SPITZER IRAC LOW SURFACE BRIGHTNESS OBSERVATIONS OF VIRGO

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Introduction to ICL -- Observations

- Diffuse:
  - ICL is ubiquitous (Krick et al., 2007; Gonzalez et al., 2005; Zibetti et al.,2005)
  - There are potentially/not correlations with cluster property (Krick et al. , 2007; Gonzalez et al., 2007; Zibetti et al.,2005)
    - Redshift, M1-M3, Richness, Mass
  - Color = age = formation mechanism
    - In situ (young)
    - Formed in galaxies before stripping (old)

WHY IR / IRAC?

- Relative ages from colors – near the peak of the SED
- Unseen population of old stars
- Dust!

WHY IR / IRAC?

- Spitzer is an 85cm telescope with (at the moment) 2 bands at 3.6 and 4.5 microns, a 5’ FOV, & 1.2” pixels
- The advantage of an earth-trailing orbit: you can observe all the time.
- The advantage of space IR: zodiacal light is the only background (non-instrumental)

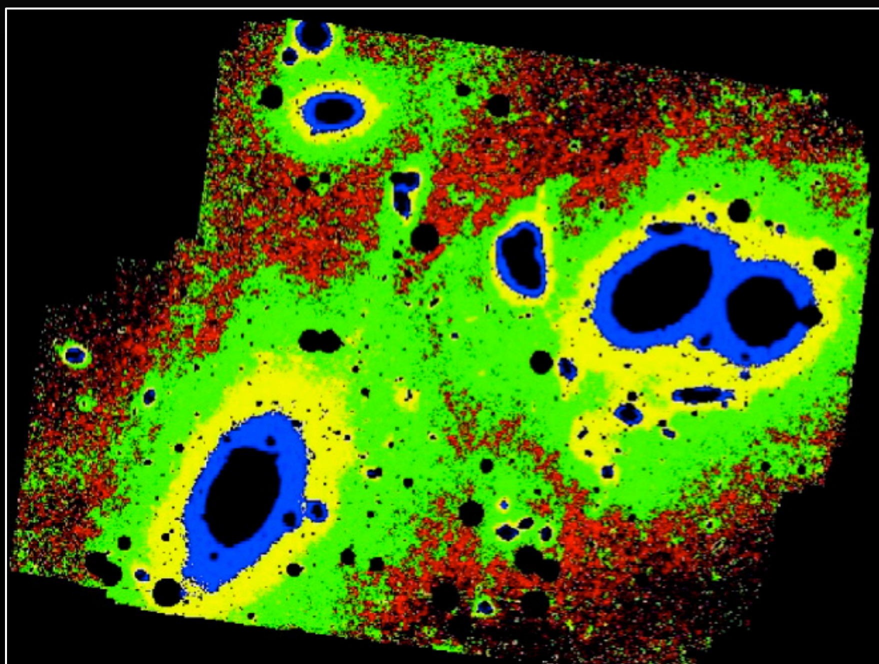
- IRAC has larger field of view than WFC3
- Nearby clusters are practically impossible to observe with WFC3

The Advantages of Virgo

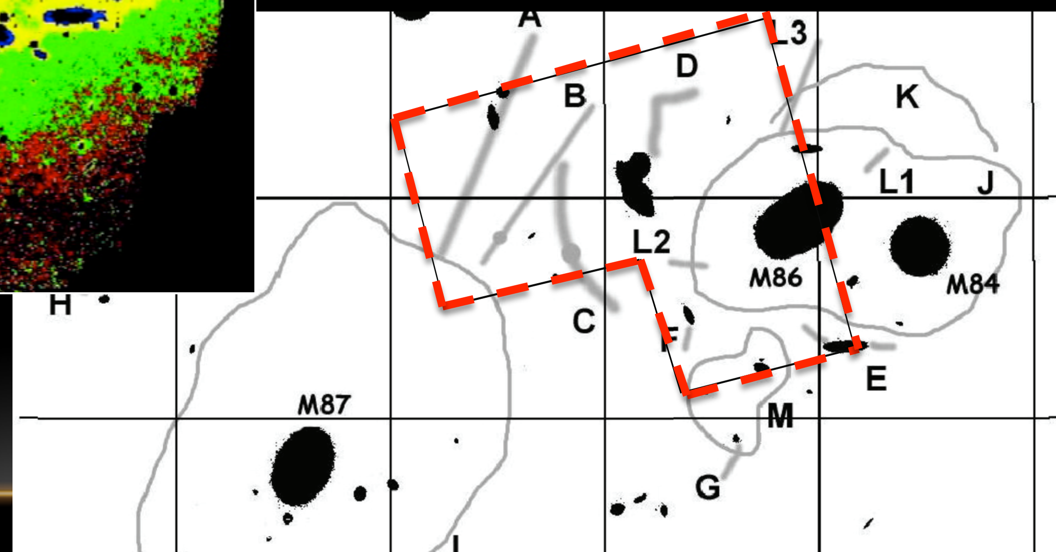
- Extremely well studied with lots of ‘Ancillary data’
  - Large-scale optical imaging– see Rudick talk…
  - Pointed observations at many other wavelengths
    - There are > 600 references to Virgo in NED
- Many resolution elements per square kiloparsec
- Cluster has substantial substructure which keeps things interesting (Schindler et al. 1999, Kenney et al., 2008)
- (1+z)^4 SB dimming is not killing us
- Disadvantage – Large area imaging is a challenge for instruments and reduction techniques for doing proper background subtraction.

NASA/ESA

THE SPITZER PROGRAM



100 hours over 0.77 sq. degrees
50 minutes per pixel



Mihos et al., 2005

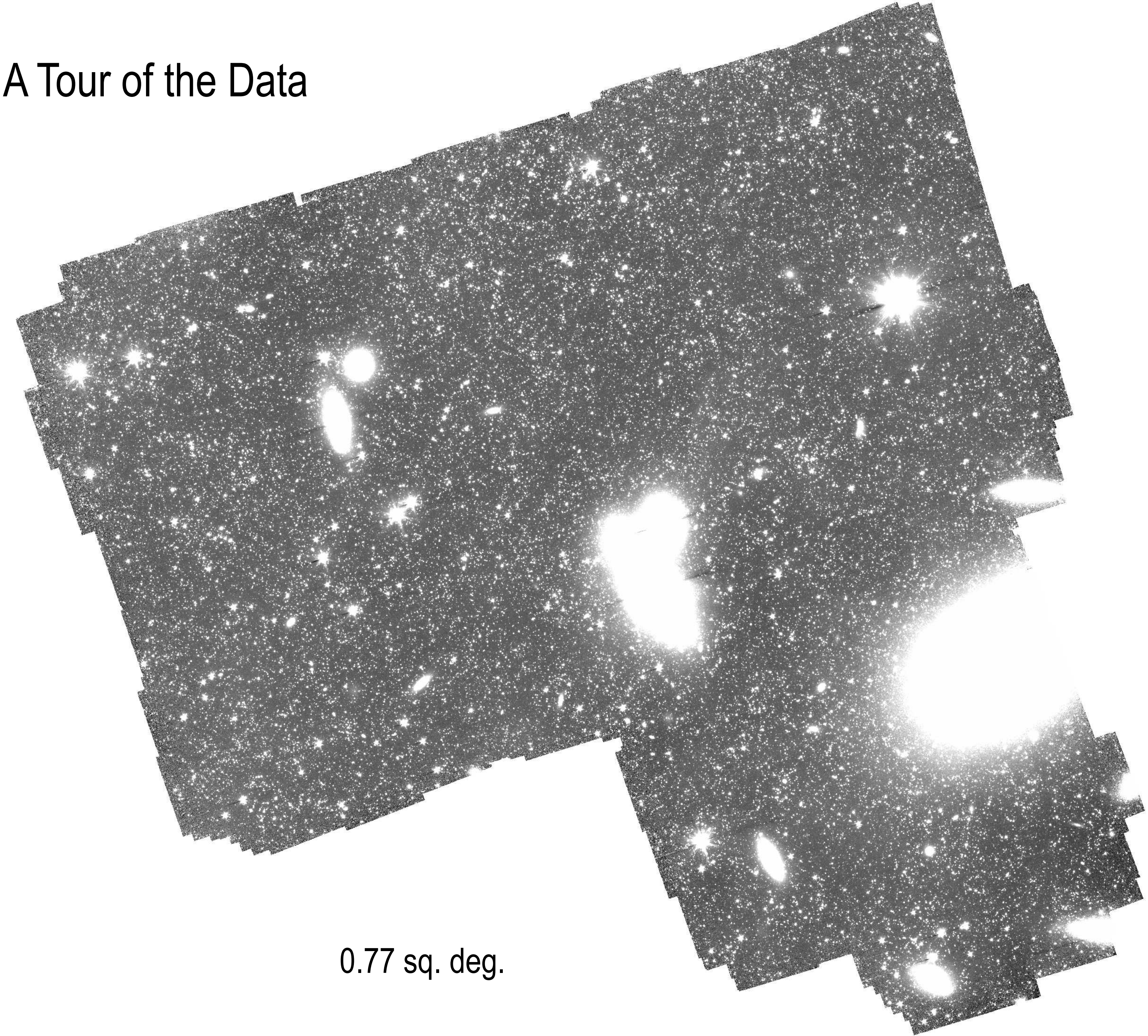
TECHNICAL DETAILS- ALL LSB WORK IS HARD

Pipeline

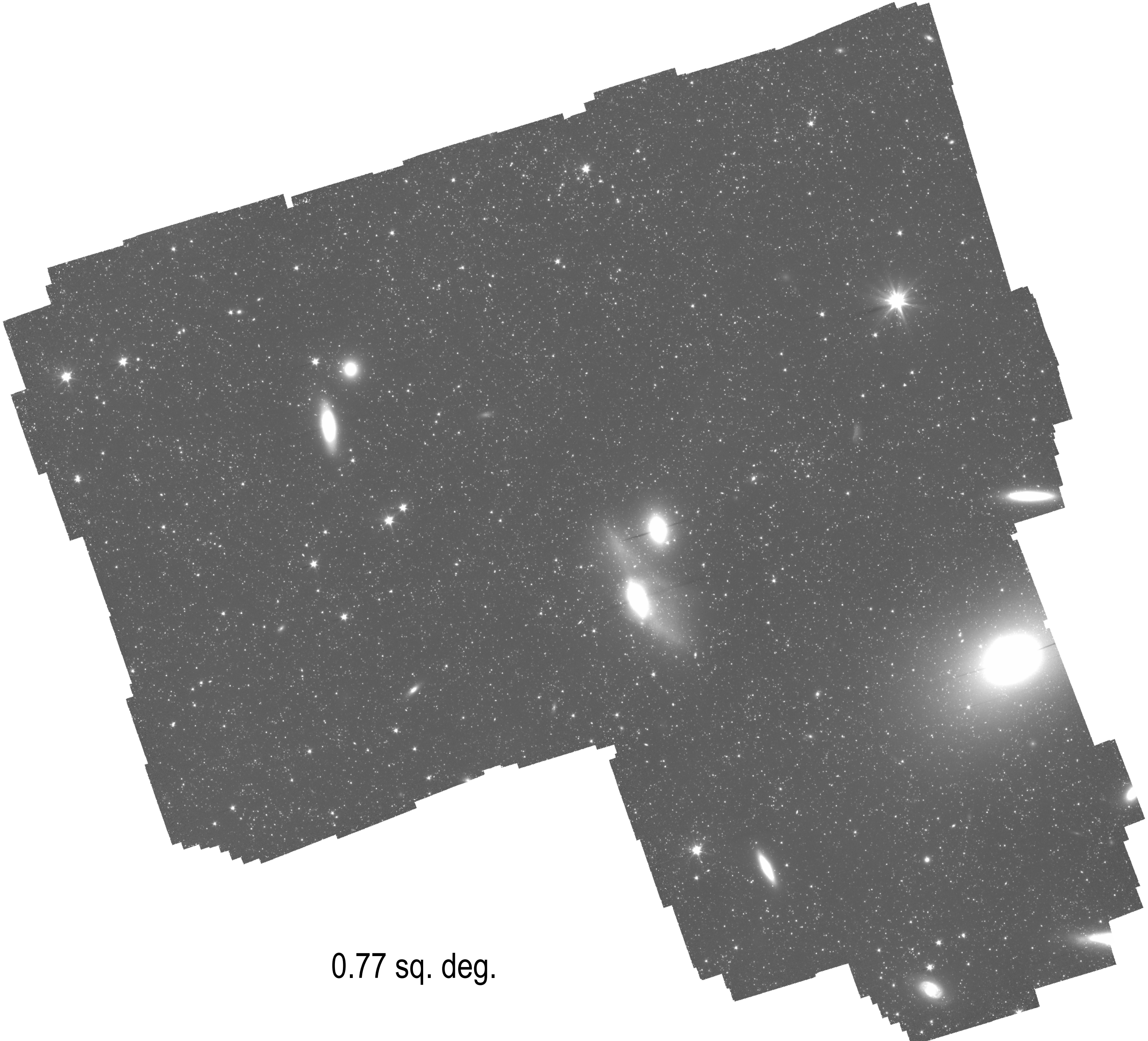
- Illumination correction
- Zodiacal light removal
- First frame effect removal
- Clock time effect removal
- Background determination & subtraction

MOSAICS!

A Tour of the Data

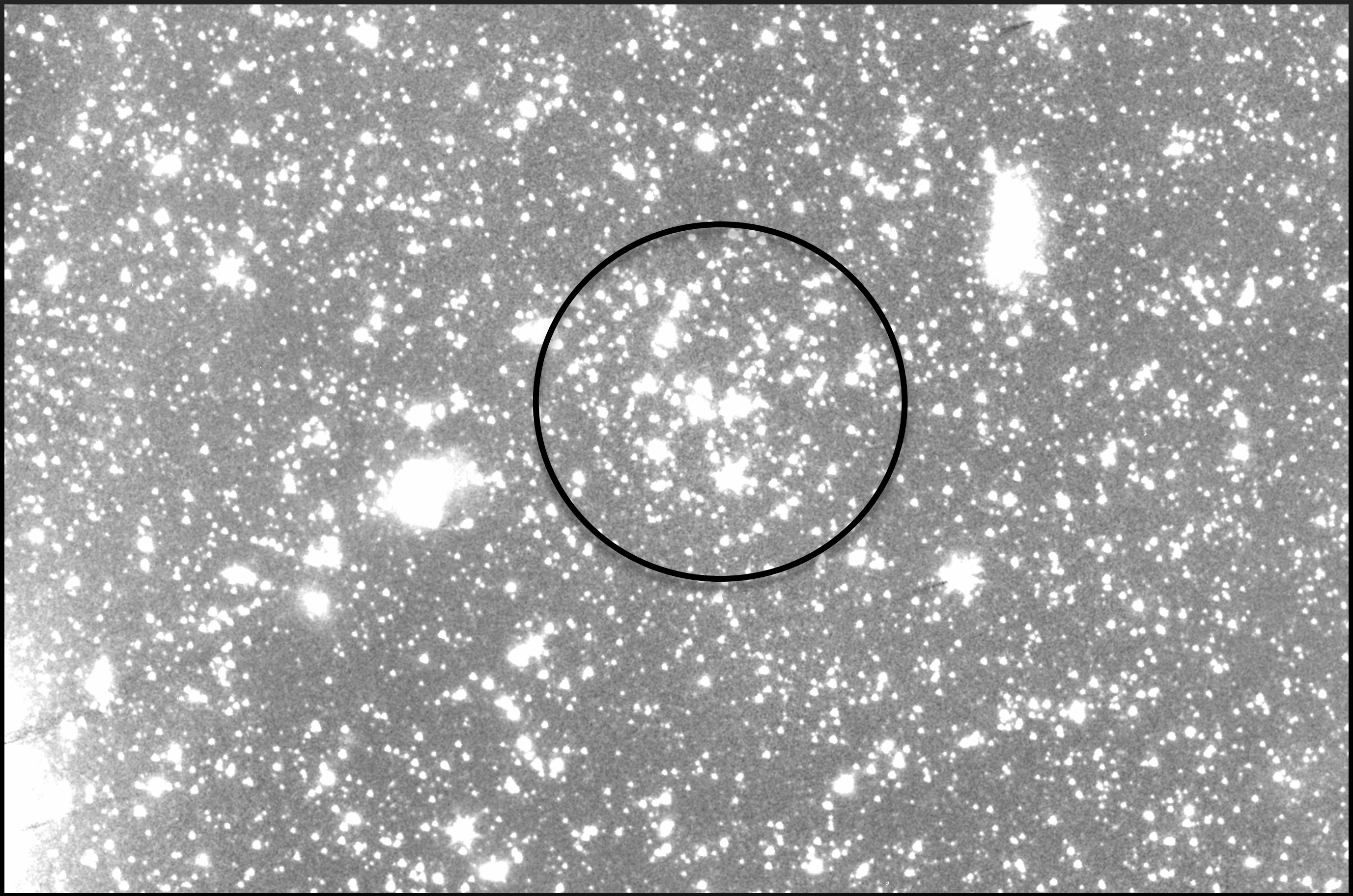


0.77 sq. deg.

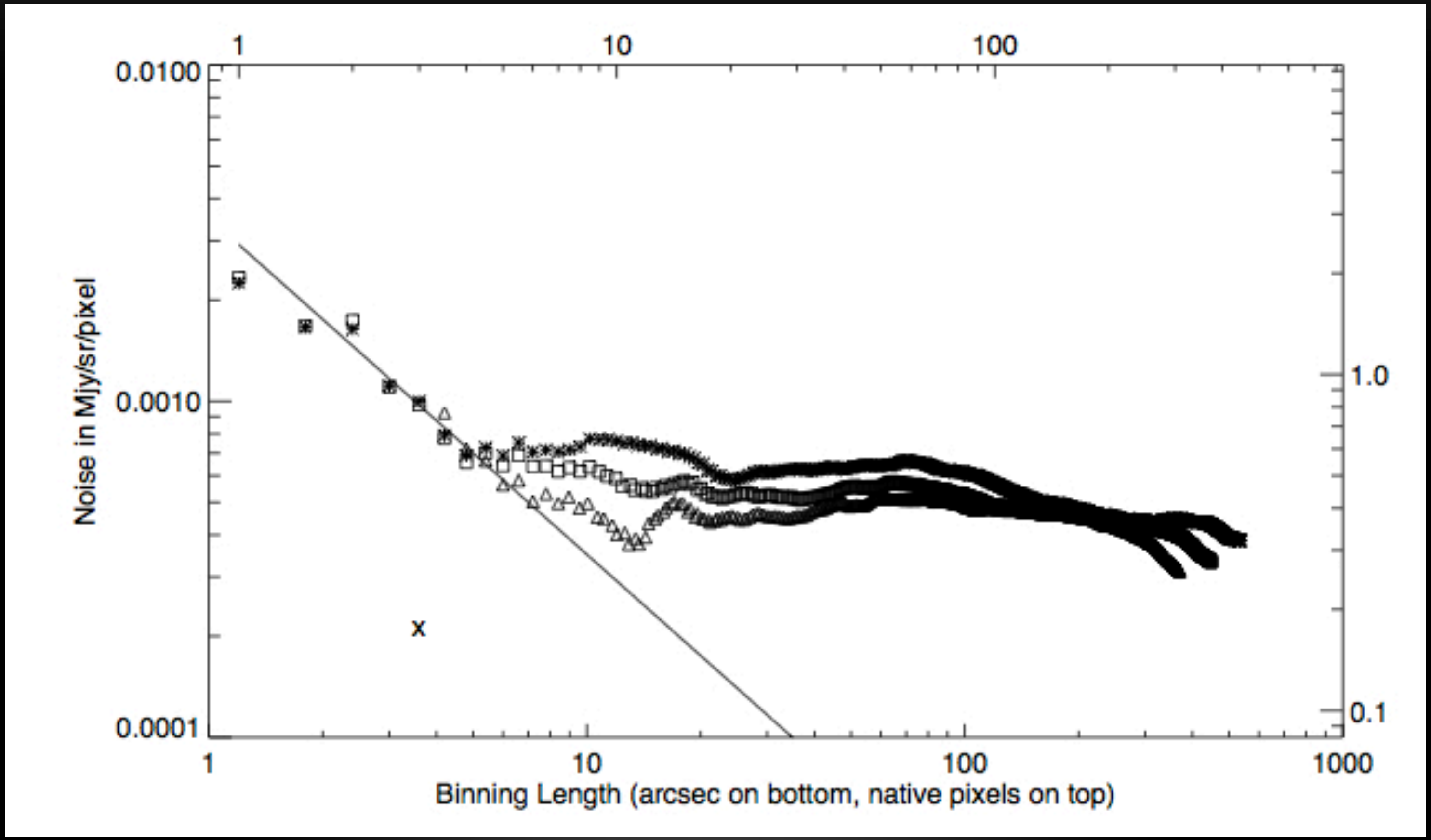


0.77 sq. deg.

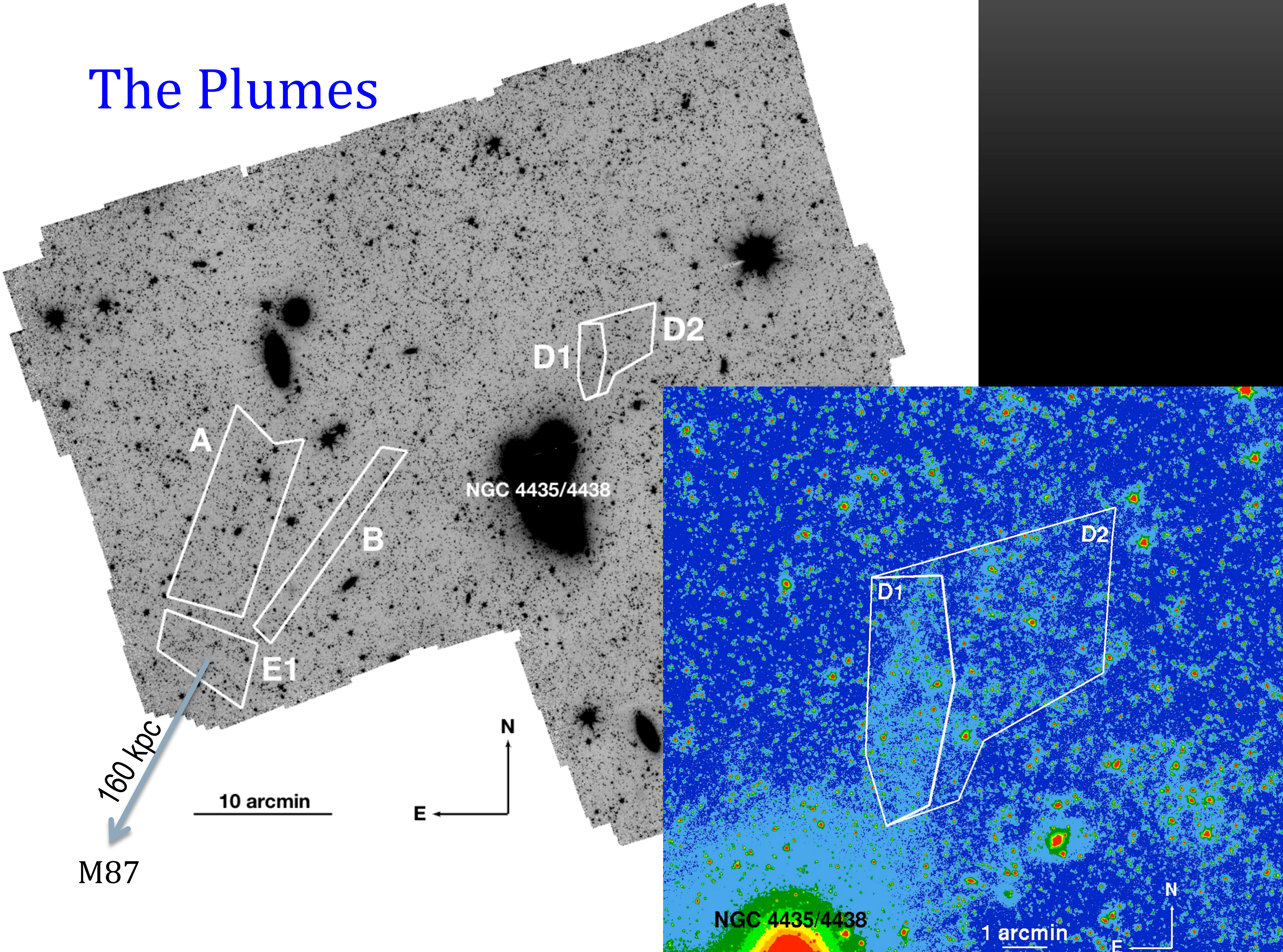
A NEW CLUSTER? Z ~0.4



Empirical Measurement of the Noise



The Plumes

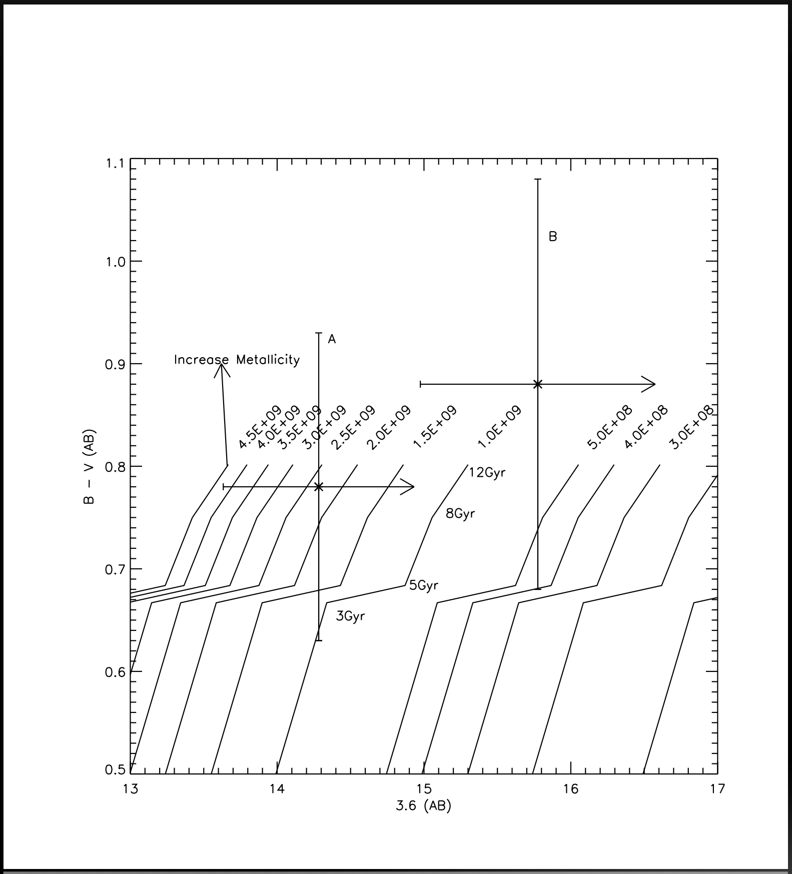


D1
D2
A
B
E1
NGC 4435/4438
160 kpc
M87
10 arcmin
N
E
D1
D2
NGC 4435/4438
1 arcmin
N
E

Plume Properties

	Plume ID	Signal MJy/sr	Signal AB mag.	Unmasked Length arcsec	Real Length arcsec	1σ noise MJy/sr	1σ noise AB mag.	# of sigma
CH1	A	0.00067	14.28	322	668	0.00036	0.65	1.9
	B	-0.00039	15.78 *	203	410	0.00045	0.76	< 1
	D1	0.00256	15.16	111	228	0.00048	0.21	5.3
	D2	0.00155	15.05	156	308	0.00046	0.34	3.4
	E1	0.00129	14.68	186	401	0.00046	0.41	2.8
CH2	A	0.00065	14.32	347	668	0.00052	1.2	1.3
	B	0.00043	15.56 *	218	410	0.00055	0.78	< 1
	D1	0.00128	15.91	118	228	0.00068	0.65	1.9
	D2	0.00030	16.84	166	308	0.00062	1.2	< 1
	E1	0.00111	14.84	197	401	0.00059	0.65	1.9

Age & Stellar Mass



Optical color -> age

- Slope of the Wien side of blackbody is more sensitive to age than the RJ side.

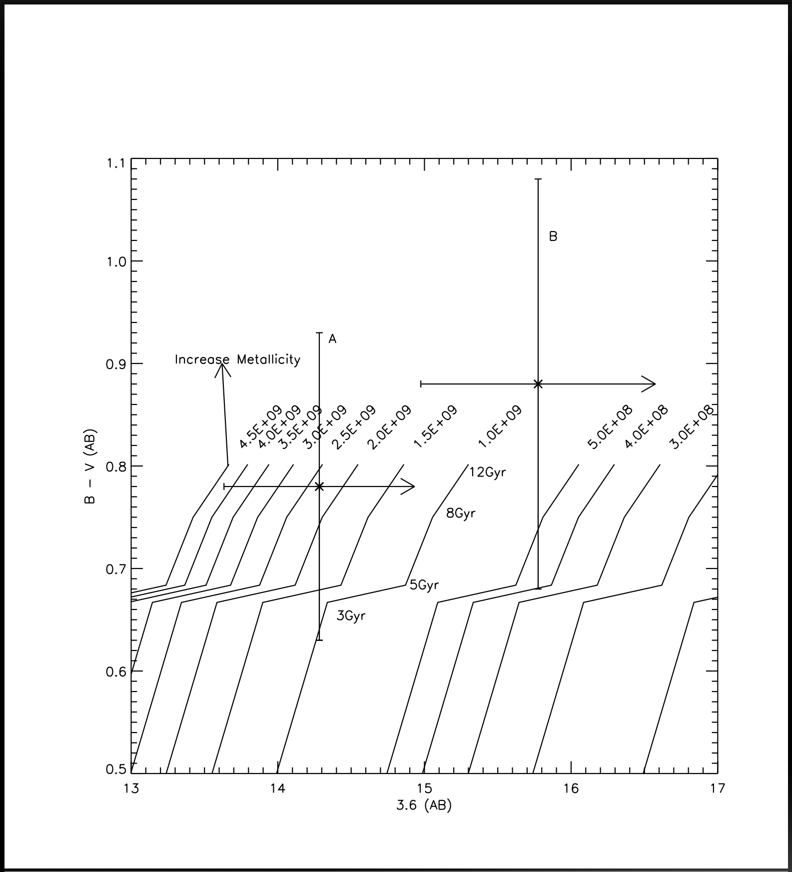
IRAC upper limits-> upper limit on stellar mass

- Infrared M/L is relatively constant over entire age range, whereas optical is not (especially for old populations)

Optical -> lower limit on stellar mass

- Any stellar population that falls below our observations is ruled out.

Age & Stellar Mass



Plume A:

- > 3Gyr
- 5.5x10^8 – 4.5x10^9 solar masses

Plume B:

- > 5Gyr
- 2.1x10^8 – 1.5x10^9 solar masses

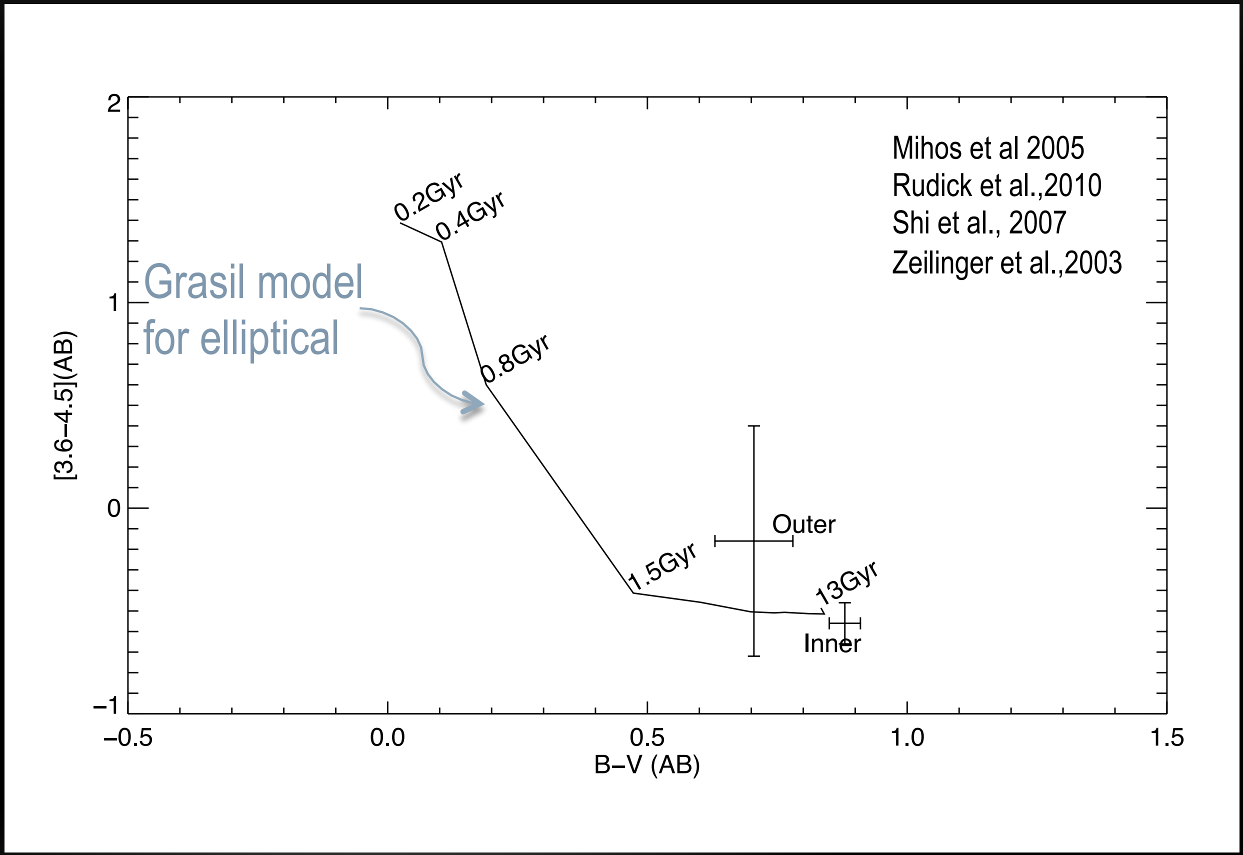
Total cluster stellar mass = 1.5x10^14

(Rines & Geller 2008)

Conclusion: A few percent of the mass of the cluster is in plumes. With basic assumptions about the plume lifetimes and cluster lifetimes, these plumes could account for all of the ICL as measured in diffuse component.

M87 OUTER HALO

IR data allows us to understand if there is a dust component affecting the optical estimates of age.



CONCLUSIONS

- IR ages are consistent with optical implying that dust is not extincting the previous optical measurements
- See no evidence for an older/missed population in the IR
- First measurement of the mass of large ICL plumes.
- Our data is consistent with gravitational processes that generate bright plumes as being the dominant mechanisms for making the ICL.
- Data are consistent with a flat color profile from the inner to outer region of M87 implying no young population of ICL has been recently infused into M87 halo.

- And please talk to me about other uses for this dataset or Spitzer for clusters