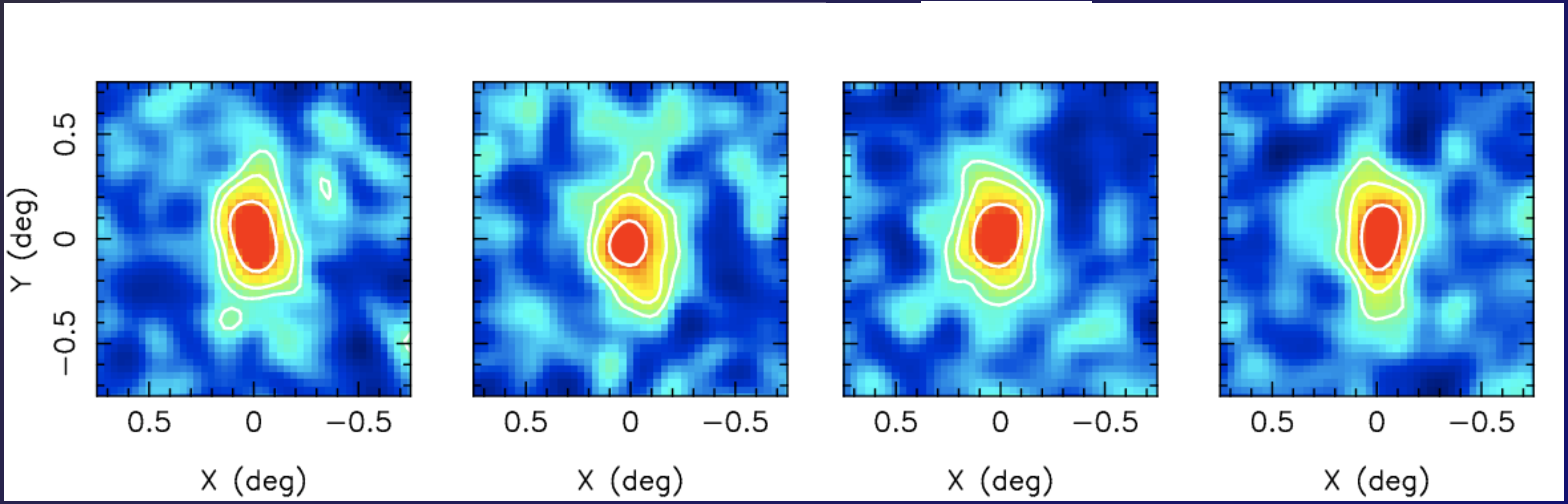
Musings on faint dwarf galaxies



Nicolas Martin, Jelte de Jong & Hans-Walter Rix (MPIA)

(2008, ApJ 684, 1075)

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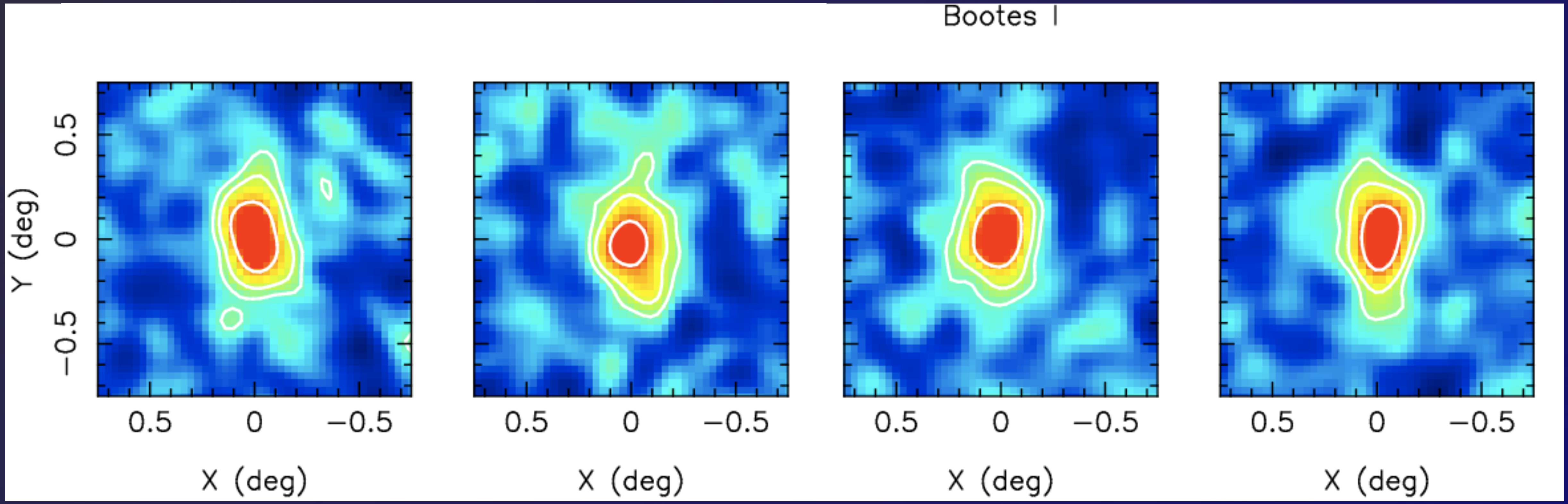

Nicolas Martin, Jelte de Jong & Hans-Walter Rix (MPIA)

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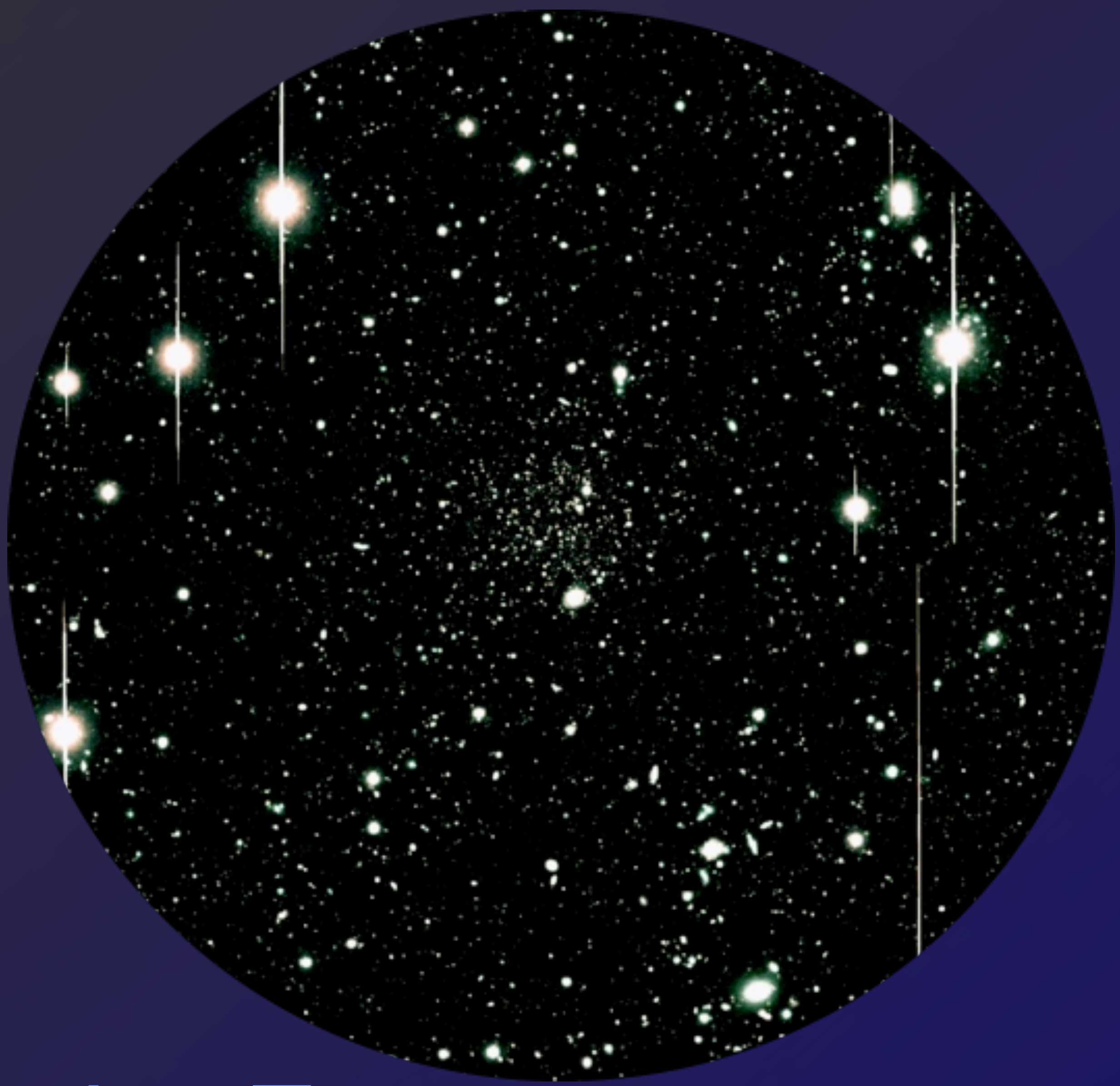
Faint Local Group satellites

Number of large LG satellites more than doubled

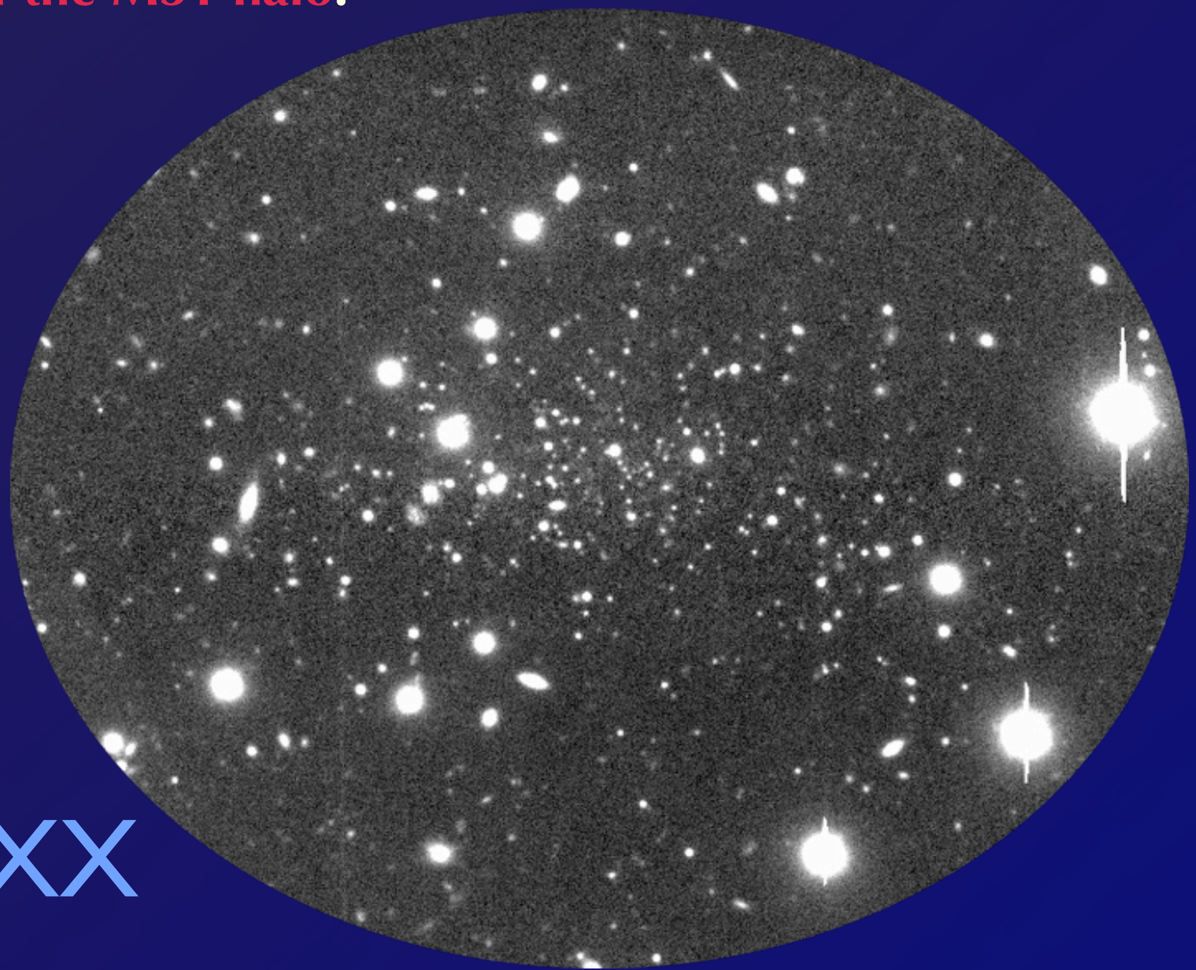
- MW: Boötes I (-6.4), Boötes II (-4.2), Canes Venatici I (-8.6), Canes Venatici II (-4.9), Coma Berenices (-4.1), Hercules (-6.6), Leo IV (-5.0), Leo V (-4.3), Leo T (-8.0), SDSSJ1058+2843 (-0.4), Segue 1 (-1.5), Ursa Major I (-5.4), Ursa Major II (-4.1), Willman 1 (-2.6) found in the SDSS (quarter of the MW halo)

  [M_V = -8.8 for Draco, previously known faintest MW satellite]

- M31: And IX (-8.3), And X (-8.1), And XI (-7.3), And XII (-6.4), And XIII (-6.9), And XIV (-8.5), And XV (-9.4), And XVI (-9.2), AndXVII (-8.5), And XVIII (-9.1), And XIX (-9.7), And XX (-6.5) & … from large surveys of roughly a third of the M31 halo.

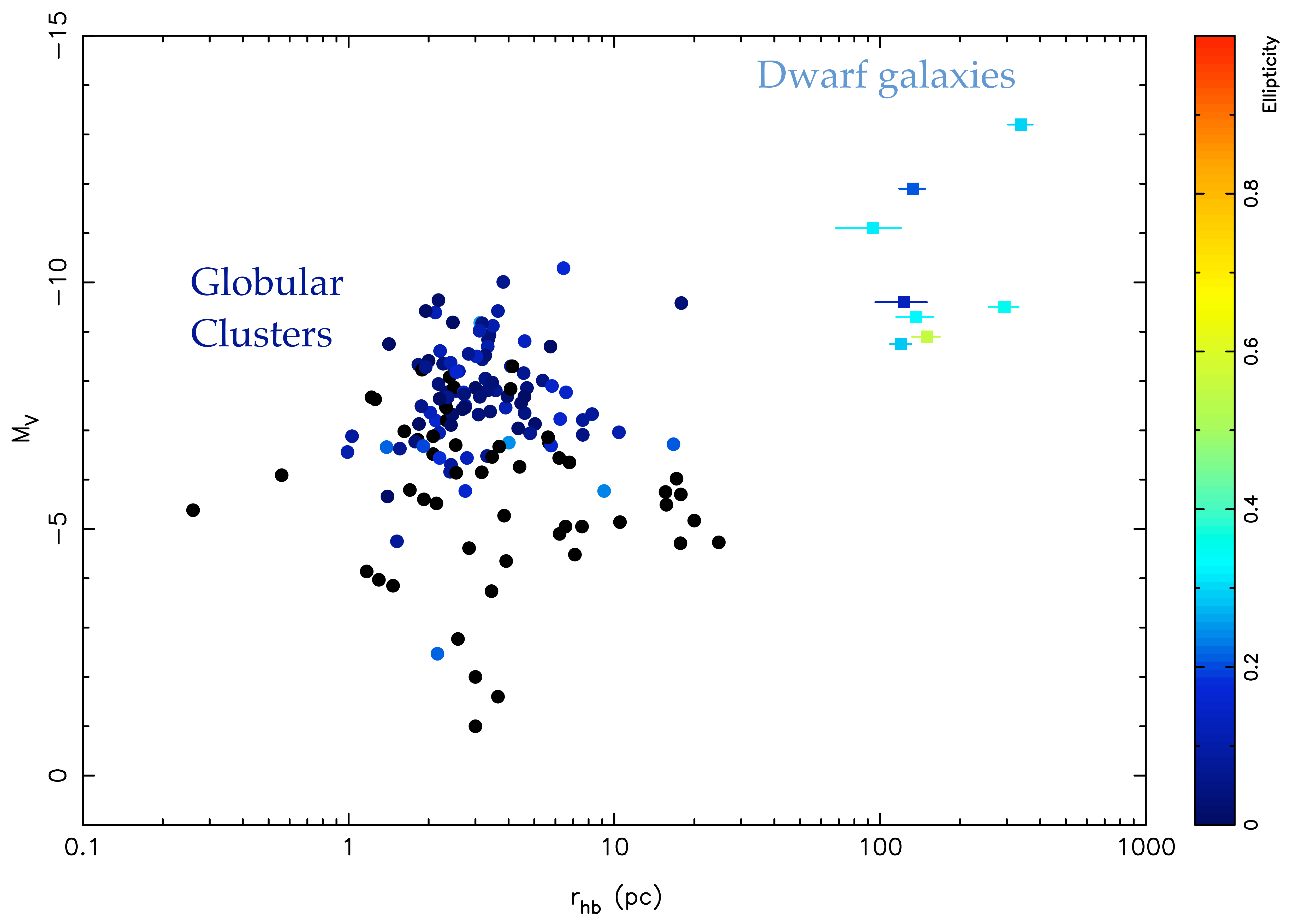


Leo T



And XX

Milky Way satellite system



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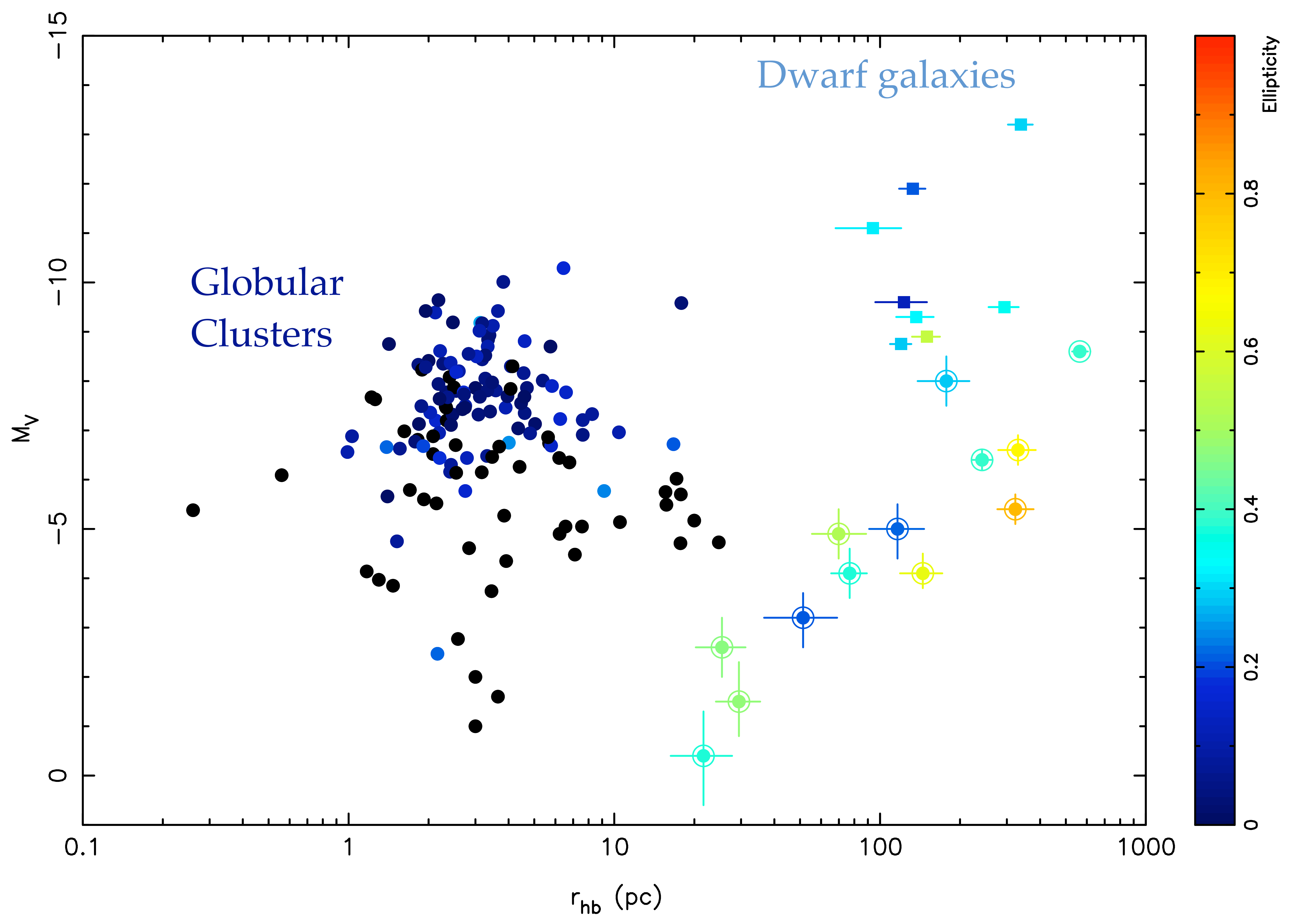

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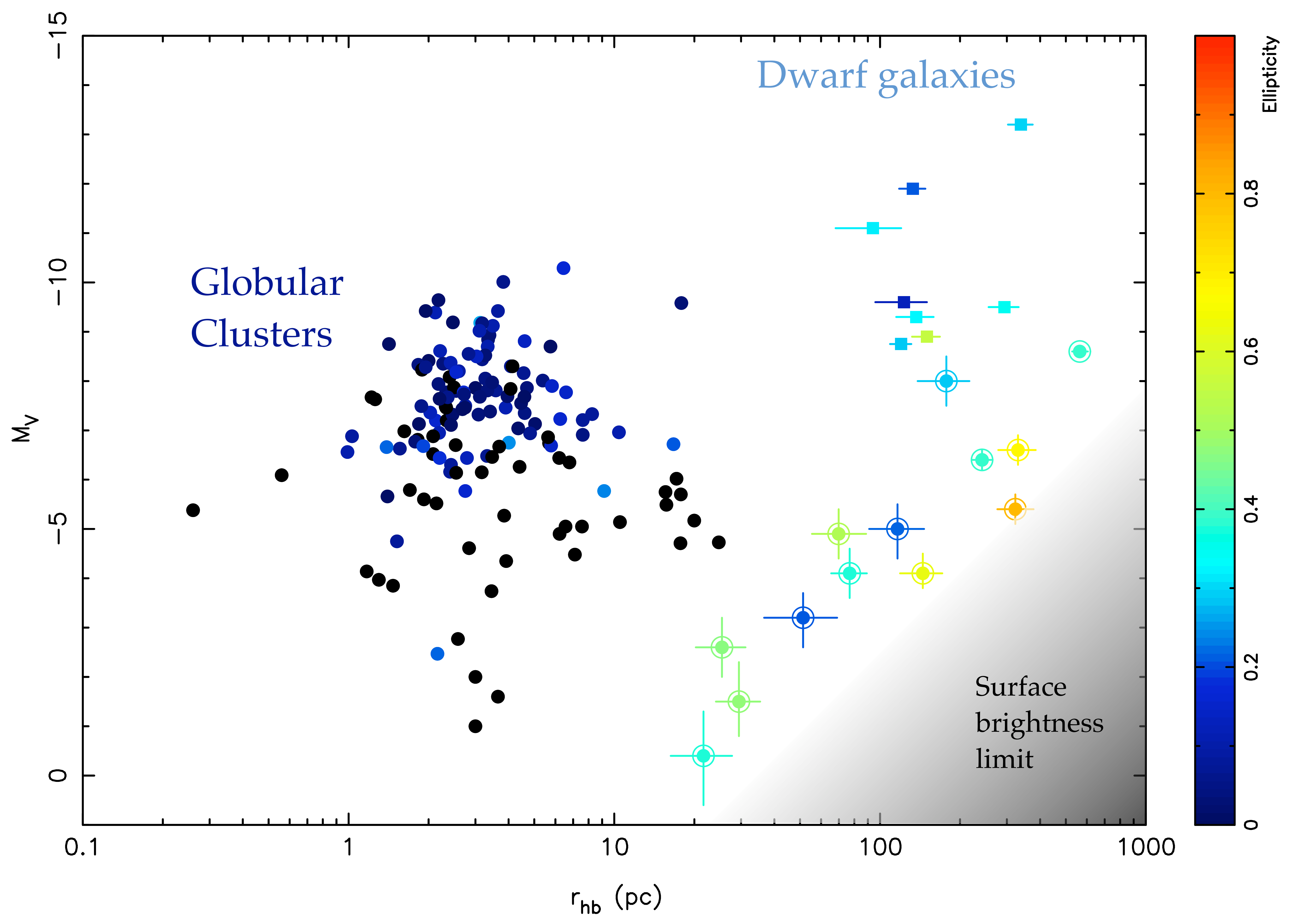
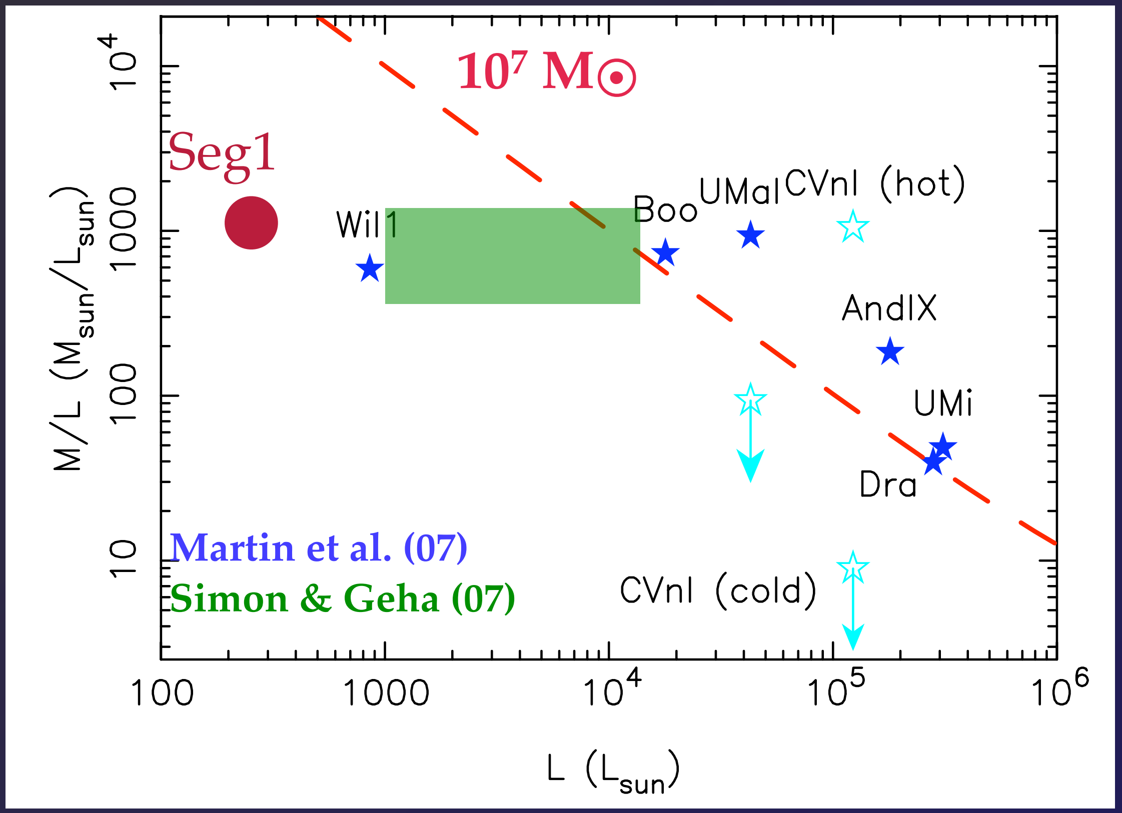


Faint Local Group satellites



Number of large LG satellites more than doubled

Around both MW and M31

What are they?

- Are they faint dwarf galaxies? Some overlap with previously known galaxies (especially around M31).
- DM dominated from spectroscopic surveys (Mass estimates)
- Why smaller? (completeness)

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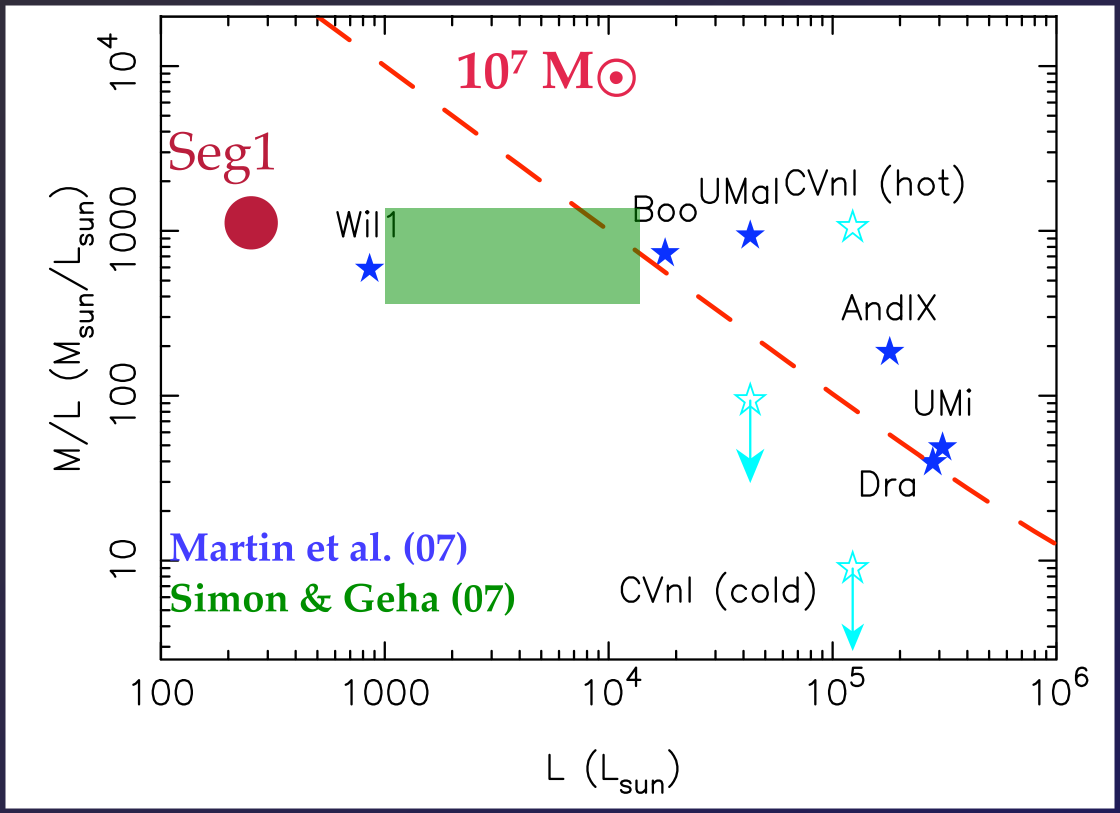

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➔ *What are their properties?*

- Very low number of stars (30 – 400 stars in SDSS)
- Reliable structural parameters? (α_0, δ_0, θ, ϵ, r_h) + N* → M_V? Are they really distorted?

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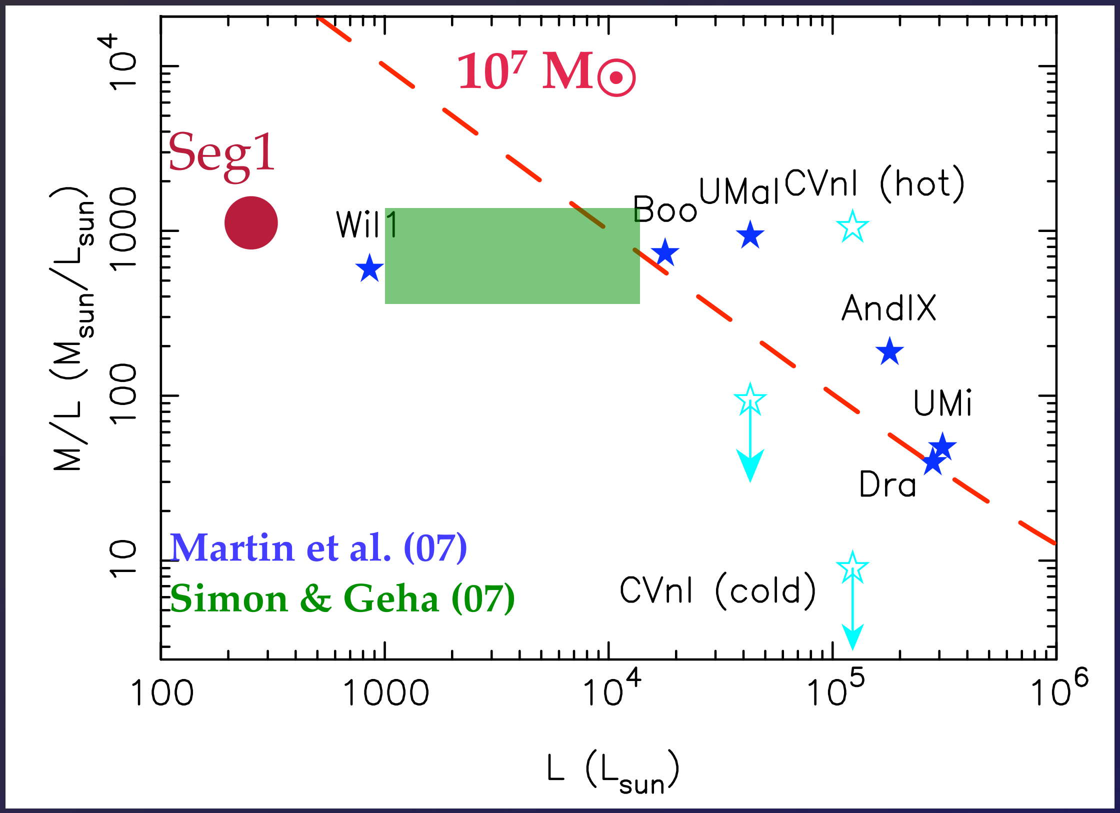

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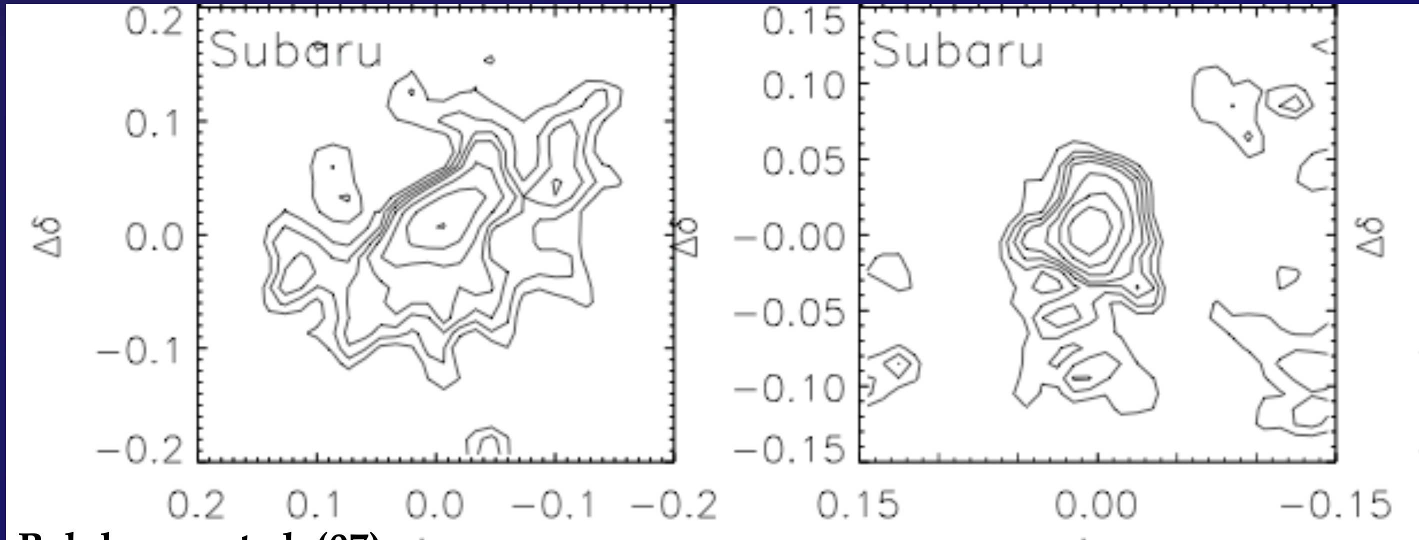


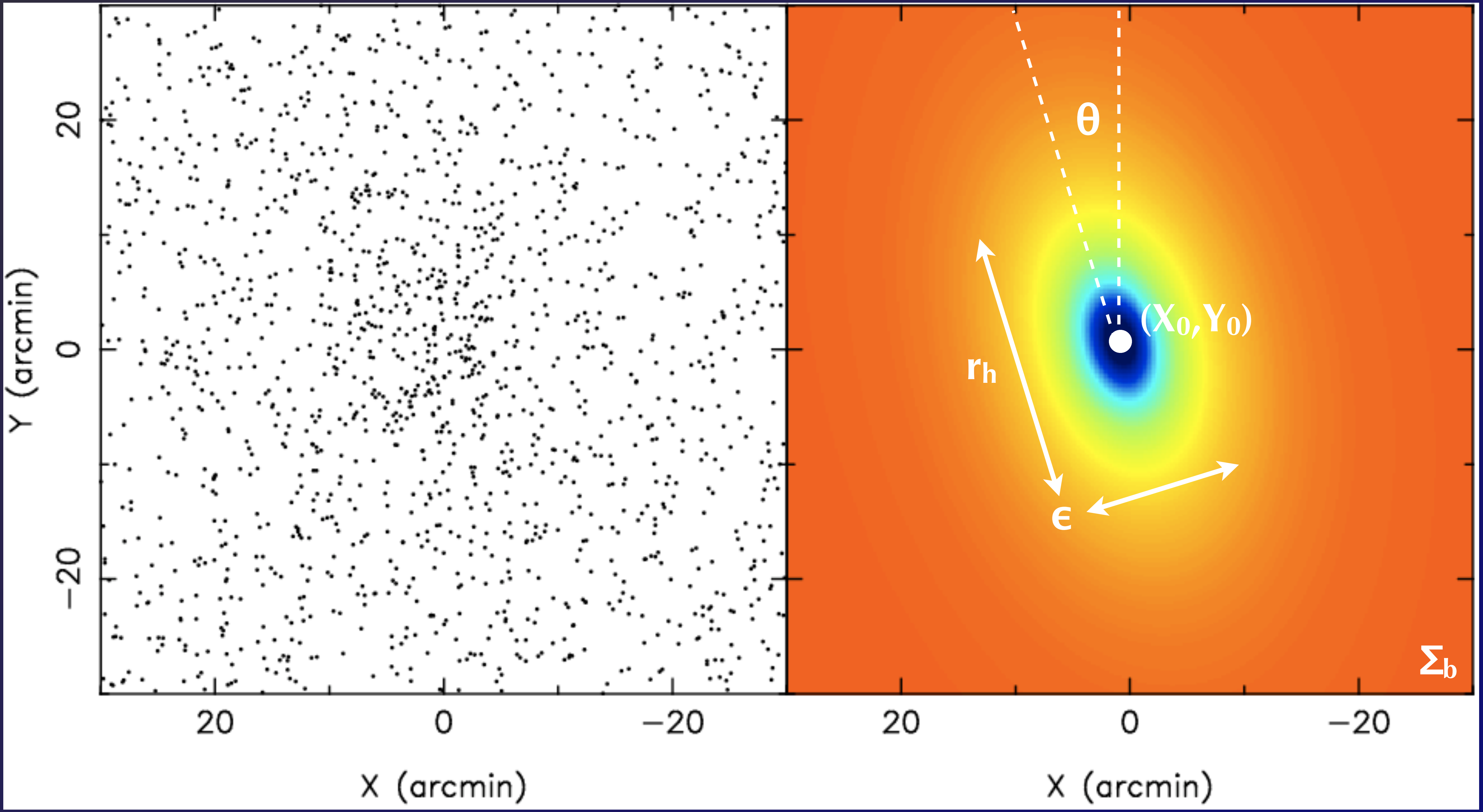
Belokurov et al. (07)

Structural properties?

Martin, de Jong & Rix (2008b)

From SDSS data, homogeneous structural parameters and properties:

- **Best model with exponential density profile**



Fitting structural properties

Previous structural parameter estimates with assumptions:

- **smoothing (pixel size, smoothing kernel, background threshold)**
- **ϵ=0...**
- **+ Σ(*r*) model**

Maximum Likelihood, only Σ(*r*) model:

$$\mathcal{L}(p_1, p_2, \ldots, p_j) = \prod_i \ell_i(p_1, p_2, \ldots, p_j)$$

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$$\ell_i(X_0, Y_0, \epsilon, \theta, r_h, \Sigma_b) = \frac{N_*}{2\pi\left(\frac{r_h}{1.68}\right)^2(1-\epsilon)} \exp\left(-1.68\frac{r_i}{r_h}\right) + \Sigma_b$$

$$r_i = \left(\left(\frac{1}{1-\epsilon}\left((X_i - X_0)\cos\theta - (Y_i - Y_0)\sin\theta\right)\right)^2 + \left(\left((X_i - X_0)\sin\theta + (Y_i - Y_0)\cos\theta\right)\right)^2\right)^{1/2}$$

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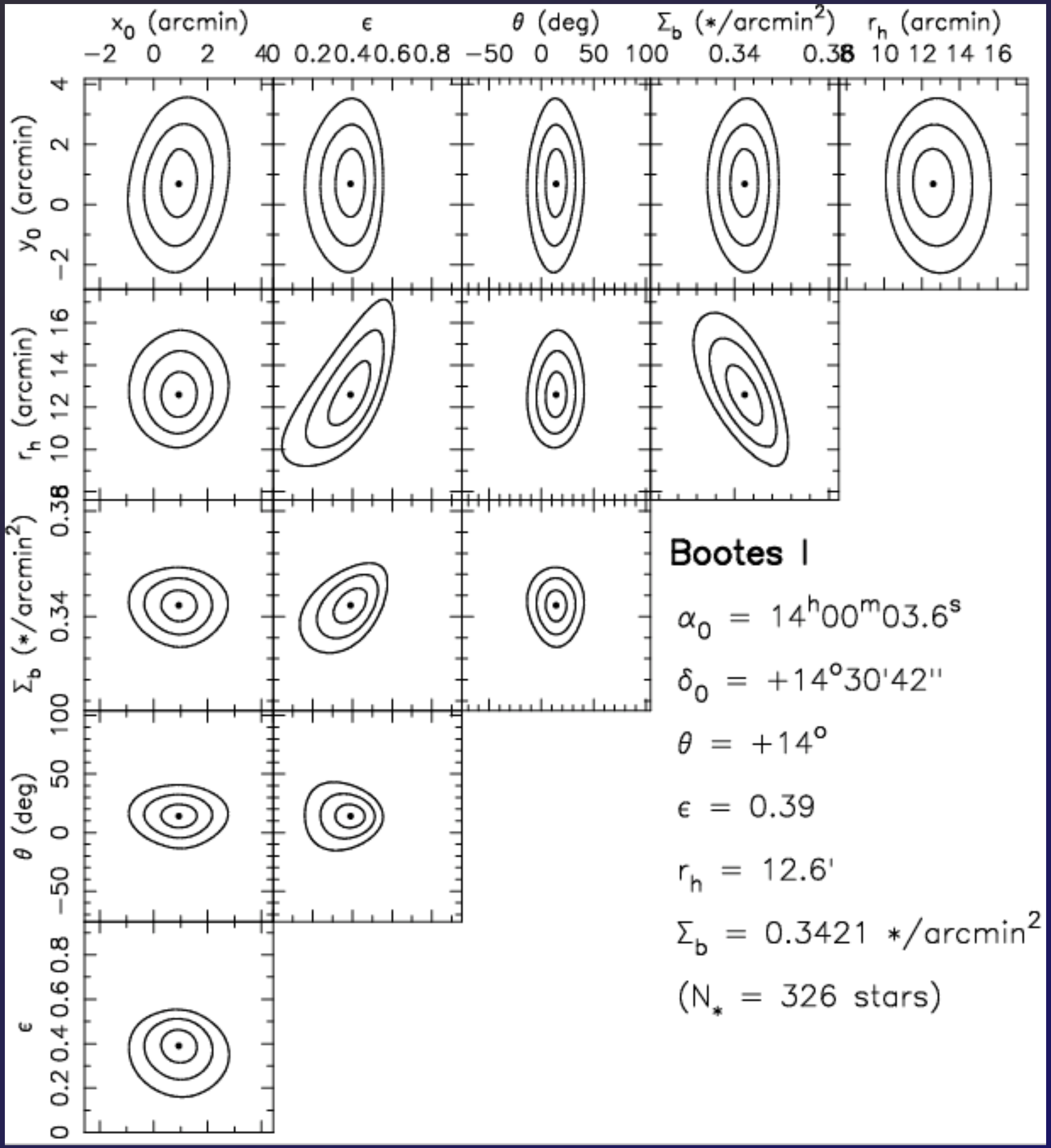
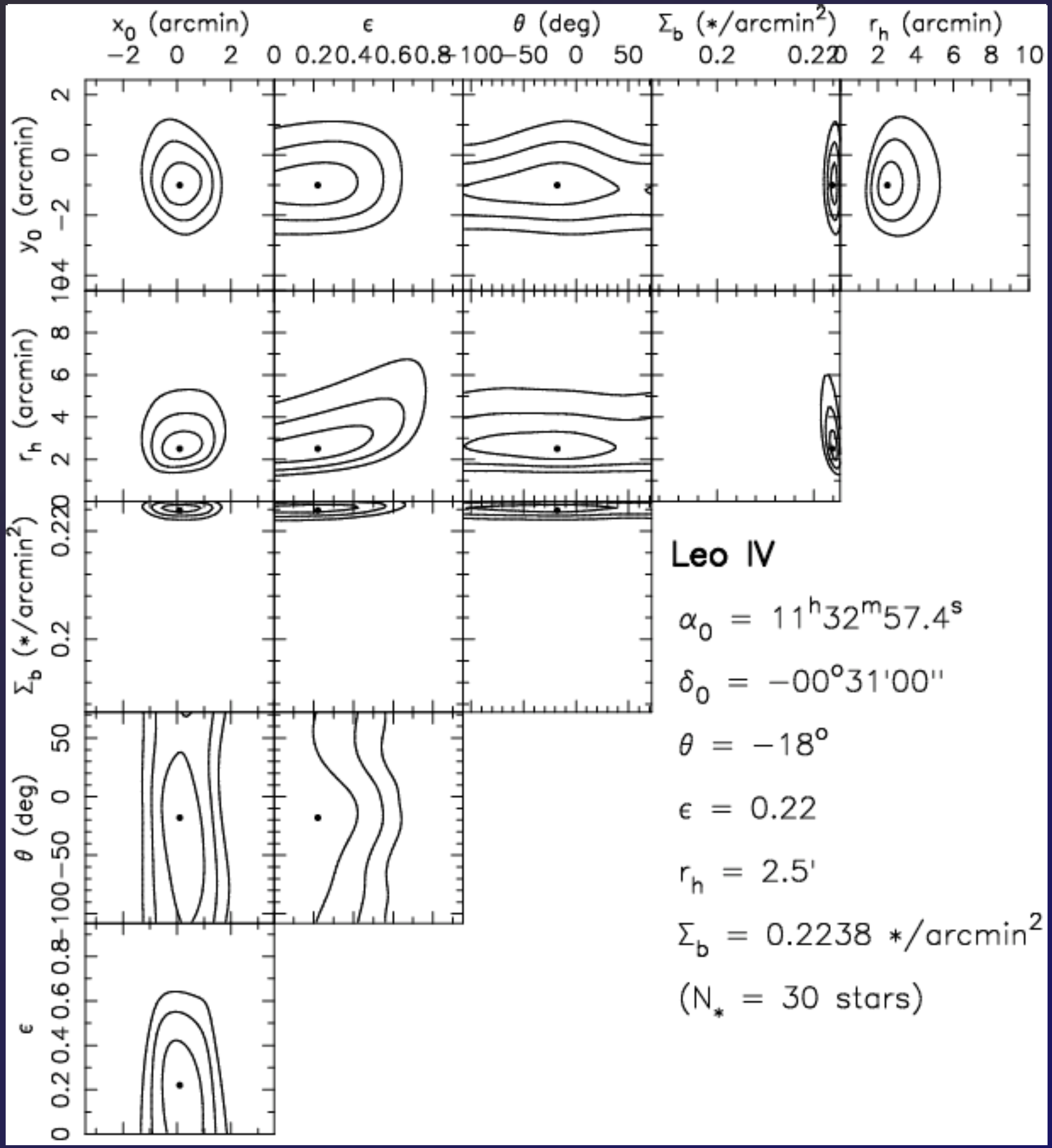
For all stars *i* around a satellite, compute $\mathcal{L}(p_1, p_2, \ldots, p_j)$ over a grid of $(p_1, p_2, \ldots, p_j)$

ML fits



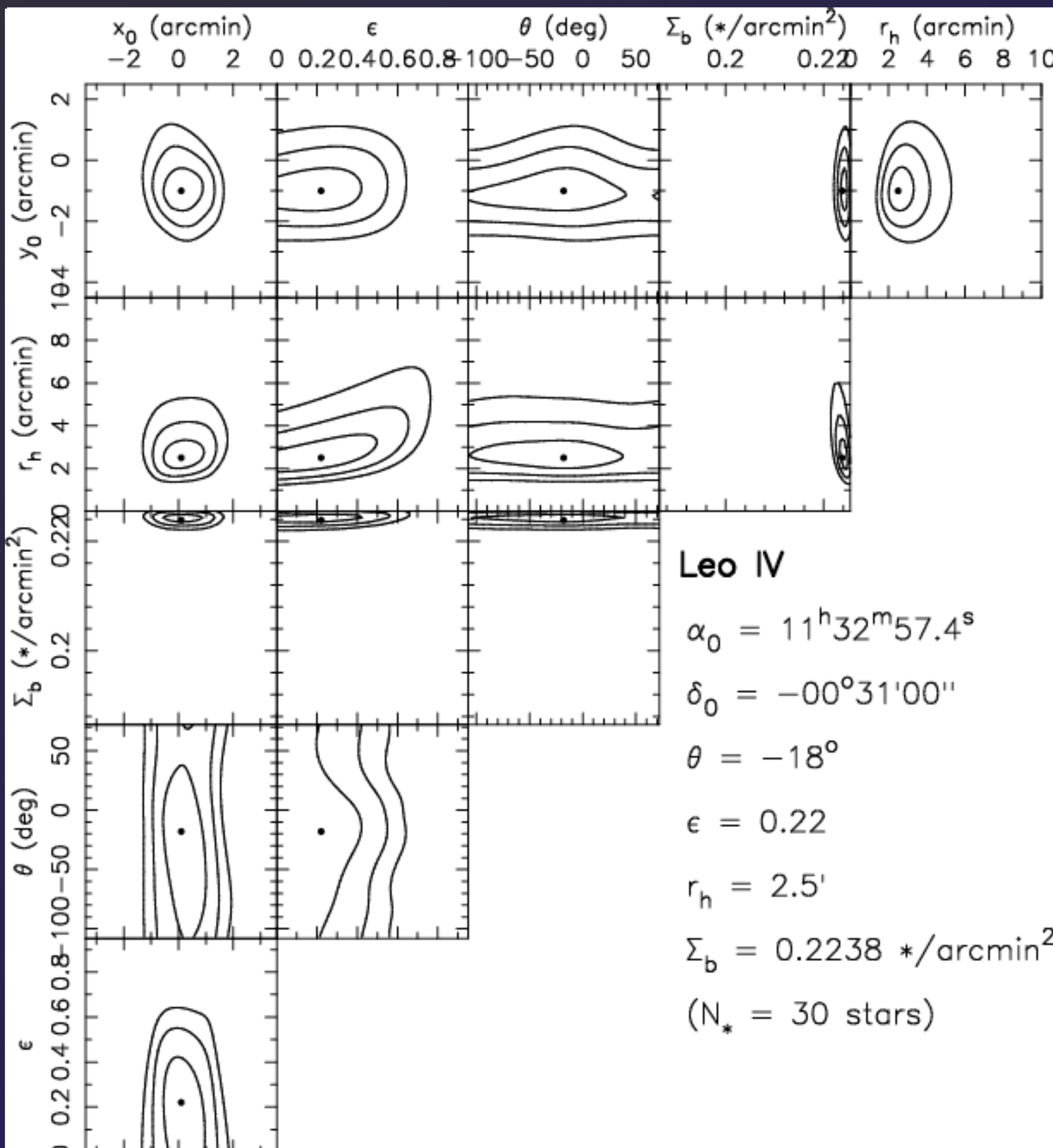
x_0 (arcmin)
ϵ
θ (deg)
Σ_b (*/arcmin^2)
r_h (arcmin)
y_0 (arcmin)
Bootes I
$\alpha_0 = 14^h00^m03.6^s$
$\delta_0 = +14°30'42''$
$\theta = +14°$
$\epsilon = 0.39$
$r_h = 12.6'$
$\Sigma_b = 0.3421$ */arcmin^2
($N_* = 326$ stars)

ML fits



Leo IV
$\alpha_0 = 11^h32^m57.4^s$
$\delta_0 = -00^\circ31'00''$
$\theta = -18^\circ$
$\epsilon = 0.22$
$r_h = 2.5'$
$\Sigma_b = 0.2238$ */arcmin^2
($N_* = 30$ stars)

ML fits



x0 (arcmin)
ϵ
θ (deg)
Σb (*/arcmin²)
rh (arcmin)
y0 (arcmin)
rh (arcmin)
Σb (*/arcmin²)
θ (deg)
ϵ
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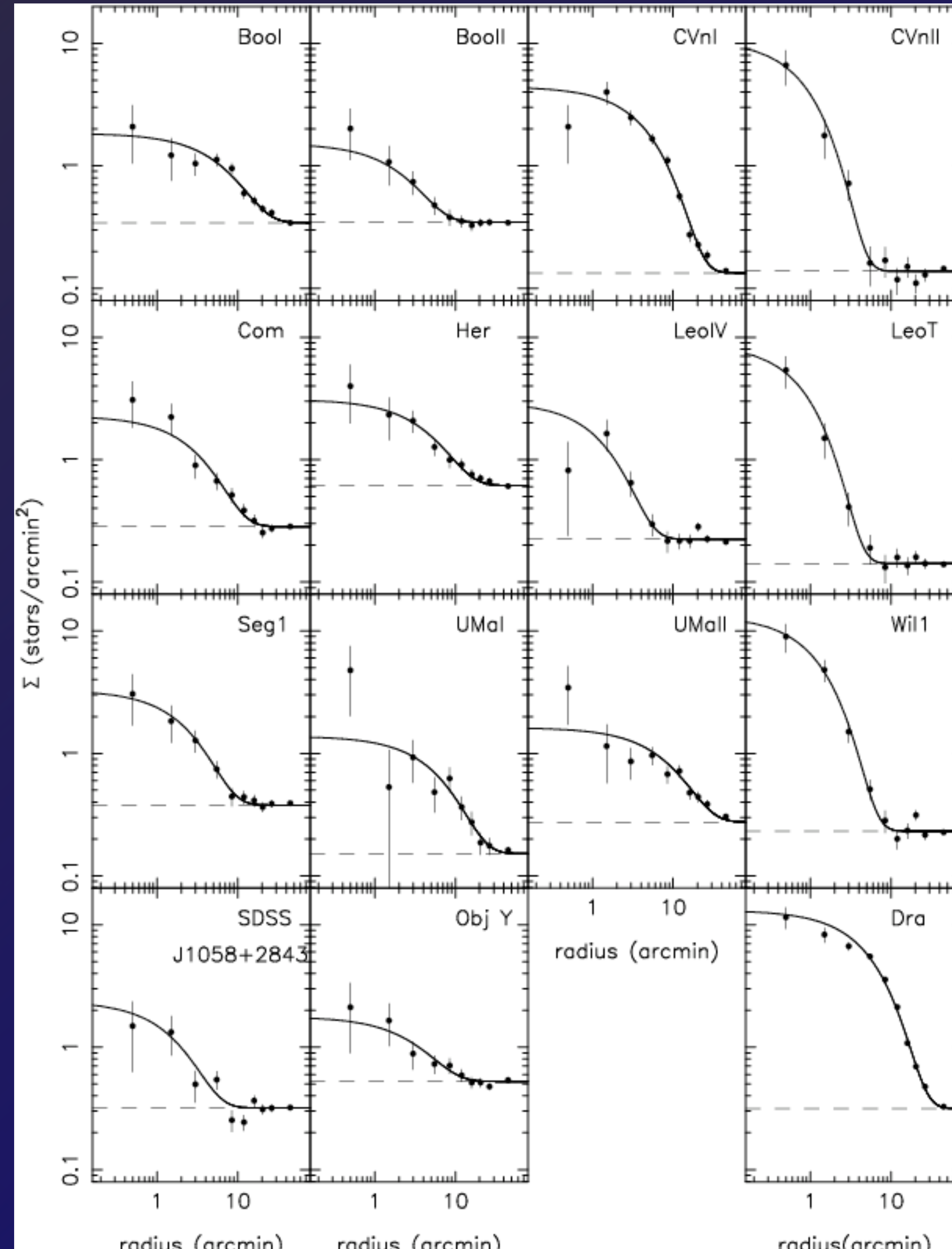
(N* = 30 stars)

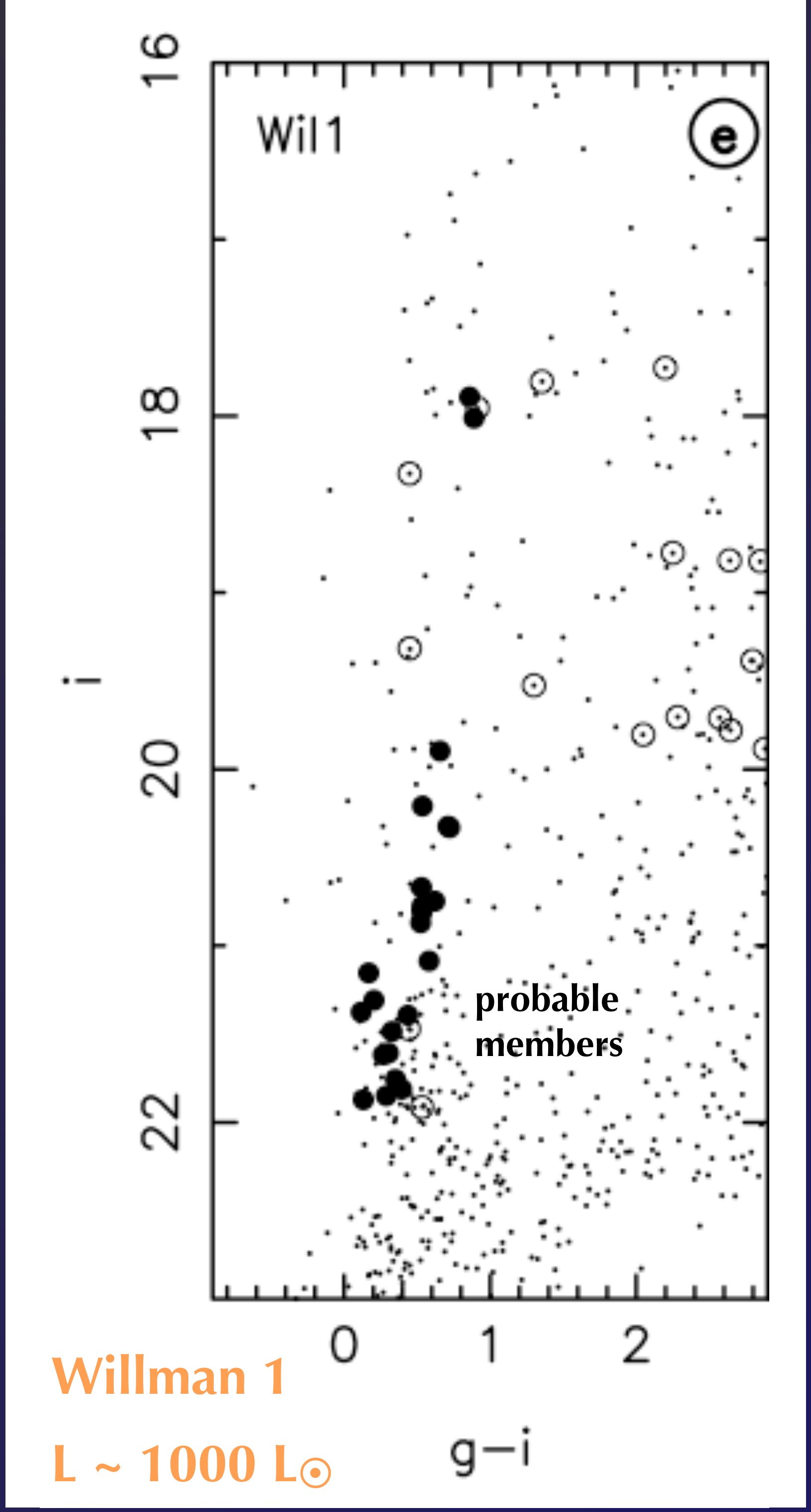


BooI
BooII
CVnI
CVnII
Com
Her
LeoIV
LeoT
Seg1
UMaI
UMaII
Wil1
SDSS J1058+2843
Obj Y
Dra
Σ (stars/arcmin²)
radius (arcmin)
radius (arcmin)
radius (arcmin)
radius(arcmin)

Magnitudes

M_V measured from member stars' luminosity suffers from 'CMD shot-noise'

ML gives N* + stellar population models (de Jong et al. 07) from the same dataset → typical M_V



Magnitudes

tip RGB

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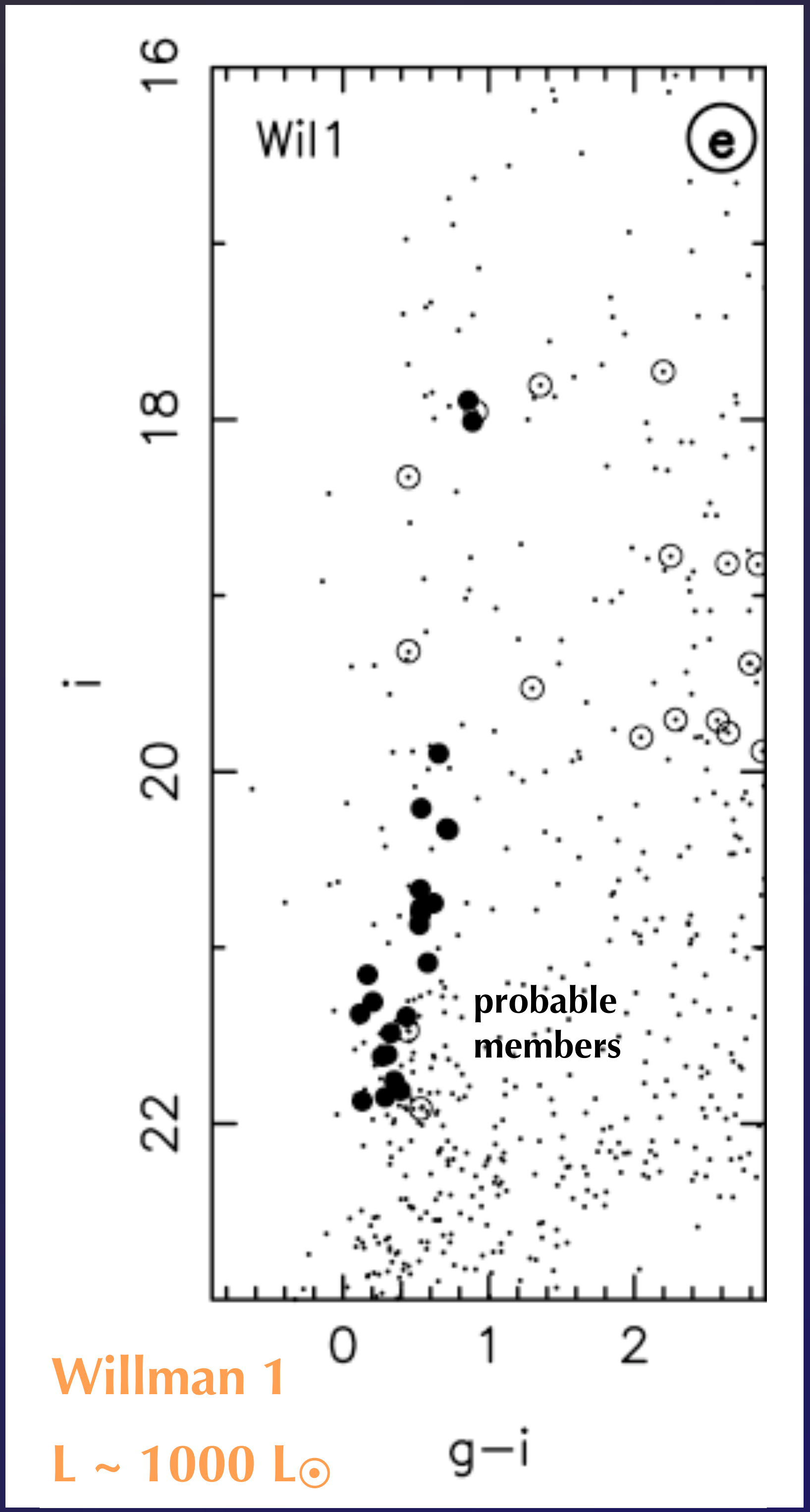

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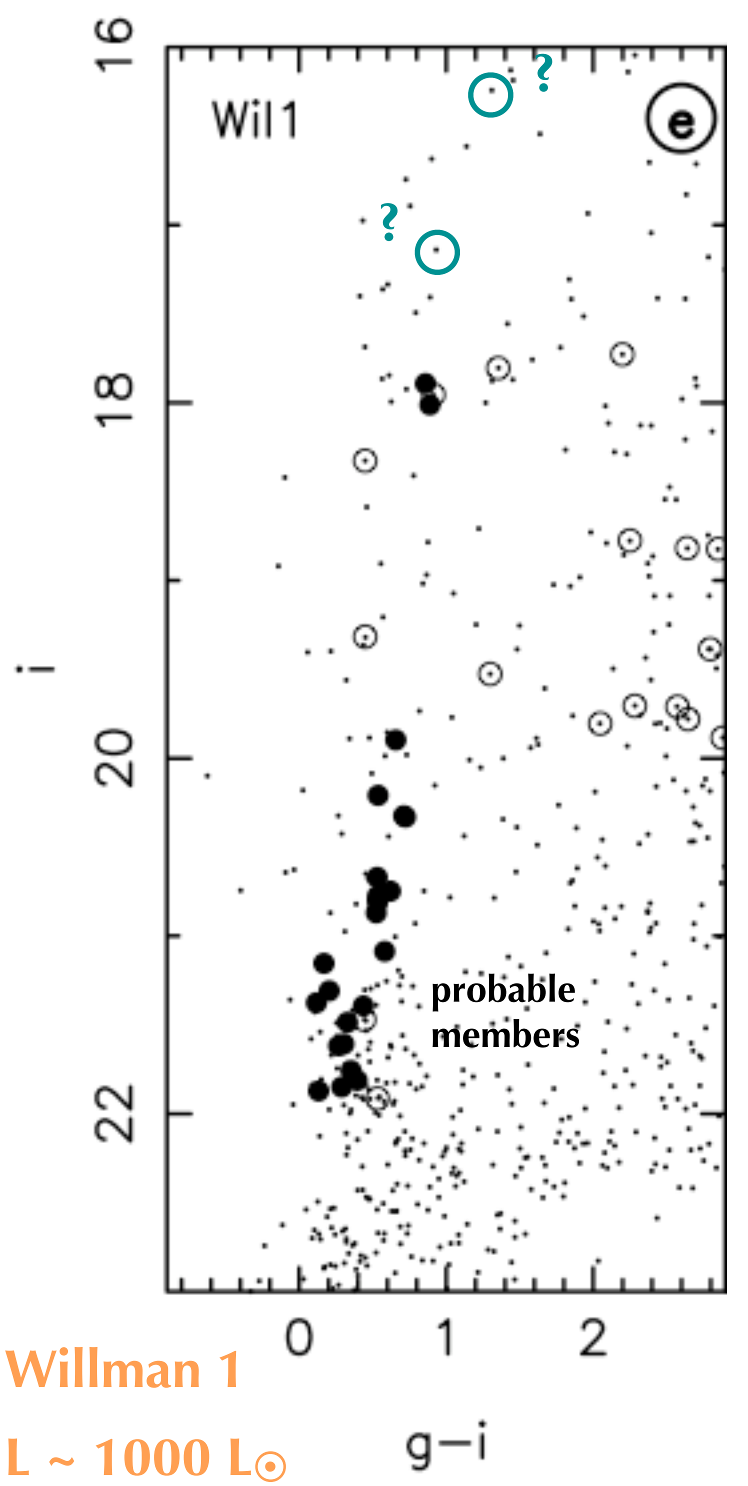

Willman 1

L ~ 1000 $L_\odot$

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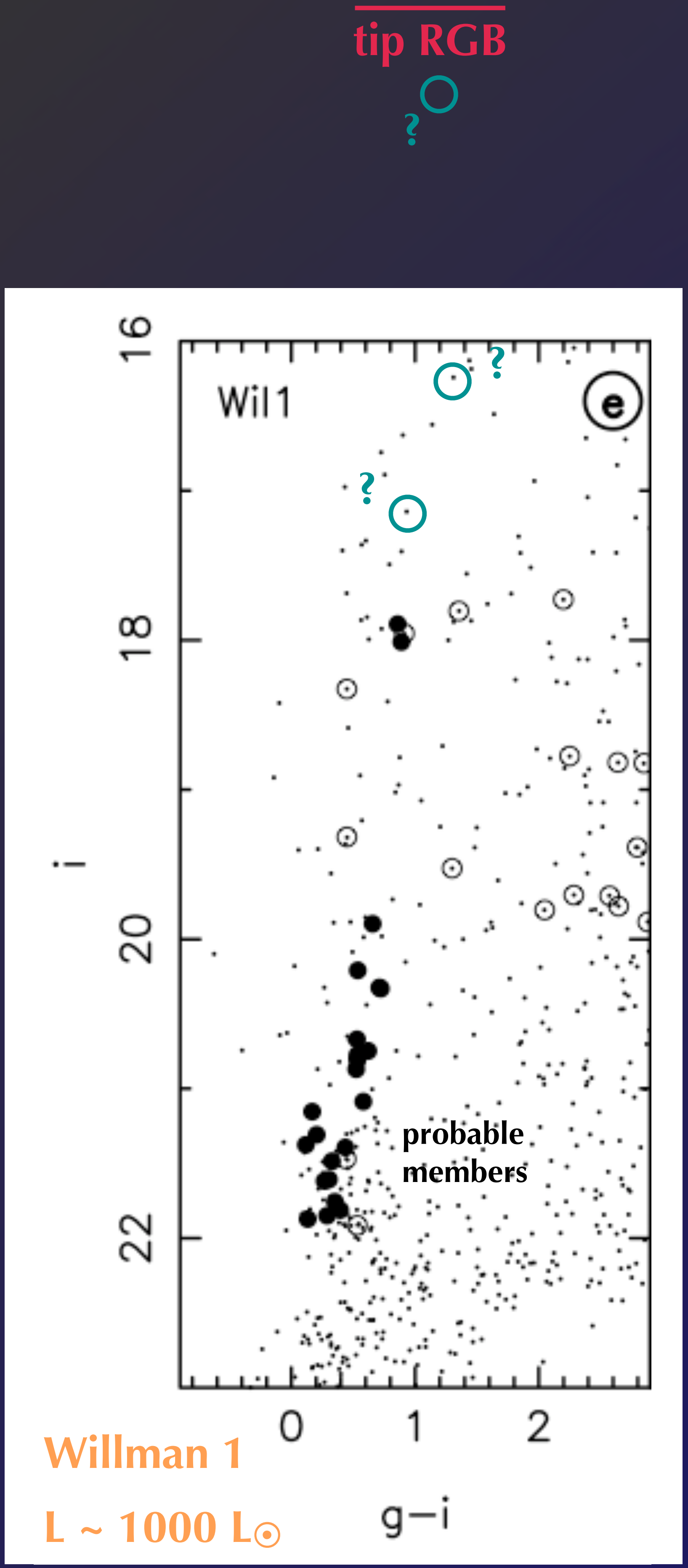

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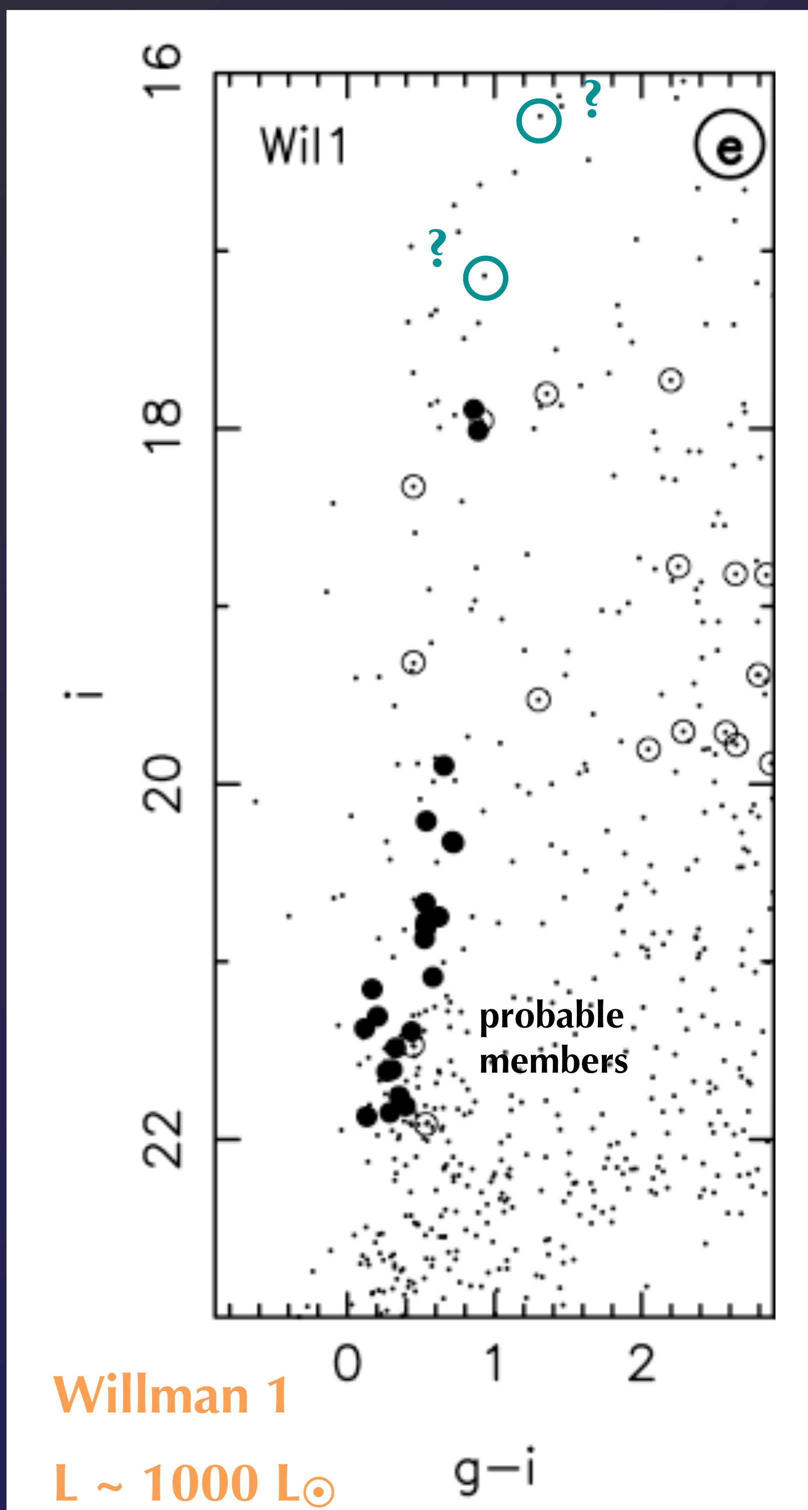
10^3 times N*±δN* —stellar pop.→ 'a' CMD —LF correction→ 'a' M_V

(& 'a' mass)



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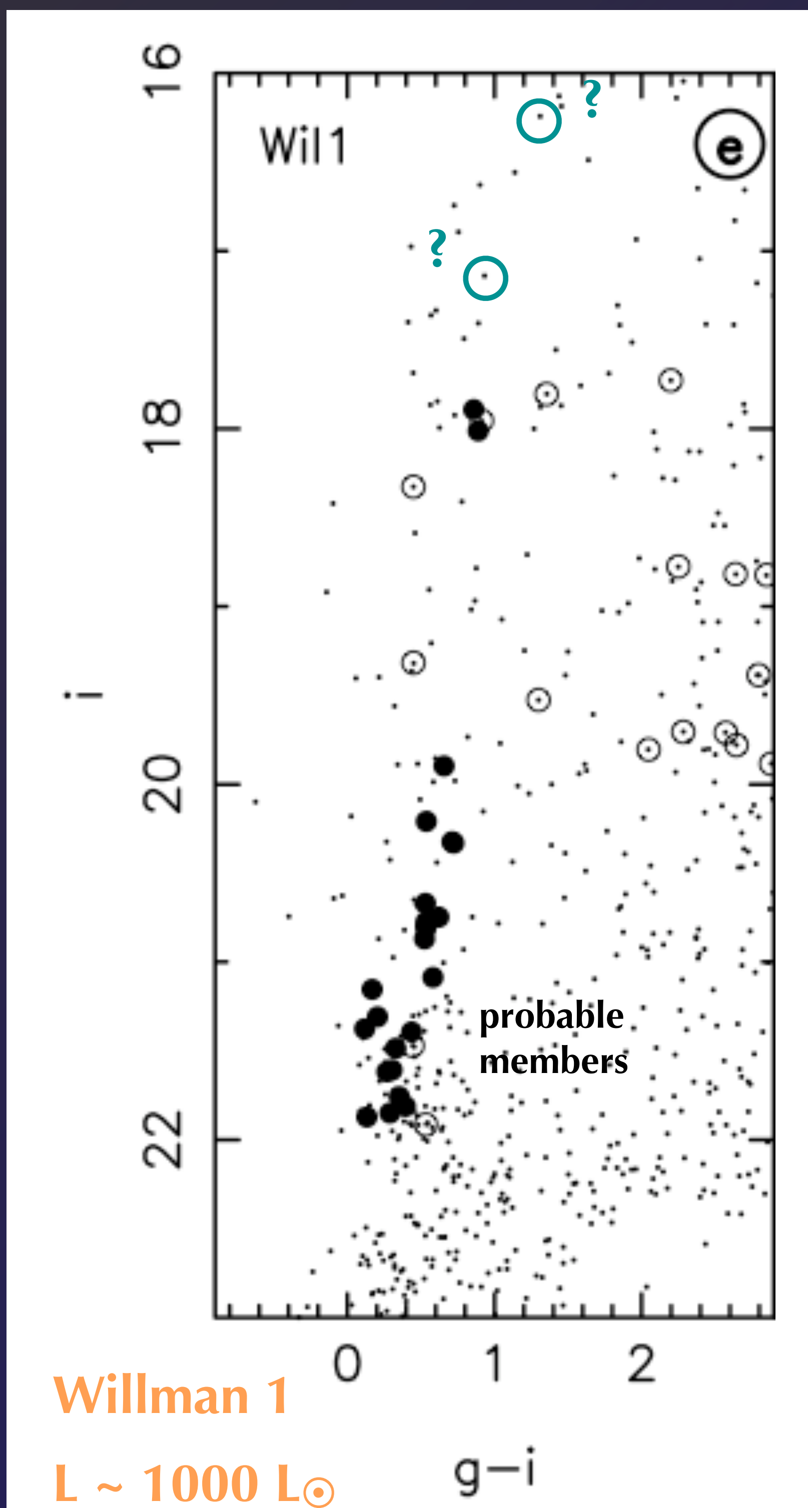

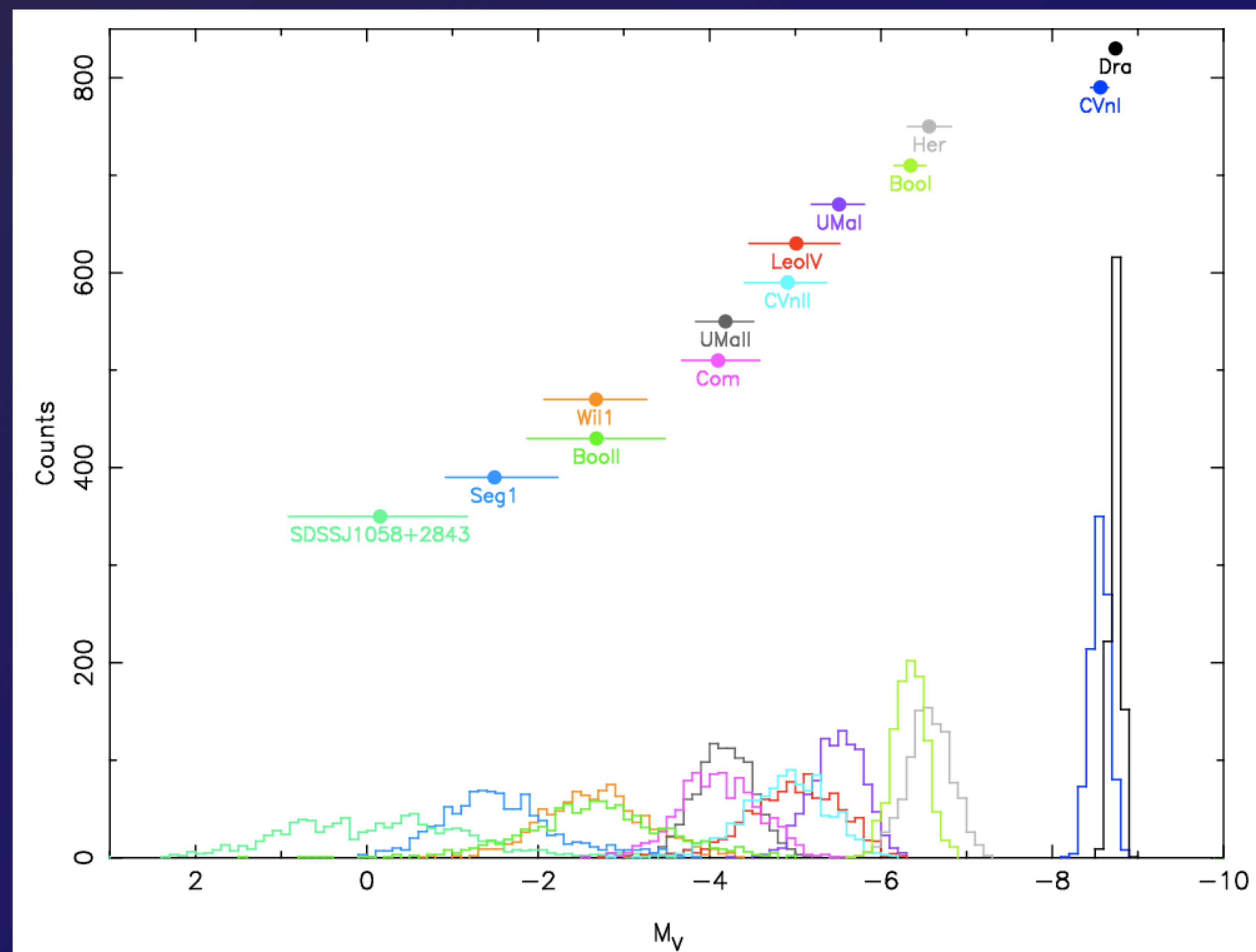

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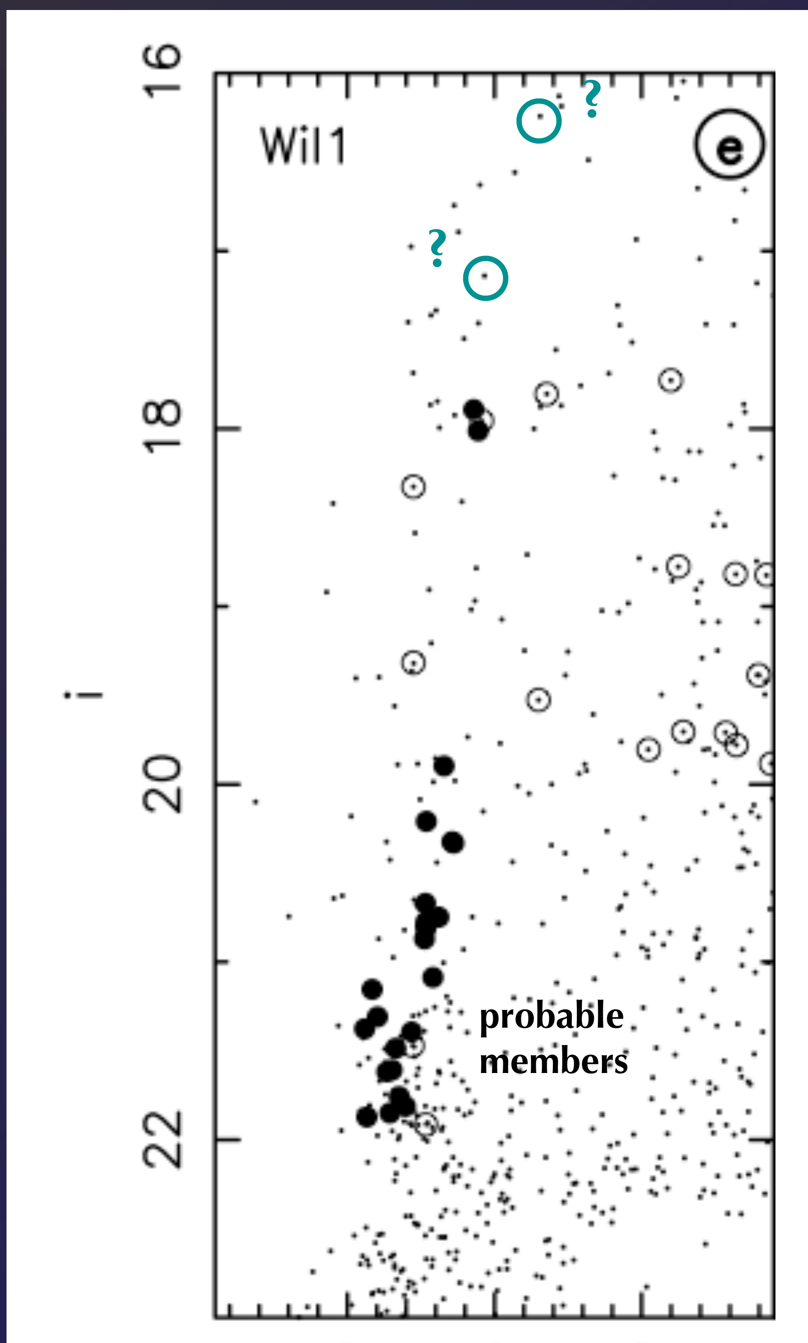

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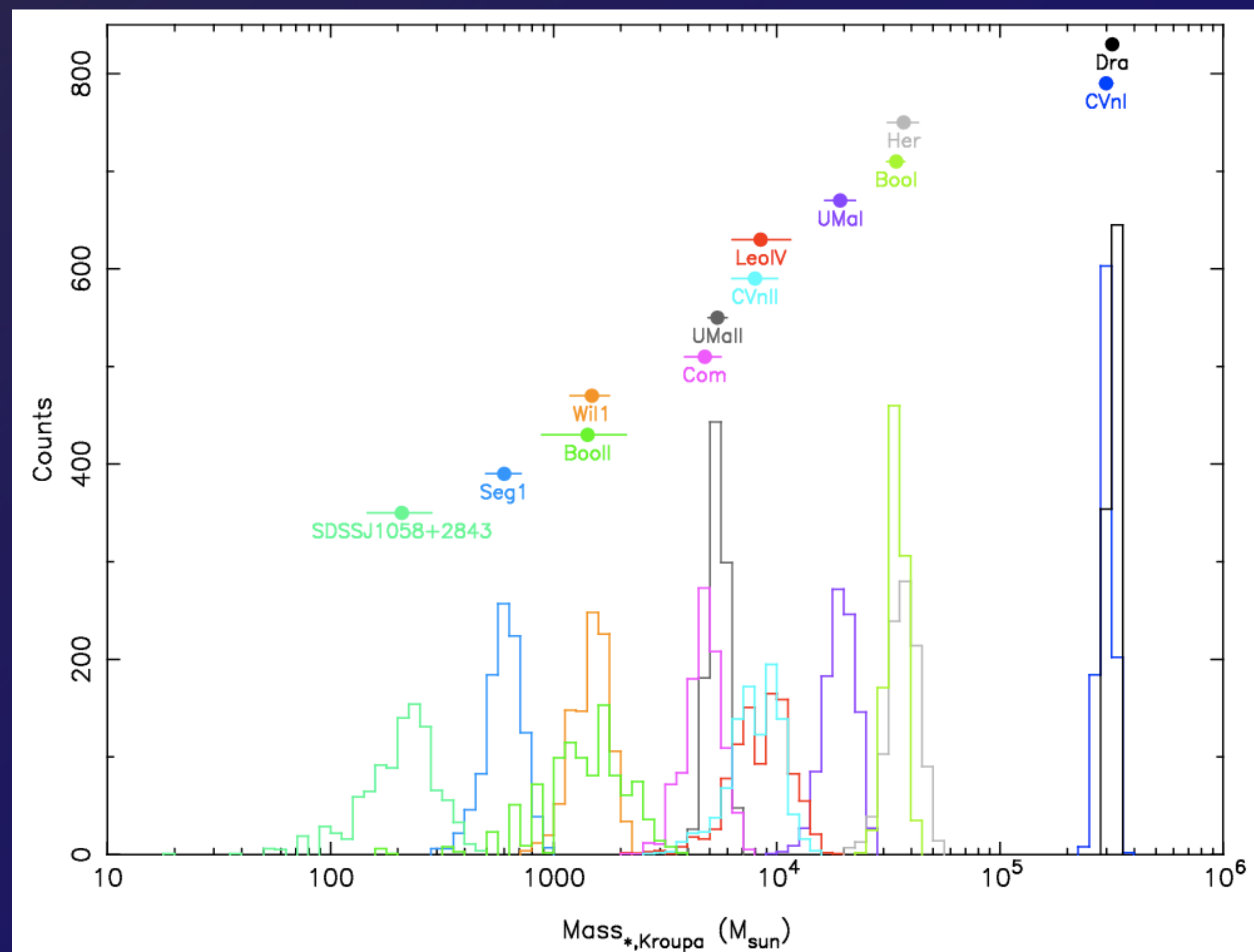
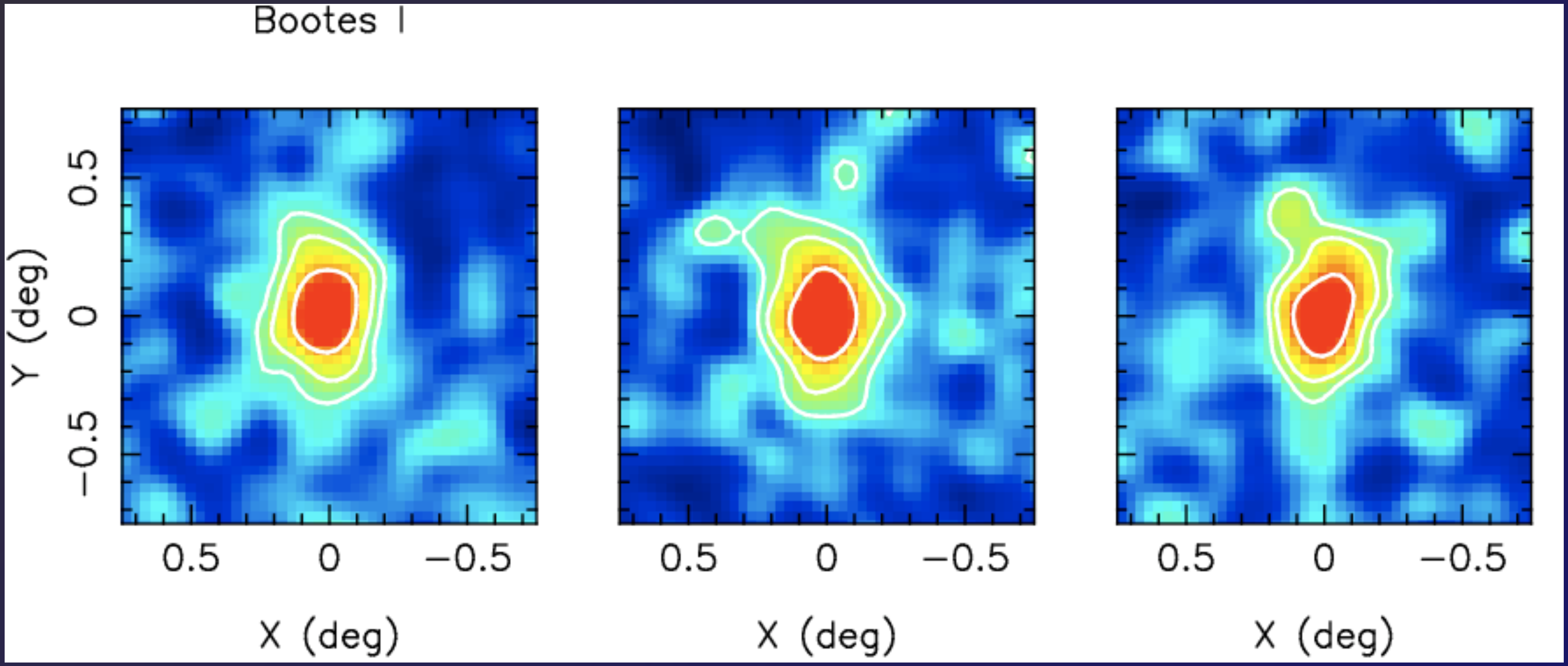


Signs of Distortion?



Amount of scatter in pixel counts, accounting for Poisson noise with 4 pixel grids:

$$\left(\frac{\sigma_{\rm sc}}{\rm total}\right)^2 = \left(\frac{1}{N}\sum_{i=1}^{N}(D_i - M_i)^2 - \frac{1}{N}\sum_{i=1}^{N}(P_i - M_i)^2\right).\left(\frac{1}{N}\sum_{i=1}^{N}D_i\right)^{-2}$$

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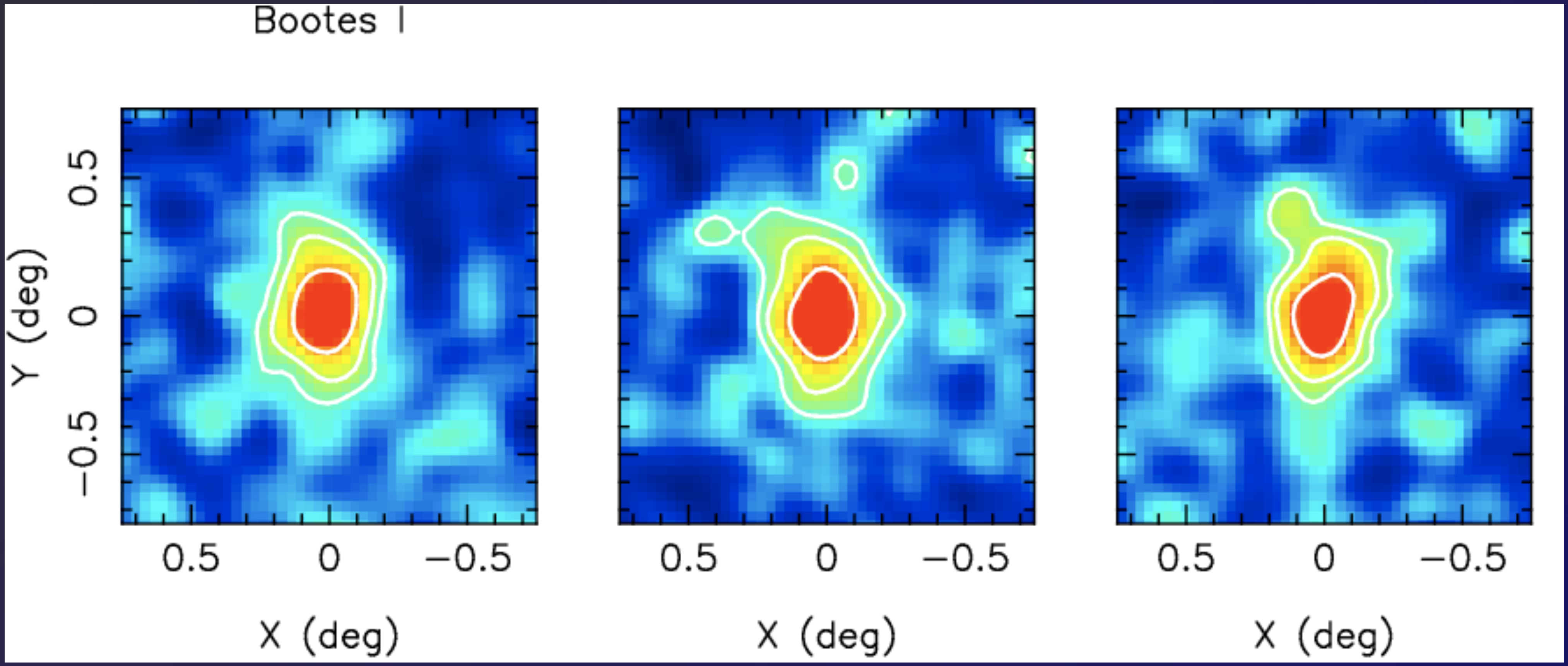

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Scatter in the data wrt model

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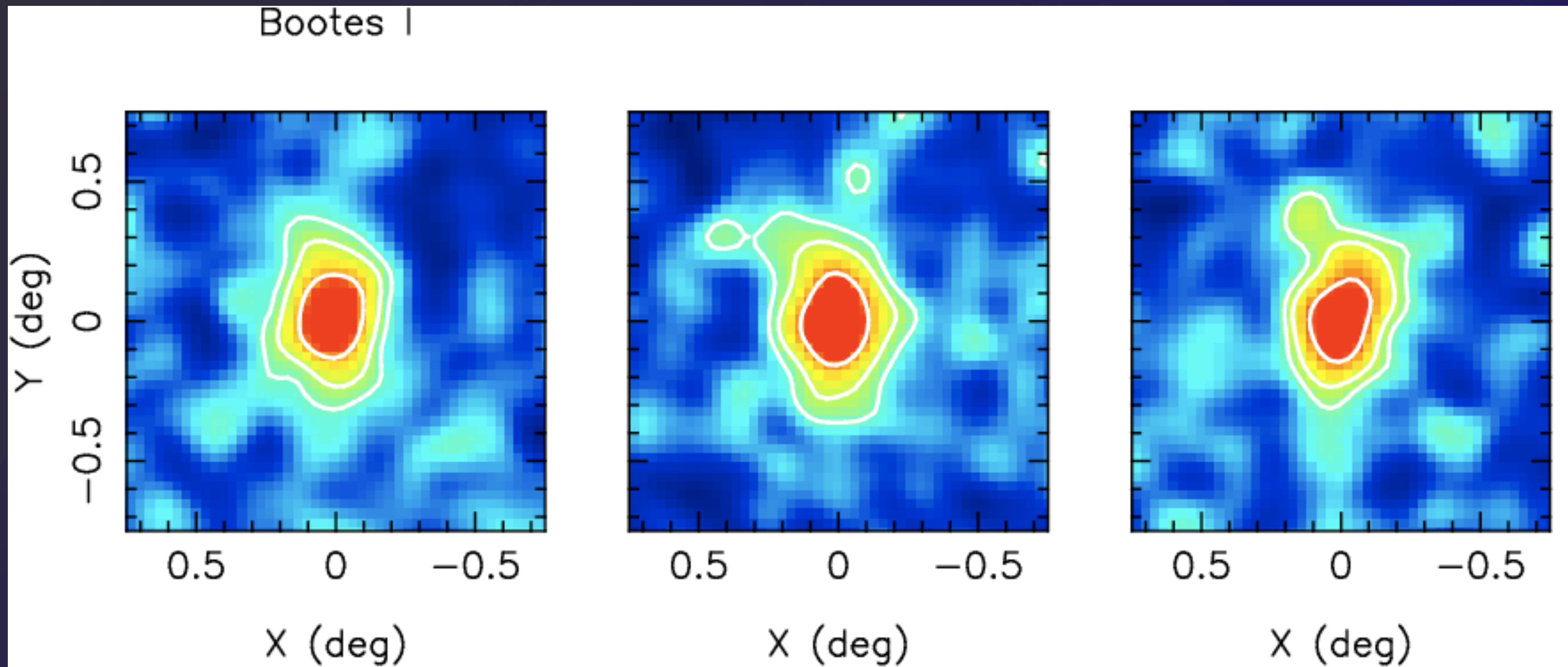

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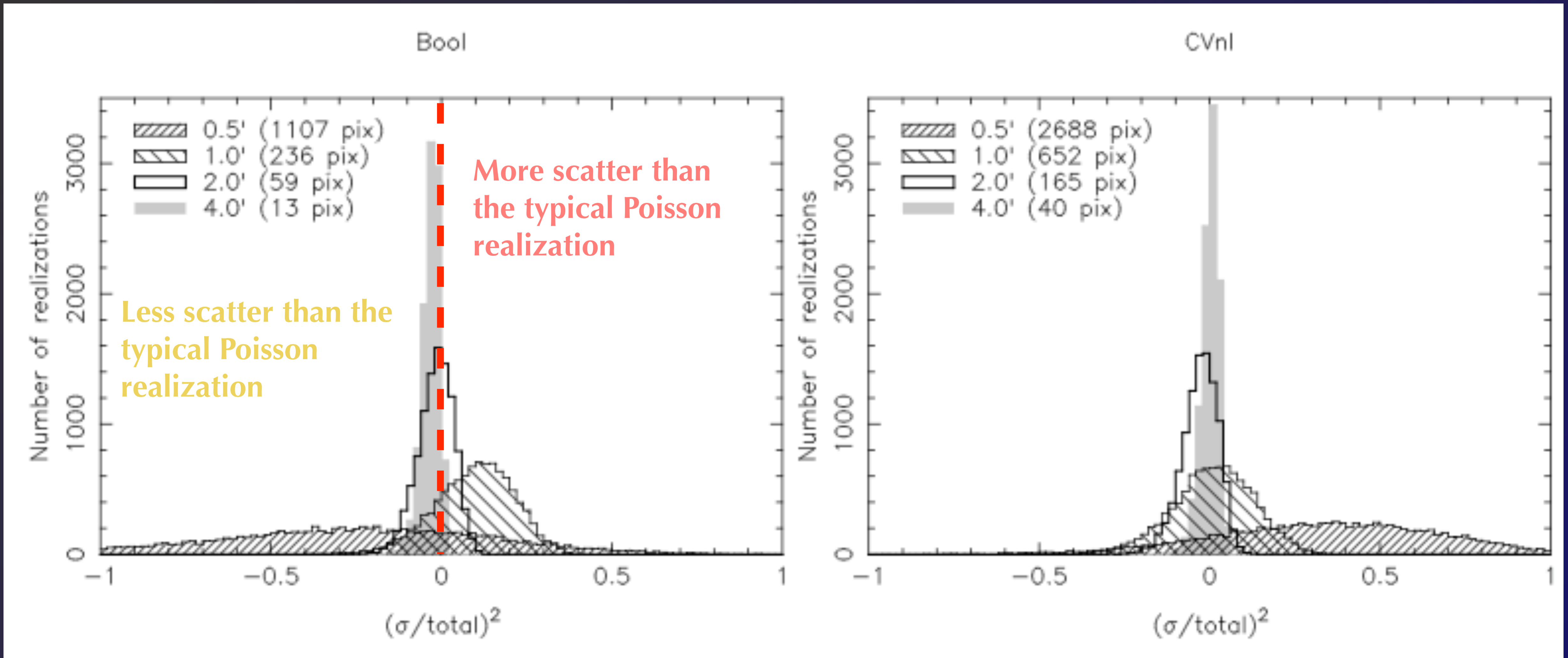
Scatter in the data wrt model

Scatter in a Poisson realization of best model



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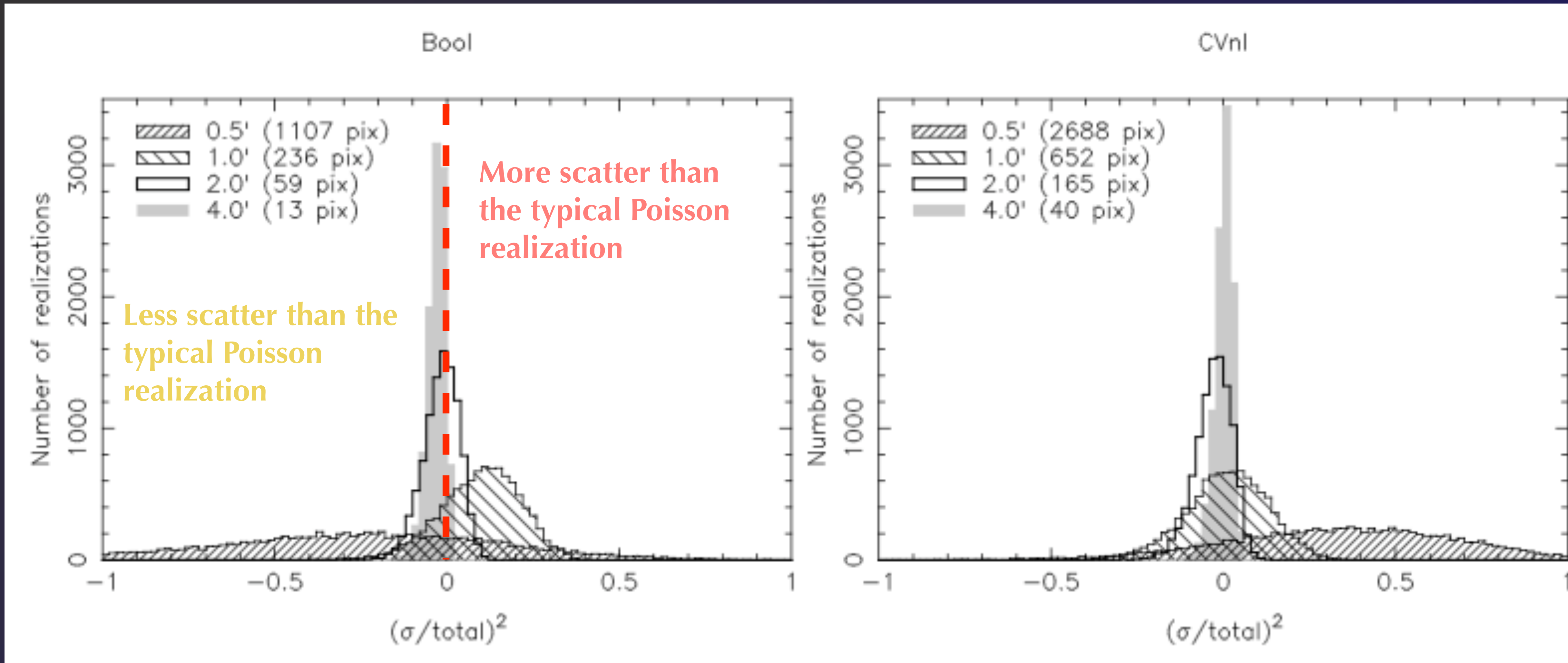

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Scatter in the data wrt model

Scatter in a Poisson realization of best model

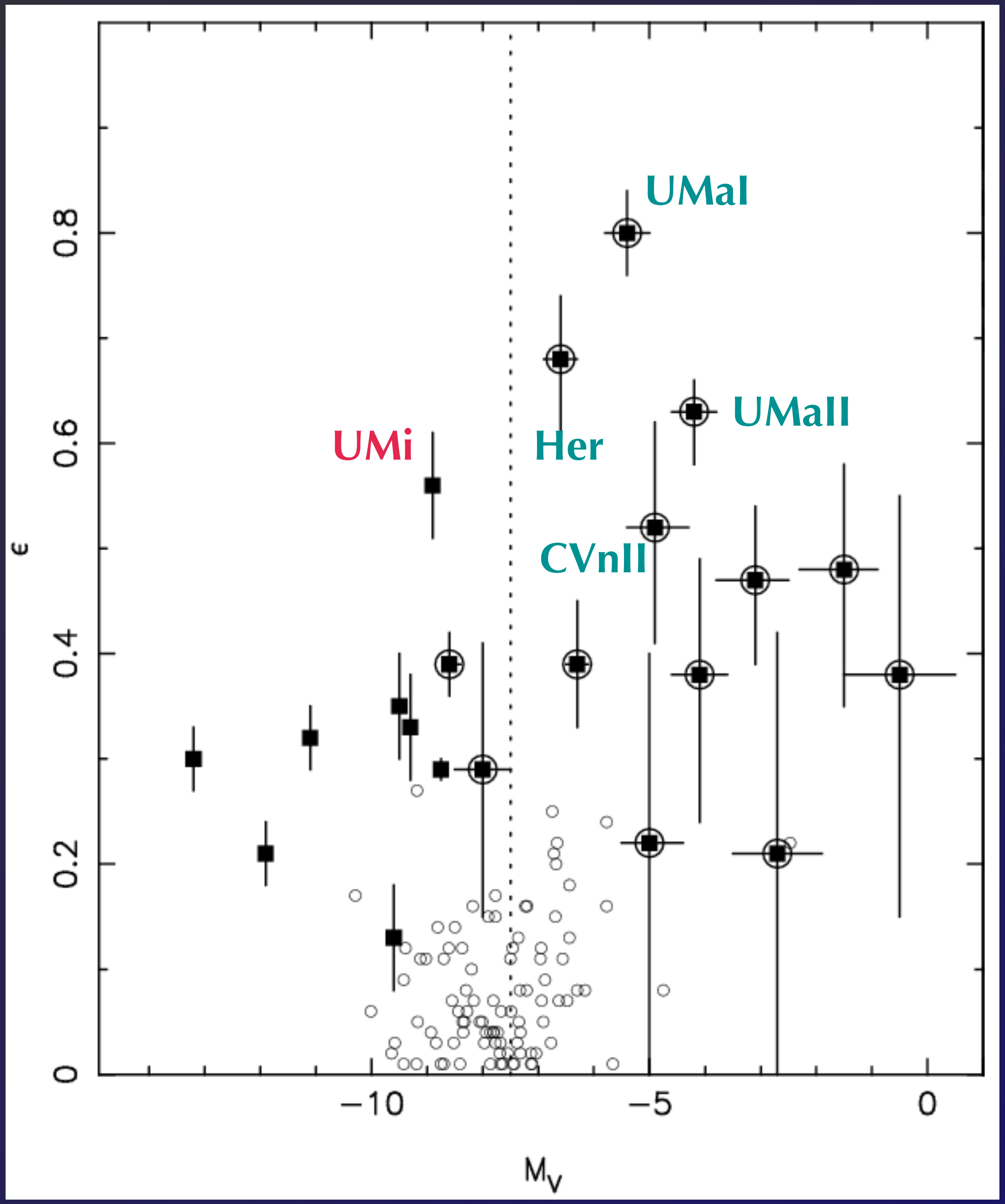
Marginal distortions (1-2σ) detected in CVnI & UMaII but none otherwise

→ No distortions or SDSS not deep enough to find them

Ellipticity

Faint galaxies appear flatter than bright galaxies

- mean $\epsilon = 0.32 \pm 0.02$ ($M_V > -8.0$) vs. $\epsilon = 0.47 \pm 0.03$ ($M_V > -8.0$)
- KS test: 99.6% proba that different subsamples
- 3 most flattened systems are faint



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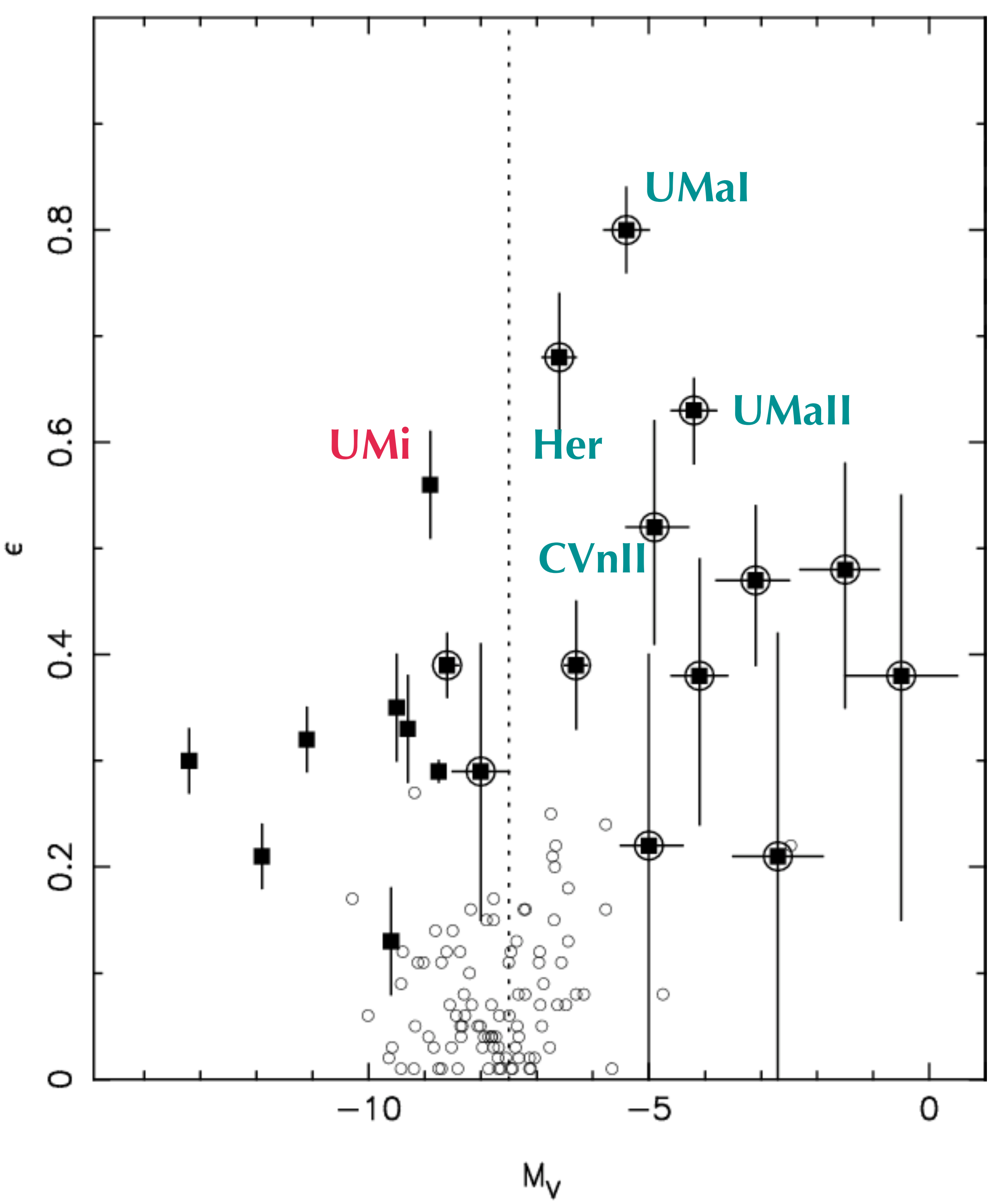
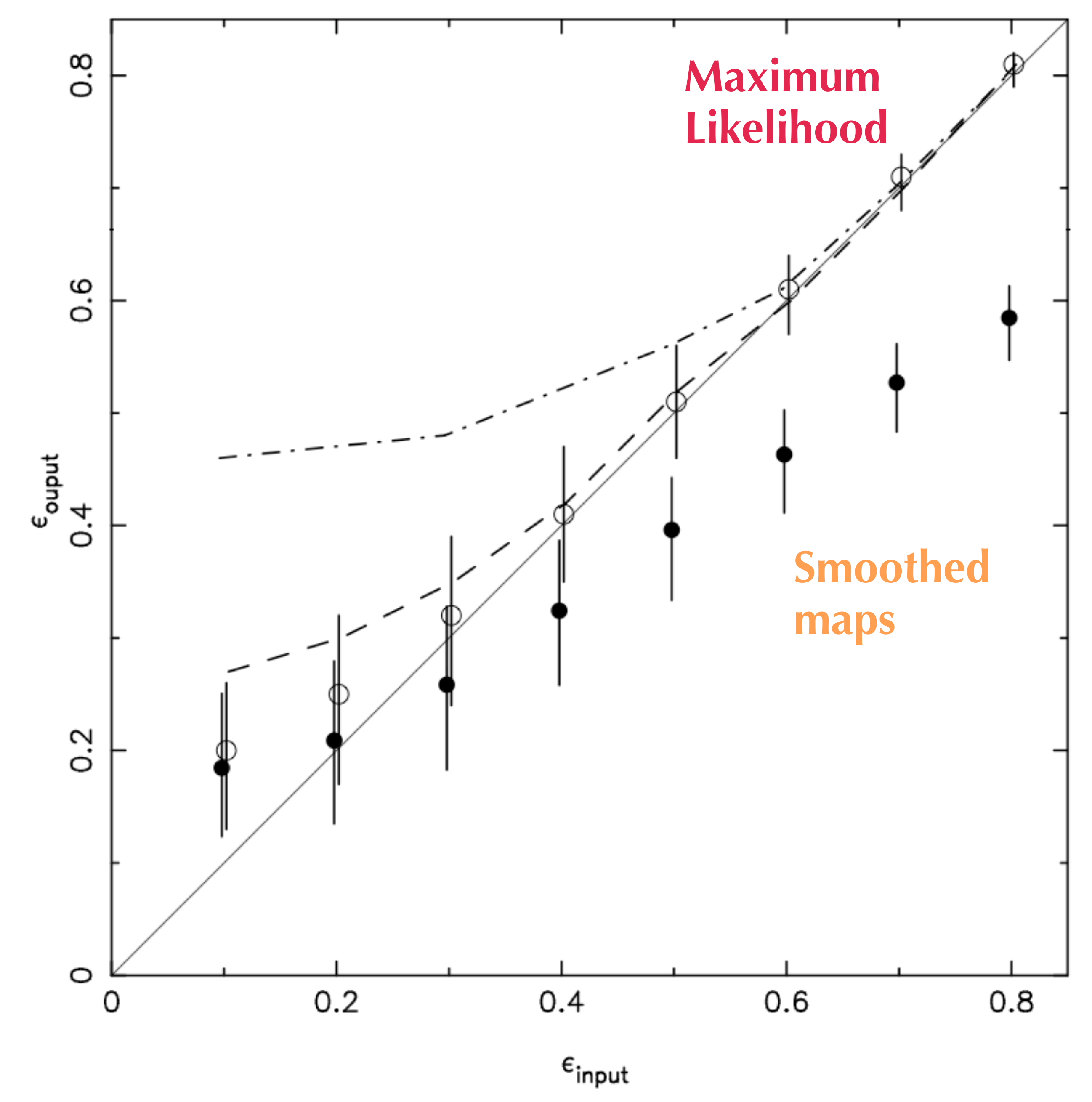
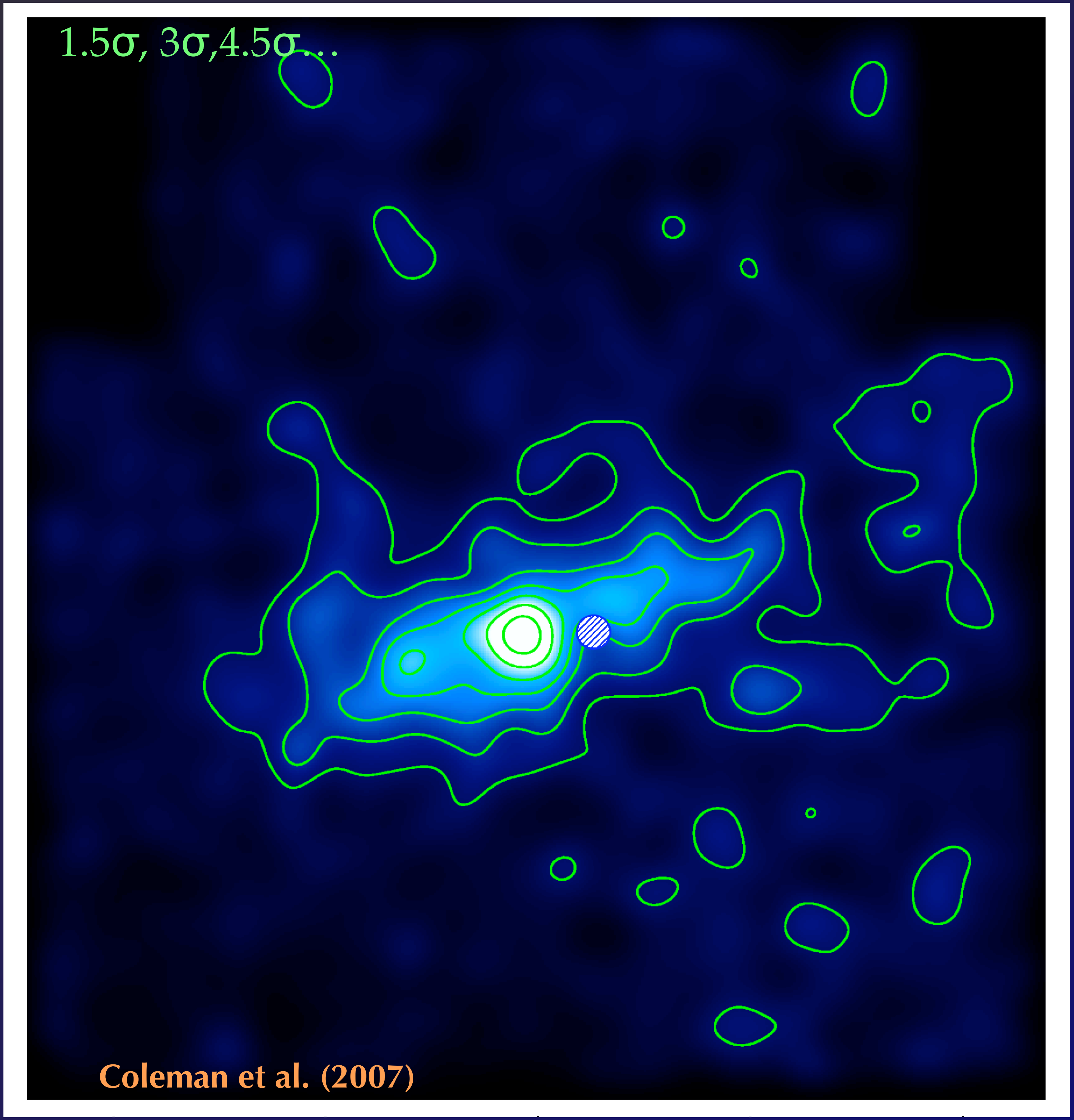
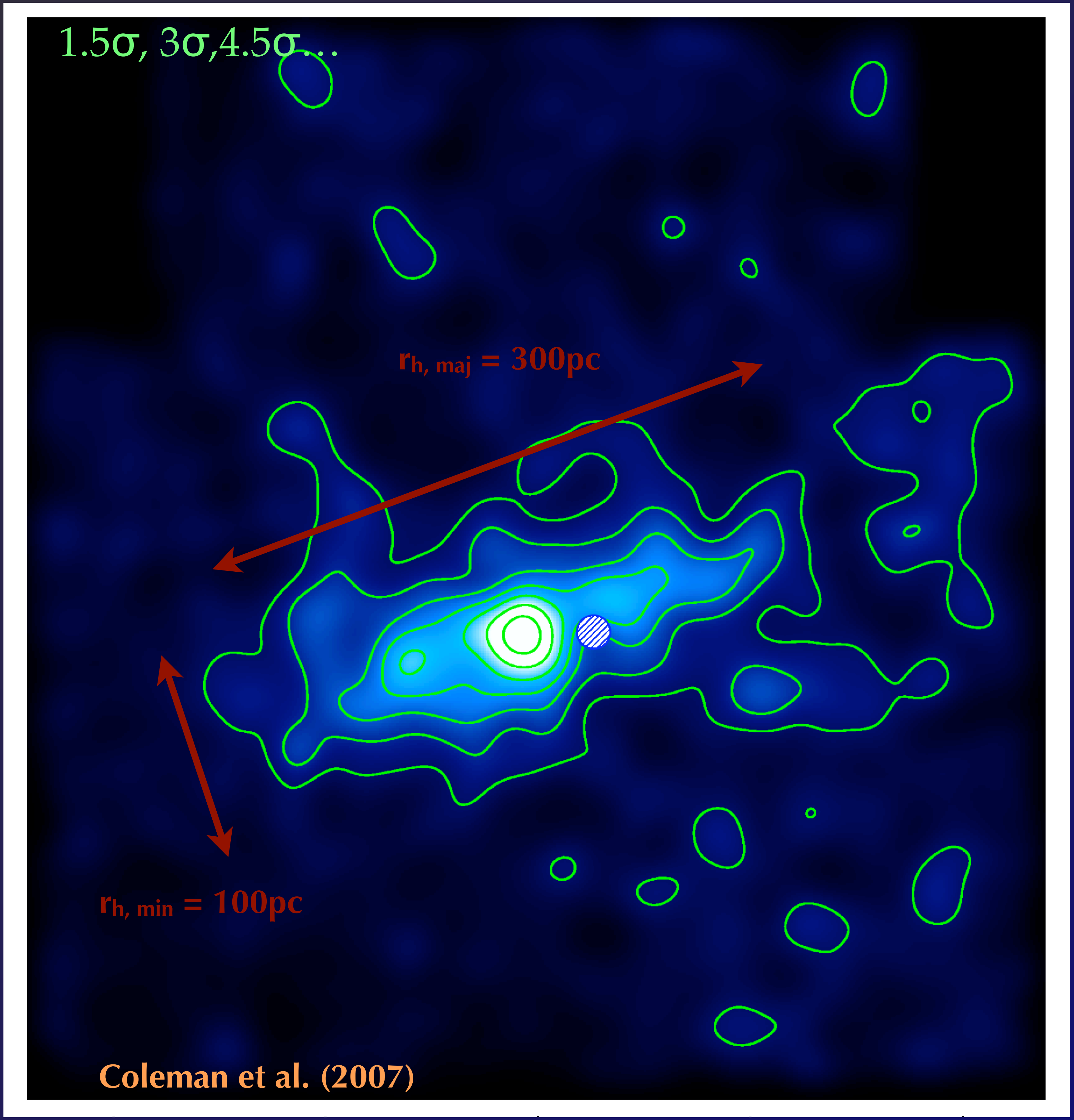




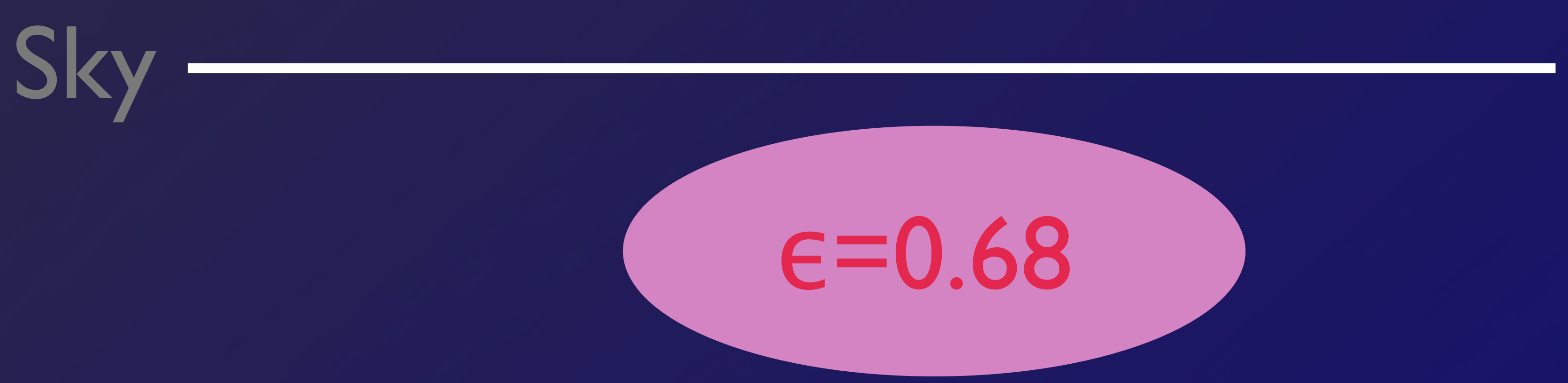
Hercules



Hercules

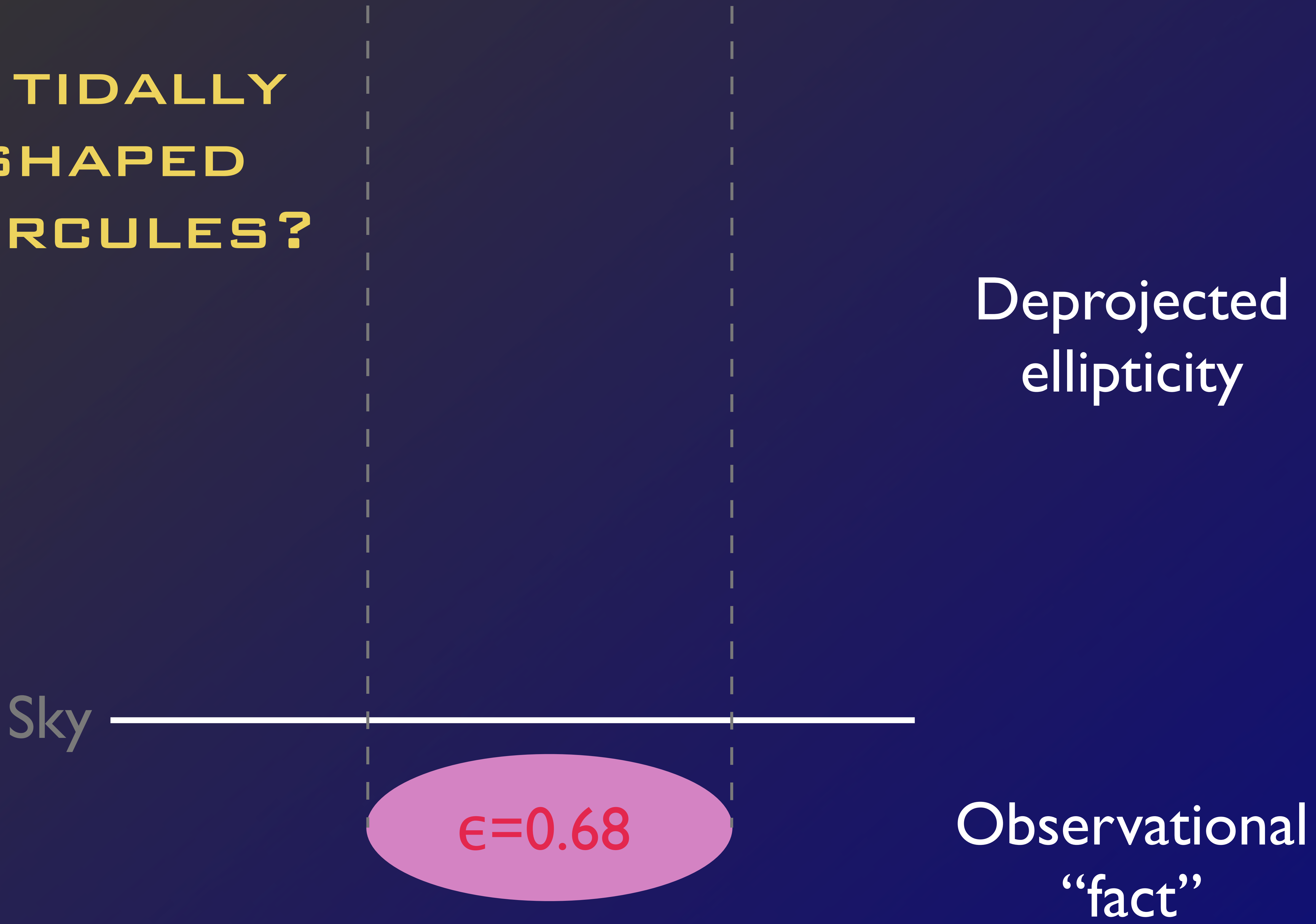


A tidally shaped Hercules?

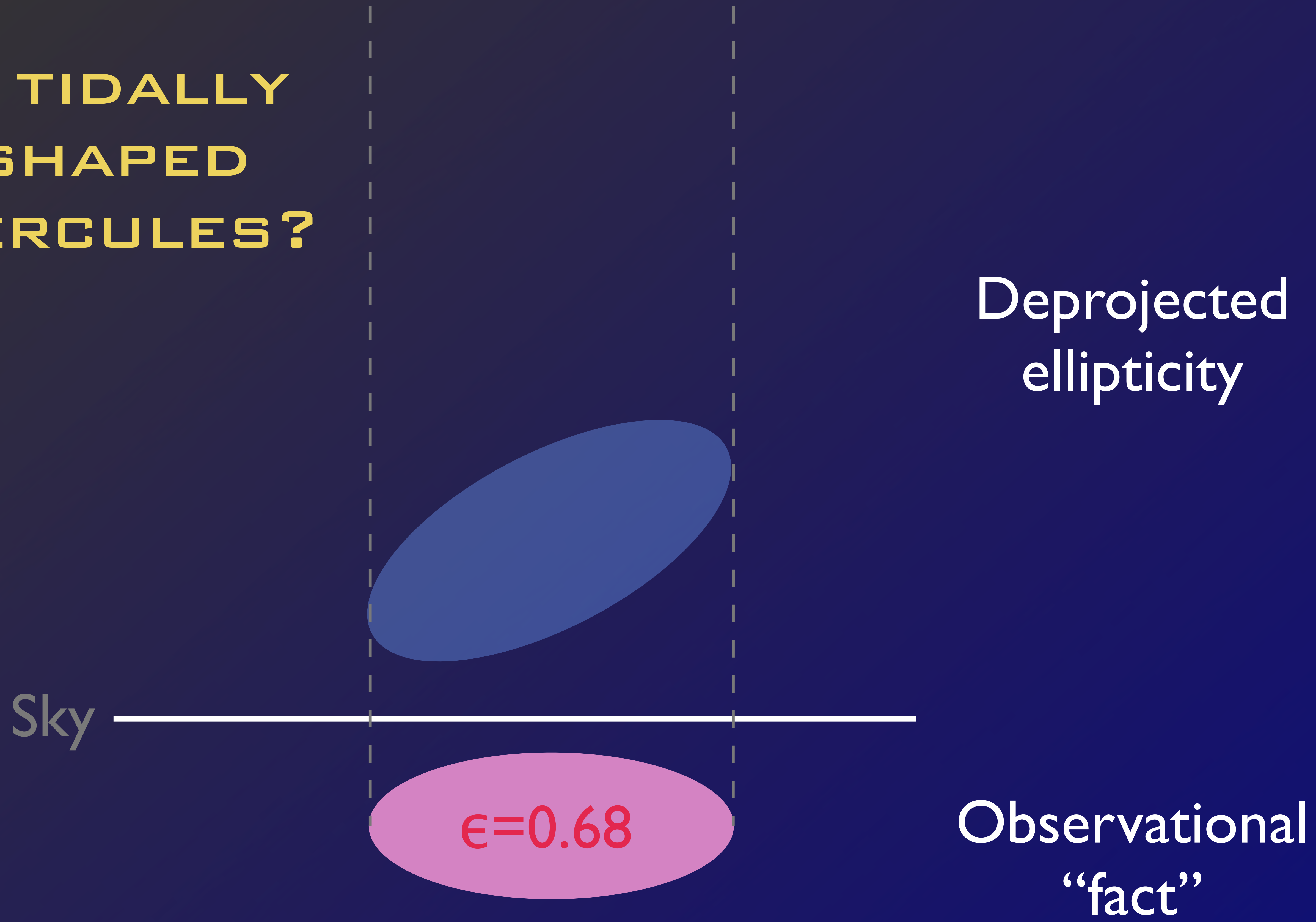


Observational
“fact”

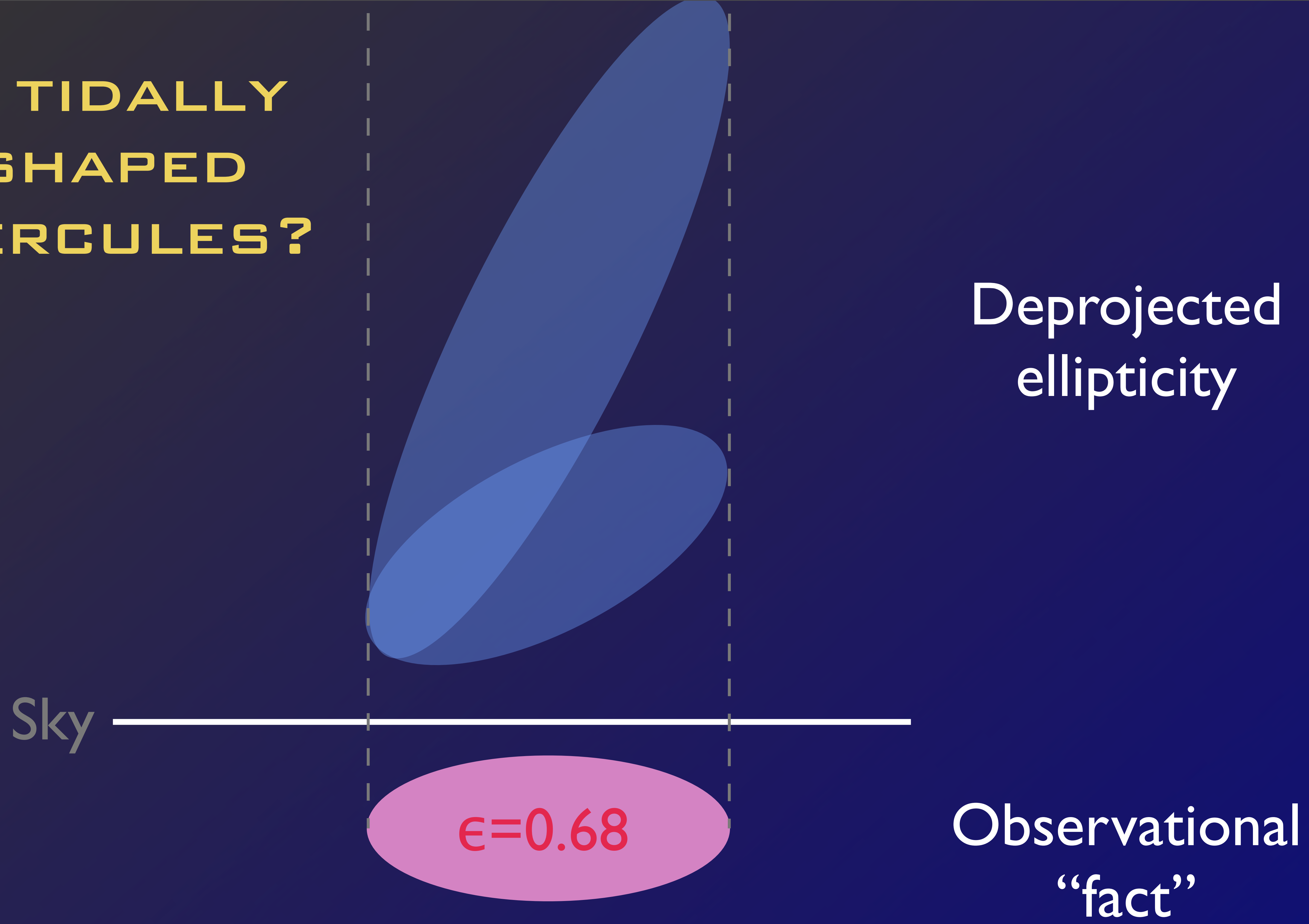
A tidally shaped Hercules?



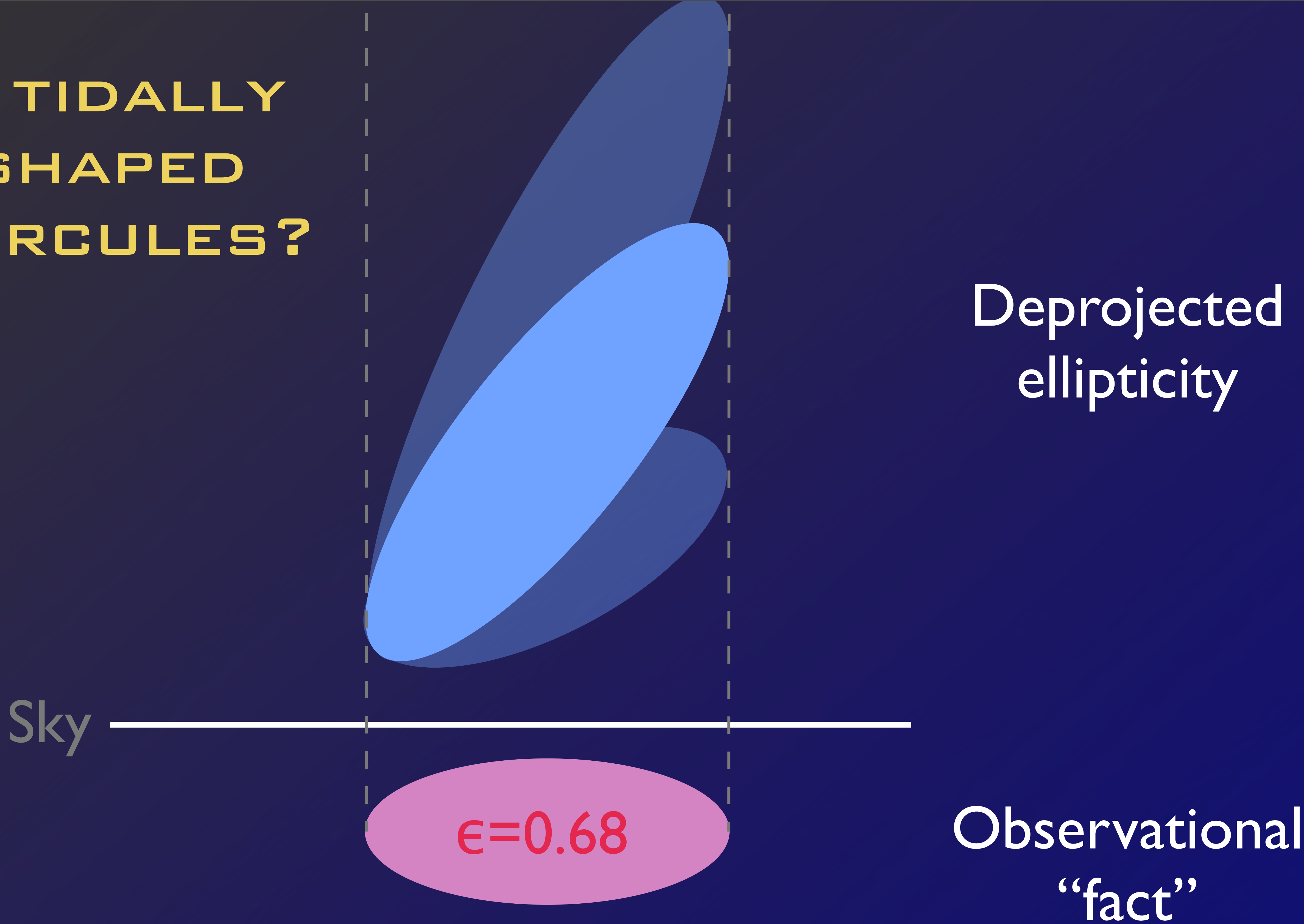
A tidally shaped Hercules?



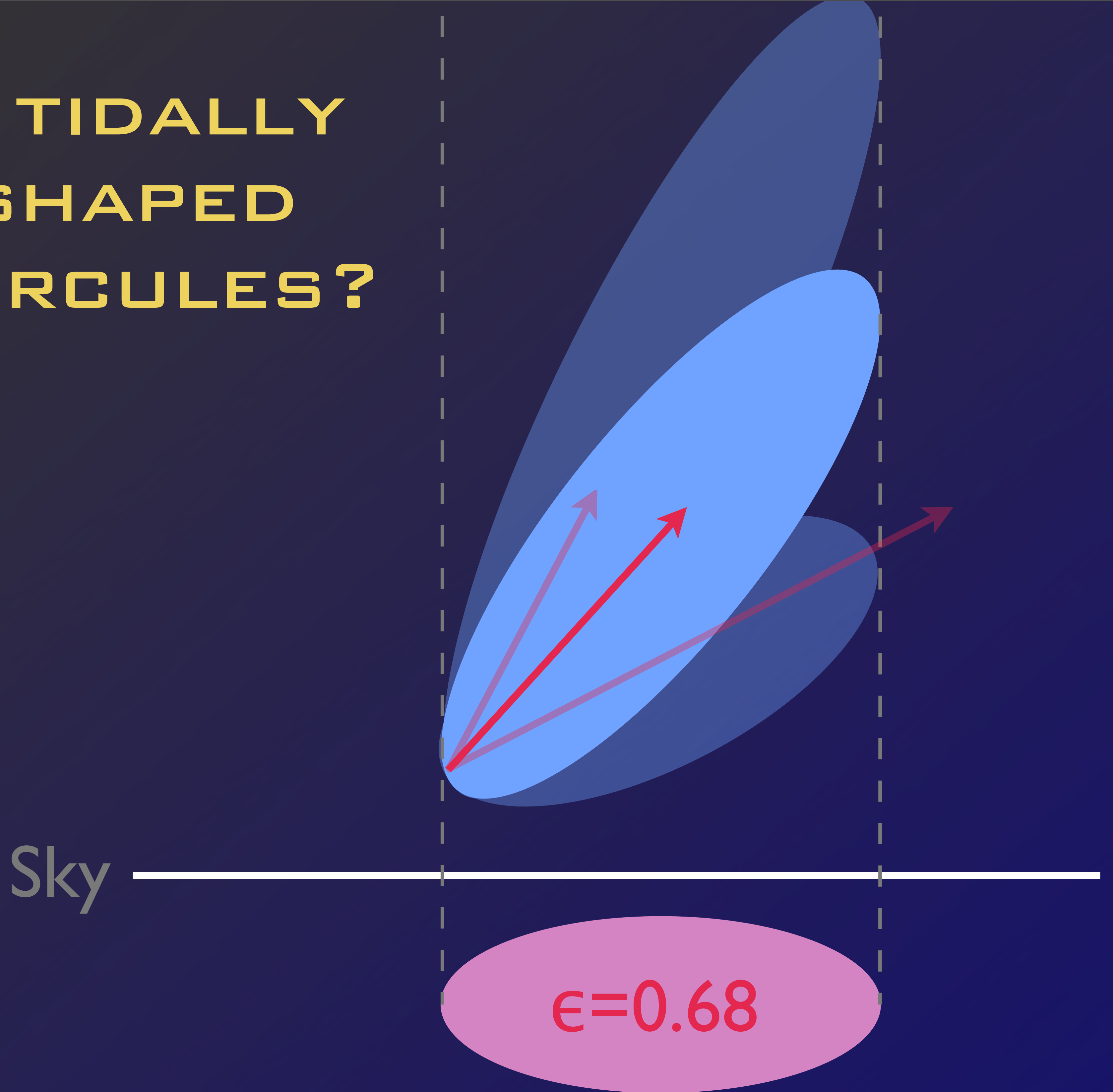
A tidally shaped Hercules?



A tidally shaped Hercules?



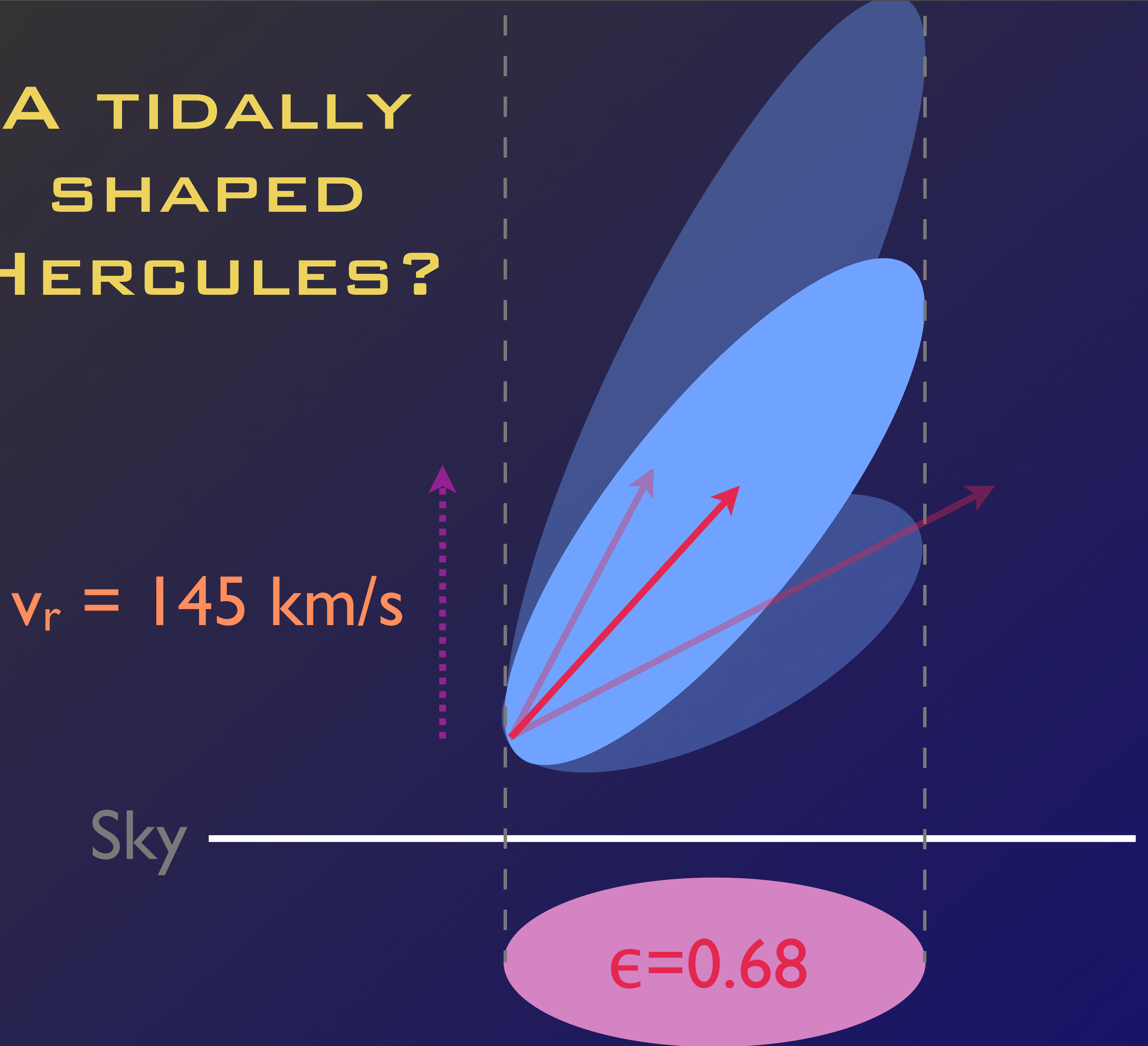
A tidally shaped Hercules?



Deprojected ellipticity

Observational “fact”

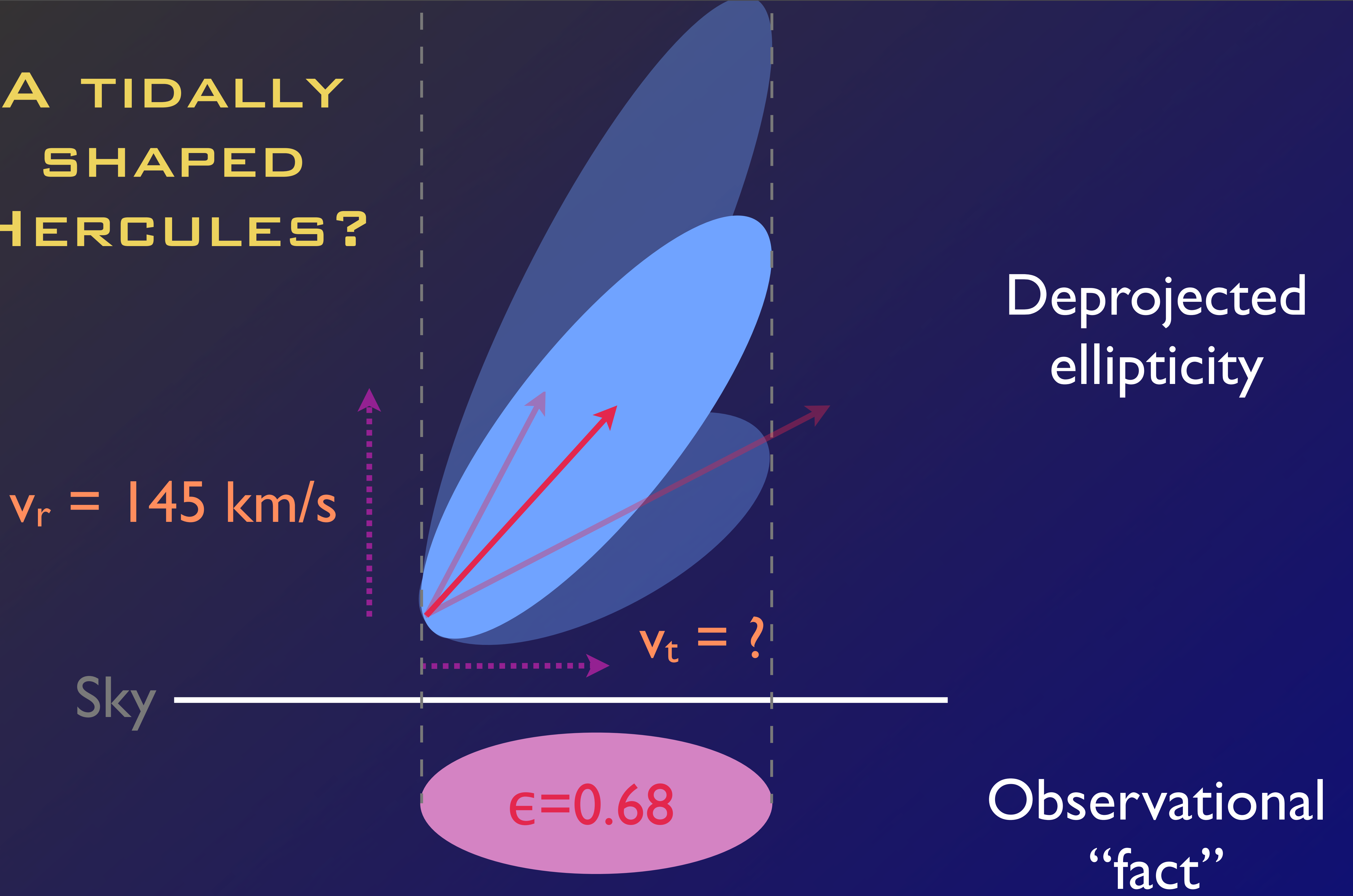
A tidally shaped Hercules?



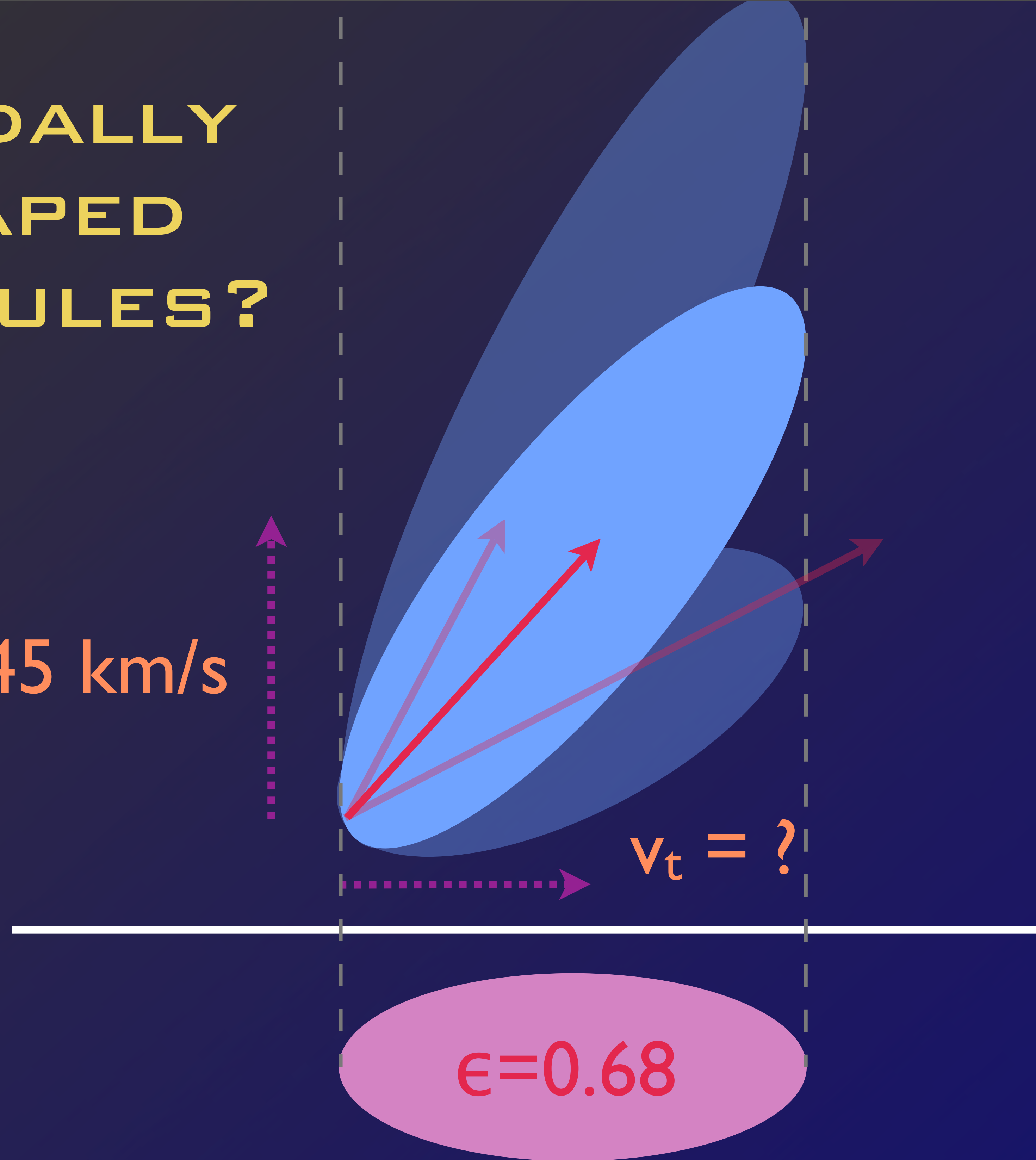
Deprojected ellipticity

Observational "fact"

A tidally shaped Hercules?



A tidally shaped Hercules?



v_r = 145 km/s

Deprojected ellipticity

Observational "fact"

$$\epsilon_{\rm true} = 1 - \left(\frac{b}{a}\right)_{\rm true} = 1 - \left(\frac{b}{a}\right)_{\rm obs}\left(1 + \frac{v_r^2}{v_t^2}\right)^{-1/2}$$

A tidally shaped Hercules?