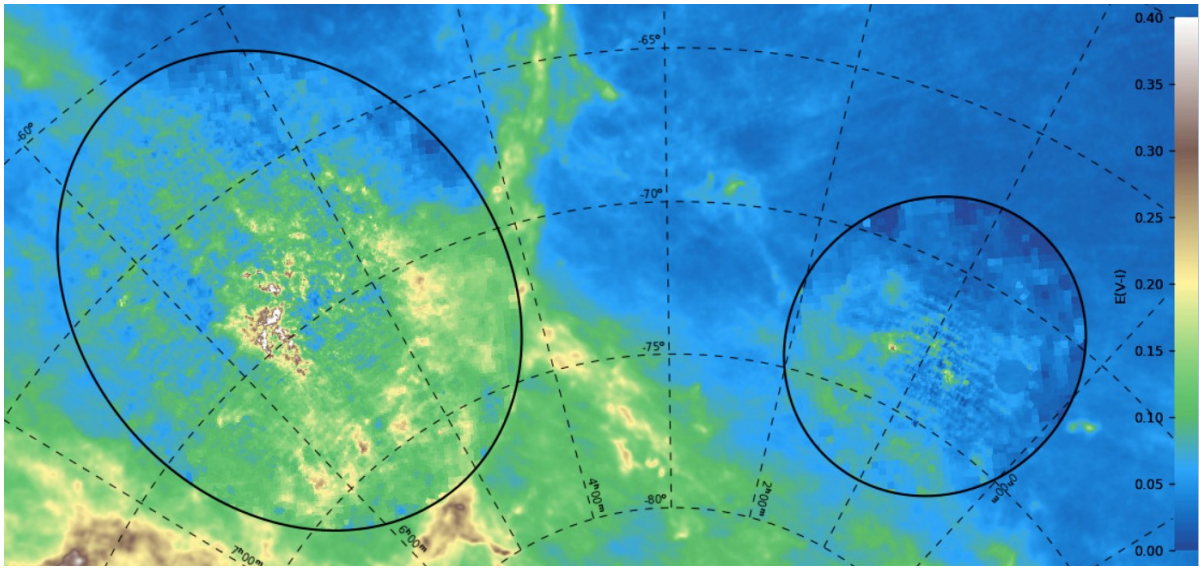
Reddening Maps of the Large and Small Magellanic Cloud based on OGLE-IV Red Clump Stars



Dorota Skowron
Astronomical Observatory, University of Warsaw

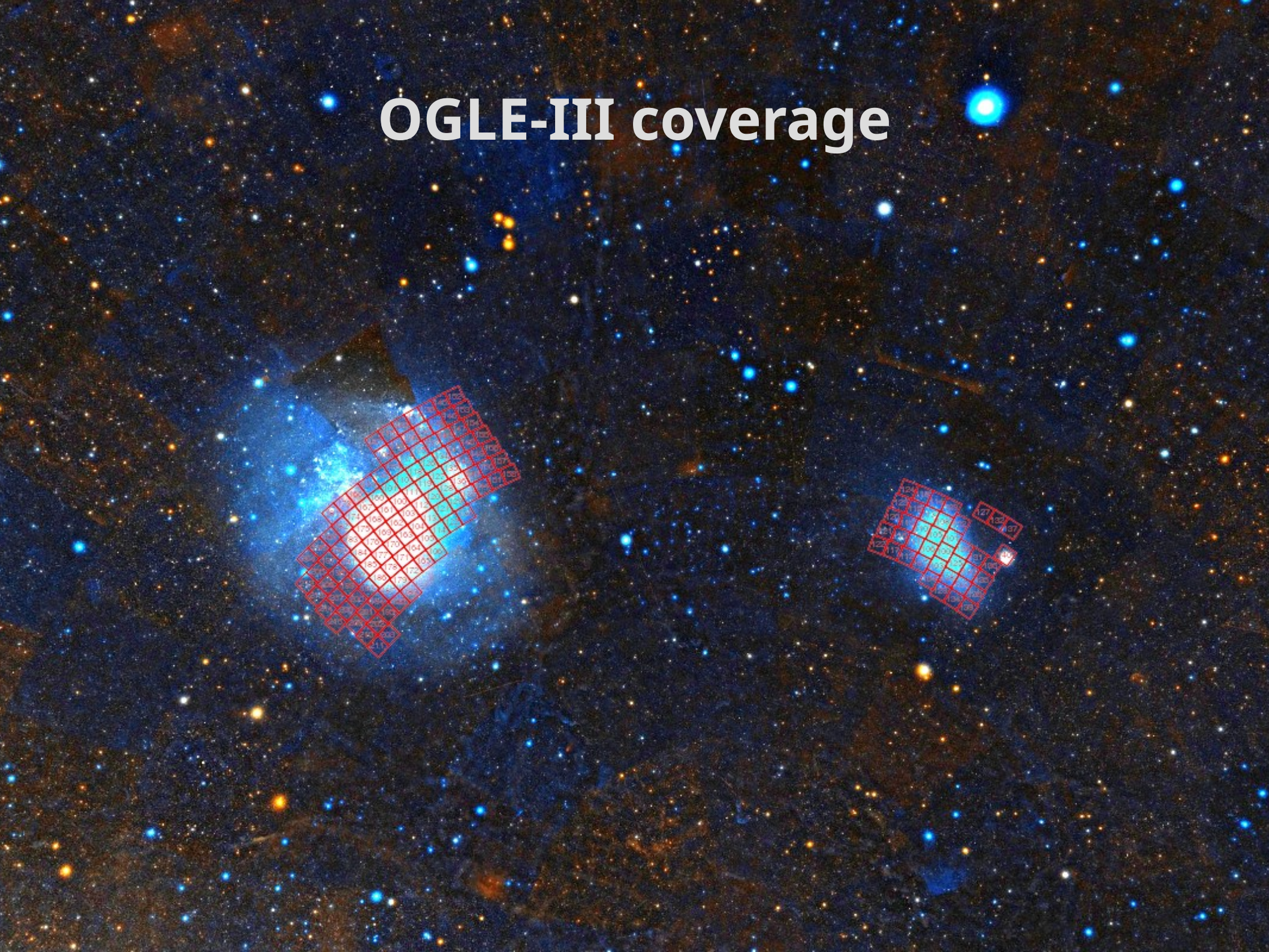
Based on the publication: **Skowron et al. 2021, ApJS, 252, 23**

The motivation

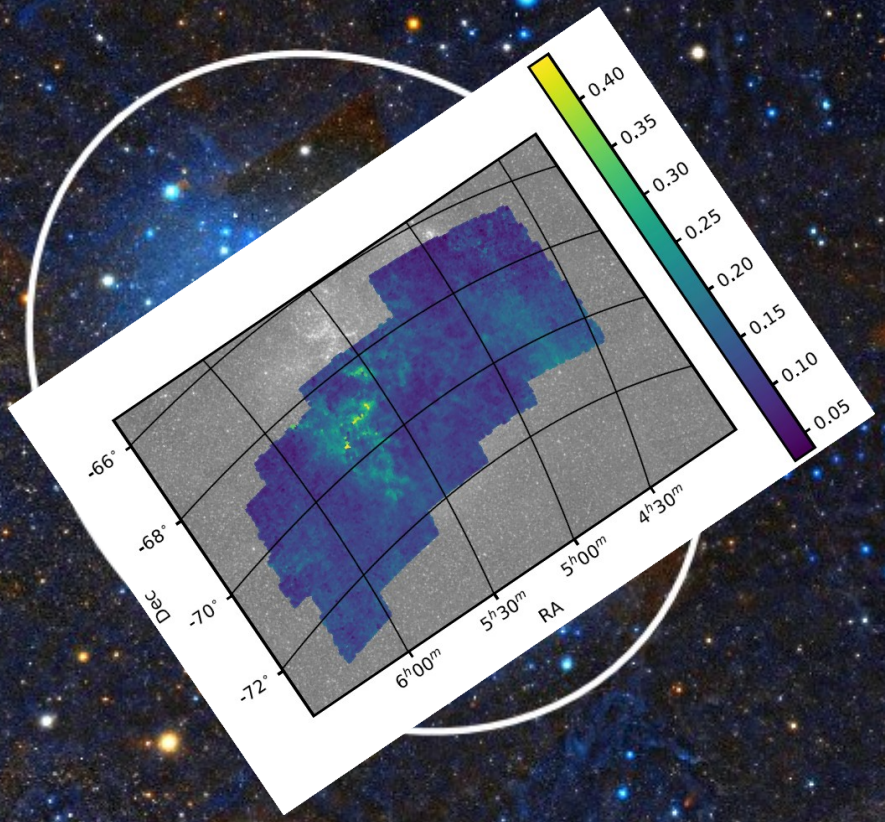
- knowing reddening is essential in practically all astrophysical studies that involve calculating distance
- knowing reddening in the Magellanic Clouds is especially important, as they are used to calibrate the cosmological distance scale
- **THE PROBLEM** – widely used reddening maps cover only a small central area of the Magellanic Clouds (Haschke et al. 2011, recently recalibrated by Górski et al. 2020)

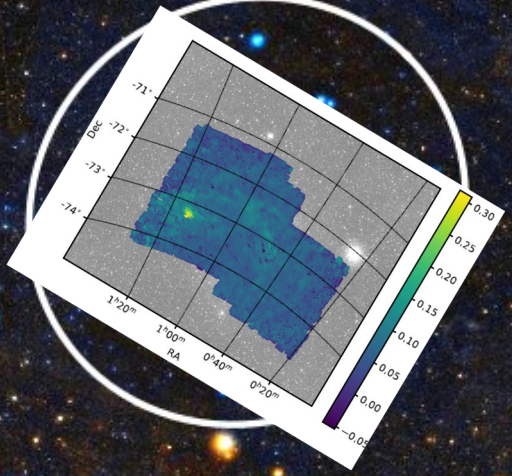

Large and Small Magellanic Clouds

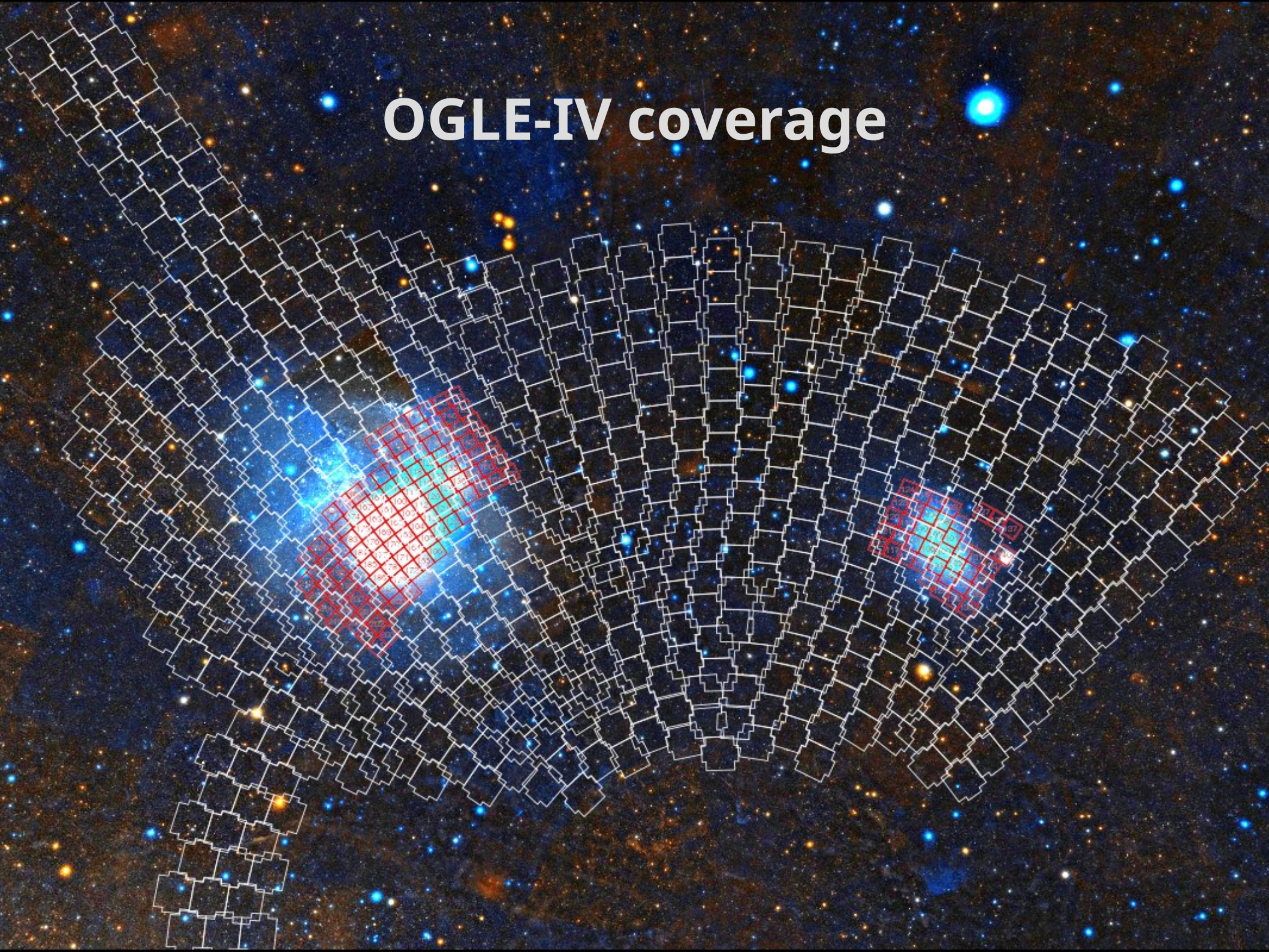
OGLE-III coverage



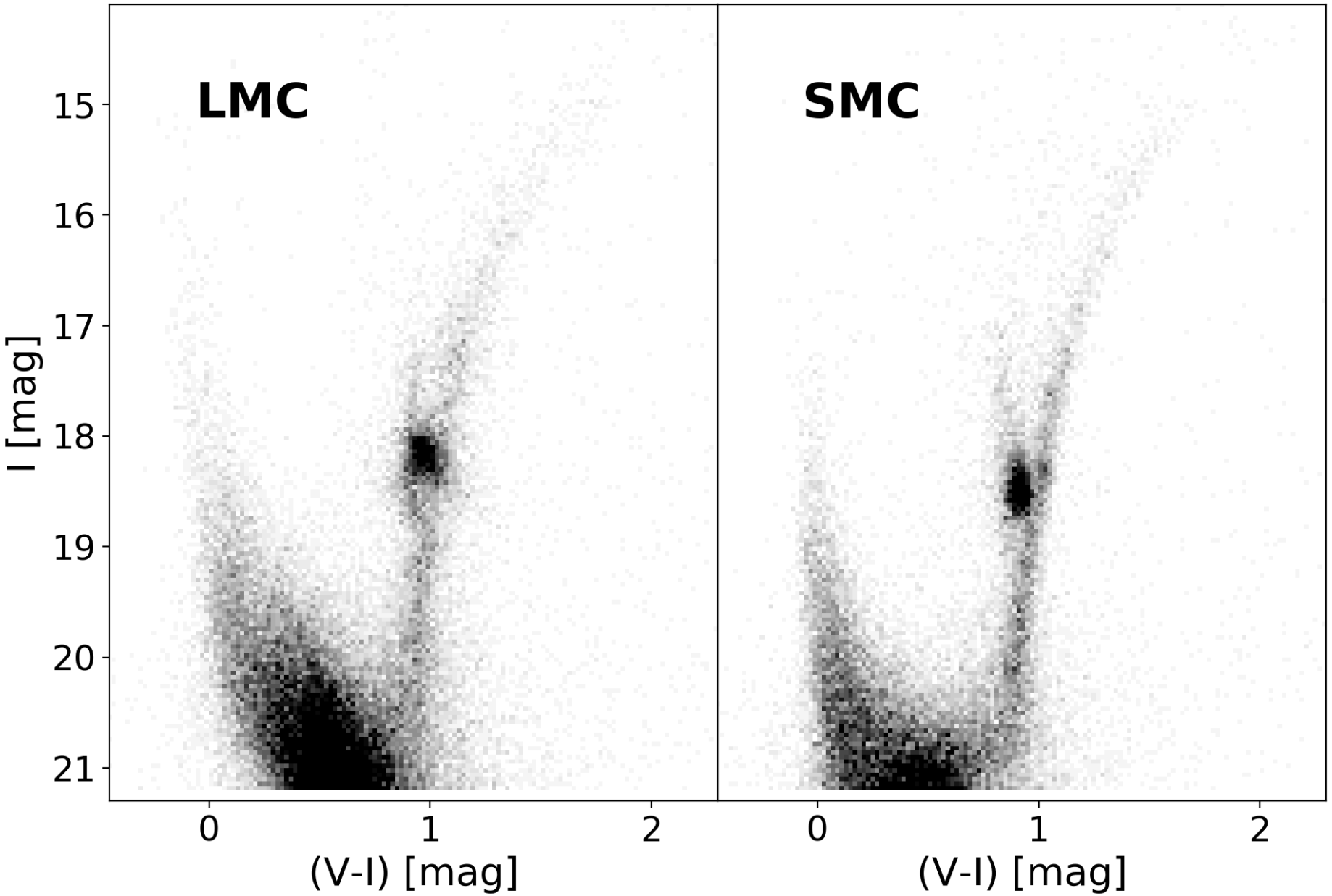
OGLE-III coverage



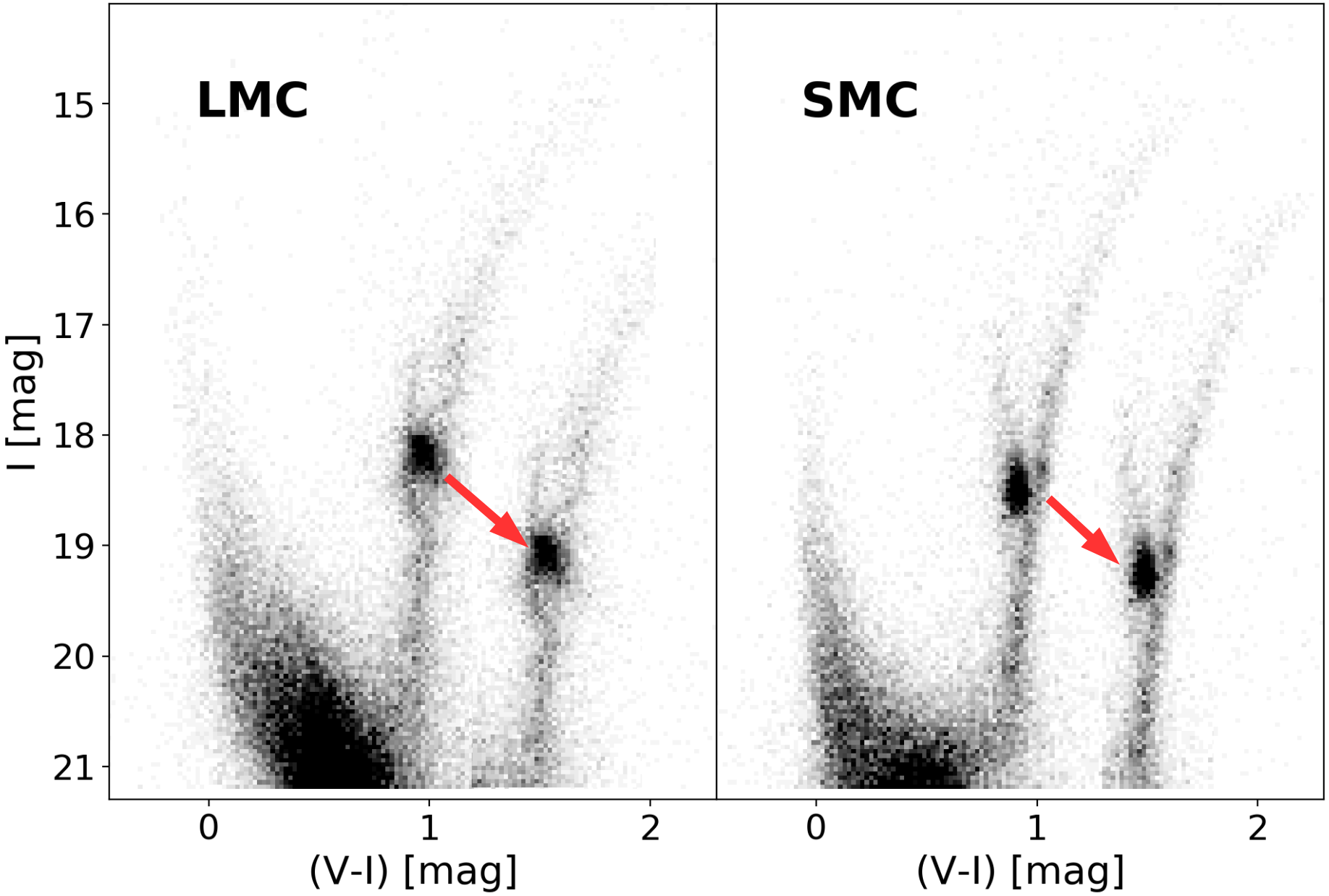



OGLE-IV coverage

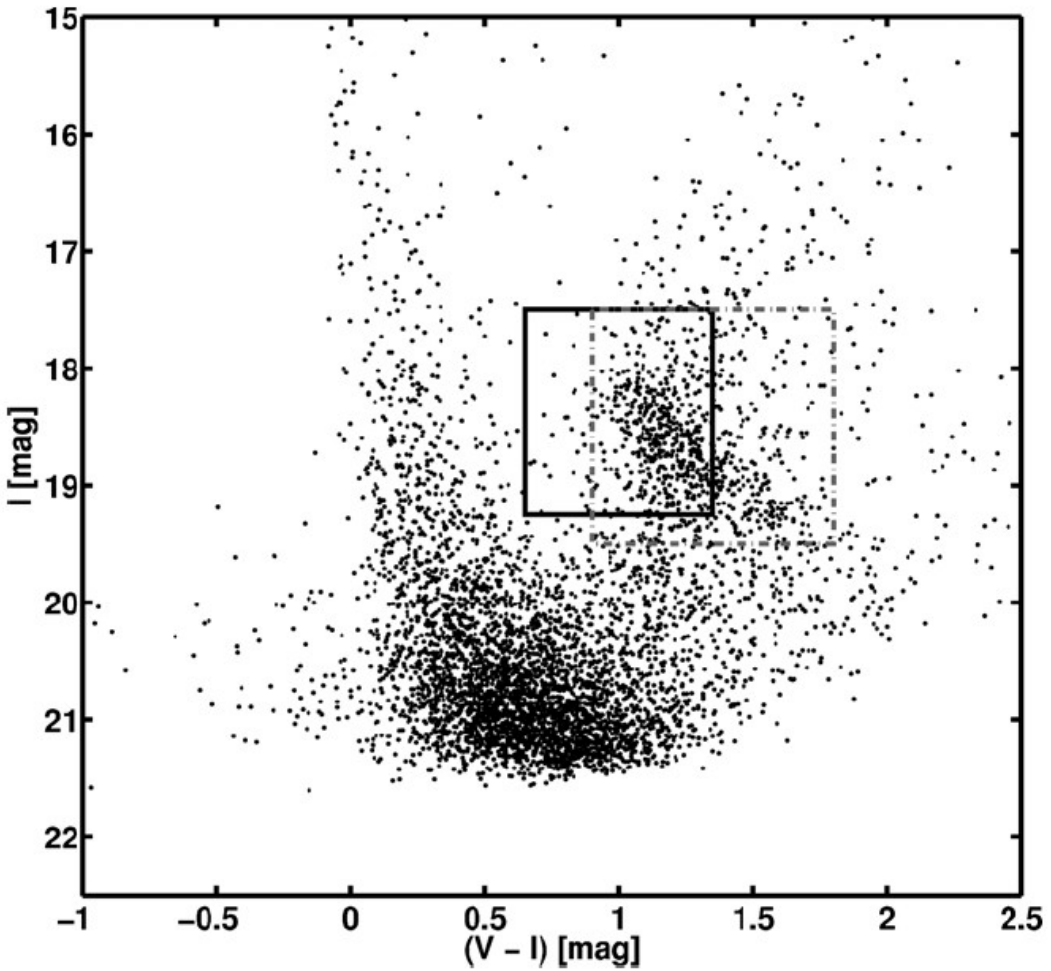
Reddening tracer – Red Clump stars



Reddening by dust in front of the Magellanic Clouds

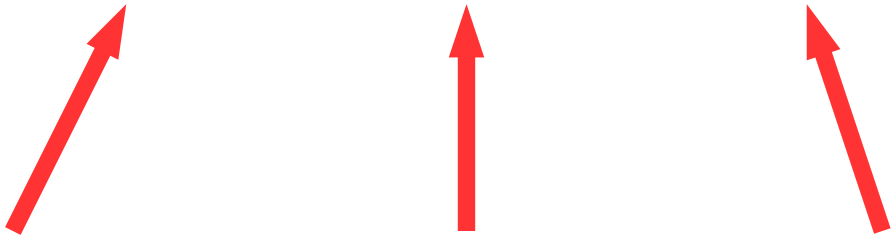


Differential reddening caused by dust within Magellanic Clouds



Reddening from the Red Clump

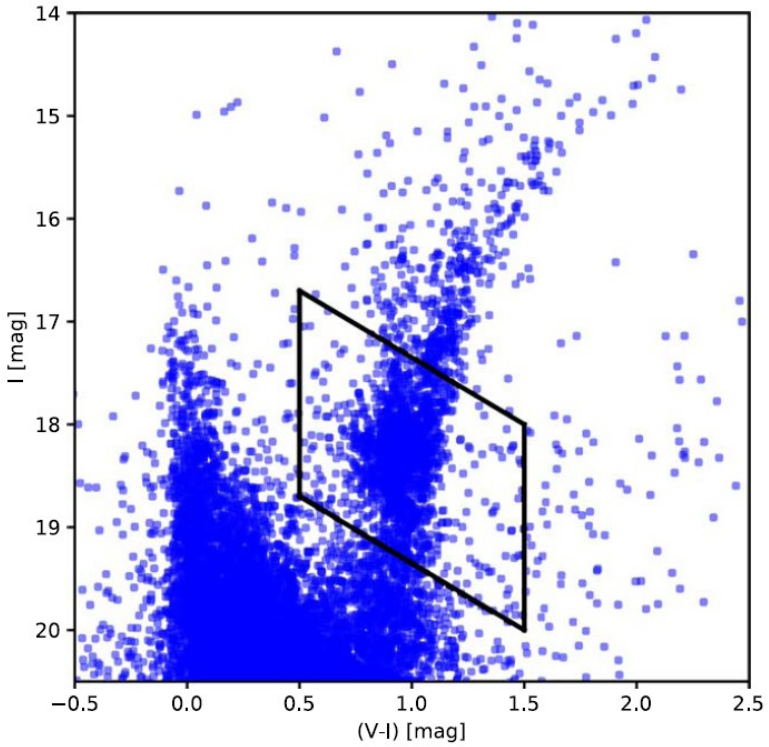
$$E(V\text{-}I) = (V\text{-}I) - (V\text{-}I)_0$$

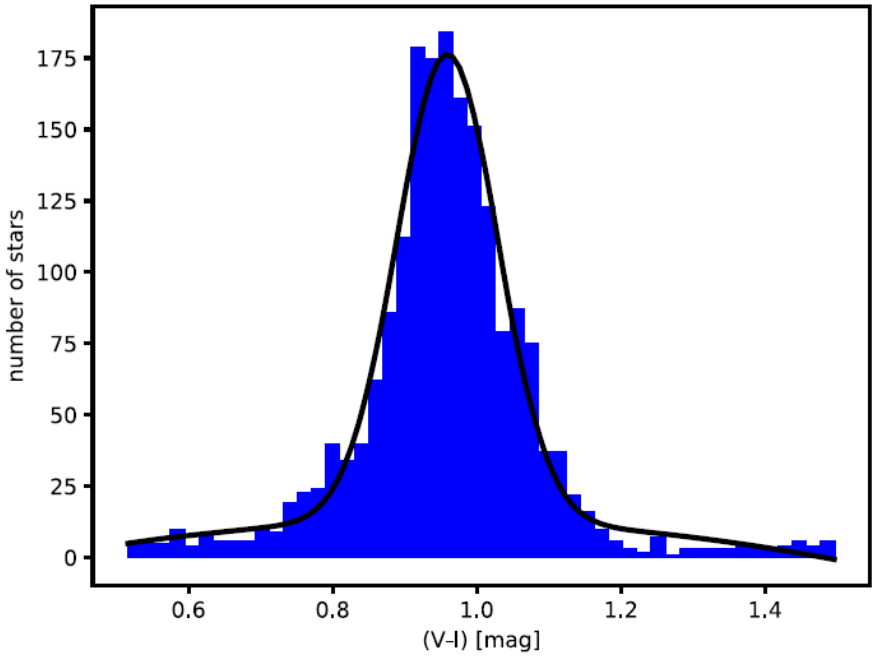


REDDENING **OBSERVED COLOR** **INTRINSIC COLOR**

Measuring the color of the Red Clump

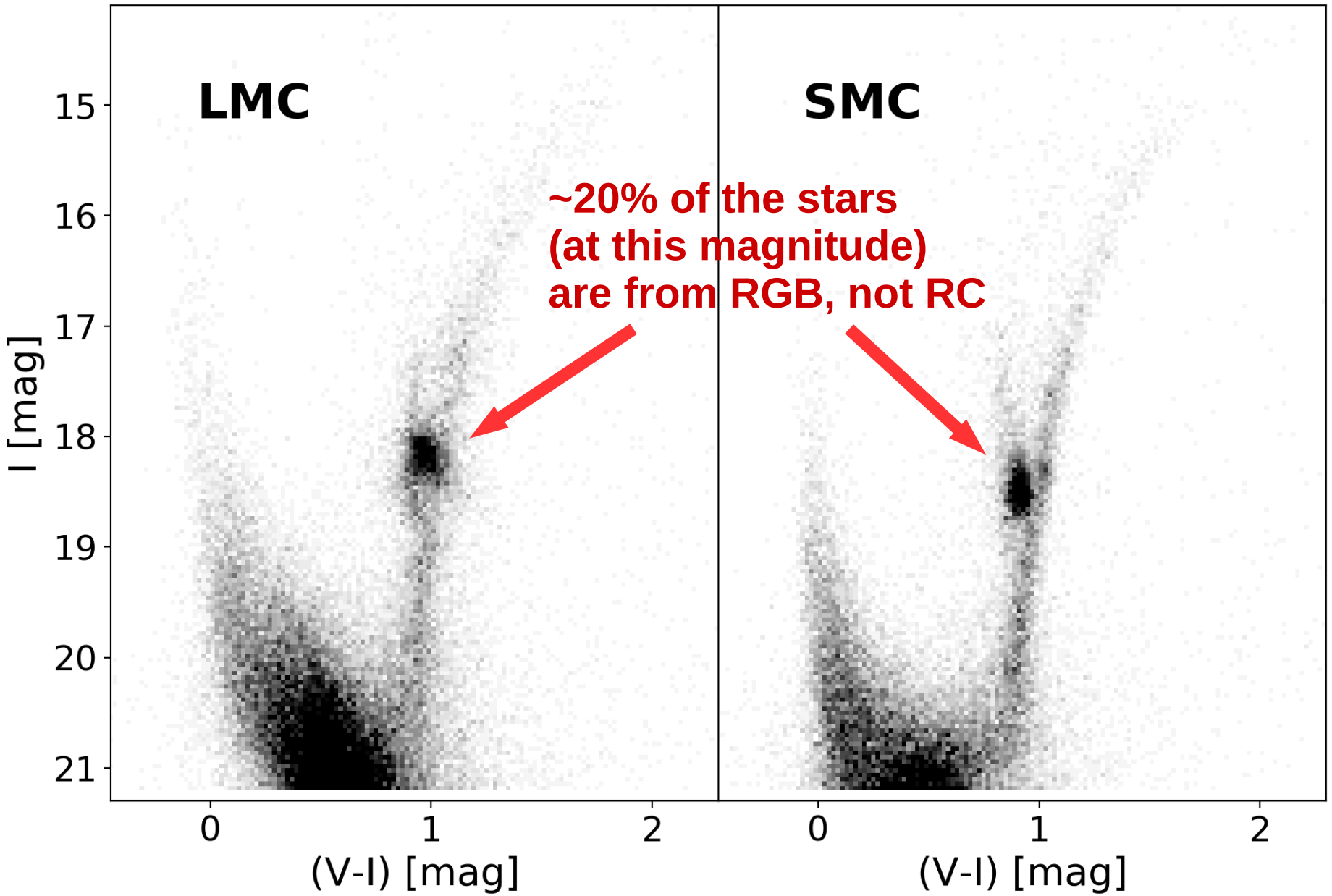
- Previous studies used a Gaussian-fit + parabola as a model of the color distribution





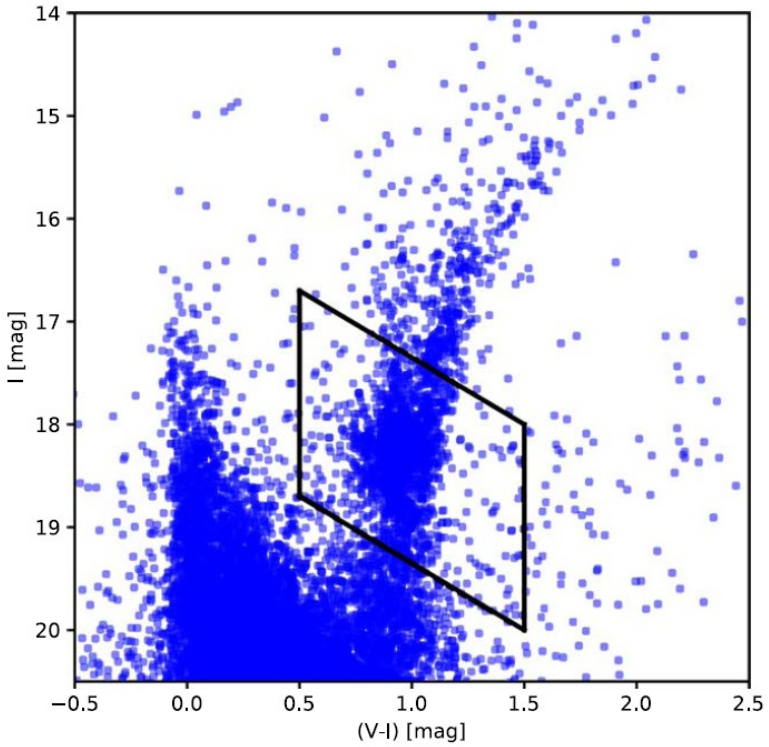
Górski et al. 2020

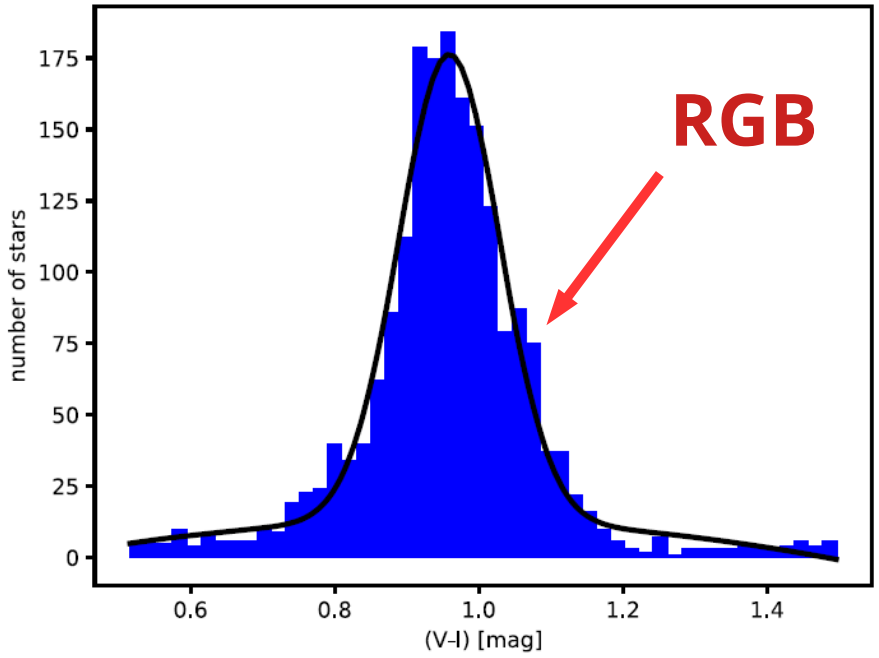
What about the RGB?



Measuring the color of the Red Clump

- Previous studies used a Gaussian-fit + parabola as a model of the color distribution

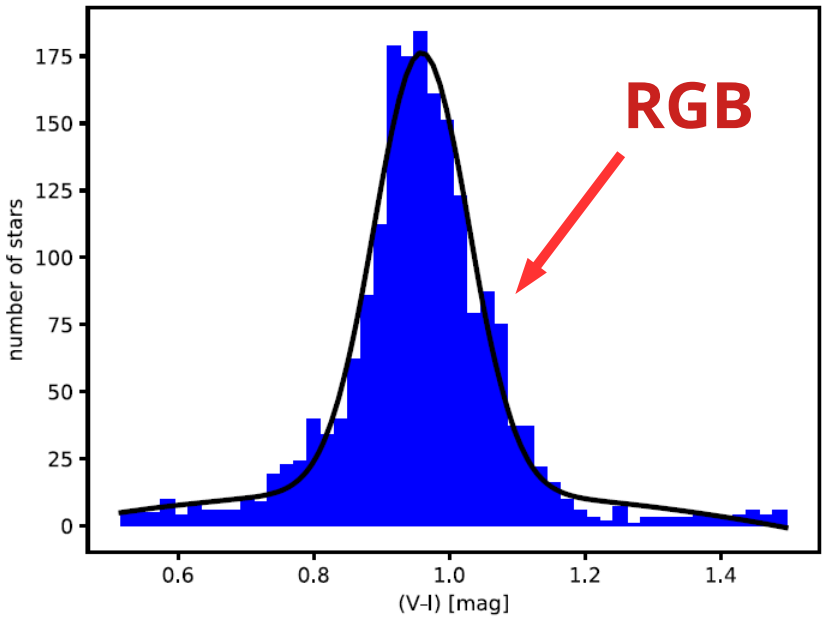


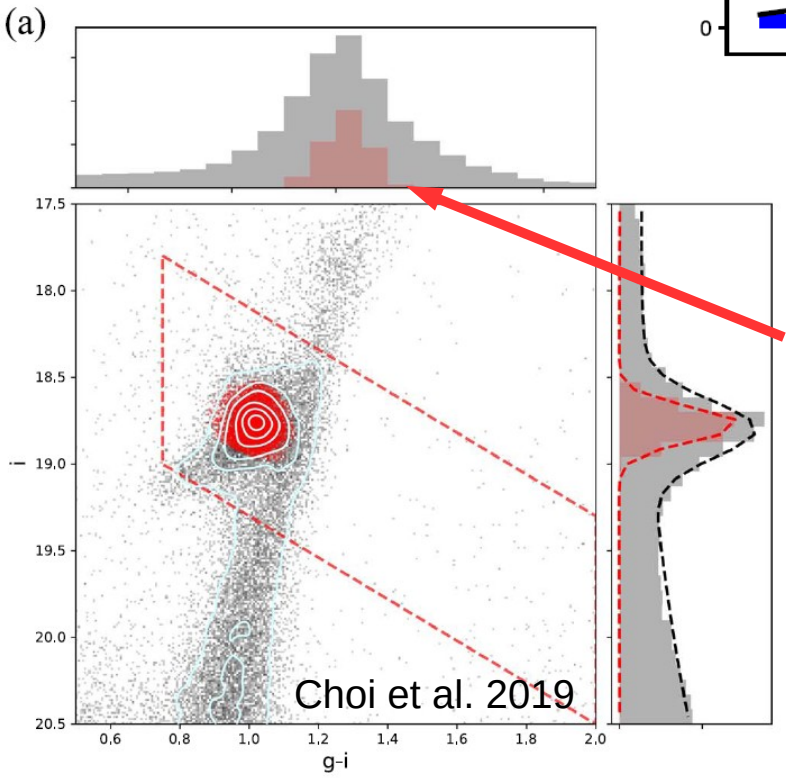


Górski et al. 2020

Problems with previous studies (Gaussian fits, means, medians, etc.)

Simple gaussian fit **overestimates** Red Clump color, due to inclusion of RGB

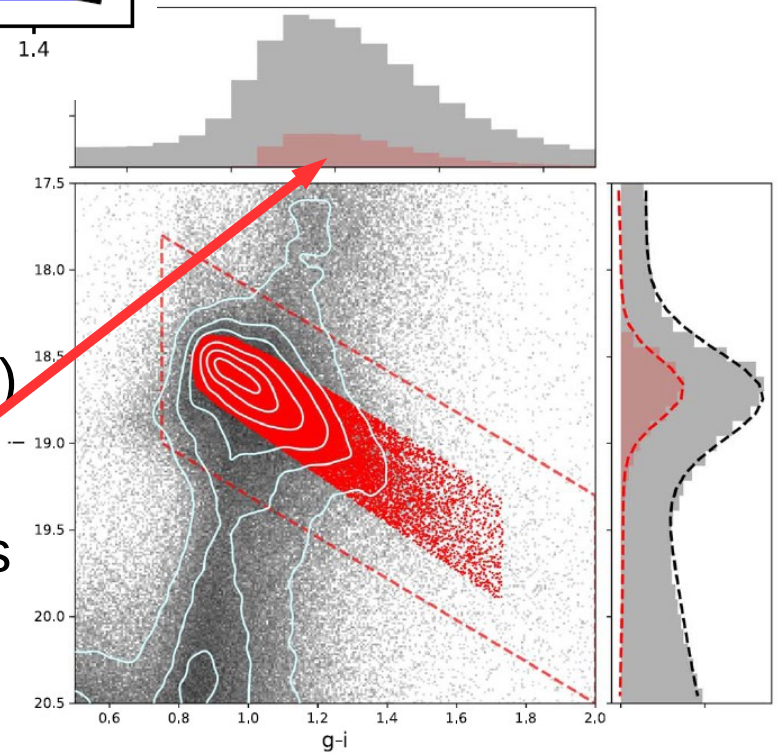




Manual cuts:

either cut **too much** (bias to lower colors)

or cut **too little** (bias to larger colors)

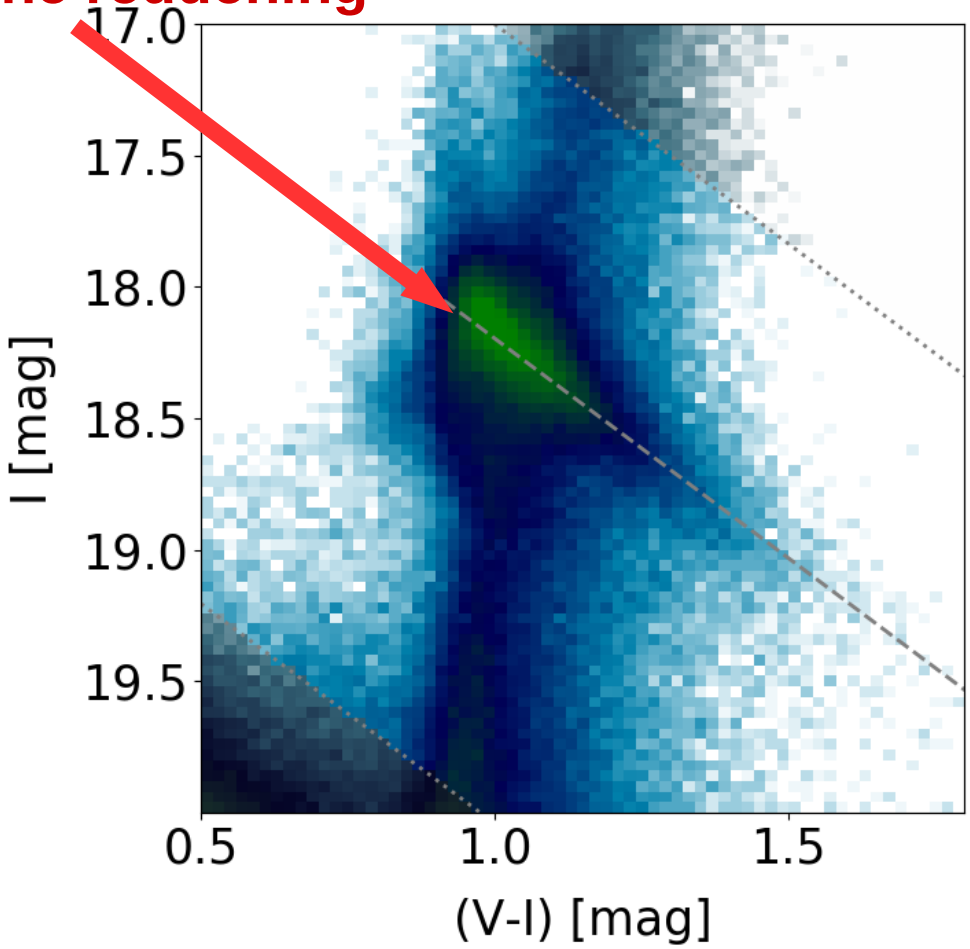


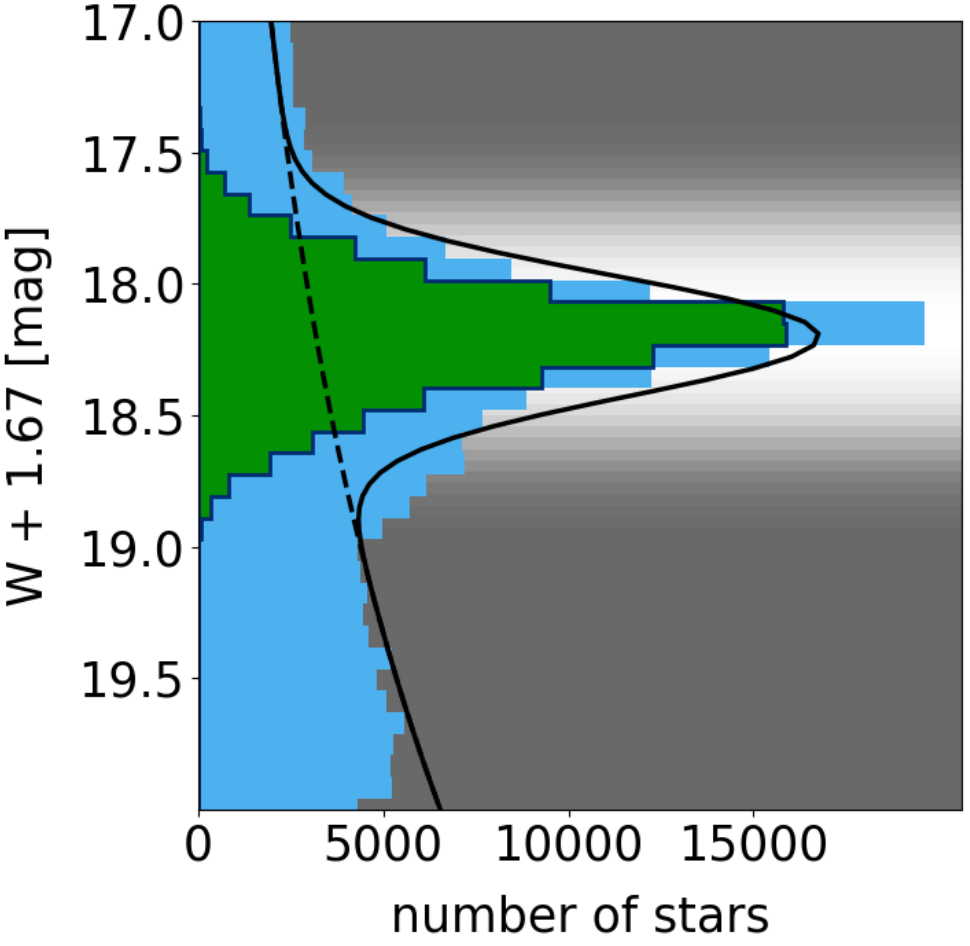
Measuring the color of the Red Clump

- Refine the method of calculating the RC color to properly account for the RGB contribution

Luminosity function fit

direction of the reddening





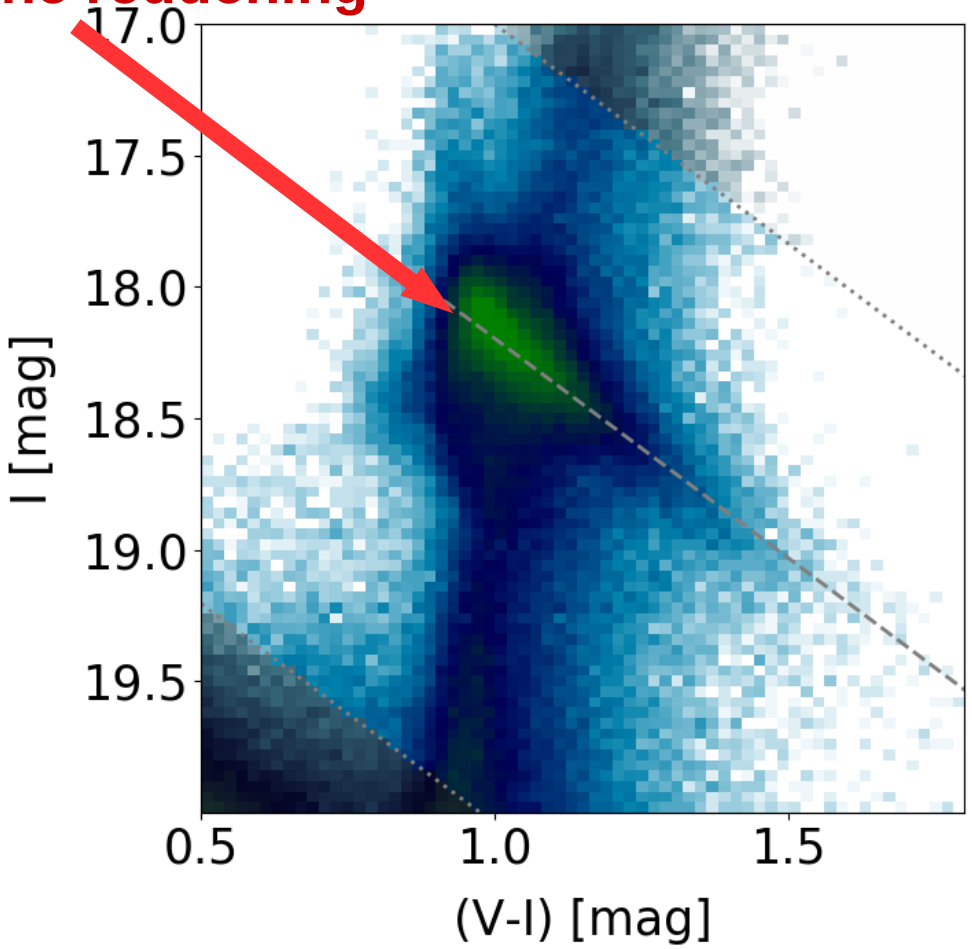
The magnitude axis is defined using a Wesenheit index:

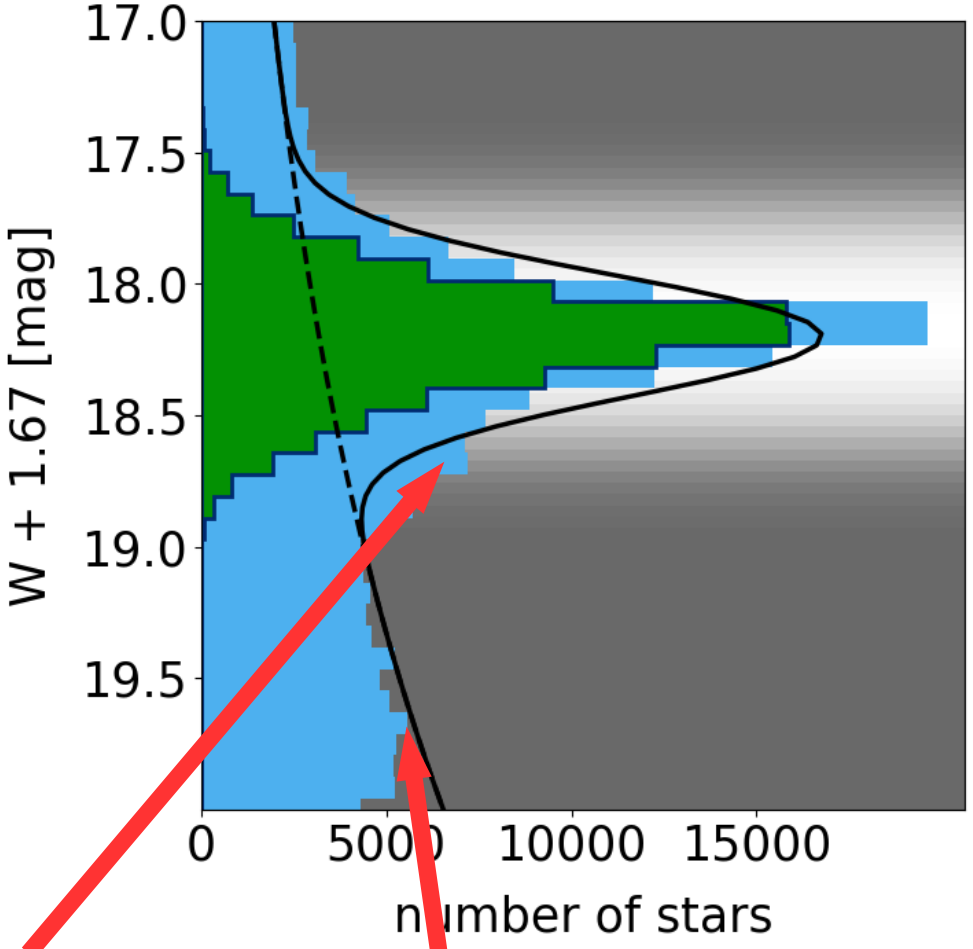
$W = I - 1.67\,(V-I)$ in the LMC

$W = I - 1.74\,(V-I)$ in the SMC

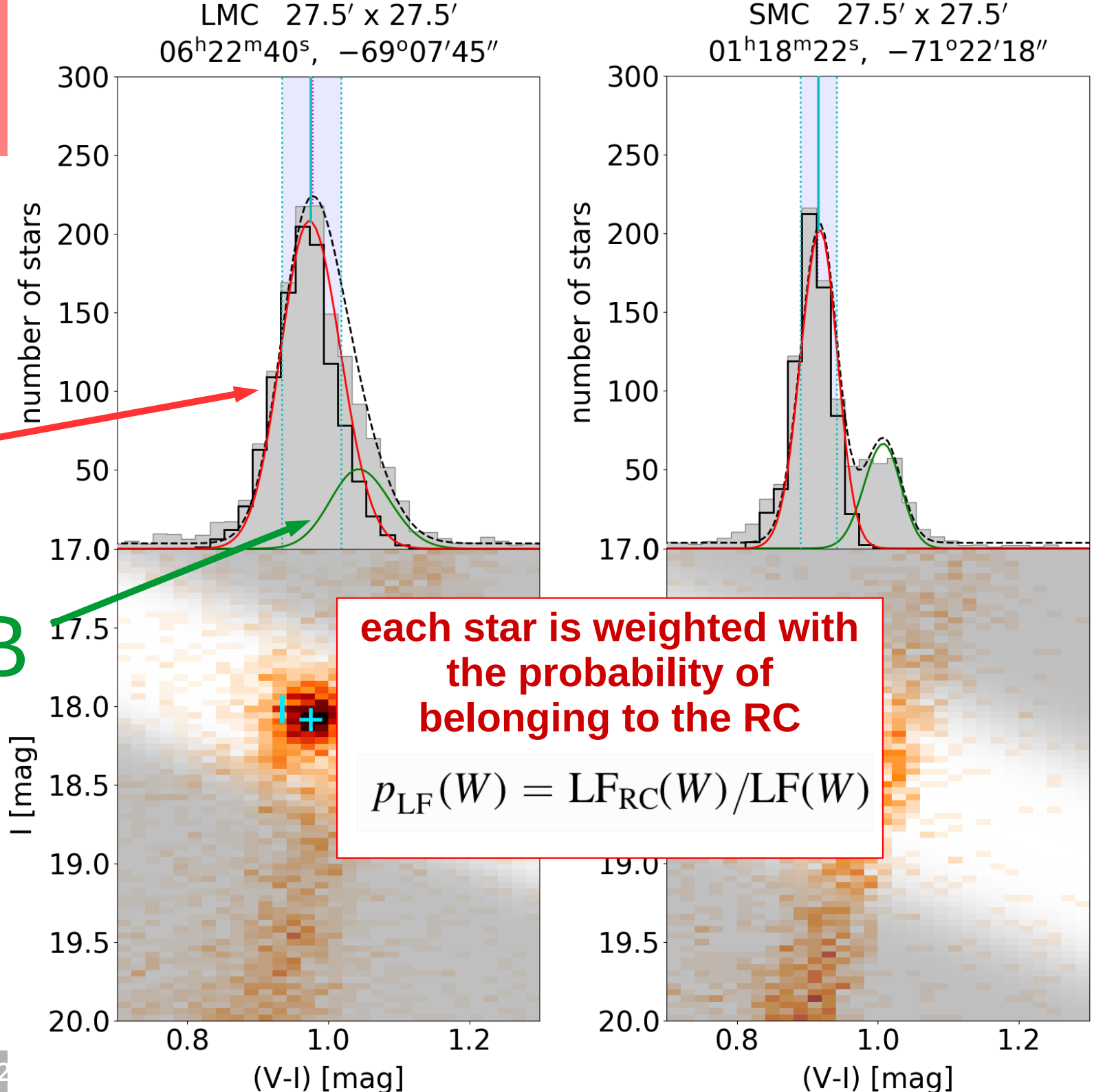
Luminosity function fit

direction of the reddening

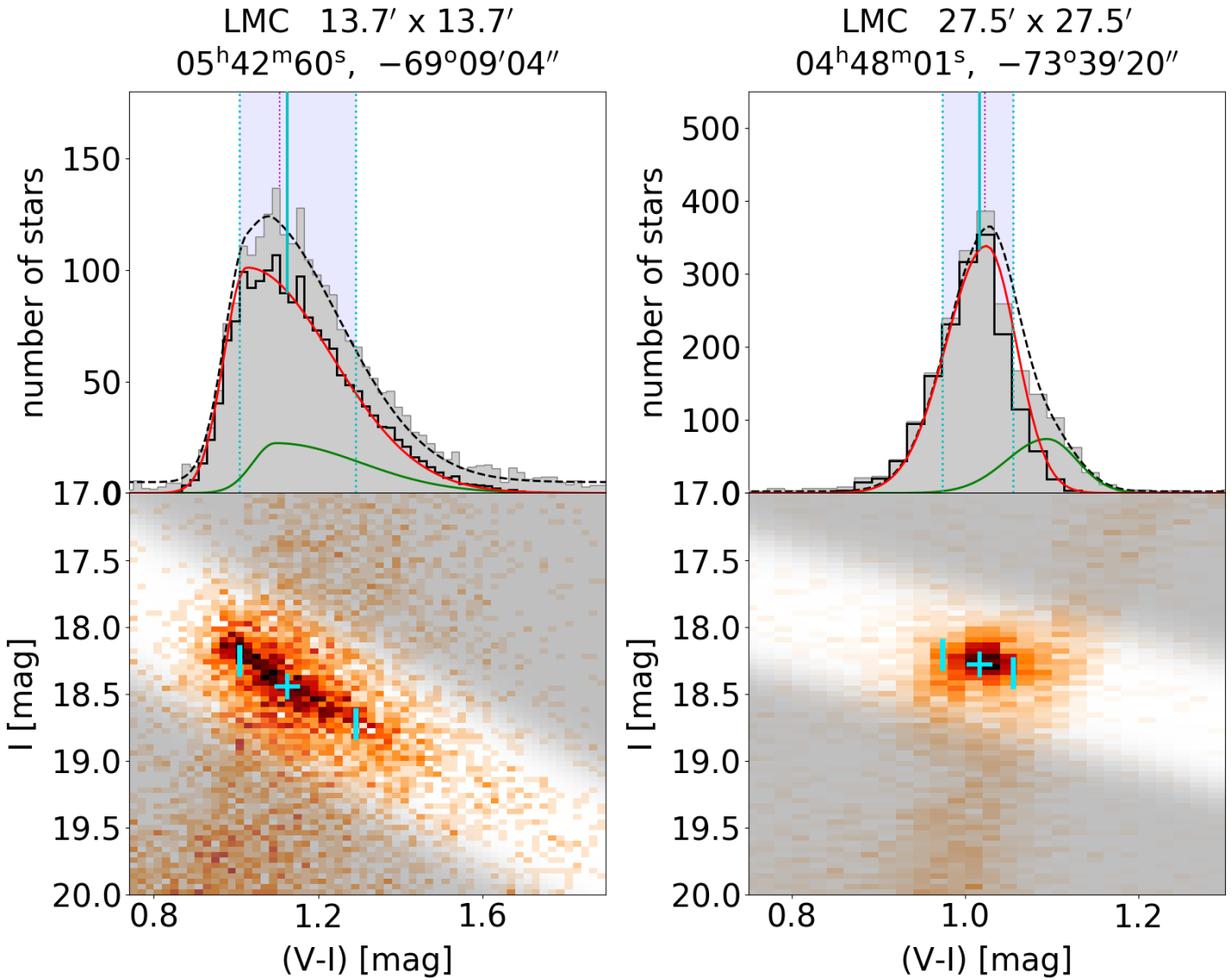




$$\mathrm{LF}(W) = \mathrm{LF}_{\mathrm{RC}}(W) + \mathrm{LF}_{\mathrm{RGB}}(W) \sim exp\left(-\frac{1}{2}\left(\frac{W-\overline{W}}{\sigma_W}\right)^2\right) + A\, exp\left(\frac{W}{2.5}\right)$$

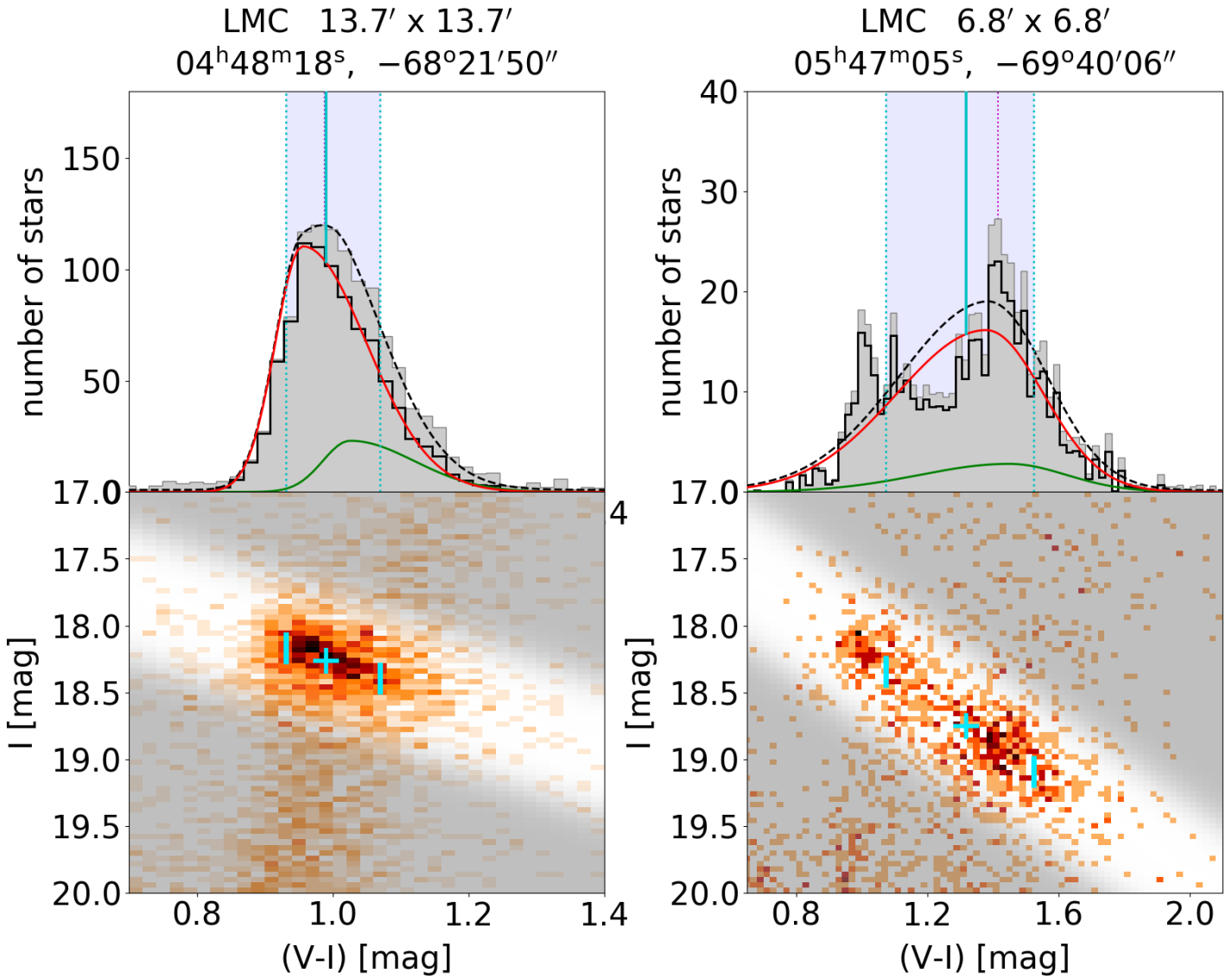

LMC 27.5′ x 27.5′
06h22m40s, −69°07′45″
SMC 27.5′ x 27.5′
01h18m22s, −71°22′18″
number of stars
I [mag]
(V-I) [mag]
RC
RGB
each star is weighted with the probability of belonging to the RC
$p_{\mathrm{LF}}(W) = \mathrm{LF}_{\mathrm{RC}}(W)/\mathrm{LF}(W)$

„Two-sigma” Gaussian

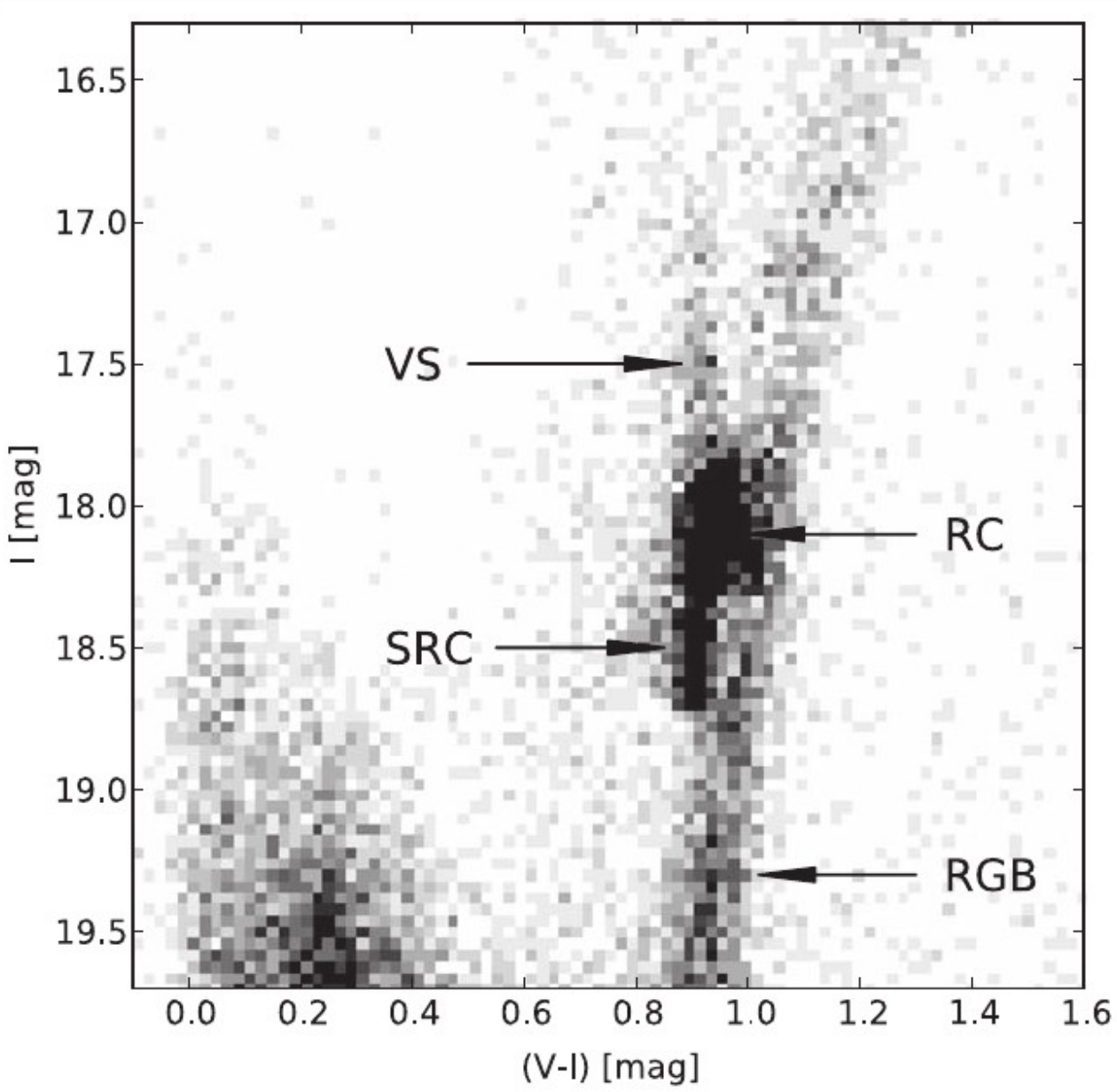


$$\mathcal{N}_2(\overline{V-I},\sigma_\mathrm{L},\sigma_\mathrm{H}) = \begin{cases} \frac{2\sigma_\mathrm{L}}{\sigma_\mathrm{L}+\sigma_\mathrm{H}}\mathcal{N}(\overline{V-I},\sigma_\mathrm{L}), & \text{for } (V-I) < \overline{V-I} \\ \frac{2\sigma_\mathrm{H}}{\sigma_\mathrm{L}+\sigma_\mathrm{H}}\mathcal{N}(\overline{V-I},\sigma_\mathrm{H}), & \text{for } (V-I) > \overline{V-I} \end{cases}$$

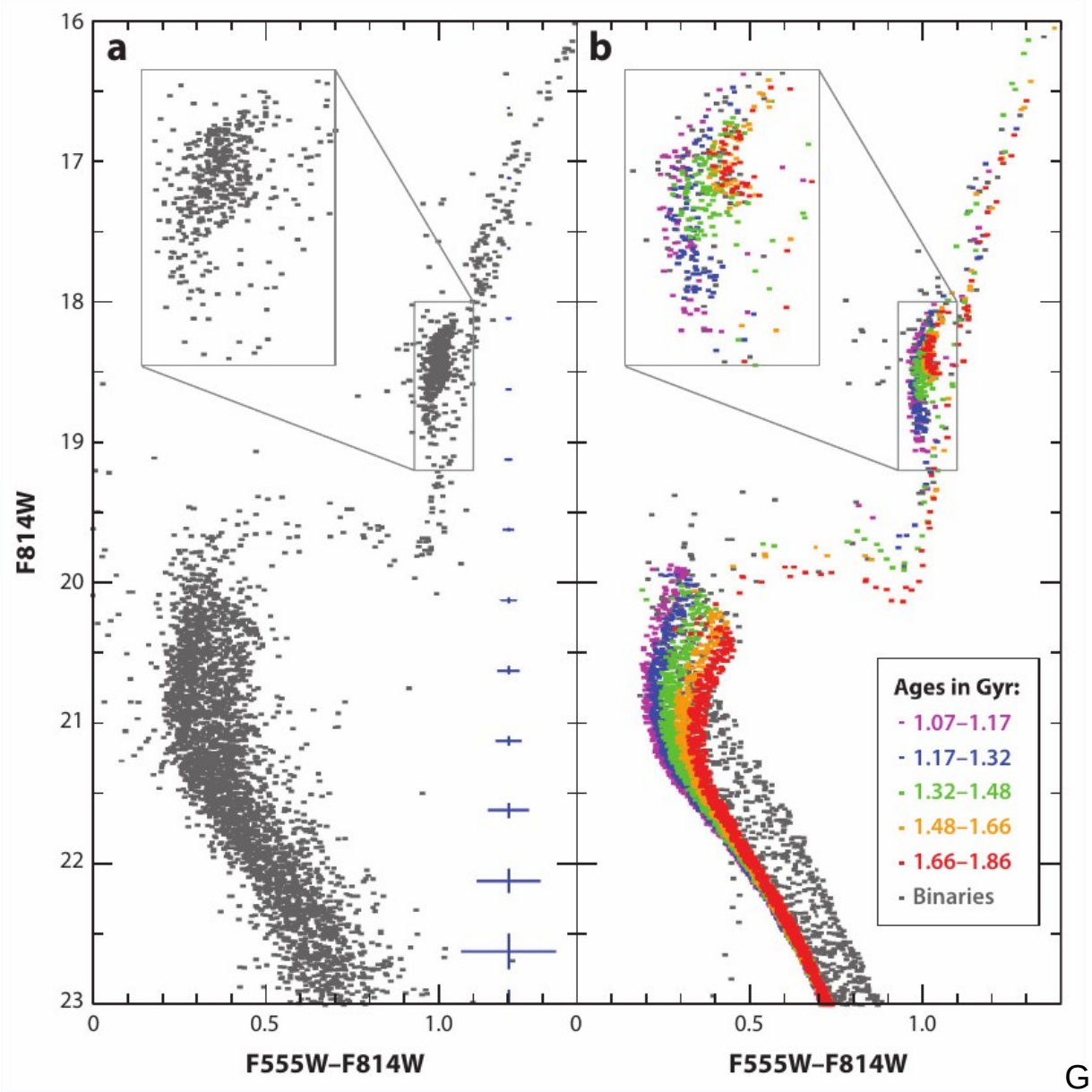
„Two-sigma” Gaussian



Red Clump complexity

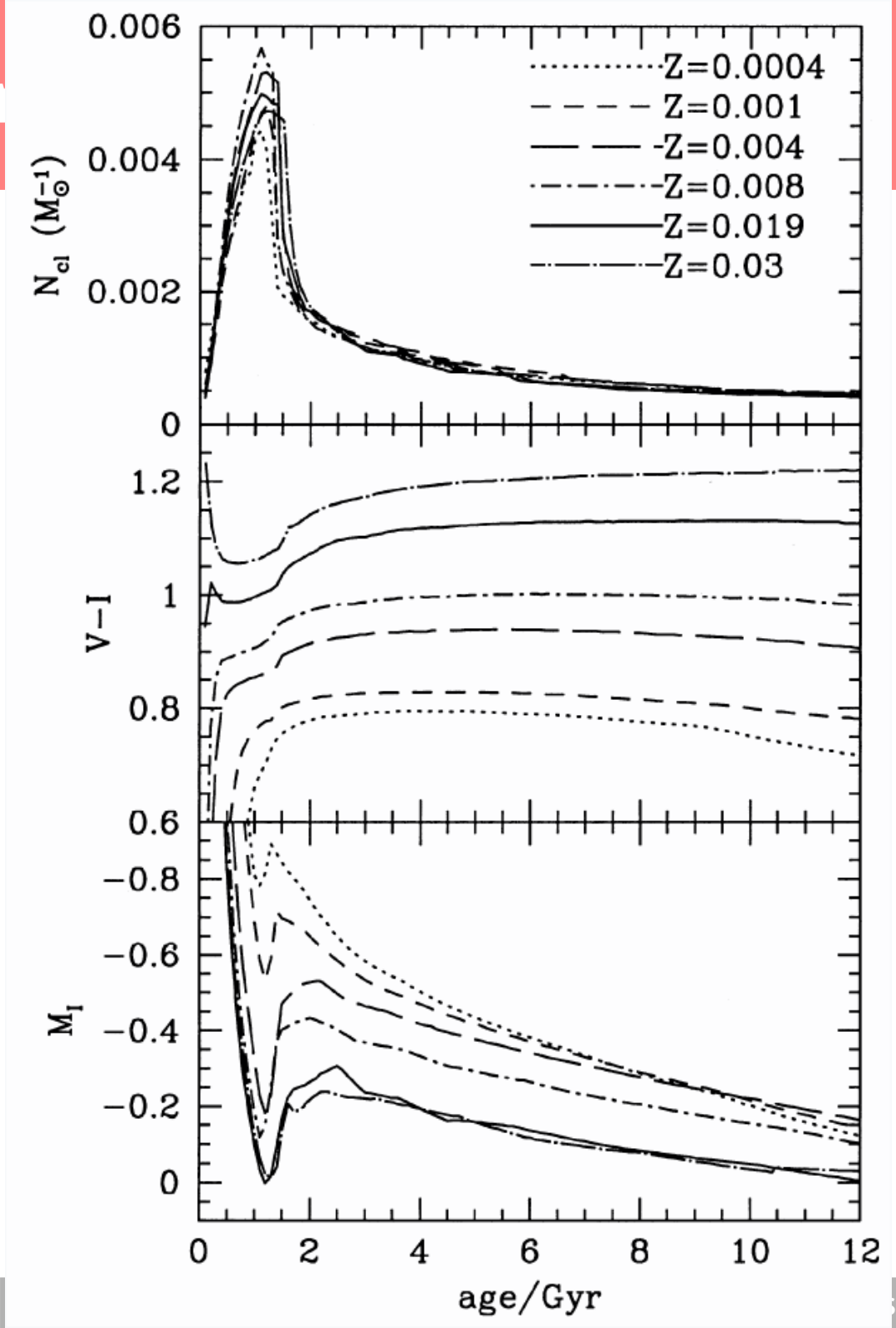


Red Clump complexity



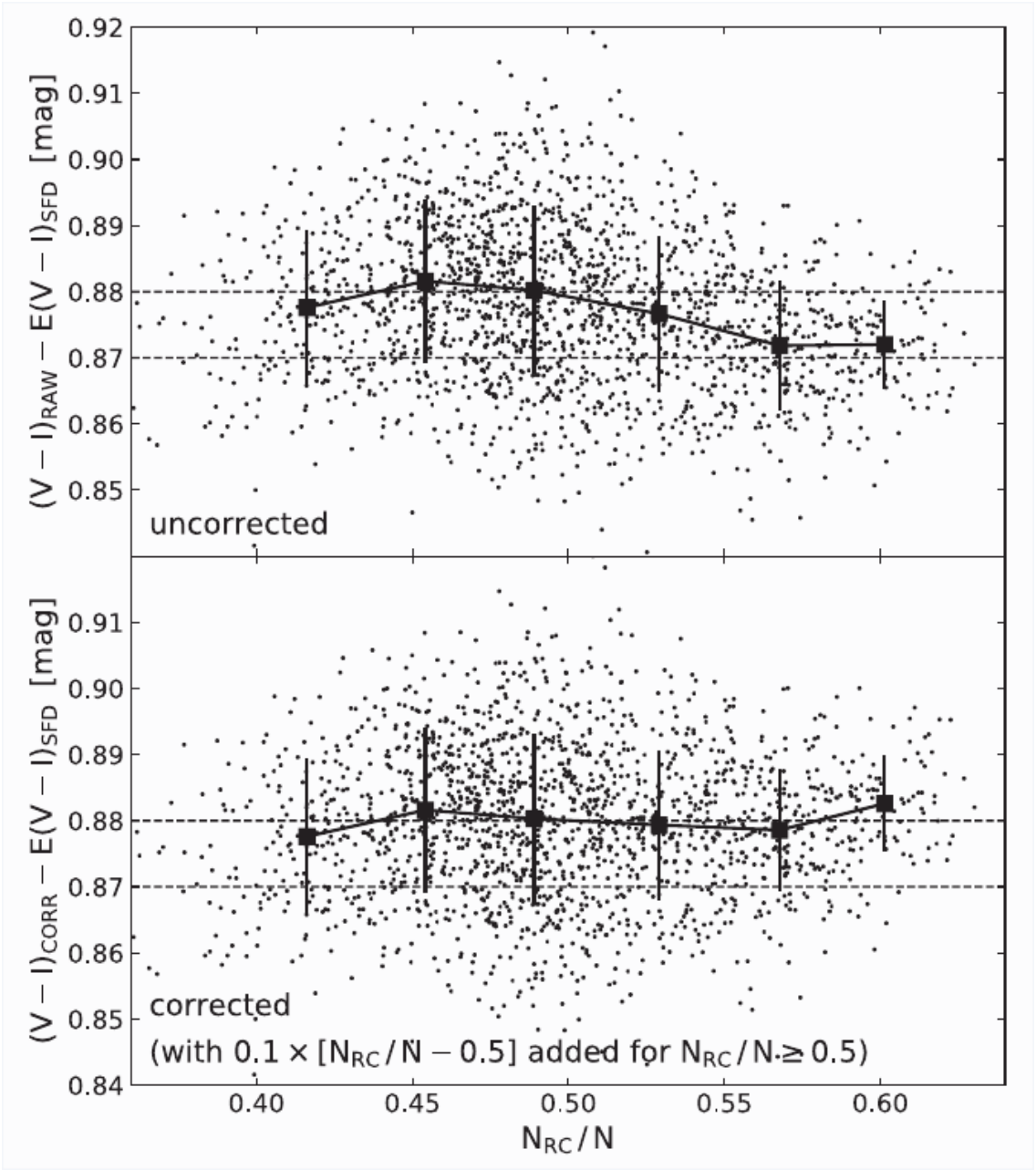
Girardi (2016)

Red Clu

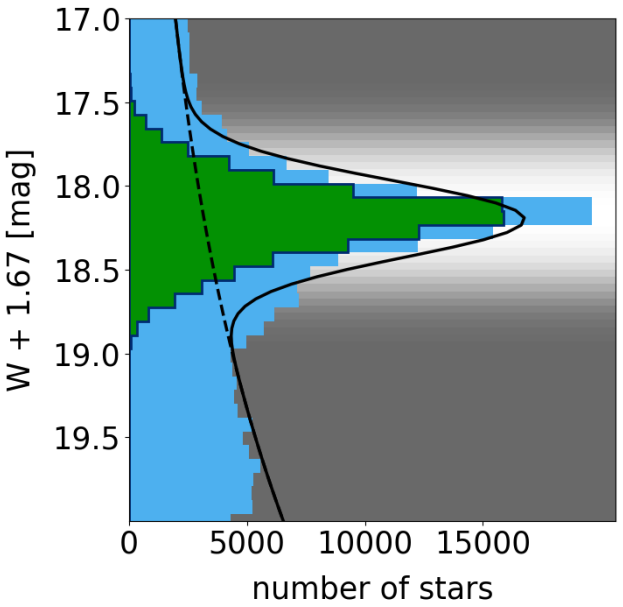


Girardi & Salaris (2001)

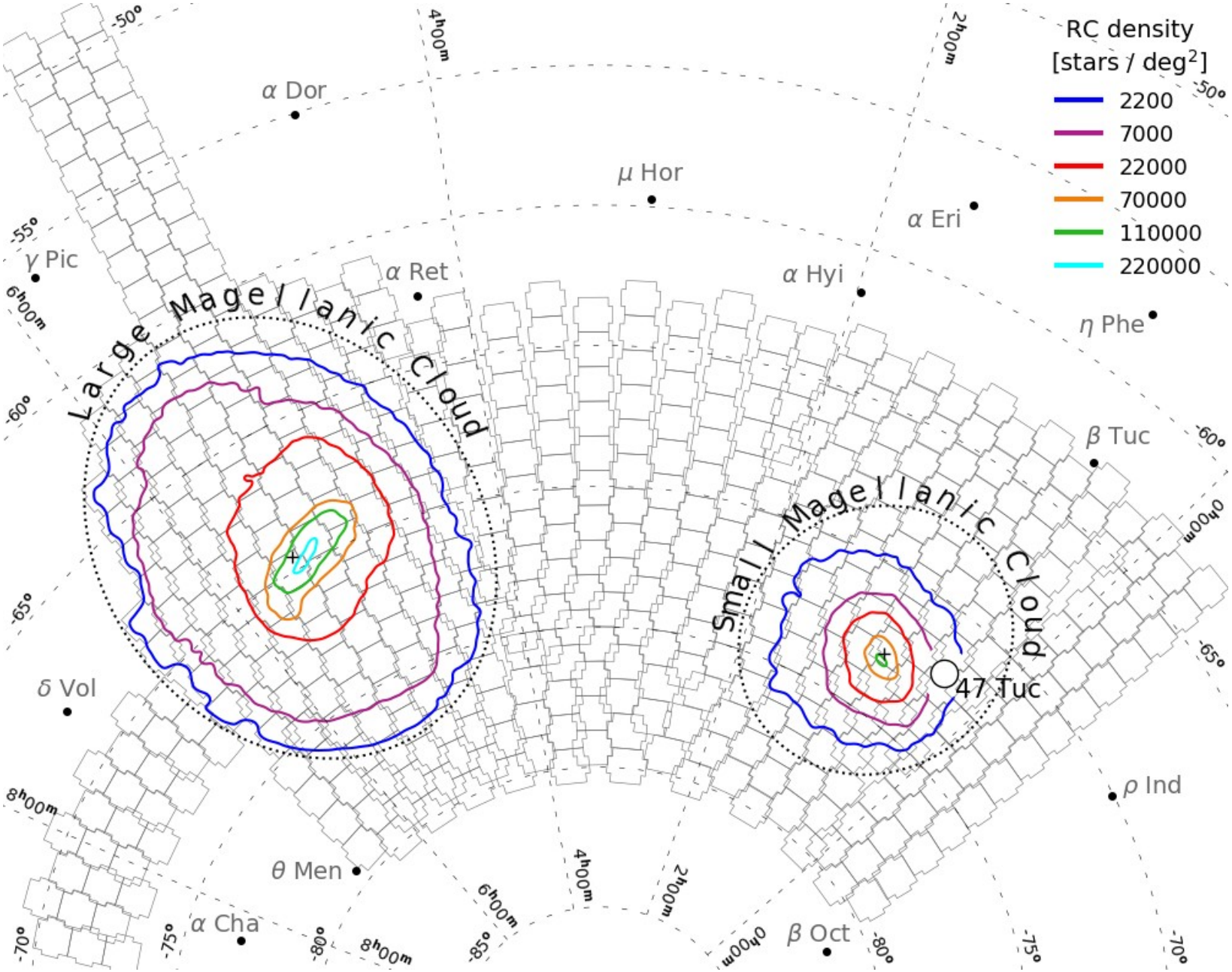
Red Clump complexity



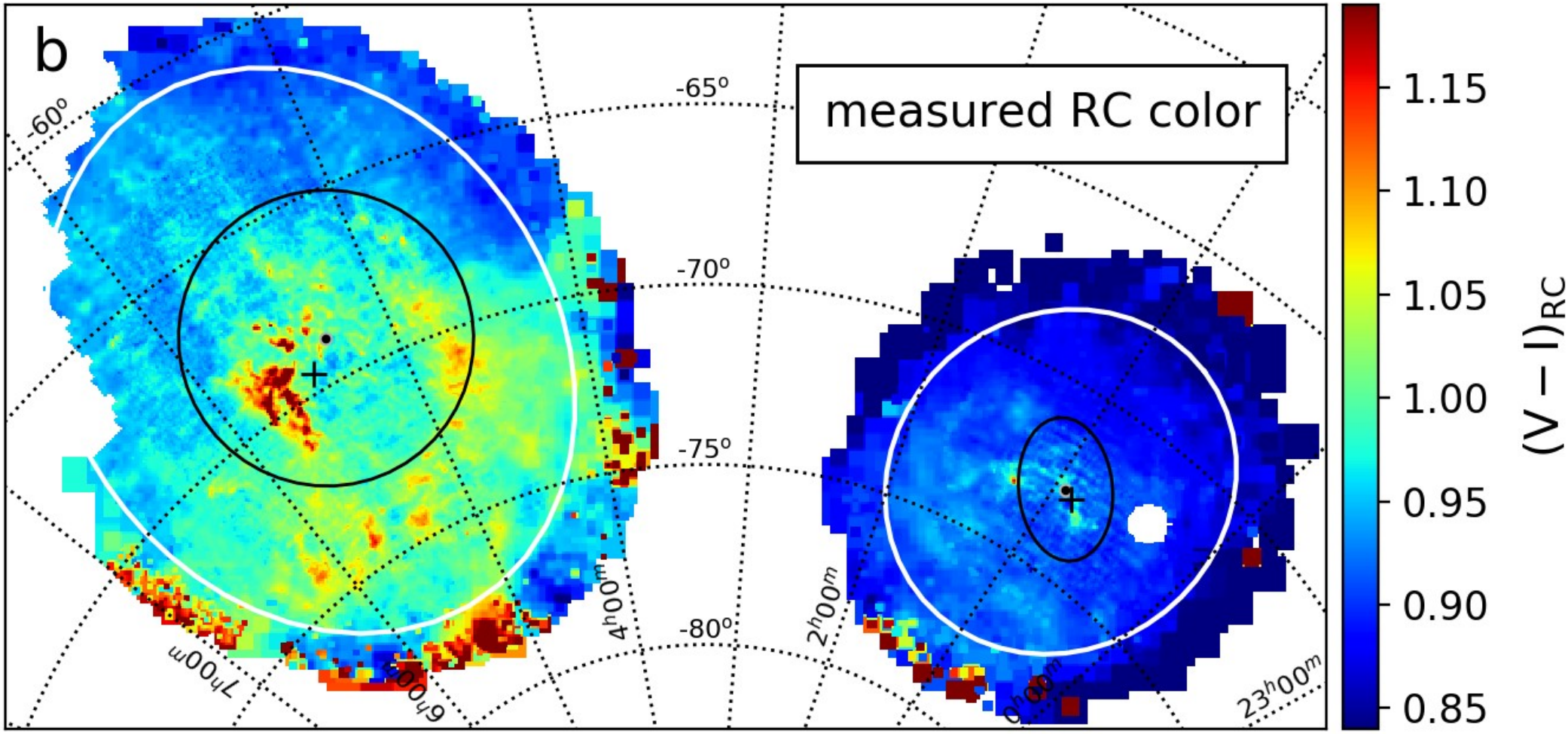
N_{RC}/N parameter – relative number of RC stars to all stars around the measured RC brightness



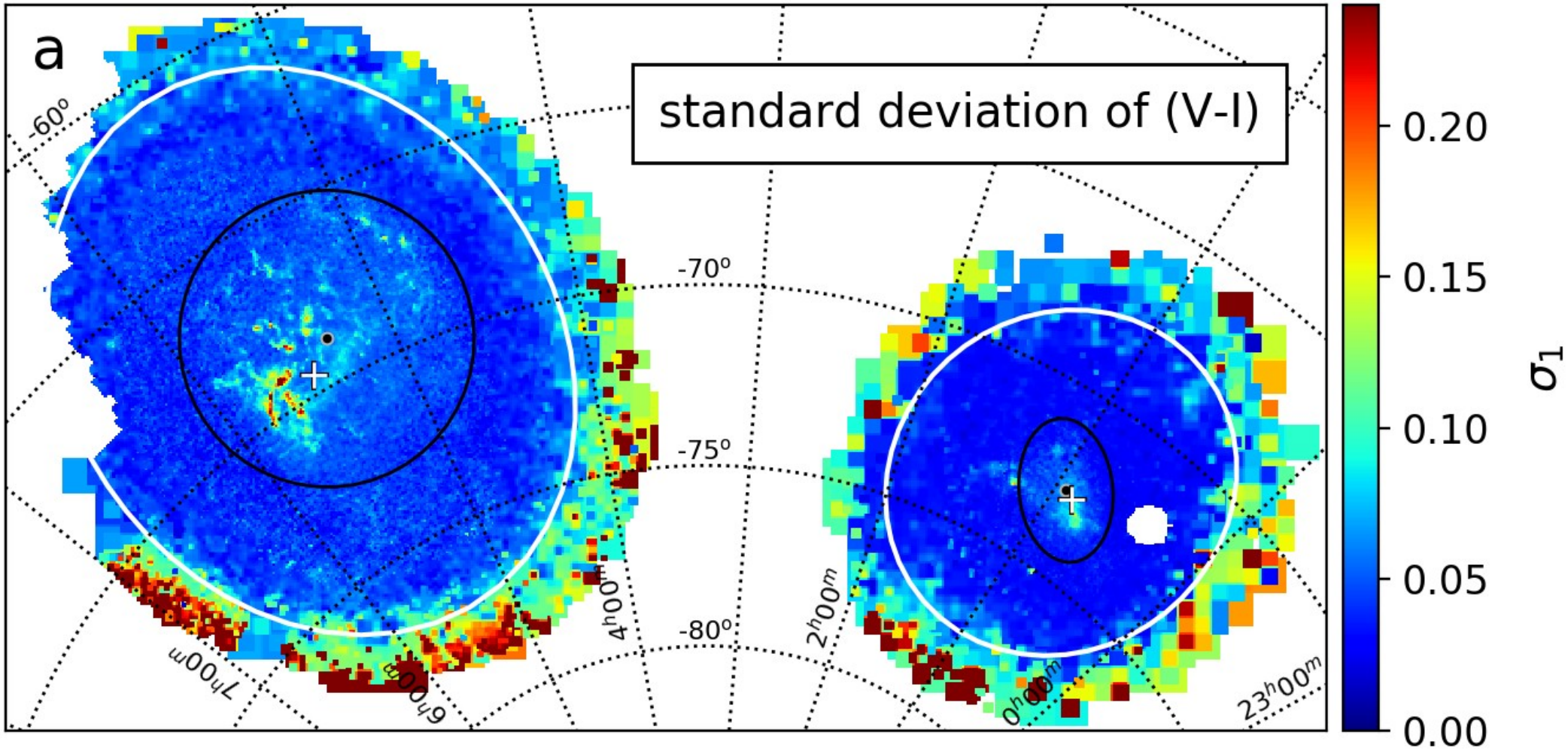
Results – density of RC stars



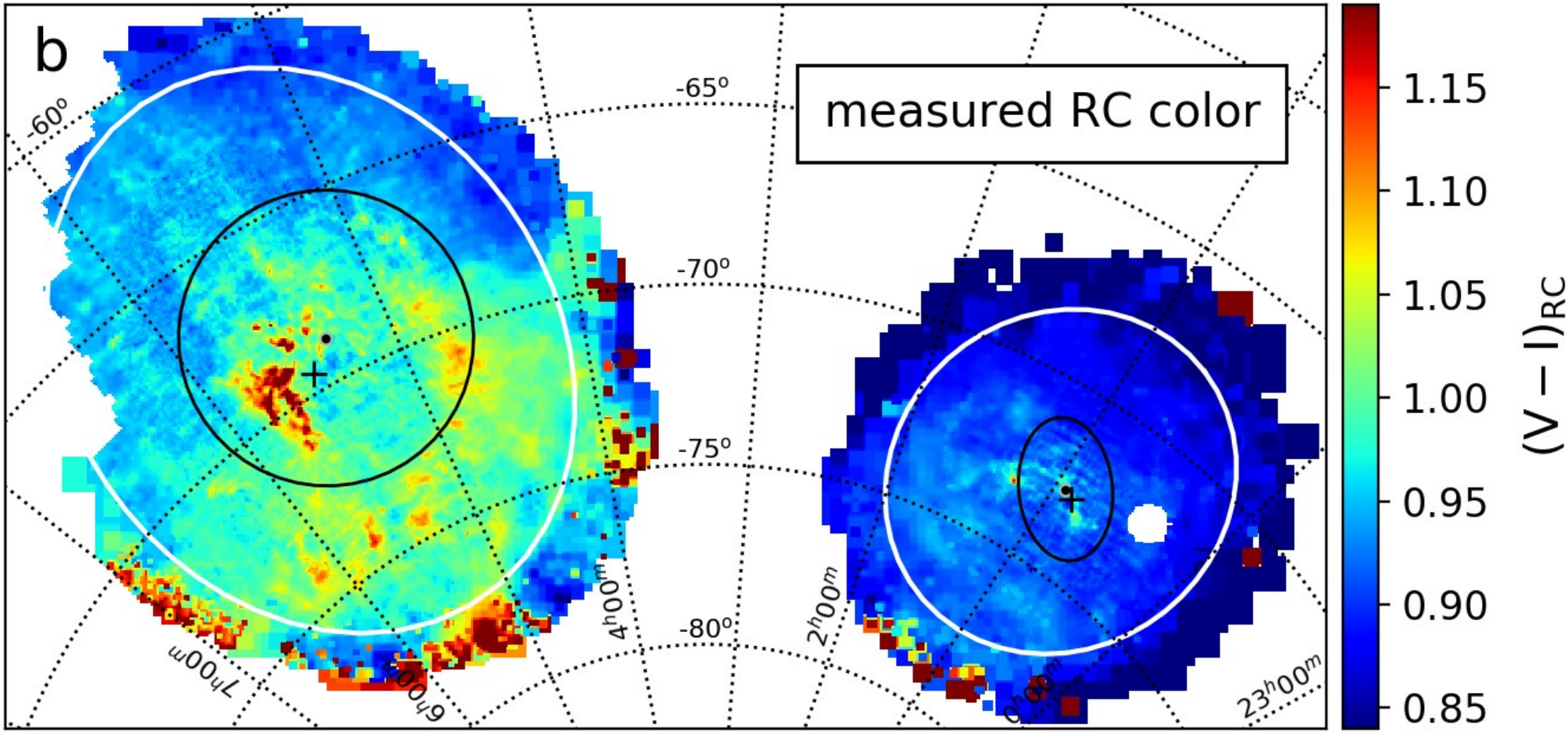
Measured RC color $(V\text{-}I)_{RC}$



Scatter of the measured color $\sigma_{(V-I)}$

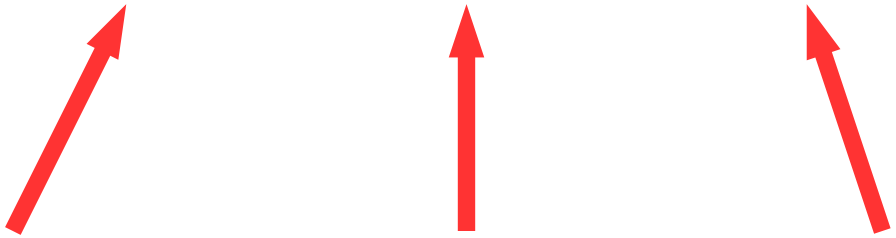


Measured RC color $(V\text{-}I)_{RC}$



Reddening from the Red Clump

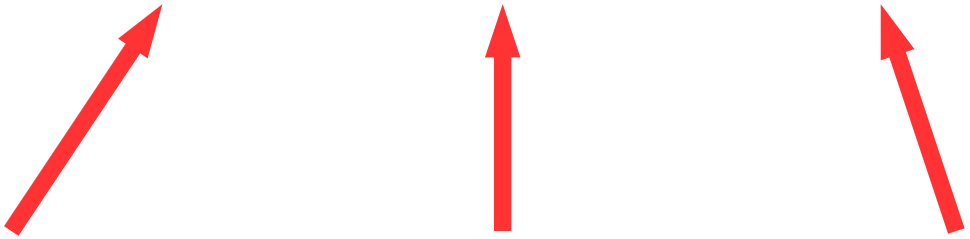
$$E(V\text{-}I) = (V\text{-}I) - (V\text{-}I)_0$$



REDDENING **OBSERVED COLOR** **INTRINSIC COLOR**

Reddening from the Red Clump

$$(V\text{-}I)_0 = (V\text{-}I) - E(V\text{-}I)$$

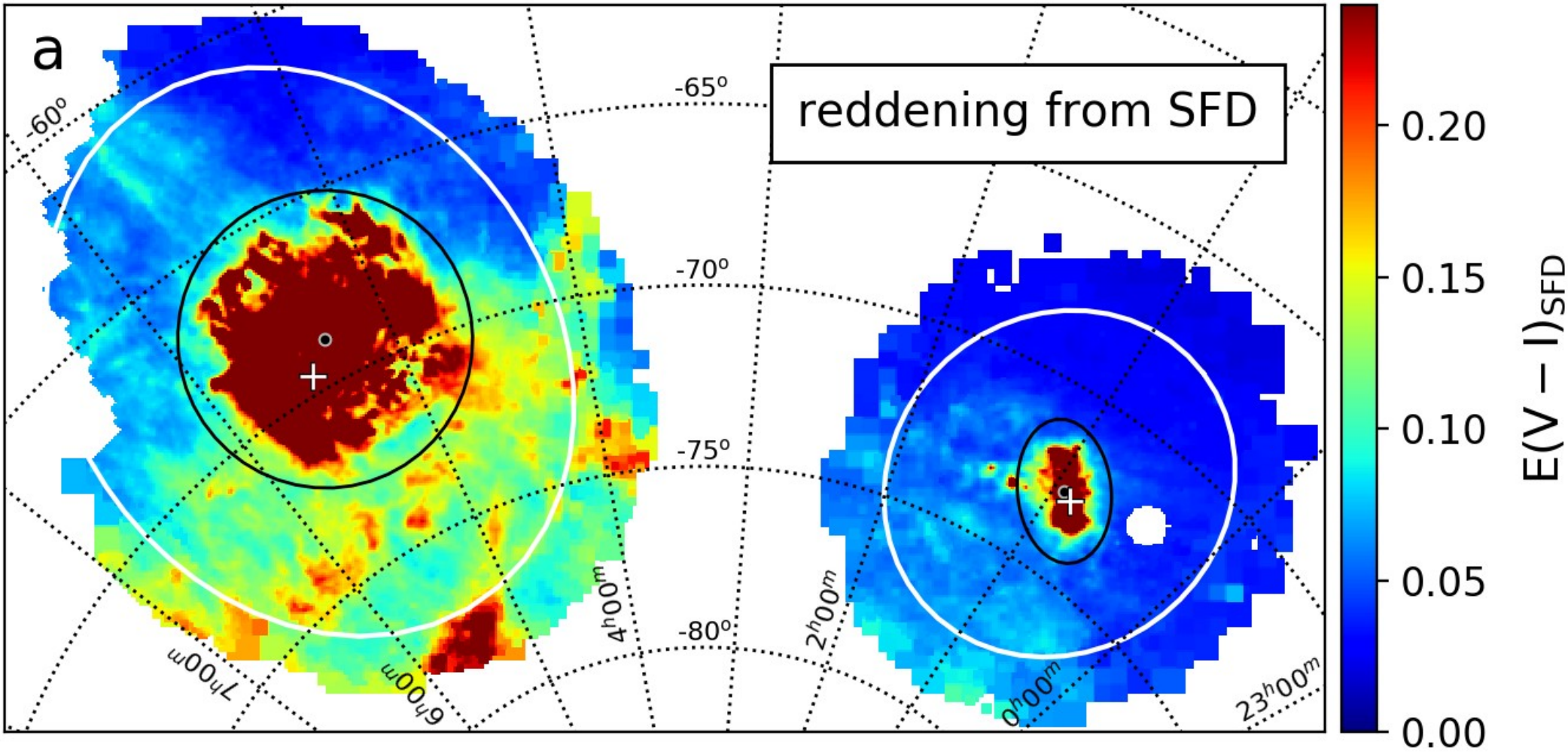


INTRINSIC COLOR

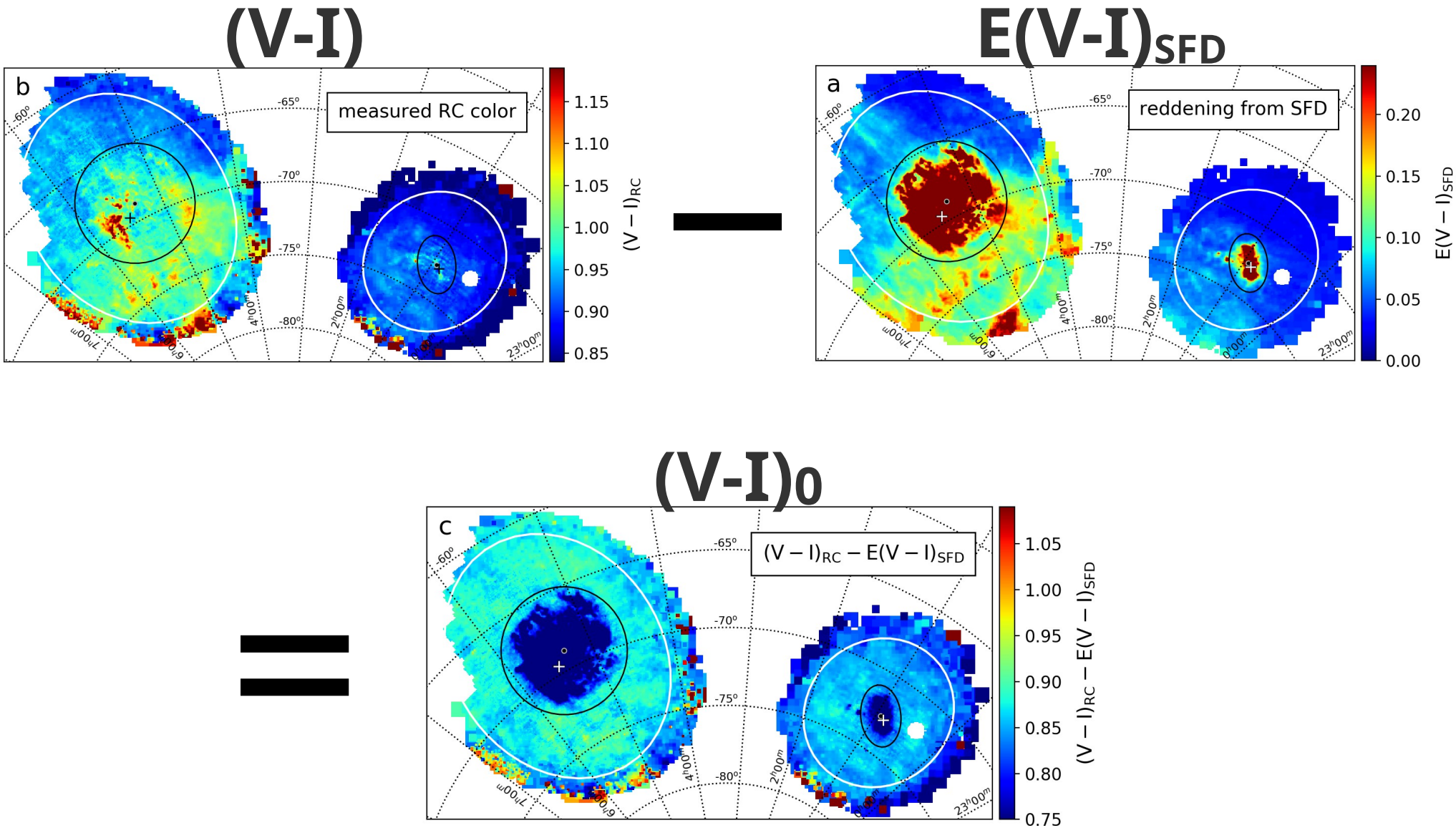
OBSERVED COLOR

REDDENING

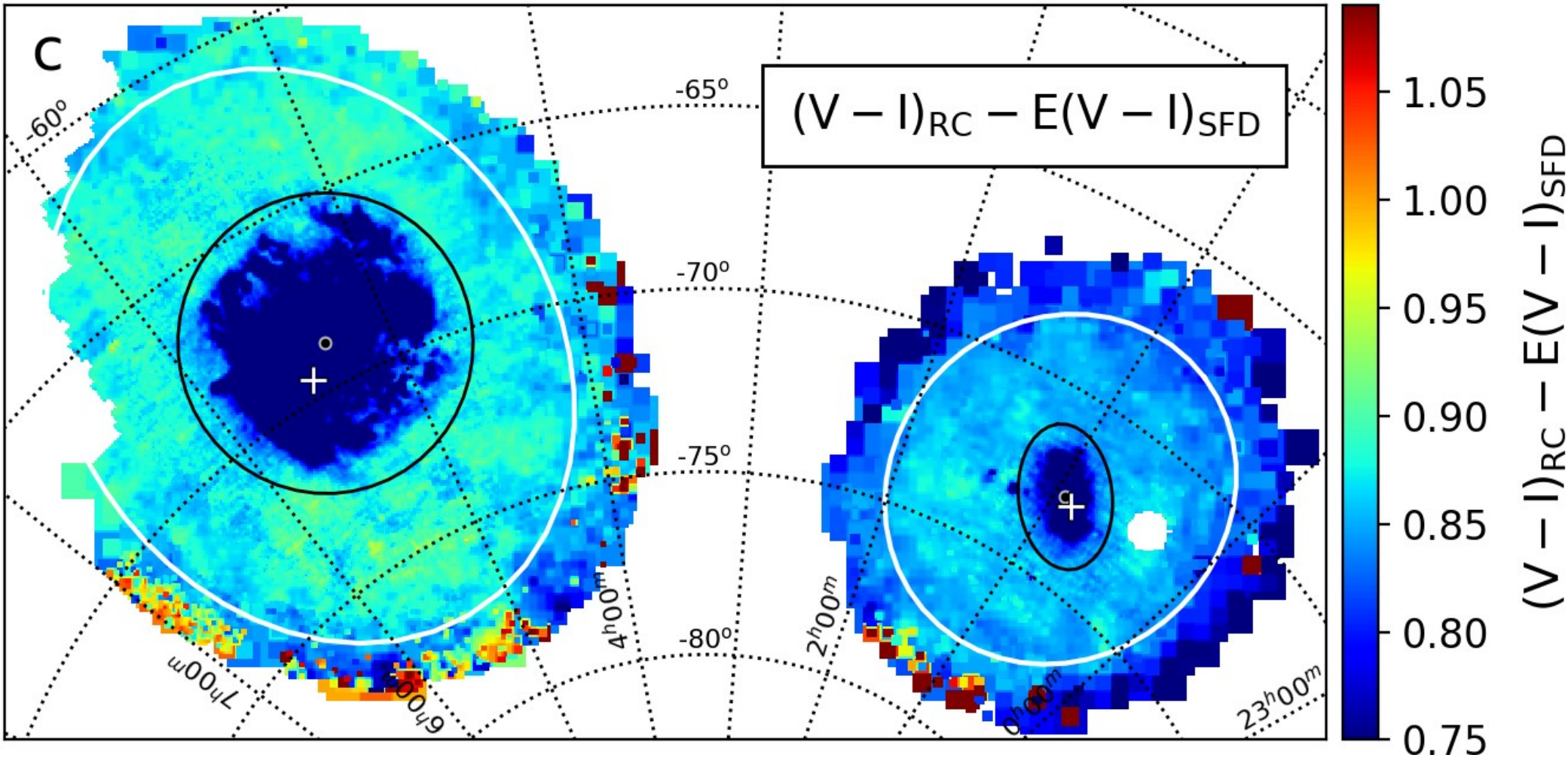
Reddening based on Schlegel, Finkbeiner, & Davis (1998) - $E(V-I)_{SFD}$



Intrinsic Red-Clump color $(V-I)_0$

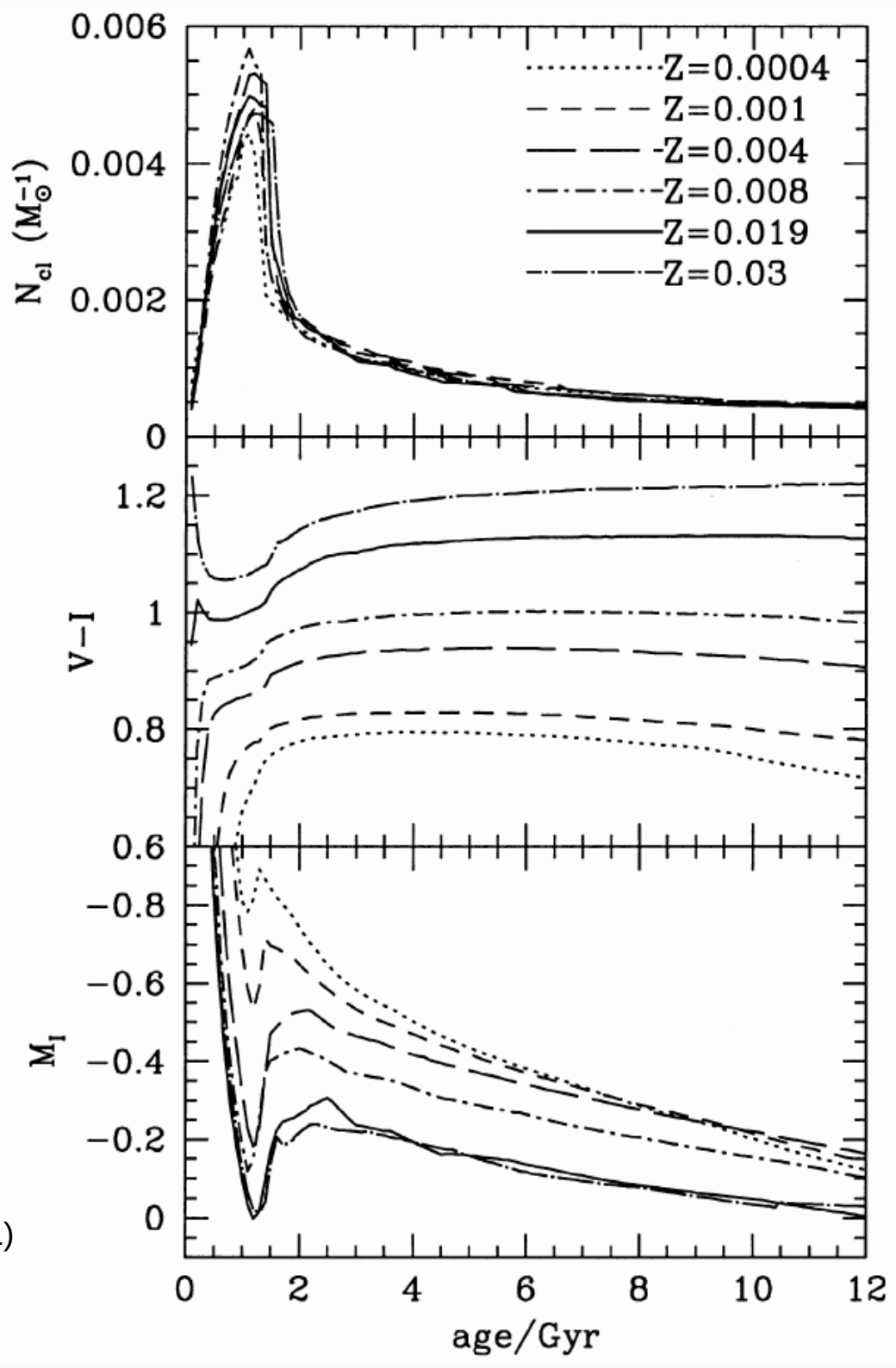


Intrinsic Red-Clump color $(V\text{-}I)_0$



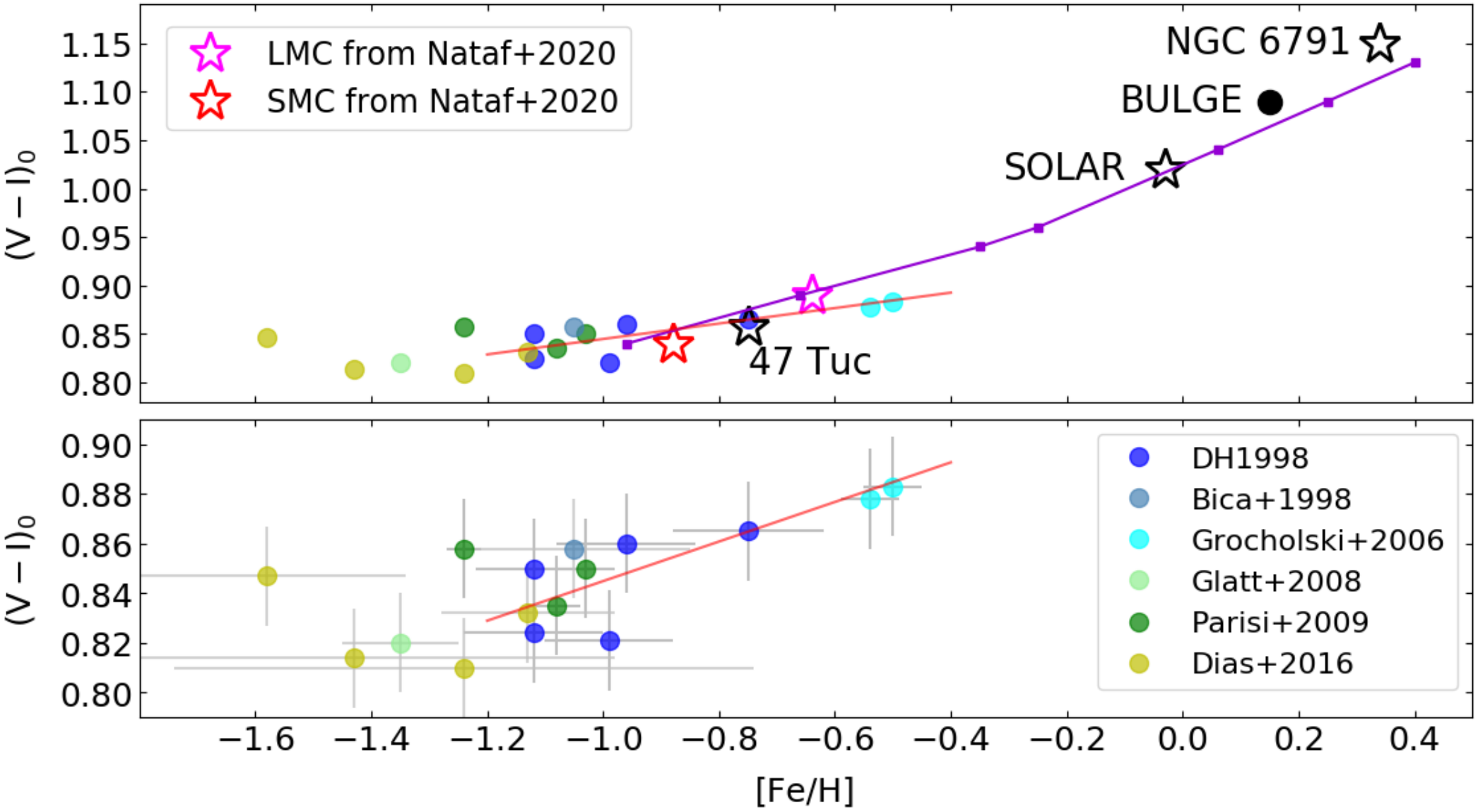
Intrinsic Red-Clump

- Depends on **age** and **metallicity**

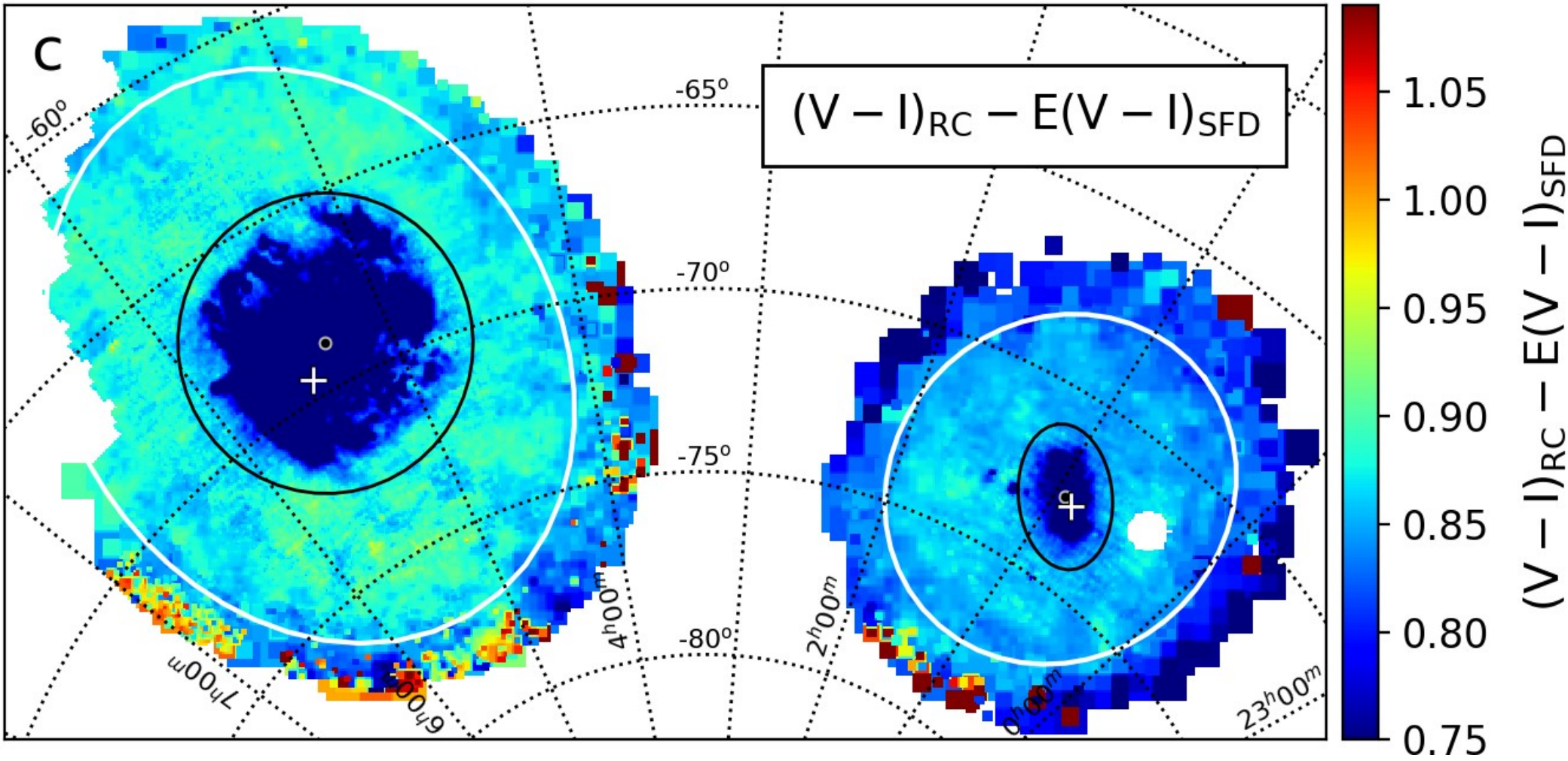


Girardi & Salaris (2001)

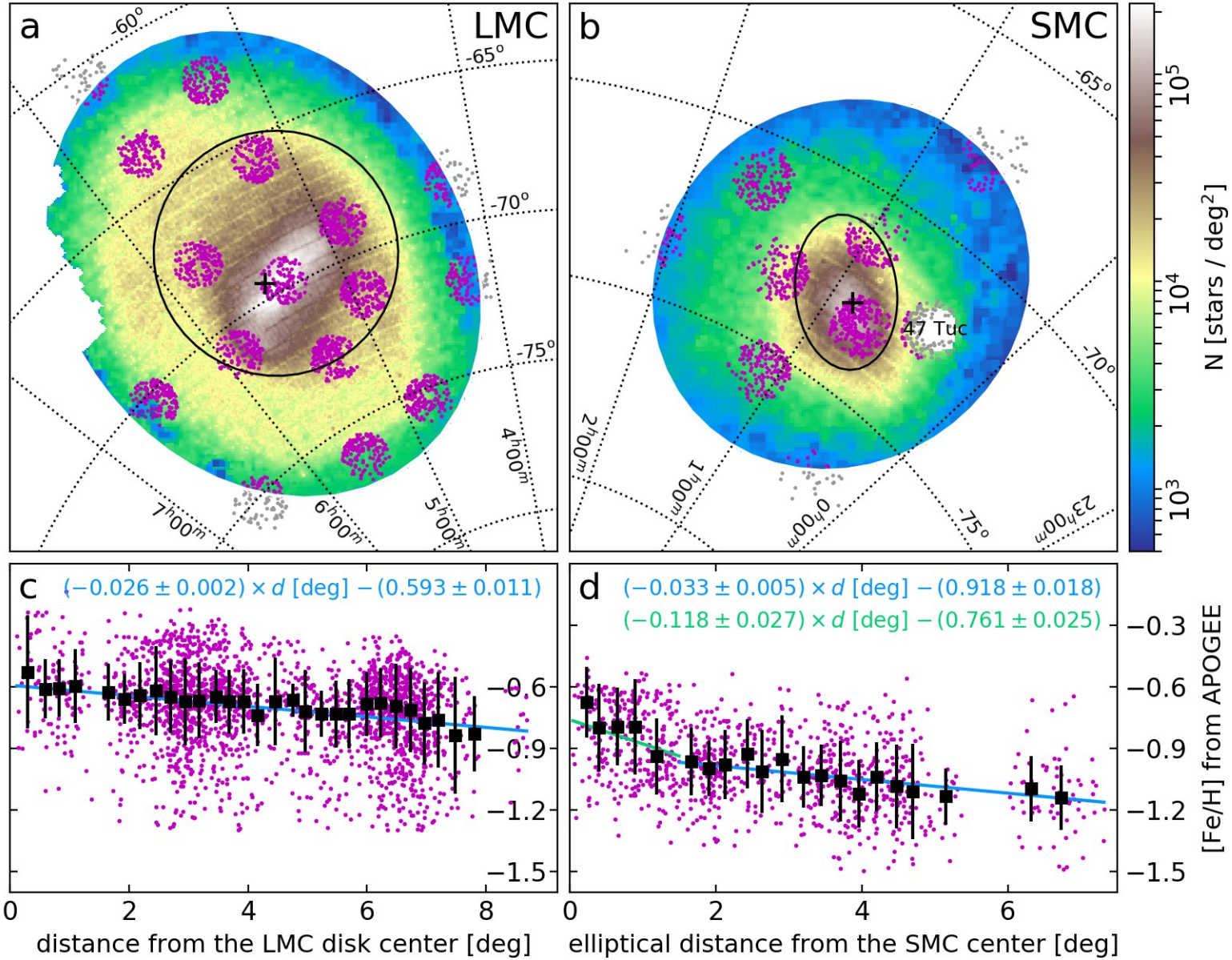
$(V-I)_0$ gradient may be due to metallicity



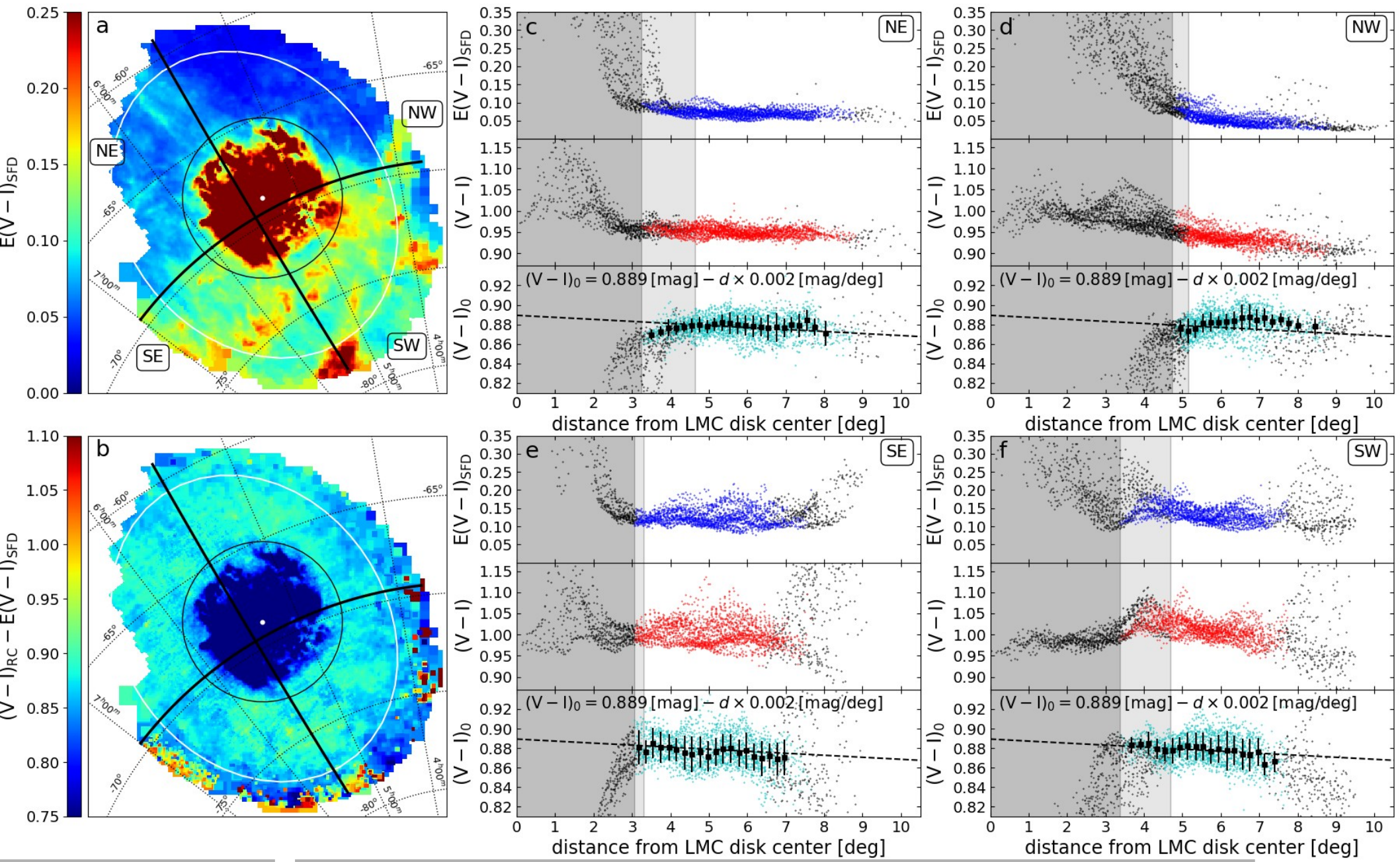
Intrinsic Red-Clump color $(V\text{-}I)_0$



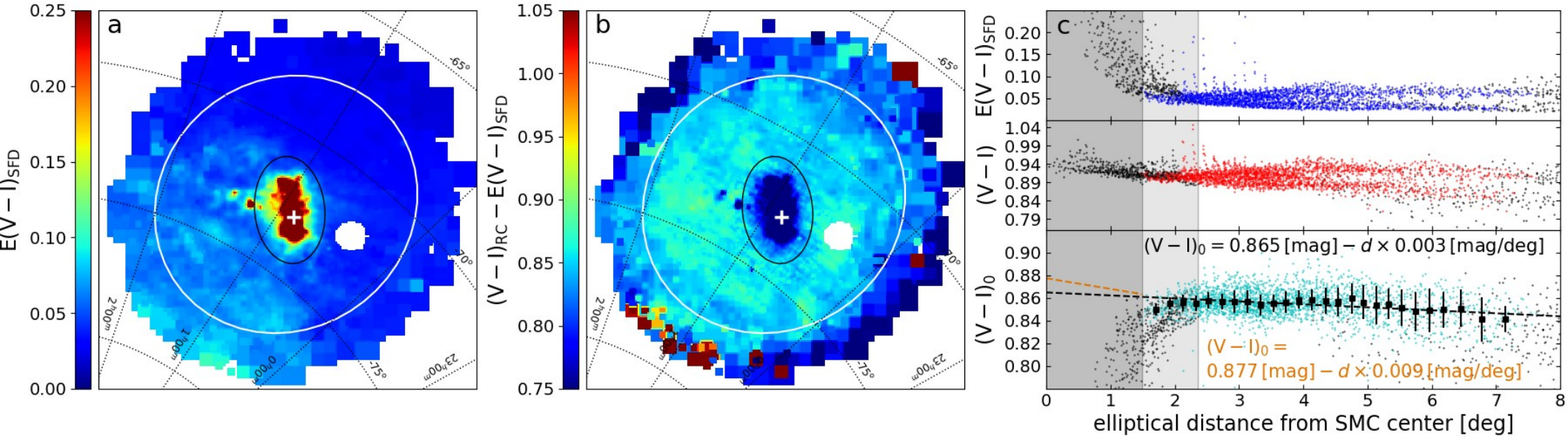
Red giant metallicity from APOGEE



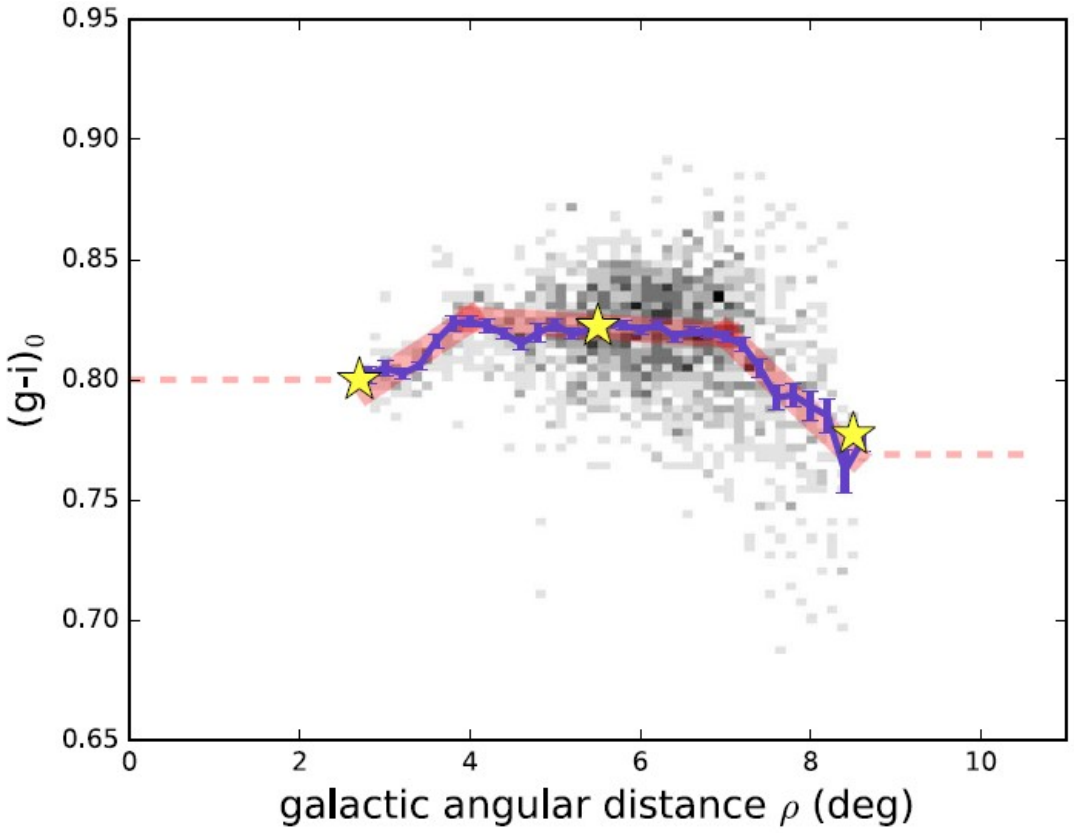
Intrinsic Red-Clump color $(V\text{-}I)_0$ in the LMC

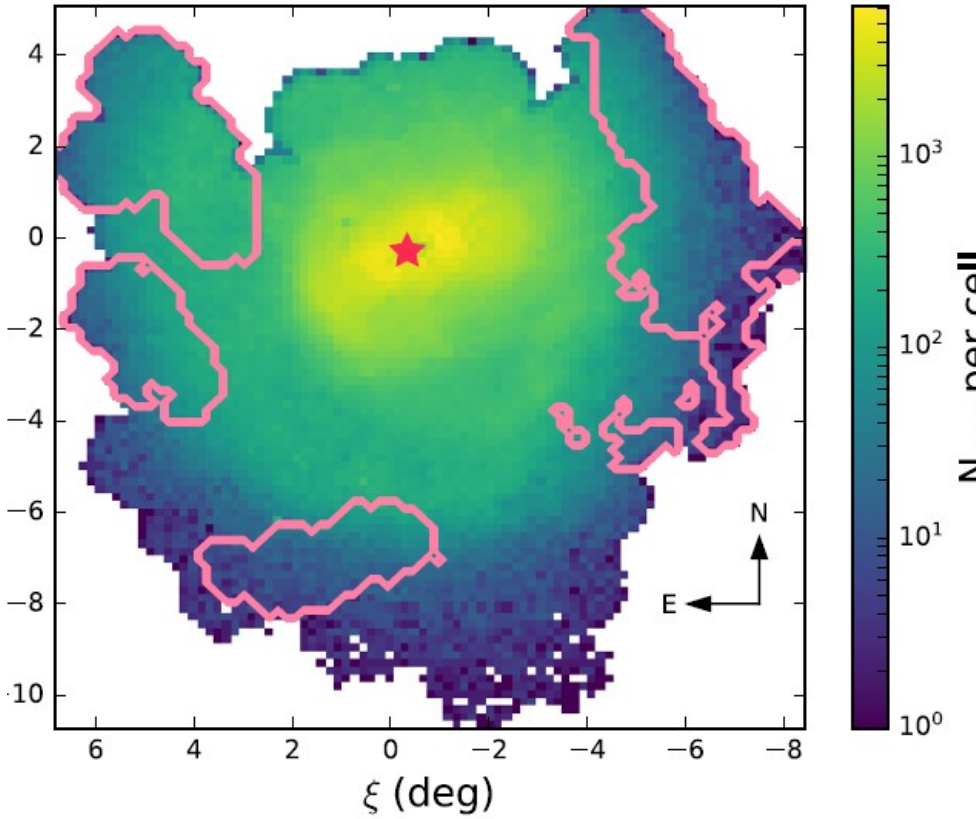


Intrinsic Red-Clump color $(V\text{-}I)_0$ in the SMC



Varying $(V-I)_0$ of the Red Clump in the LMC?

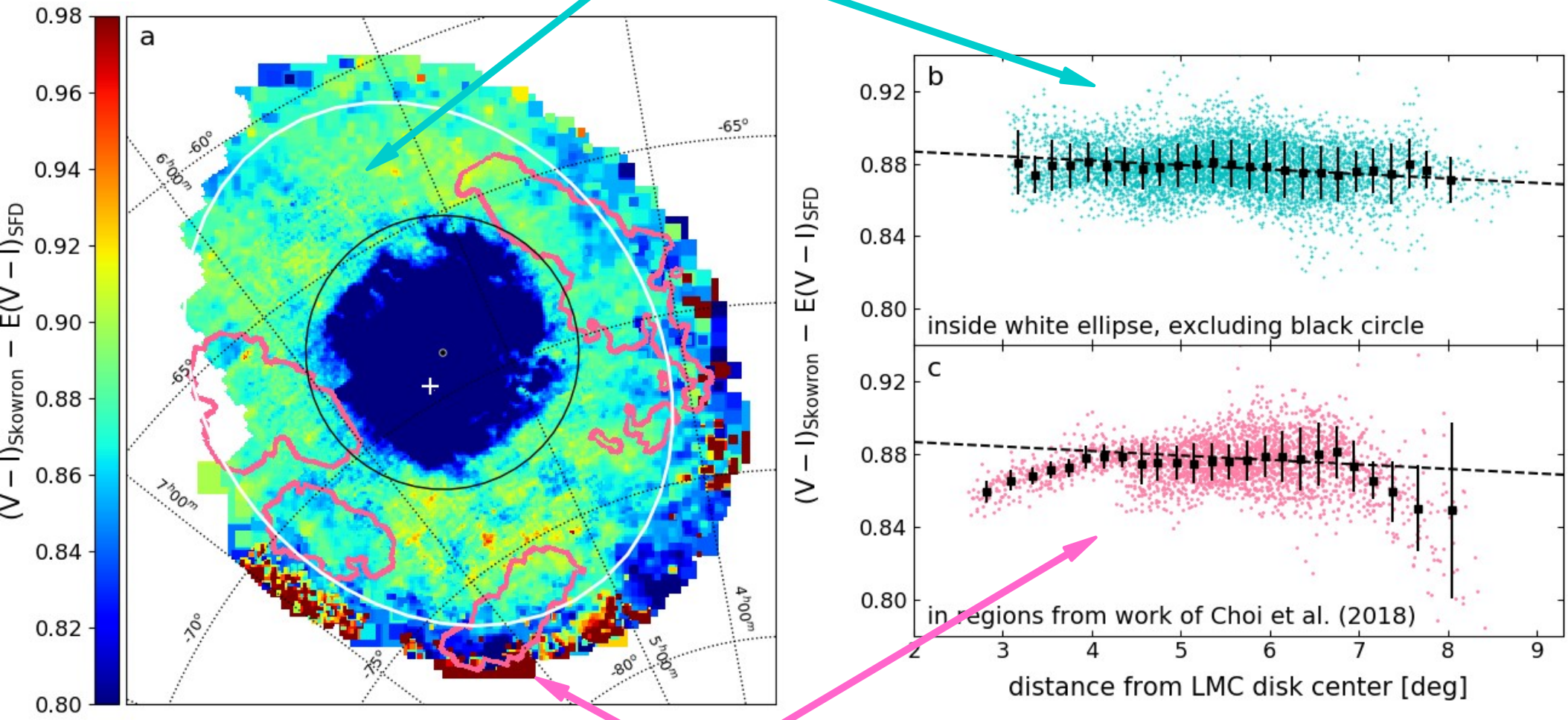




Choi et al. (2019)

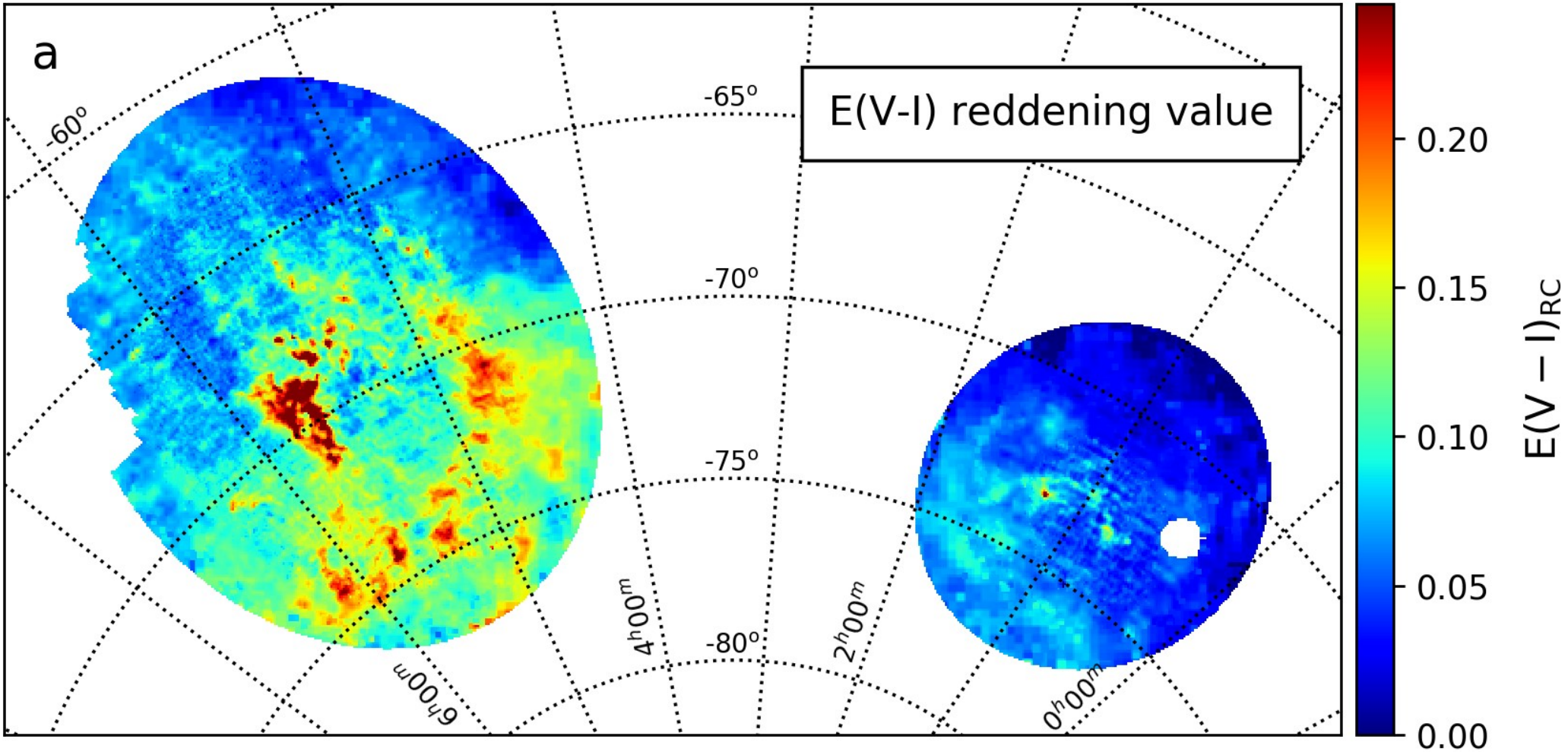
Varying $(V-I)_0$ of the Red Clump in the LMC?

Our regions for determining intrinsic color (all inside ellipses)

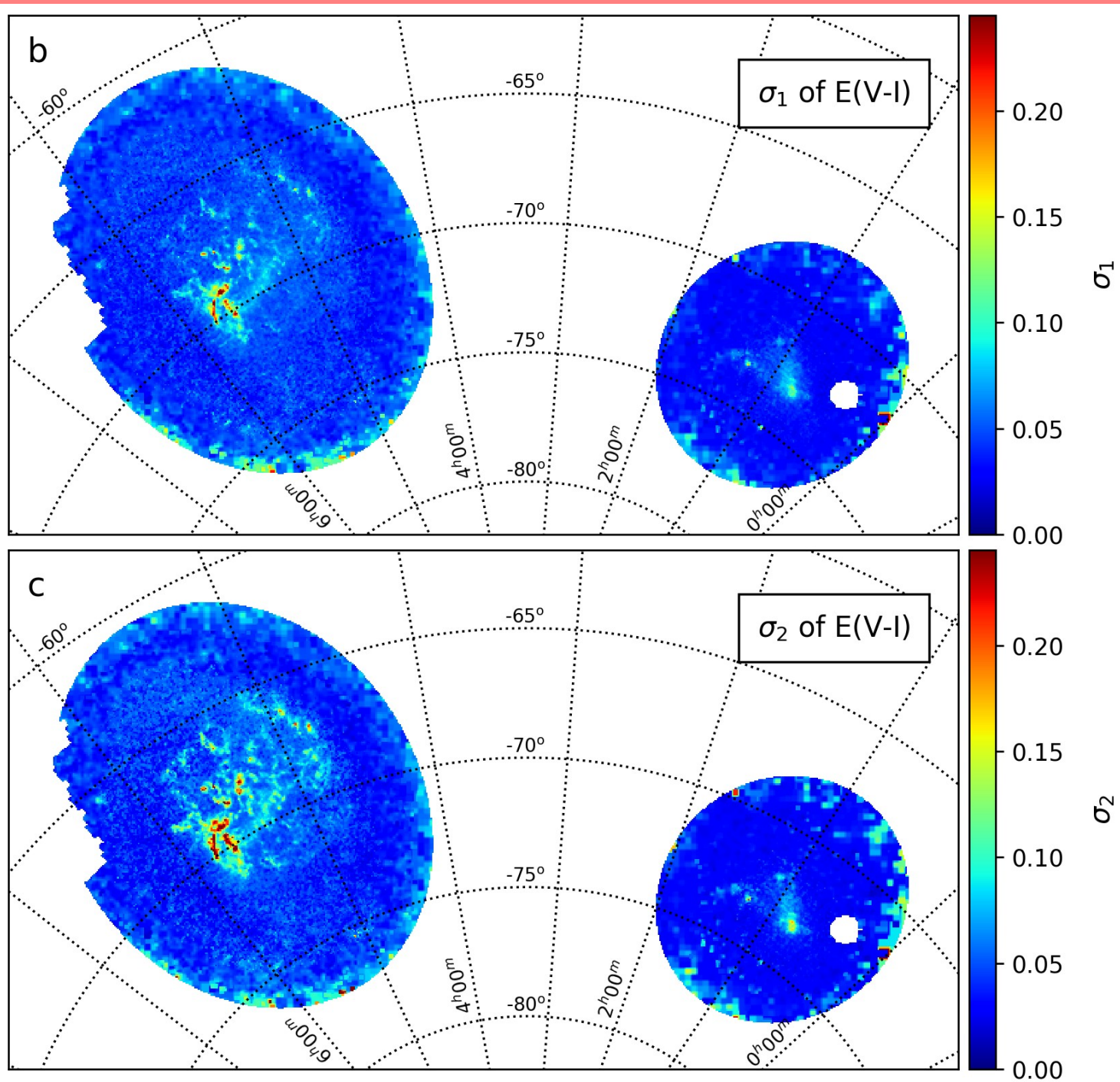


Choi et al. regions for determining intrinsic color (inside pink contours)

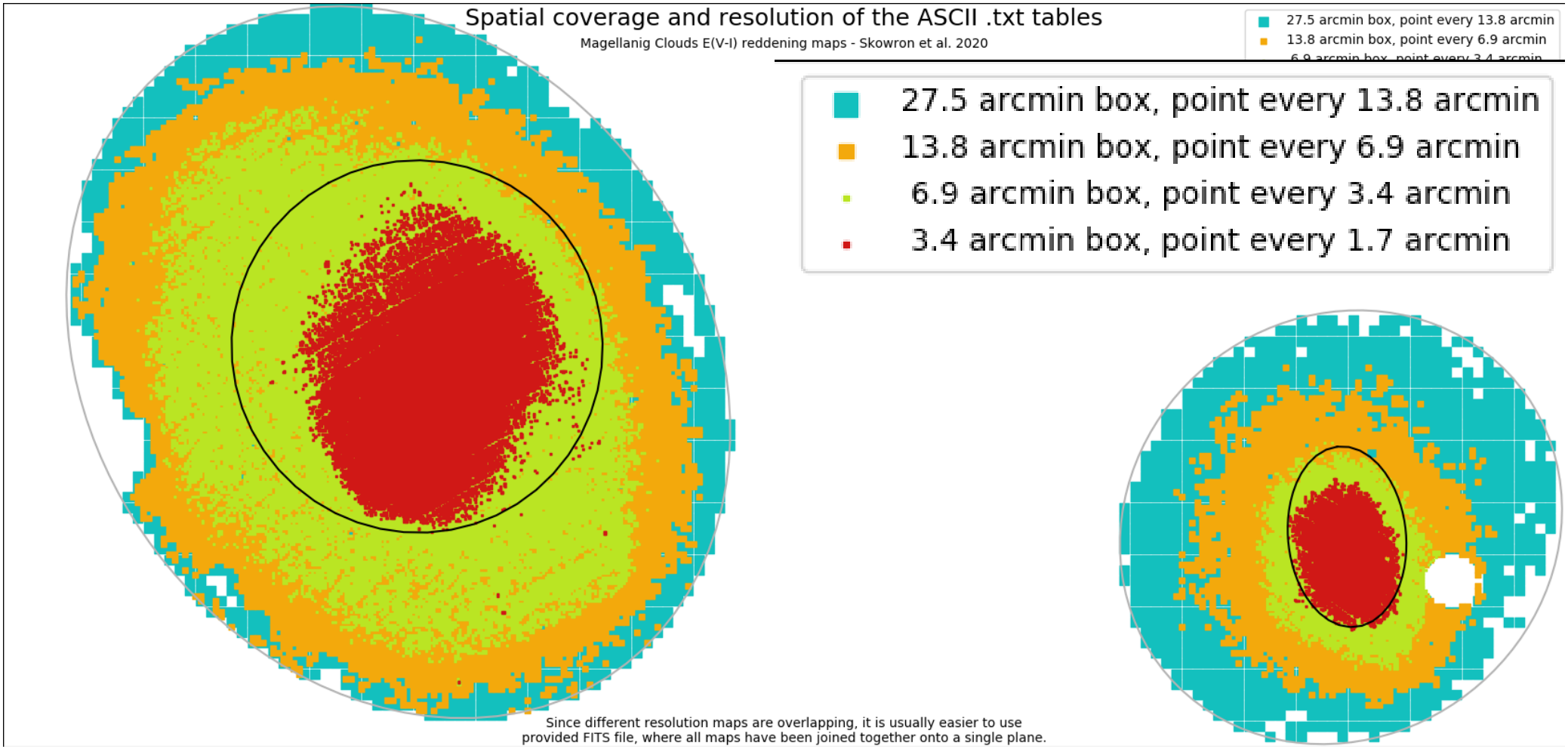
Final E(V-I) reddening map



Differential reddening

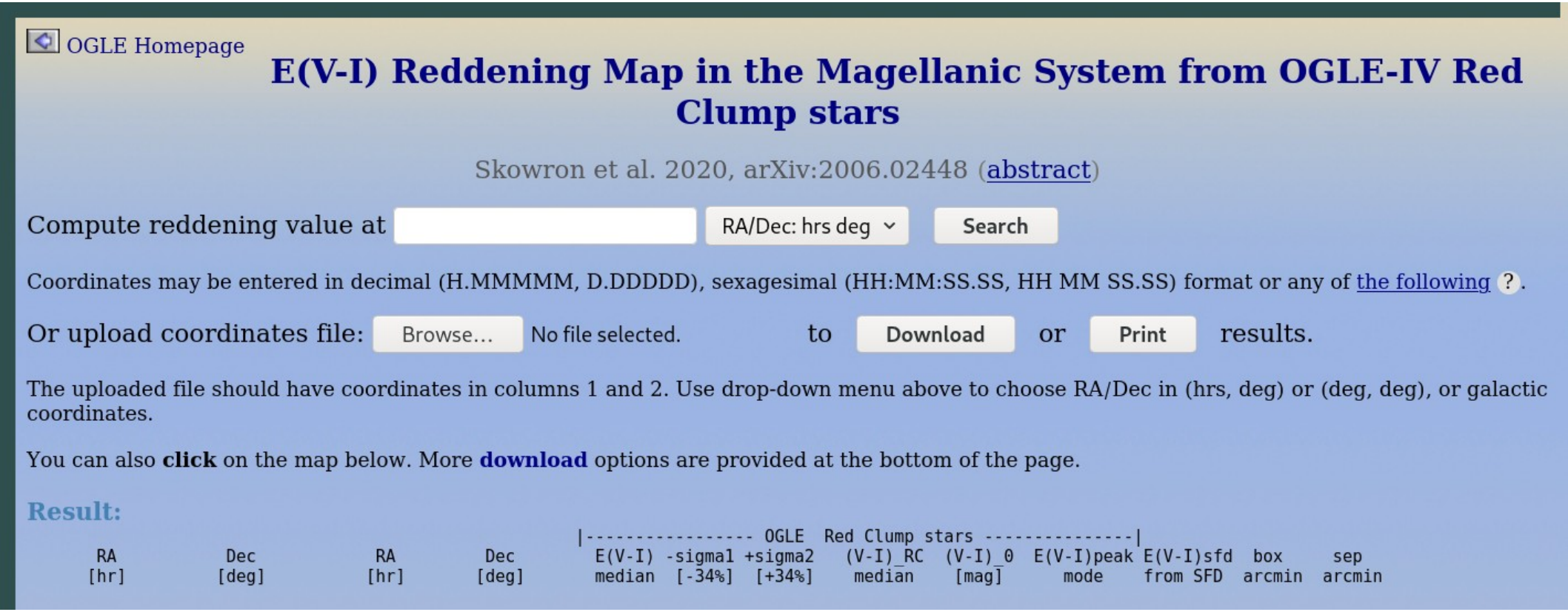


Resolution of the reddening map

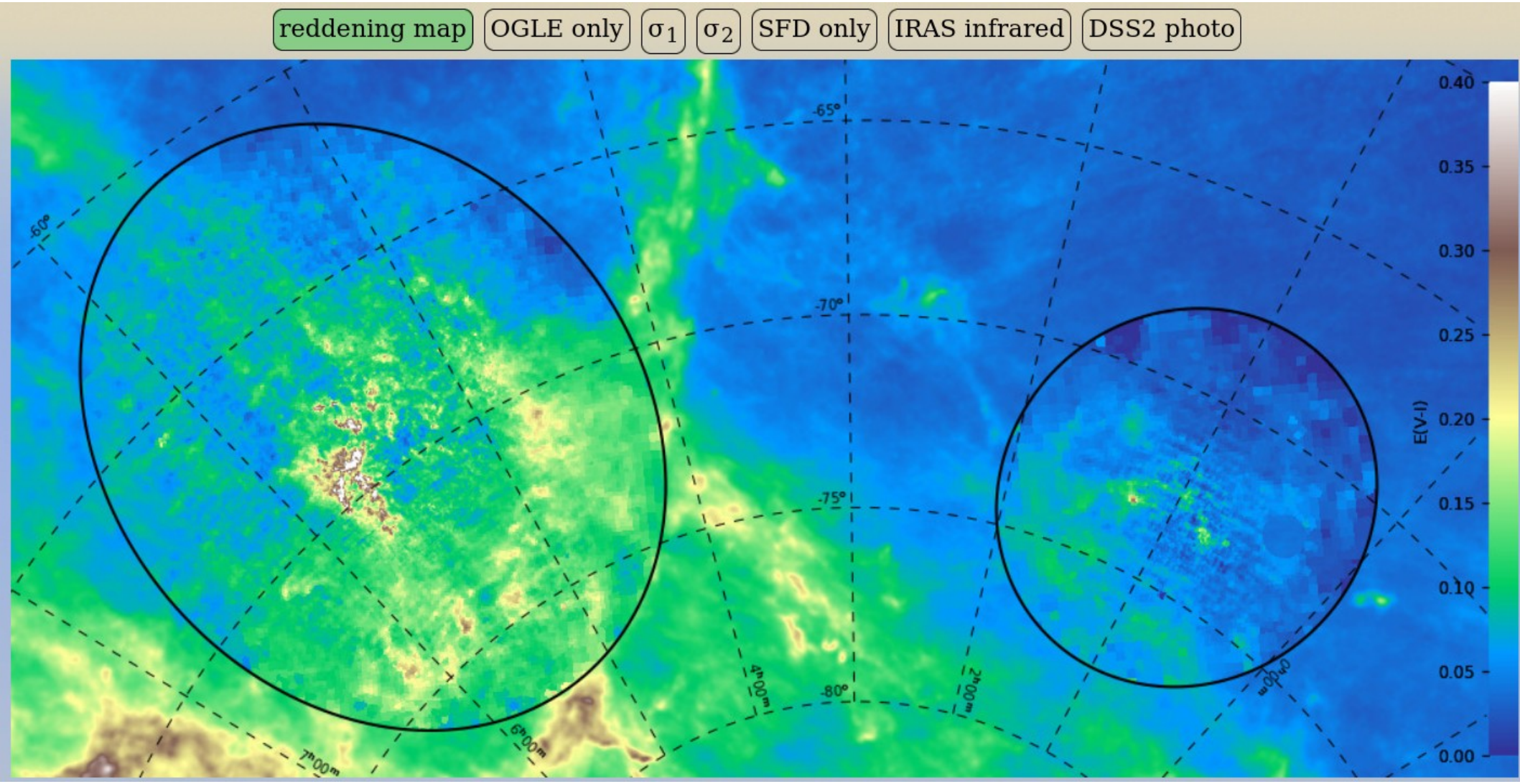


Website (an interactive interface)

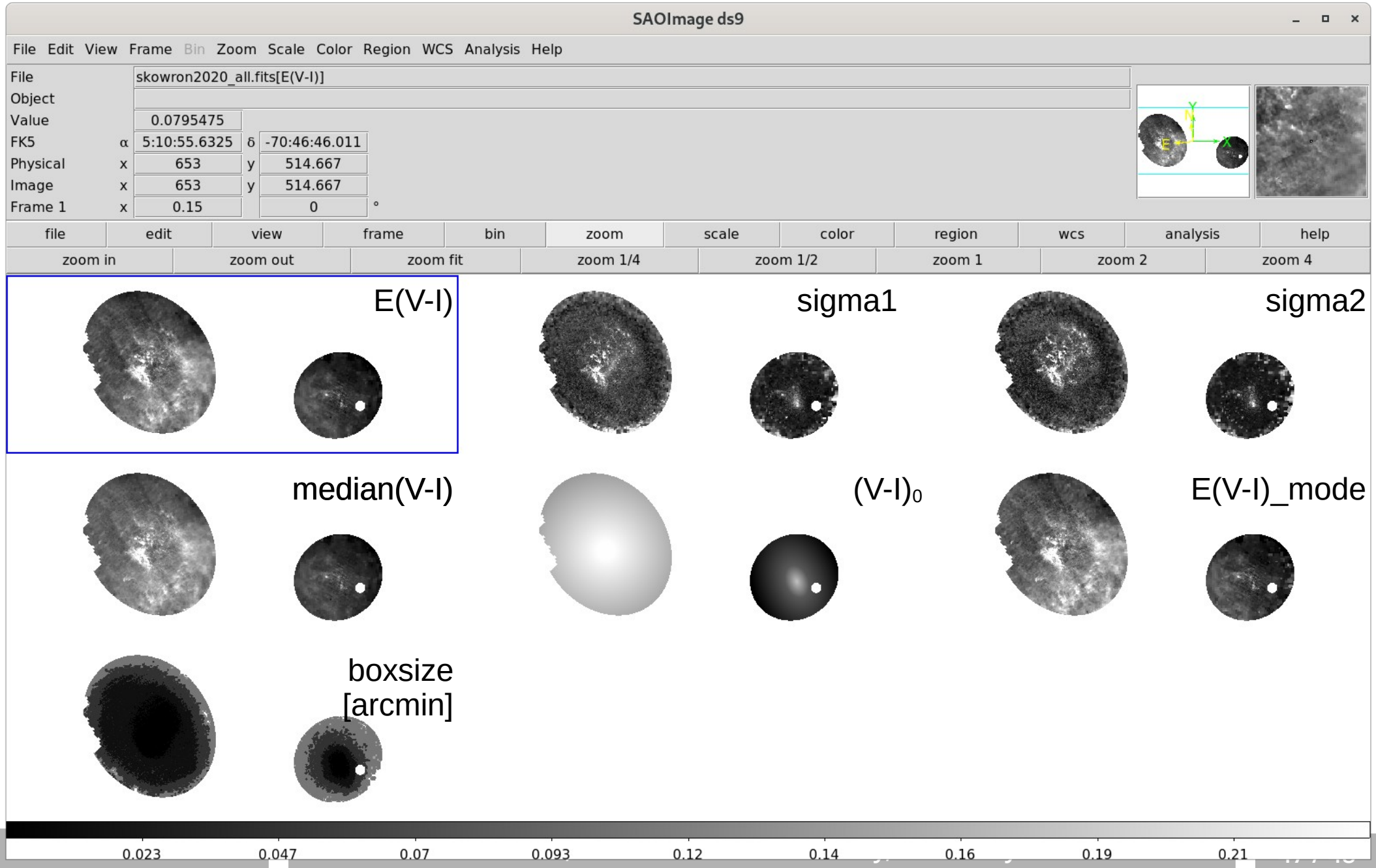
- http://ogle.astrouw.edu.pl/cgi-ogle/get_ms_ext.py



Website (an interactive interface)

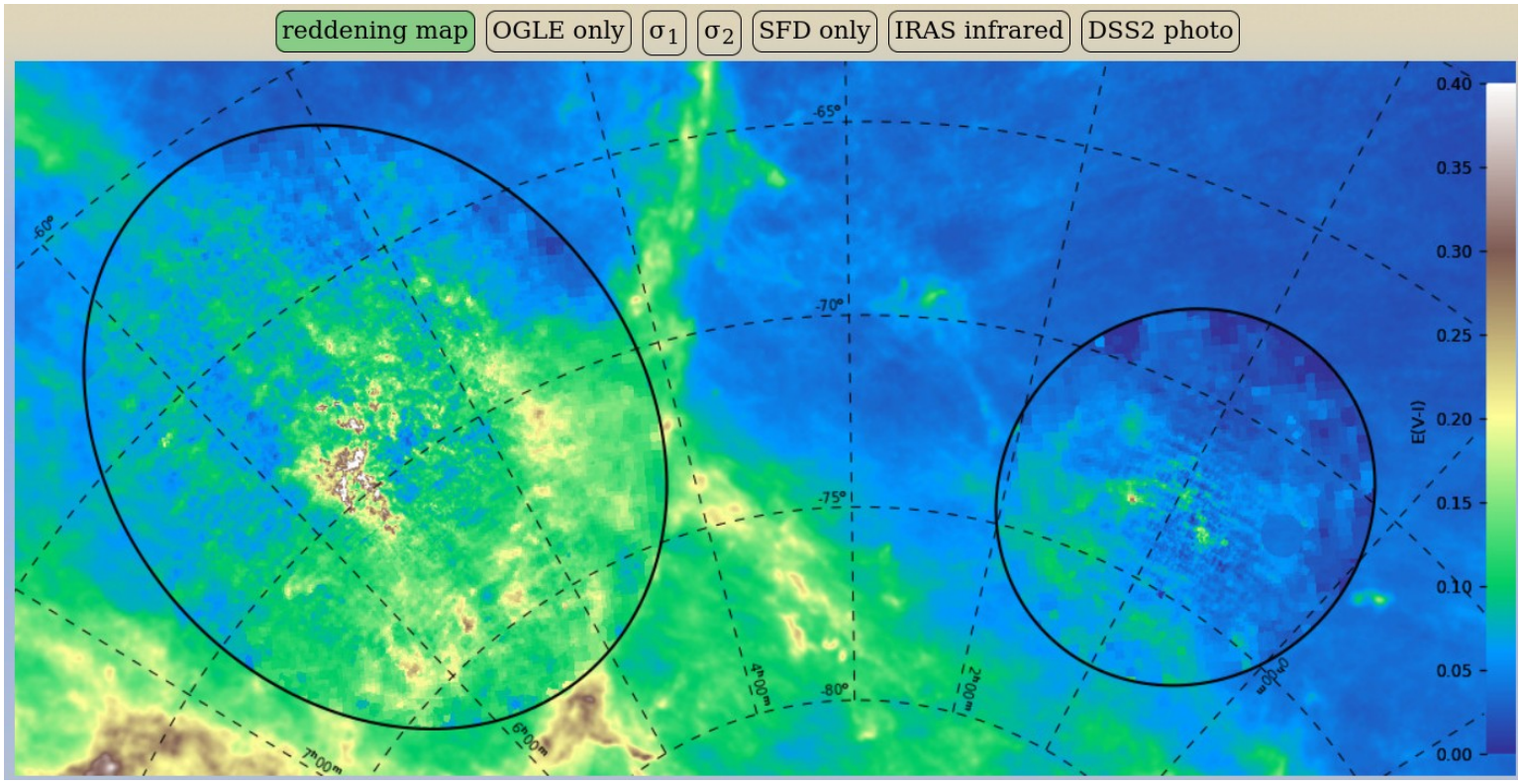


Data in FITS format



Reddening Maps of the Magellanic Clouds from OGLE-IV Red Clump Stars

- http://ogle.astrouw.edu.pl/cgi-ogle/get_ms_ext.py



Skowron et al. 2021, ApJS, 252, 23