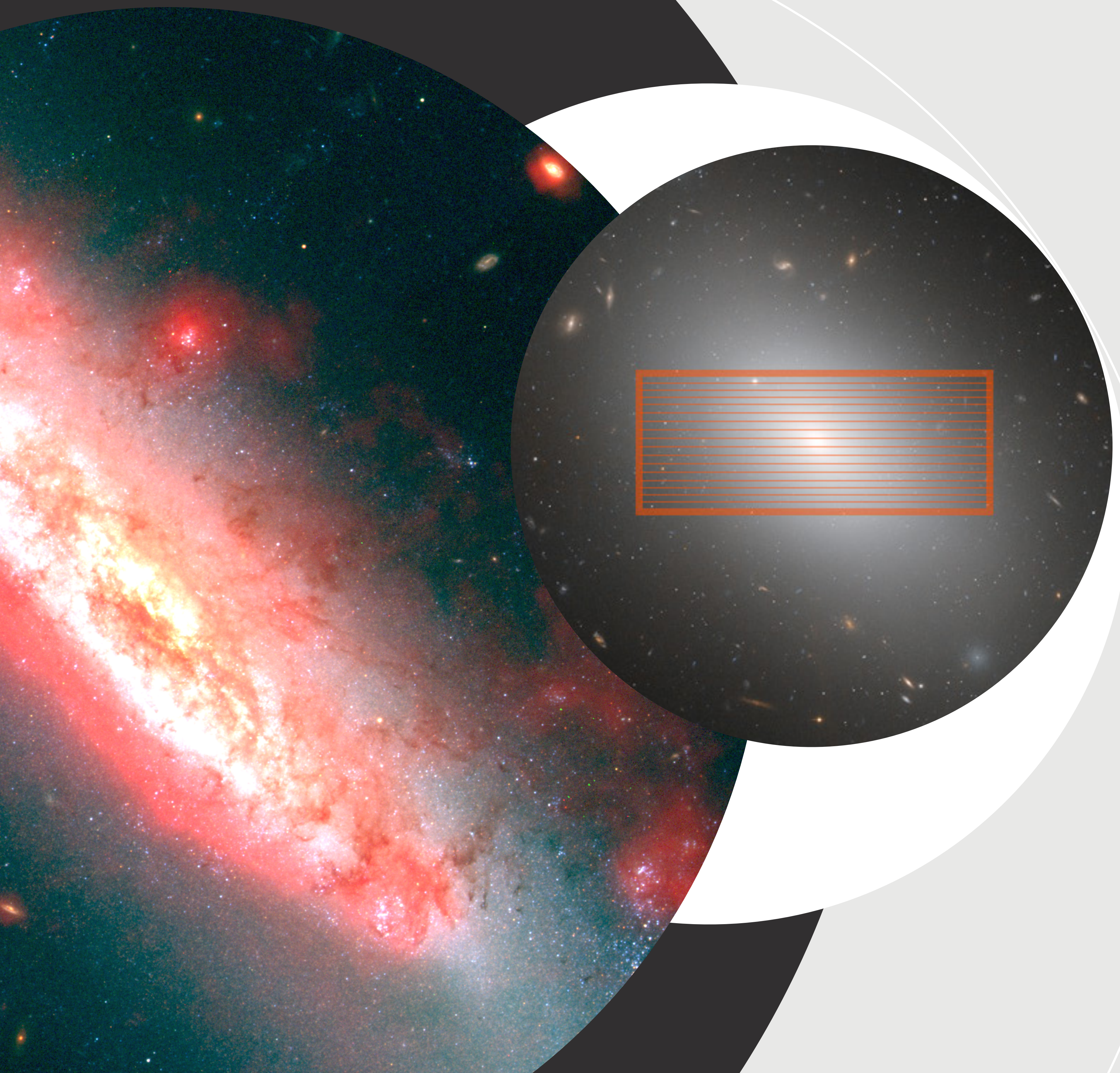

DUNLAP INSTITUTE
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Wide Integral Field Infrared Survey of Nearby Galaxies

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Dunlap Institute
University of Toronto

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Students: *E. Meyer (Toronto), M. Jarvis (MPA)*

Dunlap Institute for
Astronomy & Astrophysics
UNIVERSITY OF TORONTO

Cozumel 2016

Age of Large Scale IFS Surveys

Visible

★ Several wide integral fie
spectroscopic survey

★ Focus mainly on ne

- **SAURON (N_{ga}**
- **ATLAS[3D] (N_{ga}**
- **CALIFA (N_{gal}**
- **SAMI (Ongoin**
- **MaNGA (Ongoi**

★ **Increasing utility of 2**
telescopes

?

Infrared

w integral field
surveys

galaxies (z~1-4) or
galaxies

60)

(N_{gal} = 600)

(N_{gal} = 1000)

aperture 8-10 meter class

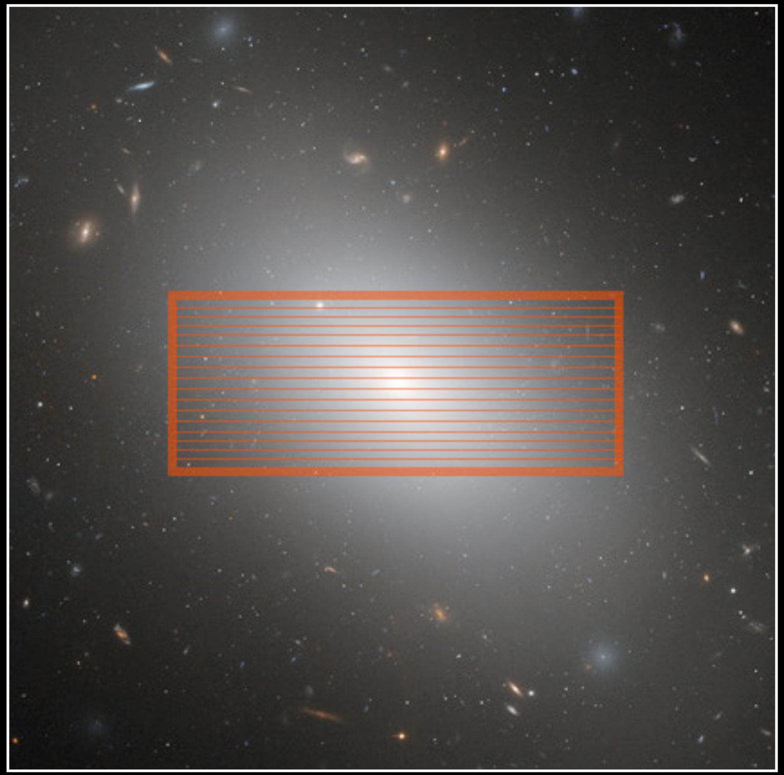
Observing Galaxies in the IR

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



NGC1132 with large integral field overlaid

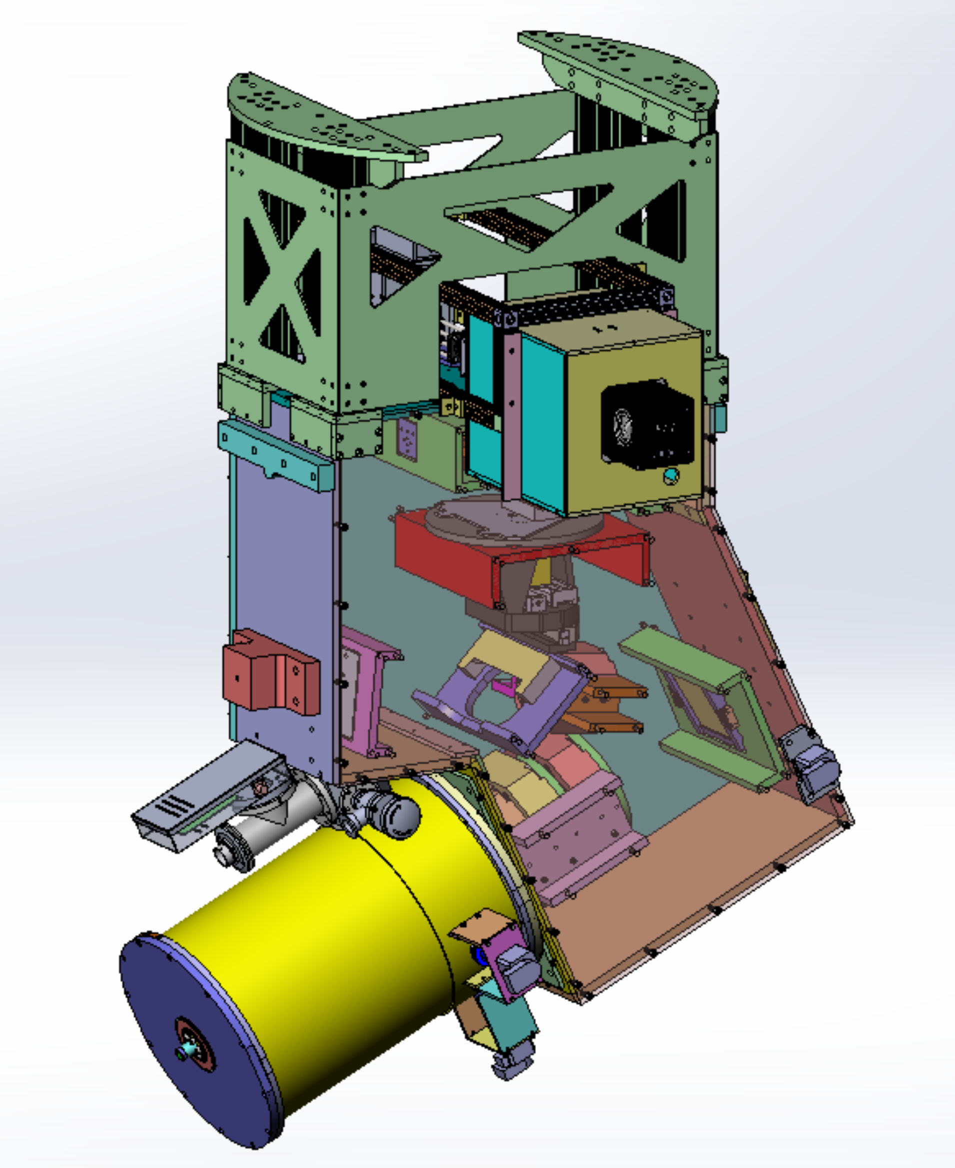
For nearby galaxies, NIR spectral range is hardly explored compared to the visible

WIFIS: Wide Integral Field Infrared Spectrograph

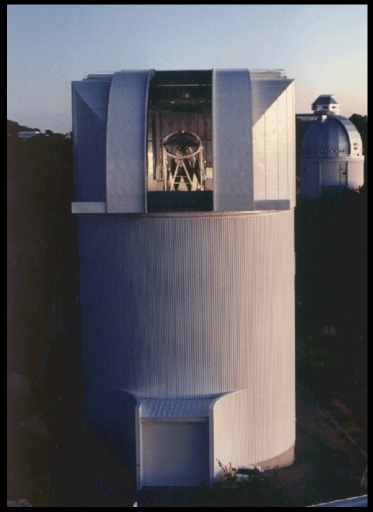
PI: D.-S. Moon
Project/Instrument Scientist: S. Sivanandam

Instrument Parameters		
Field of View	50" x 20"	
Spatial Sampling	1.1"x1.1"	
Telescope	UAz Bok 2.3-meter (90")	
Modes	0.9-1.35 μm	1.5-1.7 μm*
Detector	HAWAII-2RG 1.7μm	
Spectral Resolution	3,000	2,200

* Reduced sensitivity due to thermal background



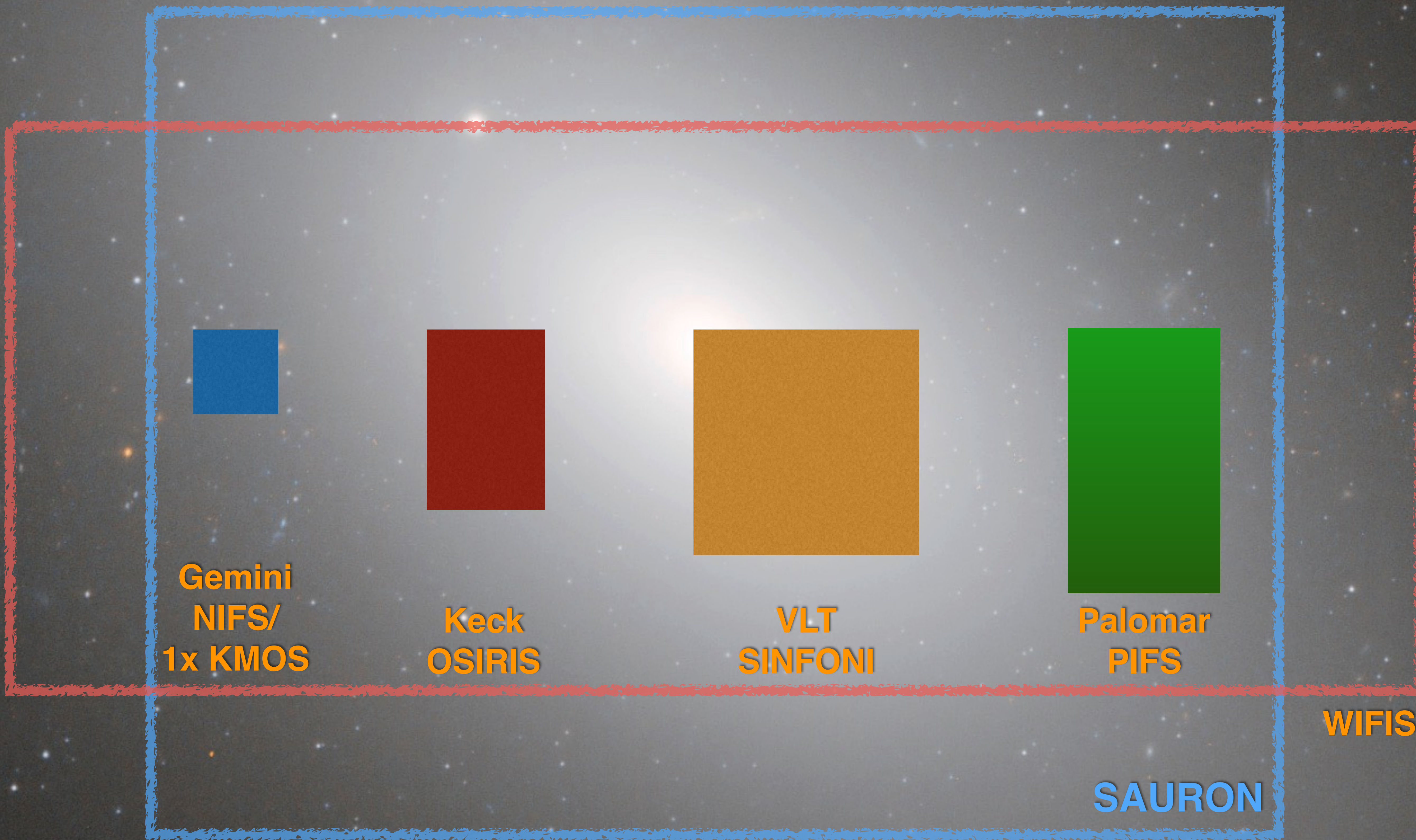
CAD Model of WIFIS



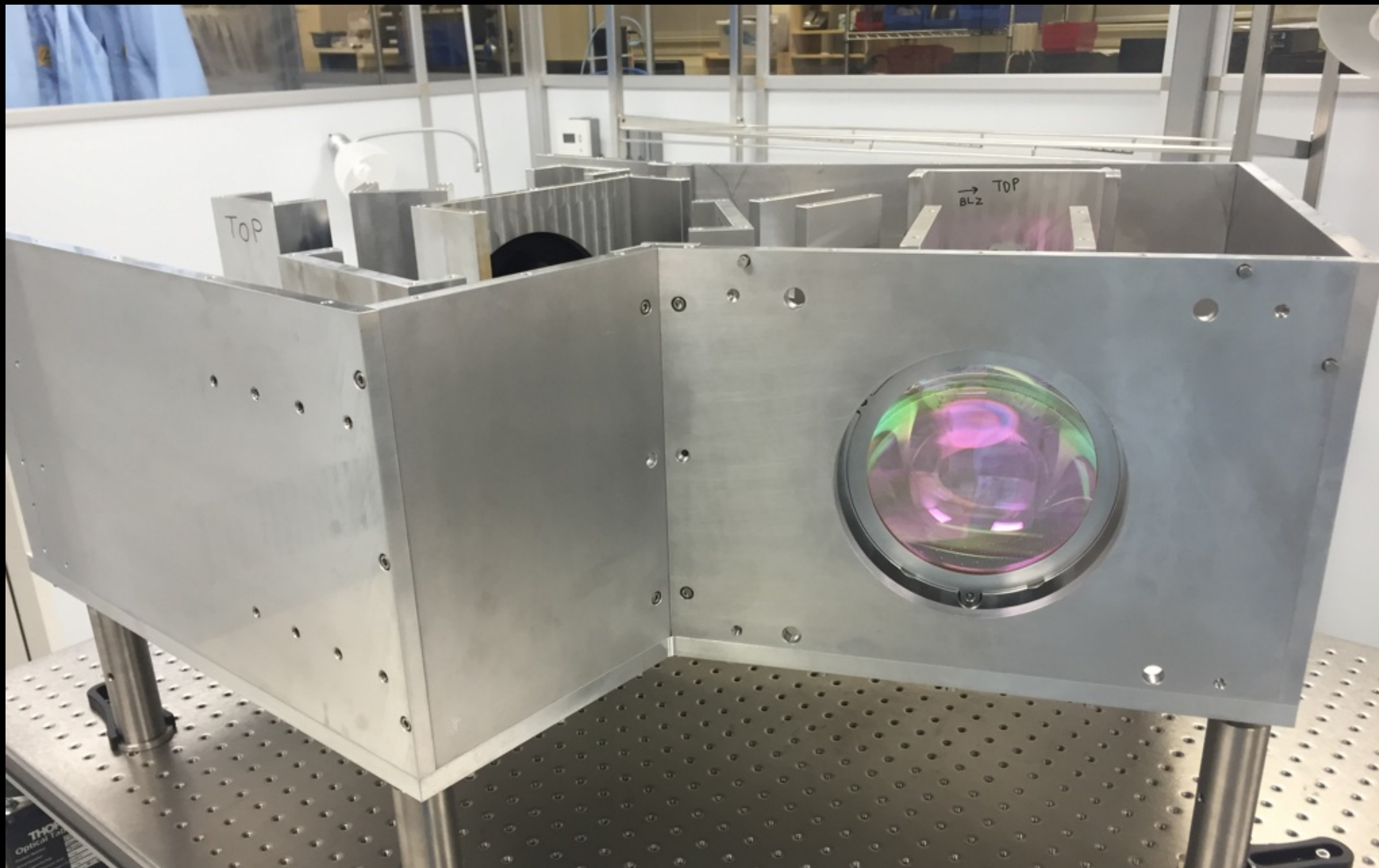
Arizona 90" Bok Telescope (Credit: UAz)

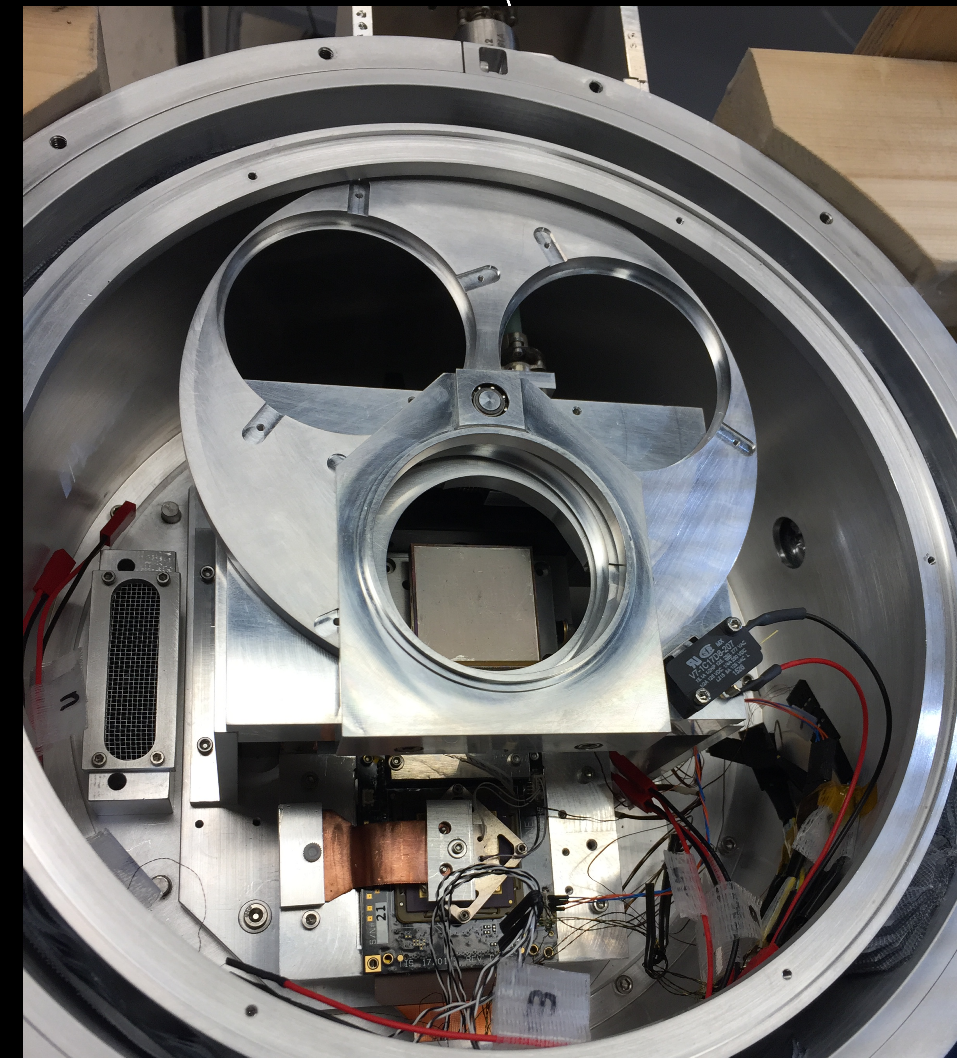
- Commissioning second half of this year

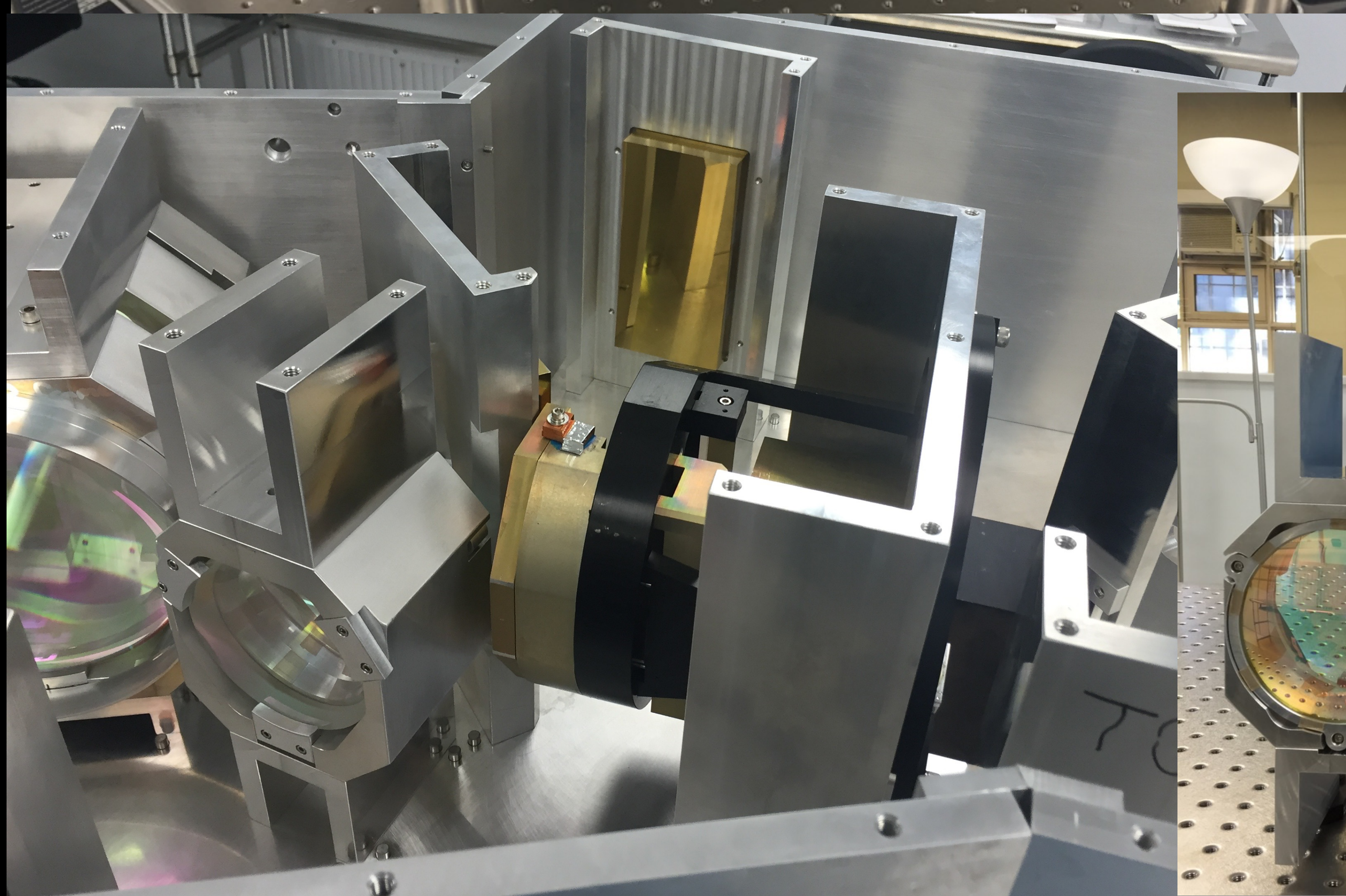
Comparison of Fields of View of IR IFSes

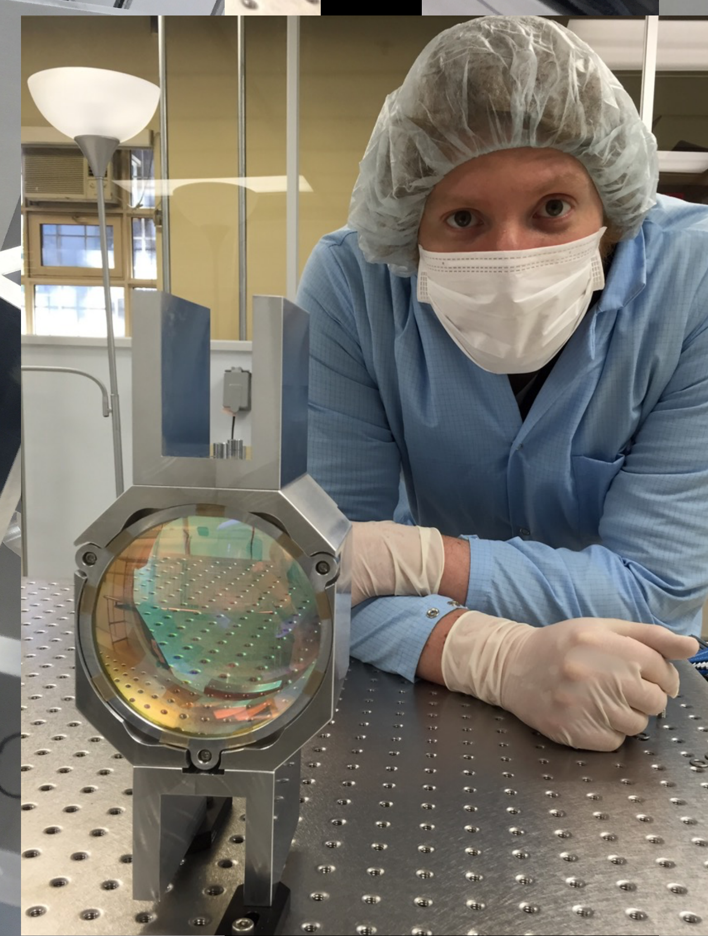


Visible IFS, Infrared IFS


TOP
BLZ TOP





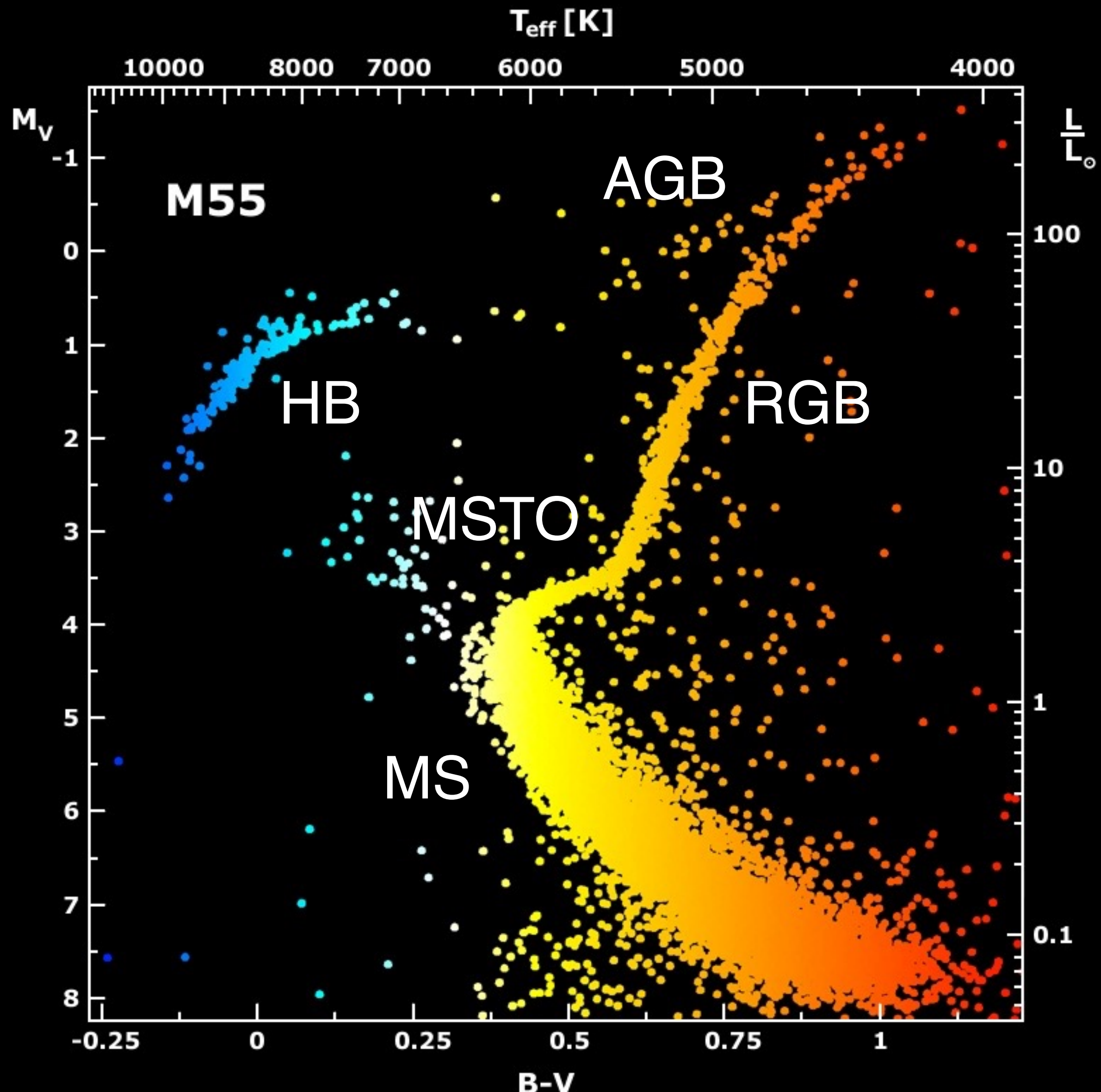


Stellar Populations in the INfrared Survey (SPINS)

Study Stellar Populations in Nearby Galaxies through IR Integral Field Spectroscopy

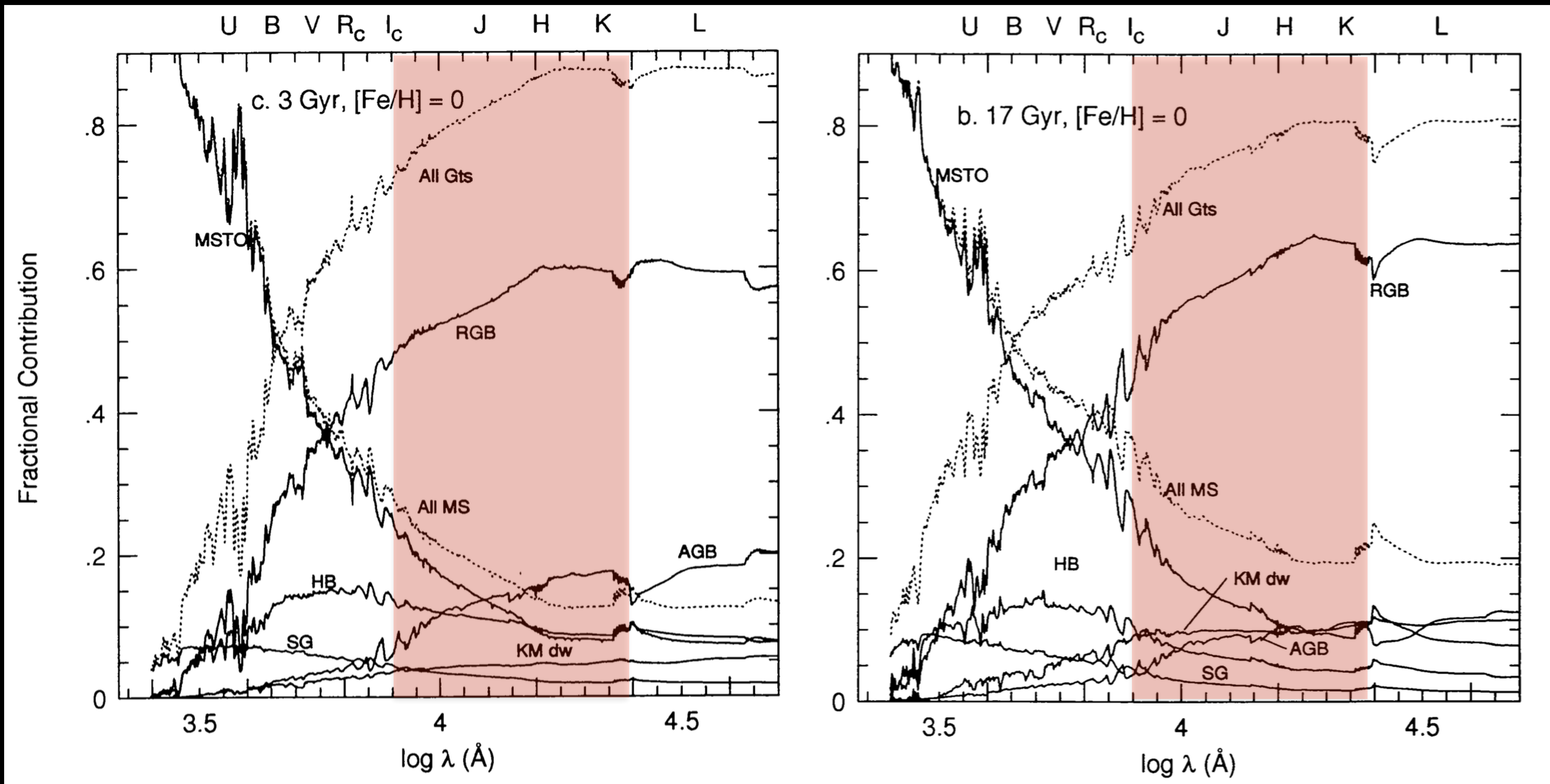
Primary Scientific Questions:

- 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?



HR Diagram of M55
12 Gyr old Globular Cluster - Stellar astrophysicist's view
(Credit: Mochejska & Kaluzny)

Relative Stellar Contributions to IR Light

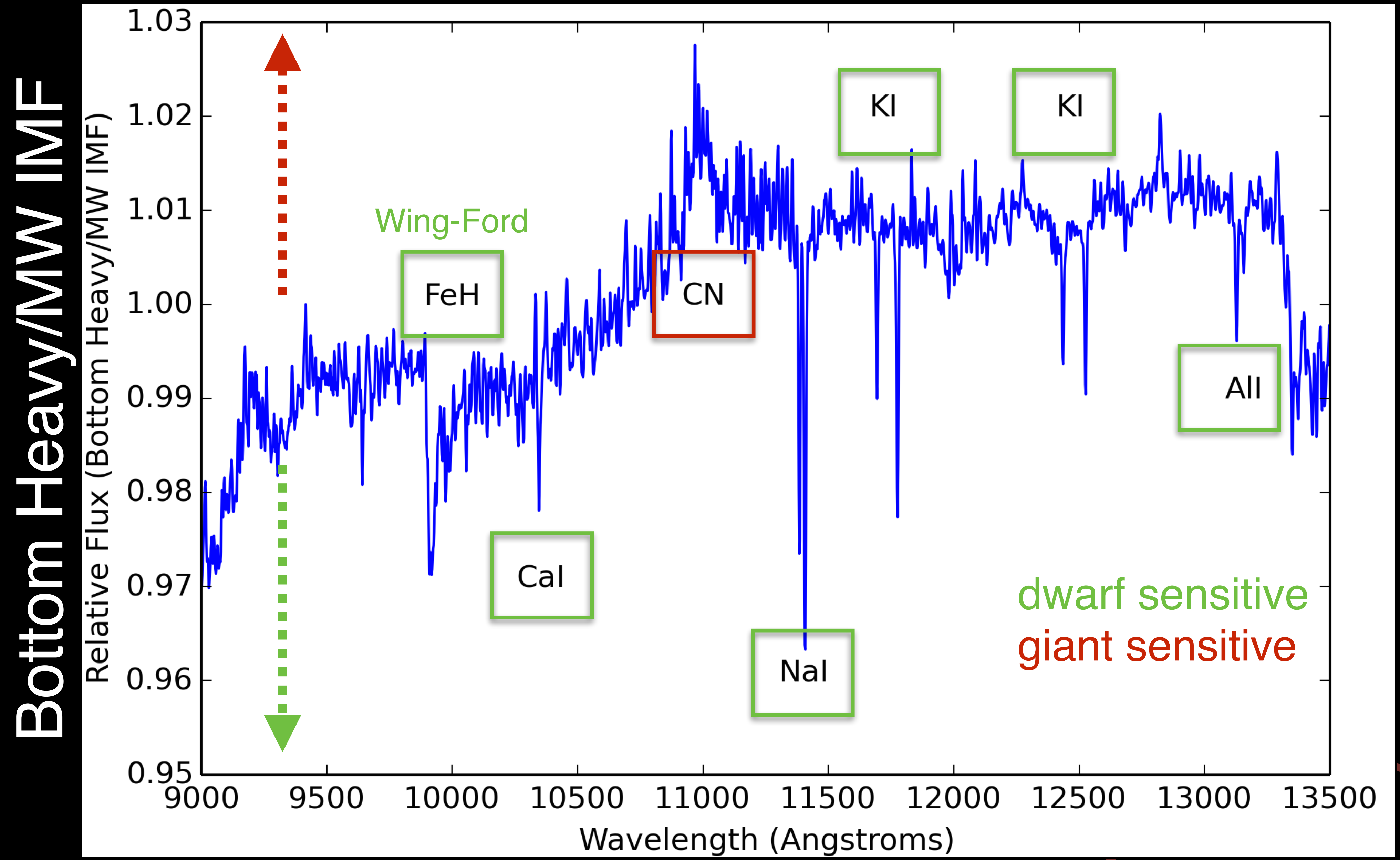


Worthey (1994)

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

WIFIS Measurements of Low-Mass IMF in Galaxies

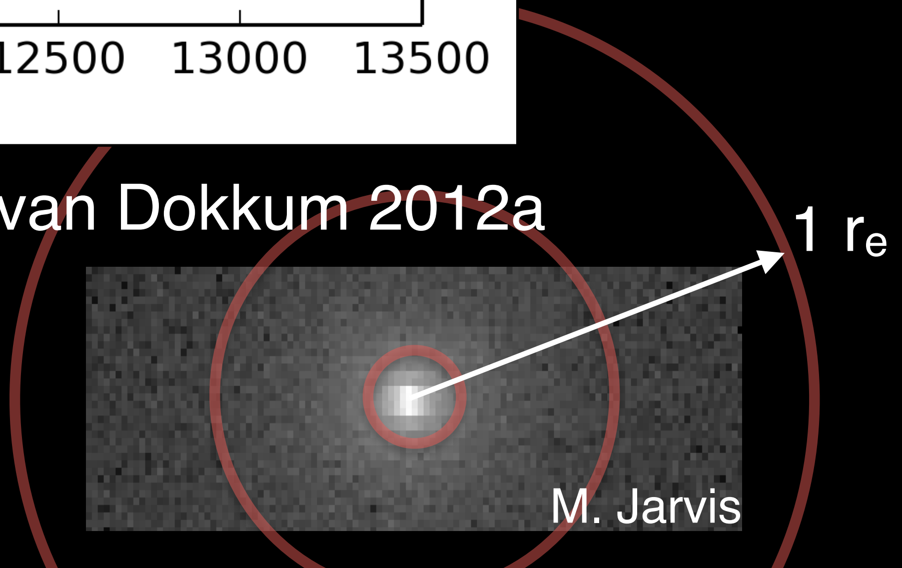
Measuring the IMF of Early Types and Spiral Bulges



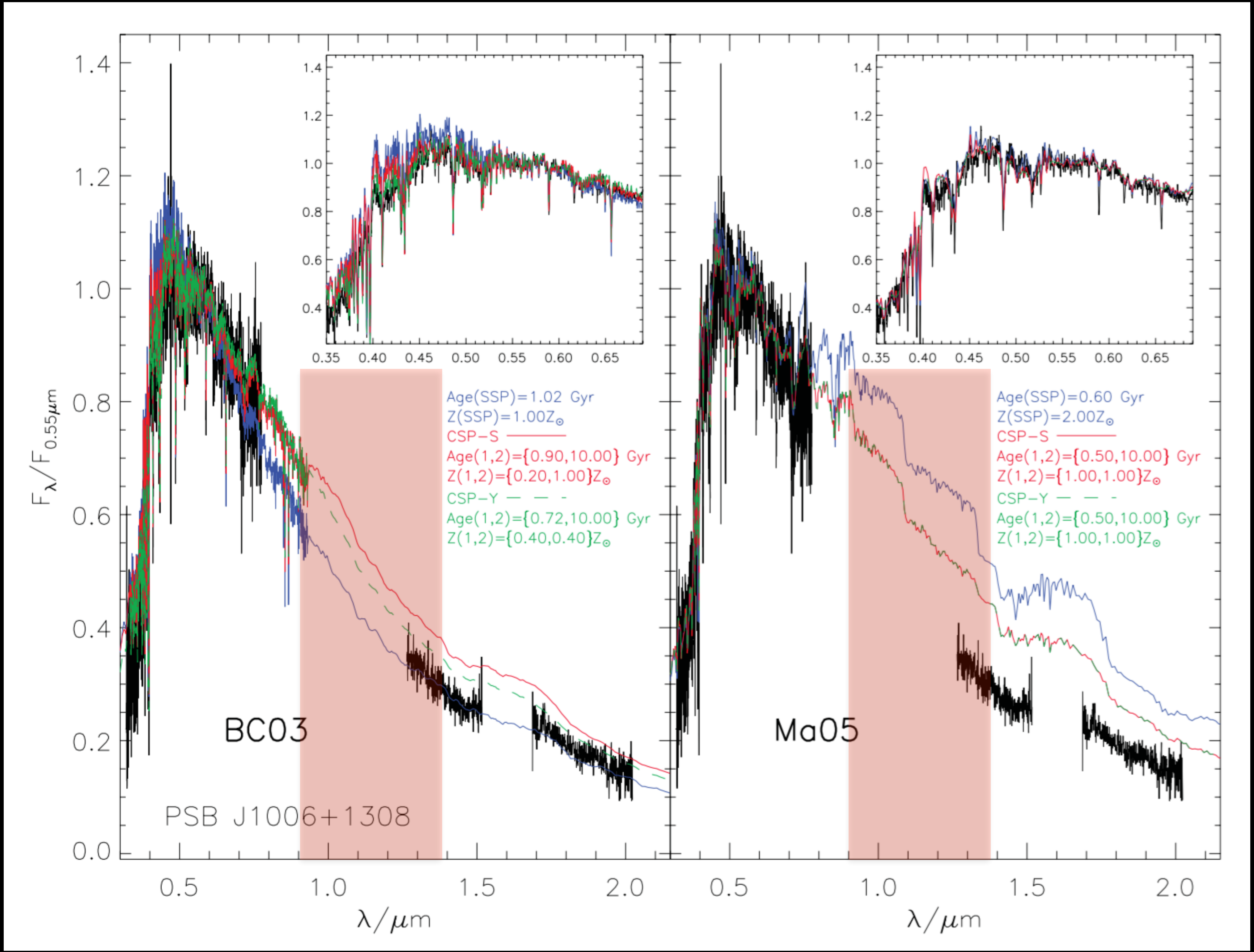
11 Gyr old solar metallicity models from Conroy & van Dokkum 2012a

Spatially Resolved Spectroscopy of Prototypical Elliptical Galaxy (~10^{11} $M_\odot$)

- $t_{int+overhead}$ = 4 hours (for required SNR)



Thermally Pulsating AGB Stellar Contribution



Observations of z ~ 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

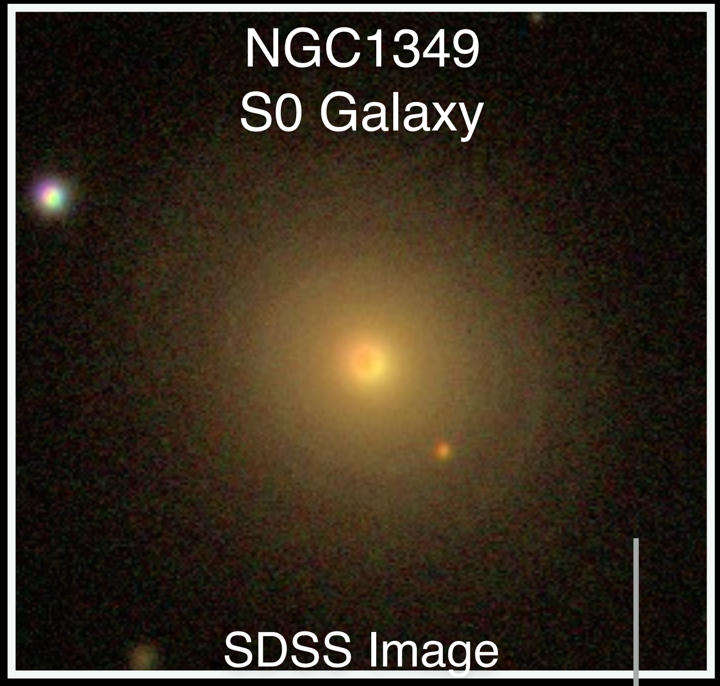
- Broad range of velocity dispersion and metallicity
- Existing optical wide integral field data

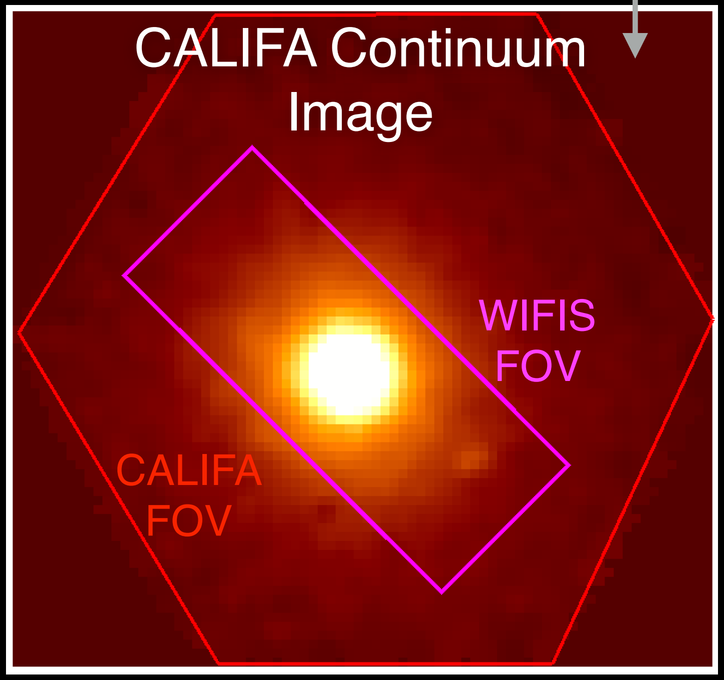
10 nearby post-starburst galaxies

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

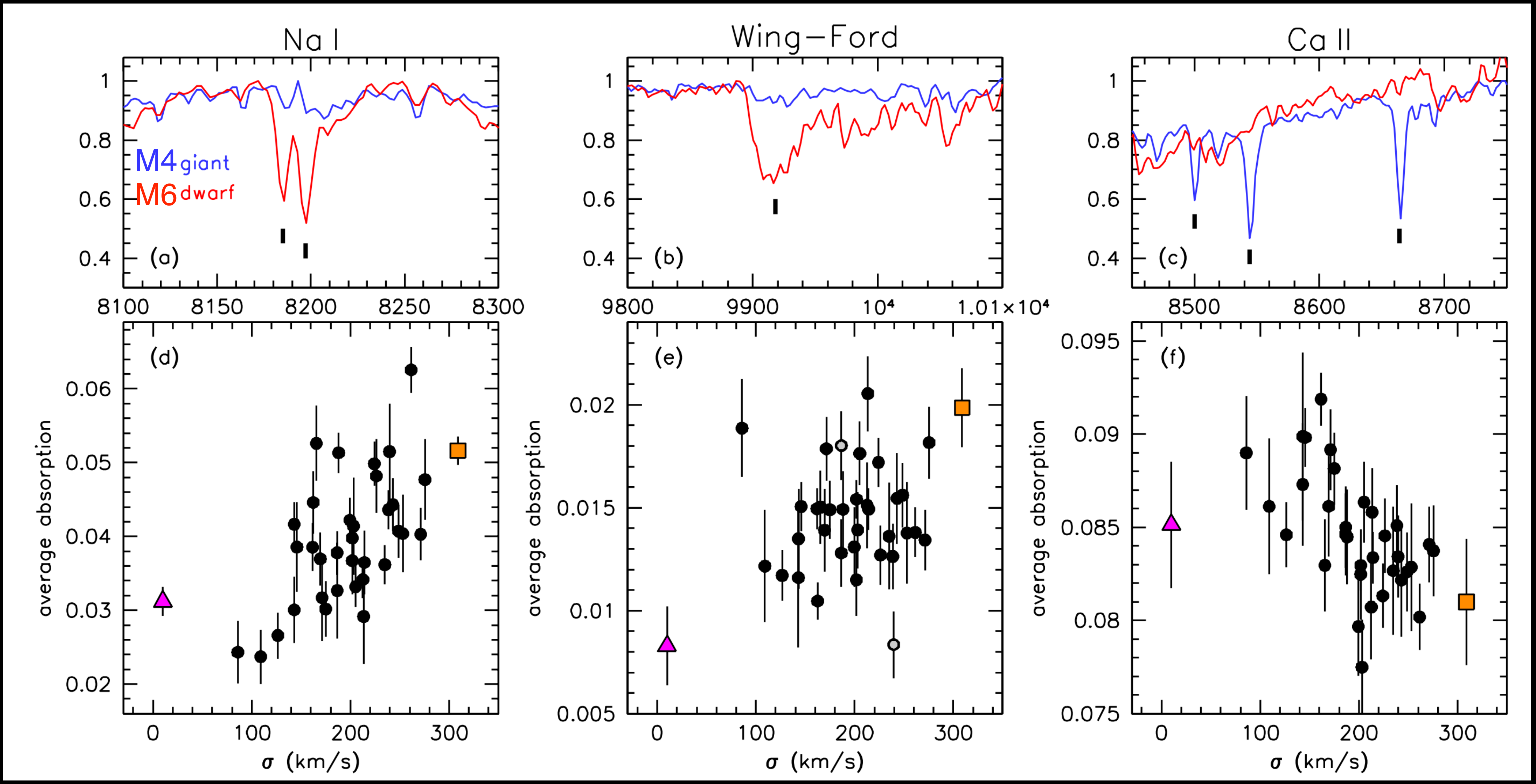
Opportunities for Nearby Galaxies:

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

Interested in Potential Collaborators

Extra Slides

Stellar IMF from Extragalactic Observations



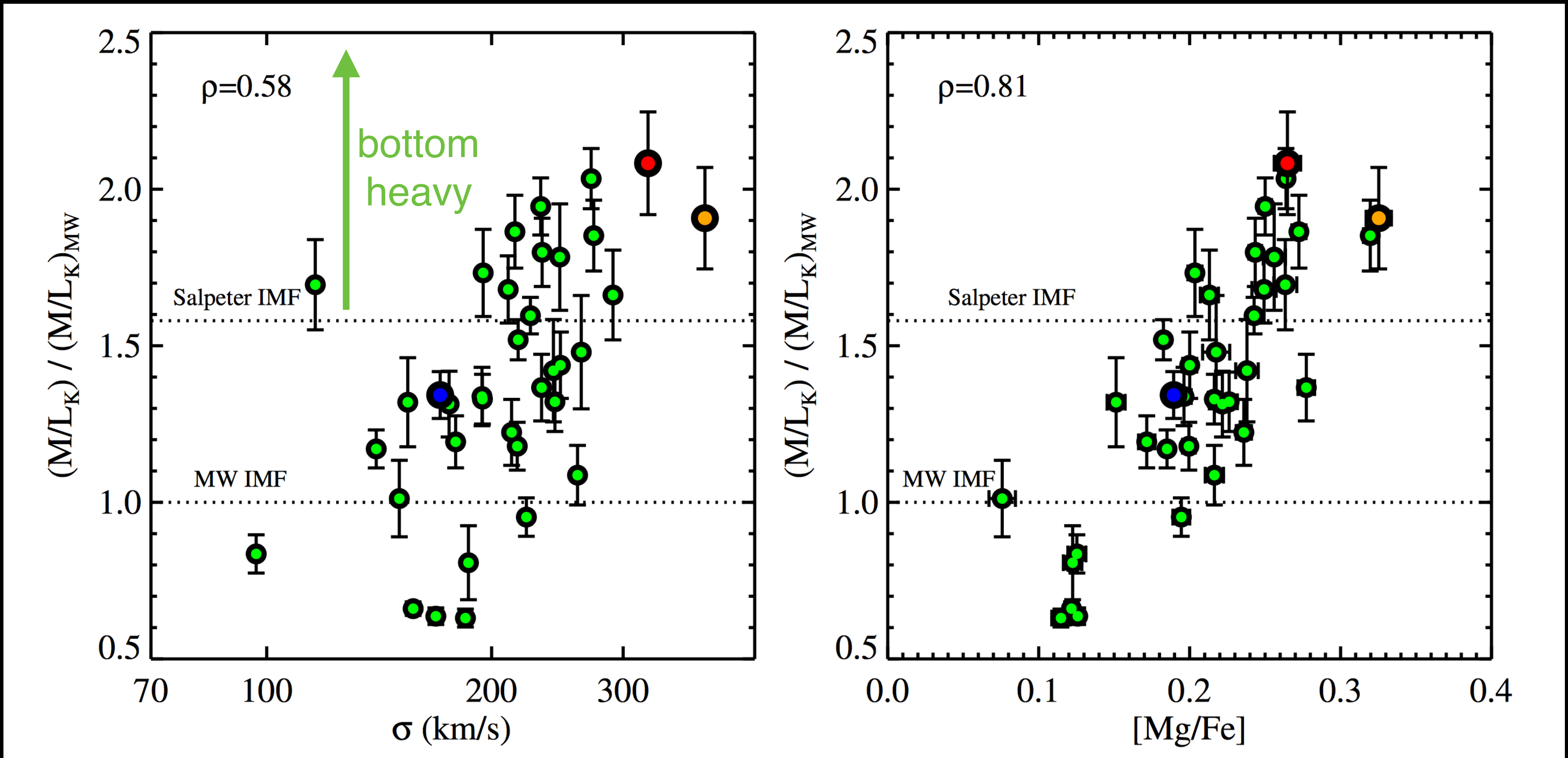
Nearby Elliptical Galaxies

Long slit measurements

van Dokkum & Conroy (2012)

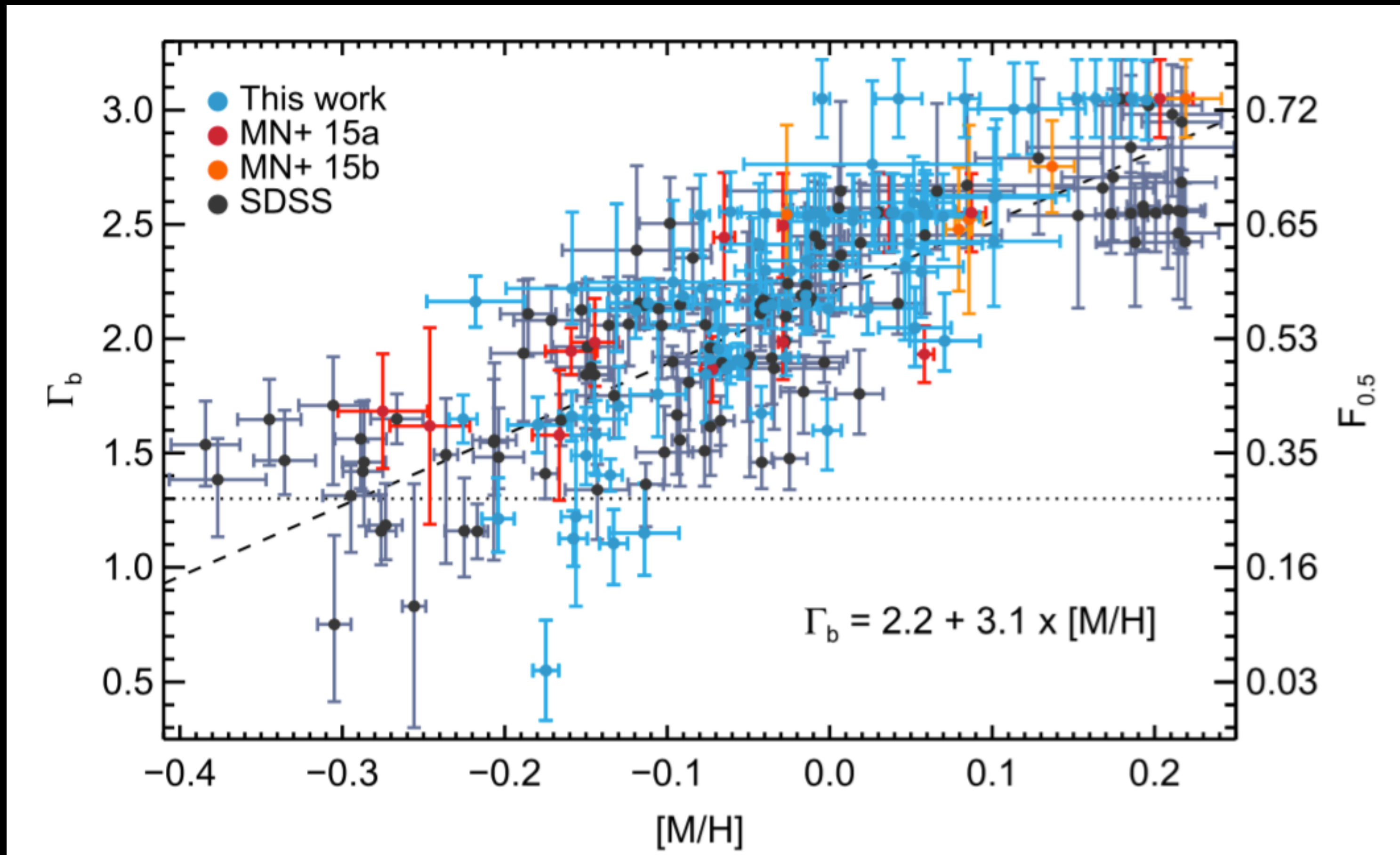
Recent work suggests significant variation in IMFs in different galaxies

Stellar IMF from Extragalactic Observations



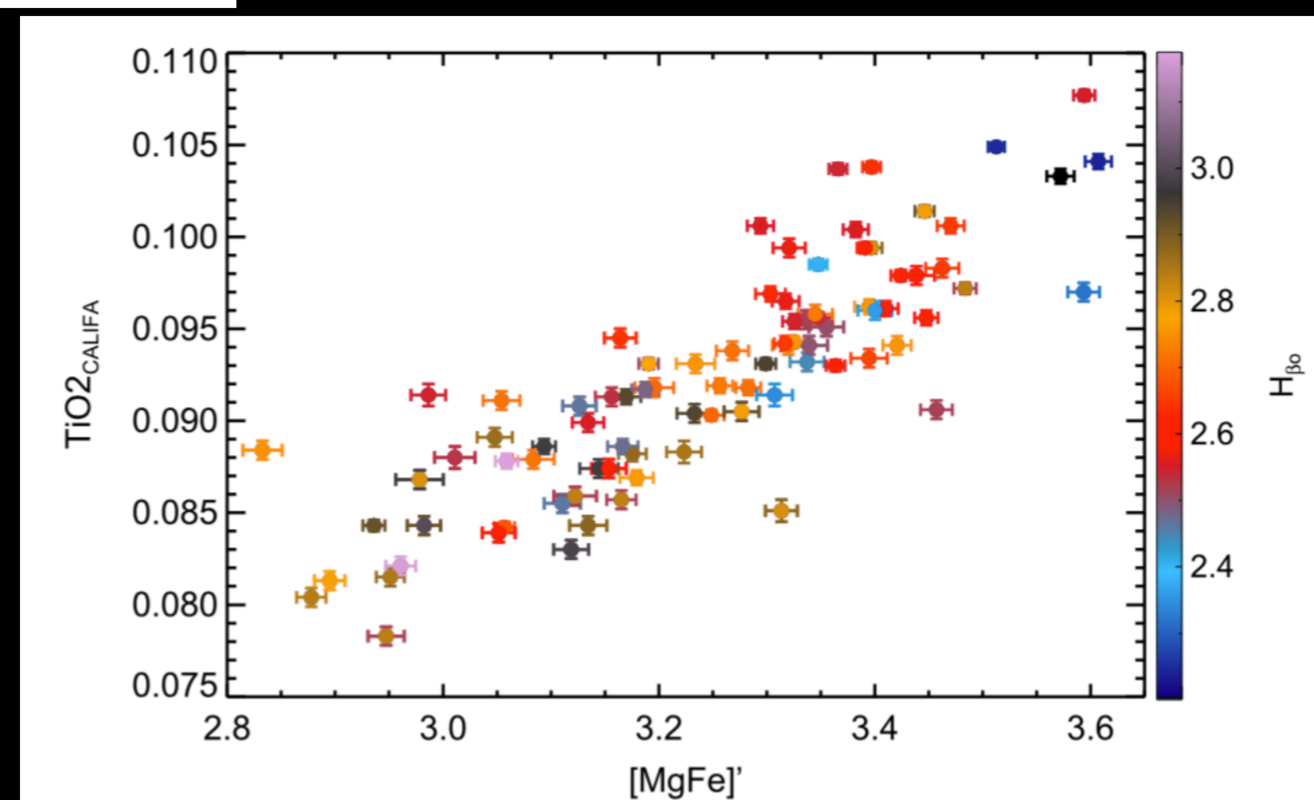
Stellar Population Synthesis (SPS) Analysis Conroy & van Dokkum (2012b)

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

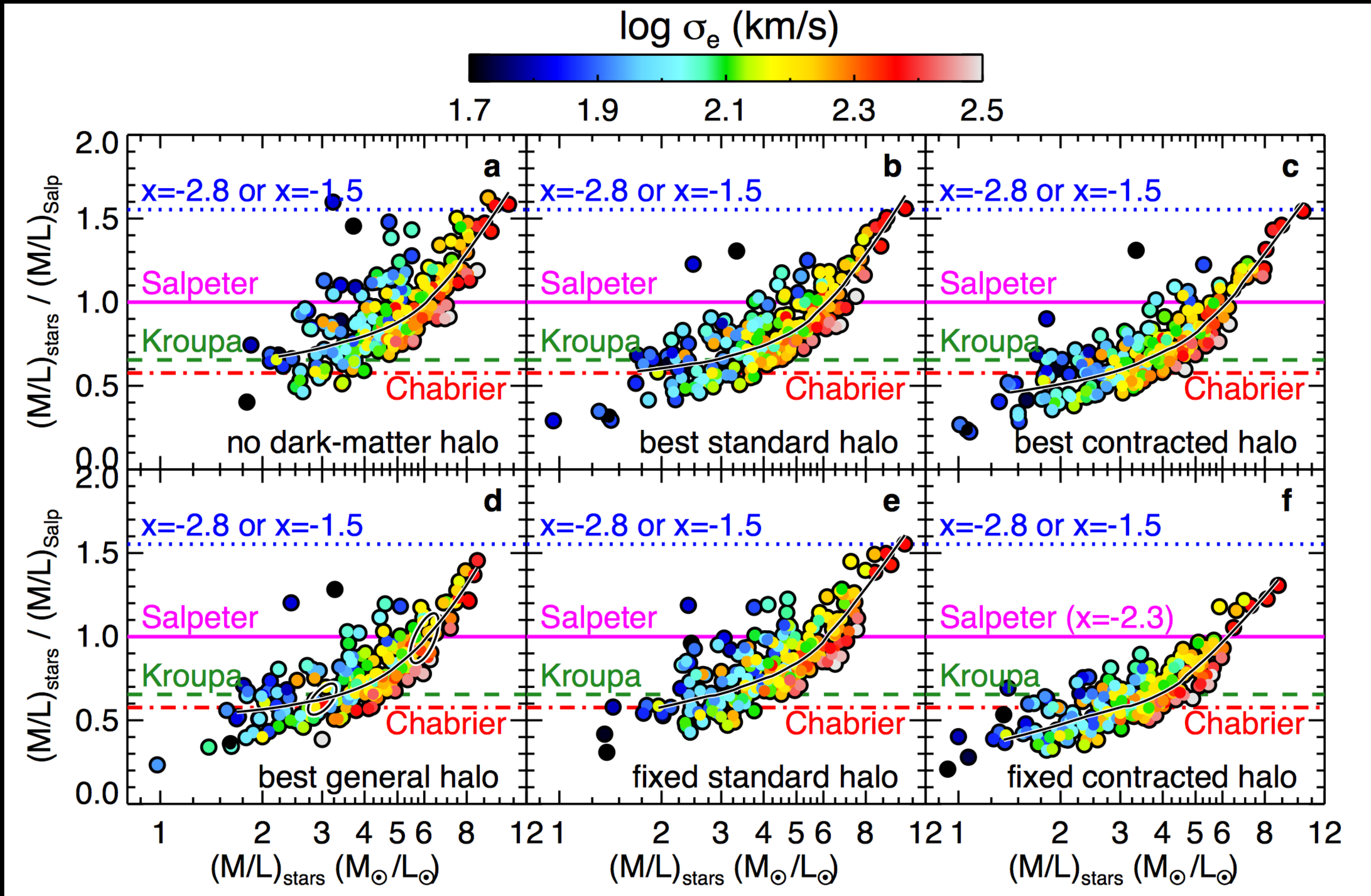


Martinez-Navarro et al. (2015)

CALIFA Integral Field Survey
Study of IMF variation in galaxy sample



Stellar IMF from Extragalactic Observations

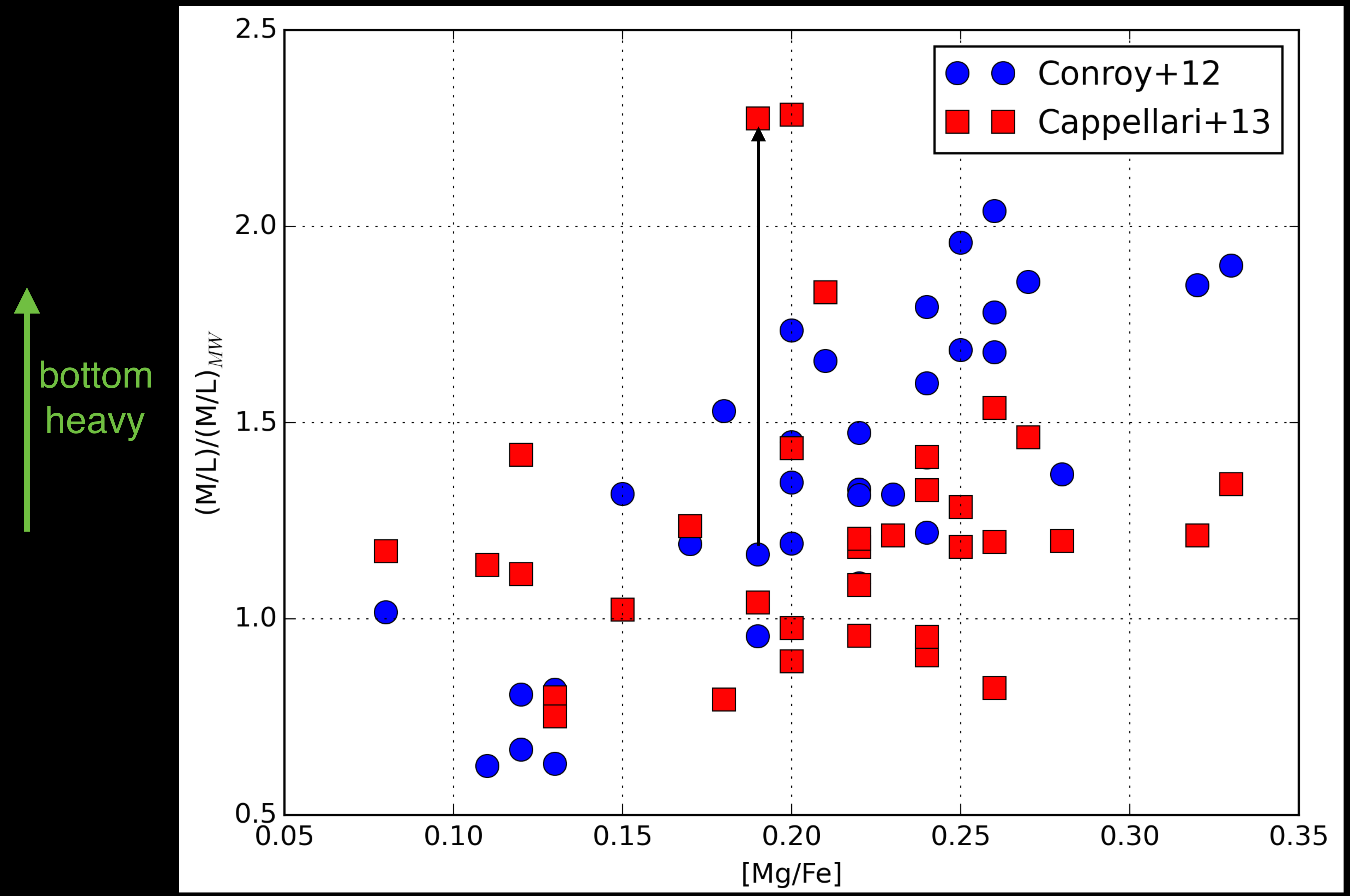


Early-type Galaxies (ATLAS^{3D})

Cappellari et al. (2012)

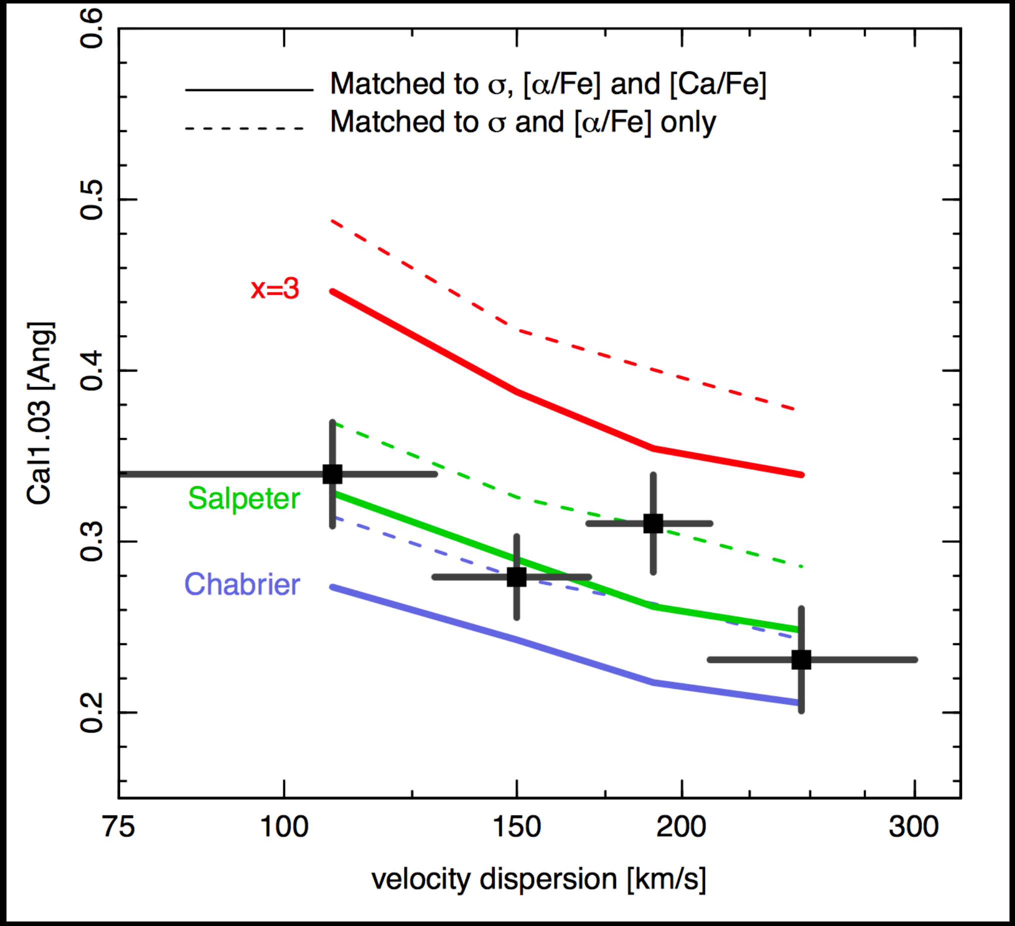
Kinematic Measurements of IMF

Studies of the Same Galaxies Inconsistent

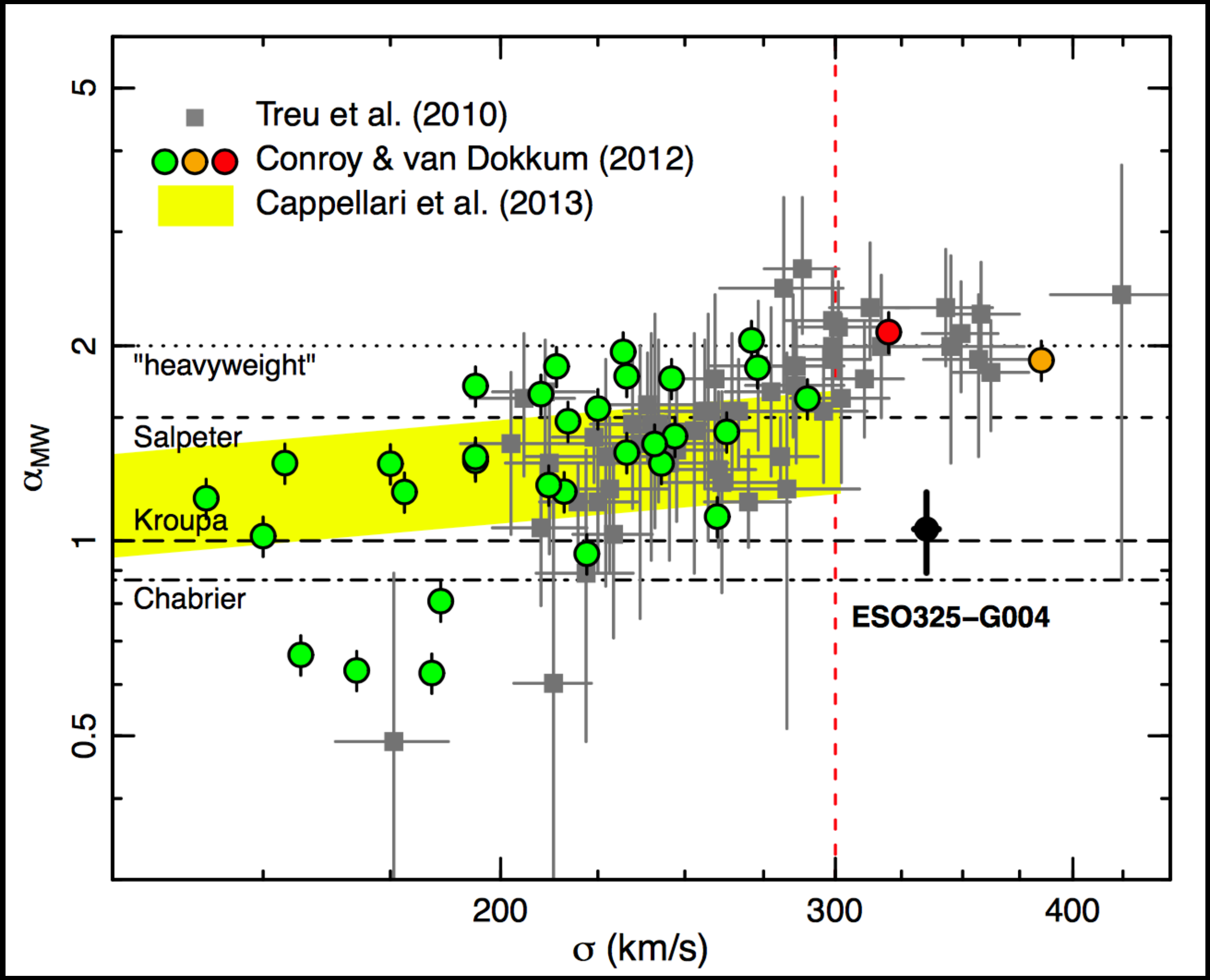


Stellar IMF from Extragalactic Observations

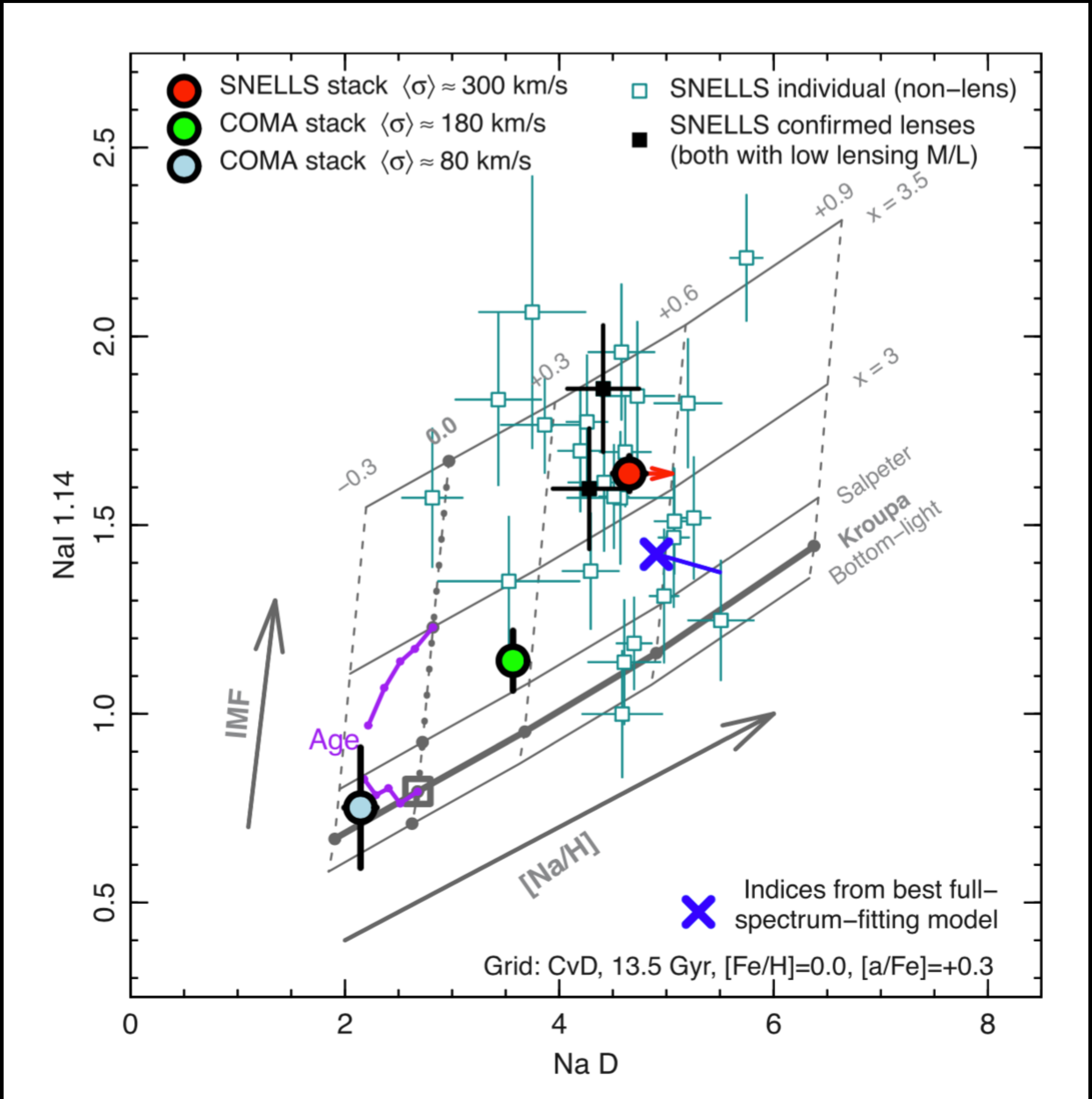
Not all results of stellar IMF variation in agreement



Coma Galaxies Smith et al. (2012)

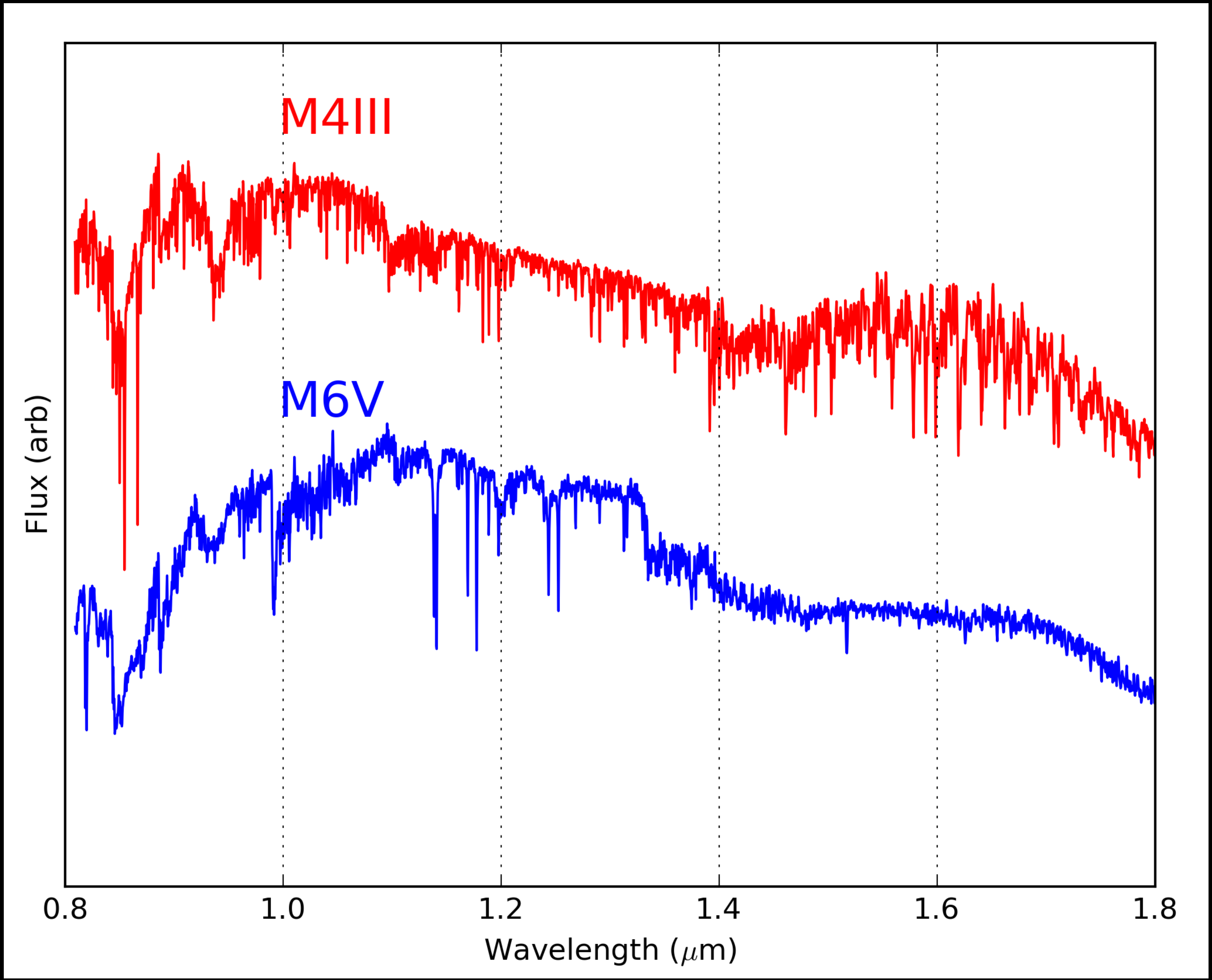


Lensing Measurement Smith et al. (2013)



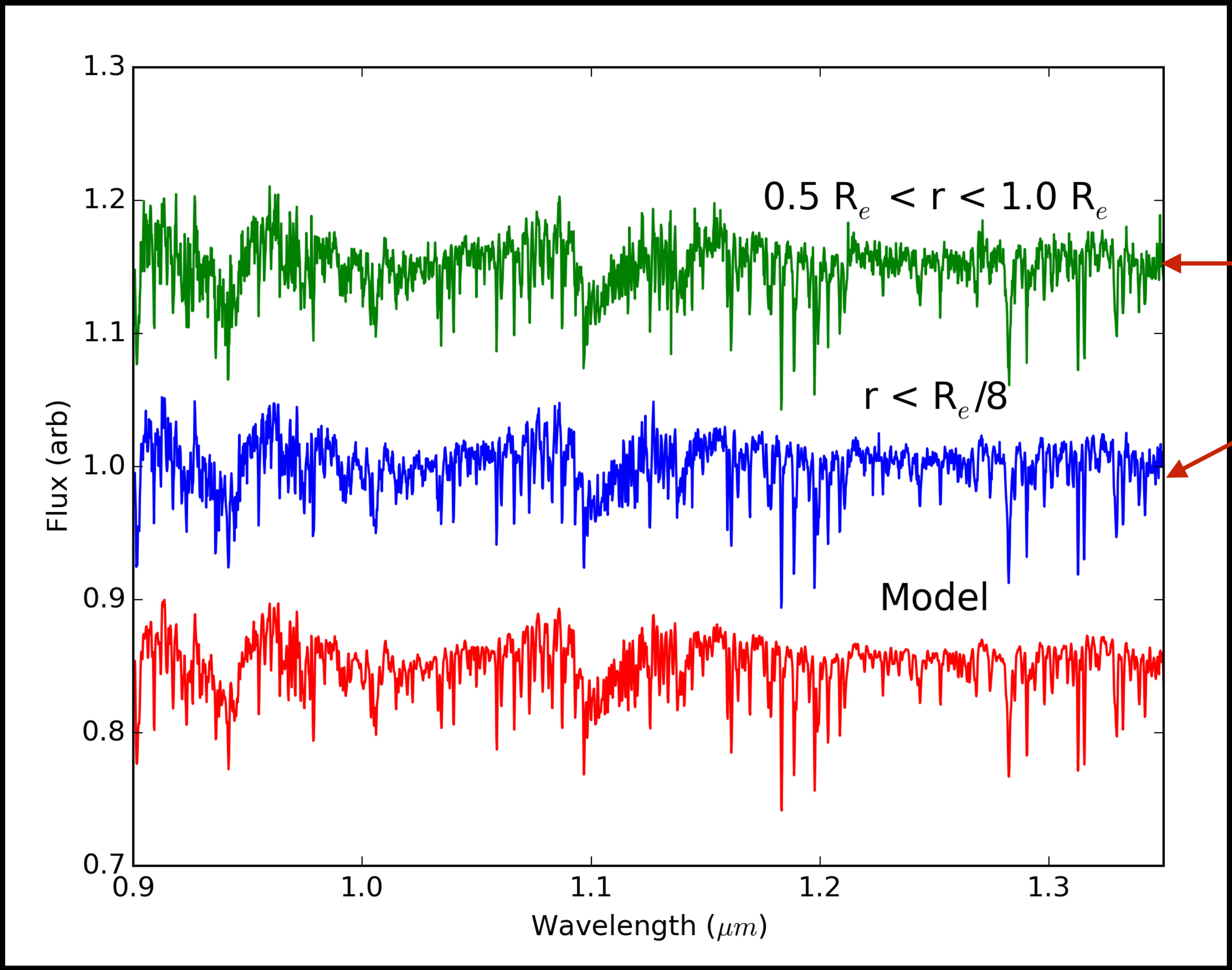
Smith et al. (2015)

Signatures of Dwarfs and Giants in the NIR

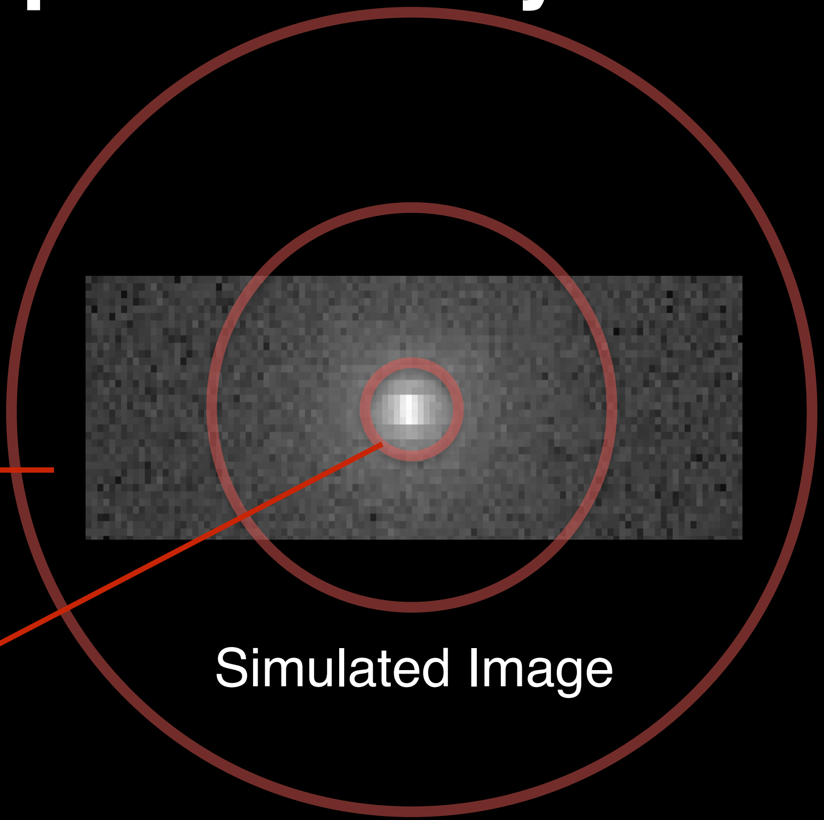


IRTF Spectral Library (Rayner et al. 2009)

Simulated Observations of A Typical Galaxy



(Jarvis et al. to be submitted)



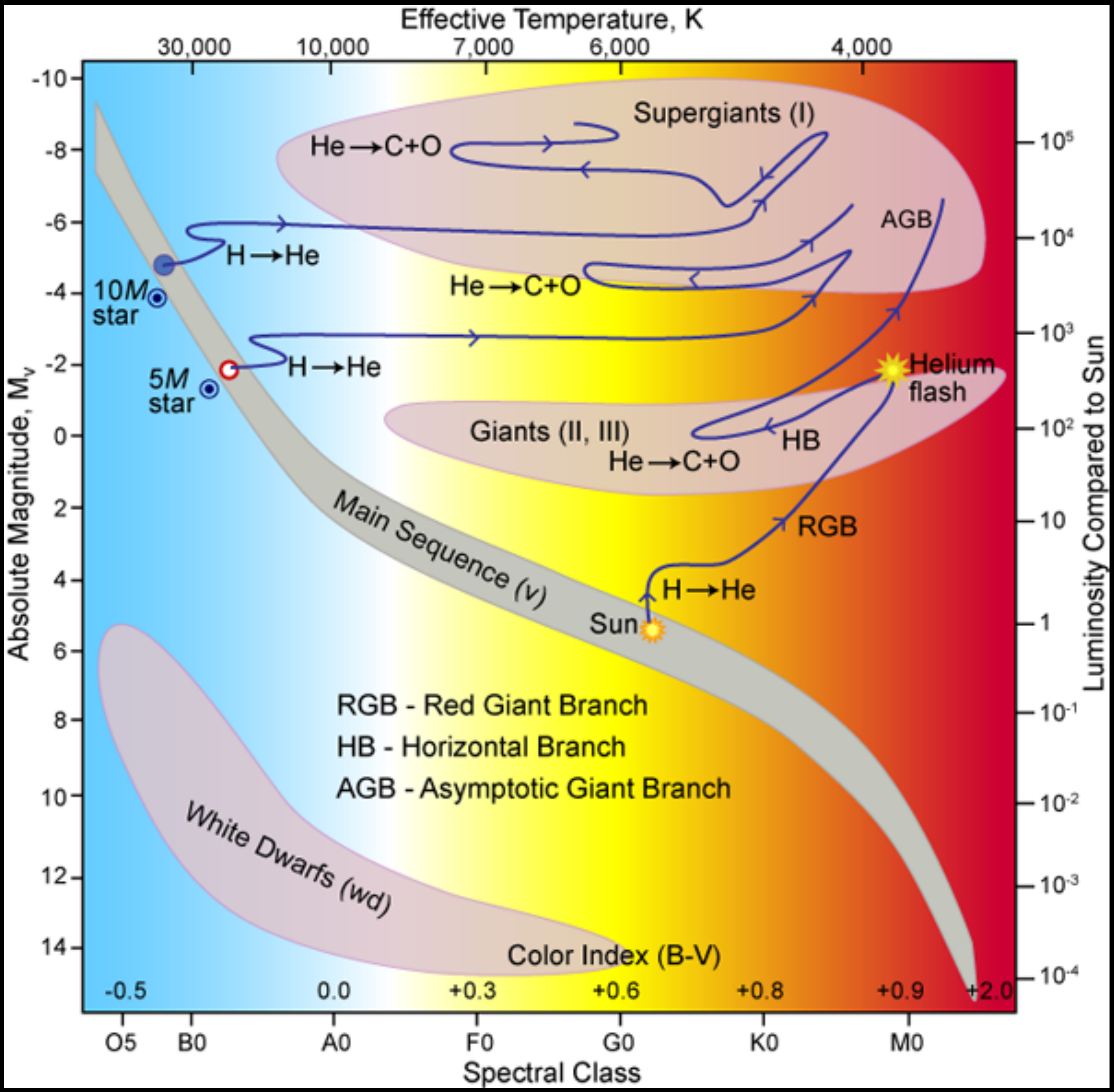
Prototypical Elliptical

- J_{tot} = 10 mag
- R_e = 30” (~10 kpc at 0.02)
- deV profile
- 3 Gyr Chabrier IMF
- $t_{int+overhead}$ = 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?

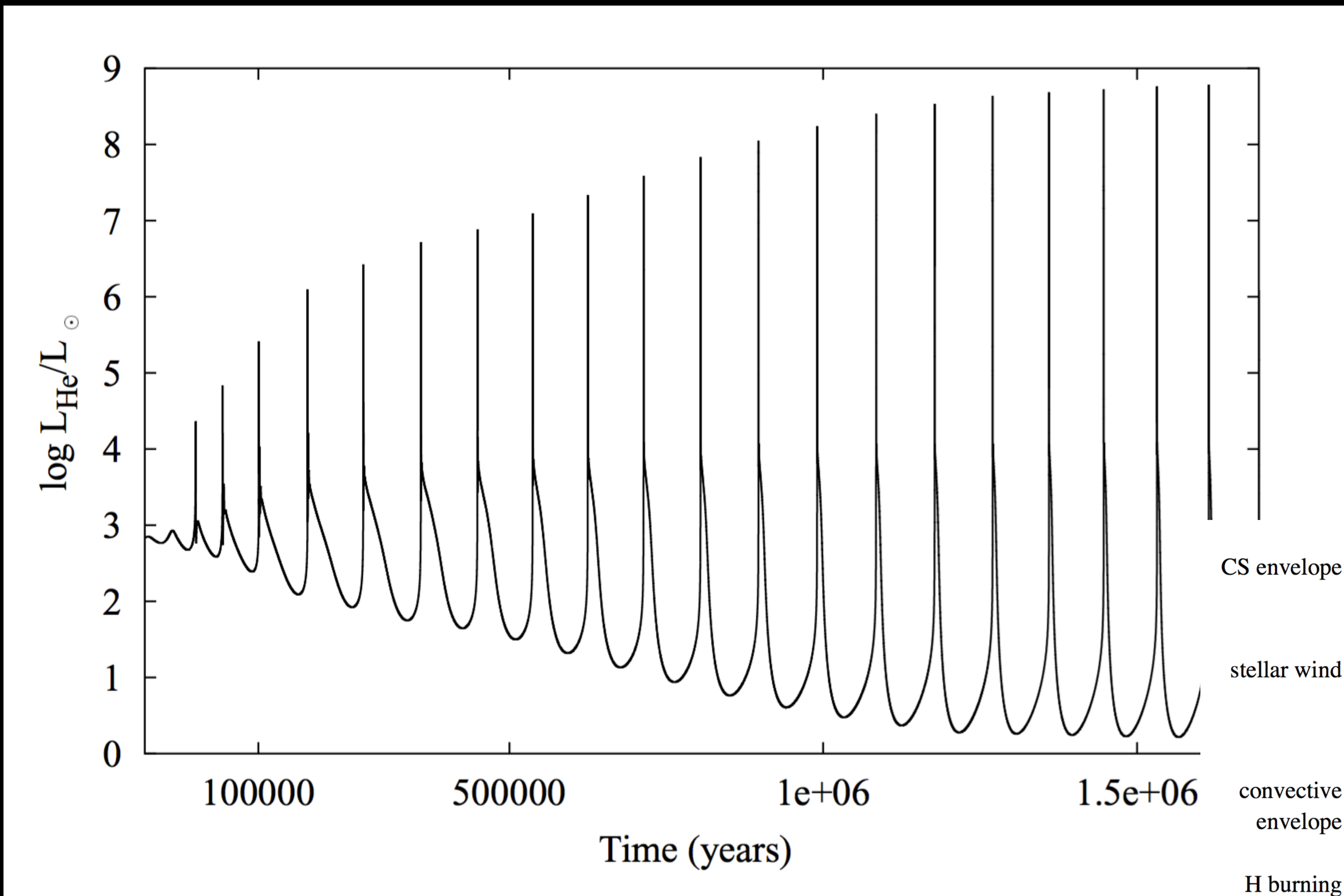
Late Evolution of Low and Intermediate Mass Stars



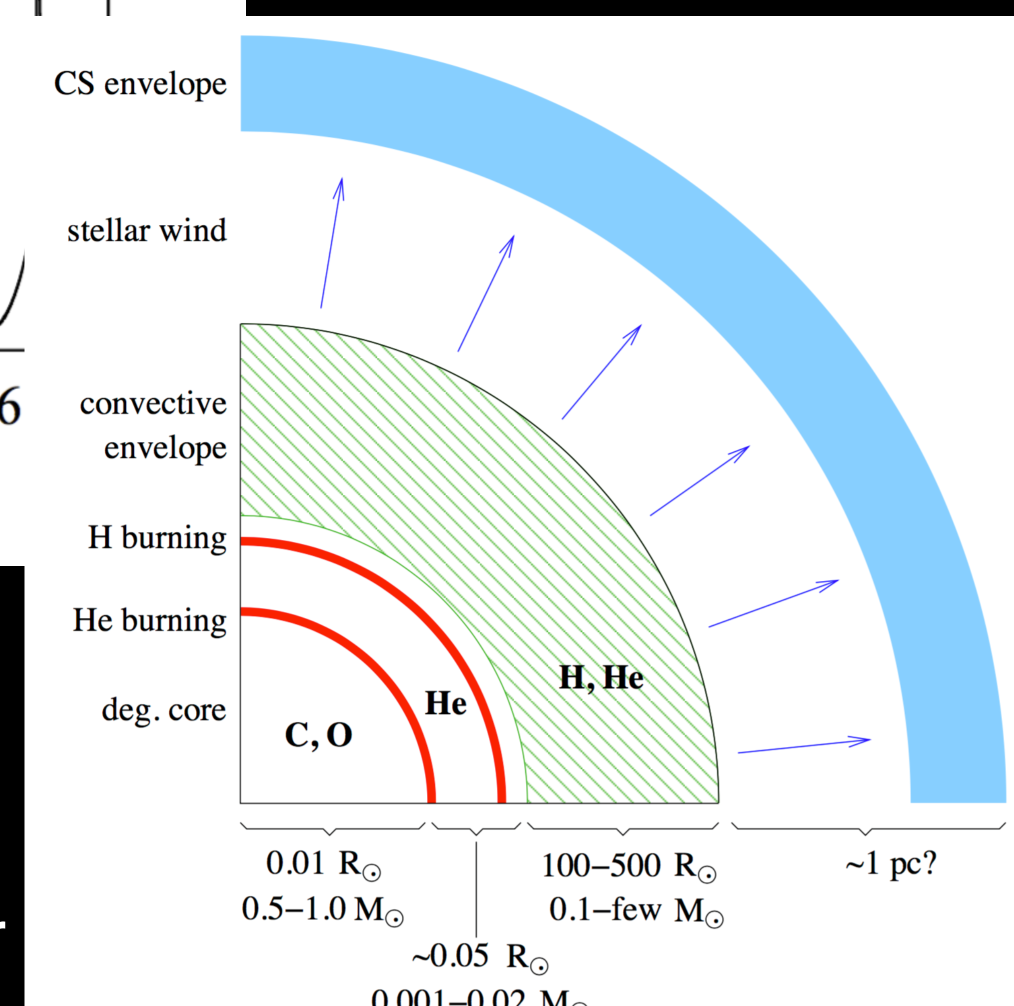
(Wiescher 2009)

- 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

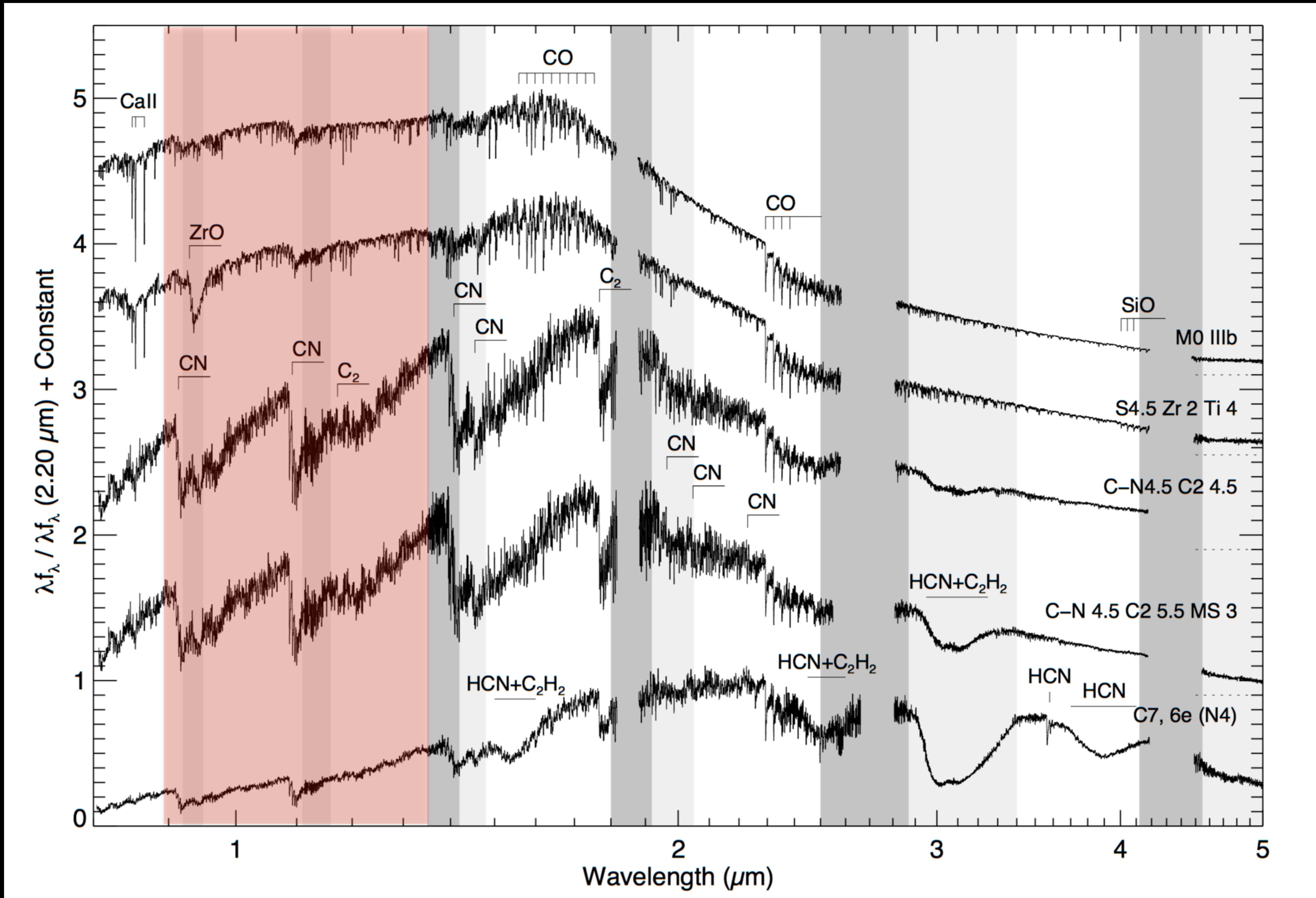
Thermally Pulsating AGB Stars



Helium shell burning luminosity for 3 $M_\odot$ in TP-AGB phase (Stancliffe et al. 2004)



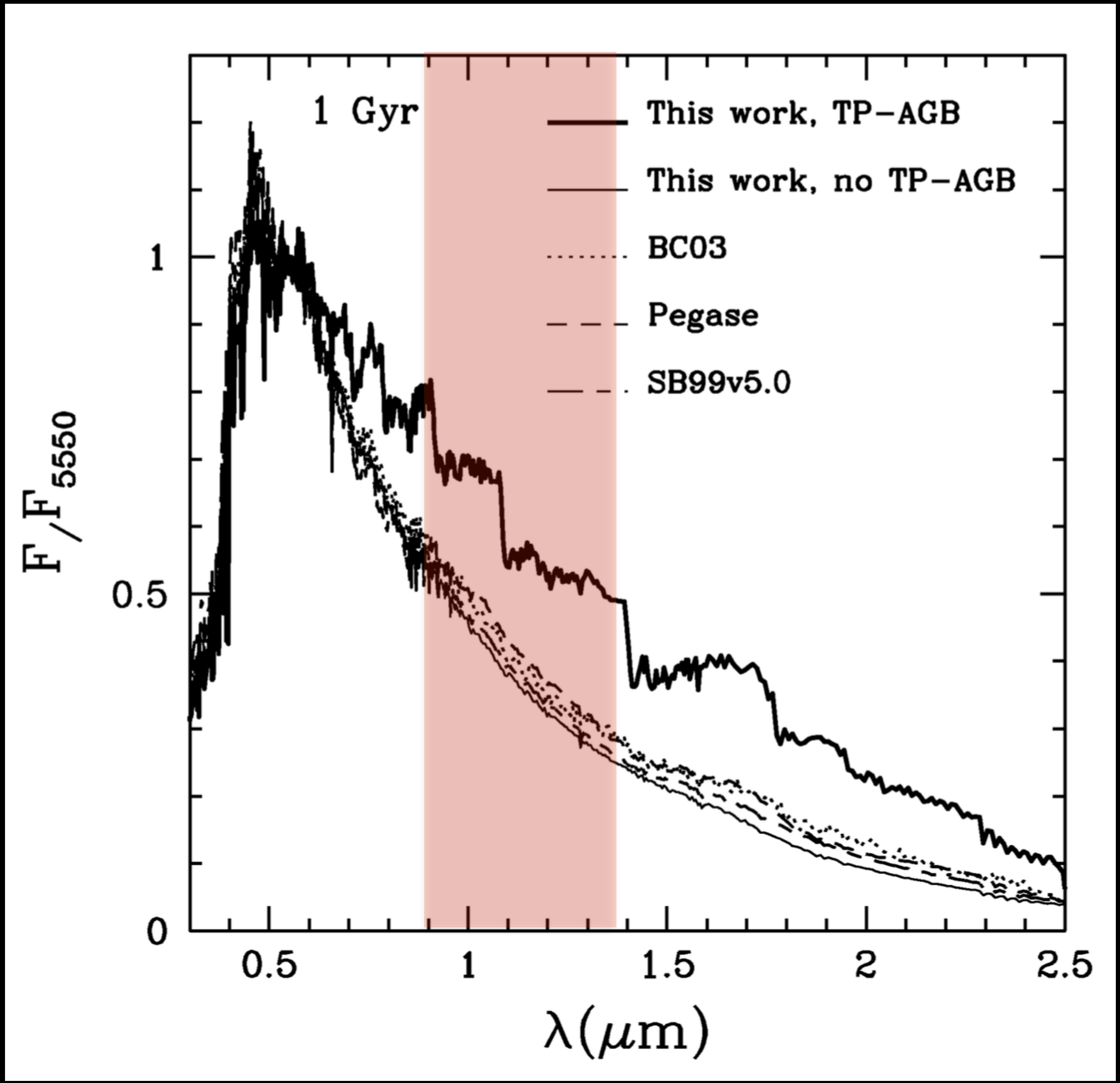
Structure of TP-AGB star



The range of stellar spectra for AGB stars (carbon-rich/oxygen-rich)

(Rayner et al. 2009)

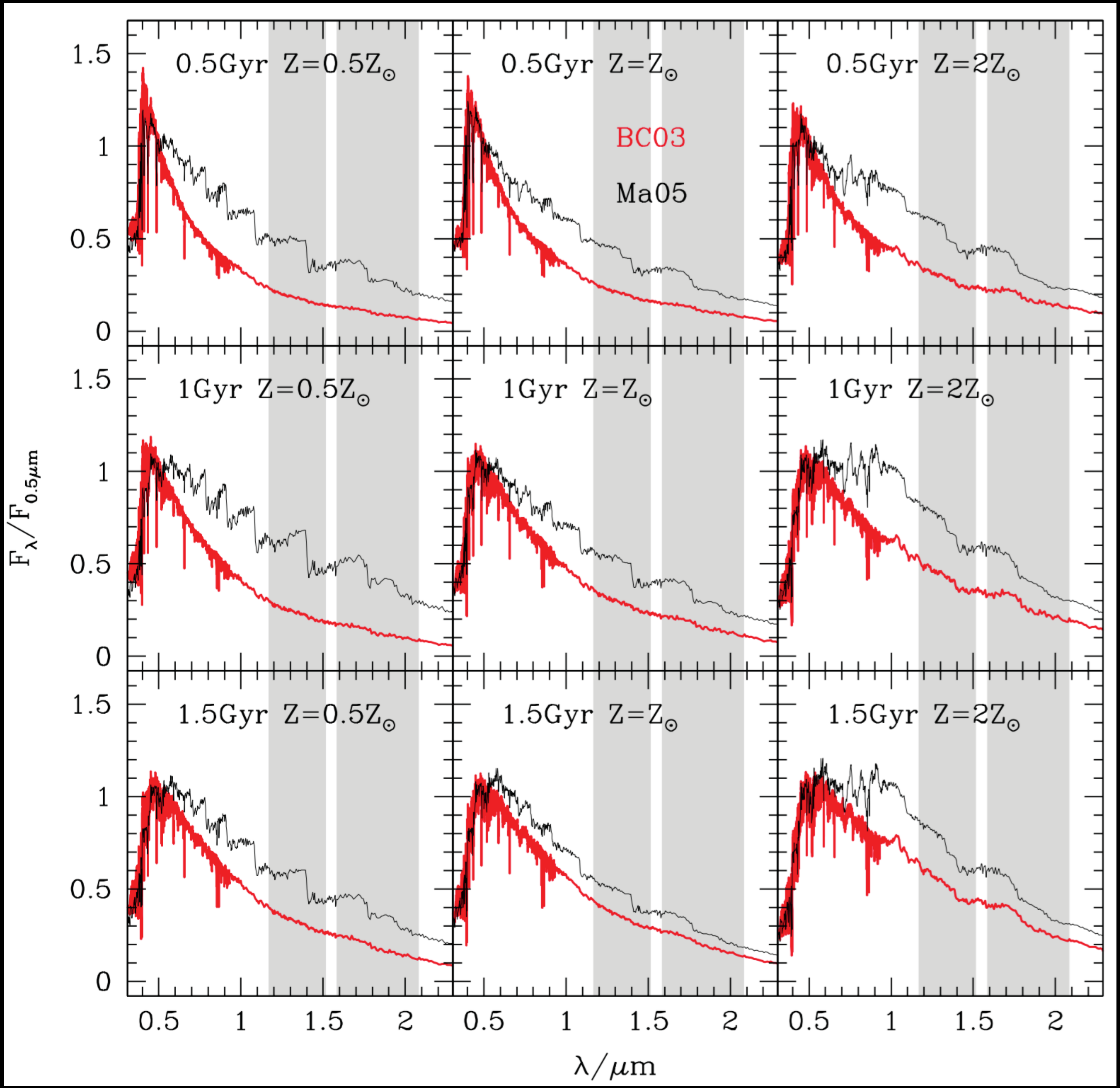
Thermally Pulsating AGB Stellar Contribution



Solar Metallicity 1Gyr old Population Model
(Maraston 2005)

- 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

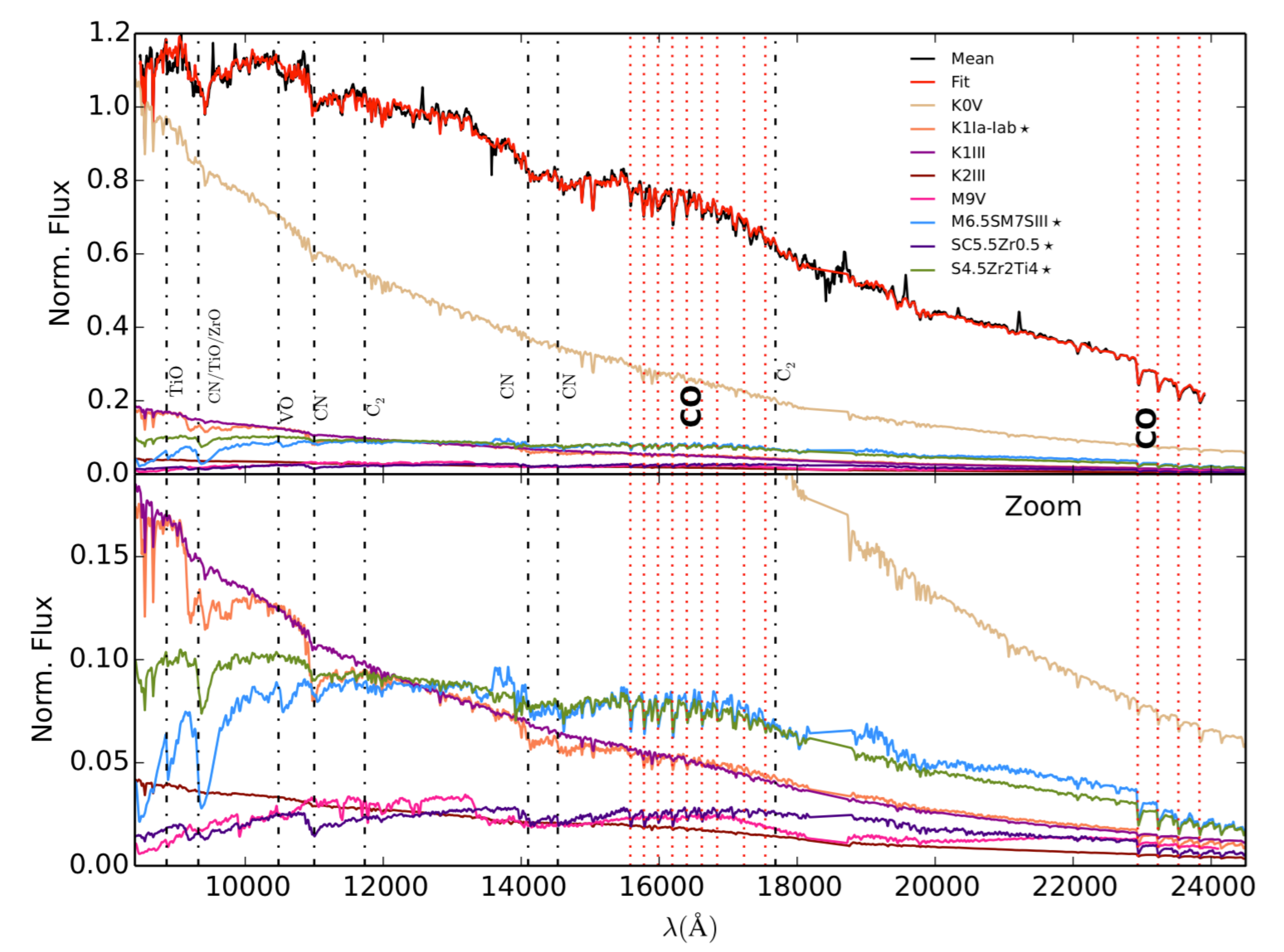
Thermally Pulsating AGB Stellar Contribution



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

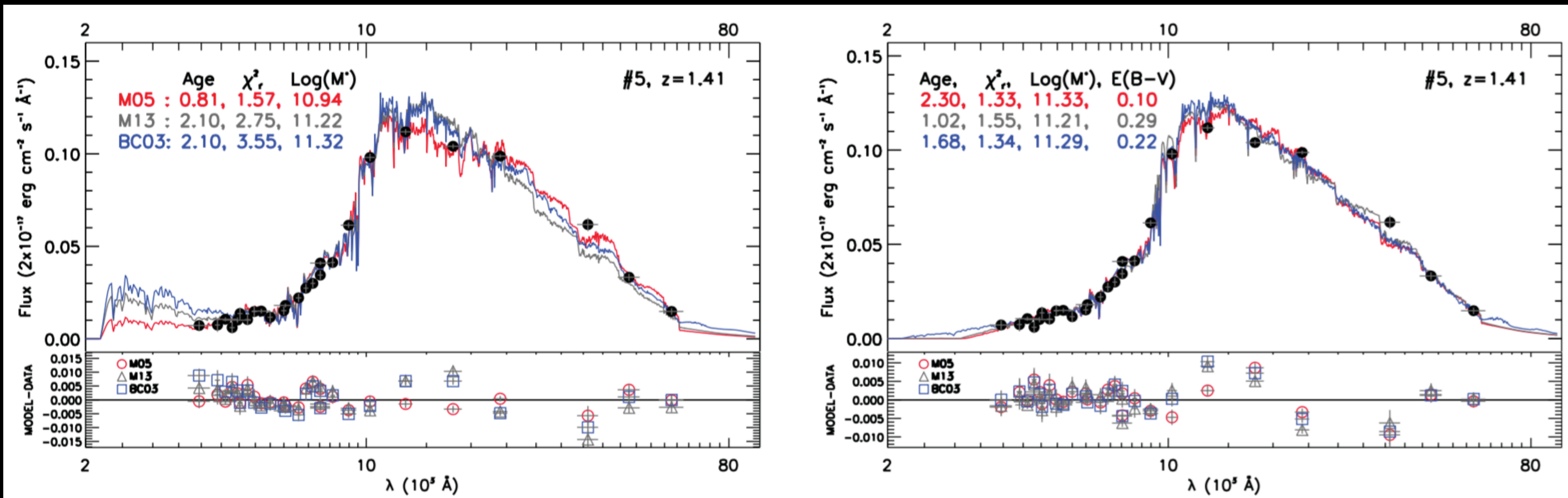
Thermally Pulsating AGB Stellar Contribution



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



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

- 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