The Stellar Populations of IC 10 and NGC 1569 observed with Keck LGSAO and HST

William D. Vacca
(USRA-SOFIA)
Chris Sheehy
James Graham
(UC Berkeley)
Nate McCrady
(UCLA)
Properties of IC 10

• Small irregular starburst (BCD) galaxy on outskirts of Local Group
  – \( R \sim 1 \text{ kpc} \)
  – \( M \sim 1-2 \times 10^9 \text{ M}_\odot \)

• Low metallicity \((Z \sim 0.2-0.3 \text{ Z}_\odot \sim Z_{\text{SMC}})\)

• Brief, galaxy-wide burst of SF occurred within last 10 Myr
  – Numerous HII regions
  – Large H\(\alpha\) and FIR luminosity
    • Highest SFR of any LG dwarf (> 0.7 \text{ M}_\odot \text{ yr}^{-1})
  – Large population of W-R stars \((N_{\text{WR}} > 24; \text{ SMC has } \sim 8)\)
    • Highest surface density of W-Rs in LG \(( \sim 8 \text{ kpc}^{-2}; \text{ MW } \sim 2.5 \text{ kpc}^{-2})\)
    • Anomalously high WC/WN ratio \(( \sim 1-2)\) for its Z \((10\times \text{ too large!})\)
    • Have WN stars been missed in surveys?

• \( b = -3.3^\circ \)
  – Uncertain reddening: \( A_V = 1.2 - 6.0 \text{ mag} \)
  – Uncertain distance: \( D = 0.5 - 3.0 \text{ Mpc} \)

• Ideal extragalactic target for NIR observations with LGSAO
  – Nearby, relatively large \( A_V \) (foreground and internal), high \( \rho_\star \)
  – Bright tip-tilt guide stars available
IC 10
HST/ACS/WFC
F435W, F606W, F814W

1” ≈ 4 pc
WR Object: [MAC92] 24

- Brightest W-R candidate in IC10
- Lies within prominent H II region HL 111c
- Lies at center of a young stellar cluster (Hunter 2001)
- Uncertain spectral type
  - Weak, broad He II 4686 emission (Massey & Holmes 2002)
  - WN+OB?
- Three components (A, B, C)
- Cluster itself?

Crowther et al. (2003)

HST/WFPC2 F555W
Observations

• NIR Data:
  – NIRC2/Keck II/LGSAO H and K’
  – 0.01”pixel⁻¹
  – Final FOV = 12.2” x 12.2”
  – $t_{exp} = 1200$ s (H); 1500 s (K’)
  – FWHM = 0.048” (H); 0.051” (K’)
  – Strehl $\sim 18\%$ (H); 32% (K’)

• Optical Data:
  – HST/ACS/WFC F814W
  – 0.05”pixel⁻¹
  – $t_{exp} = 1080$ s
  – FWHM = 0.08”
ACS WFC / NIRC2 Comparison

HST/ACS/WFC F814W

Keck II/NIRC2/LGSAO $K'$
IC 10 IHK’

12.2” x 12.2”
47 pc x 47 pc

Vacca, Sheehy, & Graham (2007)
CMD of IC 10 [MAC92] 24 Region

Optical Data:
- PSF fitting (Anderson & King 2006)
- 690 stars found in F814W
- $[F814W]_{\text{lim}} \sim 25.25$
- $\sigma < 0.04$ mag for $[F814W] < 23.0$

NIR Data:
- MTF-fitting method (Sheehy et al. 2006)
- 661 stars found in H
- $H_{\text{lim}} \sim 22.3$ (50% complete)
- $\sigma_H < 0.05$ mag for $H < 21.5$
- 585 stars found in $K'$
- $K'_{\text{lim}} \sim 21.5$ (50% complete)
- $\sigma_K < 0.05$ mag for $K' < 21.5$
- $[F814W]-K'$ for 380 stars
CMD of IC 10 [MAC92]WR 24 Region

- DENIS/2MASS catalogue of SMC (Zaritsky et al. 2002)
  - $Z \sim 0.2 Z_\odot$
  - E(B-V) (blue ★) = 0.65
  - E(B-V) (red ★) = 0.95
  - DM $\sim 24.5$ (D $\sim 790$ kpc)
- Lejeune & Schaerer (2001) isochrones
  - $Z \sim 0.4 Z_\odot$
  - E(B-V) (blue ★) = 0.60
  - E(B-V) (red ★) = 0.95
  - DM $\sim 24.5$ (D $\sim 790$ kpc)
- Two stellar populations:
  - MS and BSGs ($\tau < 20$ Myr)
  - RGs and AGBs ($\tau \sim 150-500$ Myr)
  - Differential reddening
- TRGB: $DM_0 = 24.48 \pm 0.16$ mag
  - Confirmed by Sanna et al. (2009) using entire ACS/WFC field
Advantages of High Resolution

- Resolved the (blue) central components of a young stellar cluster ($r_h \sim 3.2$ pc)
- WR 24 A and B resolved into multiple bright, blue components
  - 4 WN candidates with $([F814W]-K')_0 \sim -0.6$ ; $-4 > M_K > -6$
- WN/O ratio $\sim 0.14$ : $\tau_{SB} < 5$ Myr
NGC 1569
HST/WFPC2
F336W, F555W, F658N, F814W

D ~ 2 Mpc
NGC 1569
‘Deep Field’
ACS/HRC F814W + NIRC2 HK'

\[ t_{\text{exp}} = 390 \text{ s (F814W)} \]
\[ t_{\text{exp}} = 2400 \text{ s (H)} \]
\[ t_{\text{exp}} = 1500 \text{ s (K')} \]

McCready, Vacca & Graham, in prep.
NGC 1569: Preliminary CMDs

- 2520 stars in F814W, 1146 stars in H, 1233 stars in K’
  - ~1000 stars with H-K’, ~700 with [F814W]-K colors
- Analyzing CMDs to determine:
  - $A_V$, $D_{TRGB}$, SF age, SF history
Conclusions

- NIR LGSAO + HST/ACS is a powerful combination for high spatial resolution studies of extragalactic stellar populations, particularly for starburst regions with large $A_v$ and $\rho_\star$
- Photometry with high precision and accuracy is achievable with LGSAO even on extragalactic objects