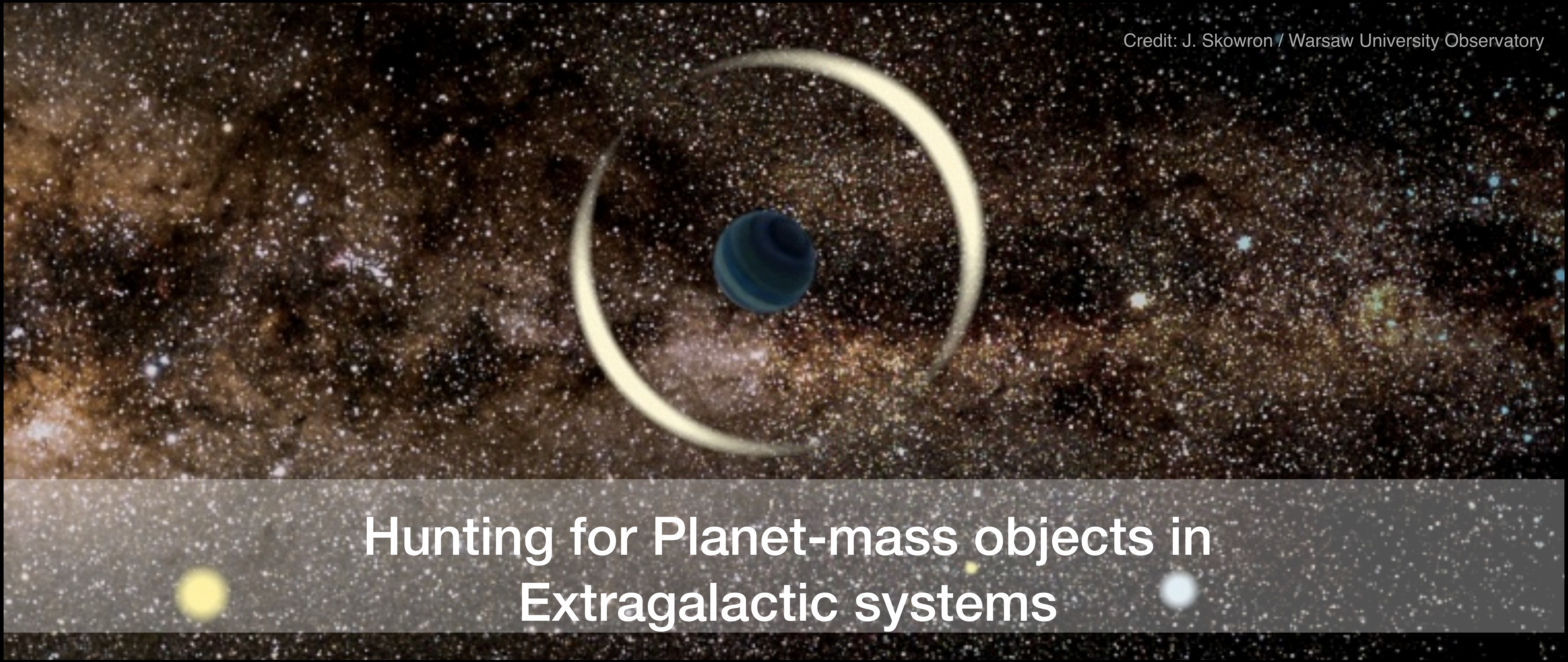


Credit: J. Skowron / Warsaw University Observatory

Hunting for Planet-mass objects in Extragalactic systems

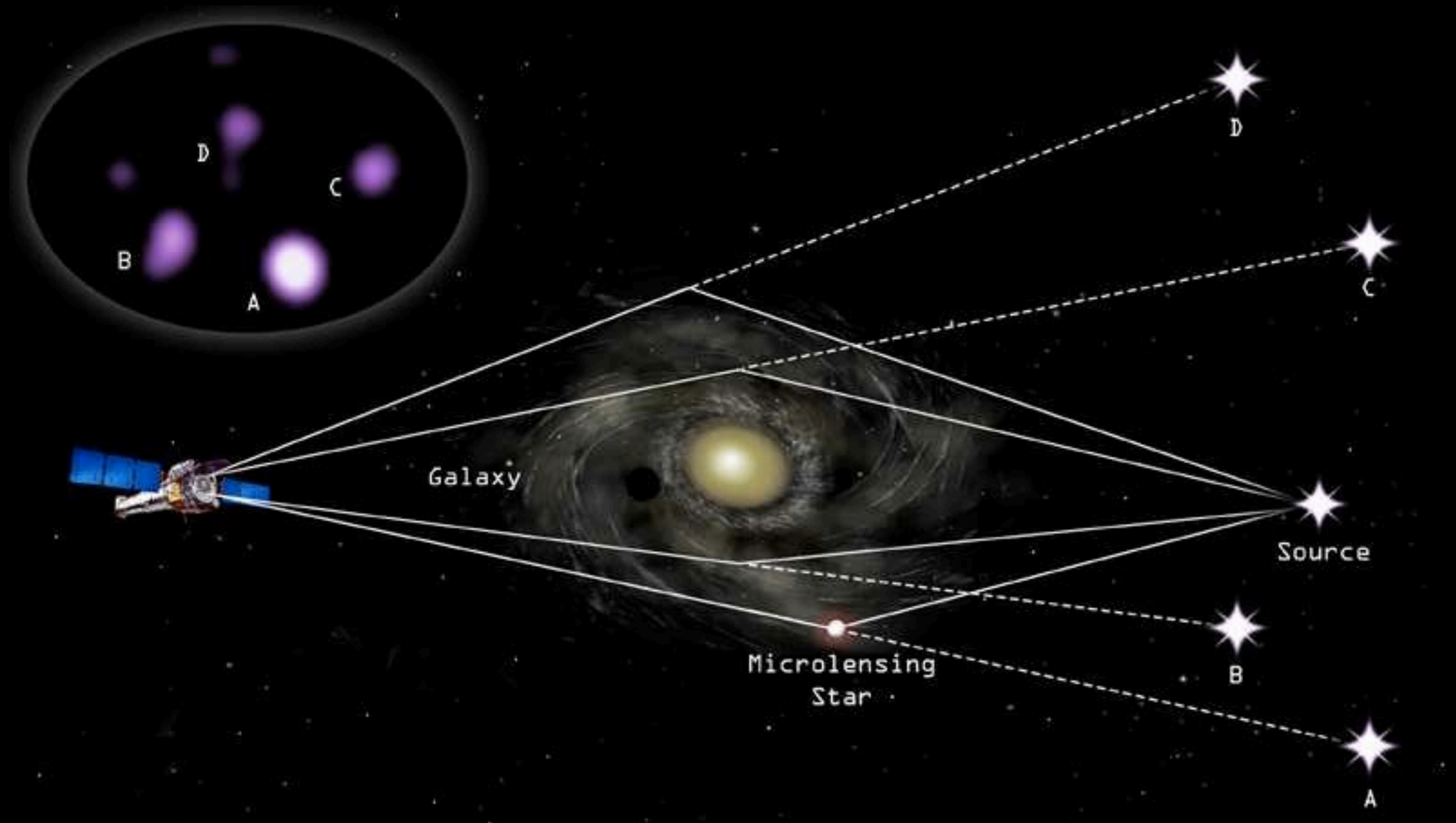
13th Serbian Conference on Spectral Line Shapes in Astrophysics

Speaker: Saloni Bhatiani

Co-authors: Xinyu Dai , Eduardo Guerras

University of Oklahoma

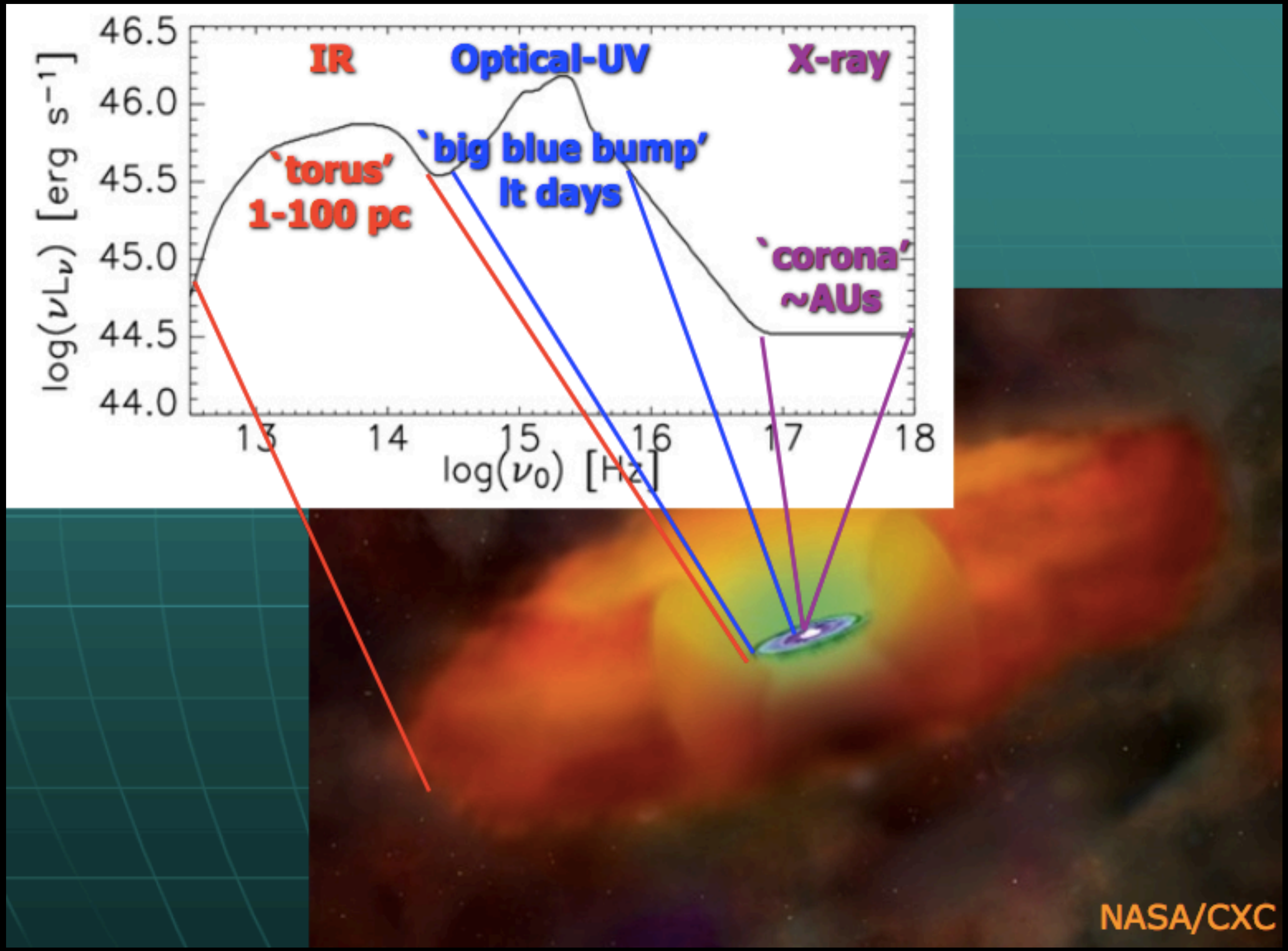
Quasar microlensing

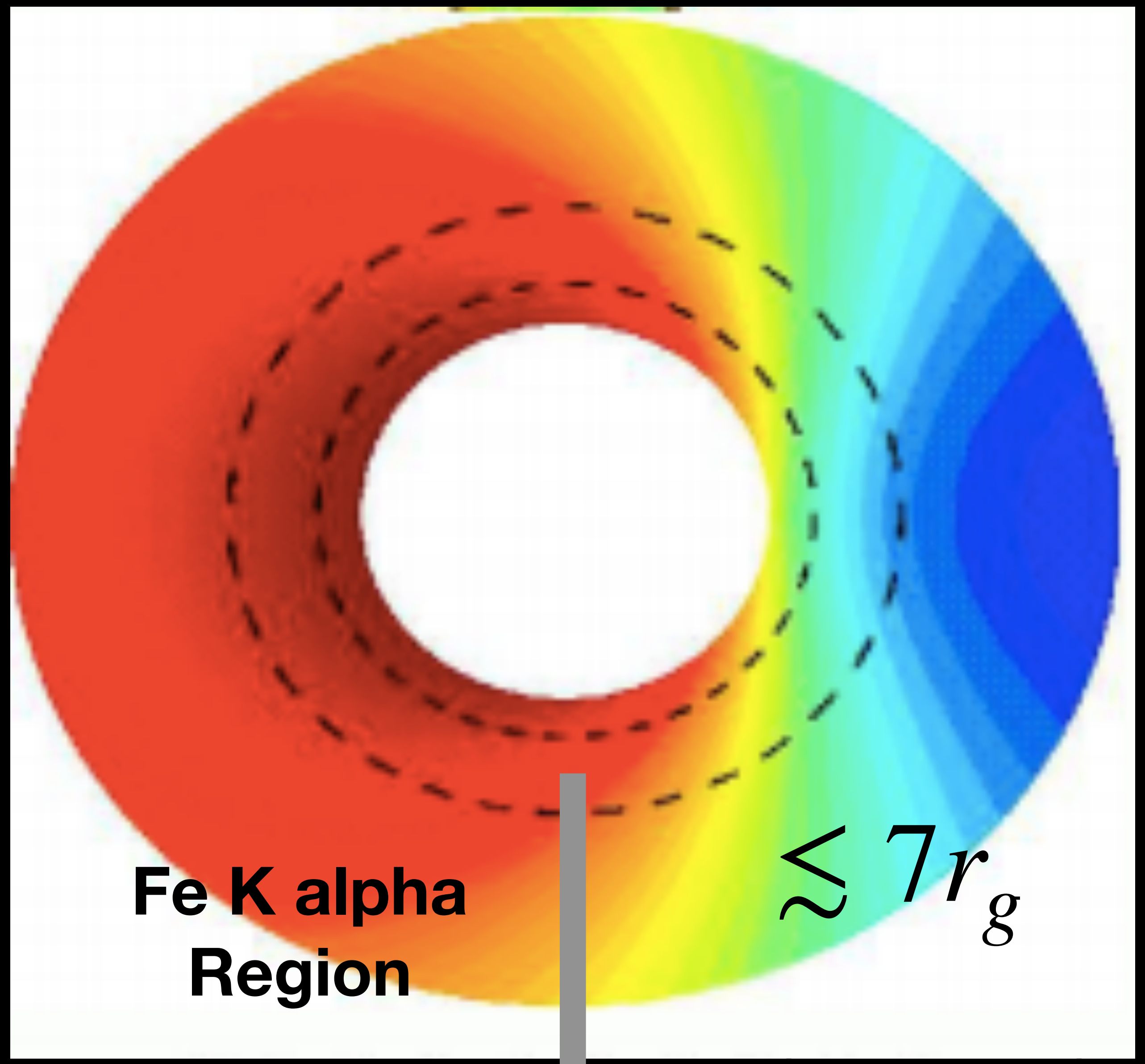


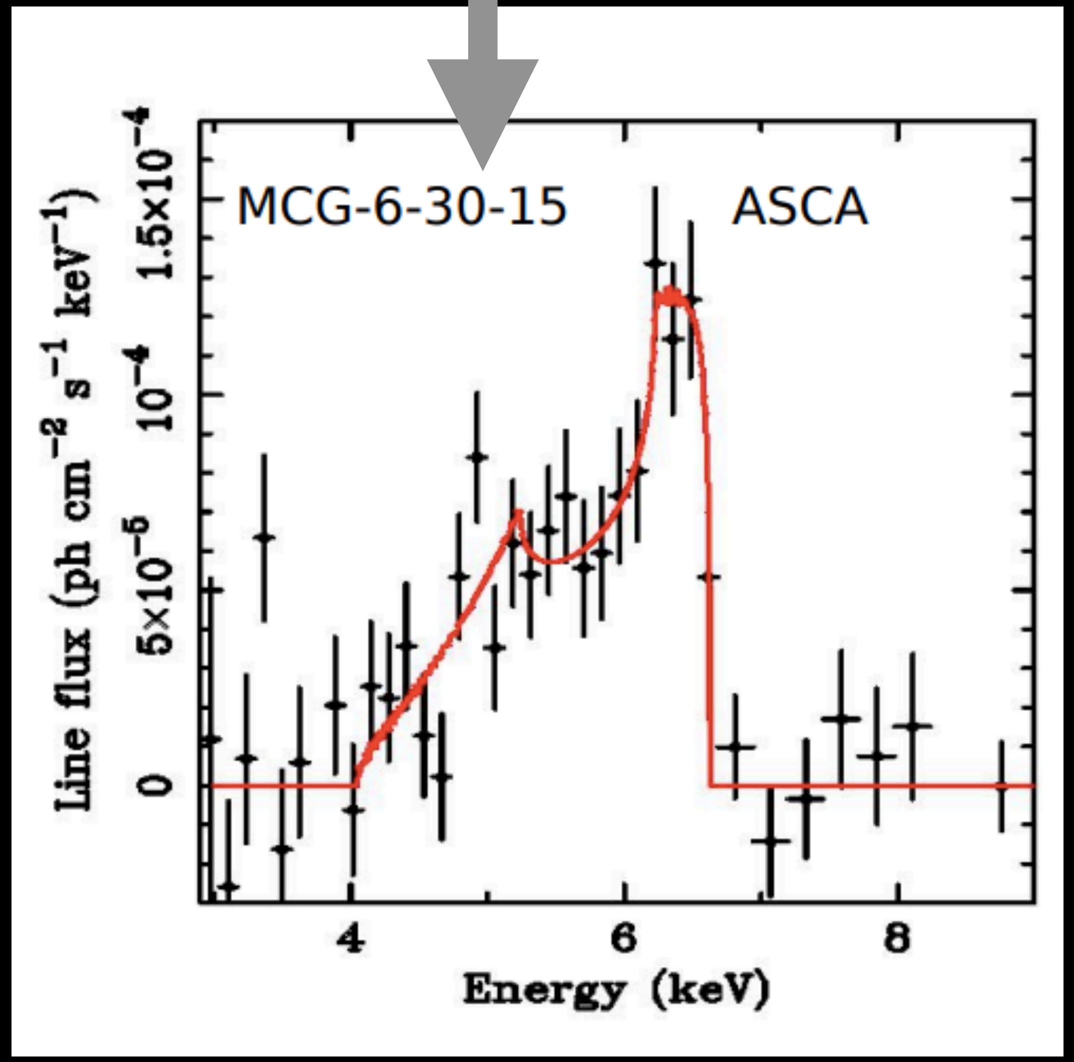
- Study the structure of the accretion disk around the SMBH.
- Properties of mass distribution in the lens galaxy.

NASA/CXC/M.Weiss

How to probe planet mass objects?

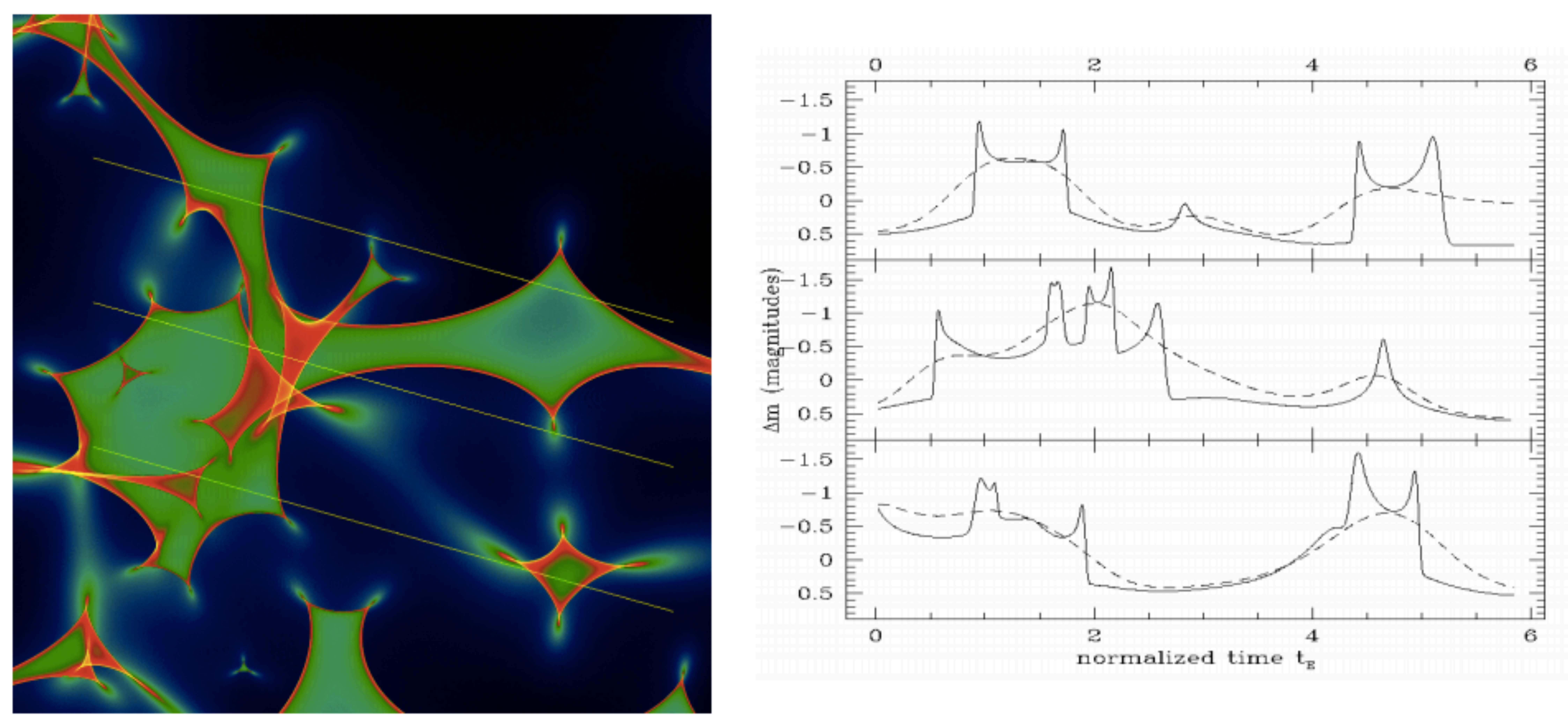




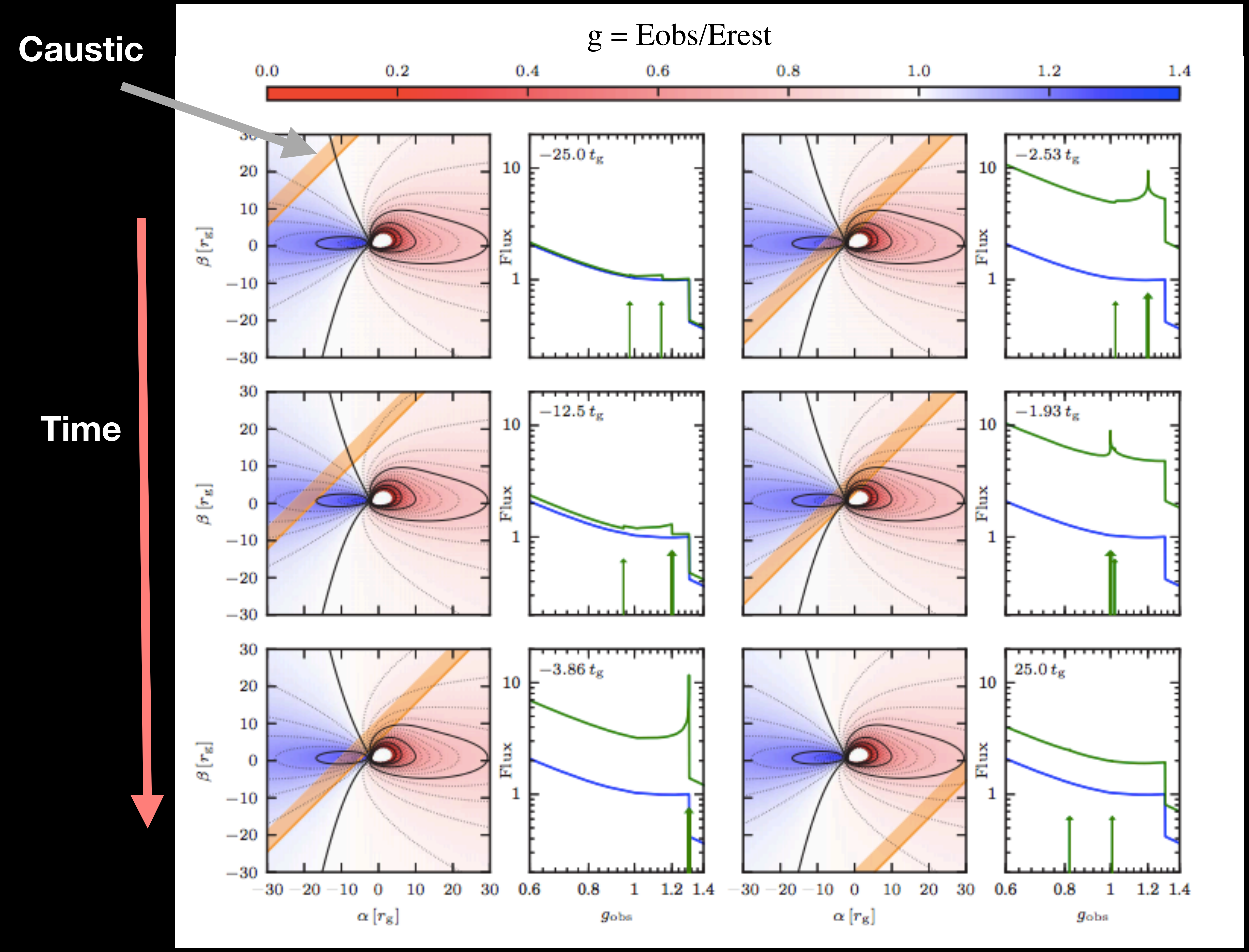


Size of Fe Kα emission region ~ Einstein ring of a planet

Stellar microlensing events in the Optical light curves



Microlensing signatures in the X-ray spectrum



$$g = \frac{E_{obs}}{E_{rest}}$$ (Line shift parameter)

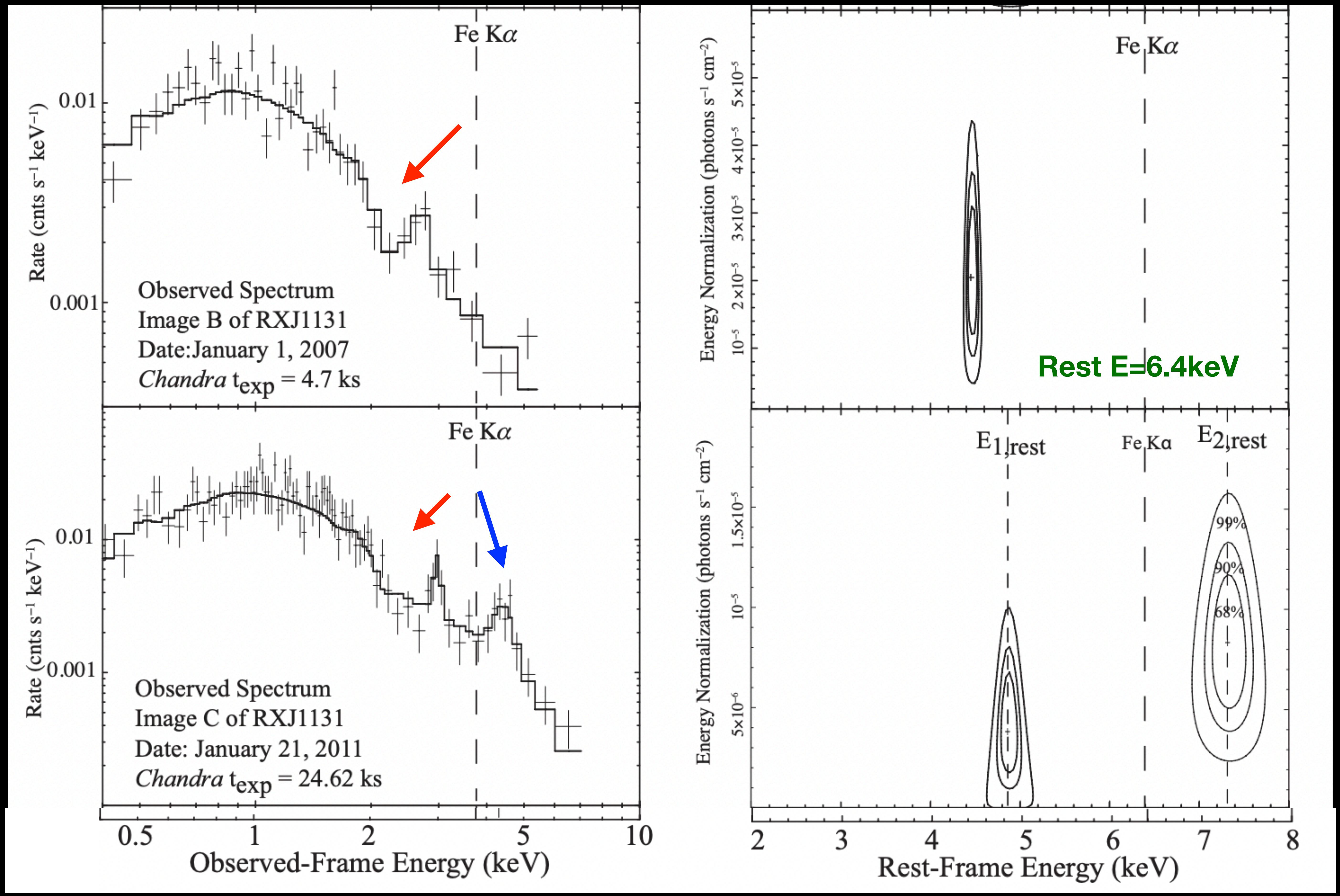
Passage of caustic causes differential magnification of g values

Caustic passing Event → Line shift

[Popovíc et al. (2003, 2006) , Jovanovíc et al. (2009)]

Ledvina et al. 2018

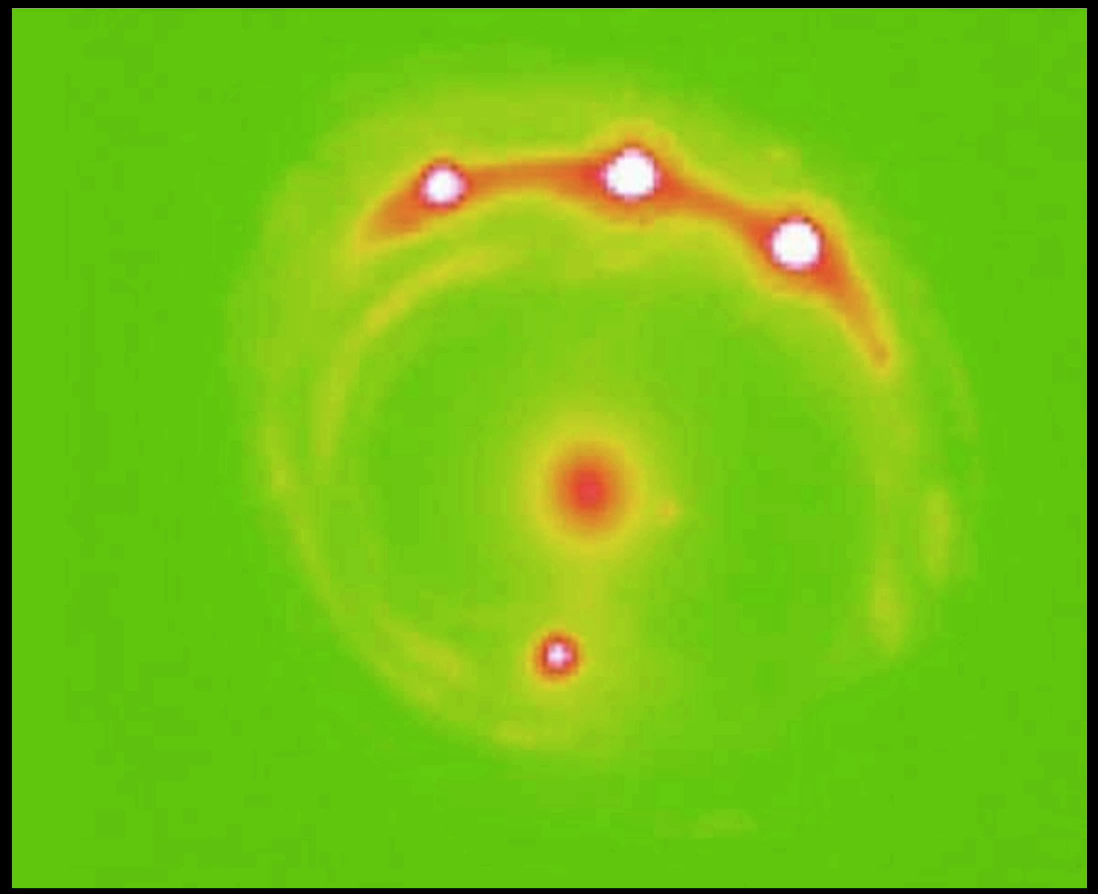
Chandra observations



- Iron K line in the X-ray spectrum show large line peak variations and double line features
- Line peak is observed to vary over a large range of energies
- In non lensed AGNs, peaks of FeKalpha lines shows little variability
- Line variations are uncorrelated and detected with high frequency

Chartas et al. 2017

Lensed systems



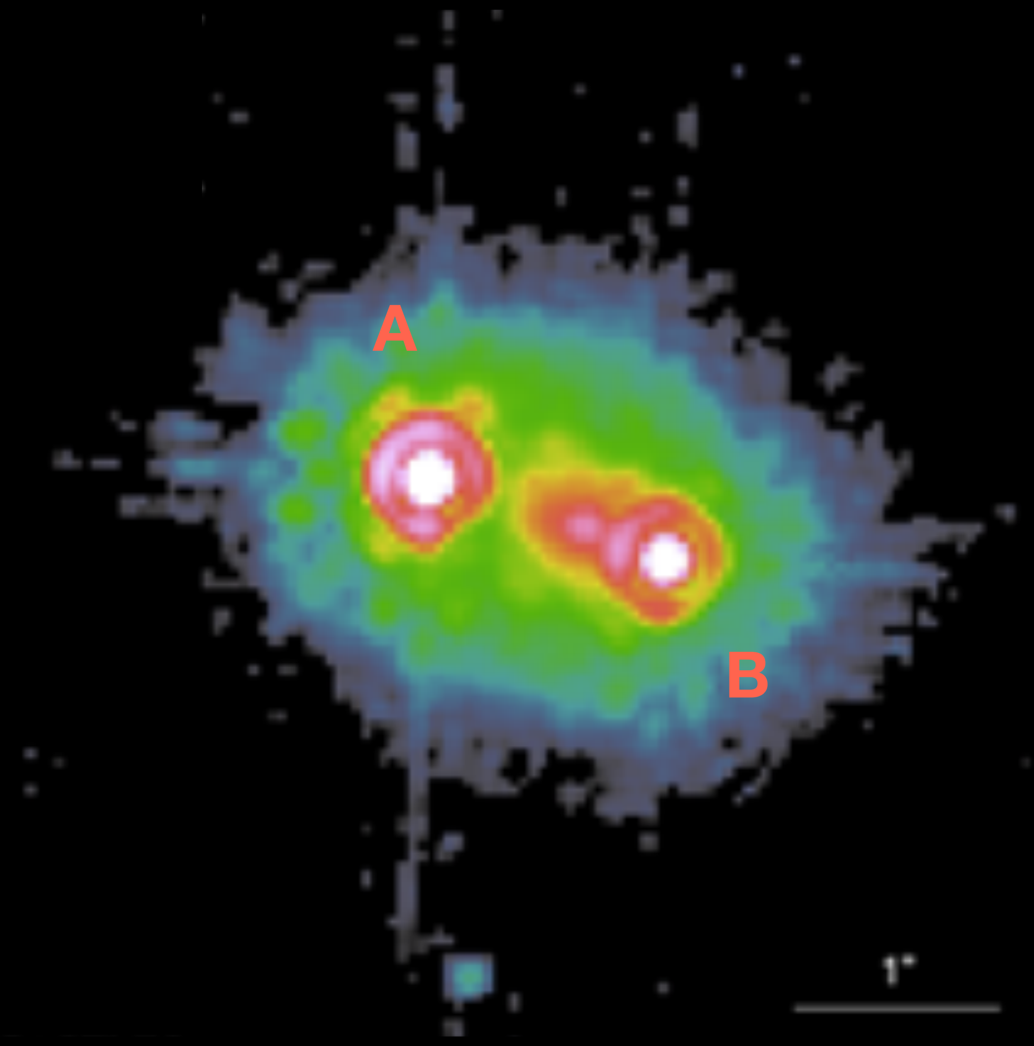
RX J1131-1231

Galaxy Lens

$z_l = 0.29$

$z_s = 0.65$

Dai & Guerras 2018



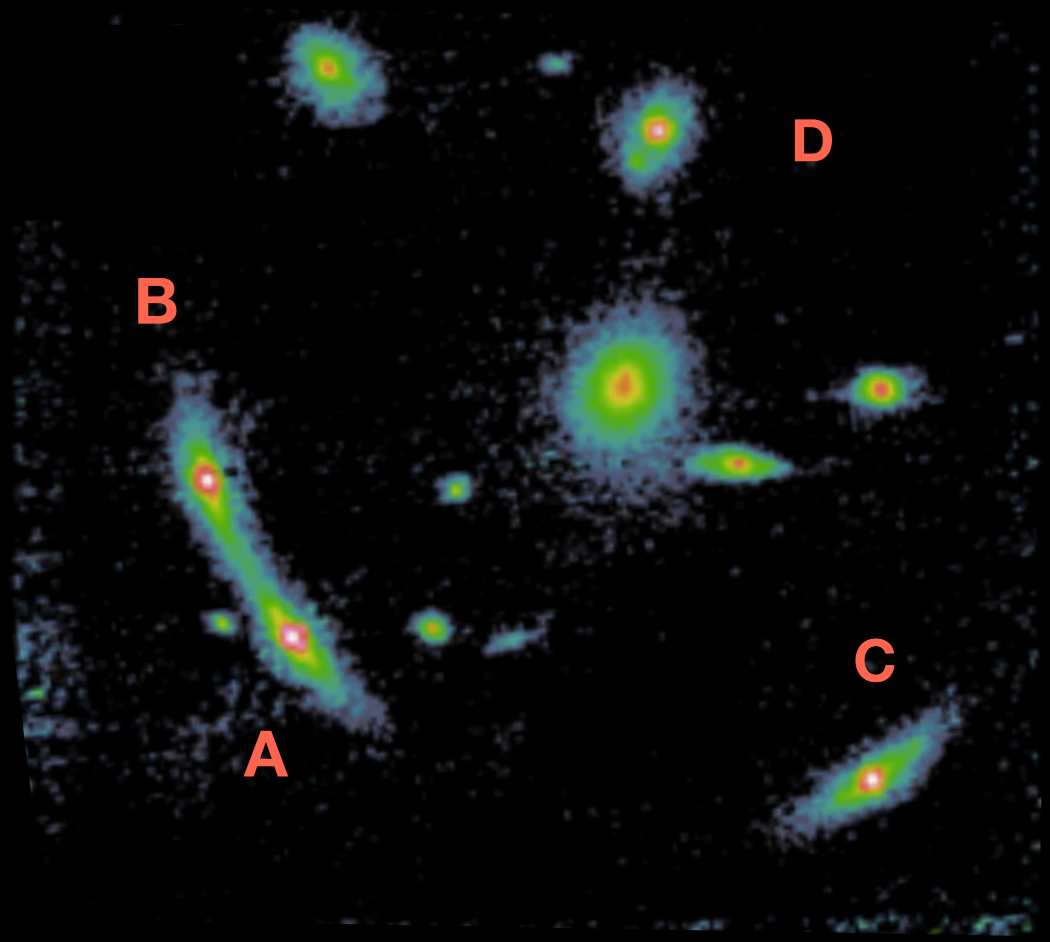
Q J0158-4325

Galaxy Lens

$z_l = 0.31$

$z_s = 1.29$

CASTLES



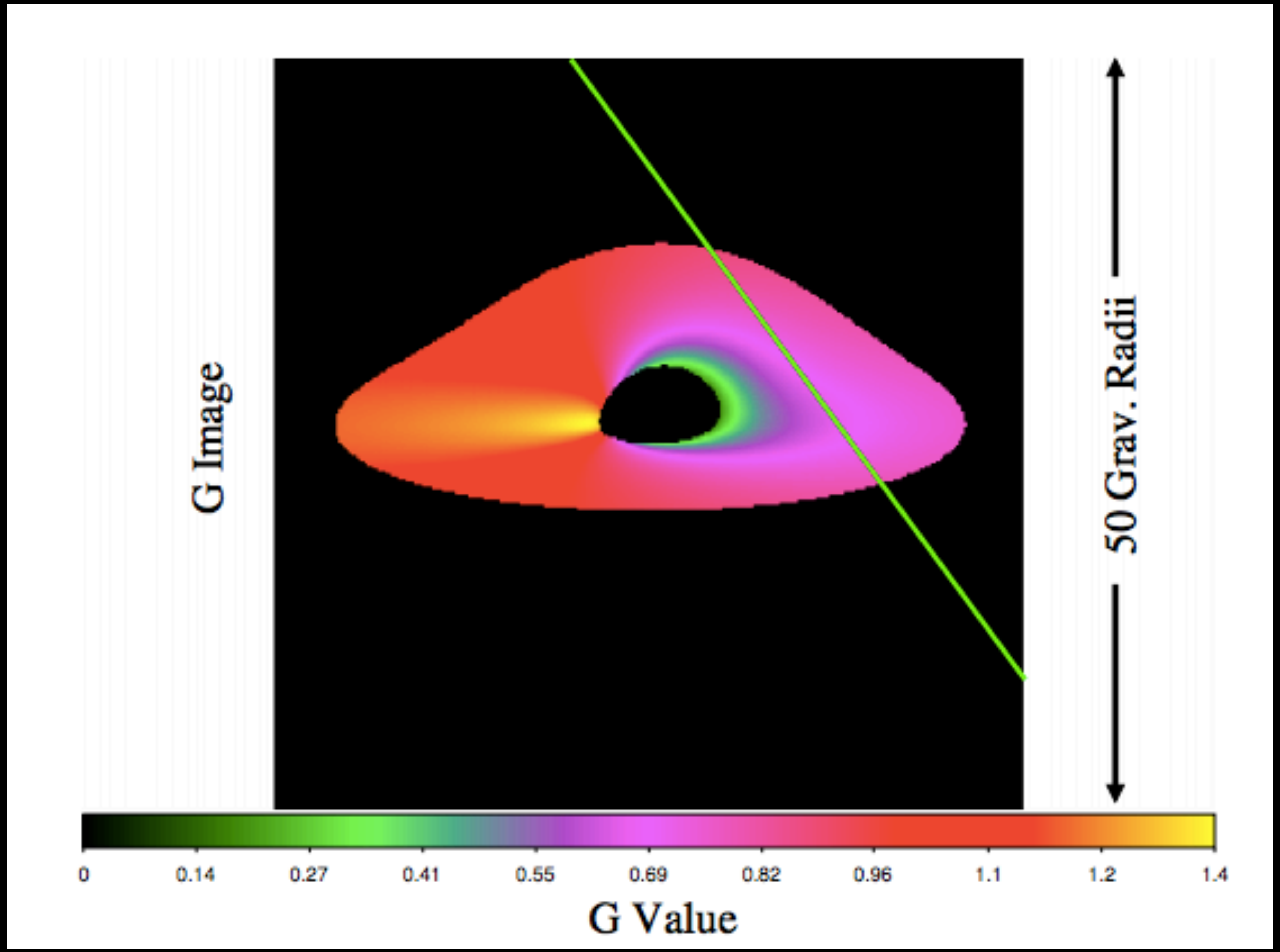
SDSS J1004+4112

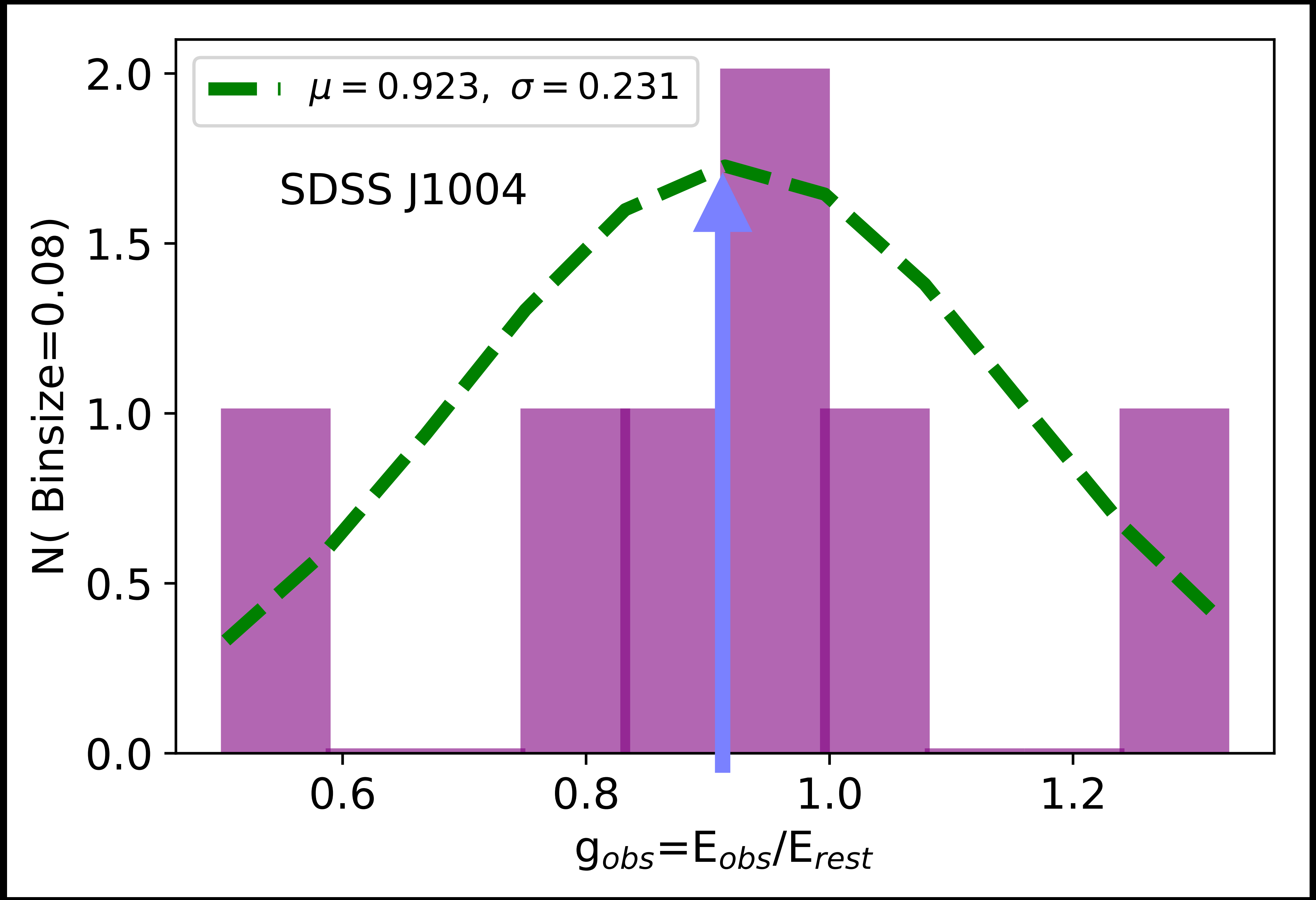
Galaxy cluster Lens

$z_l = 0.68$

$z_s = 1.73$

Bhatiani et al. 2019





Dai & Guerras 2018

Bhatiani et al. 2019

$$g = \frac{E_{obs}}{E_{rest}}$$

Observed Line shift rate = $\dfrac{\text{Observations with } >3\sigma \text{ line shift}}{\text{Total observations}}$

Microlensing Analysis

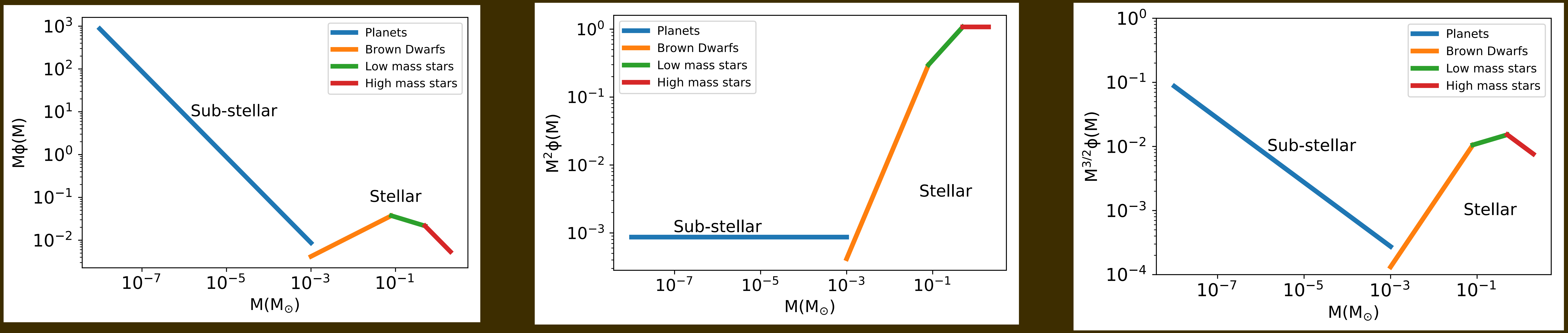
Macrolens model (from literature)

- κ [Convergence]
- γ [Shear]
- κ_* [stellar surface mass density]

Microlens model

- $\phi(M)$ [Mass functions]
- $\alpha_* = \frac{\kappa_*}{\kappa}$ [stellar mass fraction]
- α_p [planet mass fraction]

Free



Number **Mass** **Caustic density**

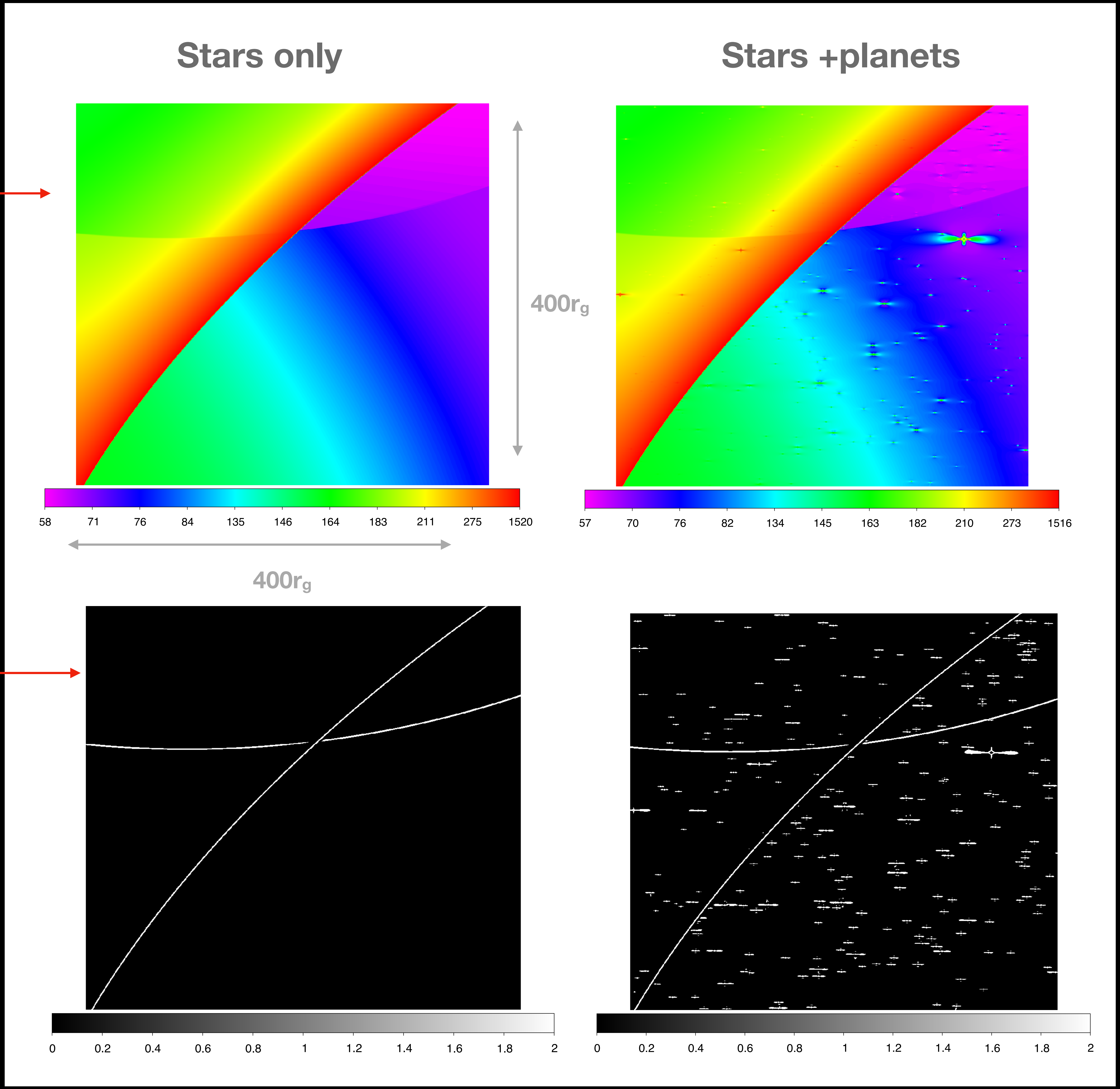
Bhatiani et al. 2019, ApJ

Magnification maps

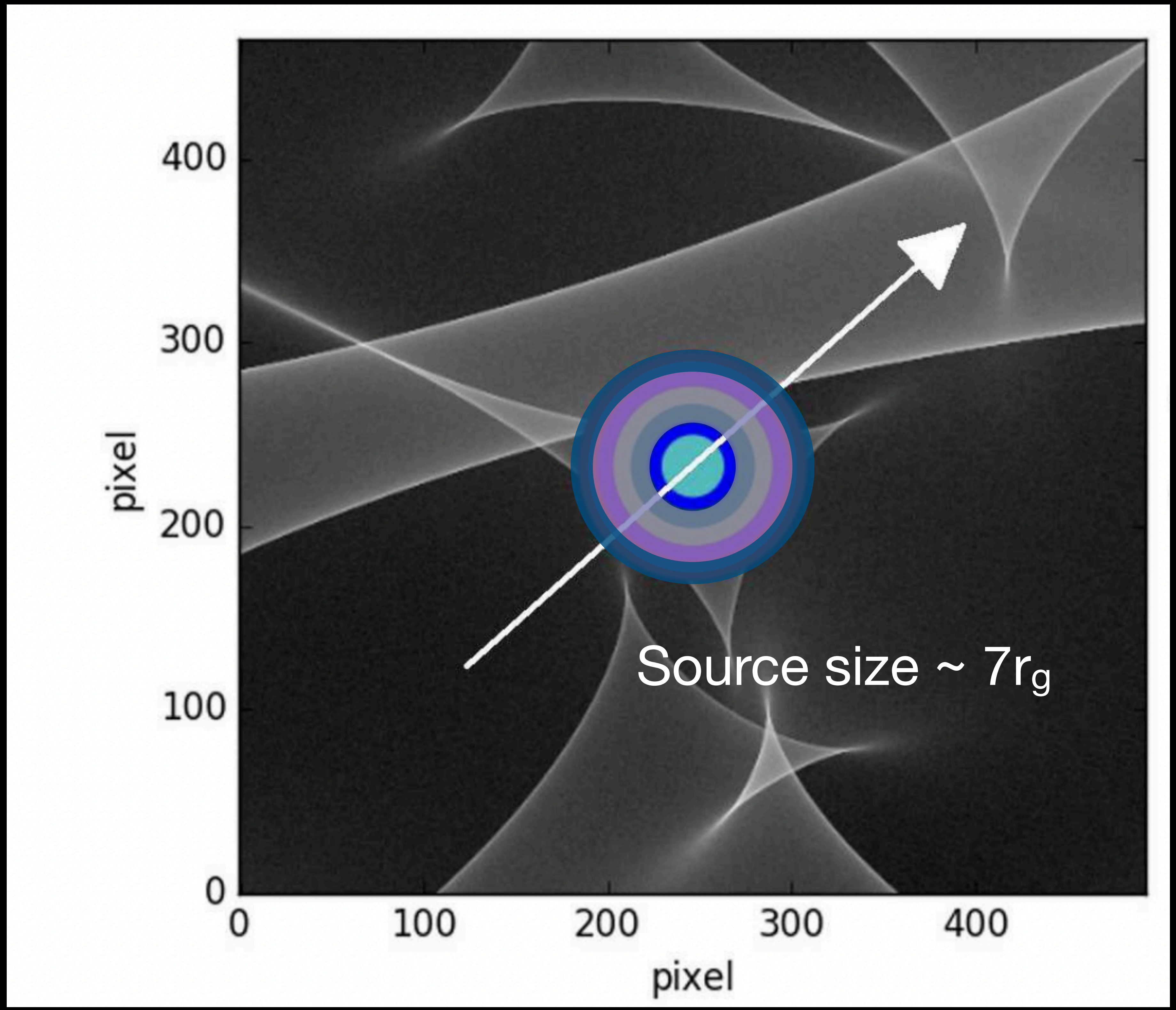
- ⋆ Generated random realizations of magnification maps

Edge detected maps

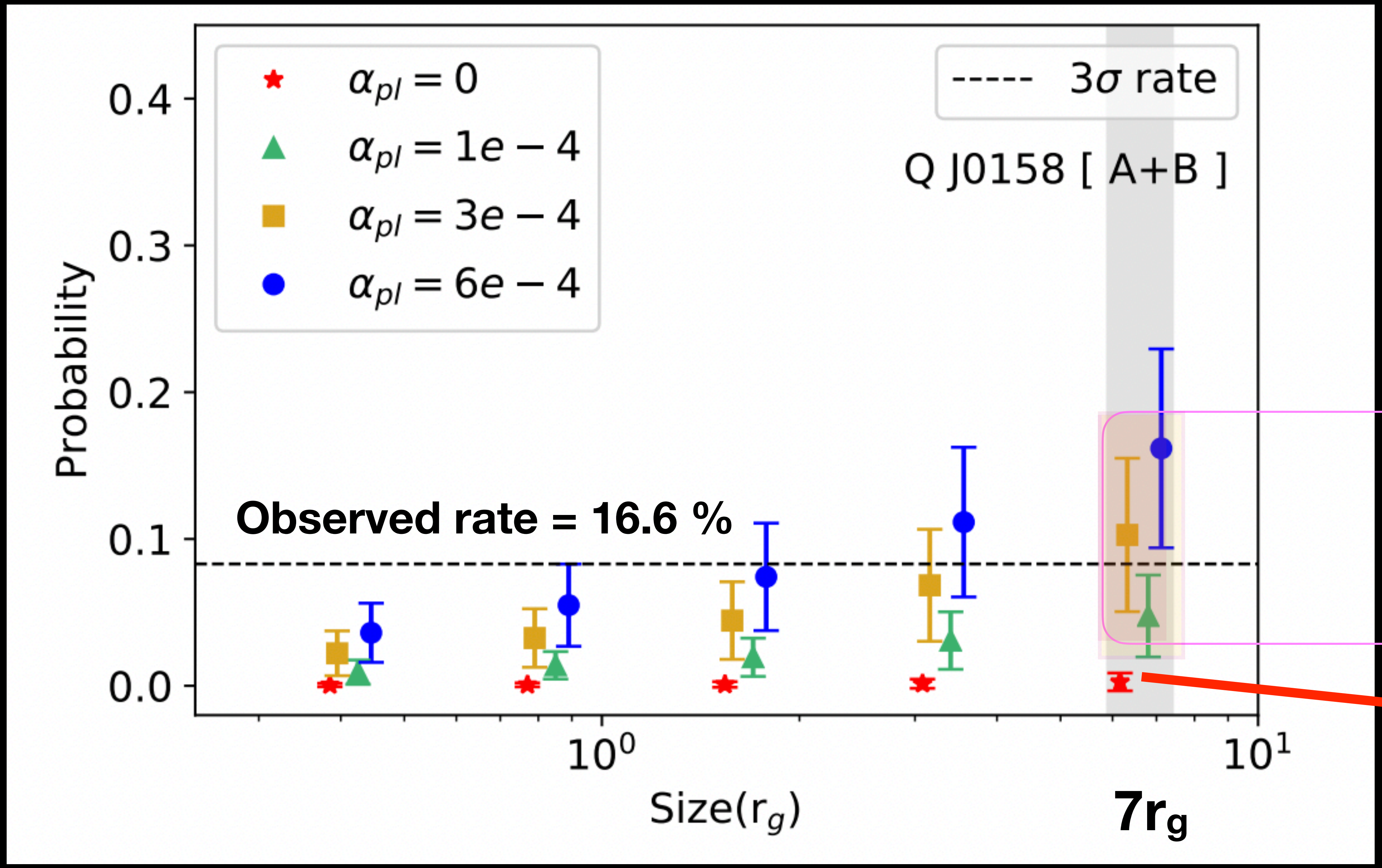
- ⋆ Maps are convolved with kernels for different source sizes
- ⋆ Caustic edge crossing probability calculated



Bhatiani et al. 2019



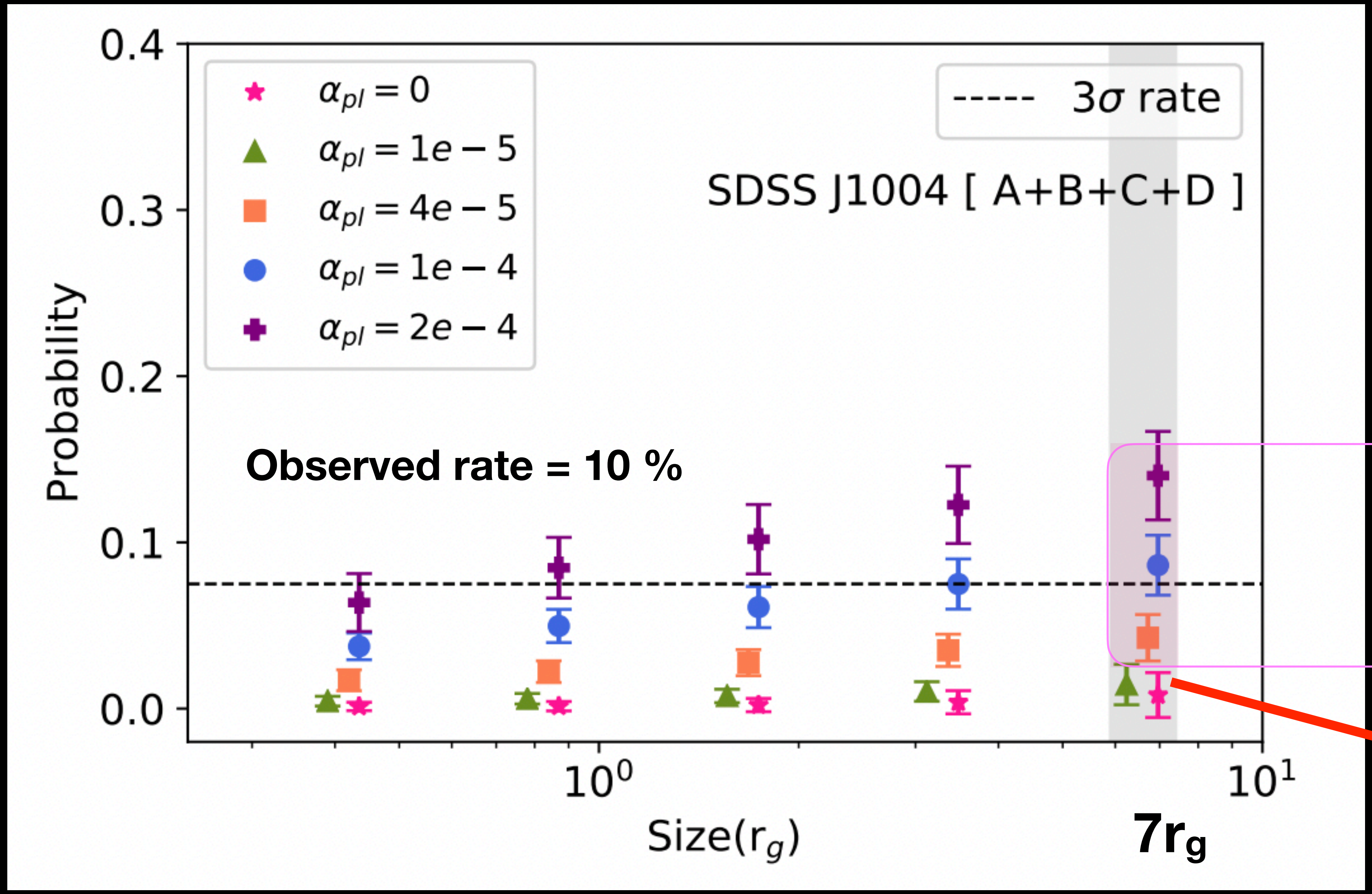
Source size is the
size of Iron Alpha emission region



Favored models

$1e-4 < \alpha_p < 6e-4$

Stars only



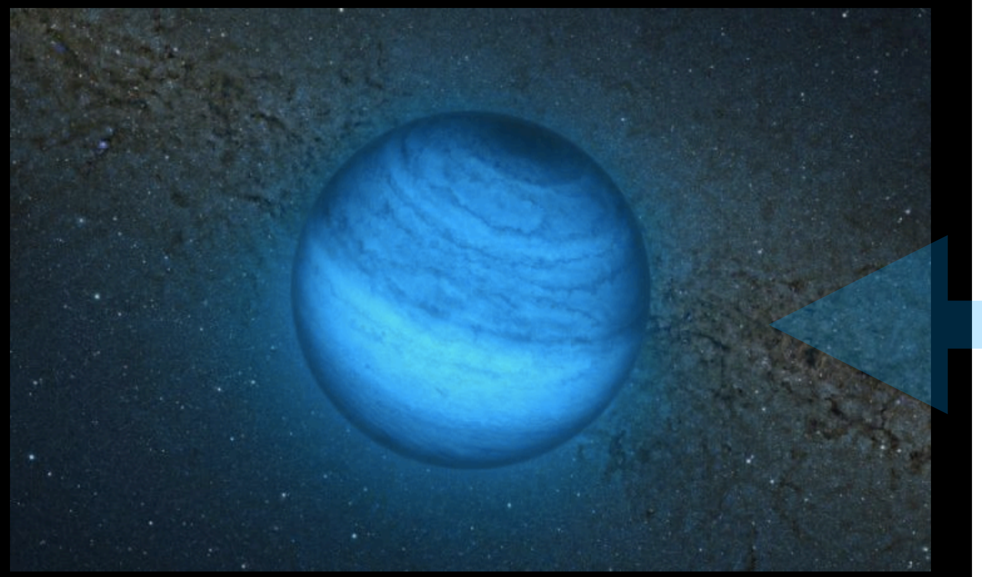
Favored models

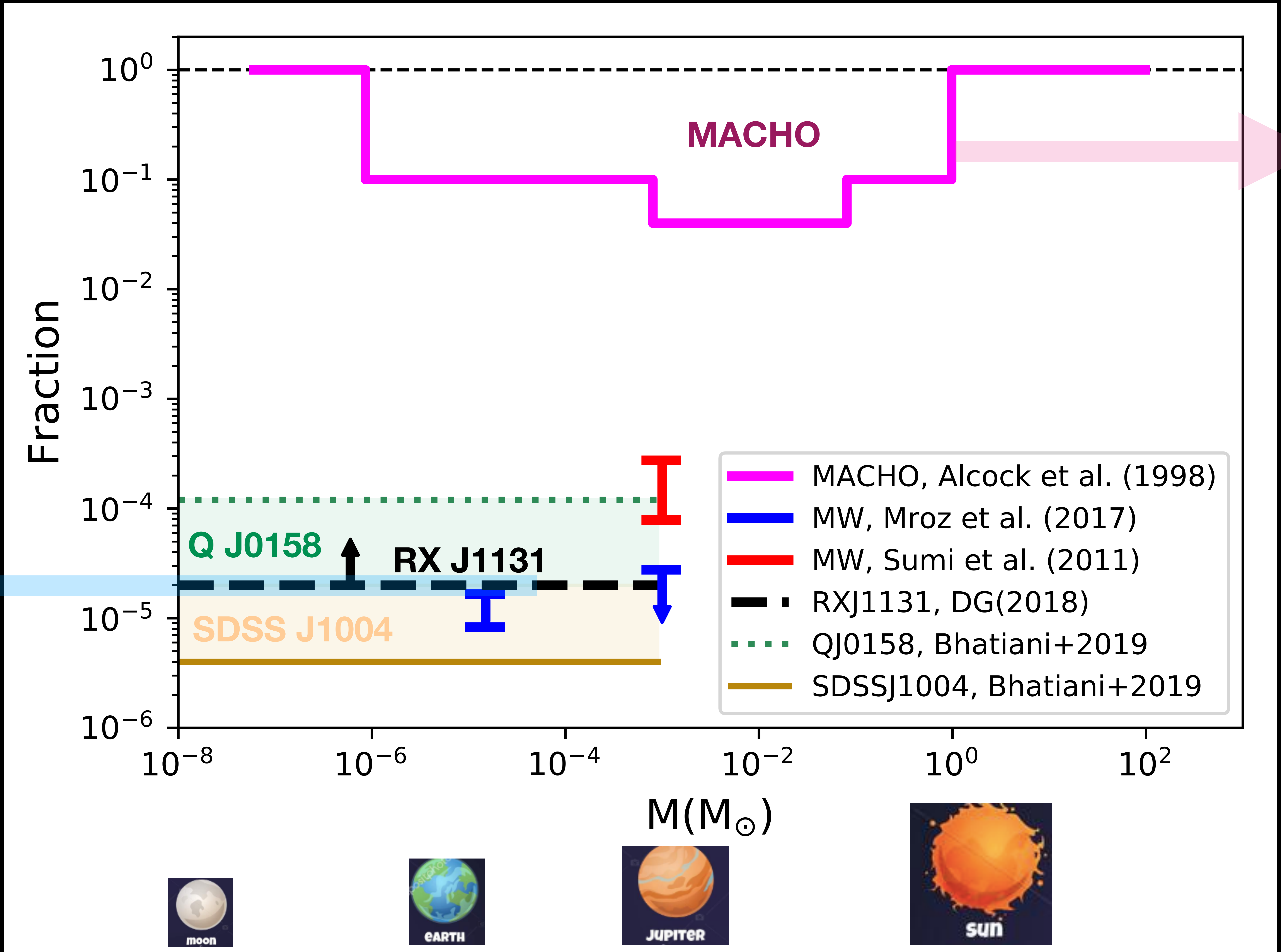
$2e-5 < \alpha_p < 1e-4$

Stars only

Bhatiani et al. 2019

Free-floating planets or Primordial BHs?





Unbound planet-mass compact objects are universal in galaxies!

Bhatiani et al. 2019

What’s ahead?

- Measuring the frequency of line shifts and microlensing analysis of Q2237+0305 and HE0435-1223 using Chandra archival data

- Newer and deeper observations and improved modeling to impose tighter constraints

- With LSST and Euclid, more interesting candidates for X-ray microlensing studies will be revealed.

Thank you!

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