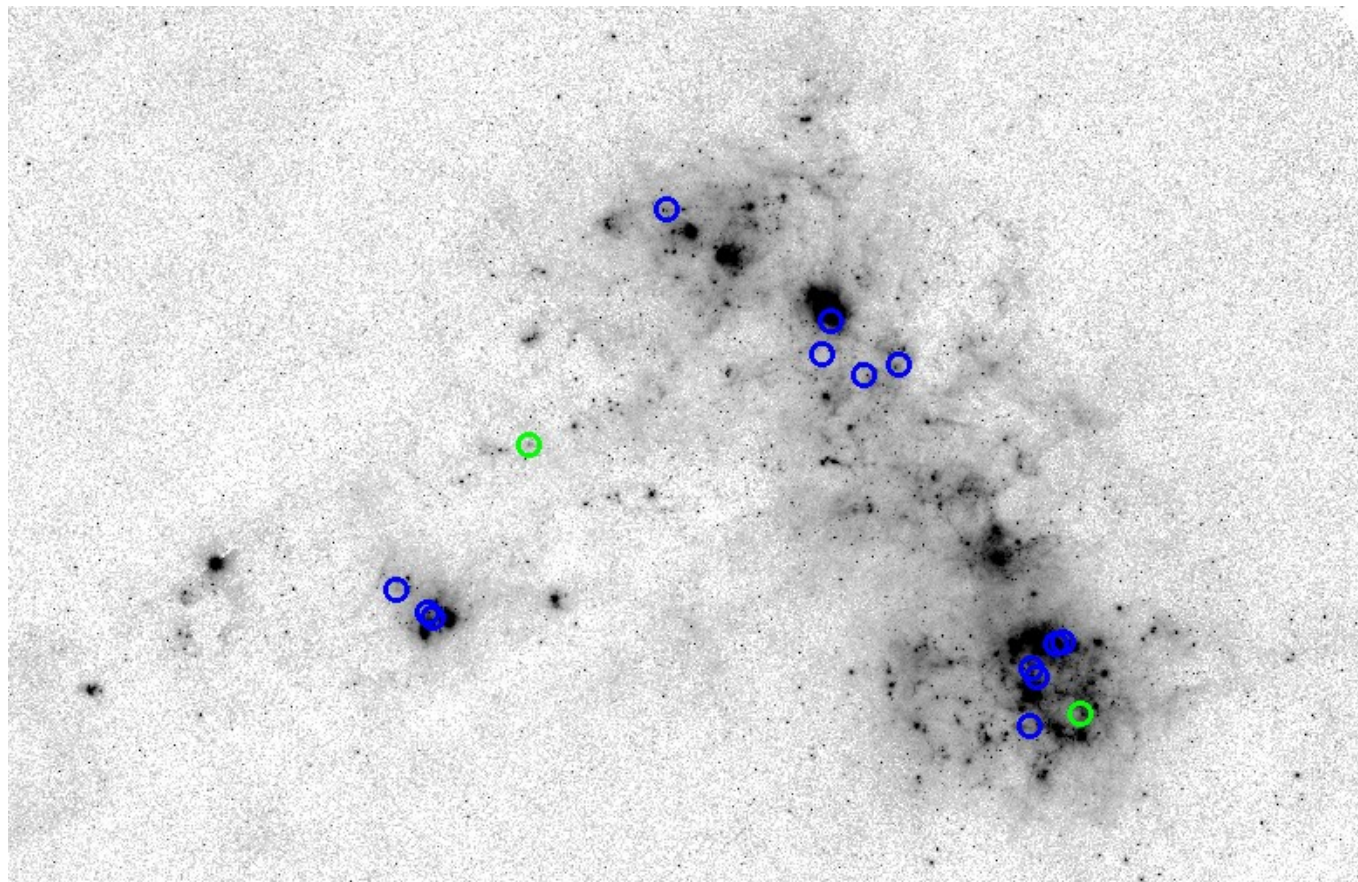


# Dust at Low Metallicities



Karl D. Gordon  
Astronomer  
STScI, Baltimore, MD  
First UVEX Community Workshop  
15 Mar 2023

“Have Dust – Will Study”

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Slides on [speakdeck@karllark](https://speakdeck.com/karllark)

# Summary

- Extinction at low metallicity different and quite variable
- SMC shows largest variations
- LMC shows strong variations influenced by “mini-starburst”
- Low metallicity = clues to earlier times
- Variations clues to dust grain evolution
  - Formation in evolved stars
  - ISM grain growth
  - Processing by harsh radiation fields
- UVEX potential is large

# Low Metallicity Dust

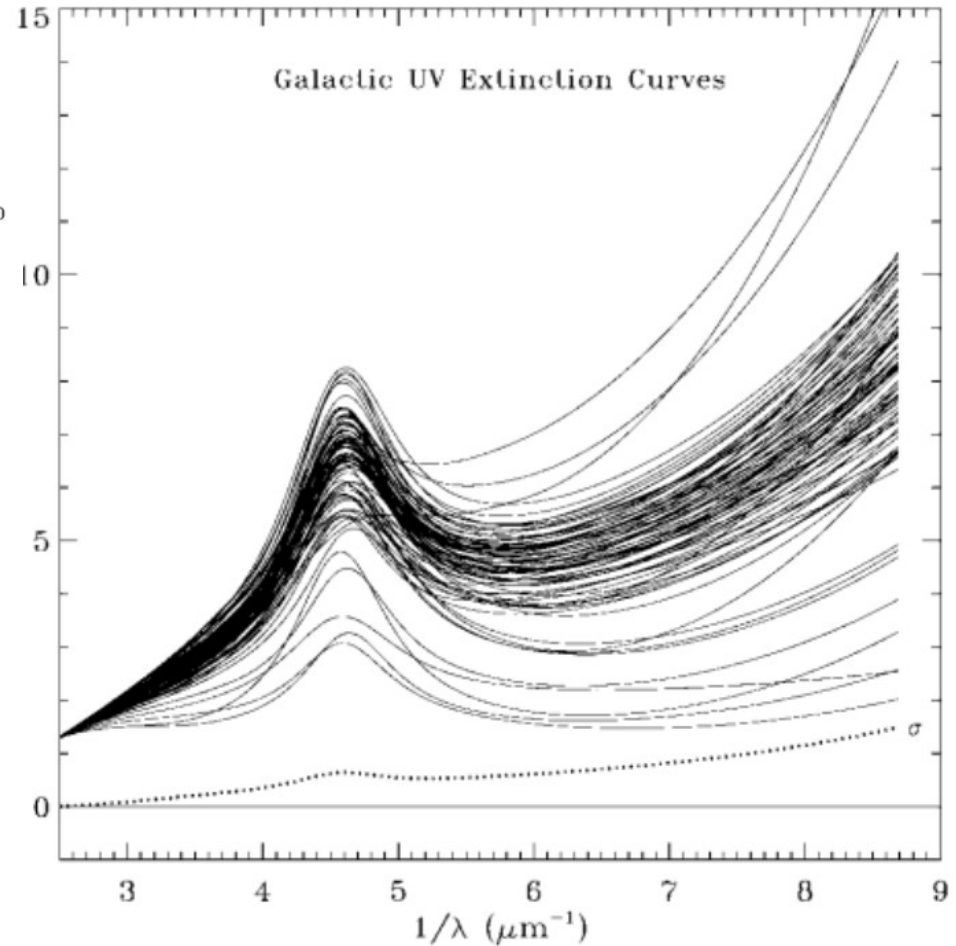
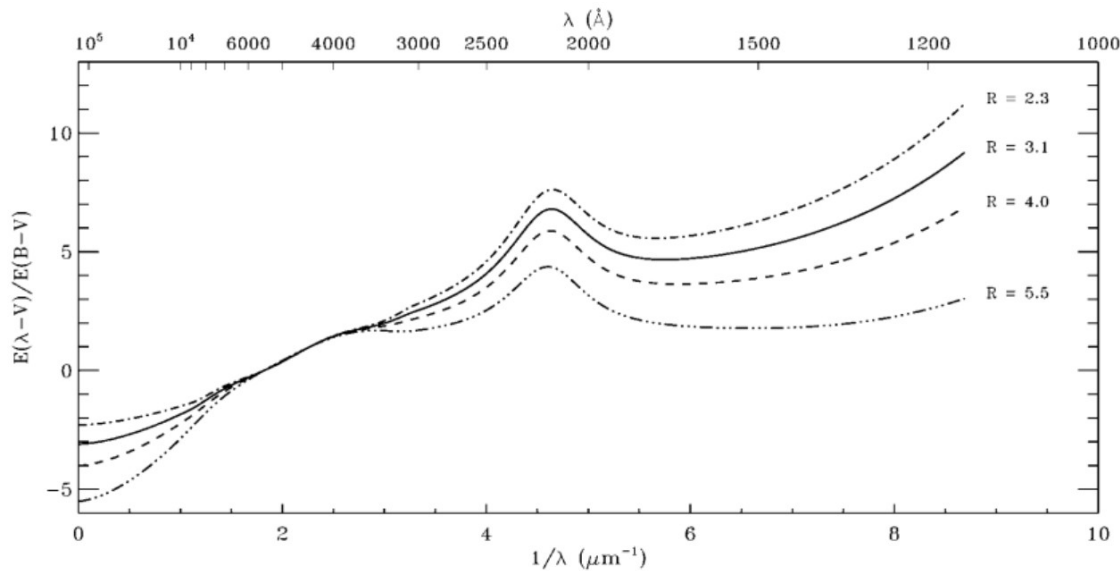
- Interesting results seen in the UV and IR
- IR: emission
  - Strong variation in MIR → aromatic/PAH features
  - Strong variation in far-IR → emissivity slopes
- UV: dust abundances (via gas phase lines [depletions])
  - Strong variations in implied dust grain compositions
- UV: extinction (focus of this talk)
  - Strong variation in 2175 Å feature and far-UV

# Why

- Extinction
  - Major constraint on dust sizes and compositions
- Low metallicity
  - less chemically evolved
  - Connection to galaxies at all redshifts
- Magellanic Clouds
  - Nearby
  - Interesting metallicities (straddling “transition” metallicity)
  - External – can easily study across entire galaxy

# Milky Way Extinction

400+ sightlines studied  
UV spectroscopic extinctions



Fitzpatrick (1999, PASP, 111, 63)  
Valencic et al. (2004, ApJ, 616, 912)

## STARBURST-LIKE DUST EXTINCTION IN THE SMALL MAGELLANIC CLOUD

KARL D. GORDON AND GEOFFREY C. CLAYTON

THE ASTROPHYSICAL JOURNAL, 515:128–139, 1999 April 10

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## A REANALYSIS OF THE ULTRAVIOLET EXTINCTION FROM INTERSTELLAR DUST IN THE LARGE MAGELLANIC CLOUD

K. A. MISSELT, GEOFFREY C. CLAYTON, AND KARL D. GORDON

THE ASTROPHYSICAL JOURNAL, 594:279–293, 2003 September 1

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## A QUANTITATIVE COMPARISON OF THE SMALL MAGELLANIC CLOUD, LARGE MAGELLANIC CLOUD, AND MILKY WAY ULTRAVIOLET TO NEAR-INFRARED EXTINCTION CURVES<sup>1</sup>

KARL D. GORDON,<sup>2</sup> GEOFFREY C. CLAYTON,<sup>3</sup> K. A. MISSELT,<sup>2</sup> ARLO U. LANDOLT,<sup>3</sup> AND MICHAEL J. WOLFF<sup>4</sup>

A&A 541, A54 (2012)

DOI: [10.1051/0004-6361/201118712](https://doi.org/10.1051/0004-6361/201118712)

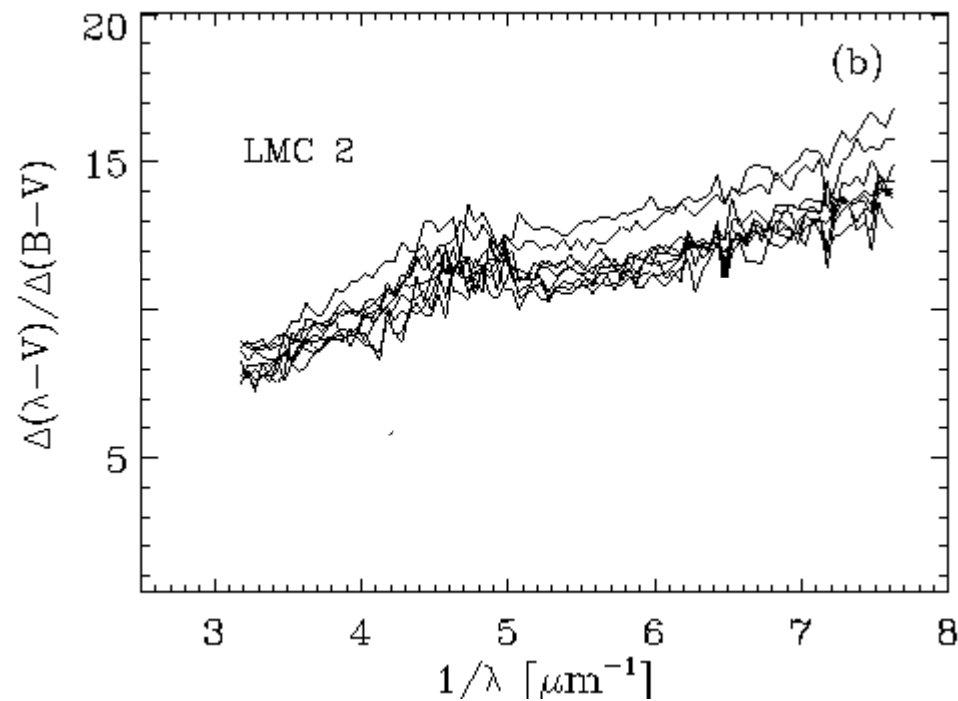
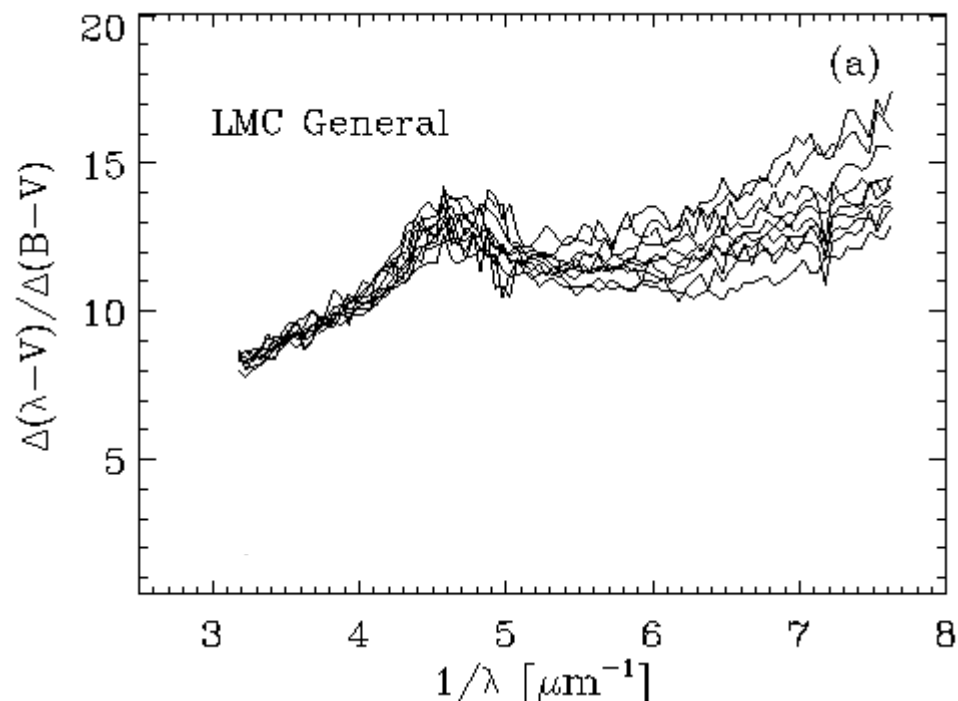
© ESO 2012

**Astronomy  
&  
Astrophysics**

## Ultraviolet extinction toward a quiescent molecular cloud in the Small Magellanic Cloud

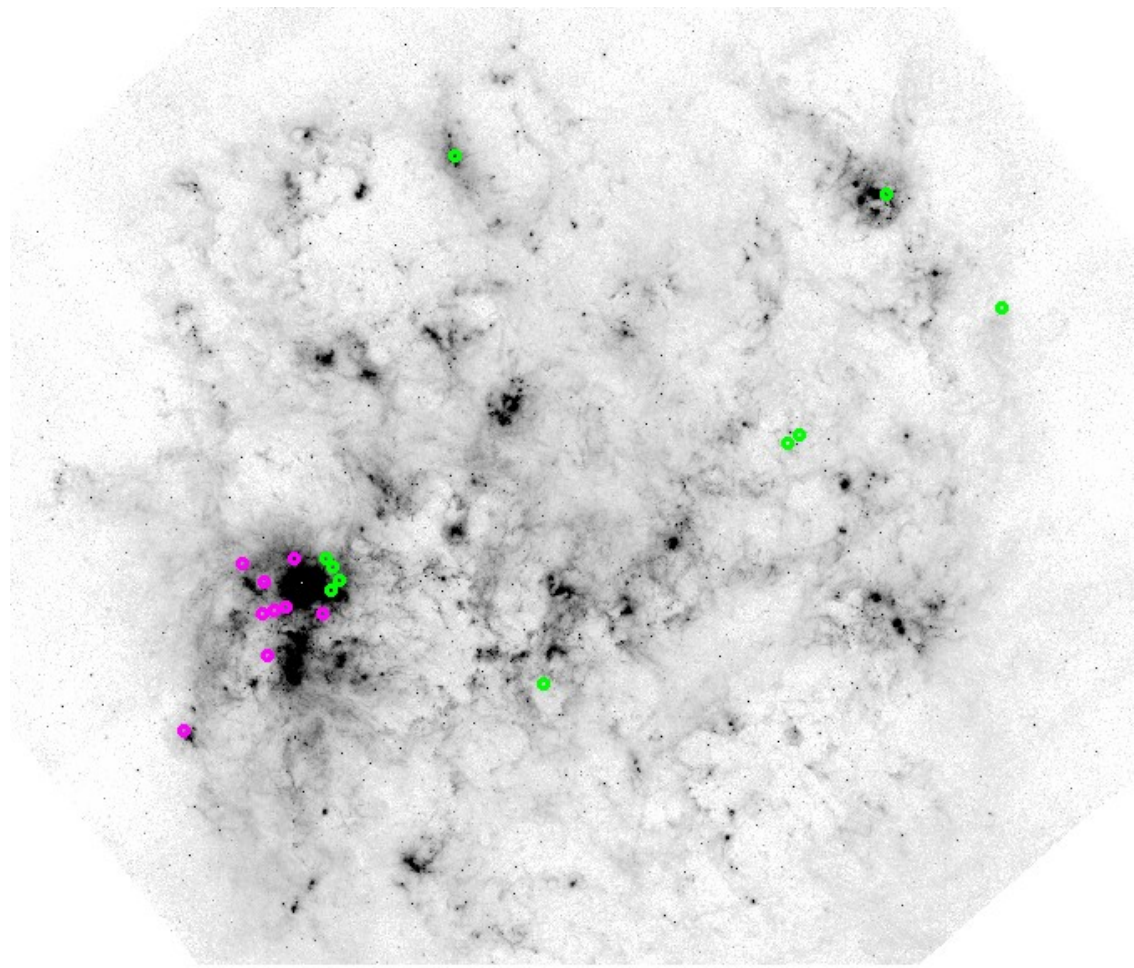
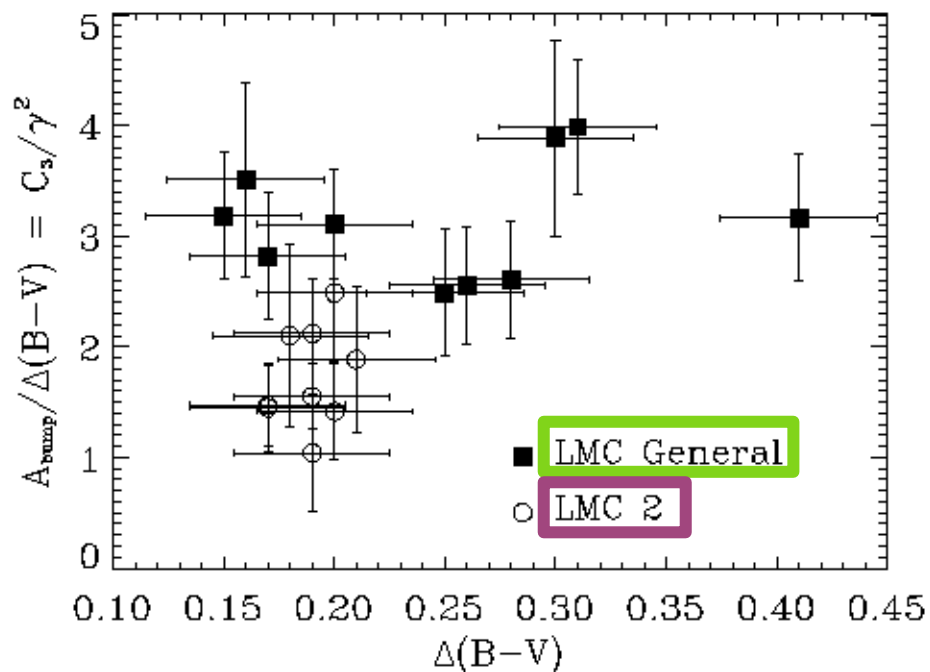
J. Maíz Apellániz<sup>1</sup> and M. Rubio<sup>2</sup>

# Large Magellanic Cloud Extinction Curves



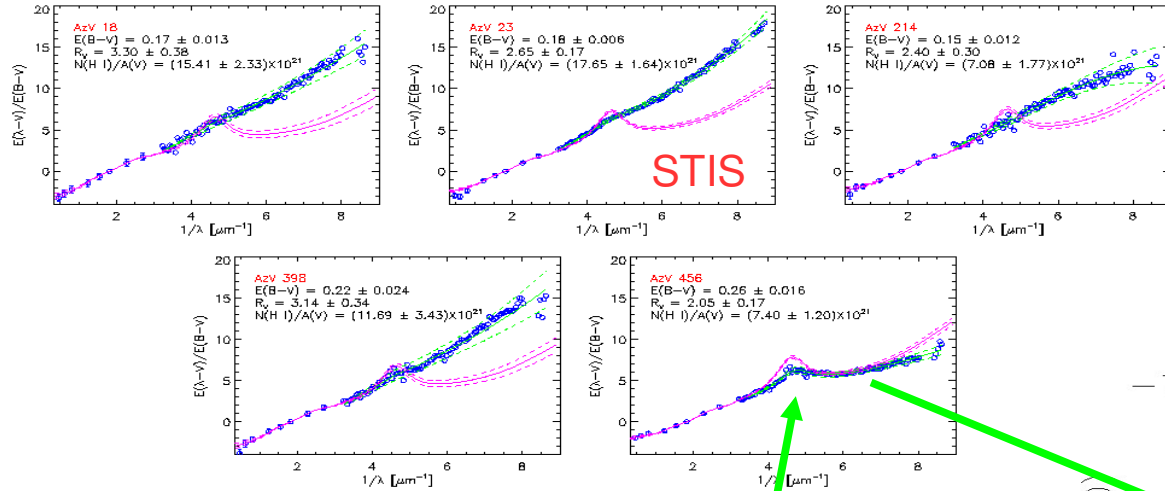
Misselt et al. (1999, ApJ, 515, 128)

# Spatial Distribution



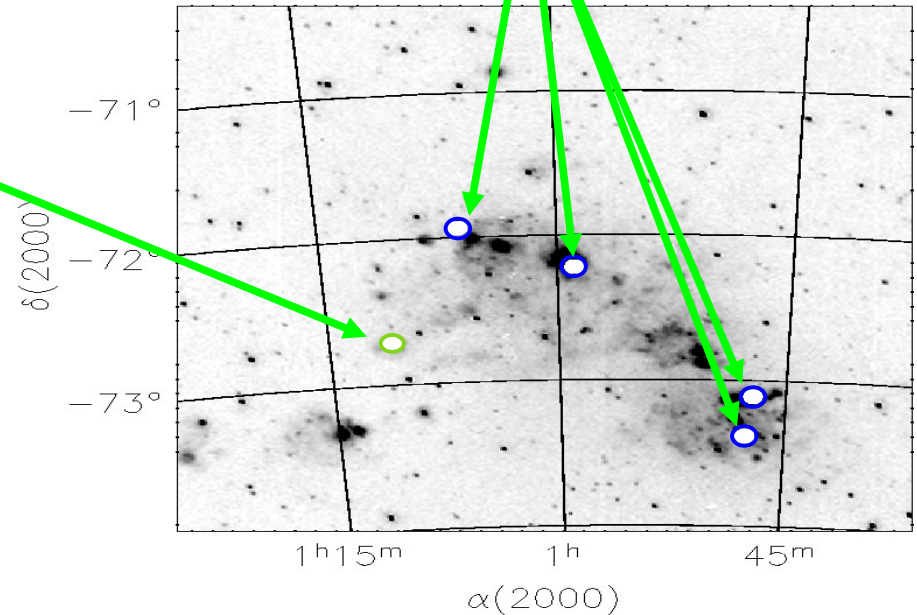
Misselt et al. (1999, ApJ, 515, 128)

# Small Magellanic Cloud Extinction Curves



**Milky Way-like!**  
(2175 Å bump)

4 similar curves are found in the star forming bar of the SMC!

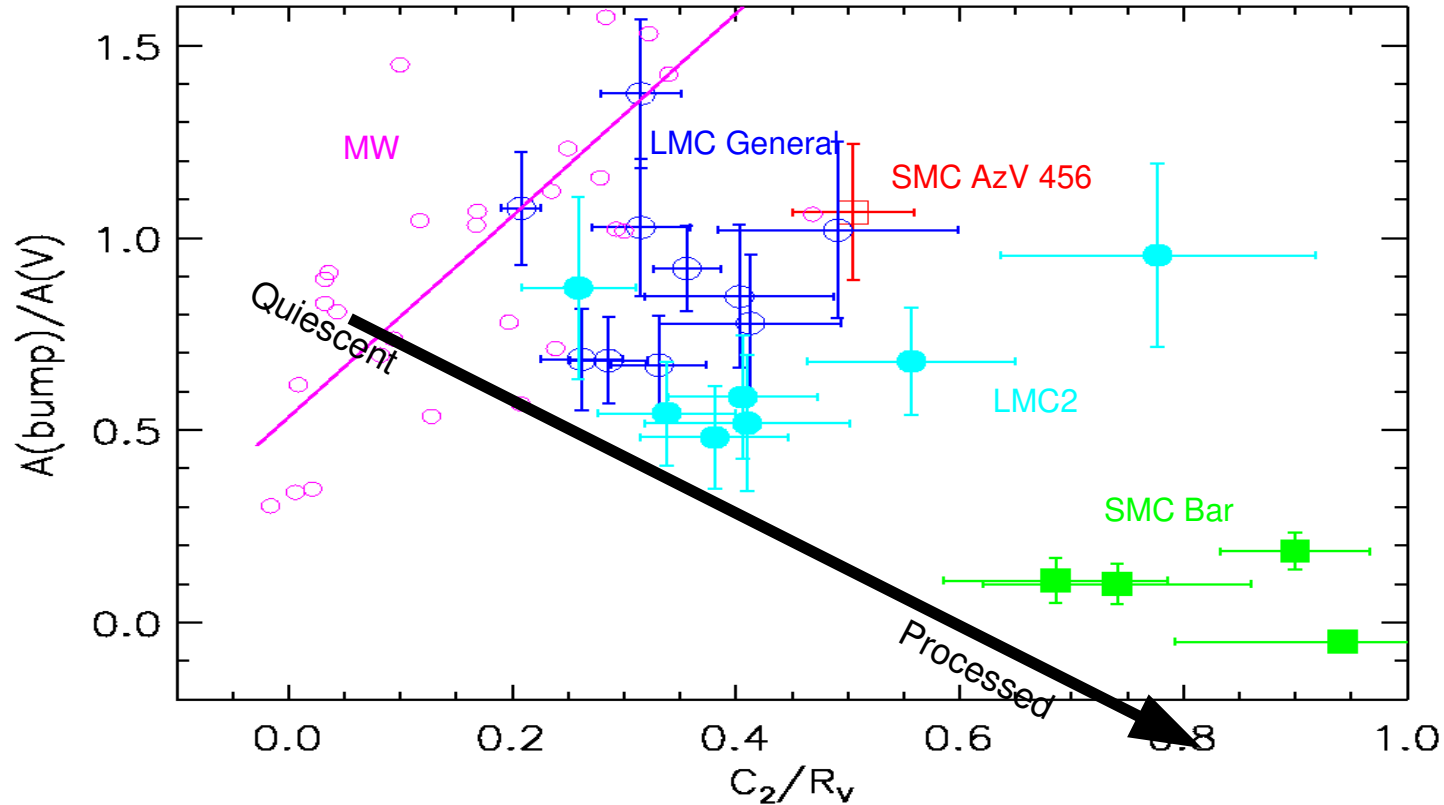


Gordon et al. (2003, ApJ, 594, 279)

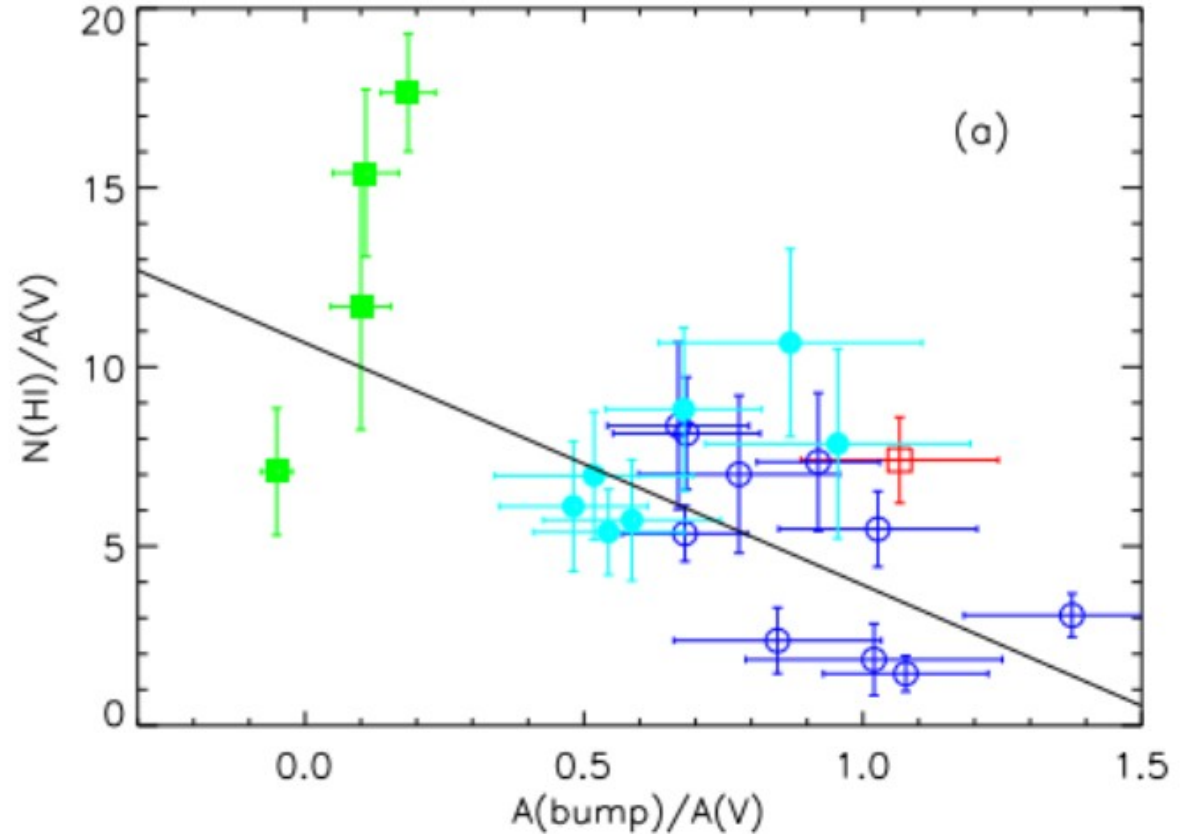
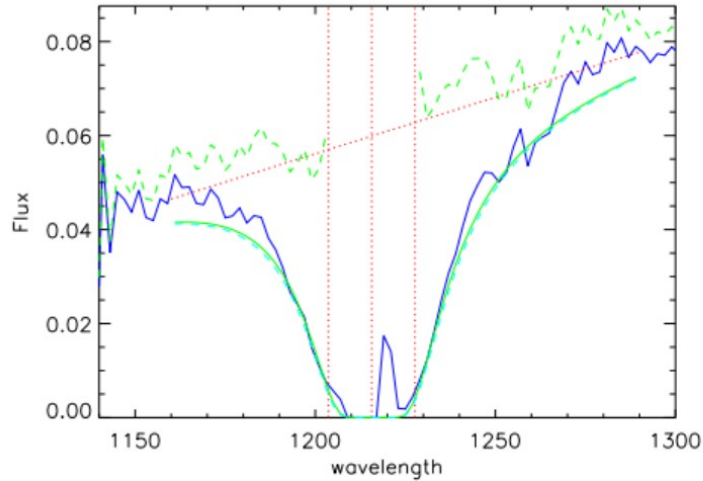
$\text{H}\alpha$  image of the SMC

# Known UV Extinction Curves:

## Continuum of Properties

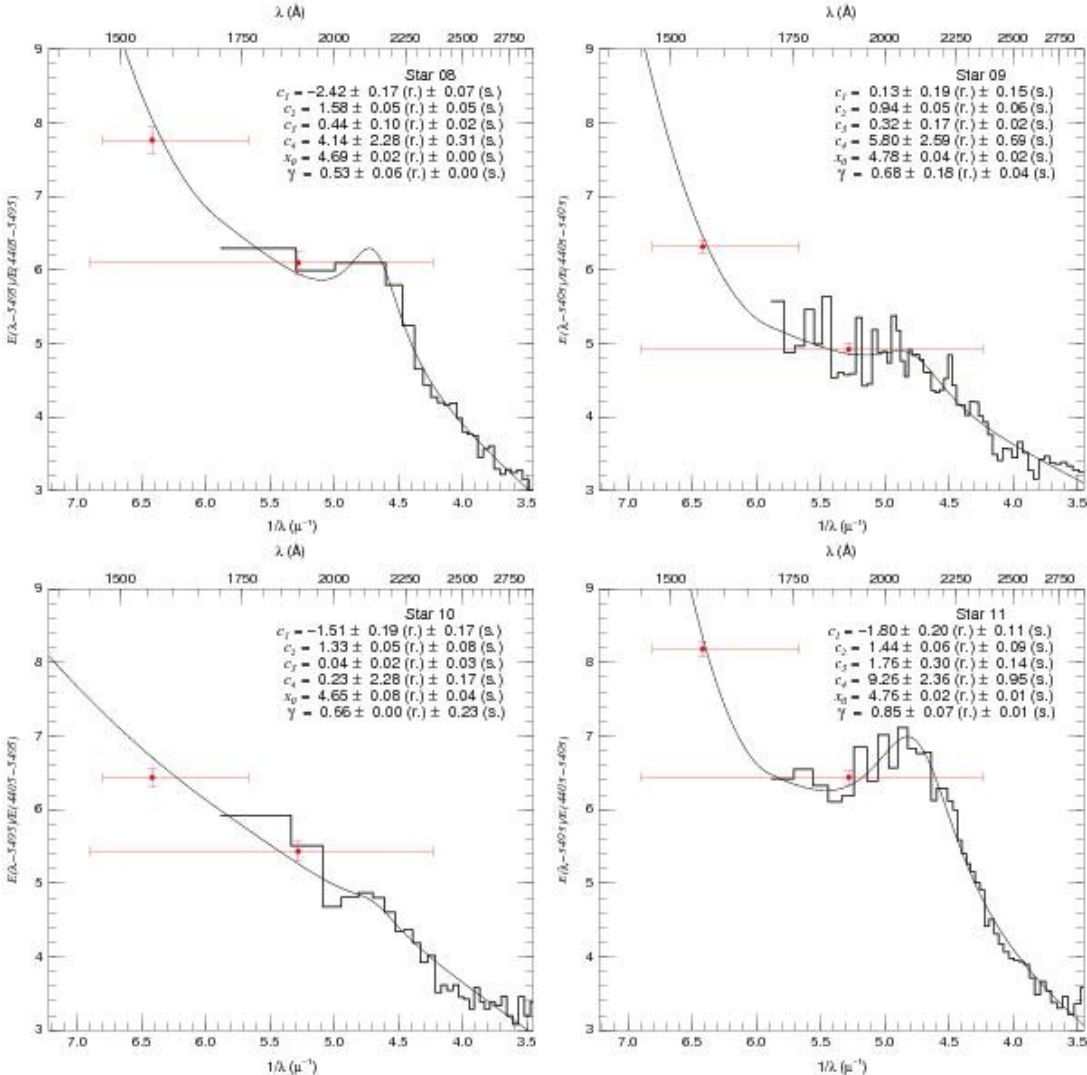
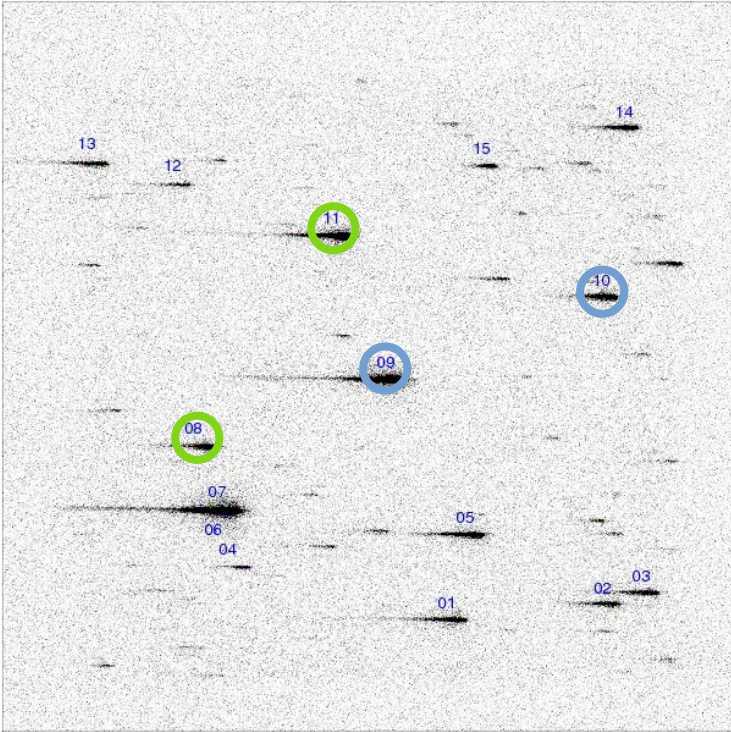


# Very(!) tentative trend w/ $H I/A(V)$



# Ultraviolet extinction toward a quiescent molecular cloud in the Small Magellanic Cloud

J. Maíz Apellániz<sup>1</sup> and M. Rubio<sup>2</sup>



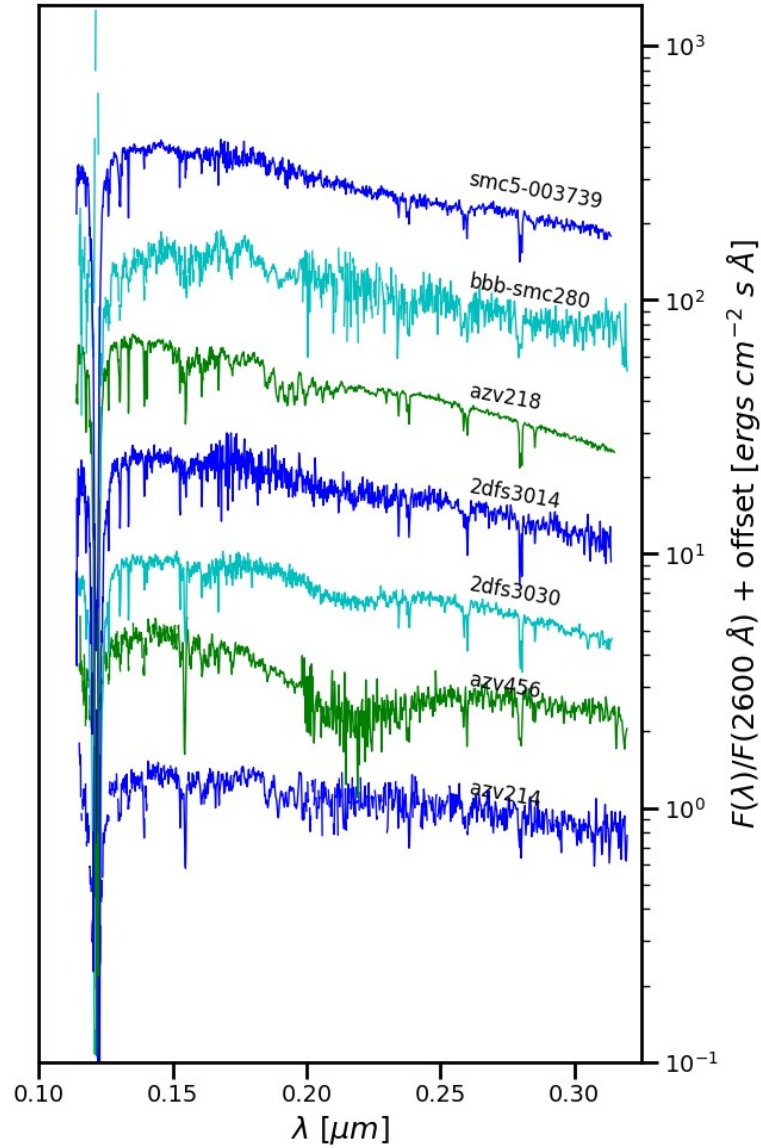
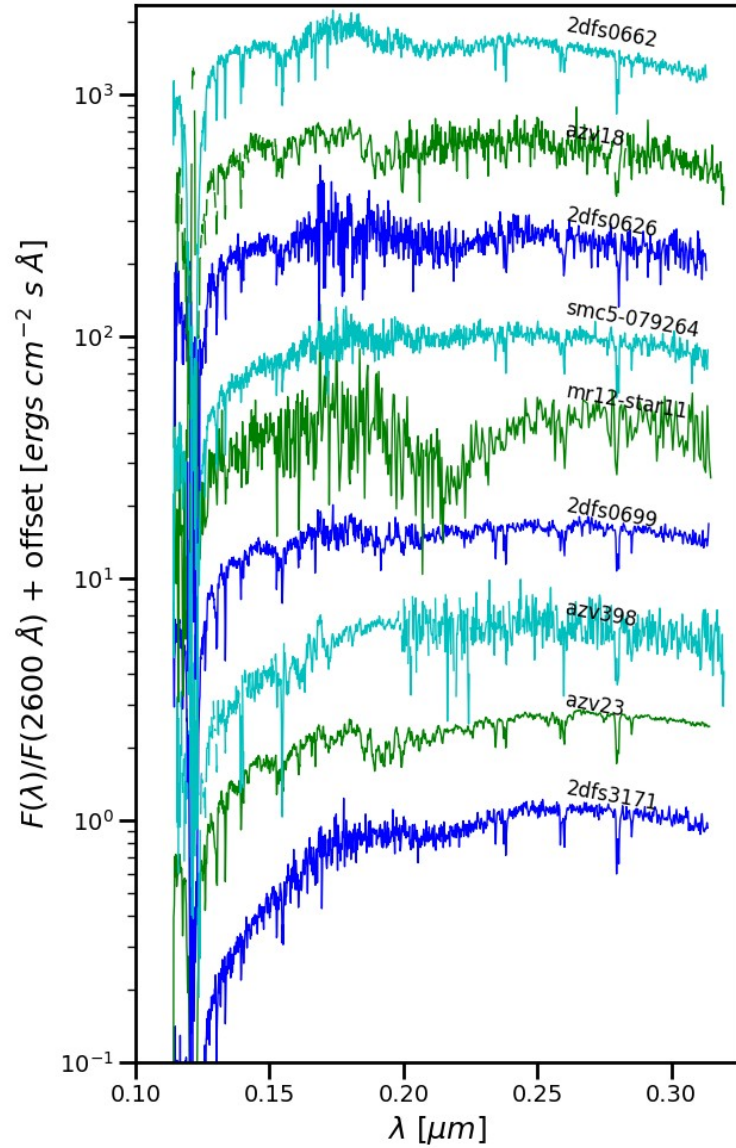
# In progress:

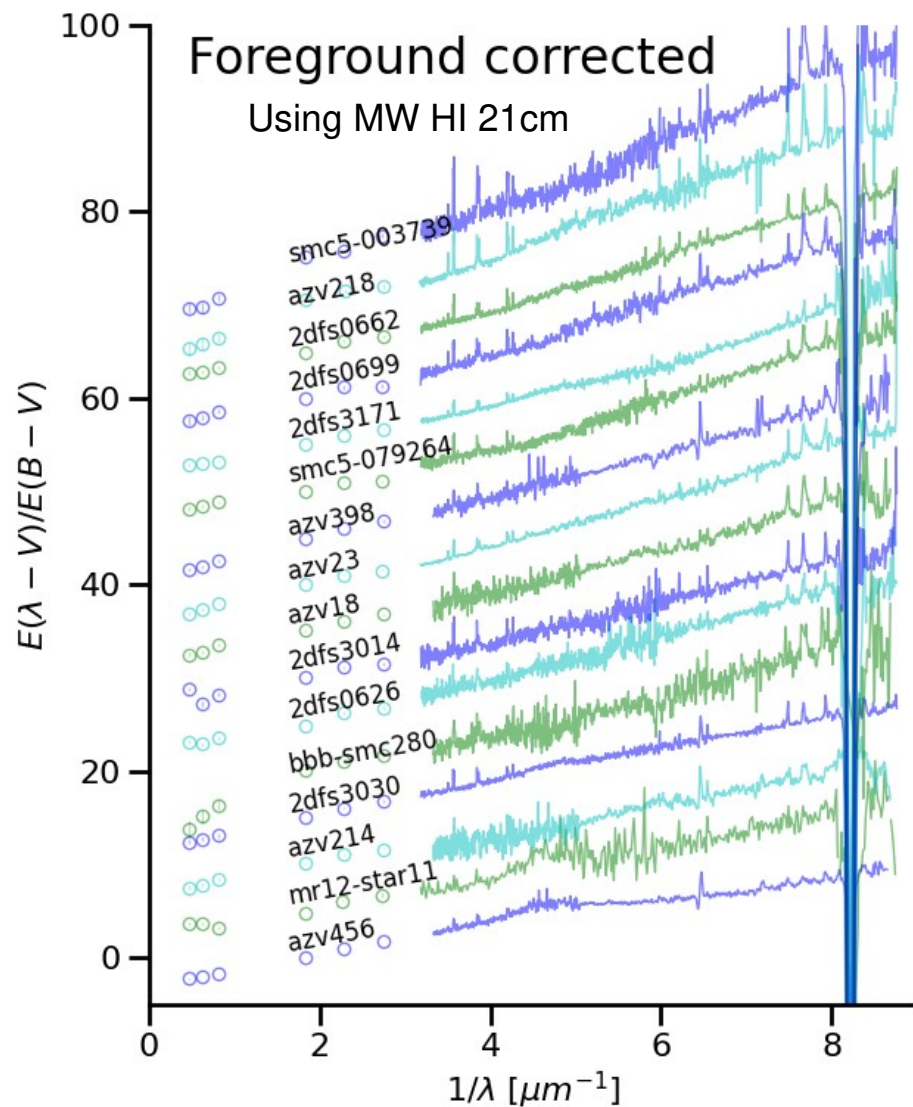
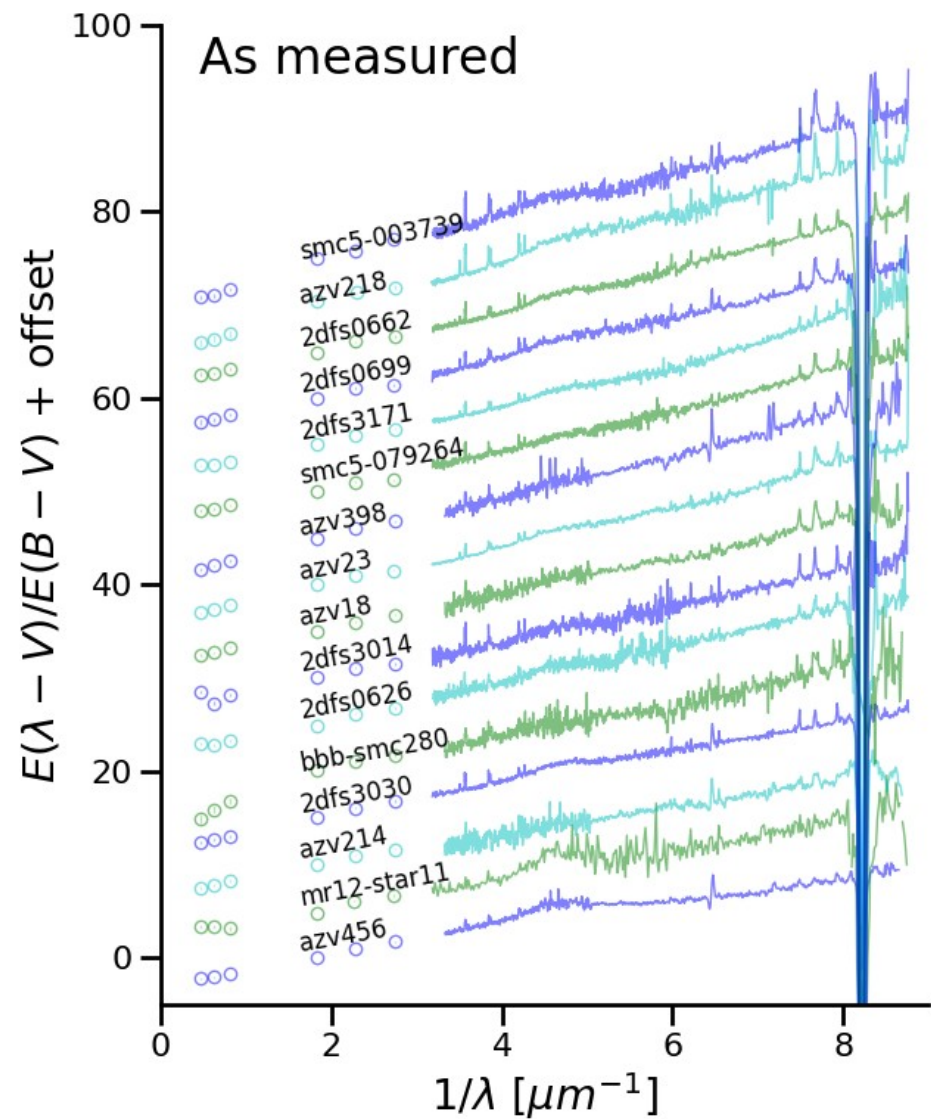
## Expanded SMC extinction sample

- Includes IUE+STIS data
  - STIS from 3 HST programs (PI: Gordon)
    - Picked to just get more sightlines, sample range of  $q_{\text{PAH}}$ , and get MR12 stars over full UV & w/ slit
- Use stellar models
  - Pro: no observed comparisons needed
  - Con: Total extinction = SMC + MW foreground
- Extinction for 16 sightlines
  - Tripling of sample

# Expanded Sample of Small Magellanic Cloud Ultraviolet Dust Extinction Curves: 2175 Å Feature Still Rare\*

KARL D. GORDON <sup>1,2</sup>, E. L. FITZPATRICK <sup>3</sup>, DERCK MASSA <sup>4</sup>, RALPH BOHLIN <sup>1</sup>, JEREMY CHASTENET,<sup>2</sup>  
CLAIRE MURRAY,<sup>1</sup> GEOFFREY C. CLAYTON <sup>5</sup>, DANIEL J. LENNON,<sup>6</sup> KARL A. MISSELT,<sup>7</sup> AND KARIN SANDSTROM<sup>8</sup>





# Spatial Distribution

2175 A bump  
Yes / No

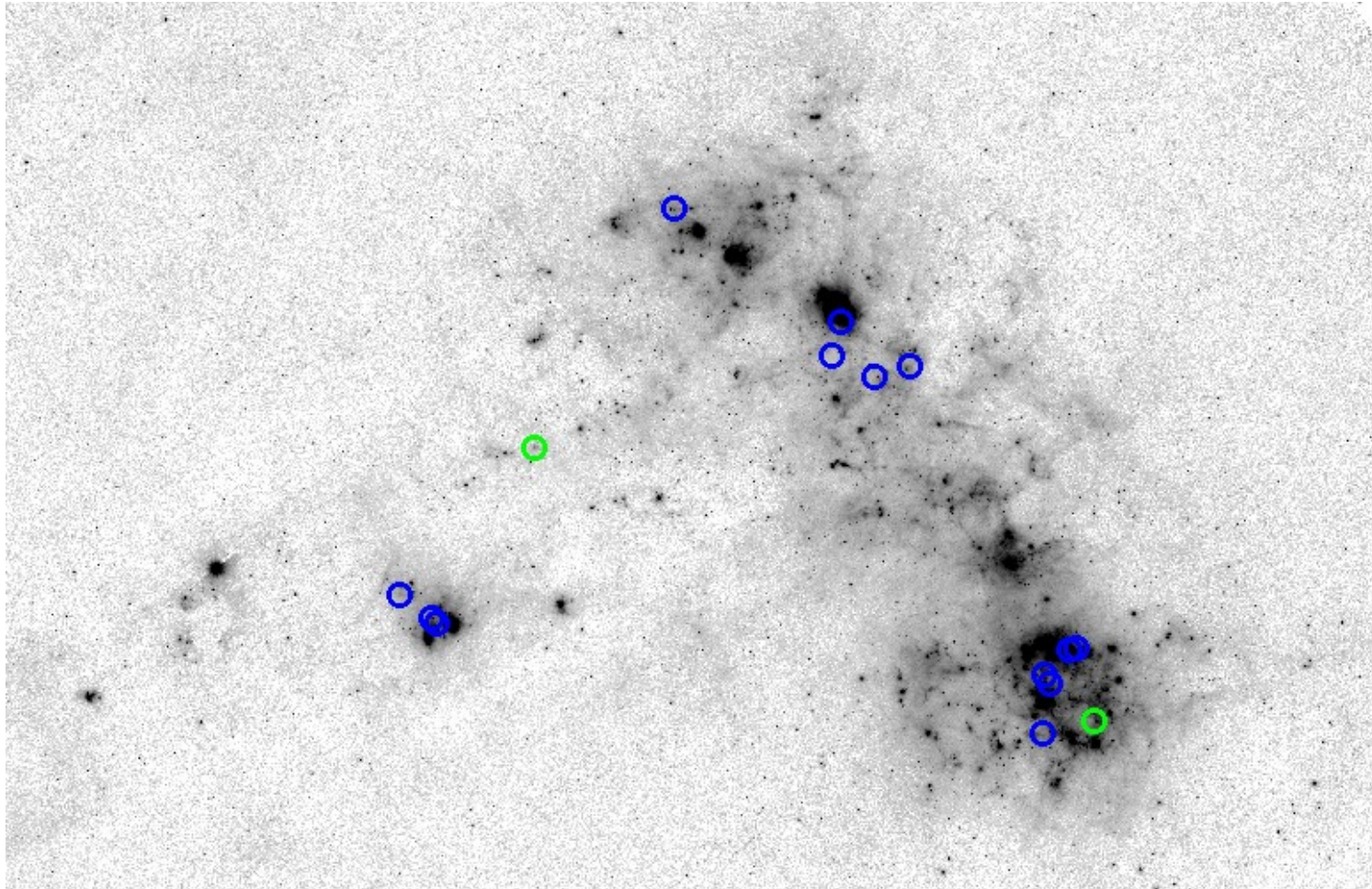
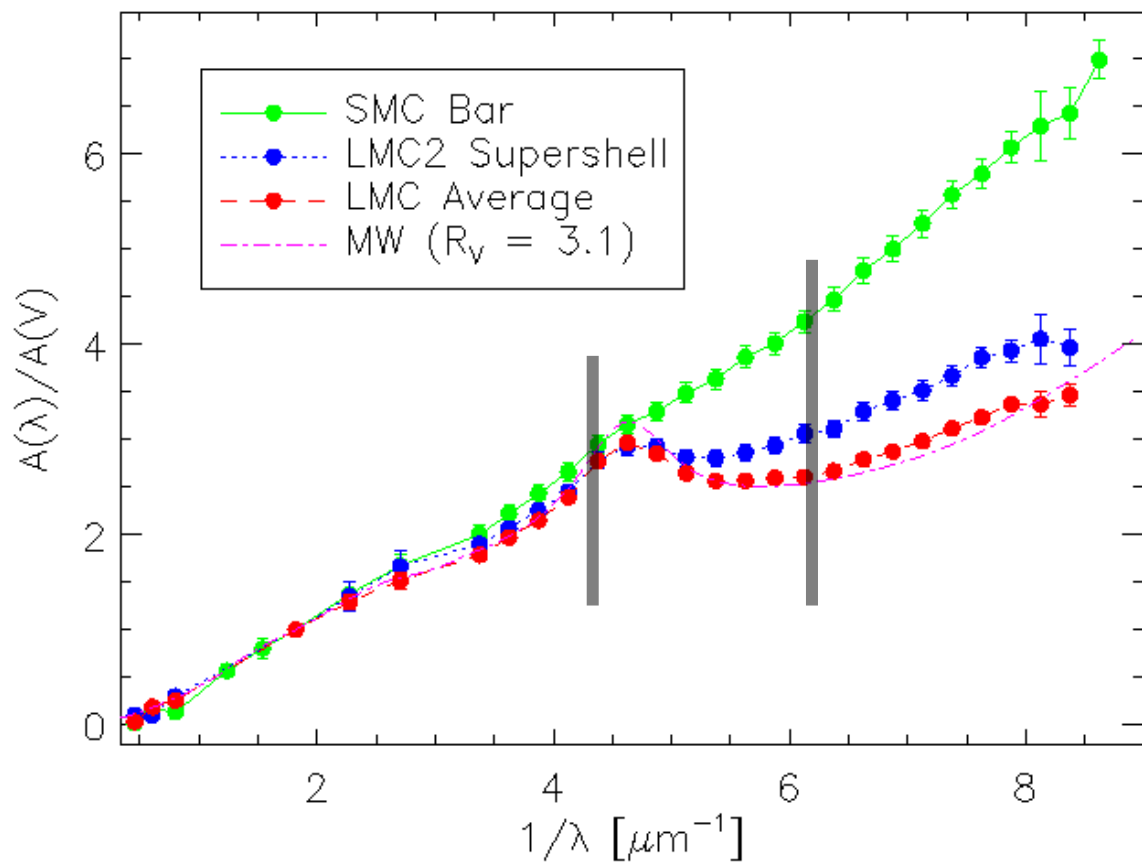


Image:  
MIPS 24um

# UVEX!

- FUV/NUV photometry of all(?) OB stars
- Great target list
- 1<sup>st</sup> cut at type of extinction



# UVEX!

- 1000 OB spectra in LMC and SMC
  - IUE → STIS → **UVEX**
- Could easily expand the extinction sample by factors of 10 or more(!!!!)
  - LMC: 19 current sightlines (may add 5-10 from ULLYSES)
  - SMC: 16 current sightlines (none reddened enough in ULLYSES)
  - Other nearby/low-metallicity galaxies?: ?? sightlines
- Pick reddened sightlines to O7-B3 stars [ $E(B-V) > 0.2$ ]
- Pick set of lightly reddened comparison stars in each galaxy
  - Empirically correct for foreground extinction

# Other UVEX ideas

- Milky Way
  - Imaging to find high/low  $R(V)$  sightlines
  - Spectral followup
- Reflection Nebulae (MW, LMC, SMC, etc.)
  - Dust radiative transfer
    - Derive single scattering albedo and phase function
    - Diagnostic of dust composition (silicates versus carbonaceous grains)
  - Imaging for all, spectral mapping for some (1 deg slit rocks)
- MW Diffuse Galactic Light (big reflection)
  - Same as above

# Summary

- Extinction at low metallicity different and quite variable
- SMC shows largest variations
- LMC shows strong variations influenced by “mini-starburst”
- Low metallicity = clues to earlier times
- Clues to dust grain evolution
  - Formation in evolved stars
  - Processing by harsh radiation fields
  - ISM grain growth
- UVEX potential is large

# Thanks

# New Mixture Model encompassing all known Local Group Extinction Curves

