TMT
THIRTY METER TELESCOPE

Quantifying the Assembly History of Elliptical Galaxies

Abstract of Scientific Justification (will be made publicly available for accepted proposals):
We propose to undertake a large photometric and spectroscopic survey of the elliptical galaxy populations within a complete sample of high-z clusters ($0.75 < z < 2.0$) . The available data for low-z clusters reveals that the structural scaling relations of elliptical galaxies, e.g., various projections of the fundamental plane (FP), have preserved a fossil signature of their assembly history. Specifically, the distribution of galaxies within the various projections of the FP suggests that ellipticals can be separated into two broad classes: those that originate through gaseous mergers and those that form from the mergers of gas-poor systems, i.e., wet vs. dry mergers. We propose to acquire similar, high quality data with IRIS and IRMS that will enable us to fully characterize the FP over a broad range of cluster mass and redshift. Our survey will require complete samples of 100 elliptical galaxies within each of 15 clusters in order to characterize the FP over these redshifts. The imaging data will be acquired as part of the TMT Clusters Survey. The spectroscopic data proposed here will provide the internal kinematics but also enable the measurement of the Lick spectral indices that are sensitive to age and metallicity (H, MgII and Fe). This will allow us constrain the elemental enrichment history as a function of stellar mass. Together these data will allow us to quantify the assembly history of the elliptical galaxies and clusters.

Goals of the Key Program

- **Characterize the Evolution of the Fundamental Plane (FP) of Ellipticals**
  - **Obtain R = 5000 and S/N > 30 Spectroscopy of Cluster Elliptical Populations**
    - **Measure Velocity Dispersions and Traditional Line Indices**
  - **Combine with High-res. Imaging from JWST and TMT/IRIS to Construct FP Ellipticals**
    - **Es Separate into Two Families Suggestive of Wet vs. Dry Merger Origins**
  - **Quantify Relative Populations Within FP with z and Mass Indicators (e.g. SZ)**
  - **Use Traditional Line Indices to Constrain Ages and Metallicities**
  - **Hβ Emission will Constrain Downsizing of Star Formation with z and Environ.**
- **Sample the Velocity Dispersion Distribution Function (VDDF)**
  - **Provides Quantitative Measure of a Given Cluster Population's Assembly History**
- **Obtain IRIS IFU Spectroscopy of Brightest (L > L*) Members**
  - **L > L* Es Have Complex Velocity Fields: Multiple SMBHs from Dry Mergers?**

Instruments and Observing Modes

- **WFOS**
  - **R = 5000 Spectroscopy of Rest-Frame $4800 < \lambda < 5800$ at z ~ 0.75**
  - **Two Nights for Four Clusters (4 Masks Each)**
  - **However Dynamical Timescale: $t \sim R/\sigma$**

    2 arcsec at Coma ~ 1 kpc, so 200 km/sec -> $t \sim 5 \times 10^6$ yrs

    Phase Mixing Should Quickly Wash Out Stellar Streams
- **IRMS**
  - **75 nights for <z> = 1.0, 1.25, 1.5, 1.75, 2.0**
  - **Need More Than Two Nights per Cluster for z > 2**
- **IRIS**
  - **10s of Nights for L > L* Galaxies in Selected Clusters**
- **MOAO IFUs Ideal**
  - **About 10 L > L* Galaxies in a Given Cluster**
  - **Mapping Complex Velocity Fields (e.g., SAURON) vs z Necessary to Constrain Assembly History**

Synergies with Other Key Programs & Facilities

- **TMT Cluster Lensing Survey (Dell' Antonio et al)**
  - **Accurate Individual M/L Measures Are Essential For Precision Lens Models and Cosmology Using Strong Lenses**
  - **Separate Constraints on the Small-Scale Baryonic and Non-Baryonic Mass Distributions**
  - **Morphologies and Kinematics of High-z Lensed Galaxies (rare)**
- **DESI, JWST and ALMA Cluster Surveys**
  - **Will Identify Residual Star Formation within Cluster and Infalling Populations**
  - **Follow-up Intermediate Spectroscopy with TMT is Essential**
- **Community Input and Participation Welcome**