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.
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? $z \sim 0.4$
Empirical Measurement of the Noise
The Plumes

M87

NGC 4435/4438
## Plume Properties

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<th>Plume ID</th>
<th>Signal MJy/sr</th>
<th>AB mag.</th>
<th>Unmasked Length arcsec</th>
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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.
Plume A:
- $> 3\text{Gyr}$
- $5.5 \times 10^8 – 4.5 \times 10^9$ solar masses

Plume B:
- $> 5\text{Gyr}$
- $2.1 \times 10^8 – 1.5 \times 10^9$ solar masses

Total cluster stellar mass = $1.5 \times 10^{14}$
(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.
IR data allows us to understand if there is a dust component affecting the optical estimates of age.

Grasil model for elliptical

Mihos et al 2005
Rudick et al., 2010
Shi et al., 2007
Zeilinger et al., 2003
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