Wide Integral Field Infrared Survey of Nearby Galaxies

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Cozumel 2016
Visible

- Several wide integral field spectroscopic surveys
- Focus mainly on nearby galaxies
  - SAURON ($N_{\text{gal}} = 72$)
  - ATLAS$^3$D ($N_{\text{gal}} = 260$)
  - CALIFA ($N_{\text{gal}} = 667$)
  - SAMI (Ongoing, $N_{\text{gal}} \sim 3000$)
  - MaNGA (Ongoing, $N_{\text{gal}} \sim 10000$)
- Increasing utility of 2-4 meter class telescopes

Infrared

- Several narrow integral field spectroscopic surveys
- Focus on distant galaxies ($z \sim 1-4$) or centres of nearby galaxies
  - SINS ($N_{\text{gal}} = 60$)
  - KMOS$^3$D ($N_{\text{gal}} = 600$)
  - KROSS ($N_{\text{gal}} = 1000$)
- Require large aperture 8-10 meter class telescopes
Observing Galaxies in the IR

Current State:

- Near-IR IFS surveys mostly target high-z galaxies
  - FOV better fit high-z targets
  - Study rest-frame optical features

Potential Opportunities for Nearby Galaxies:

- Large range in wavelength
- Low extinction
- Rich in spectral features of late-type and evolved stars

For nearby galaxies, NIR spectral range is hardly explored compared to the visible
# WIFIS: Wide Integral Field Infrared Spectrograph

**PI:** D.-S. Moon  
**Project/Instrument Scientist:** S. Sivanandam

## Instrument Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field of View</td>
<td>50” x 20”</td>
</tr>
<tr>
<td>Spatial Sampling</td>
<td>1.1”x1.1”</td>
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<tr>
<td>Telescope</td>
<td>UAz Bok 2.3-meter (90”)</td>
</tr>
<tr>
<td>Modes</td>
<td>0.9-1.35 μm, 1.5-1.7 μm*</td>
</tr>
<tr>
<td>Detector</td>
<td>HAWAII-2RG 1.7μm</td>
</tr>
<tr>
<td>Spectral Resolution</td>
<td>3,000, 2,200</td>
</tr>
</tbody>
</table>

* Reduced sensitivity due to thermal background

- **Commissioning second half of this year**

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**Arizona 90” Bok Telescope (Credit: UAz)**

**CAD Model of WIFIS**
Comparison of Fields of View of IR IFSes

Visible IFS, Infrared IFS
**Stellar Populations in the INfrared Survey (SPINS)**

Study Stellar Populations in Nearby Galaxies through IR Integral Field Spectroscopy

**Primary Scientific Questions:**

- Does the low-mass end of Initial Mass Function (IMF) vary with galaxy properties?
- What is the contribution of thermally pulsing AGB (TP-AGB) stars to stellar light in the infrared?

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HR Diagram of M55
12 Gyr old Globular Cluster - Stellar astrophysicist’s view
(Credit: Mochejska & Kaluzny)
Relative Stellar Contributions to IR Light

- ~40-50% RGB
- ~10-20% other MS dwarfs
- ~10% KM dwarfs
- ~10-20% AGB

Worthey (1994)
WIFIS Measurements of Low-Mass IMF in Galaxies
Measuring the IMF of Early Types and Spiral Bulges

11 Gyr old solar metallicity models from Conroy & van Dokkum 2012a

Spatially Resolved Spectroscopy of Prototypical Elliptical Galaxy ($\sim10^{11} M_\odot$)
• $t_{\text{int}+\text{overhead}} = 4$ hours (for required SNR)
Thermally Pulsating AGB Stellar Contribution

Observations of $z \sim 0.2$ Poststarburst Galaxies - Claim no need for TP-AGB stars
Low resolution IR spectra (Zibetti et al. 2013)
Sample

50 nearby elliptical galaxies/spiral bulges
- Broad range of velocity dispersion and metallicity
- Existing optical wide integral field data

10 nearby post-starburst galaxies

Preferred Parent Sample: CALIFA
- Good match of angular extent and spatial resolution
- Large sample of nearby (0.005 < z < 0.03) galaxies
- Covers the entire Hubble sequence

Future plan: MaNGA galaxies

Complement optical large-field IFS surveys
Extensions of WIFIS Nearby Galaxy Survey

- **Star Formation**
  - High Mass Star Formation
  - Star Formation in Merging Systems

- **Stellar Populations**
  - Population Gradients in Spirals

- **Dust Distribution in Galaxies**
  - Extinction Maps (Hα/Paβ)

- **Kinematics**
  - Merging System Dynamics
  - Stellar Dynamics
  - Characterization of Pseudo-Bulges

- **Active Galactic Nuclei**
  - Nuclear Activity in Seyfert Galaxies

**Opportunities for Nearby Galaxies:**

- Low extinction
- Rich in spectral features of late-type and evolved stars
- Light not dominated by the youngest stars

**Interested in Potential Collaborators**
Stellar IMF from Extragalactic Observations

Recent work suggests significant variation in IMFs in different galaxies.

van Dokkum & Conroy (2012)

Nearby Elliptical Galaxies
Long slit measurements

Recent work suggests significant variation in IMFs in different galaxies.
Stellar IMF from Extragalactic Observations

Stellar Population Synthesis (SPS) Analysis

- Corroborated by other SPS works of early types (e.g. Spinnello+12)
- Bottom-light IMF observed in low mass dwarf spheroidal galaxies (Geha+13)

Conroy & van Dokkum (2012b)
Martinez-Navarro et al. (2015)

CALIFA Integral Field Survey
Study of IMF variation in galaxy sample
Stellar IMF from Extragalactic Observations

Kinematic Measurements of IMF

Early-type Galaxies (ATLAS$^{3D}$) Cappellari et al. (2012)
Studies of the Same Galaxies Inconsistent
Stellar IMF from Extragalactic Observations

Not all results of stellar IMF variation in agreement

Coma Galaxies Smith et al. (2012)

Lensing Measurement Smith et al. (2013)
Smith et al. (2015)
Signatures of Dwarfs and Giants in the NIR

IRTF Spectral Library (Rayner et al. 2009)
Simulated Observations of A Typical Galaxy

Prototypical Elliptical
- $J_{tot} = 10$ mag
- $R_e = 30''$ (~10 kpc at 0.02)
- deV profile
- 3 Gyr Chabrier IMF
- $t_{\text{int+overhead}} = 4$ hours

Systematic errors from sky subtraction and telluric absorption not included
Are thermally pulsing AGB (TP-AGB) stars a significant contributor to stellar light in the infrared?
Late Evolution of Low and Intermediate Mass Stars

- 0.8-8 M\(_\odot\) stars undergo an asymptotic giant branch phase where they exhaust their almost all of their nuclear fuel.

- During the AGB phase, the luminosity of these objects increases several orders of magnitude when they begin to thermally pulsate.

(Wiescher 2009)
Thermally Pulsating AGB Stars

Helium shell burning luminosity for 3 M⊙ in TP-AGB phase (Stancliffe et al. 2004)

Structure of TP-AGB star
The range of stellar spectra for AGB stars (carbon-rich/oxygen-rich) (Rayner et al. 2009)
Thermally Pulsating AGB Stellar Contribution

- Previous models neglected their contribution because of the short timescale.
- Important contributors for galaxies with stellar ages within 0.2-2 Gyr.
- Overestimate stellar mass by factor of 2 when using NIR luminosities.

Solar Metallicity 1Gyr old Population Model (Maraston 2005)
Thermally Pulsating AGB Stellar Contribution

Contribution of TP-AGB stars is a strong function of metallicity and age (Zibetti et al. 2013)

- Complexities arise from the lack of understanding of TP-AGB star physics
- Ratios of carbon-rich or oxygen-rich stars need to be determined
Thermally Pulsating AGB Stellar Contribution

Observations of Nearby Spirals - Show Strong Evidence of TP-AGB Stellar Features

Moderate resolution IR spectra (Riffel et al. 2015)
High-z Thermally Pulsating AGB Stellar Contribution

Studies seems to go back and forth between needing the TP-AGB stars for high-z galaxies.

Most recent work looking at ~50 spectroscopically confirmed, high-z (1 < z < 3) galaxies suggests that TP-AGB heavy models are favoured but including reddening to TP-AGB light models produces good results too.

This issue will be crucial to JWST studies of high-z galaxies when it launches in 2018.

SED Fit of high-z Galaxy with different stellar population synthesis models
(Capozzi et al. 2016)