Observational Constraints on Globular Cluster Structure

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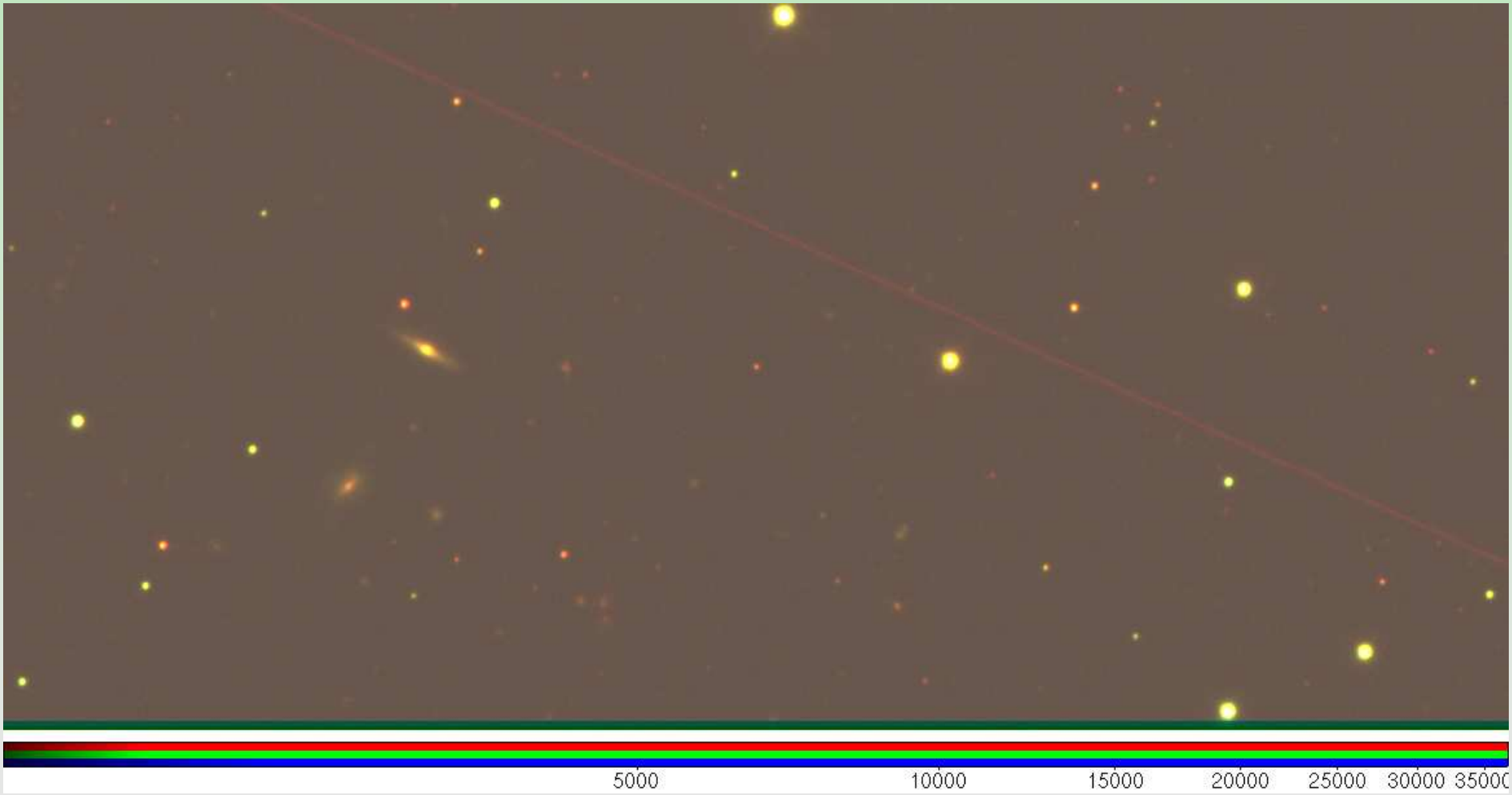
First: that Quasar from Coffee:



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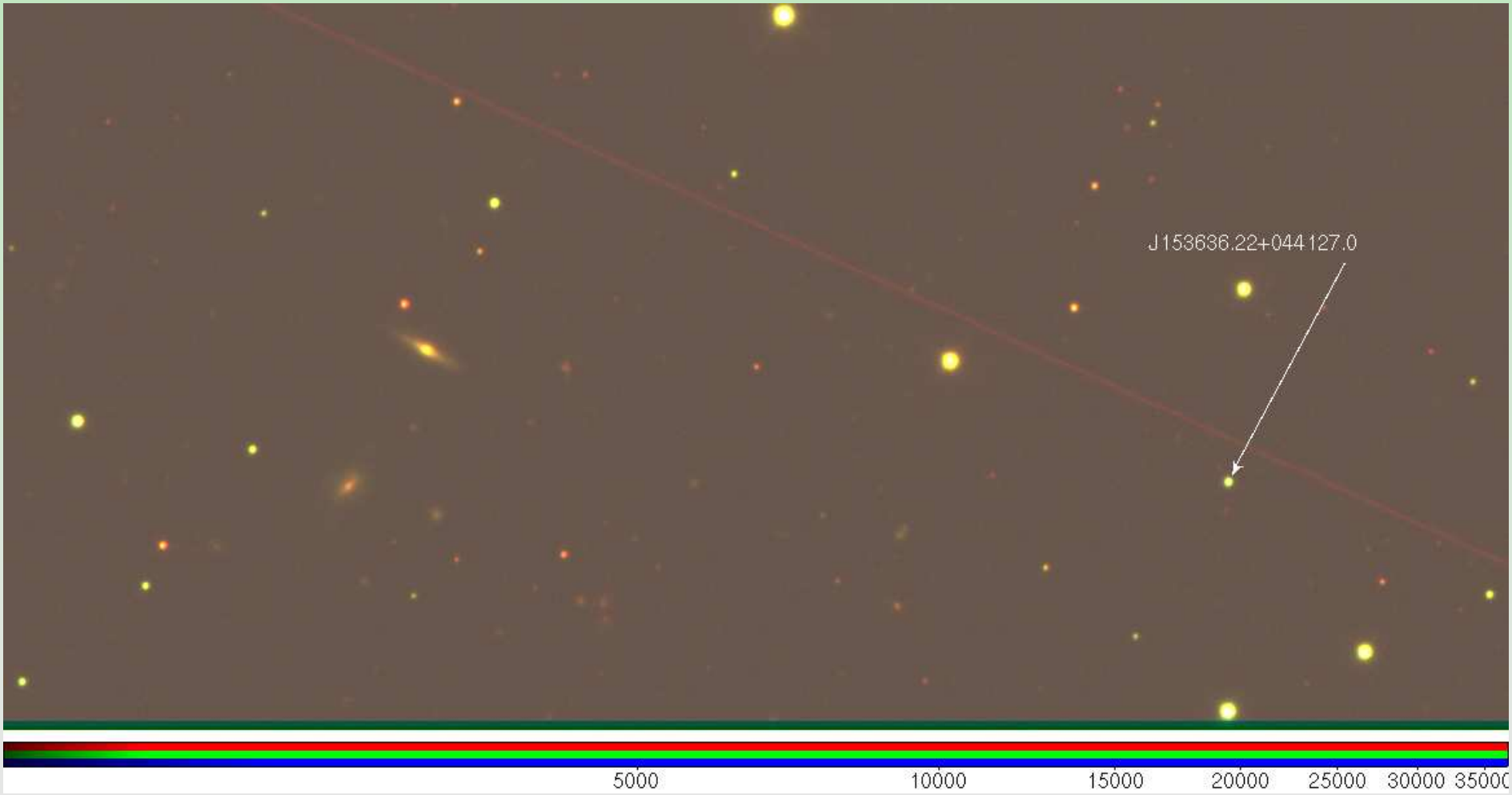
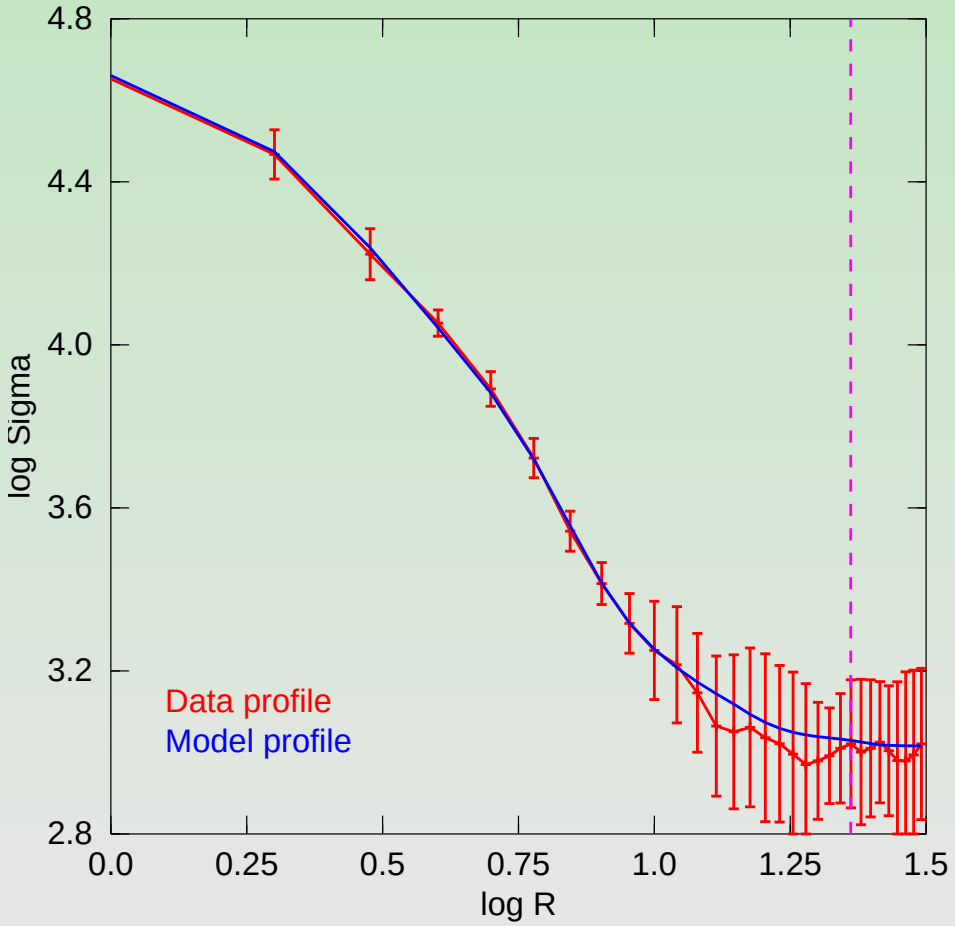


Why even bother?

- HST observations of GCs resolve them, so ignoring the structure can cause problems in the photometry.
- Other galaxies have far more clusters than the Milky Way, providing a order of magnitude increase in sample size.
- See if cluster structure is universal.
- Add observational constraints to cluster evolution.
- Look for structural sources for observed features (such as LMXBs).

Why use King (1966) models?

- Decent approximation for GC surface brightness
- Measured quantities reasonably well defined:
  - $r_c = \sqrt{9\sigma^2/4\pi G\rho_0}$
  - $\rho(r_t) = 0$
  - $c = \log_{10} \frac{r_t}{r_c}$



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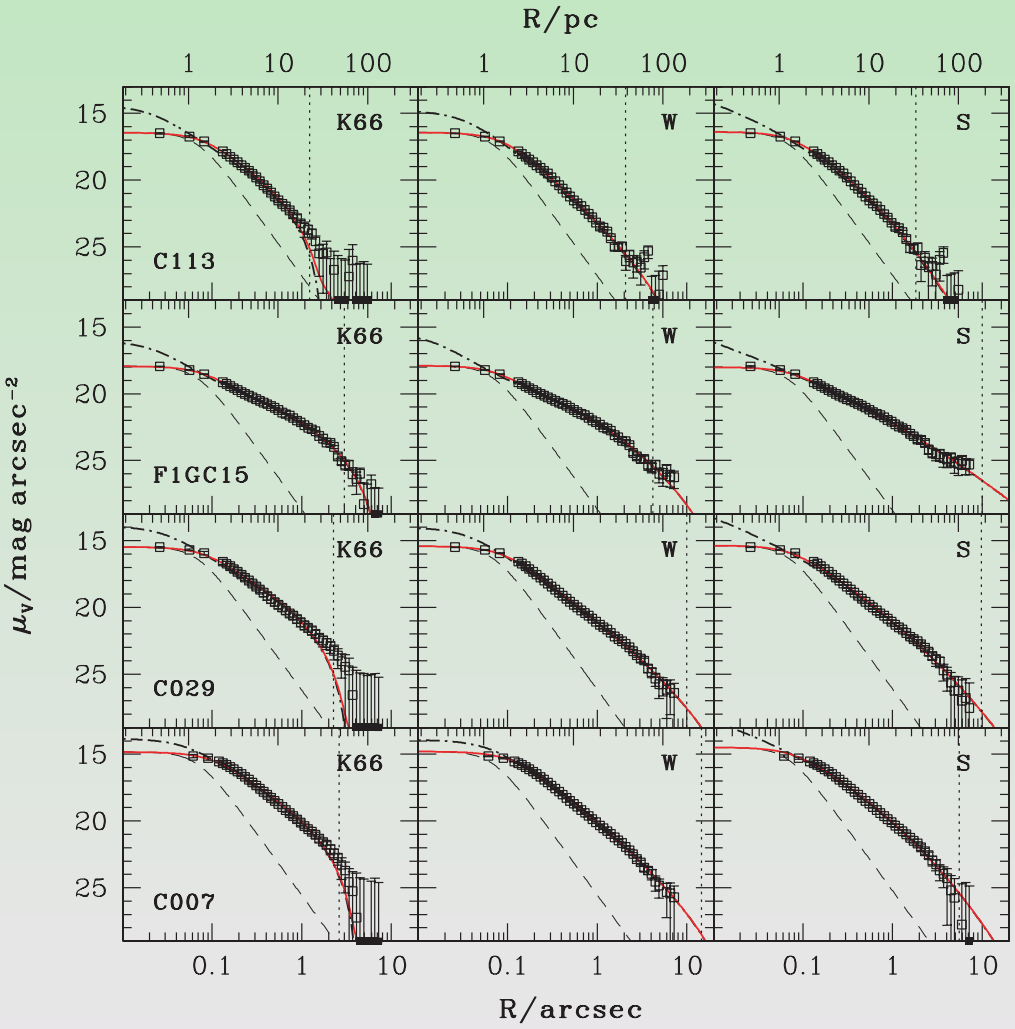

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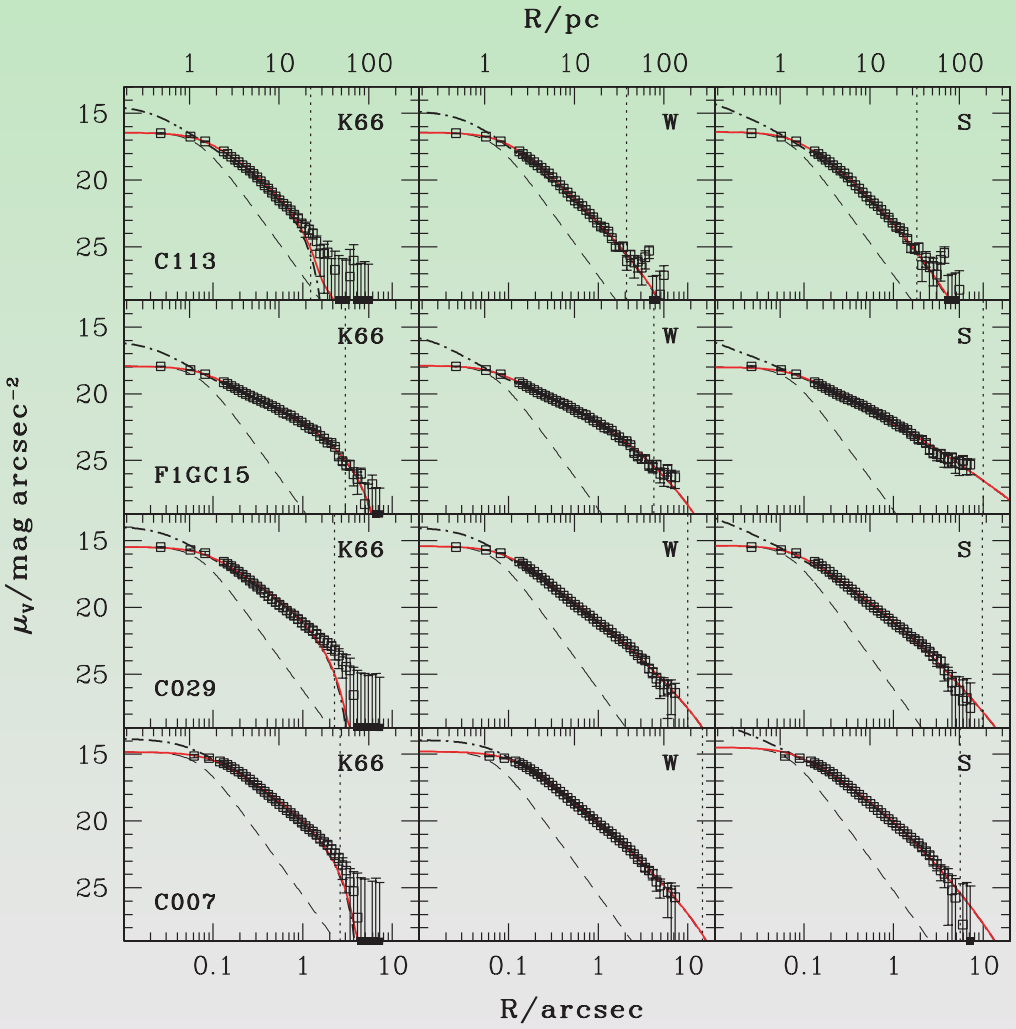
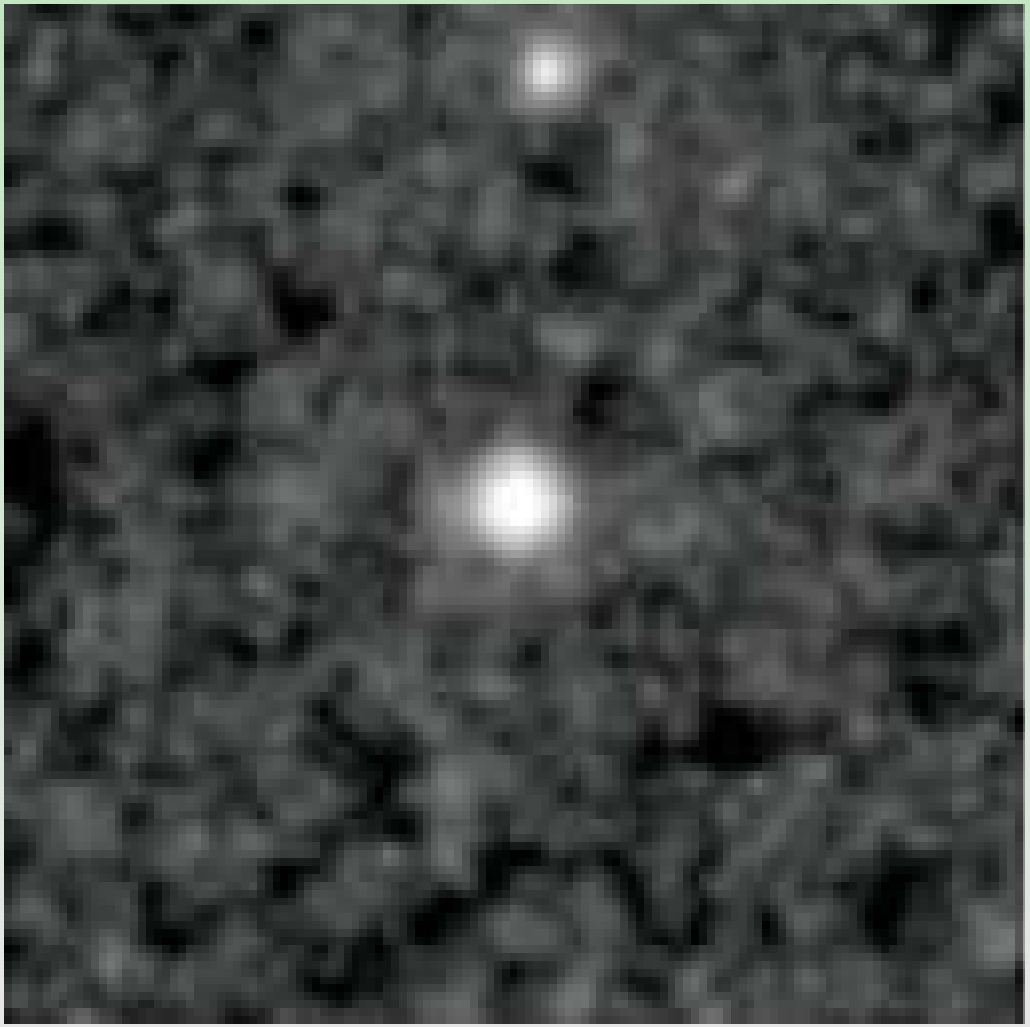
- More complicated models differ mainly in the noise.
- Used to fit MW clusters



How is the fitting done?

- Convolve 2D King model with PSF
- Calculate χ^2 value
- Repeat
- Find best fitting (c, r_t, x_0, y_0, F, B) to minimize χ^2
- 2089 total clusters
- 1579 with reliable fits



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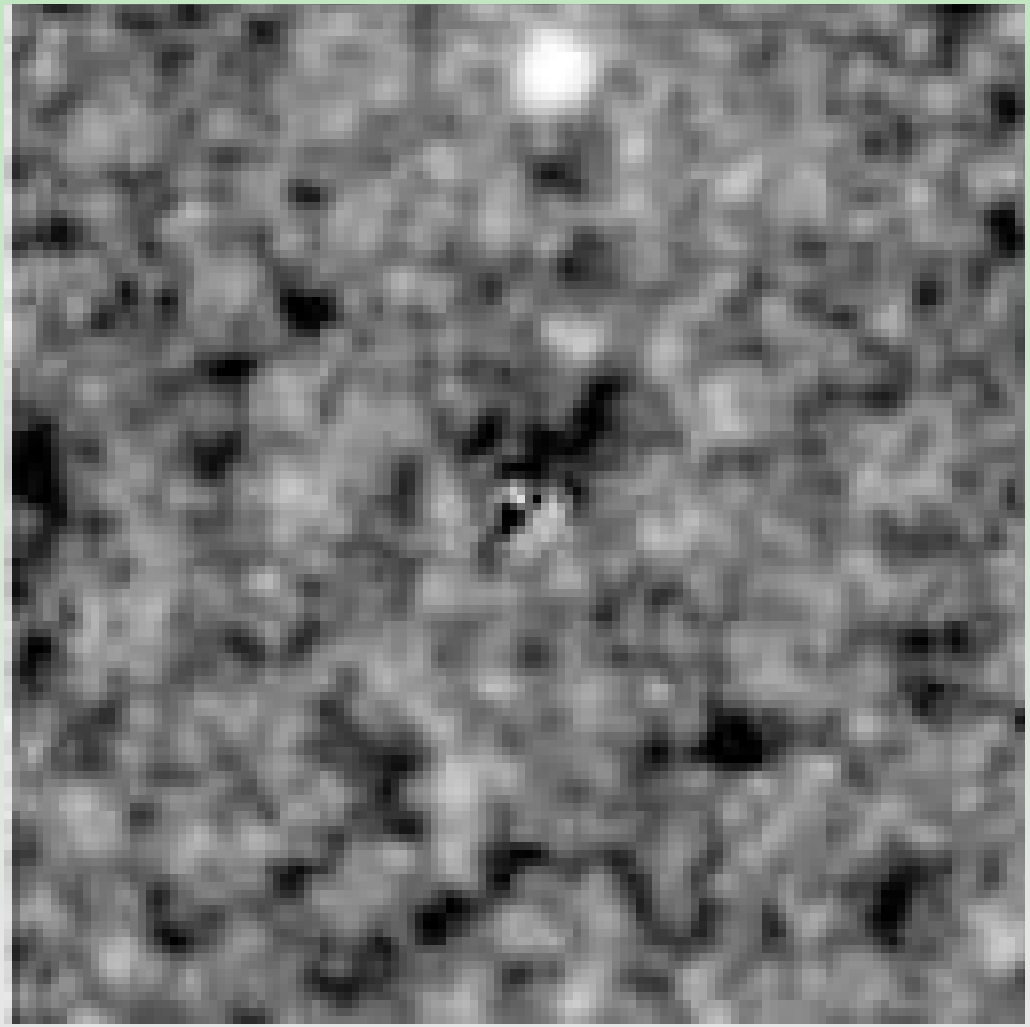

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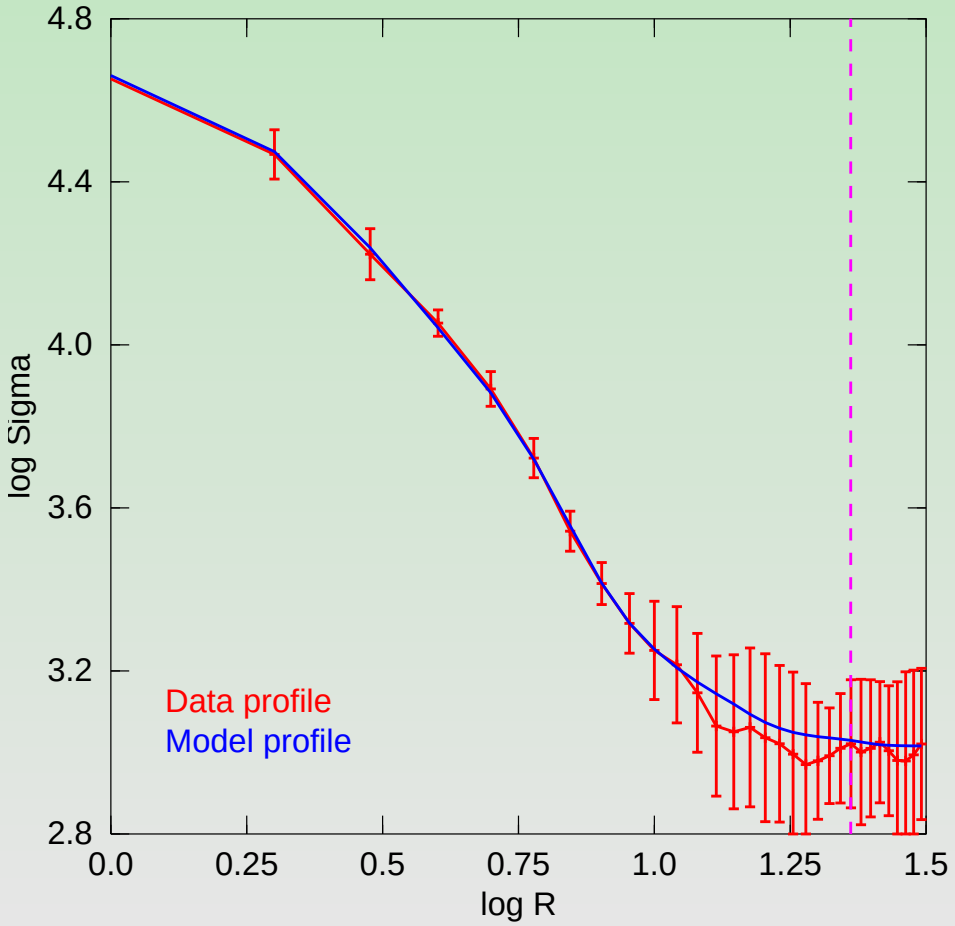
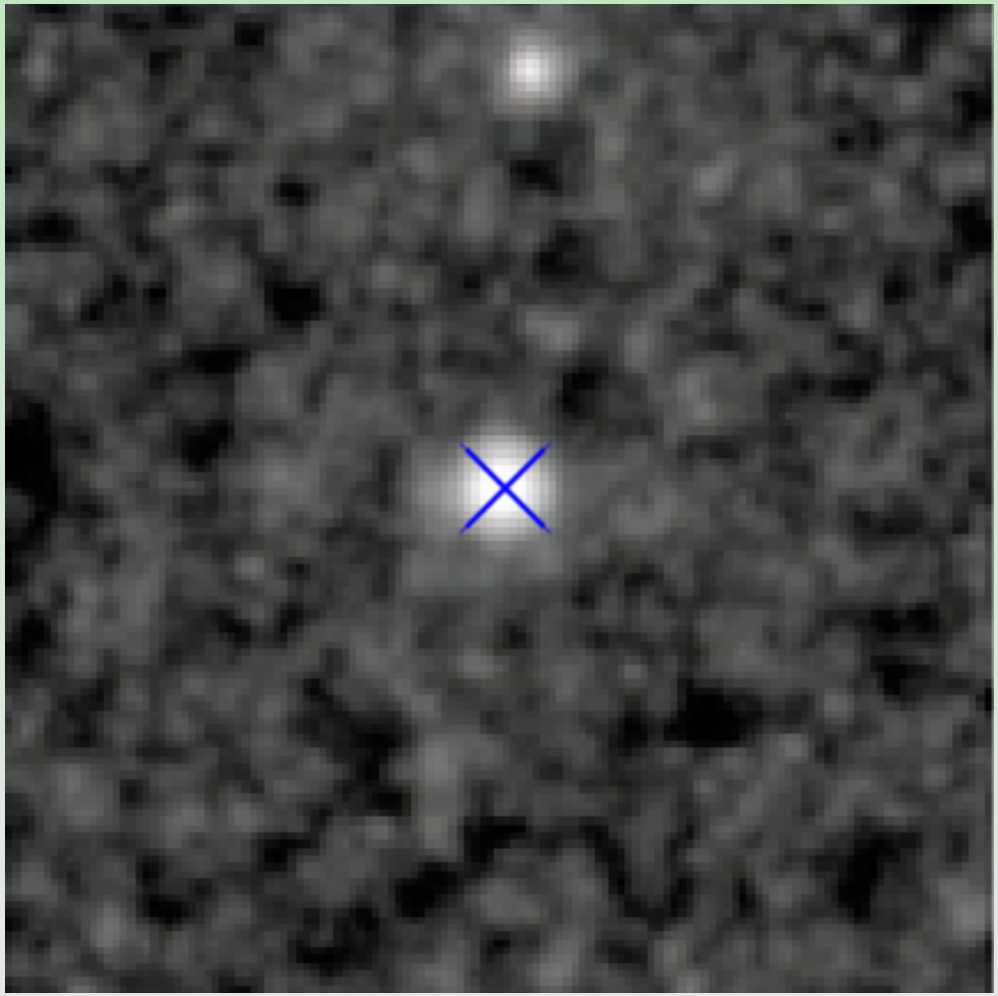


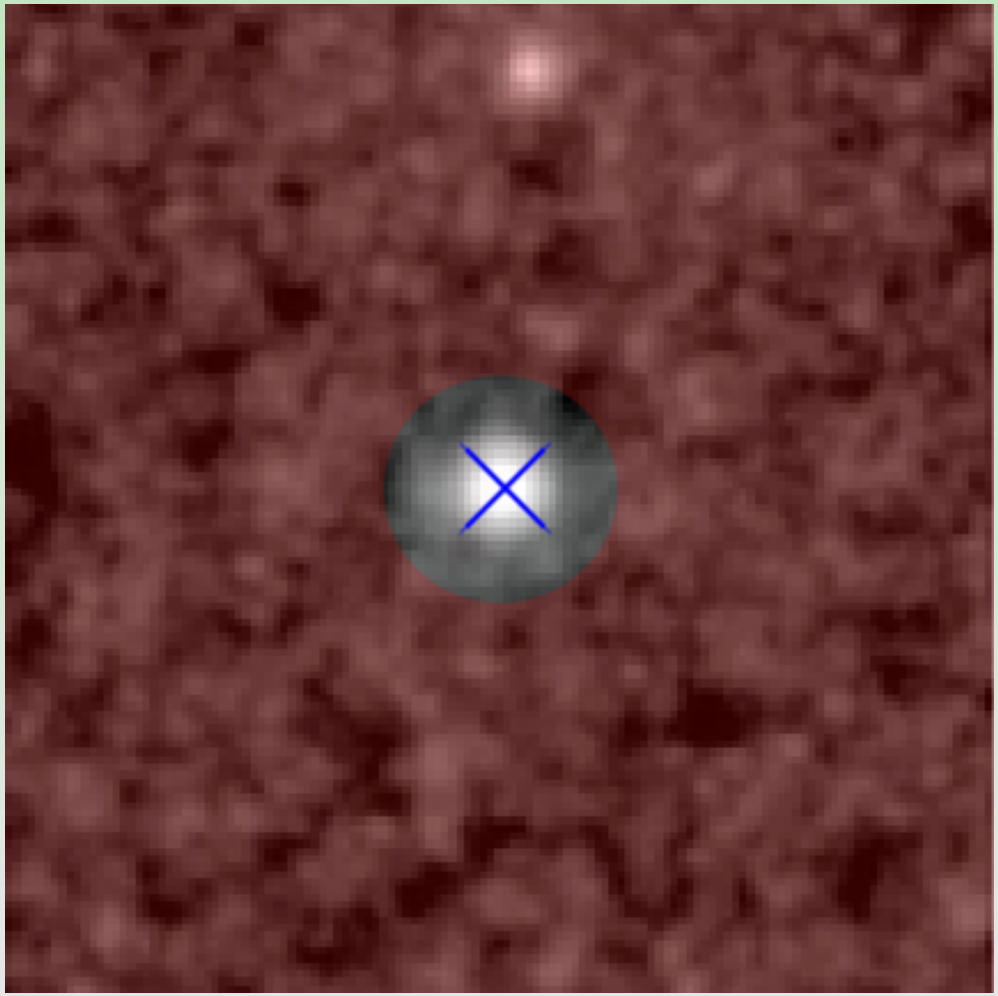
What really happens:

- Identify cluster center.



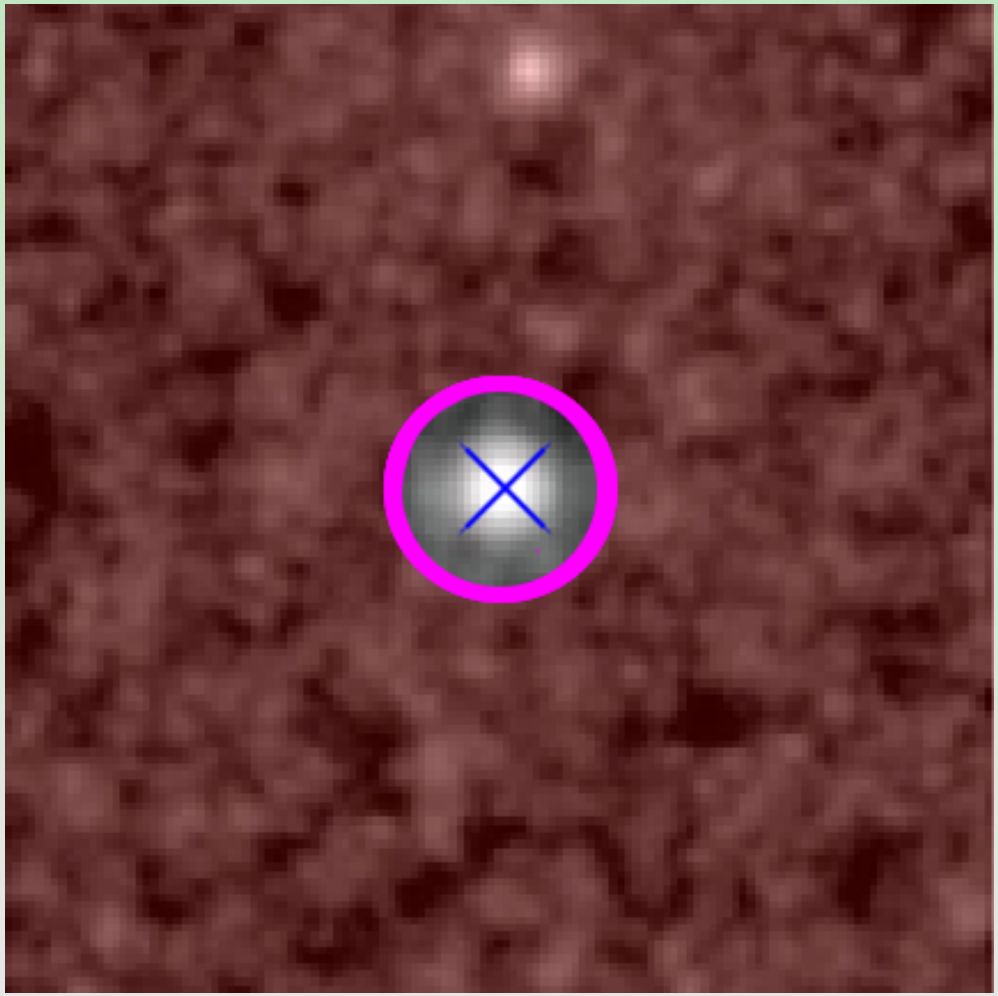
What really happens:

- Identify cluster center.
- Estimate B from background.
- Find the cluster F.



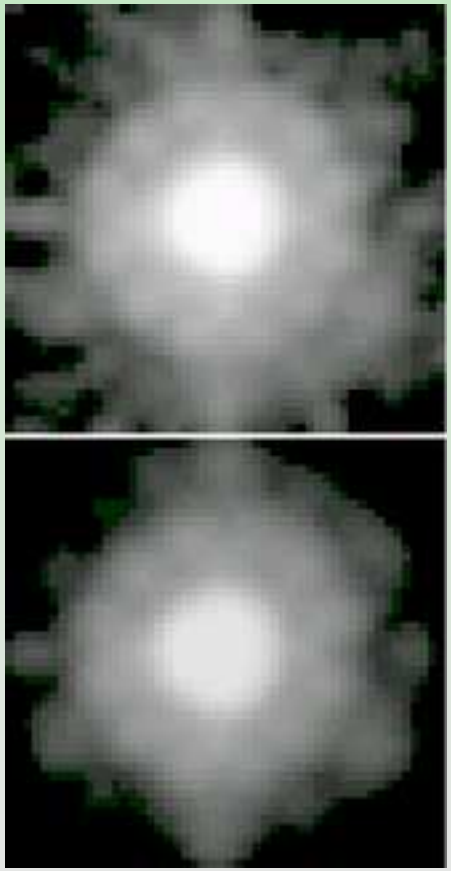
What really happens:

- Identify cluster center.
- Estimate B from background.
- Find the cluster F.
- B estimate fixes r_t.
- Given r_t, use cluster shape to constrain c.
- Repeat and converge.



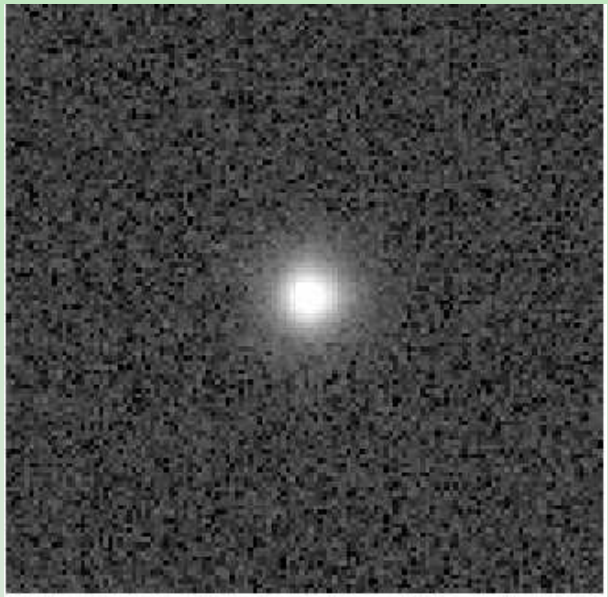
Complications:

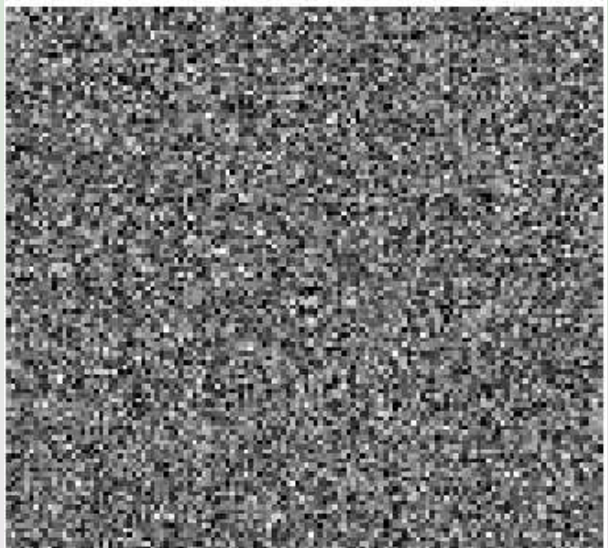
- Requires a very good PSF.
  - Use empirical Anderson & King (2006) PSF models
  - Combine in same way as data to ensure accuracy
  - Match the one unsaturated star well.
- Parameter space is degenerate, requiring care to avoid local minima.
- Carlson and Holtzman (2001) suggest $S/N \sim 500$ is required



Why should you trust the fits?

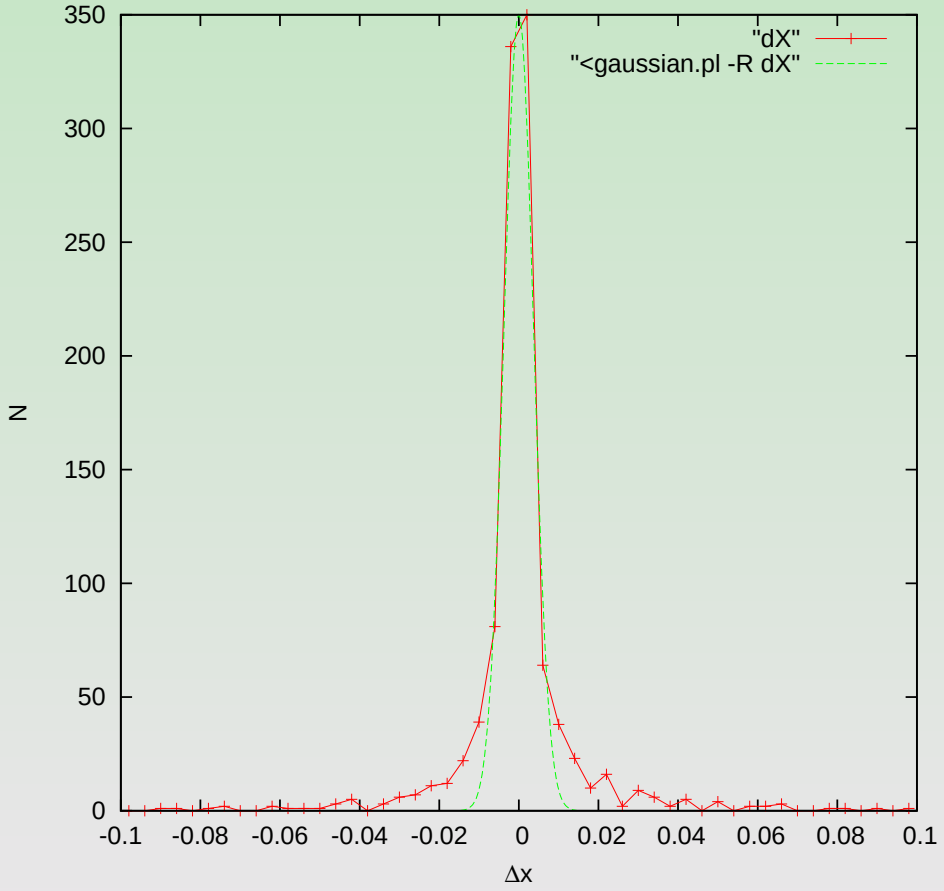
- Create simulated clusters
- Fit them using the code
- Determine the region of parameter space that can be believed.
  - Input: $W_0 = 9.2$, $R_t = 30$, $m = 20.166$
  - Output: $W_0 = 9.26$, $R_t = 30.25$, $m = 20.167$

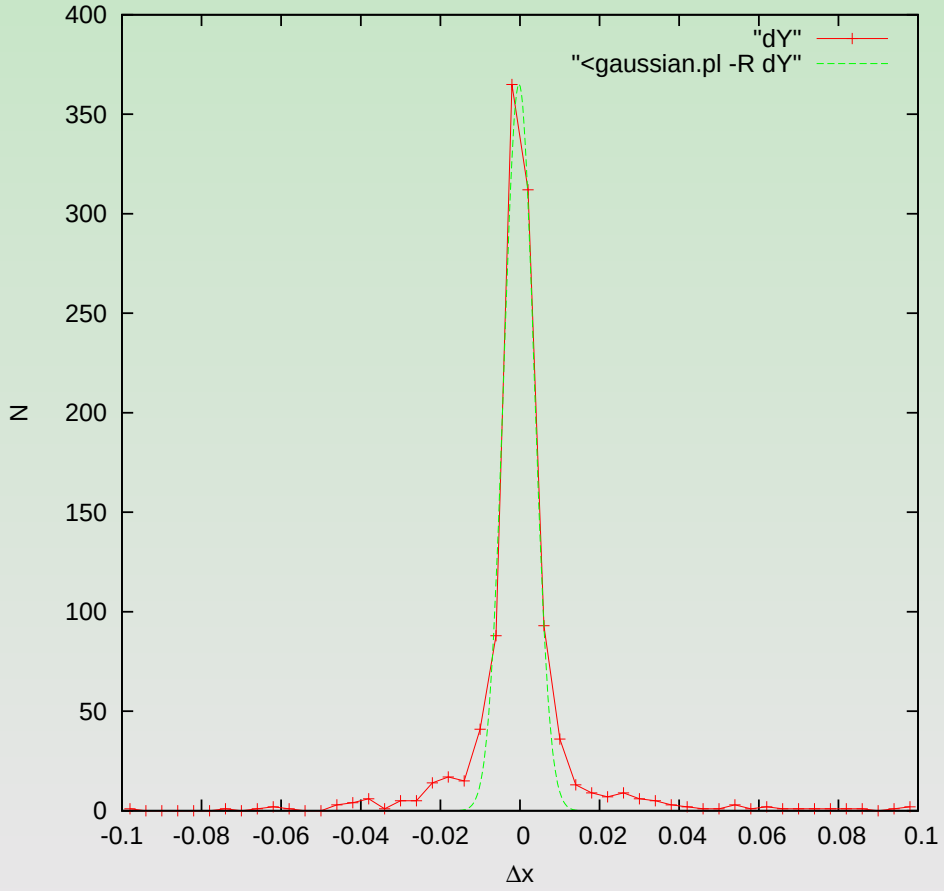




Position:

$$\Delta x \sim -1.38E-5 \pm 3.71E-3 \qquad \Delta y \sim -2.54E-4 \pm 3.79E-3$$

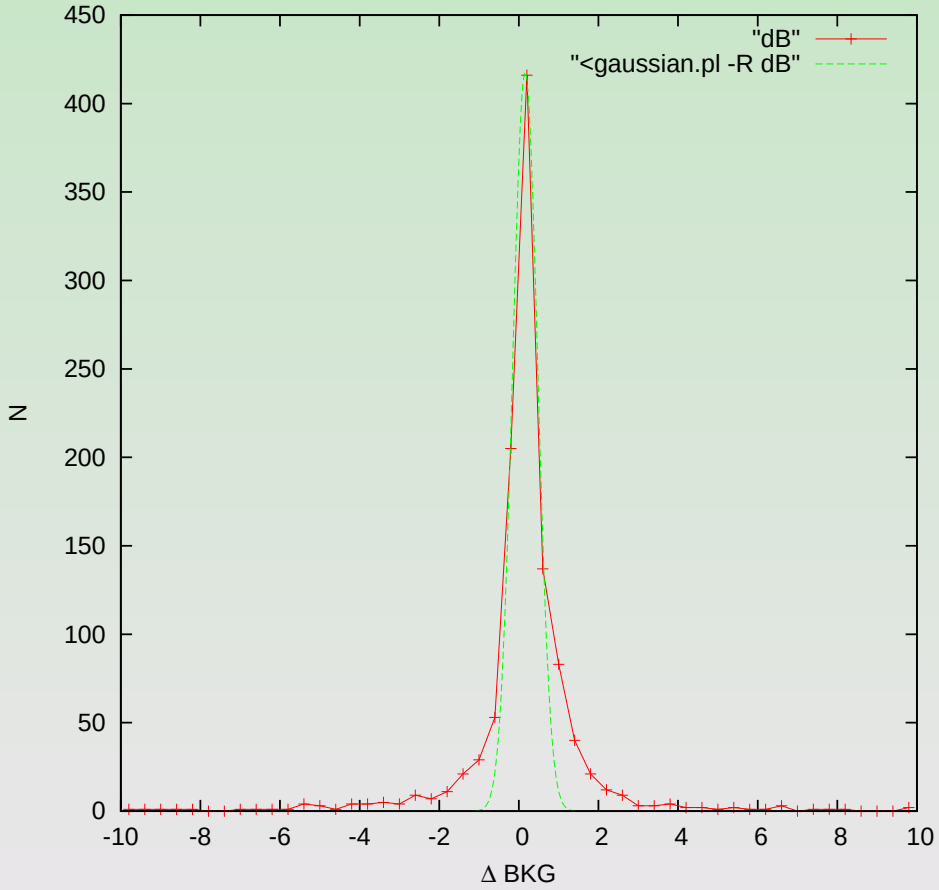


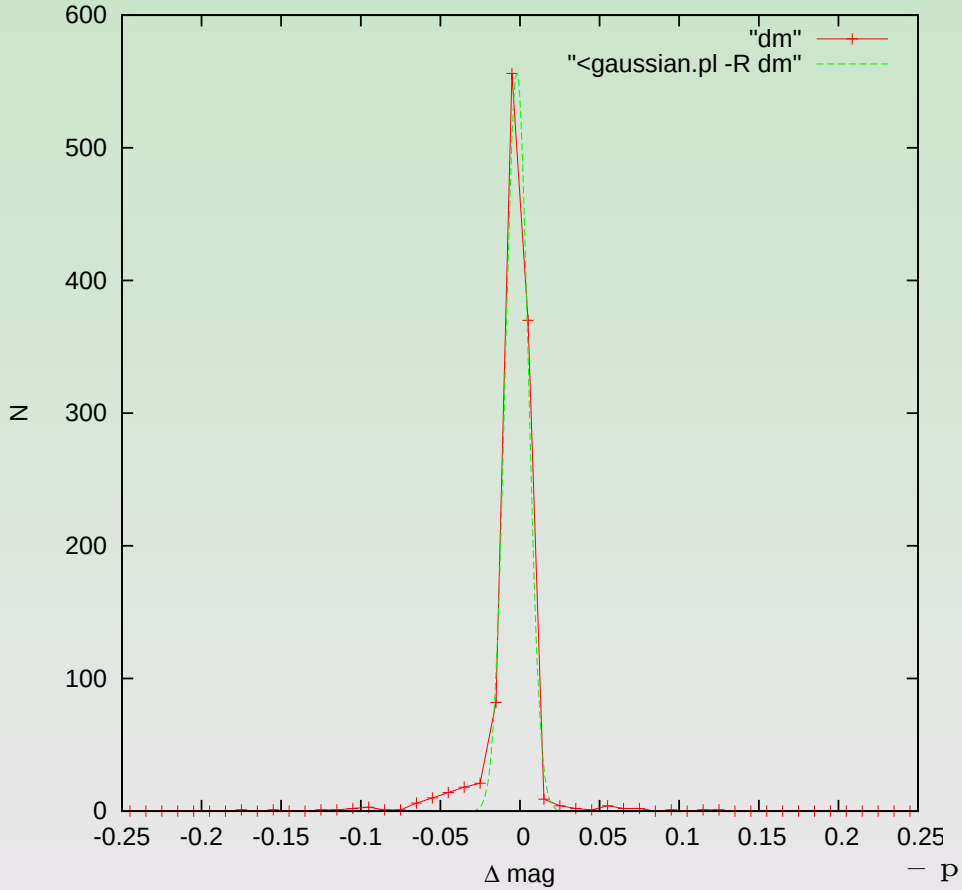


Photometry:

$\Delta B \sim 0.158 \pm 0.313$

$\Delta m \sim -0.002 \pm 0.007$
Constraint: $m < 25$, consistant with Carlson & Holtzman (2001)



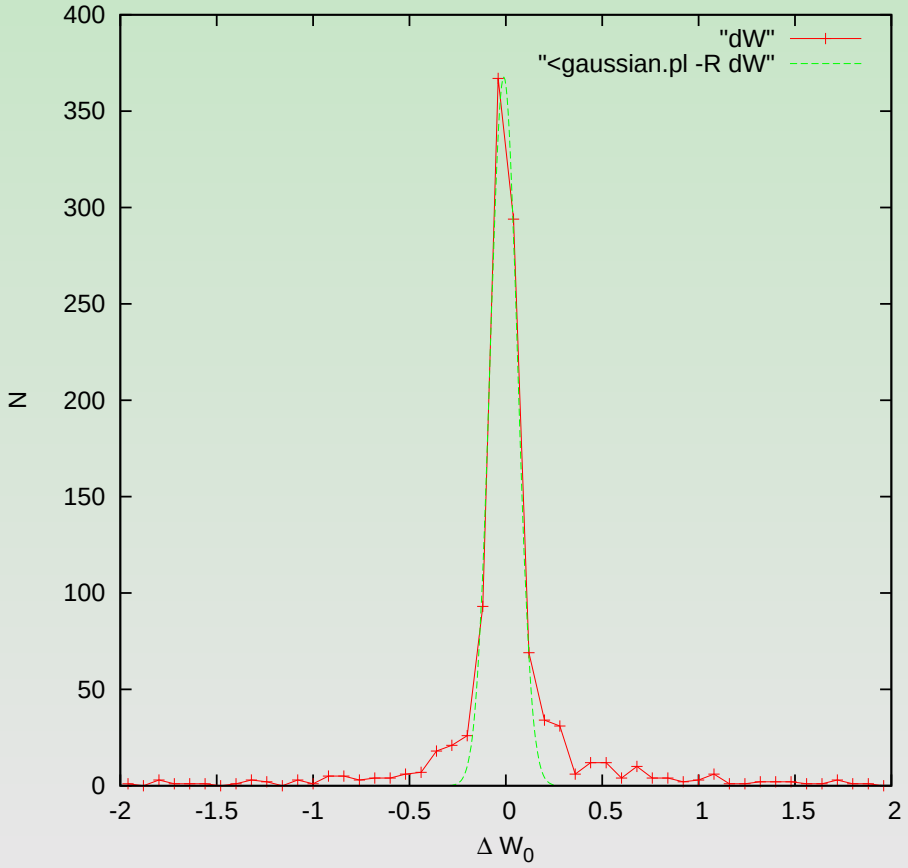


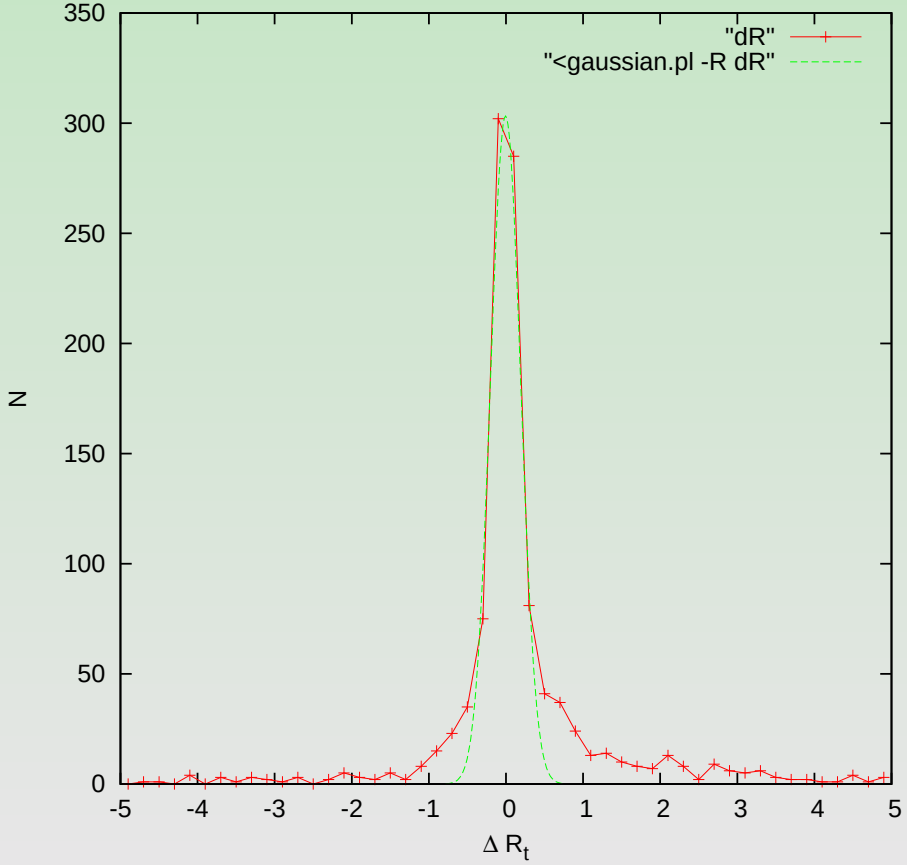
Structure:

$\Delta W_0 \sim -0.011 \pm 0.071$

$\Delta R_t \sim -0.005 \pm 0.195$

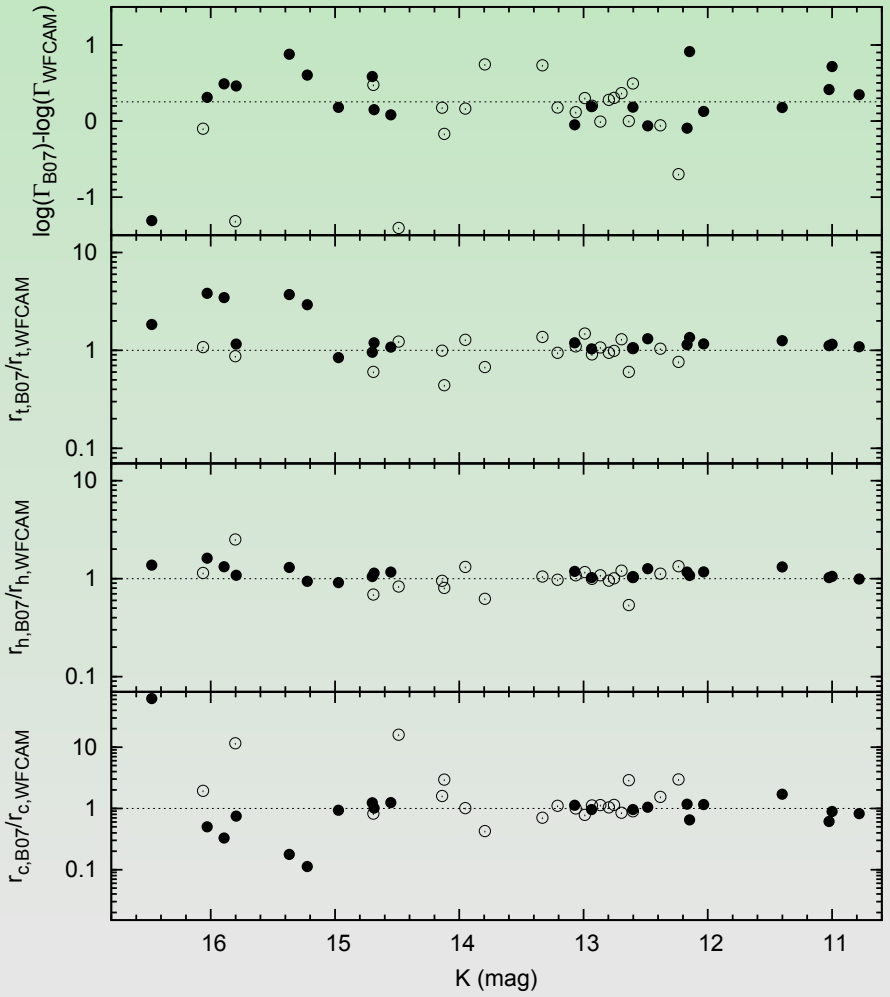
Constraint: $R_t > 5pxl$, $R_t < 0.5 R_{Image}$





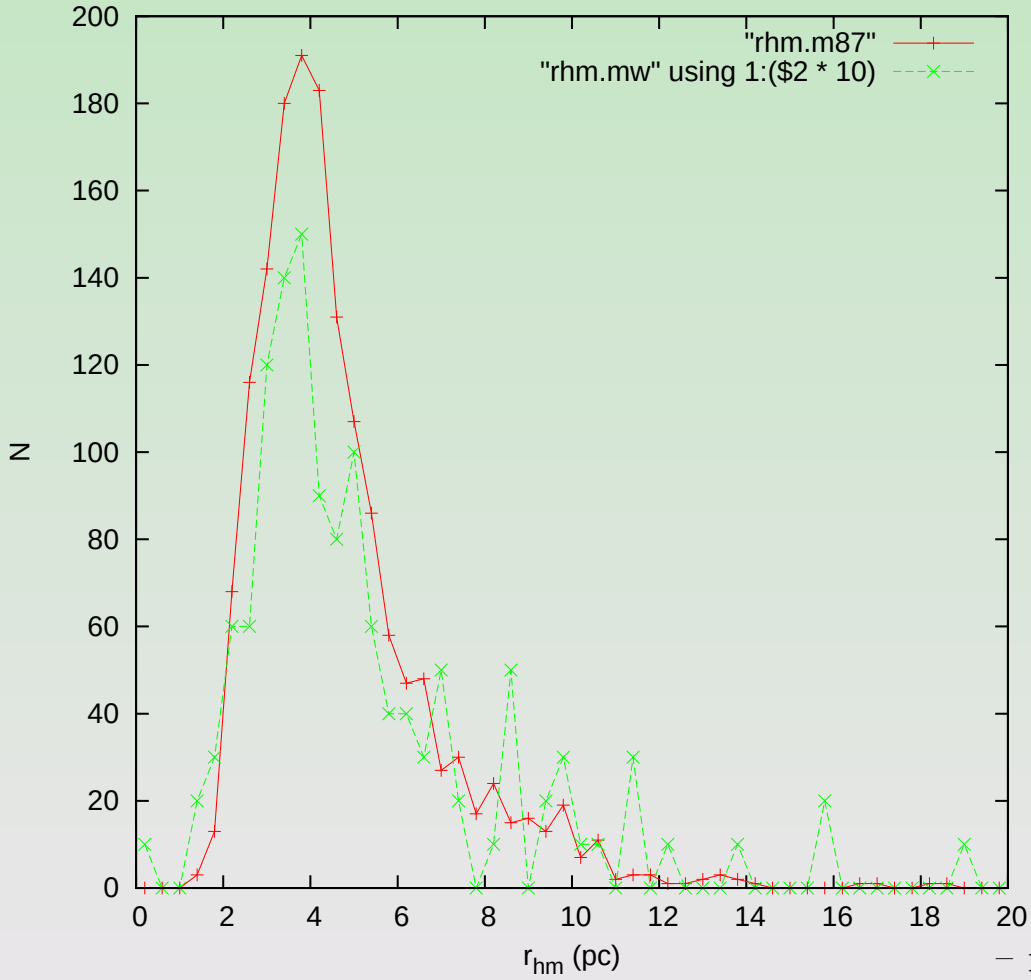
But that's just a simulation:

- Find other data sets with reliable measurements, and compare.
- Peacock et al. (2009) compares 33 M31 clusters (WFCAM) to Barmby et al (2002, 2007) fits (HST)
- Good agreement above $K \sim 15$, consistent with the S/N requirement.



Compare to Milky Way

- Look at distributions and parameter trends:
  - r_{hm}



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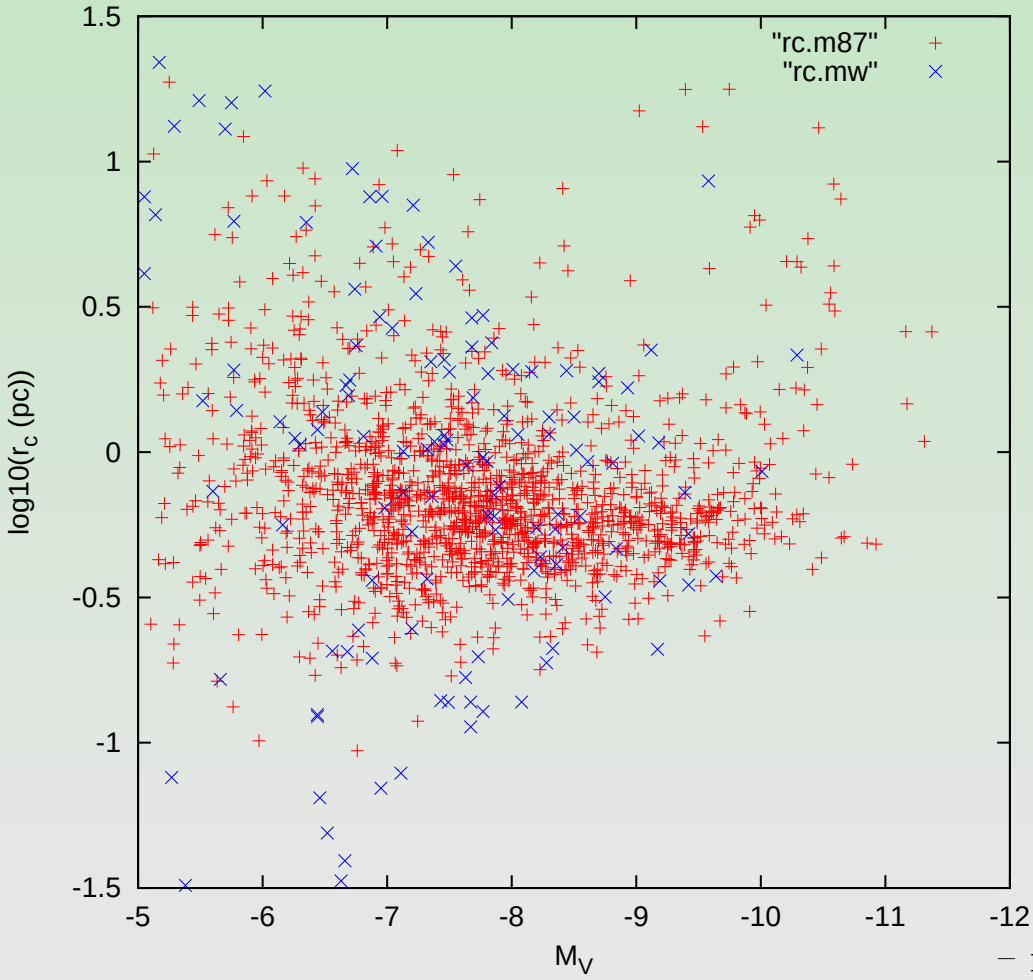

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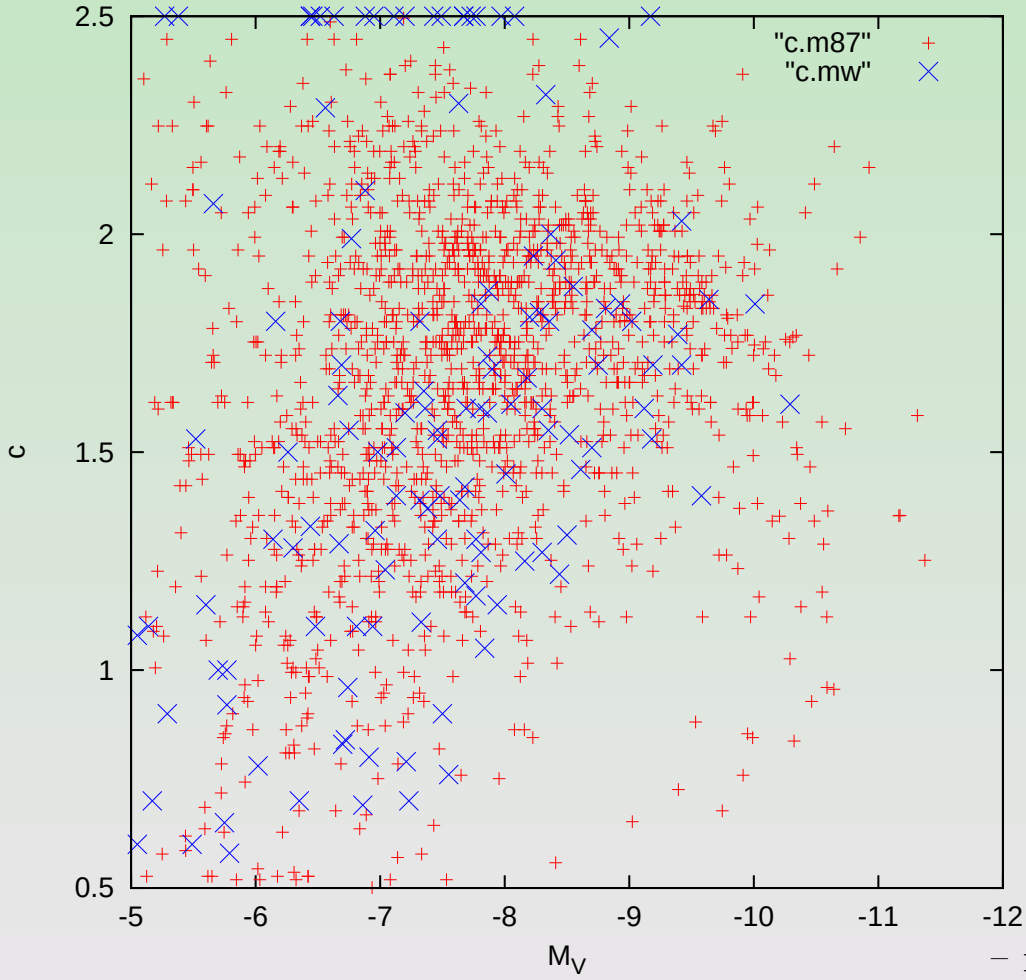

Any chance of seeing tidal effects?

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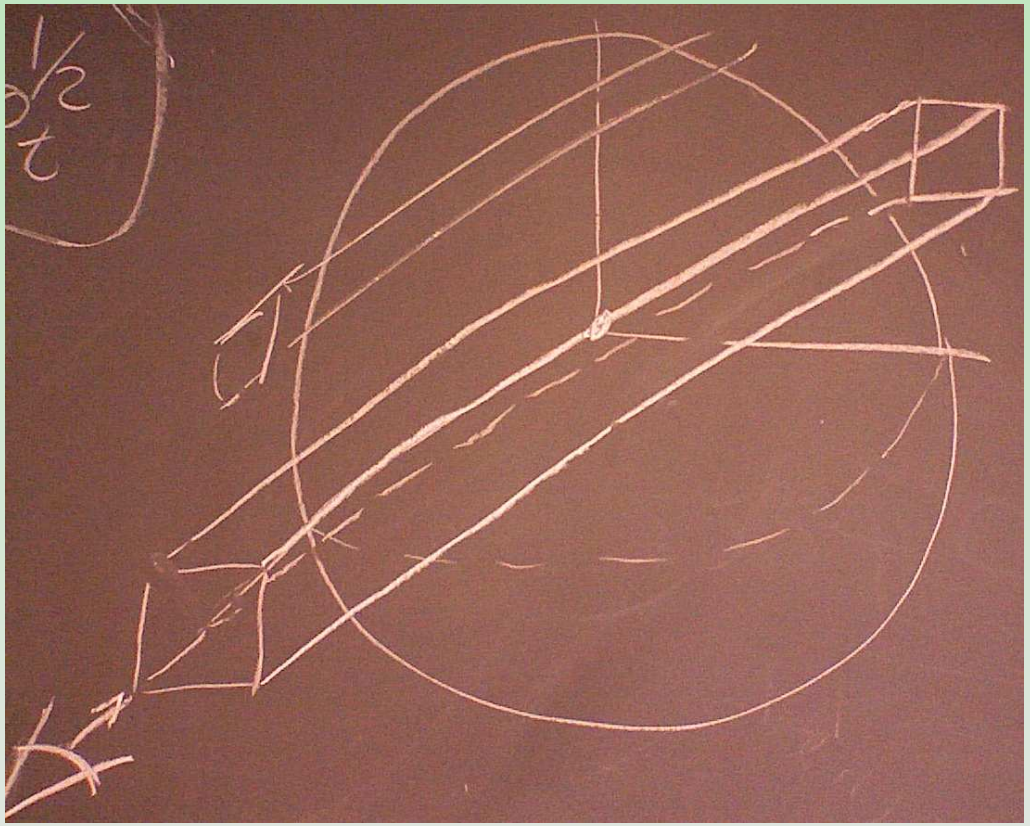
- Radius between galaxy and cluster is along line of sight.
- Projection also limits ability to investigate radial dependences.



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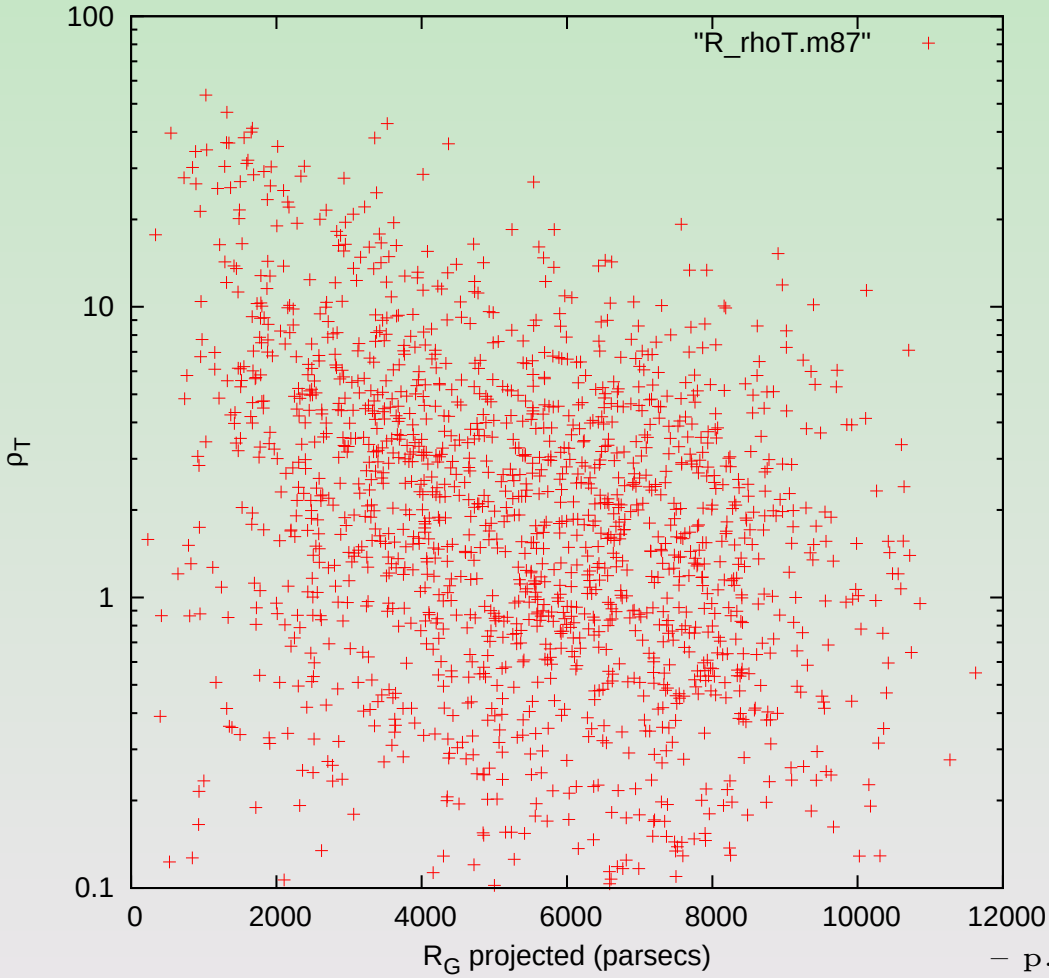
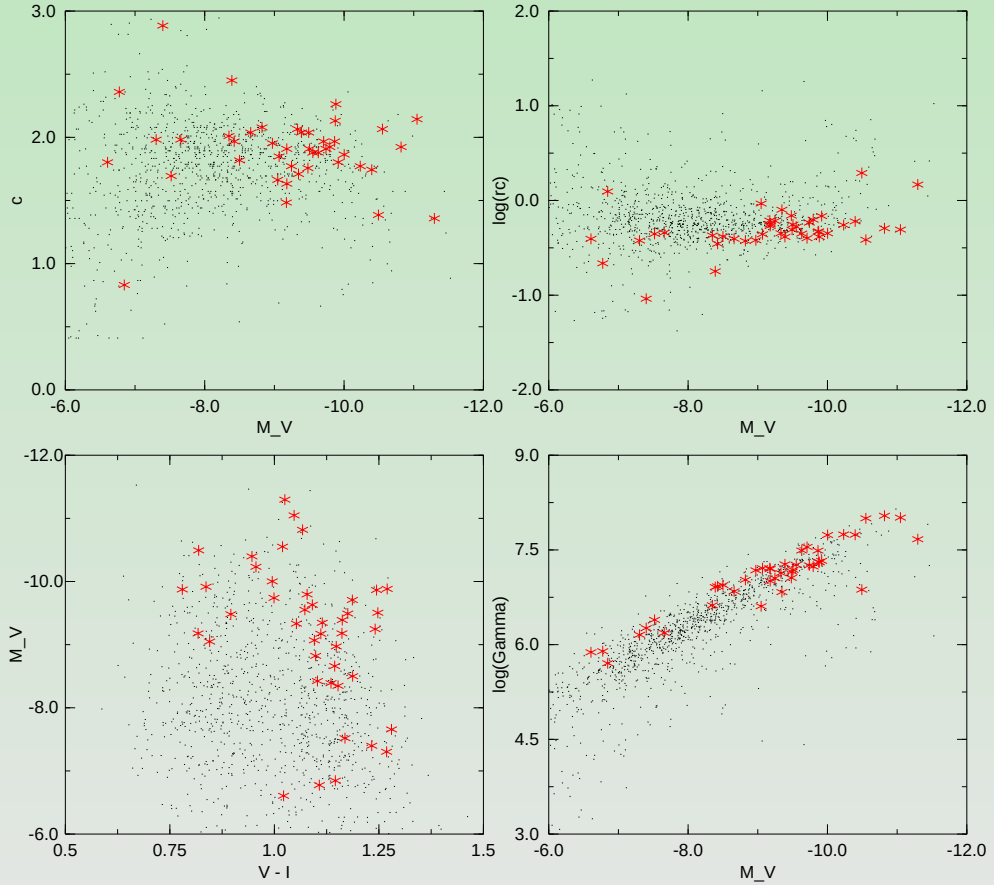
- Density does drop with increasing radius.



What about LMXBs?

- Does $\Gamma \sim \rho_0^{1.5} r_c^2$ predict better than mass?



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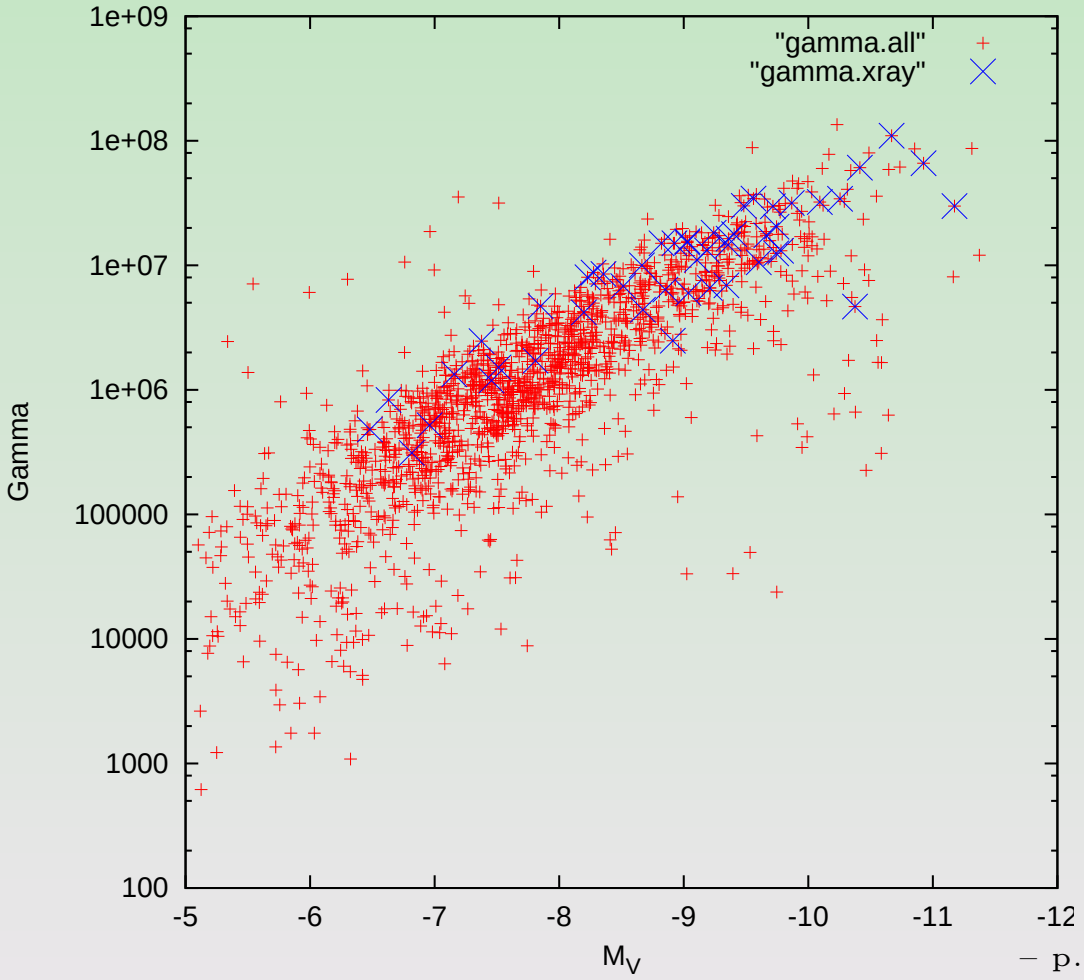

What about LMXBs?

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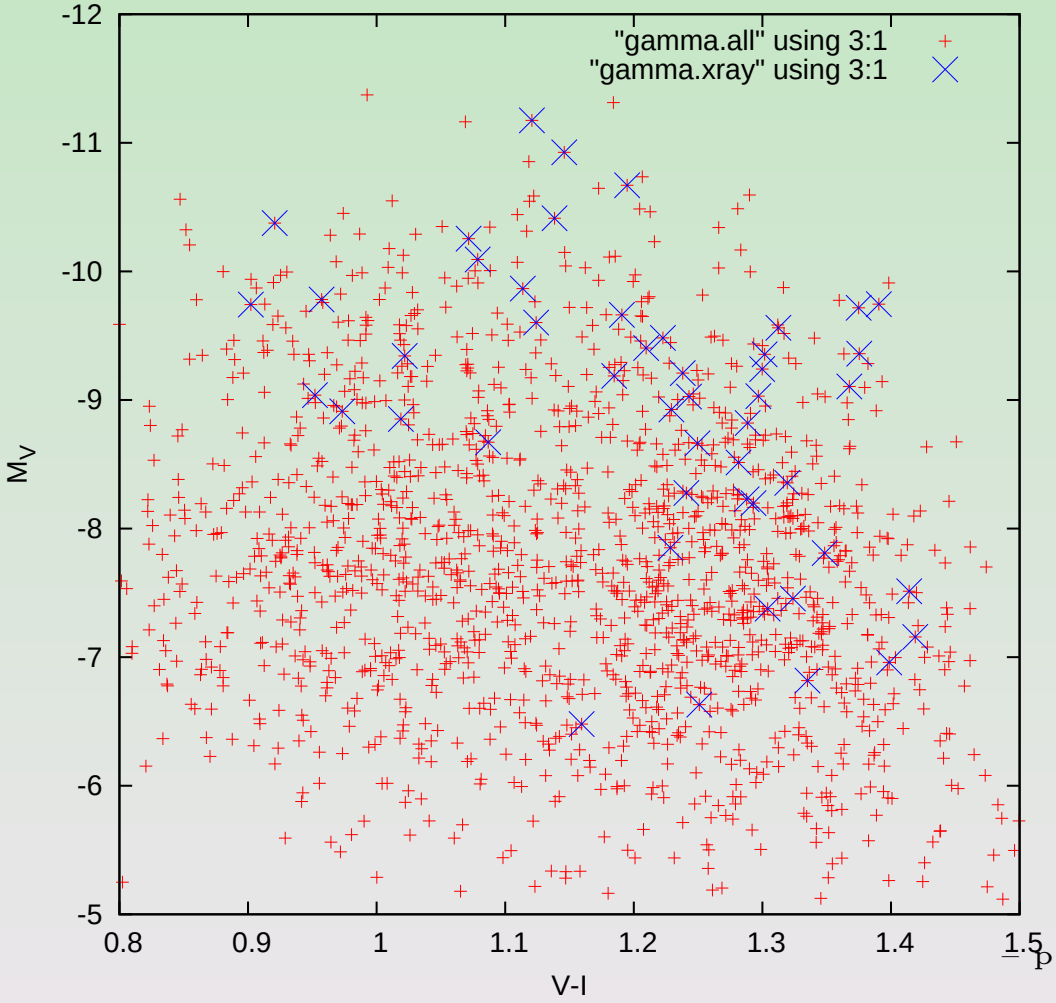
- Possibly just color dependence?



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  - Yes.
  - Assuming all clusters are spherical, and have King (1966) profiles.
  - In any case, they're consistent with what has been measured before.
  - Appear that structure trends are largely universal.