The Only Interstellar Extinction Talk at this Conference

David M. Nataf

Australian National University

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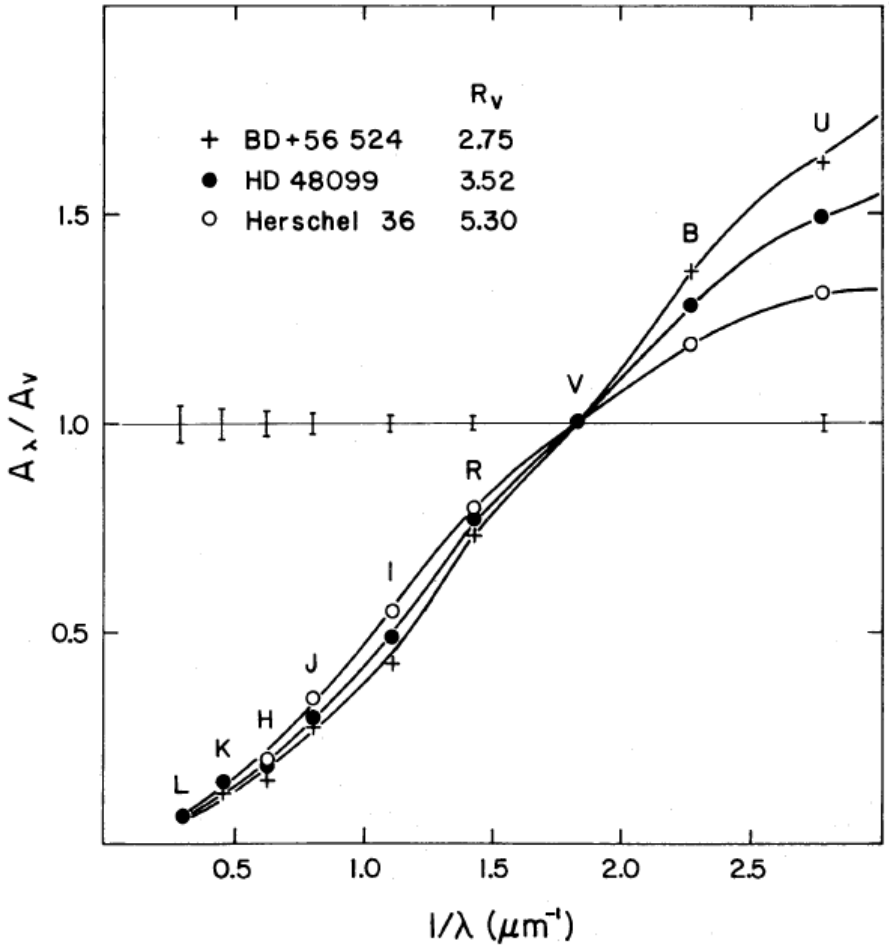
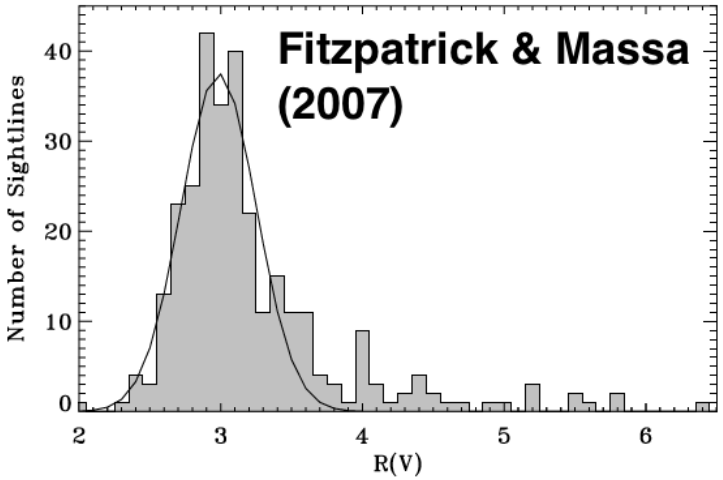
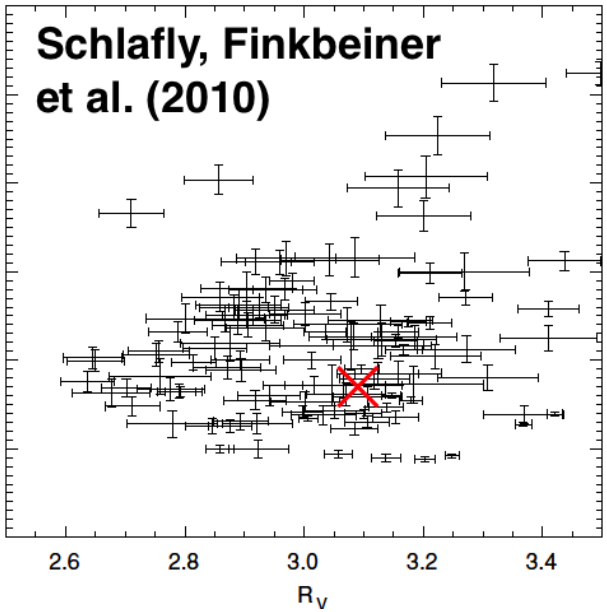
Shape of the extinction once thought a solved problem

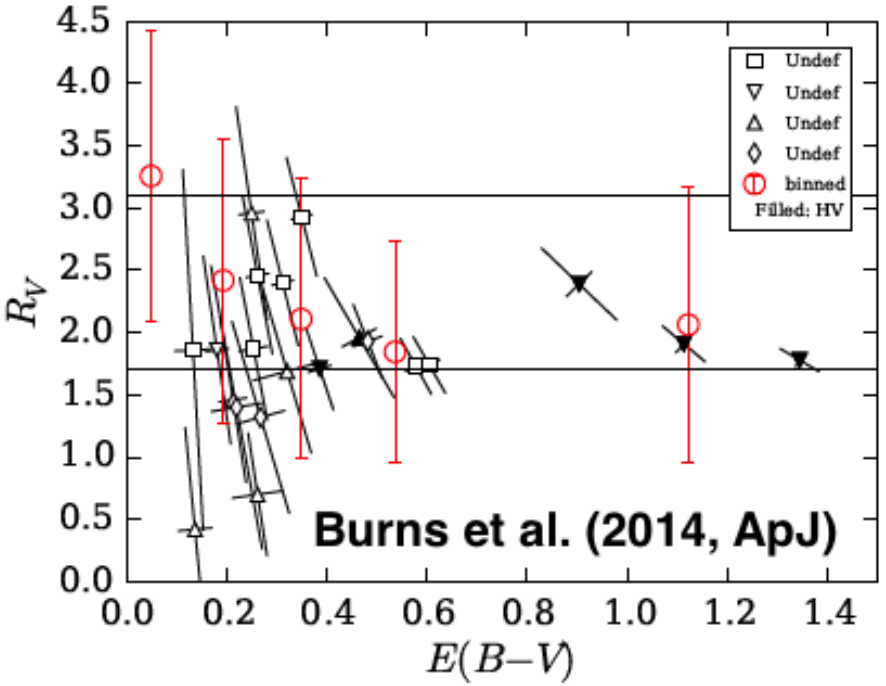
- Cardelli, Clayton, & Mathis (1989, 5,553 citations) solved for the dependence of extinction from ≈0.125-3.50 μm on $R_V=A_v/(A_B-A_V)$.
- $R_V=3.1$ almost everywhere in the Milky Way.



A Paradox: Stars in other Spiral Galaxies Show a Different Mean Extinction Curve than the Milky Way

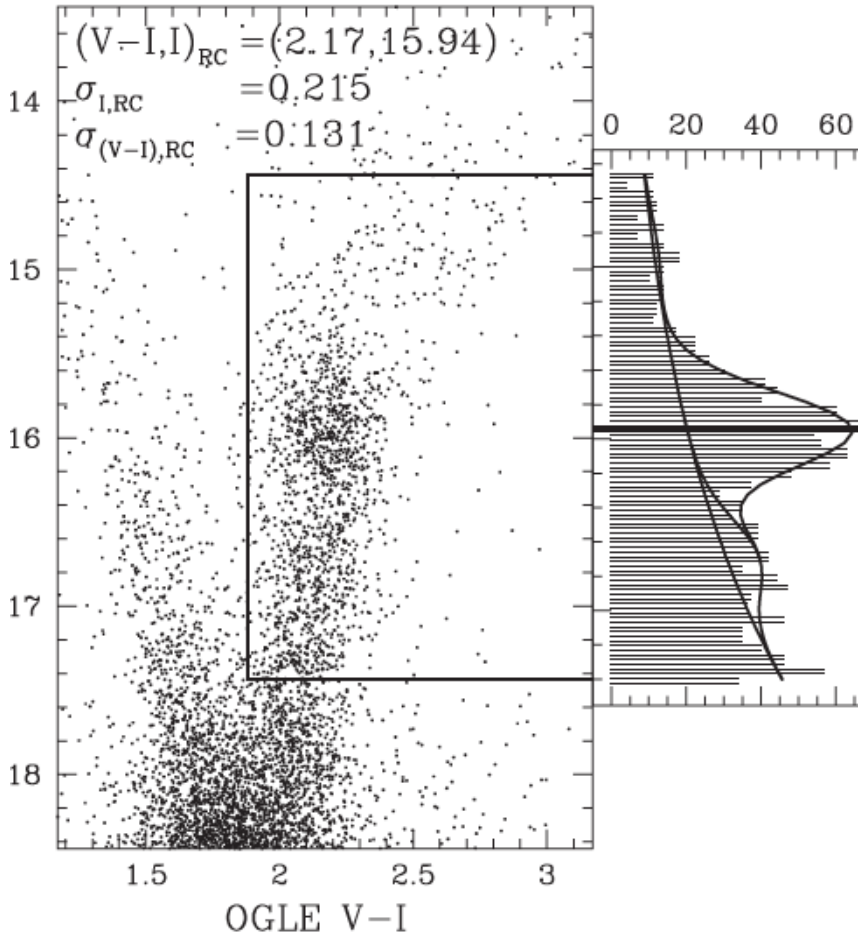


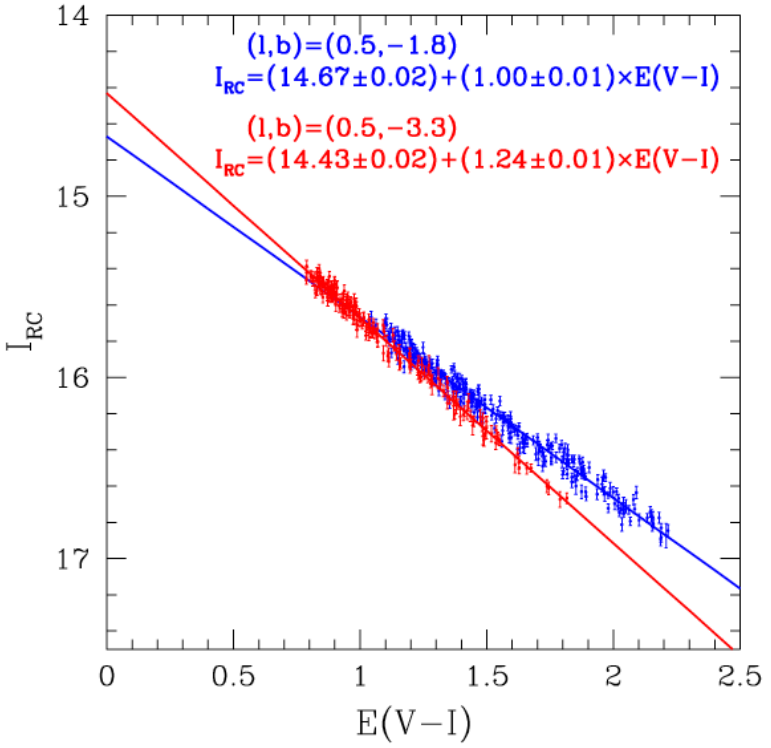




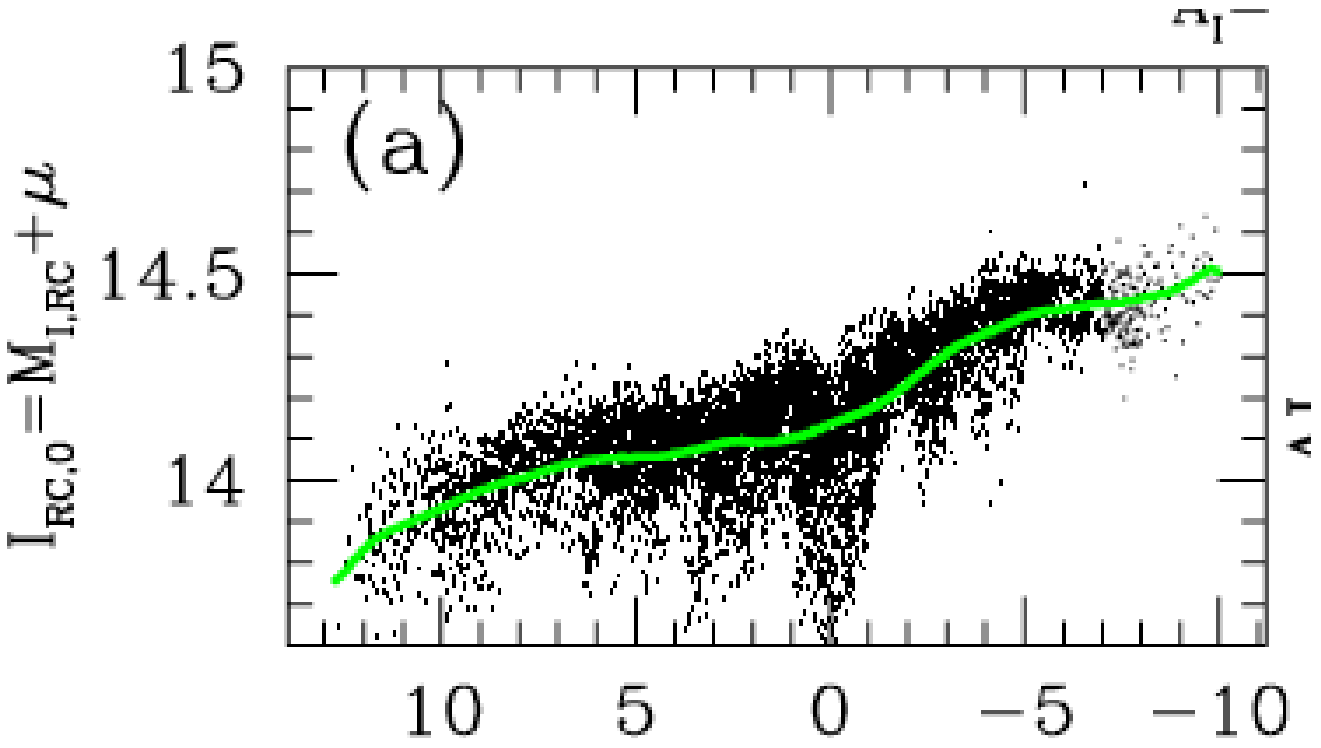
Demonstration of variable and thus non-standard optical extinction toward the inner Galaxy (Nataf et al. 2013B).

See also Udalski (2003), Nishiyama et al. (2009), Zasowski et al. (2009), Revnivtsev et al. (2010), and Fritz et al. (2011)

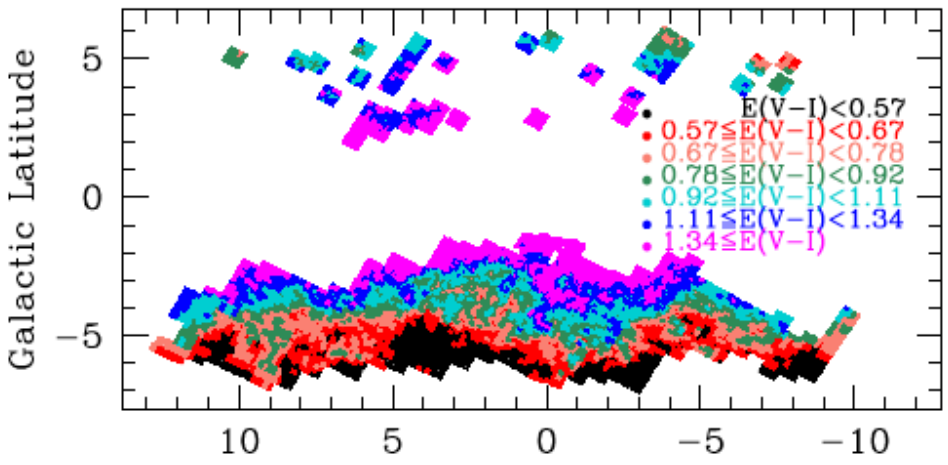




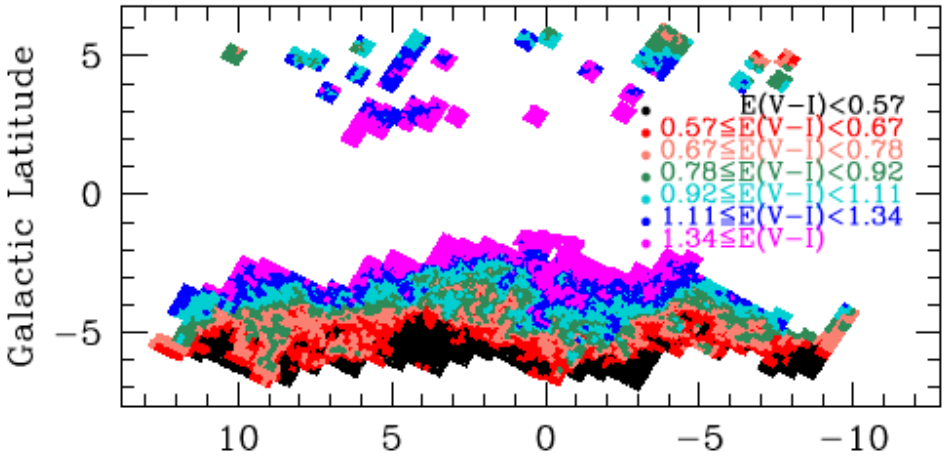
Non-standard extinction => Hard to model the Galactic bar

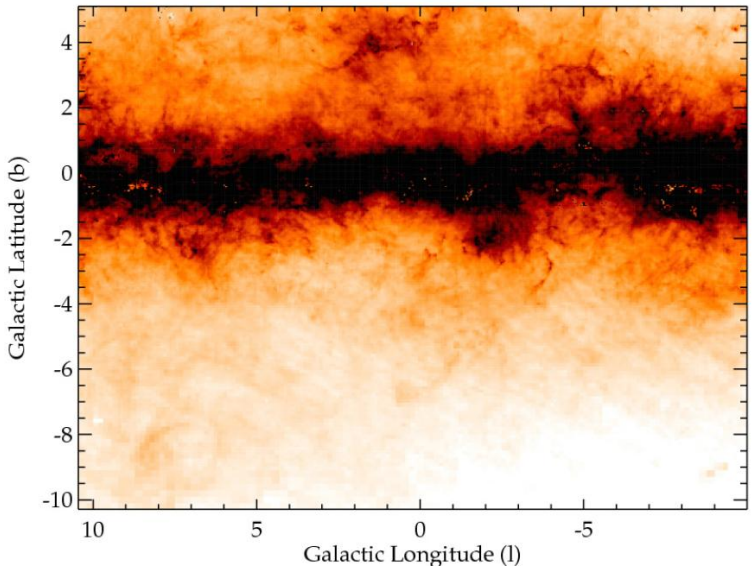


Optical (E(V−I)) Reddening Maps Toward the Inner Galaxy (Nataf et al. 2013B)



Optical (E(V−I)) and infrared (E(J−K_s)) Reddening Maps Toward the Inner Galaxy (Nataf et al. 2013B, Gonzalez et al. 2013A)





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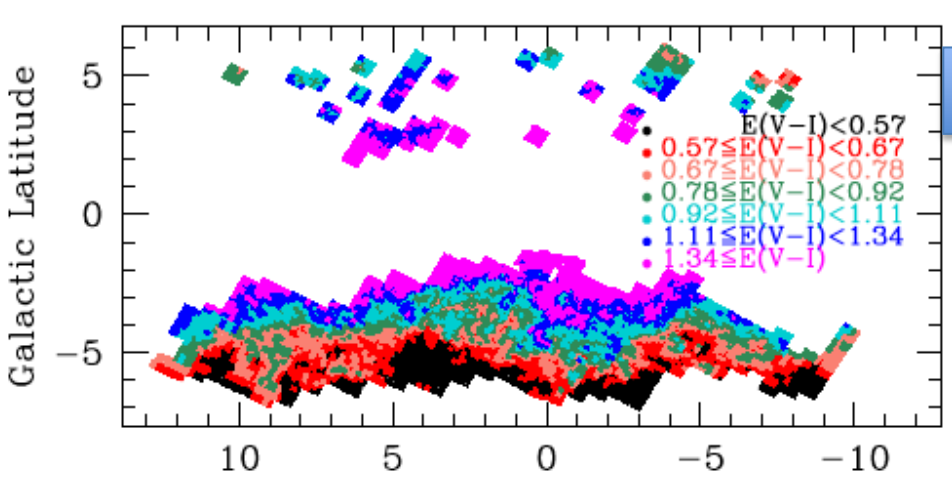
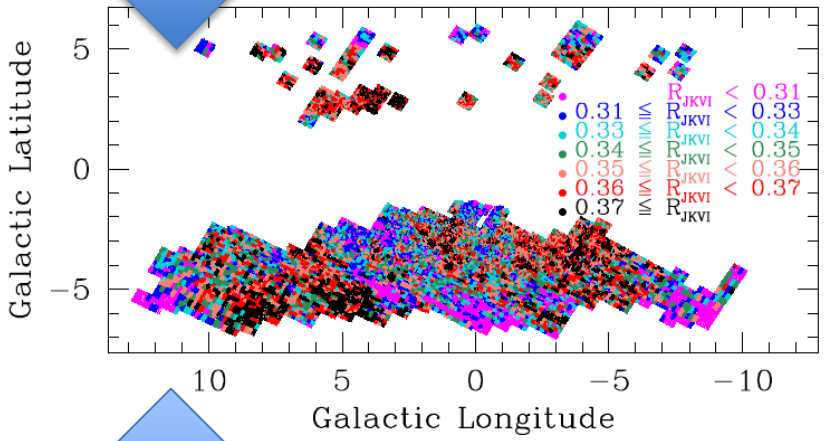
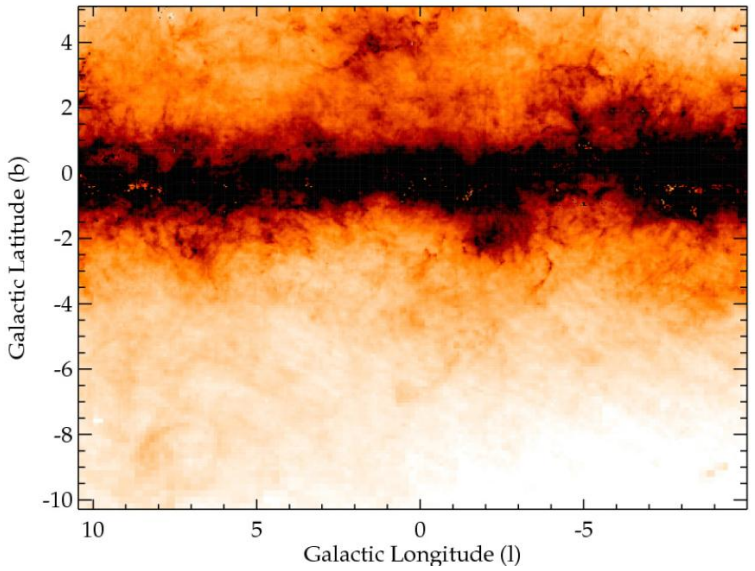






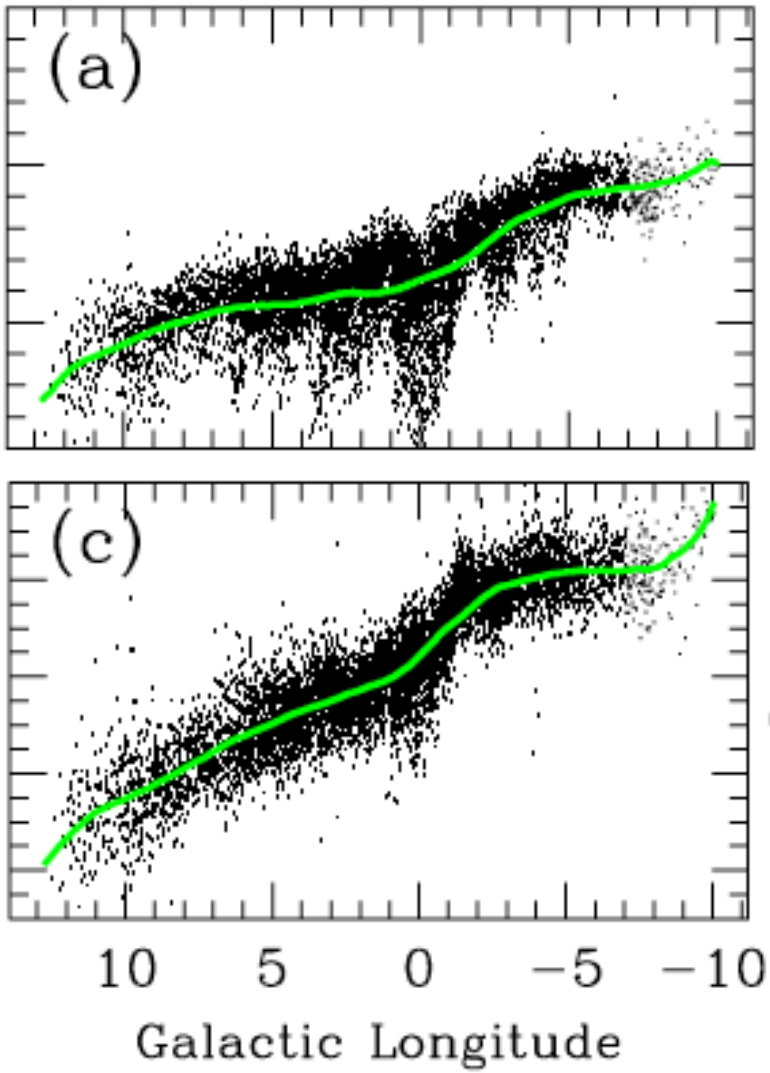
Corrected Extinction Cleans up the Galactic Bar

Wesenheit slope:

$$A_I = 1.45 \times E(V-I)$$

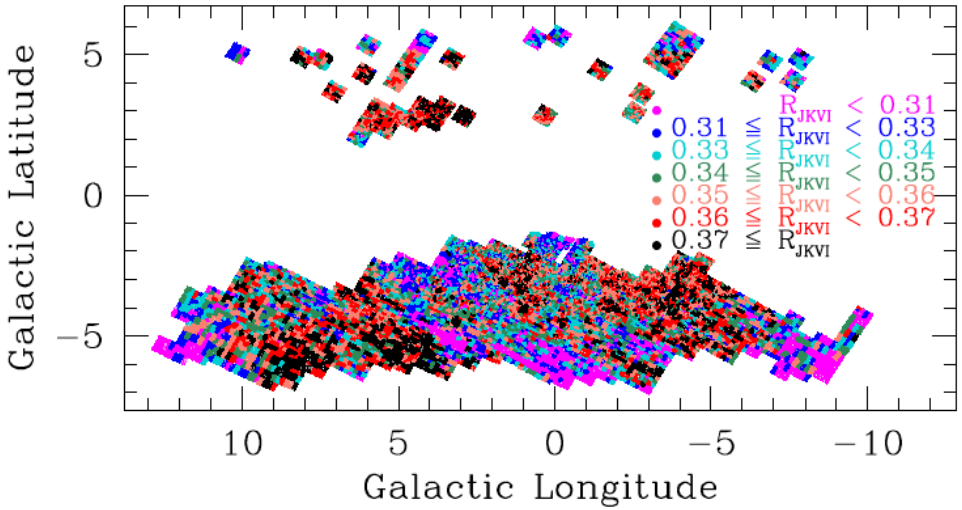
Uber-Wesenheit slope:

$$A_I = 1.217 \times E(V-I)\left[1 + 1.126 \times (R_{JKVI} - 0.3433)\right]$$
$$= 0.7465 \times E(V-I) + 1.3700 \times E(J-K_s),$$



$E(J-K_s)/E(V-I)$ is variable, ergo, extinction curve is variable

Extinction computed from both one and two colours: A_I=0.7465*E(V−I)+1.3700*E(J−K_s) – "uber-wesenheit" index more accurate than extinction from one colour, since confirmed by independent studies of RR Lyrae (Pietrukowicz et al. 2015).



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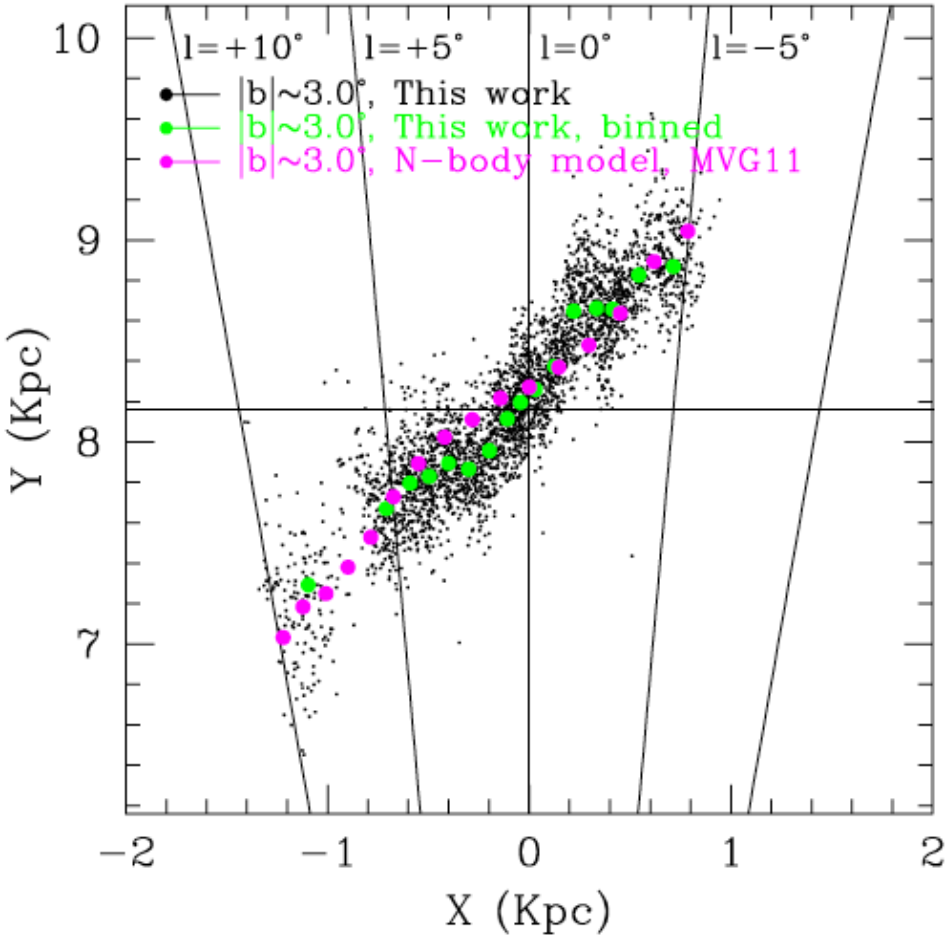
$$= 0.7465 \times E(V-I) + 1.3700 \times E(J-K_s),$$

Consistency check #1: Galactic Bar in Projection from Nataf et al. (2013) Agrees with Predictions of Martinez-Valpuesta & Gerhard (2011)



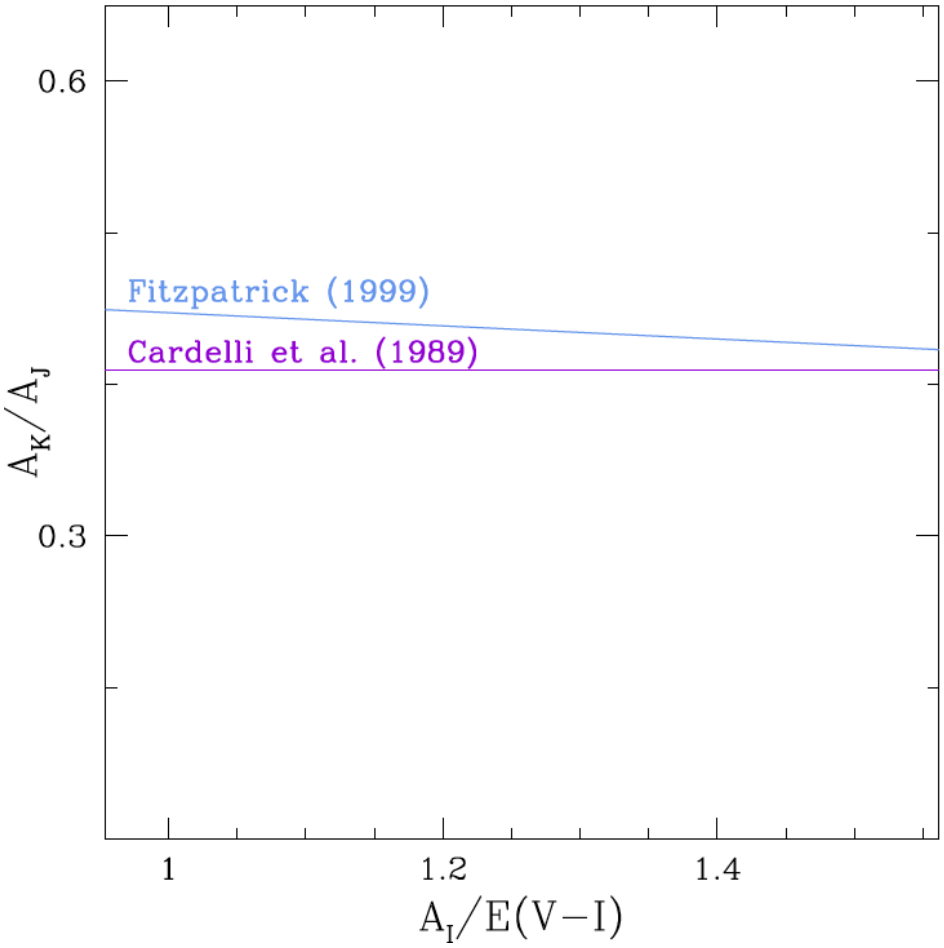
Consistency Check #2: Distances to the Galactic Centre

- R_{GC} = 7.40 ± 0.2 ± 0.4 Kpc (Francis & Anderson 2014)
- R_{GC} ≈ 7.90 Kpc (Wegg & Gerhard 2014)
- R_{GC} ≈ 7.90 ± 0.20 ± 0.30 Kpc (Matsunaga et al. 2011)
- **R_{GC} ≈ 8.20 Kpc (Nataf et al. 2013)**
- **R_{GC} = 8.27 ± 0.29 Kpc (Schoenrich 2012)**
- R_{GC} = 8.27 ± 0.01 ± 0.40 Kpc (Pietrukowicz et al. 2014)
- R_{GC} = 8.33 ± 0.05 ± 0.14 Kpc (Dekany et al. 2014)
- **R_{GC} = 8.36 ± 0.10 Kpc (Chatzopoulos et al. 2015)**
- R_{GC} = 8.4 ± 0.4 Kpc (Ghez et al. 2008)
- R_{GC} = 8.7 ± 0.5 Kpc (Vanhollebeke et al. 2009)

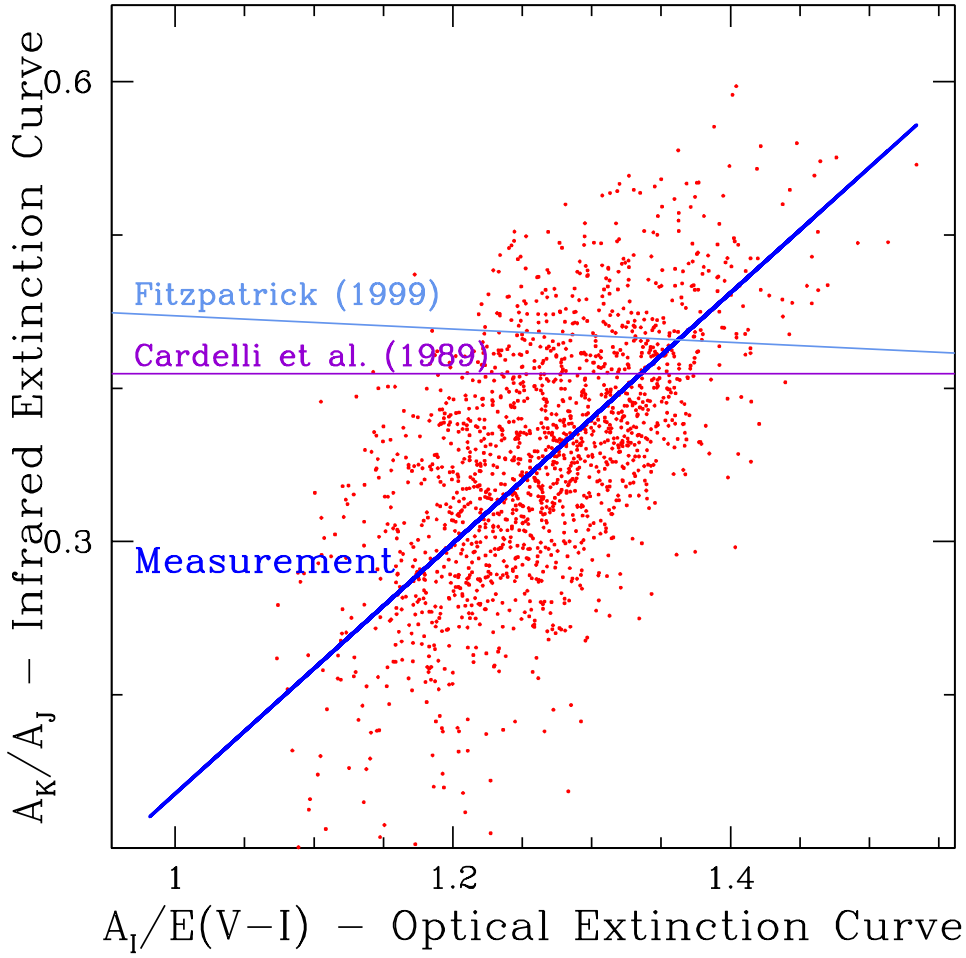
Follow-up: Is the shape of the near-infrared extinction curve a universal constant? [$A_\lambda \alpha \lambda^{-1.61}$]

- "The shape of the extinction law for long-wavelengths ($\lambda \geq \approx 0.7$ μm) is independent of R_V." - Cardelli et al. (1989);
- "The results are thus consistent with an invariant IR extinction curve. At wavelengths greater than ≥≈ 1 μm, the extinction curve roughly resembles a power law with an index of ≈ 1.5." – Fitzpatrick (1999);
- "changing the reddening parameter for the Cepheids from R_V=3.1 to R_V=2.5 … changes the distance to M31 by <0.02 mag. " - Riess et al. (2012) … [note: Riess et al. are now working in F160W (H-band), partially because the extinction coefficients are independent of R_V.

Theoretical predictions: Constant or nearly-constant near-infrared extinction curve shape

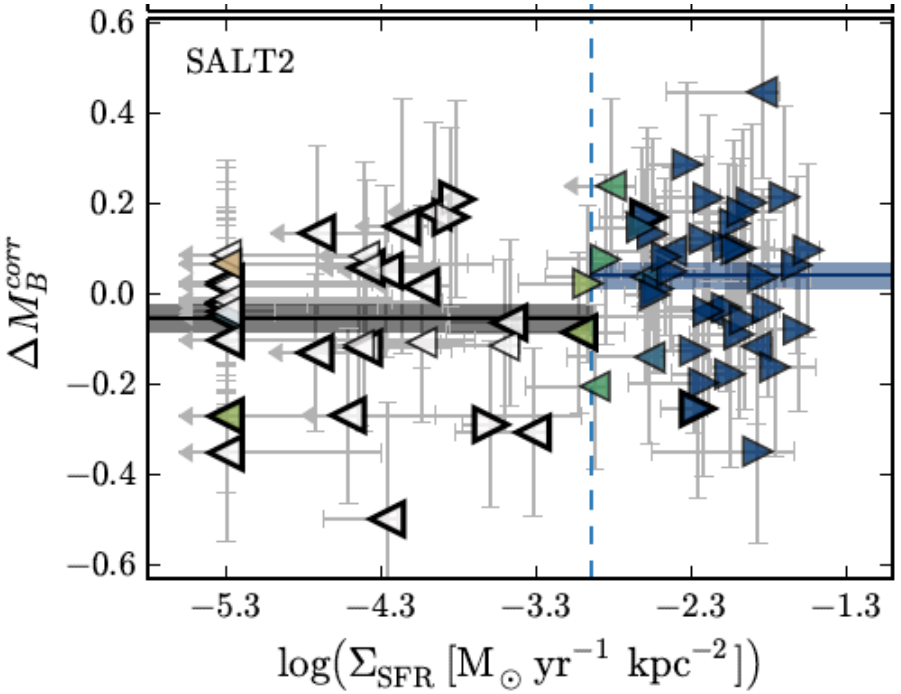


Data: Near-infrared extinction curve is fact variable and correlated with R_V, ≈300% variations in a hitherto universal constant



Requested topic: Confirmation of a Star Formation Bias in Type Ia Supernova Distances and its Effect on Measurement of the Hubble Constant, Rigault et al. (2014, arXiv:1412.6501)

- Claim that Type Ia SNe in star-forming environments are dimmer by a colossal ≈0.12 mag.
- assume R_V=1.7,2.5, or 3.1 for all spiral galaxies in the universe.
- Perhaps they should read Kriek & Conroy (2013)? Rigault et al. assume that R_V is independent of environment.



Conclusions

- The shape of the extinction curve varies within the Milky Way, particularly toward the inner Milky Way, and this is not well-parameterized.
- Source of tremendous systematic error for infrared flux method (exoplanets, ages), dark energy equation of state parameter “w”, Hubble’s constant, and radius measurements of neutron stars.
- James Bullock should not leave the conference early -- The Milky Way manifestly scores a 5/5 for relevance to cosmology.
- See also Carnegie-Chicago-Spitzer program (Freedman, Kollmeier, et al.) will measure the local group distance scale to 1% with RR Lyrae in a nearly reddening-independent manner.