KWFI Science Case

Globular Clusters, Compact Elliptical Galaxies and Ultra Diffuse Galaxies

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Executive Summary

Galaxy halos and surrounds contain important chemodynamics and accretion histories. KWFI will compile an unprecedented census in all galaxy types and environments beyond our local group. KWFI will map stellar halos and ultra diffuse galaxies to 10s of Mpc, including their density, metallicity, and substructure. KWFI is ideal to detect low-surface brightness galaxy halos and streams but also ultra-diffuse, and ultra-faint galaxies. These halos also contain globular clusters and compact elliptical (cE) galaxies.

Background

Galaxy halos hold a record of their assembly histories and star formation in diffuse components and satellites. Deep u-band enables resolved star isolation and metallicity sensitivity over redder optical bands. KWFI enables mapping of resolved stellar halos and galaxy satellites to ~10 Mpc, including their density, metallicity, and substructure. Globular clusters (GCs) are bright tracers of halo chemodynamics in galaxies beyond the Local Group. Deep, wide-field *u*-band is crucial for reducing GC photometric sample contamination. Keck spectroscopic follow-up will reach to ~30 Mpc and GC systems probed photometrically with KWFI can reach the luminosity function turnover mag out to ~100 Mpc. This capability would allow for an unprecedented census (numbers, spatial density profiles, colors as proxies for metallicities) of GCs in a variety of galaxy types and environments, and unique constraints on their host accretion histories. KWFI will be a powerful detector of compact elliptical galaxies (cEs), as well as low-surface brightness targets, including ultra-diffuse galaxies (UDGs), ultra-faint dwarfs, stellar streams and shells. KWFI can efficiently map galaxy outer regions for low level star formation and to improve SEDs, as well as the distribution of dust and escaping radiation.

The big questions

What is the origin of outer halo globular clusters?

Galaxies are thought to have formed in two phases: from in-situ formation and ex-situ or accreted material. In the most massive galaxies the fraction of accreted mass is predicted to dominate over in-situ formed mass. It is difficult observationally to test this prediction using galaxy field stars as they are well mixed. However, GCs are robust to mergers and long-lived. By identifying outer halo GCs one can hope to determine the fraction of accreted versus in-situ mass. These observations can be done efficiently with the wide field u-band capability of KWFI. Follow-up spectroscopy of GCs within 30 Mpc may reveal different mean ages to those in-situ formed GCs in galaxy central regions.

What is the relative frequency of compact elliptical galaxies that are stripped remnants versus an extension of the low mass elliptical galaxy family?

Only a few hundred compact elliptical galaxies (cEs) have been catalogued. It appears that most are the compact remnant of a larger stripped galaxy. However, a few examples are found in isolated environments too far from any nearby galaxy to have been stripped. These are good candidates for low mass ellipticals that are simply an extension of the elliptical galaxy family to the lowest masses. Wide area imaging is required to identify further examples of cEs in dense environs but also particularly those outside of groups/clusters. Once large samples have been gathered their properties can be contrasted to better determine their true origin, lending insight into the process of galaxy formation.

What is the abundance and properties of field ultra diffuse galaxies?

Figure 1: Image of an Ultra-Diffuse galaxy (middle, far right) along with several high surface brightness galaxies. Interacting galaxies (near the top) show tidal tails and stellar streams, and well as faint sources.

UDGs are relatively rare class of galaxy, with most found in group and cluster environments and a small fraction in the field. In groups and clusters, UDGs are typically red and quiescent, while those in the field have been found to be both blue and star forming or red and quiescent. Recently, simulations have provided an explanation for red and quiescent field UDGs, showing that these field UDGs can form as 'backsplash' galaxies on unbound or eccentric galaxy group and cluster orbits (Benavides et al. 2021). However, these simulations expect more UDGs in the field than observed and require deep, wide-field searches to test the predictions.

Ultra diffuse galaxies (UDGs) are very rare in the field but they are important clues to the formation and evolution of UDGs more generally. The ability to take deep imaging with a large field of view (1×1 degree) over a large photometric baseline (u-band to z-band), the Keck Wide Field Imager is uniquely poised to build a statistical sample of UDGs in the field. Its unprecedented ability to deeply image in u through z bands will allow photometric redshifts, providing far quicker environmental confirmation than is currently available (a single spectroscopic redshift for a UDG can take many hours of 10m-class telescope time). This large photometric coverage will also allow SED fitting which has proven to be an effective tool to distinguish between UDG formation mechanisms in small samples (e.g., Pandya et al. 2018). In addition, the unparalleled ability of KWFI to deeply image in the u-band will allow an investigation of star formation in UDGs. While other instruments (e.g., LSST, Euclid, HSC) can provide small parts of this science, they lack the u-band sensitivity of KWFI and so lack the accuracy and discriminatory power that its wide photometric baseline will provide. Ultimately, KWFI is the only instrument currently proposed that will be able to build an accurate, statistical sample of UDGs in field environs.

KWFI REQUIREMENTS

Deep, wide-field ($\sim 1 \times 1$ degree) u-band imaging to enables science, such as GC and galaxy selection and detection.

Full ugriz broadband imaging over the wide field.