The Gaia Red Clump: calibration and characterisation

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Parallaxes

Standard candles
Standard candle → Good distance indicator

$M_i$ weakly dependent on colour, age and chemical composition

Age ~ 2 Gyr
[Fe/H] ~ 0.0

Many RC stars in solar neighbourhood

Colours → Extinction → Absolute Magnitude → Distances

Hipparcos New Reduction
$\sigma_\omega / \omega < 0.2$
× Models do not fit observations

× Unavailable Gaia calibrated filter model for the DR1

Ruiz-Dern et al., 2017 (in prep.)
Colour vs G-K

Effective Temperature vs G-K
Sample selection

High Photometric quality

- G / B H p V I / B T V T / J K
- GDR1 / Hipparcos / Tycho2 / 2MASS + Laney et al. [2012]

Binarity and Multiplicity removal

- Hipparcos Binary Flag
- Tycho Double System Catalogue
- SB9, Simbad

Spectroscopic Metallicity

- APOGEE, RAVE, LAMOST, PASTEL, GALAH,...

Giants selection

- Colour G – K > 1.6
- Parallax (ω): \( m_G + 5 + 5 \log (\omega + 2.3 \sigma_\omega) < 2.5 \)
Interstellar extinction handling

- $A_0 < 0.03$
- Based on:
  - 3D extinction map TGAS data (Capitanio et al. 2017, in prep.)
  - 2D extinction map (Schlegel et al. 1998)

1329 stars

Poster C19
Model selection method

\[
\text{Colour} = a_0 + a_1 (G - K) + a_2 (G - K)^2 + a_3 \left[ \frac{\text{Fe/H}}{} \right] + a_4 \left[ \frac{\text{Fe/H}}{} \right]^2 + a_5 (G - K) \left[ \frac{\text{Fe/H}}{} \right]
\]

- **Monte Carlo Markov Chain (MCMC)**
  - account for all variables uncertainties

- **Deviance Information Criterion (DIC)**
  - Model selection: penalization by the complex terms

- **Outliers at 3\(\sigma\) from fit**
  - Checked one by one

\[ \begin{align*}
B & V_p \\
H & B_T \\
V_p & B_T \\
G & V_T \\
I & G \\
J & I \\
K & J \\
\end{align*} \]
G-J vs G-Ks

N = 1322
0.5% outliers
rms 0.03

B-Ks vs G-Ks

N = 202
12.6% outliers
rms 0.01

Ruiz-Dern et al., 2017 (in prep.)
Giants selection
High Photometric quality
Spectroscopic Metallicity
Interstellar extinction handling

$T_{\text{eff}}$ calibrations

APOGEE (DR13)

548 stars
$T_{\text{eff}}$ vs $G-K_s$

- $N = 539$
- 1.6% outliers
- $\text{rms} = 6.73$
- $\sigma \sim 57K$

Ruiz-Dern et al., 2017 (in prep.)
Other authors:

- IRFM giants
- IRFM giants
- Interferometry
- Photometry

This work:

- $T_{\text{eff}}$ vs $V-K_s$
- $T_{\text{eff}}$ vs $G-K_s$
- $V-K_s$ vs $G-K_s$

Ruiz-Dern et al., 2017 (in prep.)
I. Gaia Red Clump *photometric calibration*

II. Gaia Red Clump *characterisation*
Need to account for extinction to use Gaia G magnitude

Gaia DR1

\( \sigma_\omega / \omega \leq 0.2 \)

Gaia Collaboration,
2016, A&A
$\sigma_\omega / \omega < 0.1$

$E_{(B-V)} < 0.015$

Secondary Red Clump

Red Giant Branch Bump

Ruiz-Dern et al., 2017 (in prep.)
Padova Isochrones

$T_{\text{eff}}$ from Padova Isochrones

$G - K_s$ obtained using $T_{\text{eff}}$ calibration
Colour – G-K_s calibrations

G-K_s – T_{eff} calibration

Extinction coefficients model
  (C. Babusiaux)

- \( k_{\lambda} = f(A_0, T_{\text{eff}}) \) and \( k_{\lambda} = f(A_0, \text{colour}) \)
  - Fitzpatrick and Massa (2007)
  - RC Spectral Energy Distribution

- \( k_G \) empirical
  - Using calibrations of this work
    (Danielski et al. 2017, in prep.)

* \( A_0 \) absorption at \( \lambda = 550 \) nm (Gaia reference value)
Effective Temperatures

![Effective Temperatures Graph](image)
✓ Interstellar extinctions

EW (Zasowski et al. 2015)

$A_0$ (this work)

$A_{K}$ (Apogee)

Zasowski +2015 relation

Relation
Gaia Data Validation

✔ Zero-point of parallaxes and their precision

\[ \text{Distance modulus calculated by Rodrigues et al. (2014) using Padova isochrones relations} \]

\[ \text{984 Tycho sources with } \sigma < 0.1 \text{ mas (APOKASC median } \sigma \sim 0.02 \text{ mas)} \]

\[ \text{Estimated distance uncertainty better than Gaia } \omega \text{ precision} \]

\[ \text{[TGAS: } \sigma_{\omega(\text{EXT})} < 0.1 \text{ mas]} \]

DR2

Larger RC sample

\[ \text{Distance modulus derived from: Calibrations of this work + Asteroseismic constraints} \]
Conclusions

DR1 Parallaxes

Gaia RC photometric calibration (Ruiz-Dern+ 2017, in prep.)
- Other Spectral Types (C. Danielski)
- $k_G$ extinction coefficients (Danielski+ 2017, in prep.)

Gaia RC characterisation
- Padova Isochrones
- RC Parameters
- New 3D extinction map (Capitanio+ 2017, in prep.)
- $M_G \rightarrow$ distances
- HR simulations (C. Hottier)

Gaia DR2: Use of calibrations for astrometric and photometric validation