Stellar and circumstellar spectroscopy in other galaxies

G. C. Sloan and many others

The Small Magellanic Cloud as seen by Spitzer and Herschel
Some key players on the team:

Martha Boyer – STScI
Martin Groenewegen – Roy. Obs. Belgium
Ciska Kemper – ASIAA
Kathleen Kraemer – Boston College
Eric Lagadec – Obs Cote d’Azur
Mikako Matsuura – Cardiff Univ.
Iain McDonald – Univ. of Manchester
Peter Wood – ANU
Albert Zijlstra – Univ. of Manchester
Extragalactic stellar spectroscopy
Extragalactic stellar spectroscopy probes stellar evolution at different metallicities and known distances.
Extragalactic stellar spectroscopy

Credit: Martha Boyer

The Small and Large Magellanic Clouds - John Drummond
Dust on the AGB

![Graph showing dust types and spectral features](image)

- **Silicate dust**
- **o Cet - M7 IIle**
- **IRC +50096 - C (N)**
- **SiC dust**
- **MgS dust**
- **Amorphous carbon dust**

F$_v$ (normalized and shifted)

$\lambda$ (\(\mu\)m)
Magellanic carbon stars

Many IRS papers:

Sloan et al. (2006)
Zijlstra et al. (2006)
Matsuura et al. (2006)
Buchanan et al. (2006)
Lagadec et al. (2007)
Leisenring et al. (2008)
Sloan et al. (2008)
Gruendl et al. (2008)
Matsuura et al. (2014)
Sloan et al. (2014)
Sloan et al. (2016)

Carbon-rich AGB sample:

144 in LMC
40 in SMC
(and 42 in Galaxy)
Carbon-rich dust and metallicity

For carbon stars, longer pulsation periods mean more dust

But carbon-rich dust production doesn’t depend on metallicity!

Assume initial mass ~ current luminosity
Mass explains width of dust-period relation

(Sloan et al. 2016)
The Milky Way System

Credit: Richard Powell
Local Group spectra

- These targets are faint!
- Need Cornell’s optimal extraction algorithm (Lebouteiller et al. 2010, 2011)
- Extracted spectra publicly available: http://cassis.sirtf.com
Dust and metallicity, Take 2

(Sloan et al. 2012)
Thank you, gravitational lensing

**OGLE III** fields and Cepheids  
(Soszynski et al. 2008, 2010)

**OGLE III** and Magellanic Variables  
**LMC** and **SMC**: Soszynski et al. (2009, 2011)

There’s also **MACHO**
Pulsation modes in AGB stars

Fundamental mode
First overtone mode
Larger amplitude
Smaller amplitude

(Sloan et al. 2015)
Pulsation and carbon-rich dust

Large pulsation amplitude = lots of dust

But OGLE misses the most embedded stars

(Sloan et al. 2015)
Wide-field Infrared Survey Explorer

**WISE**
- 2009 Dec – launched
- 2010 Sep – exhausted cryogens

**NEOWISE**
- NEO = Near Earth Object
- 2011 Feb – ordered to hibernate

**NEOWISE-R**
- 2013 Dec – R = reactivated
  (Mainzer et al. 2014)

New epoch every 6 months!

8 epochs now on IRSA
**Spitzer** imaging of the SMC

2 30-sq.-deg. surveys
2008 Jun, Sep
2 more epochs coming
2017 Aug, Nov

5 more epochs
in the core
2005, 2010-11

Images adapted from Gordon et al. (2011), Meixner et al. 2013)
Extremely red objects in the LMC

SiC in absorption!

(Gruendl et al. 2008)
From AGB to post-AGB

(Sloan et al. 2016)
New pulsation amplitudes

Reddest stars are evolving off of the AGB

(Sloan et al. 2016)
Sparse sampling of light-curves

Test concept with IRS sample

Five new periods, all deeply embedded sources

Compared to published periods, 86% agree within 5%

(Sloan et al. 2016)
DUSTiNGS

2 Spitzer epochs in 50 Local Group dwarf galaxies

(Boyer et al. 2015)
Lessons for the future

JWST will extend stellar spectroscopy beyond the edge of the Local Group.

Sparsely sampled IR lightcurves can identify and characterize AGB stars.
And the future is almost now
SiC and MgS in C-rich shells

As dust shells grow redder
- SiC strength rises, then falls
- Reddest sources have SiC in absorption!
- MgS rises as SiC falls

(Sloan et al. 2016)
Grain layering

After Lagadec et al. (2007) and Leisenring et al. (2008)

(Sloan et al. 2016)
Carbon-rich post-AGB spectra

(Sloan et al. 2014)
Class D PAHs in PNe

New class of PAH emission

Introduced by Matsuura et al. (2014)

Unusual PAH profiles at 8 and 11-14 μm