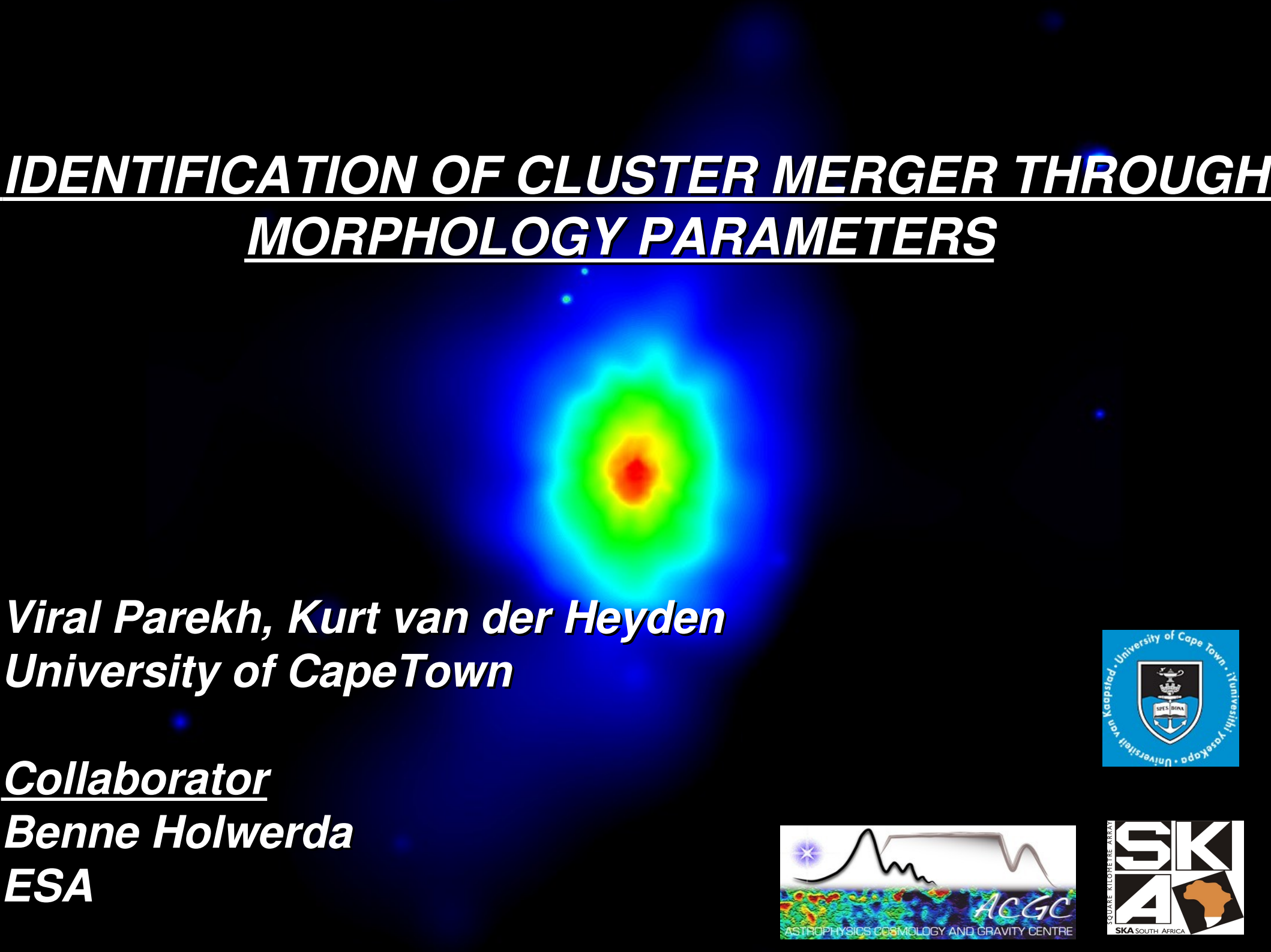
IDENTIFICATION OF CLUSTER MERGER THROUGH MORPHOLOGY PARAMETERS



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Collaborator
Benne Holwerda
ESA

In this talk....

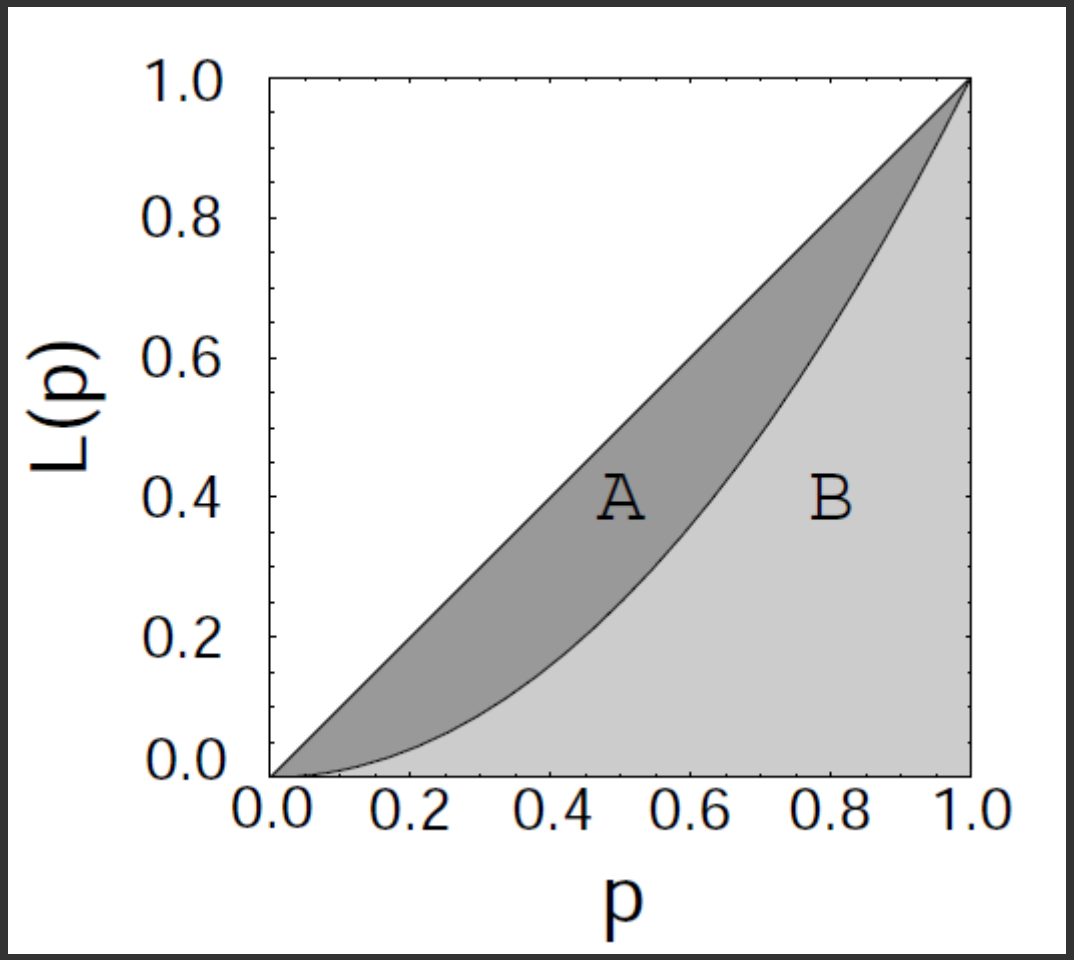
- Brief Introduction
- Morphology parameter results
  - 2D Beta profile simulation
  - Hydro dynamic simulation
  - Chandra Observation
- Future work

Introduction

- *X-ray Cluster morphology according to Jones and Forman (1992)*
- *Identification of cluster merger*
- *Existing techniques*
- *Morphology parameters- Gini, M_{20}, Concentration,*

  Asymmetry, Smoothness, Gini 2nd order and Ellipticity

1, Gini and Gini 2nd order moment (Abraham et al.2003, Lotz et al. 2004)



$$G = \frac{1}{|\bar{X}|n(n-1)} \sum_{i}^{n} (2i - n - 1)|X_i|.$$

X_i=i^{th} pixel at X

n=total number of pixels

$\bar{X}$=mean pixel value

2, M_{20} and Ellipticity parameters

$$M_{\rm tot} = \sum_i^n M_i = \sum_i^n f_i\left[(x_i - x_c)^2 + (y_i - y_c)^2\right]$$

$$M_{20} \equiv \log 10\left(\frac{\sum_i M_i}{M_{\rm tot}}\right), \text{ while } \sum_i f_i < 0.2 f_{\rm tot}$$

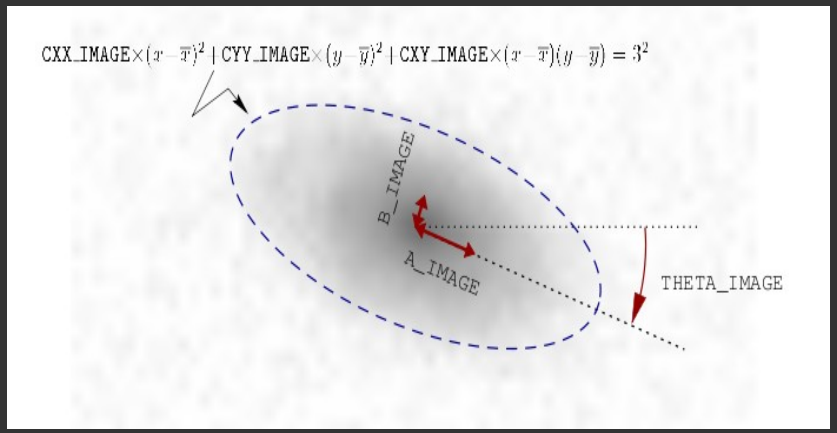
(Lotz et al. 2004)

$$\mathrm{A}^2 = \frac{\overline{x^2}+\overline{y^2}}{2} + \sqrt{\left(\frac{\overline{x^2}-\overline{y^2}}{2}\right)^2 + \overline{xy}^2},$$

$$\mathrm{B}^2 = \frac{\overline{x^2}+\overline{y^2}}{2} - \sqrt{\left(\frac{\overline{x^2}-\overline{y^2}}{2}\right)^2 + \overline{xy}^2}.$$

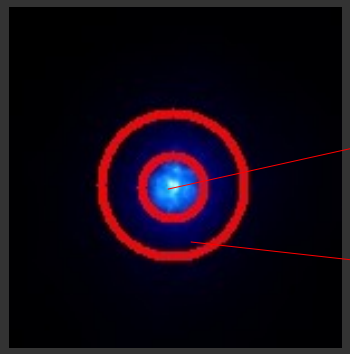
Ellipticity=1-B/A

(Stobie 1980,1986)



3,CAS parameters (Bershady et al. 2000 ,Conselice, 2003)

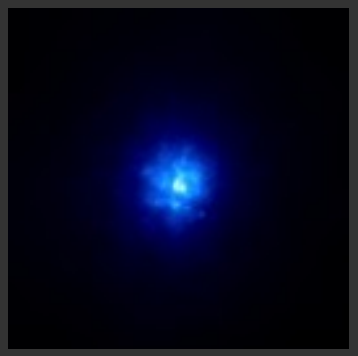
$$C = 5 \log\left(\frac{r_{80}}{r_{20}}\right)$$

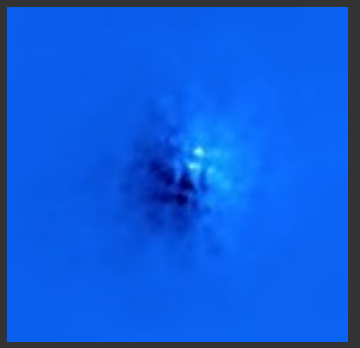


$$A = \frac{\sum_{i,j} |I(i,j) - I_{180}(i,j)|}{\sum_{i,j} |I(i,j)|} - B_{180}$$

A=abs(I-R)/I

I


R


abs(I-R)

$$S = \frac{\sum_{i,j} |I(i,j) - I_S(i,j)|}{\sum_{i,j} |I(i,j)|} - B_S$$

S=(I-B)/I

I

B

I-B

Beta model X-ray clusters simulation

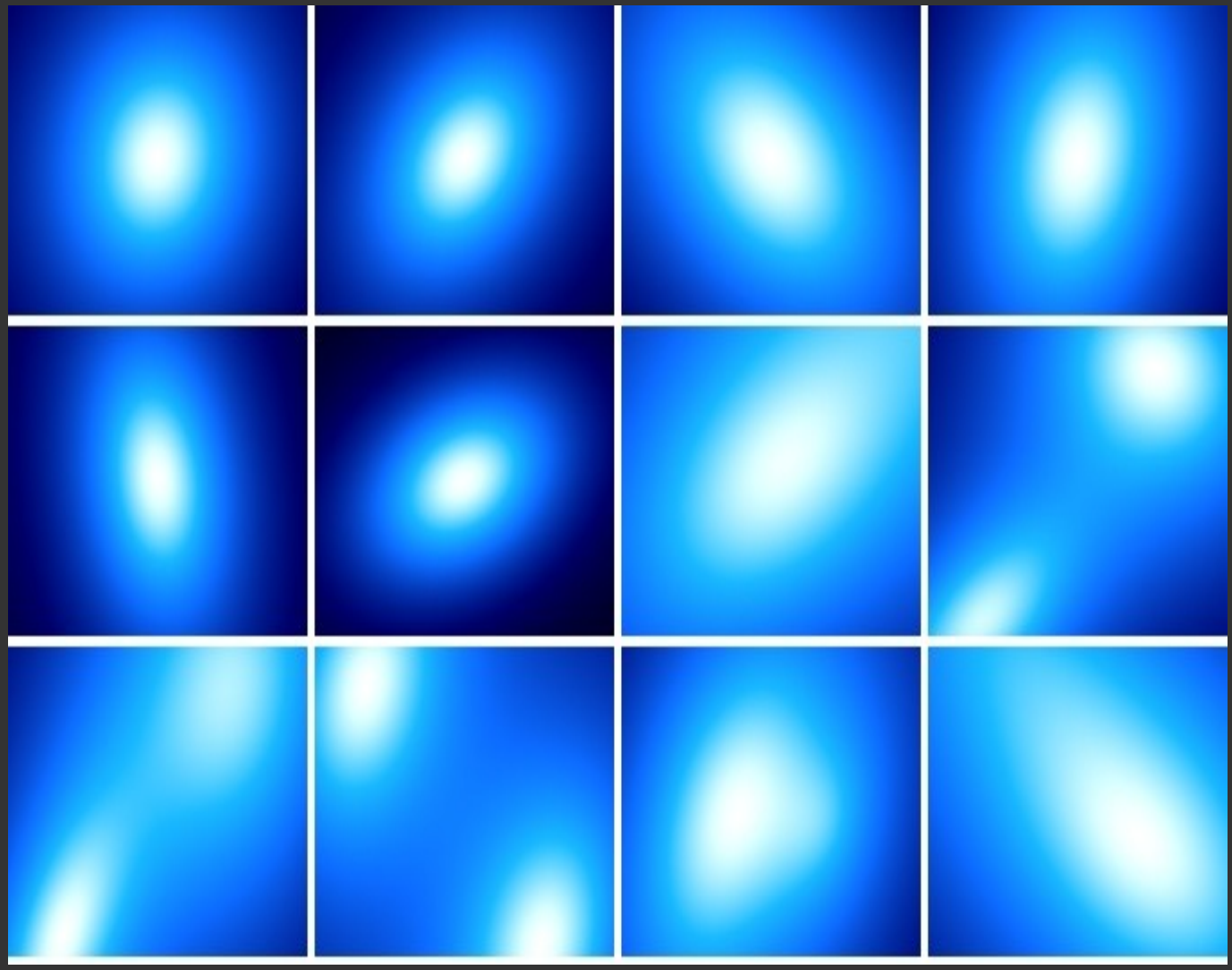
$$f(x,y) = f(r) = A \times (1 + (r / r_0)^2)^{-\beta}$$

Where A = Amplitude of flux

r_0 = core radius

β = power law index

Z=0.1, 1.85 kpc/”, pixel size=2.5”



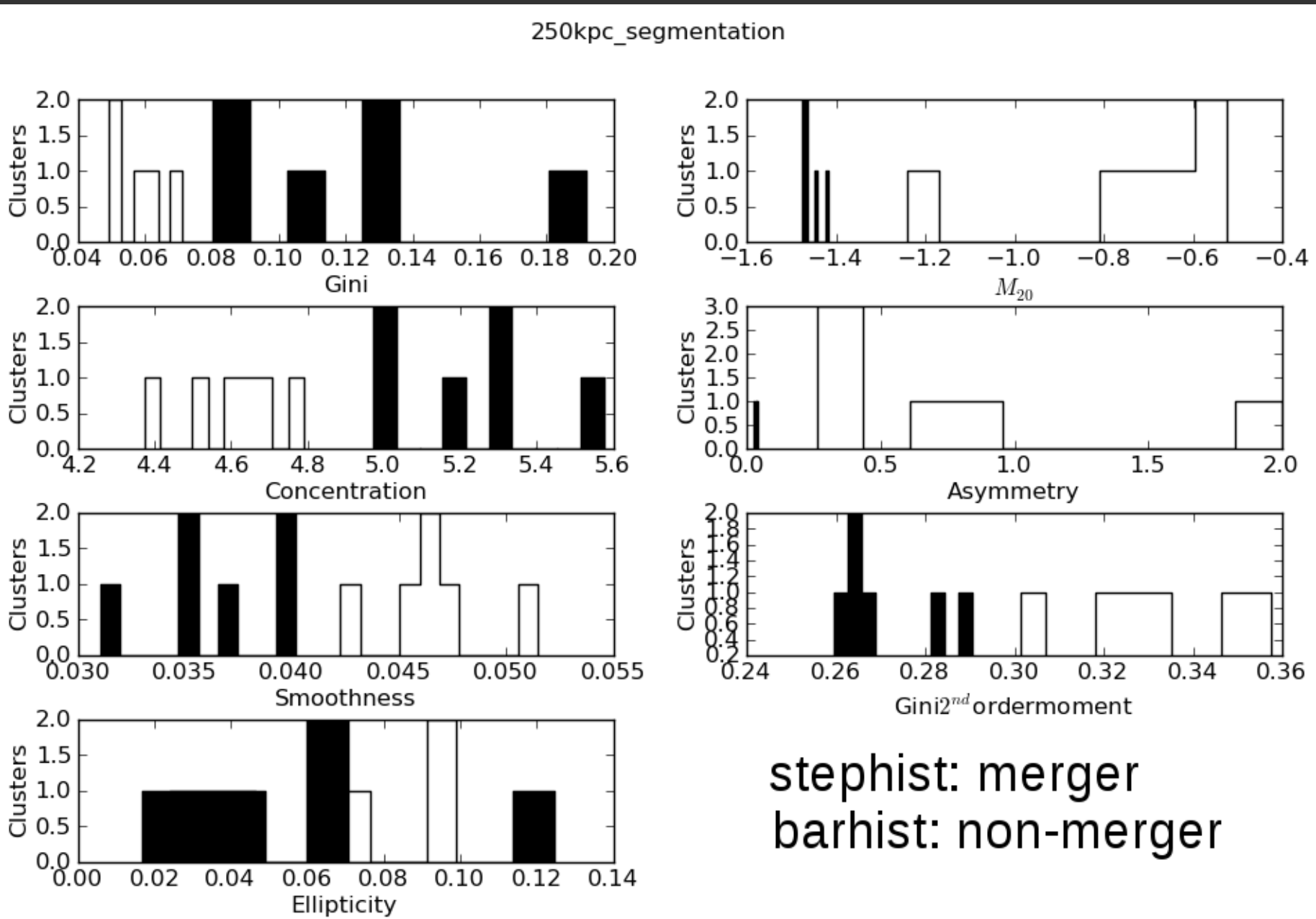
- **Barycenter of image**

$$X = \frac{\sum I_i x_i}{\sum I_i} \qquad Y = \frac{\sum I_i y_i}{\sum I_i}$$

Where X,Y are Center of image

I_i is pixel value at i^{th} pixel

x_i ,y_i are pixel position


250kpc_segmentation
Clusters
Gini
Concentration
Smoothness
Ellipticity
M_{20}
Asymmetry
Gini2ndordermoment
stephist: merger
barhist: non-merger

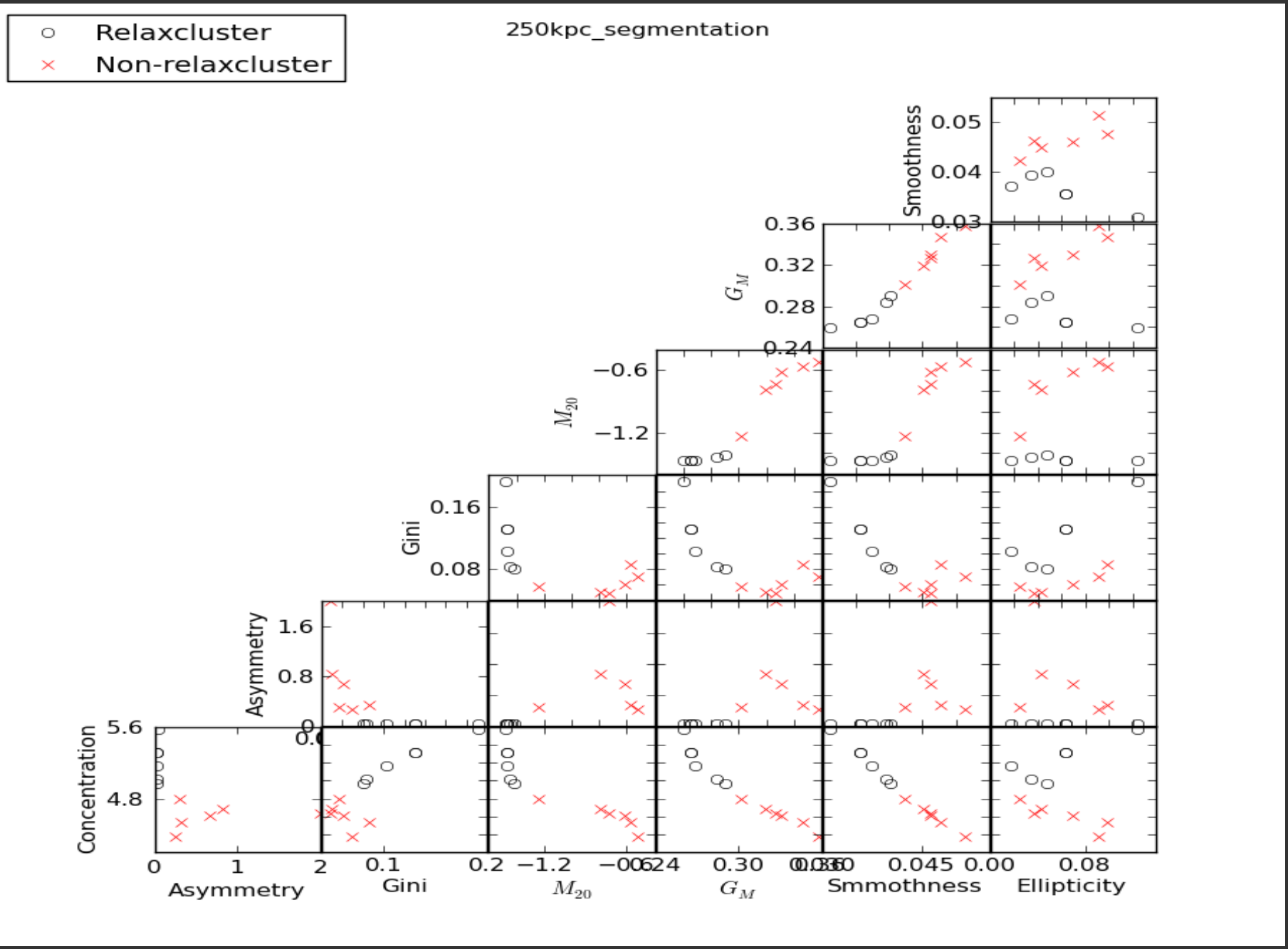

Relaxcluster
Non-relaxcluster
250kpc_segmentation
Concentration
Asymmetry
Gini
M_{20}
G_M
Smoothness
Ellipticity
5.6
4.8
1.6
0.8
0.16
0.08
−0.6
−1.2
0.36
0.32
0.28
0.24
0.05
0.04
0.03
0
1
2
0.1
0.2
−1.2
0.30
0.045
0.00
0.08

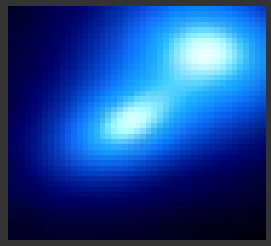
Image effects

- Effect of noise
- Effect of rebinning
- Effect of ccd gap
- Effect of point sources

S/N=0.1,bin=3

S/N=3,bin=5

S/N=11,bin=10

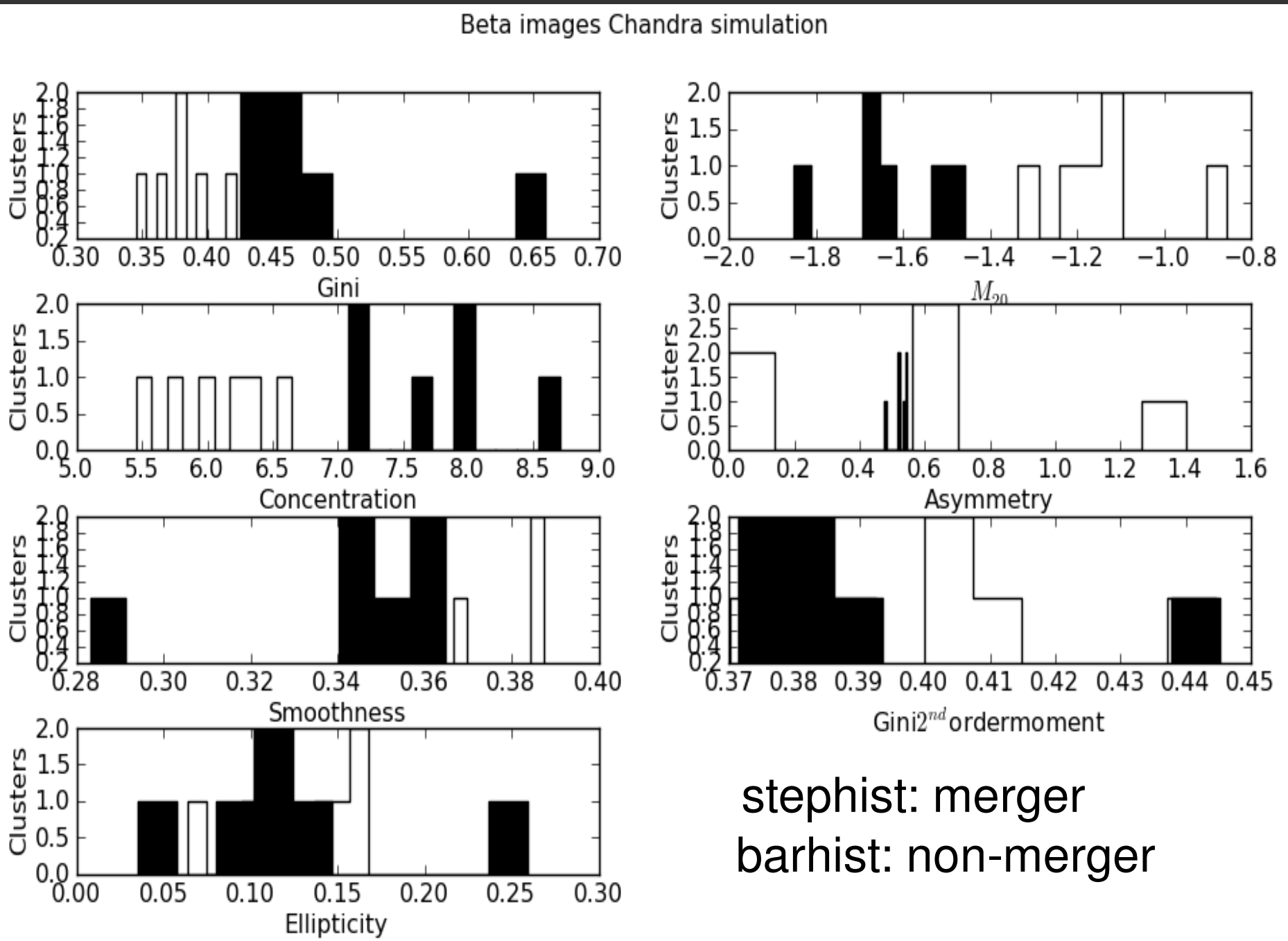


Marx Chandra X-ray telescope simulation

Simulation parameters

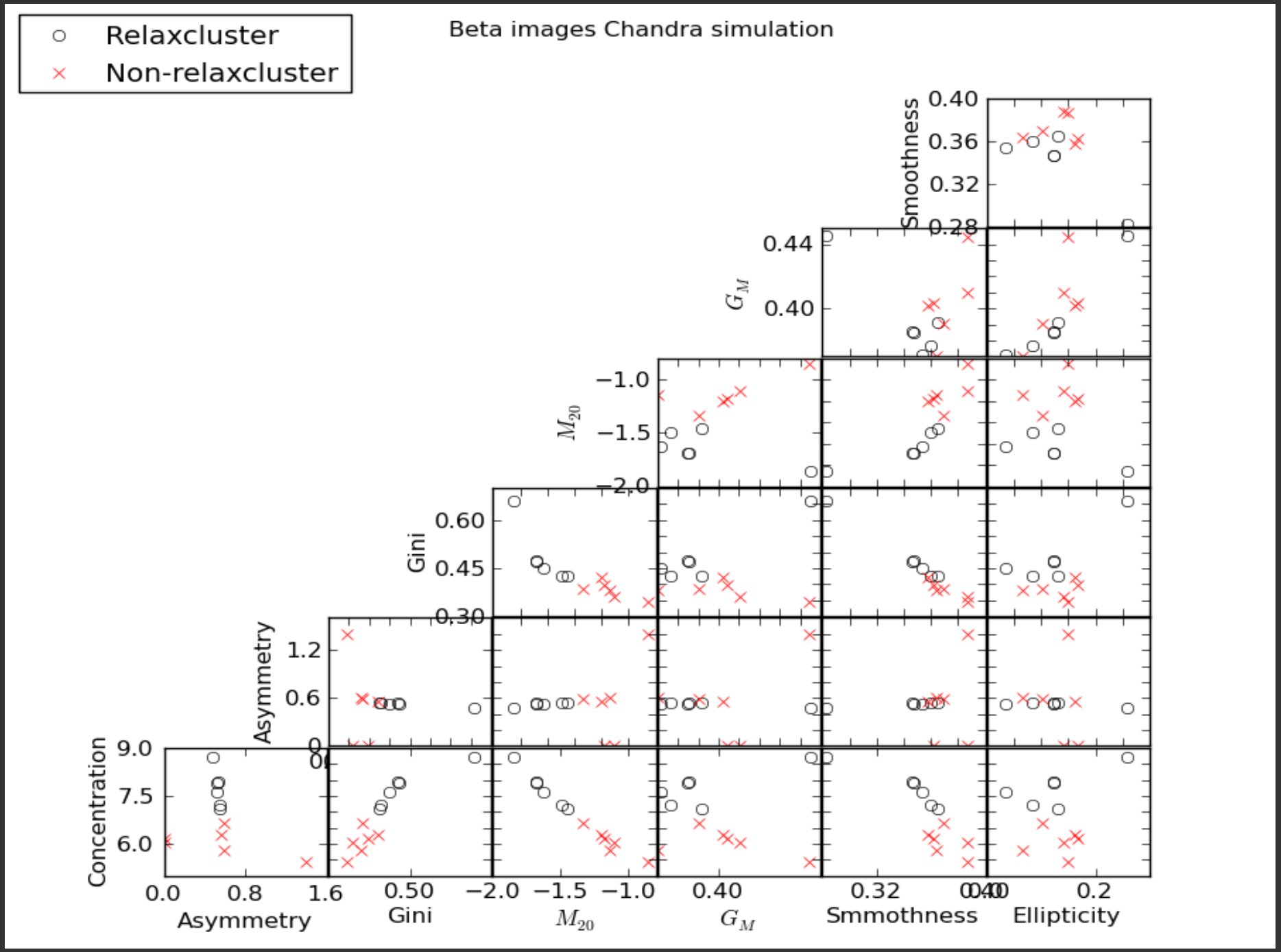
Exposure time: 50ks
Detector: ACIS-I
Spectrum: Thermal(wabs*mekal)
(0.1-10 kev)
nH=3x10^{20}
T=4kev
Abun=0.3
Pixel size=2”

Level 2 event file
(acis_process_events)



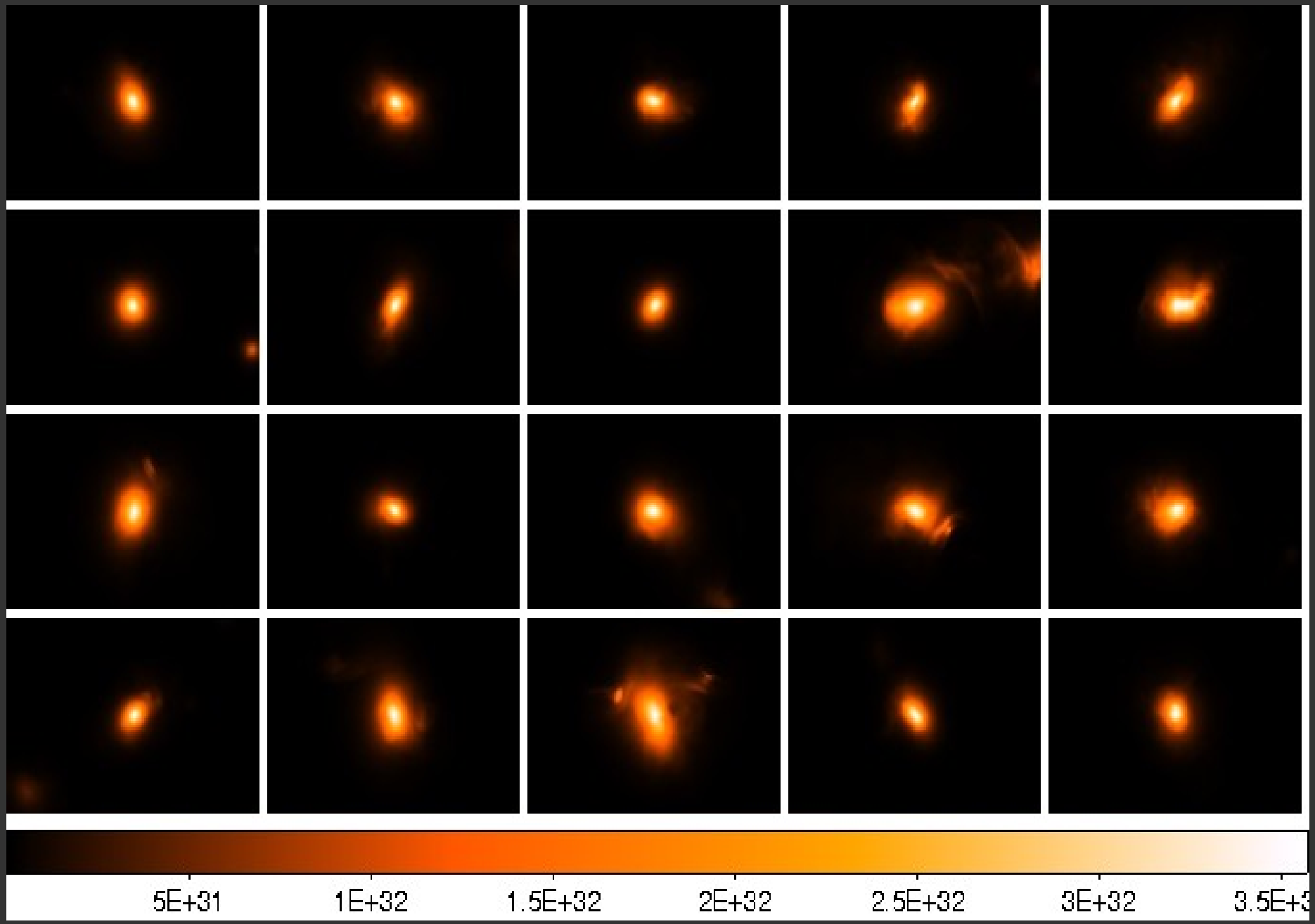
stephist: merger

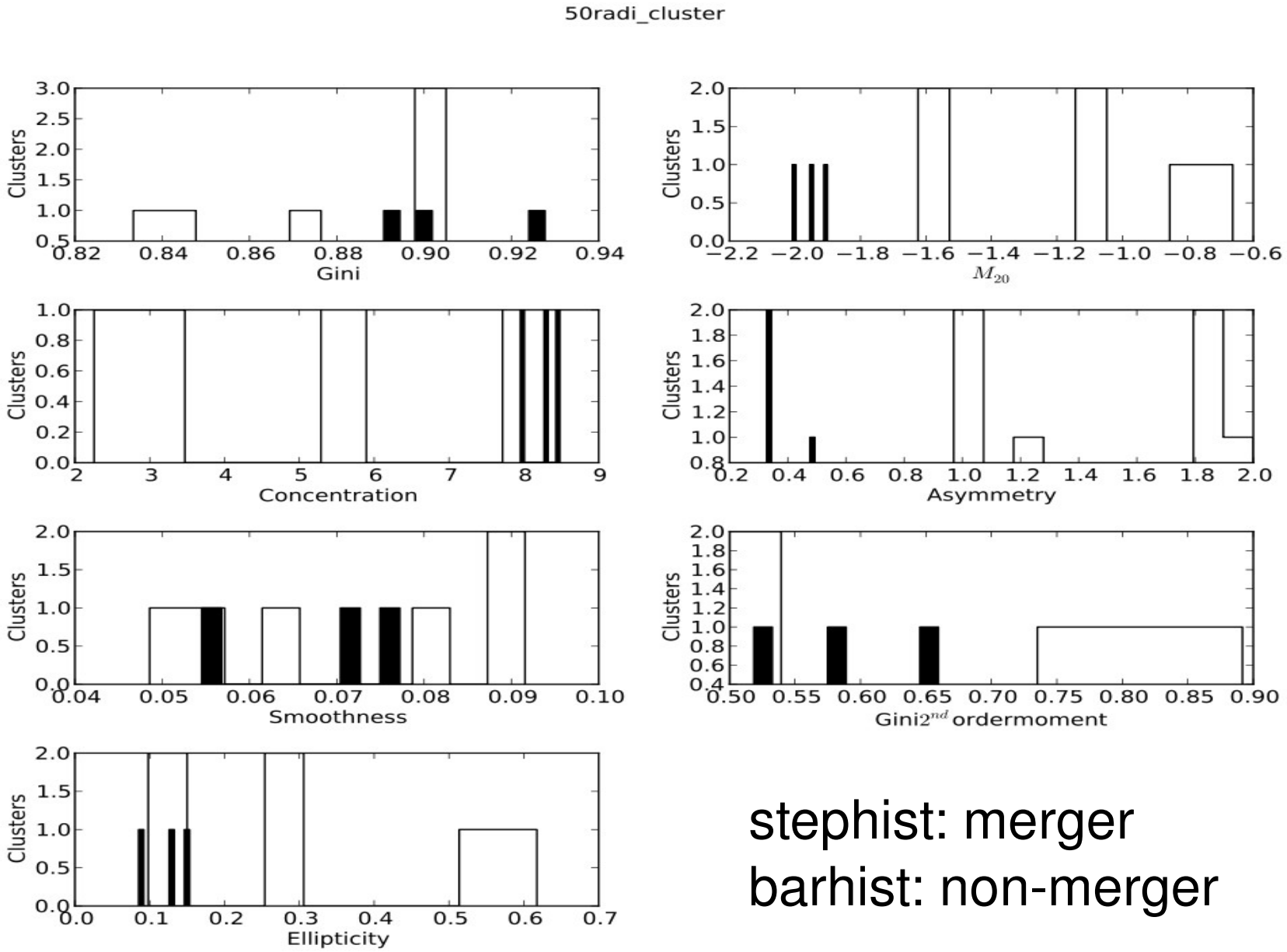
barhist: non-merger


Relaxcluster
Non-relaxcluster
Beta images Chandra simulation
Asymmetry
Gini
M_{20}
G_M
Smmothness
Ellipticity
Concentration

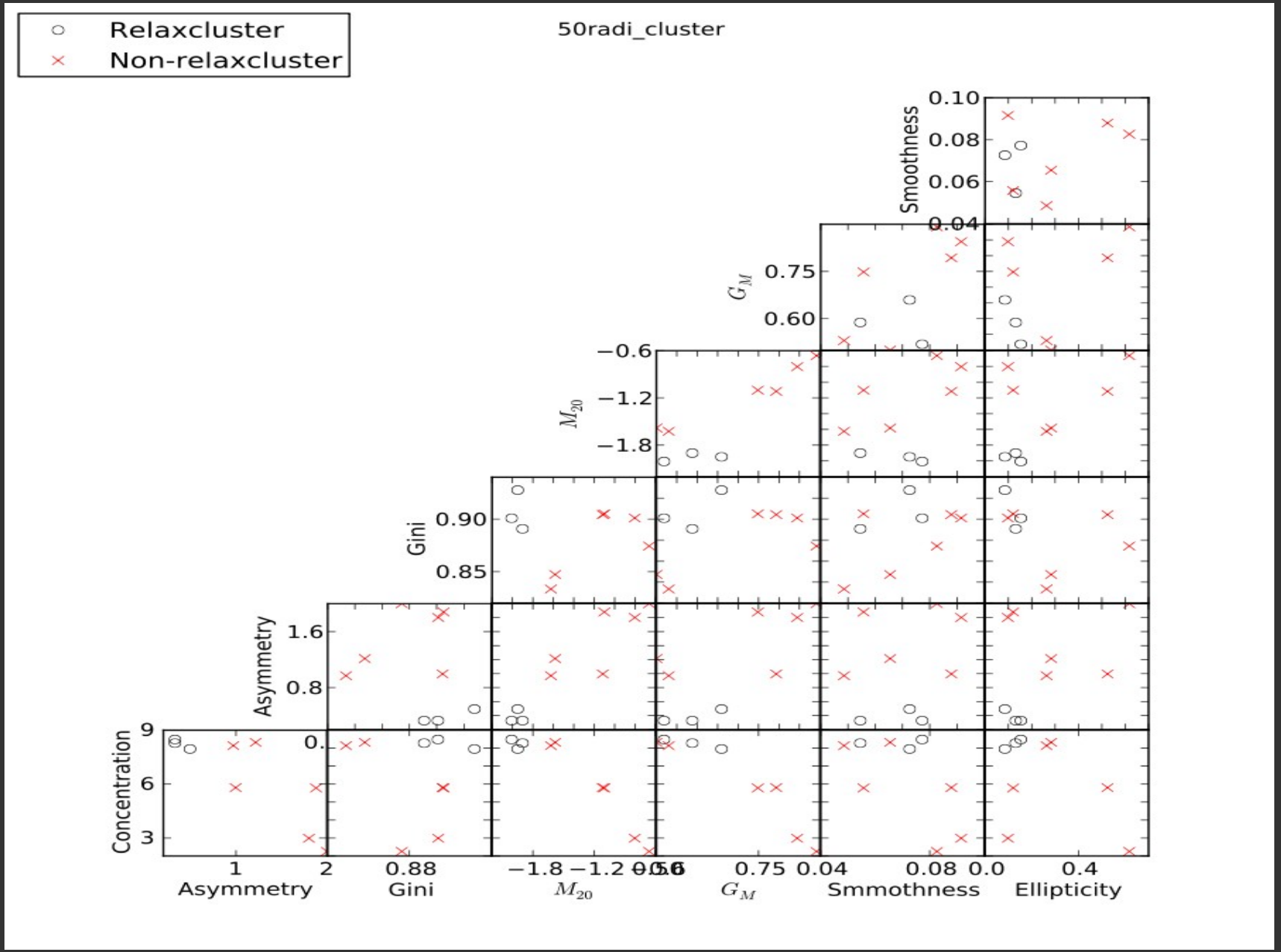
Hydrodynamic simulation

- *20 galaxy clusters of 6e14 to 2e15 M_{sun} (Vazza et al. 2010)*
- *z=0*
- *25kpc of pixel size*
- *Relaxed, post merger, complex merger*
- *Bolometric luminosity X-ray gas images*


5E+31
1E+32
1.5E+32
2E+32
2.5E+32
3E+32
3.5E+3

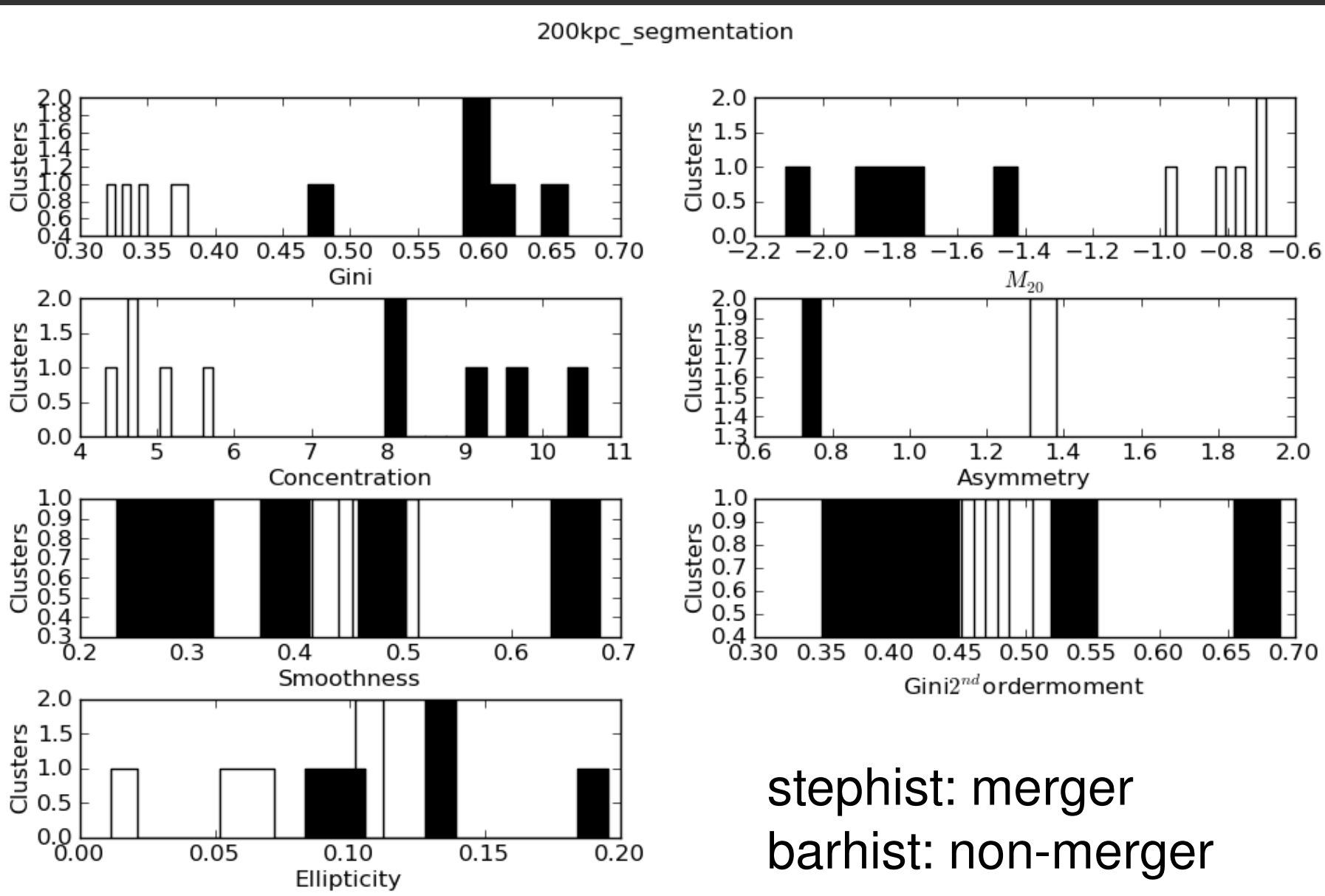


stephist: merger
barhist: non-merger

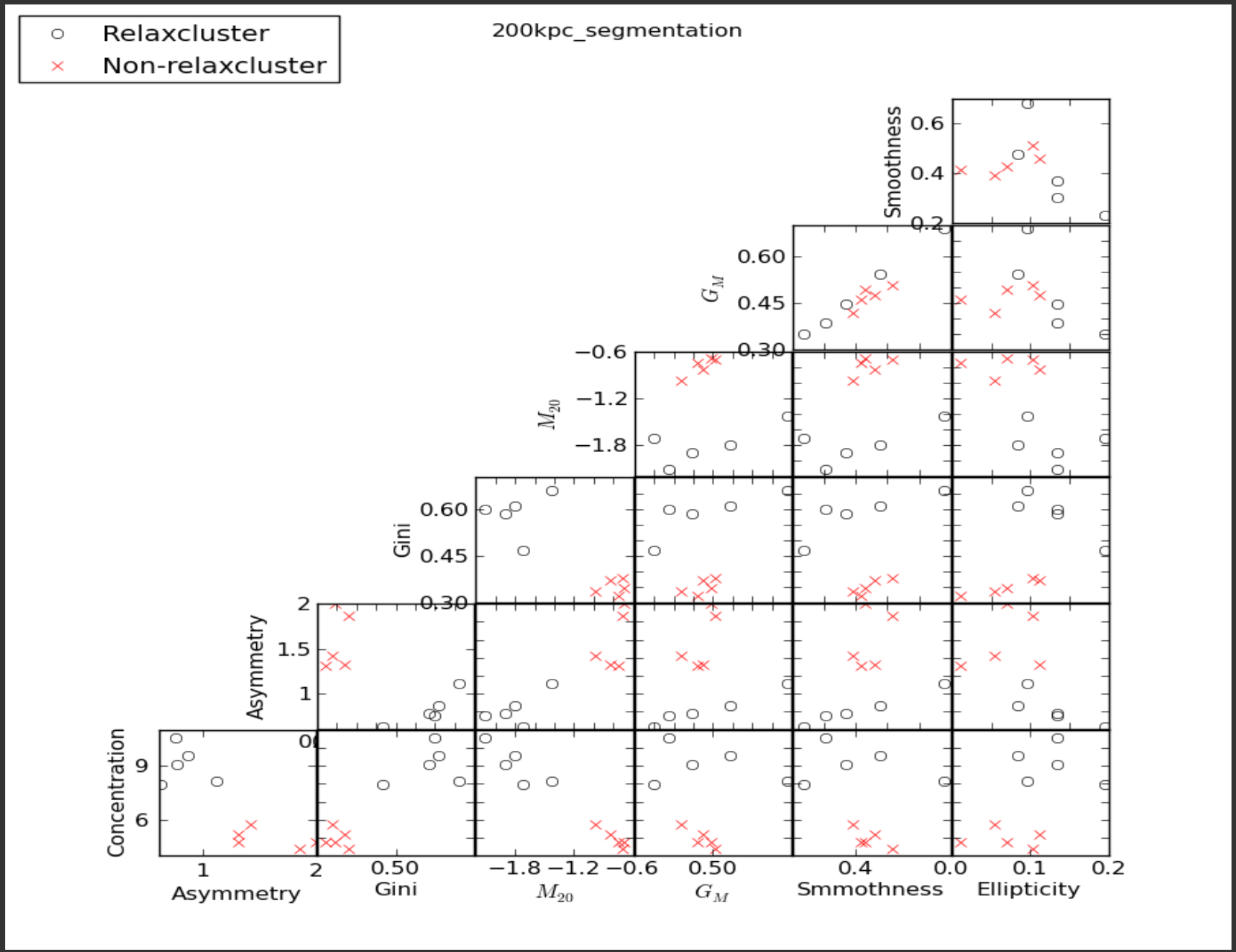

Relaxcluster
Non-relaxcluster
50radi_cluster
Concentration
Asymmetry
Gini
M_{20}
G_M
Smoothness
Ellipticity
Smmothness

Real Chandra observation

- *Sample from the Chandra X-ray Cosmology (Vikhlinin et al. 2010)*
- *100 clusters*
- *Low (0.02-0.2) and high (0.3-0.9) redshift sample*
- *Available X-ray gas properties*
- *A1795, A2597, A2029, A209, A2142*
- *A754, A3558, A2256, A2147, A3266*



stephist: merger
barhist: non-merger


Relaxcluster
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Summary and outlook

- *Morphology parameters can be used to distinguish merger and non-merger cluster*
- *morphology parameters vs. radial distance plots*
- *3D parameters plots*
- *Compare parameters with properties of X-ray gas*
- *Line of sight merger*