White Paper: Integrated Light Spectroscopy at High Reoslution with MSE

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High Resolution Integrated Light Spectroscopy: Integrated Light Spectroscopy (ILS) allows chemical abundances to be determined for distant objects whose stars cannot be resolved. Most ILS work has been completed at low- to medium-resolution ($R \lesssim 6000$), allowing determinations of age, metallicity, and α-abundances (such as Mg; e.g. Schiavon et al. 2002, Lee & Worthey 2005). Recently, IL spectra of globular clusters (GCs) have been obtained at high resolution ($R \sim 20,000 - 30,000$; McWilliam & Bernstein 2008; Colucci et al. 2009, 2013; Sakari et al. 2013, 2014), enabling high precision abundances of α, iron-peak, *and* neutron capture elements; since the various elements have different nucleosynthetic sites, these detailed abundances can be used to infer the early chemical history of the host galaxies.

Extragalactic GC Systems at High Resolution: Most high resolution ILS has been of Local Group GCs (e.g. in M31; Colucci et al. 2009, Sakari et al. *in prep*). The sole exception is the Colucci et al. (2013) analysis of 10 clusters around NGC 5128 ($\sim$ 4 Mpc away). They observed for 107.5 hours on the 6.5-m Magellan Clay Telescope to obtain 10 spectra with S/N$\sim 60 - 80$; observations of individual GCs were $5 - 17$ hours. The high [Ca/Fe] abundances of the metal rich NGC 5128 GCs indicate that NGC 5128 may have experienced a more rapid chemical enrichment than the Milky Way and M31. Because NGC 5128 is the nearest elliptical galaxy, ILS is the only way to investigate this possibility; furthermore, the precision for such abundance analyses requires high resolution. However, with abundances for only 10 GCs (out of 1300; Harris et al. 2013) it is difficult to establish conclusive evidence about NGC 5128 as a whole, or about any galaxy that hosts hundreds of GCs.

High Resolution ILS with MSE: MSE is ideally suited for high resolution ILS of extragalactic GC systems. Resolutions of $R \gtrsim 20,000$ ensure that spectral lines from individual elements will be resolved. Analyses at 500-700 nm have been well calibrated (Sakari et al. 2014); extending to 400 nm offers the Balmer lines, which are essential for determining cluster age and horizontal branch morphology (Schiavon et al. 2004). However, the real benefit of MSE is its multi-object capabilities. With MSE, up to 3200 objects can be observed at once, enabling a significant fraction of a galaxy's GC system to be studied and providing a more complete picture of the formation history of galaxies of a variety of types. Any bright galaxy within ~ 4 Mpc and above $\sim -30°$ should be a feasible target for MSE; this includes the large spiral M81 (at 3.6 Mpc and with ~ 300 GCs; Harris et al. 2013) and its companion starburst galaxy M82 (with ~ 1000 GCs, some of which may be young and massive; Lim et al. 2013).

Summary: MSE will enable high resolution ILS for a complete set of GCs in galaxies out to ~ 4 Mpc. Iron-peak, α, and neutron capture lines will be detectable at $400 - 700$ nm.

References

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