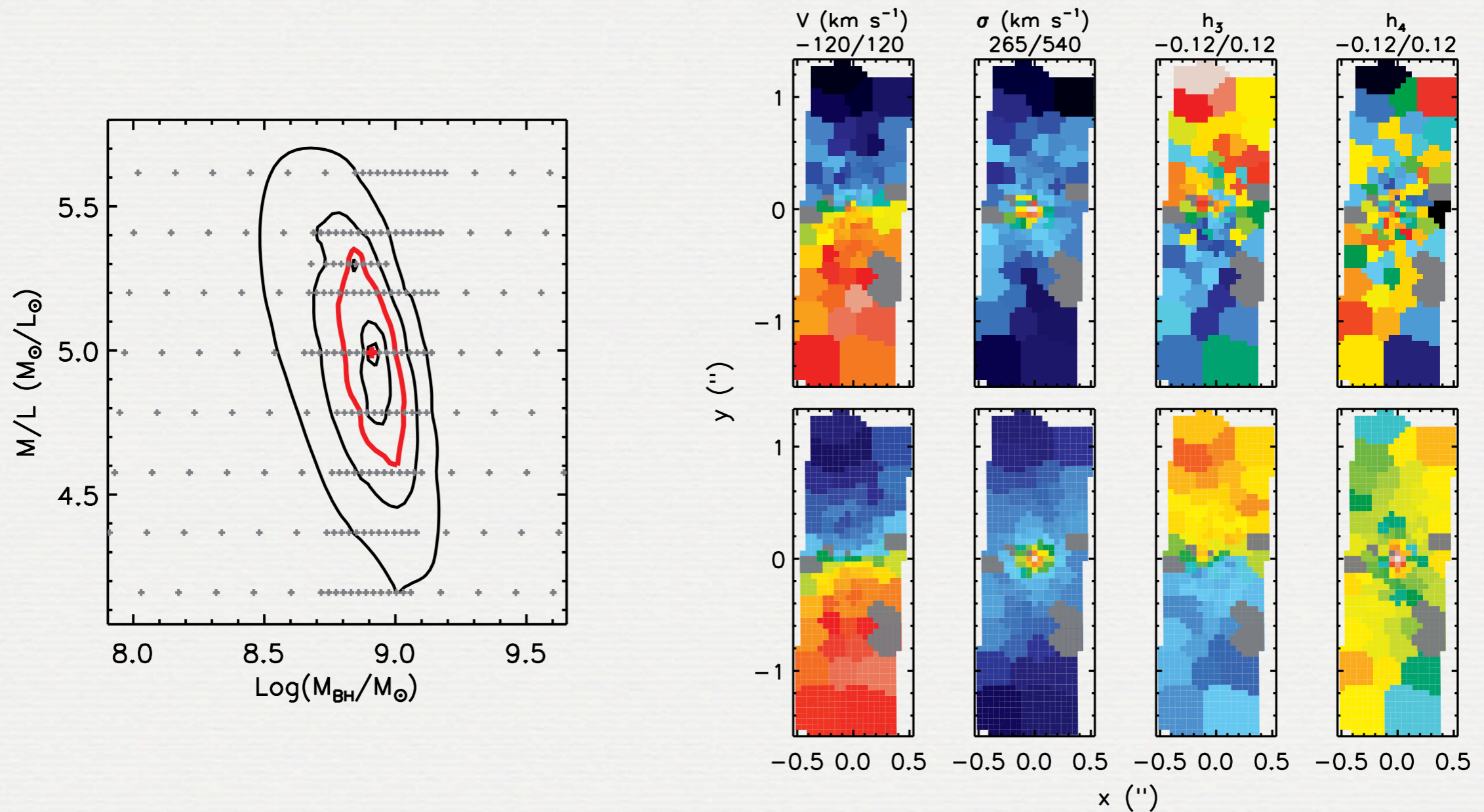
1 10 100
Radius (arcsec)



BLACK HOLES & SCHWARZSCHILD

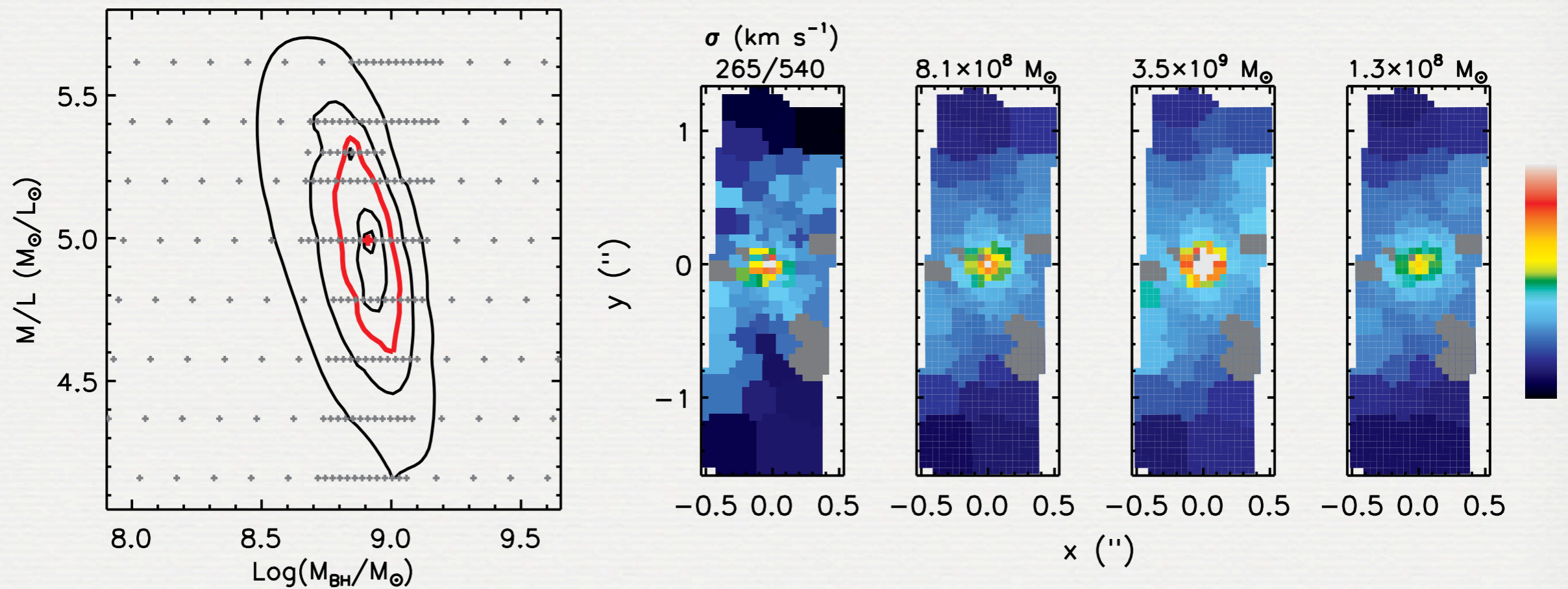


BLACK HOLE IN NGC3998



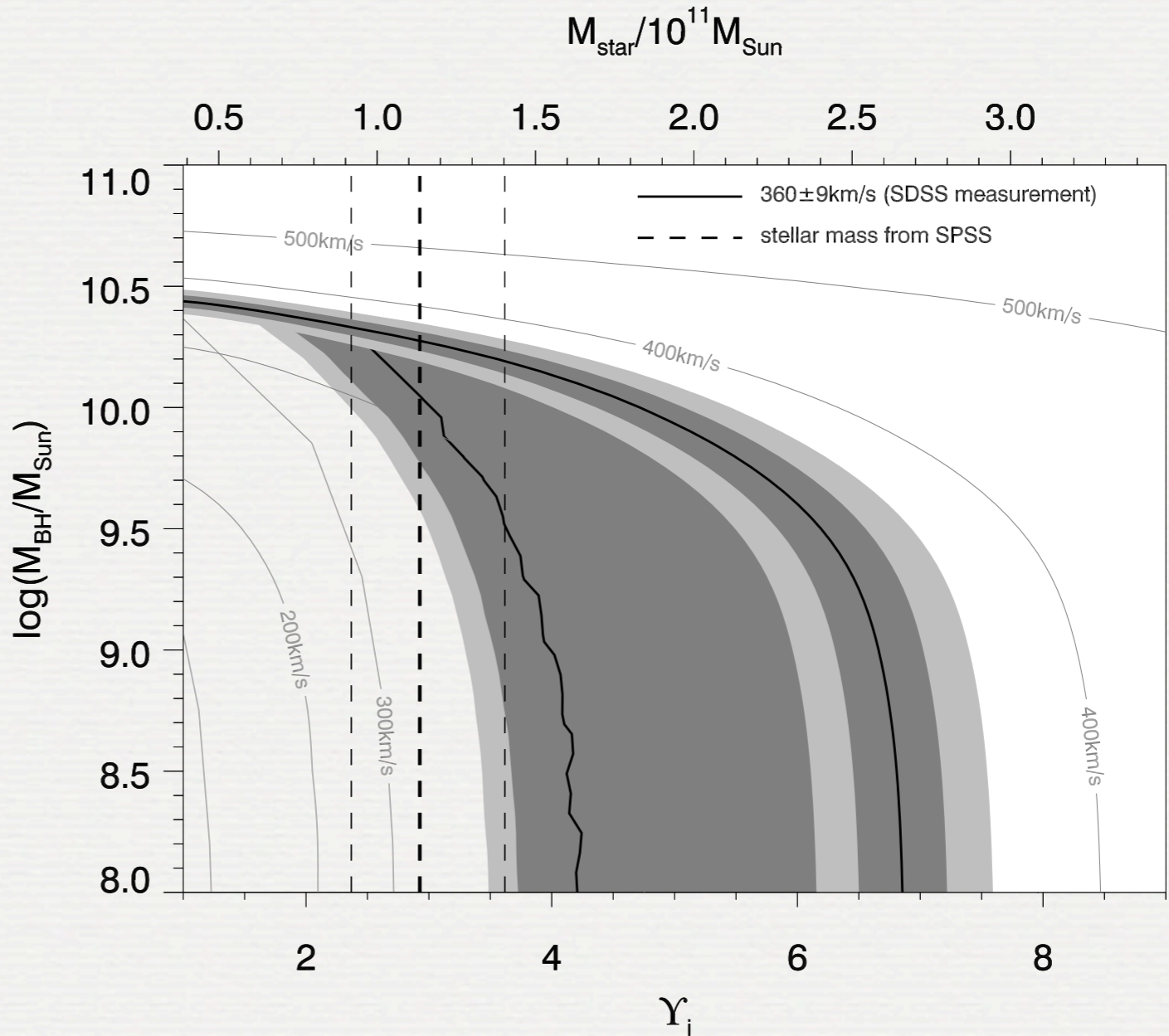
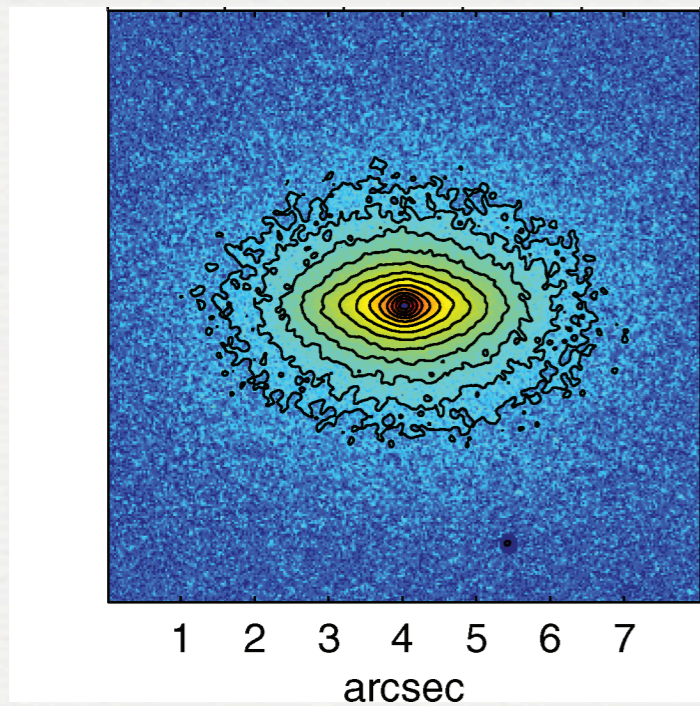
Walsh et al 2012

BLACK HOLE IN NGC3998



Walsh et al 2012

JEANS VS. SCHWARZSCHILD



Läscher et al. in prep

WISH LIST

- Non-parametric mass profiles (M15, Jardel, Thomas)
- Discrete kinematic tracers (Breddels, Watkins, Magorrian) plus priors
- Chemical Tagging
 - Full spectrum fitting of unresolved stellar pops (Houghton 2006)
 - Abundances of stars (den Brok)
- MCMC, including orbital weights (Magorrian 2006)
- Figure Rotation (Bars, Tumbling)
- Hybrids Syer-Tremaine / NMAGIC (Dehnen 2010)

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