Warm, Ionized Gas Revealed in the Magellanic Bridge Tidal Remnant

Constraining the Baryon Content and the Escaping Ionizing Photons around Dwarf Galaxies

Kat Barger
UW-Madison → U. Notre Dame in the Fall

Co-Authors: L. Matthew Haffner & Joss Bland-Hawthorn

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Magellanic System

**Inflow rate~0.4 M_☉ yr⁻¹ in HI** (van Woerden et al. 2004)

- **SMC**: d=60 kpc
- **LMC**: d=50 kpc
- **Bridge**
- **Leading Arm**


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How were these structures created? What is their fate?

“Kallivayalil et al. (2006a, 2006b) proper motion measurements suggest first orbit or pass.”
-Besla et al. 2010

≈ 200° (Nidever et al.)
Transfer of Material between Galaxies

★ Material from SMC → LMC
(see Bekki & Tsujimoto 2010 & ref therein)

★ Chemical enrichment history
(e.g., van Loon et al. 2005; Harris & Zaritsky 2009; Rubele et al. 2012)

★ Low N in young LMC stars
(e.g., Korn et al. 2002; Hill 2004; van Loon et al. 2010)

★ Some LMC ★s counter rotate
(Olsen et al. 2011)

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320 million $M_\odot$ of $H^0$ (Brüns et al. 2005)

HI: GASS Survey

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$\text{H}$\textsubscript{\alpha} Bridge

70–160 million $M_\odot$ of $H^+$ (Barger et al., in prep)

320 million $M_\odot$ of $H^0$ (Brüns et al. 2005)

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What is ionizing the Bridge?

★ Photoionization
★ MW & EGB
★ Early Type Stars
★ MCs
★ Collisional Ionization
★ Galaxy interactions
  ★ Turbulent mixing, ram pressure, & tidal shocks
★ Stars
  ★ Supernova explosions & Strong stellar winds

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What is ionizing the Bridge?

★ Photoionization
★ MW & EGB
★ Early Type Stars } ➞ with bright Hα
★ MCs
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★ Galaxy interactions
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★ Strong stellar winds
★ Supernova explosions

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\[ \phi_{LC} = 2.1 \times 10^5 \left( \frac{I_{H\alpha}}{0.1R} \right) \left( \frac{T}{10^4 K} \right)^{0.094} \text{ photons cm}^{-2} \text{ s}^{-1} \]
What is ionizing the Bridge?

★ Photoionization
★ MW & EGB } Factor of ~10 too low
★ Early Type Stars } with bright Hα
★ MCs } \( \rightarrow \) estimate of \( f_{\text{esc}} \)

Collisional Ionization
★ Galaxy interactions
★ Turbulent mixing, ram pressure, & tidal shocks
★ Strong stellar winds
★ Supernova explosions

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Cosmological Significants of $f_{esc}$

★ Reionization heated the IGM and GCM

★ Reduced gas accretion, especially in dwarf galaxies

★ Stunted galaxy formation and build up
  (Barkana & Loeb 1999, Shaviv 2003, Shapiro 2004)
Cosmological Significants of $f_{esc}$

★ Galaxies might dominate reionization (Madau et al. 1999, Bolton et al. 2005)

★ High-mass galaxies alone cannot reionize the universe (Fernandez & Shull 2011)

★ The LMC and SMC $f_{esc}$ constrains the contribution from dwarf galaxies and anchors cosmological simulations.
Assumes $T = 10^4$ K

$$f_{esc, LMC} \& f_{esc, SMC} = 3 \pm 2\%$$
Summary

★ At least 25–33% of the Bridge is ionized

★ The LMC & SMC radiate 3±2% of their ionizing photons

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