GSMT Science Use Case

Title: The Star Formation Histories of Disk Galaxies

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Abstract: We describe a program to measure the star formation and chemical enrichment histories of the bulges and disks in a sample of 10 – 100 galaxies out to 10 Mpc, spanning a range of luminosities and environmental densities. The different input physics used in hierarchical galaxy formation simulations yield very different star formation histories, and predict a strong dependence on galaxy mass and environmental density. These data will thus provide a strong test of basic ideas concerning the formation of galaxies.

Summary Table:

Summarize the observations in terms of telescope, instruments, number of nights, observing mode and instrument and AO requirements.

Telescope	Instrument	# Nights	Mode	λ range(μm)	λ/δλ	AO Mode	FOV
GMT	HRCAM	10—100	Queue	0.9-2.2	5	AO	30″
TMT	IRIS	10—100	Queue	0.9-2.2	5	MCAO	15″

Scientific Motivation:

Why is this use case of scientific interest?

The star formation histories of simulated galaxy disks are sensitive to the input physics, e.g. feedback from stars, used to follow galaxy formation, as well as to the mass of the parent galaxy. Measurements of the star formation and chemical enrichment histories of galaxy disks and bulges in nearby galaxies provide a clear way to test our understanding of the galaxy formation process.

Approach:

How can you use TMT and/or GMT and their candidate instruments to address this problem? Describe the observing strategy, including target selection and the needed measurements.

We will target the bulges and disks in a sample of ~10—100 galaxies out to ~10 Mpc, spanning a range of luminosities and environments. We will use broad-band photometry down to the faintest magnitudes allowed by crowding to determine the complete star formation and chemical enrichment histories in the galaxies. ~10 pointings per galaxy will be required to disentangle the ages, metallicities, and velocities of bulge vs. disk stars and to examine their gradients, more if we find discrete features such as past starbursts that warrant higher resolution mapping. We will follow up the observations with R<~25000 spectroscopy to examine detailed abundance patterns and measure kinematic distributions.

Limiting Factors and the Current State of the Art:

What are the limiting factors for this problem (e.g. sensitivity, spatial resolution, time resolution)? Why hasn't this problem been solved with current facilities?

In the high surface brightness bulges of disk galaxies, the crowding limit is reached in exposure times <<1 hour, such that spatial resolution is the clear limiting factor. In the surface brightness typical of galaxy disks, the time needed to reach the crowding limit is >~1 hour, such that both good spatial resolution and large collecting area are needed. For R~25000 near-IR spectroscopy, sensitivity is the predominant limiting factor.

Gemini North AO and Keck AO observations are able to resolve stars fainter than the horizontal branch in the disk of M31, and thus able to deconstruct its star formation history with ~10% resolution in age. In order to target ~100 galaxies spanning a range of environmental densities, we need to be able to reach galaxies out to ~10 Mpc. For measuring star formation histories, TMT and GMT will provide useful data out to 10 Mpc.

Technical Details:

How would you actually carry out this program? Justify the sensitivities, exposure times, number of fields, total cost in terms of telescope hours or nights. Mode of observation, queue, classical, TOO, synoptic etc.

Needed sensitivities for imaging are S/N=10 at crowding limit of chosen fields. Crowding limits calculated analytically, exposure times from rough imaging ETCs. With ~10 fields per galaxy spanning a range of surface brightnesses, we require ~10 hours per galaxy for the imaging. A sample of 10—100 galaxies thus requires 10—100 nights.

Preparatory, Supporting, and Followup Observations:

What data are needed in advance of, or in support of these projects? If these require observing time on 4-10m class telescopes estimate the amount of time needed. What followup observations are needed?

Ground-based optical/near-IR surveys are needed to identify optimal field pointings in target galaxies. 8-10m AO imaging observations can be used to identify the scientifically most interesting targets and create target lists for spectroscopy. We will follow up the observations with R<~25000 spectroscopy on GMT and/or TMT to examine detailed abundance patterns and measure kinematic distributions, which will provide extra help for disentangling the distinct bulge and disk stellar populations.

Anticipated Results:

What would you expect to get from the observations? Describe simulated data and results where appropriate.

We expect to derive star formation and chemical enrichment histories in the galaxy bulges and disks with ~10% resolution in age and ~0.3 dex in metallicity from imaging alone. We have performed simulations of selected fields in galaxies out to 10 Mpc to demonstrate our ability measure precise photometry from the AO-corrected images and recover the correct stellar population mix. Spectroscopy will provide additional information on the chemical abundances and kinematics, and enhance our ability to probe the earliest generations of stars.

Requirements and Goals Beyond the GMT and TMT Baseline Instrument Designs:

Are there capabilities needed for this science that are not in the TMT and GMT telescope, AO system and baseline instrument configurations? If so, what is the flow-down from the high level goals to the instrument requirements?

No.

Describe the need for specific observing conditions or operations mode(s) (needed image quality; atmospheric transmission; need for 'interrupt-driven' observations)

The program requires photometric conditions and image quality good enough to allow the AO system to deliver near diffraction-limited performance.

Describe the potential of the resulting database for 'mining' in service of carrying out complementary scientific programs; planning future programs

The program could (for example) be designed to target fields with background quasars, with the data serving as the first epoch for future proper motion measurements.

Describe the potential role of other ground- and space- based facilities in carrying out the proposed investigation (e.g. JWST; ALMA; LST)

JWST will be able to measure the star formation and chemical enrichment histories in the low surface brightness halos of the same galaxies, thus placing the formation histories of the halos in the context of the formation histories of the bulge and disk components. An LST survey will be needed to identify the most interesting targets and field locations.

Summary:

The spatial resolution and collecting areas of TMT and GMT will greatly expand the volume within which we can resolve stars in the high surface brightness disks and bulges of local galaxies. We will, for the first time, be able to describe the star formation and chemical enrichment histories in a statistical sample of local disk galaxies. Because disks are the most fragile of galaxy components, they are excellent laboratories for studying the formation histories of galaxies. By observing local galaxies, we will probe their entire accumulated stellar populations on a galaxy-by-galaxy basis, for comparison with snapshots of statistical galaxy samples at high redshift.