Wide Integral Field Infrared Spectrograph Nearby Galaxy Survey

Suresh Sivanandam
Dunlap Fellow
Dunlap Institute, University of Toronto

Key Personnel:
Dae-Sik Moon (PI, UofT), Richard Chou (ASIAA), Josh Eisner (Arizona)

Collaborators:
Ke Ma (UofT)  Moo-Young Chun (KASI)
Simona Lam (UofT)  Sang Chul Kim (KASI)
Maxwell Millar-Blanchaer (UofT)  Steven N. Raines (UF)
Stephen S. Eikenberry (UF)
Outline

• Background
• WIFIS in a Nutshell
• Motivation of Survey
• Proposed Science
Applications of IFS

Spatially Resolved Kinematics

ATLAS3D

Spatially Resolved Stellar Populations

SAURON

Cappellari et al. (2011)

Peletier et al. (2007)
Applications of IFS

Light Bucket Observations

VIRUS-P

M87

Kinematics out to $\sim 5 \ r_e$!

Murphy et al. (2011)
Applications of IFS

Galaxy Dynamics and Star Formation at $z \sim 2$

Near-IR IFSs: FOV much smaller compared to optical IFSs!

Förster Schreiber et al. (2009)
WIFIS *large etendue, seeing-limited, NIR IFS*

- Simultaneous wavelength coverage
  
  0.9-1.35 µm or 1.5-1.7 µm (optional future capability)

- Resolving power ~ 3,000

- Number of spectra ~ 500

- Adaptable to different size telescopes

2.3m
Large FOV
50”x20”
1.1”/slice

6.5m
High sensitivity
18”x7”
0.4”/slice
**Etendue**: Figure of Merit

Collecting area X FOV

![Graph showing etendue for various instruments](image)
Etendue: Figure of Merit
Collecting area $\times$ FOV

![Graph showing the relationship between etendue and spectral resolving power for various instruments.](image)
WIFIS in a nutshell
UA 90” (Bok) Telescope

- Site: Kitt Peak, USA
- Latitude: 32° N
- 2.3-meter f/9 telescope
- Seeing: ~1.5” (median)

UA open to large programs during bright time

Follow highly successful VIRUS-P model
Chou et al. (2010), Sivanandam et al. (2012)

See Chou’s poster for optical design/performance details
System Layout

Chou et al. (2010), Sivanandam et al. (2012)
See Chou’s poster for optical design/performance details
Integral Field Unit (FISICA)

- Imager slicer type IFU
- Transforms rectangular field to virtual long slit
- 22 slices (18 are used in WIFIS)
- On long-term loan from Univ. of Florida
- Tested at KPNO 4-m with FLAMINGOS

Pseudo-slit image

Slicer

IFU

Credit: Nick Raines

Eikenberry et al. (2004)
Detector System

Teledyne HAWAII-2RG system

- State-of-the-art array
- 2048x2048 pixels
- Teledyne ASIC Readout
- Reference Pixel Subtraction

Operating Parameters:

- QE ~ 80% (0.8 - 2.5 µm)
- Read Noise ~ 5 e⁻ (up-the-ramp)
- Dark Current < 0.02 e⁻/s/pixel
NIR Backgrounds

Sky and thermal backgrounds

Sivanandam et al. (2012)
Continuum Sensitivity

Point Source - $10\sigma$ in 1 hr on-source (in between OH lines)
Continuum Sensitivity

Extended Source - $10\sigma$ in 1 hr on-source (in between OH lines)
Continuum Sensitivity

Extended Source - 10σ in 1 hr on-source (in between OH lines)

>1 r_e for typical elliptical
Project Status

**Completed**
- Optical Design
- Optical Component Fabrication
- FISICA IFU
- Detector Subsystem

**In Progress**
- Mechanical Design
- Fabrication of Mechanical Components
- Software Development / Pipeline
- Integration and Testing

Spectrograph Camera Lens
Project Status

Completed

• Optical Design
• Optical Component Fabrication
• FISICA IFU
• Detector Subsystem

In Progress

• Mechanical Design
• Fabrication of Mechanical Components
• Software Development / Pipeline
• Integration and Testing

Expected Completion
Q4 2013
Motivation of Survey
# Age of Large Scale IFS Surveys

## Optical
- Several wide integral field spectroscopic surveys
- Focus mainly on nearby galaxies
  - **SAURON** (Survey)
  - **ATLAS3D** (Survey)
  - **VENGA** (Ongoing Survey)
  - **CALIFA** (Ongoing Survey)
  - **SAMI** (Ongoing Survey)
  - **HETDEX** (Upcoming Survey)
  - **MaNGA** (Upcoming Survey)
- ~10,000s of galaxies

## Infrared
- Several narrow integral field spectroscopic surveys
- Focus on distant galaxies
  - **SINS** (Survey)
  - **OSIRIS** (Instrument)
  - **KMOS** (Instrument)
    - 24 multiple IFUs that carry out multi-object IFS at VLT
    - Study high-z galaxies
Near-IR surveys mostly target high-z galaxies

- FOV the NIR IFSs better fit high-z targets
- Study familiar rest-frame optical features
- Expensive

For nearby galaxies, NIR spectral range is hardly explored compared to optical
Near-IR surveys mostly target high-z galaxies

- FOV the NIR IFSs better fit high-z targets
- Study familiar rest-frame optical features
- Expensive

For nearby galaxies, NIR spectral range is hardly explored compared to optical

This gap can be filled with Bok+WIFIS
Galaxies in the NIR

Virtues of Near-IR

- Larger wavelength range compared to optical window
- Low extinction ($A_\lambda/A_V \sim 0.25-0.4$ in WIFIS passband)
- Rich in spectral features of late-type stars and giants

Emission line spectroscopy (Low SNR)

- Gas ionization state, Gas kinematics, SFR and SFH, Nuclear activity
- Calibrate IR relations

Absorption line spectroscopy (High SNR)

- Stellar populations, Stellar kinematics, Abundances
- Sensitive to low mass stellar dwarf component (constrain IMF)
Proposed Science
Lines sensitive to either late-type dwarfs or giants

Conroy & van Dokkum (2012)
IMF of Nearby Galaxies

Bottom-heavy IMF, M/L ratio increases with $\sigma$ and $\alpha$ enhancement

Conroy & van Dokkum (2012)
Stellar Properties

Carry out spatially resolved characterization of IMF and stellar abundances.
Gastrophysics

- Ionization state, excitation mechanisms, star formation, kinematics
- $\text{Pa}\beta$ relatively extinction insensitive SFR indicator
- $\text{Pa}\beta/\text{H}\alpha$ ratio traces extinction
- $\text{[FeII]}$ traces shocks from AGN and SNR
- Multitude of lines that can be used for gas kinematics

Spectral Atlas of HII galaxies (Martins et al. 2013)
AGNs - Seyferts

- Seyfert AGNs heavily obscured
- Study AGN properties
- Measure large scale outflows and interactions with the rest of galaxy

Ramos Almeida et al. (2009)

Alonso-Herrero et al. (2007)
Pilot Survey Sample

- Complement optical large-field IFS surveys (e.g. CALIFA, VENGA)
- CALIFA is best matched in terms of angular extent and spatial resolution
- Large sample of nearby galaxies
- Covers the entire Hubble sequence
- Public data releases
- Final sample size ~ 50 galaxies

CALIFA observation of NGC 5406 with two WIFIS pointings (magenta) overlaid
Husemann et al. (2013)
And Many More

- Mergers
- (U)LIRGs
- Evolution of cluster galaxies
- Low surface brightness spectroscopy
- And any other ideas you might have
Summary

• WIFIS is a large etendue, seeing-limited, near-infrared IFS that is coupled to a 2.3-meter telescope

• Nearby galaxies completely new phase space

• Near-IR offers new opportunities such as:
  • Characterization of the late-type stellar component and IMF
  • Stellar kinematics and abundances
  • Low extinction measurement of spectral lines, including the near-IR SFR indicator Paβ
  • AGN activity and outflows

Please come talk to me if you are interested
Line Sensitivity

**Point Source** - $10\sigma$ in 1 hr on-source (in between OH lines)
No continuum