Scaling Relations of Spiral and Elliptical Galaxies: Similarities and Differences

Michael Pierce (University of Wyoming)

Structural Scaling Relations Reflect Assembly History

Virial Theorm plus Assumption of Constant Mass/Light Implies:
$\langle m \rangle \sim s^2/RG$

Elliptical Galaxies Should Populate a 3-parameter Plane

Two Families are Revealed:

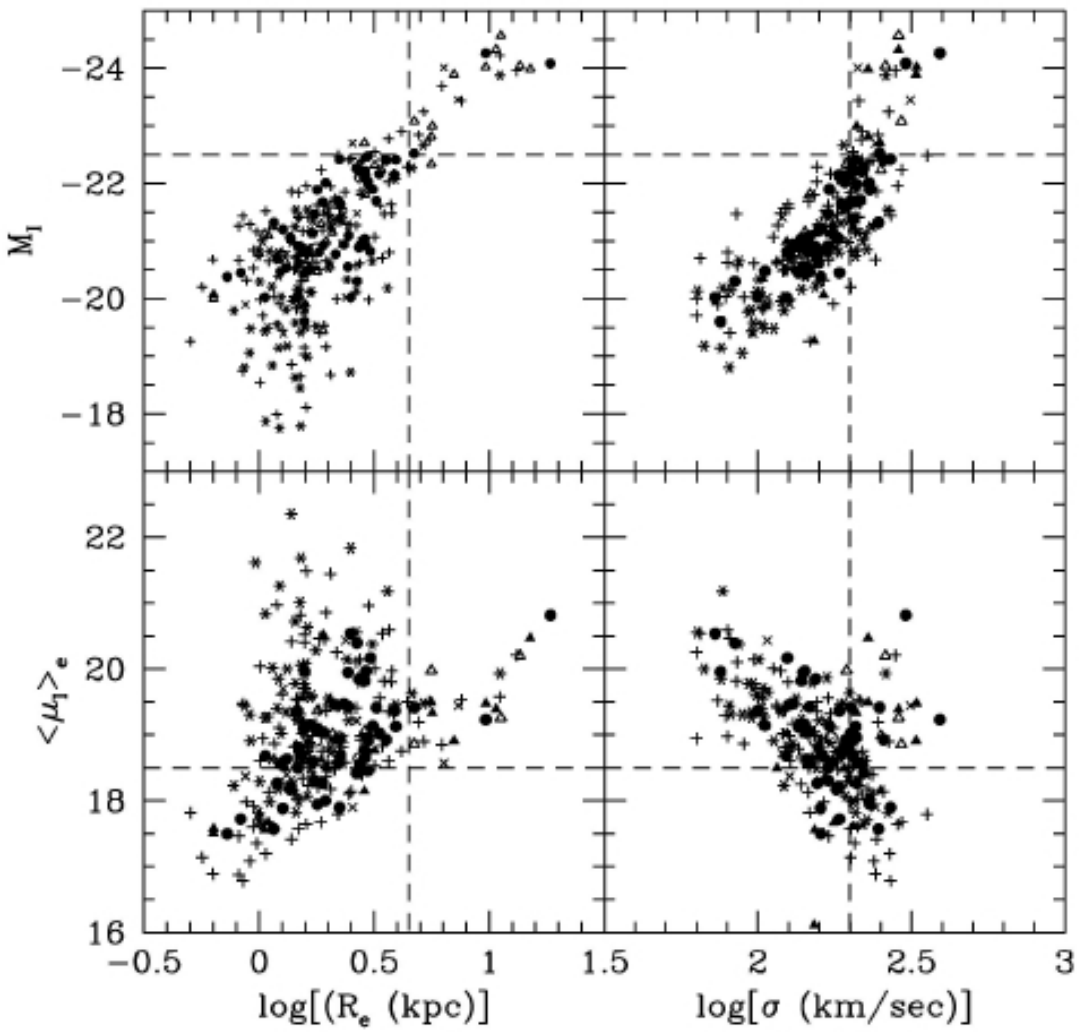
The Brightest, Most Massive Ellipticals Populate a Distinct Region (the Upper Right Region of Each Panel):

Interpreted as Evidence for Dry Merger Growth of Most Massive Systems.

Fainter, Less Massive Systems Appear to Lie Along a "Dissipational Sequence" (see Lower-Right Panel)

Merger Models Are Beginning to Include Gaseous Dissipation. But May Soon Allow Detailed Comparison With Data.

Two families have quite different structural properties: largest systems have cores with complex velocity fields, smaller systems lack cores and have regular velocity fields.



Scaling Relations of Ellipticals & Spirals

Scaling Relations of Es and Spirals are Remarkably Similar

L < L* Galaxies Lie Along a Dissipational Sequence

Do Early Wet Mergers & Outflows/ Winds Play Similar Roles in Both?

What is the HI Morphology During Assembly: 1 < z < 2?

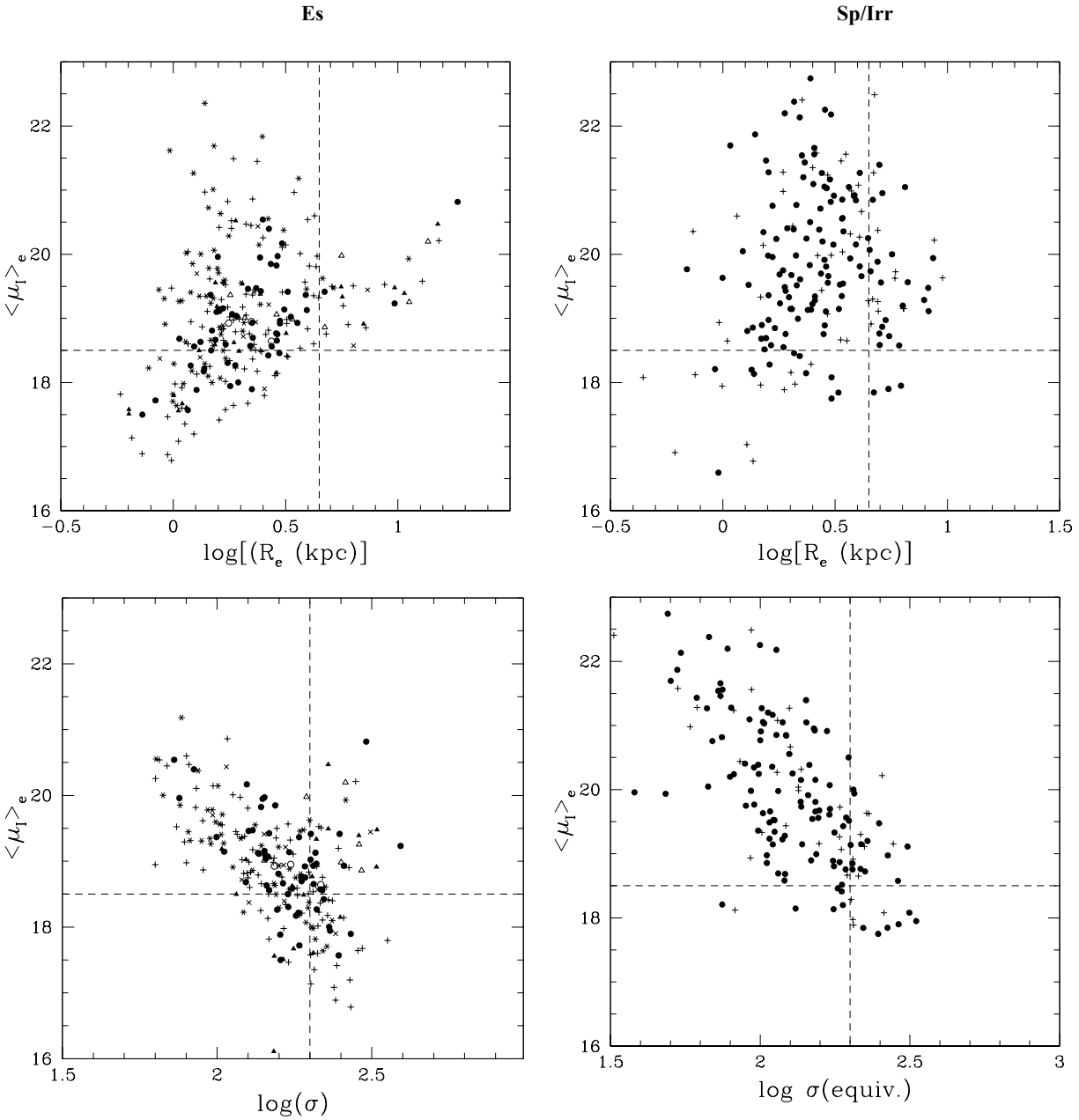
No Disk Analogs to the Small, High-SB Es

L > L* Galaxies Rather Different

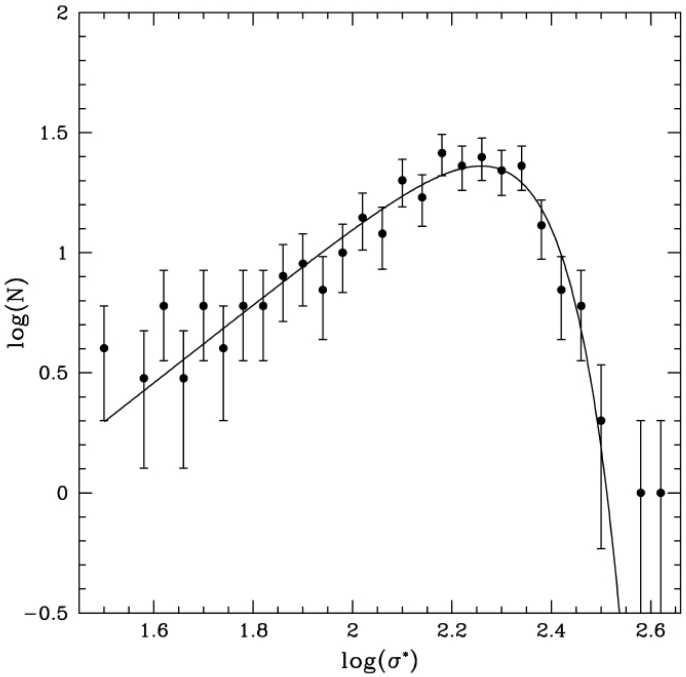
Luminous, Diffuse Es (BCGs) Form a Distinct Population

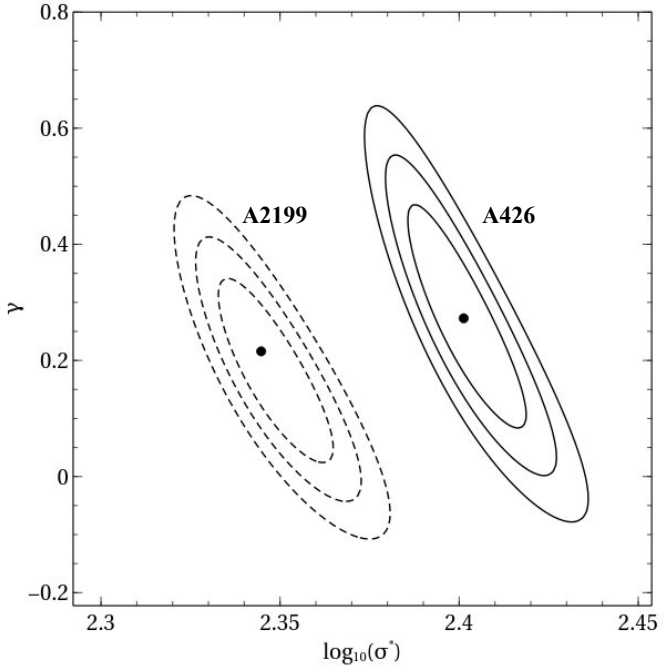
Evidence for Dry Merger Origin?

TMT & SKA Spectroscopy Would Constrain Late Assembly and Enrichment



The Velocity Dispersion Distribution Function (VDDF) of Five Nearby Clusters



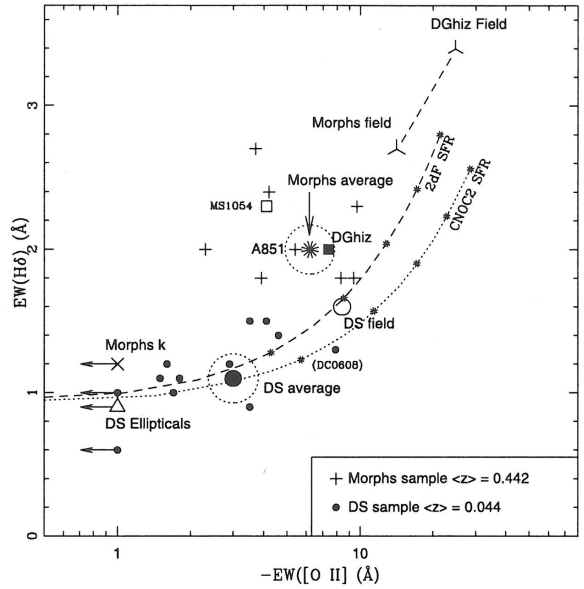


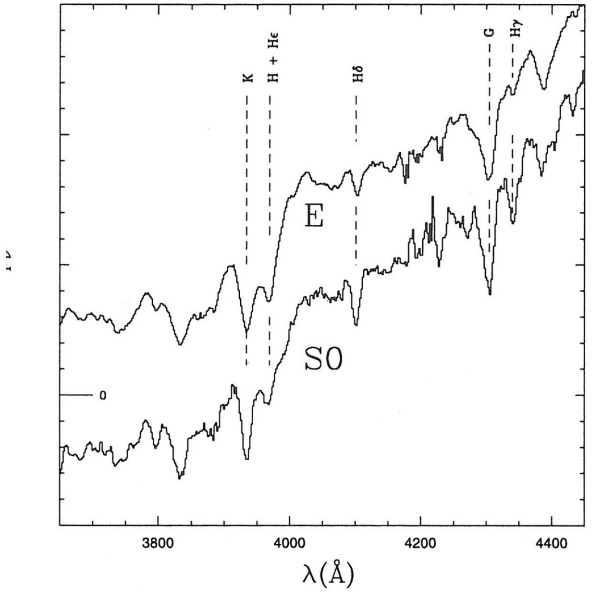
Parameterized fits to the VDDF (e.g. Schechter) offers promise for quantifying the merger history of galaxies, independent of their morphology or their stellar populations (e.g Sheth et al. 2003).

Comparison of nearby clusters imply BCGs grow via mergers: at the expense of intermediate systems. The VDDF provides a quantitative measurement of assembly history.

Star Formation History of Intermediate-z Clusters

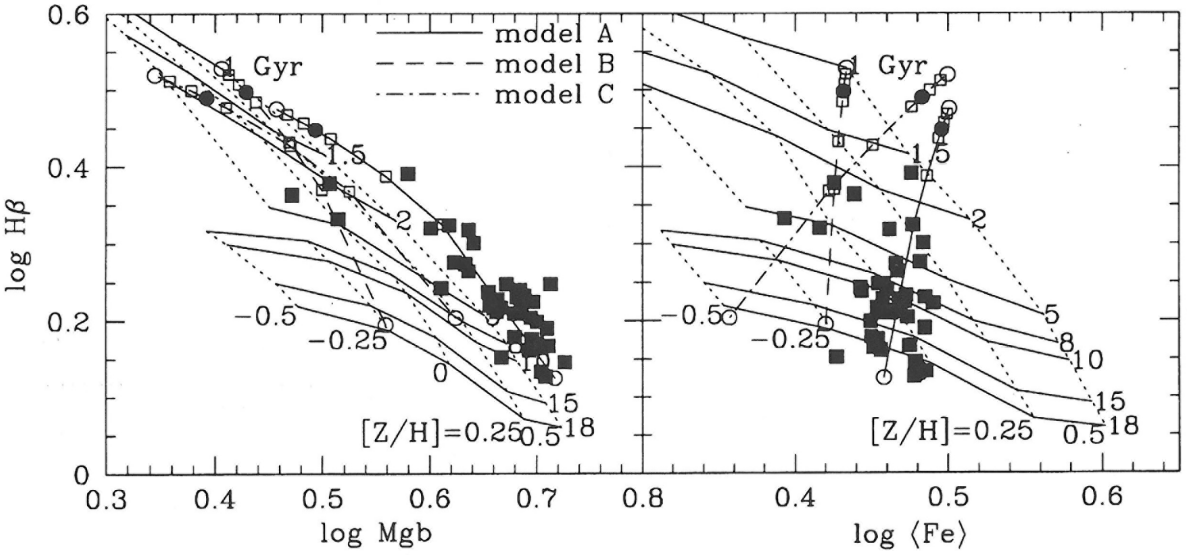
- **Composite Spectra Binned by Color and Morphology Reveal Strong Evidence for Post-Starburst Galaxies Within Z ~ 0.5 Clusters (Dressler et al. 2004)**
  - **Strong, Increasing Star Formation Rate with Redshift**
- **Hδ E.W. of Disk Galaxies Too Large for Continuous Star Formation**
  - **Very Unlike Nearby Disk Galaxies**
- **S0s Contain Intermediate Age Population**
- **Spitzer/IRAC Suggests an Additional Population of "Dusty Starbursts" (z > 0.5) More Abundant in Clusters than Field (Muzzin et a.l 2008)**
- **Together, This Suggests Rapid Evolution of Cluster Populations for Z > 0.3**
- **A Kinematic Survey with TMT Would Also Enable Absorption/Emission-line Stellar Pop. Diagnostics at Z > 1**
- **Emission Line Diagnostics to Z ~ 1 (Steidel et al. 2014)**





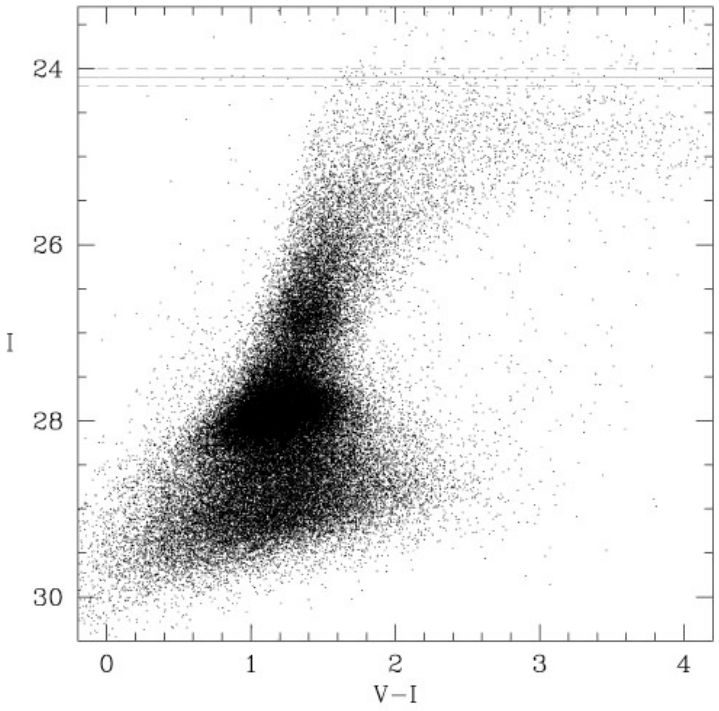
Star Formation History of Ellipticals

- **High S/N Spectroscopy of Nearby Es Allows Disentangling Age & Metallicity (Gonzalez et al. 1999; Trager et al. 2000a,b)**
  - **[Z/H] Appears to Be a Linear Combination of Both Age and Velocity Disp (σ)**
  - **[α/H] Enhanced, or [Z/H] Depleted, in High σ Galaxies**
  - **Higher SNII Yields at High σ?**
  - **"Young" Es Contain Additional, Small Intermediate-Age Population?**
  - **TMT Would Enable Measurement of the Lick Indices to Z > 1 (e.g. Belli et al. 2014)**



What About Resolved Stellar Populations?

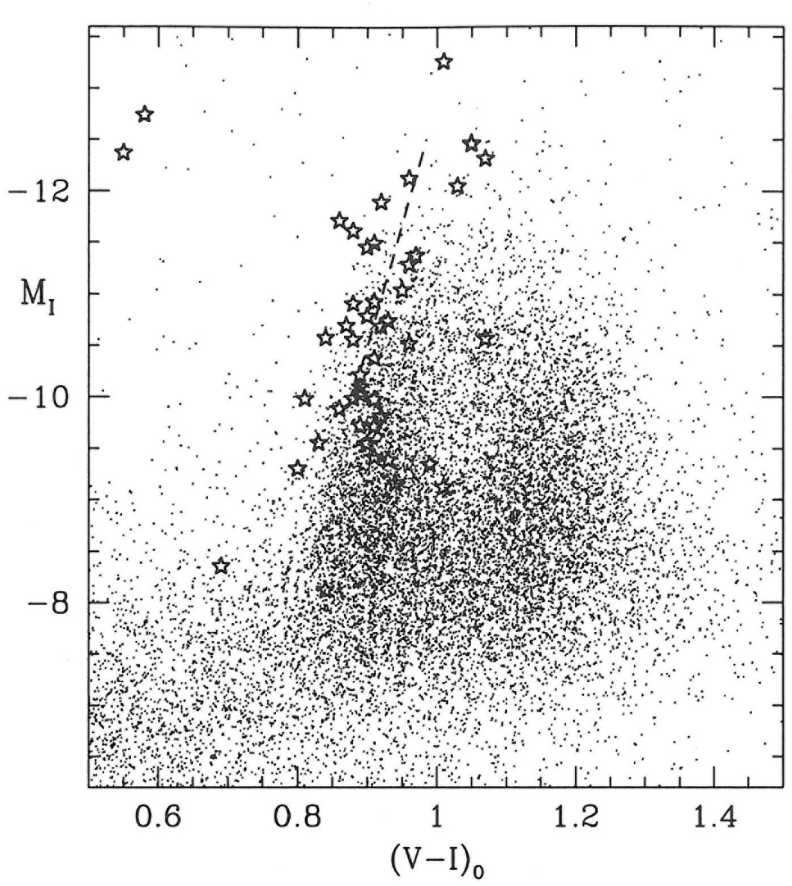
- **TMT will Also Resolve the Stellar Populations of Es and S0s Within Nearby Galaxy Clusters**
- **Metallicity Distribution from GB Width and Red Clump (HB)**
- **TMT Will Reach HB in Virgo Cluster Es and S0s**
- **TMT Could Characterize GB Width in Coma Cluster Es and S0s**
- **How Might the Stellar Metallicity Distribution Be Related to Structural Properties and Merger History?**



NGC 5128 (3.5 Mpc) with HST (Rejkuba et al. 2005)

What About Globular Cluster Populations

- **Bi-modal Distribution of Globular Cluster Colors Suggests Two Populations (Harris et al. 2006)**
- **Blue Population Similar to Dwarf Galaxies While Red Population Is Quite Different**
- **Two Locales for Star Formation and Enrichment?**
- **TMT Could Characterize Globular Cluster Metallicities in Coma Cluster Es and S0s and Beyond**
- **Are the Color Distributions Related to Structural/Assembly Differences?**
- **What are the Implications for High-z Star Formation and Early Enrichment in Deep Potentials?**



Summary

- **Scaling Relations of Elliptical and Spirals are Remarkably Similar**
  - **L < L* Galaxies Appear to Form a Dissipational Sequence**
  - **Indicative of Similar Outflow/Feedback Processes?**
  - **L > L* Galaxies Quite Different**
  - **Bright Spirals Along the Dissipational Sequence**
  - **Brightest Ellipticals (BCGs) are Quite Different: Evidence for Dry Merger Origin?**
- **Necessary Kinematic Data Would Also Enable Stellar Population Diagnostics**
  - **Emission Lines and High-order Balmer Lines Would Constrain Young, intermediate, and Old Populations**
  - **Lick Indicies Would Constrain [Z/H] and[α/H]: SN II vs SNIa Enrichment**
- **Synergy with Resolved Stellar Populations will Be Possible**
  - **TMT Will Resolve Stellar Populations in Nearby Clusters Containing a Significant E and S0 Population**
  - **Globular Cluster Color Distributions Imply Two Formation/Enrichment Locales and TMT Will Enable Characterization of the Full Range of Morphological Types.**