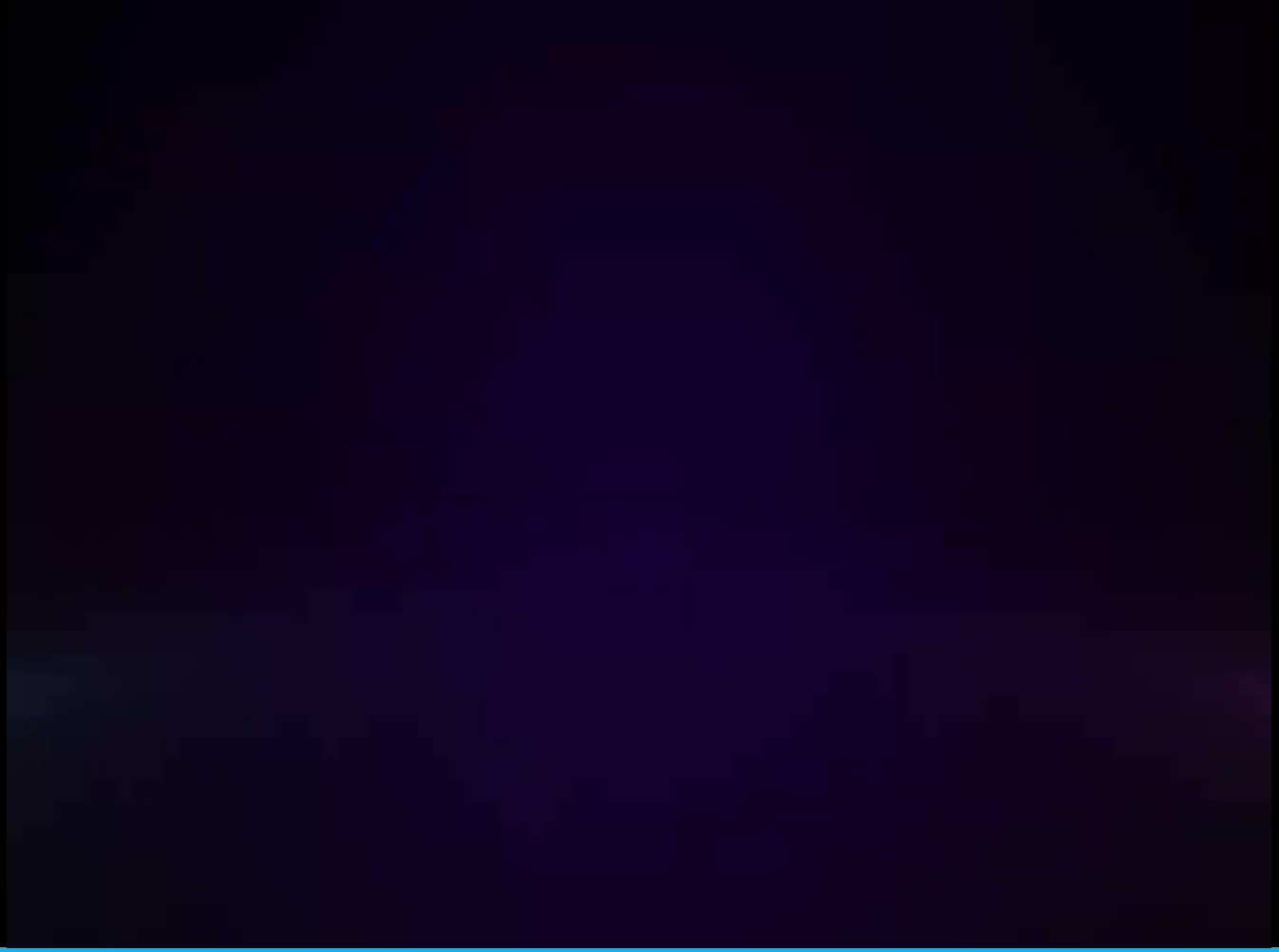
A scientific guide to Gaia Astrophysical Parameters

Day 2

organized by Coordination Unit 8



ATHENS

ESP-UCD Extended Stellar Parametrizer for UltraCoolDwarfs

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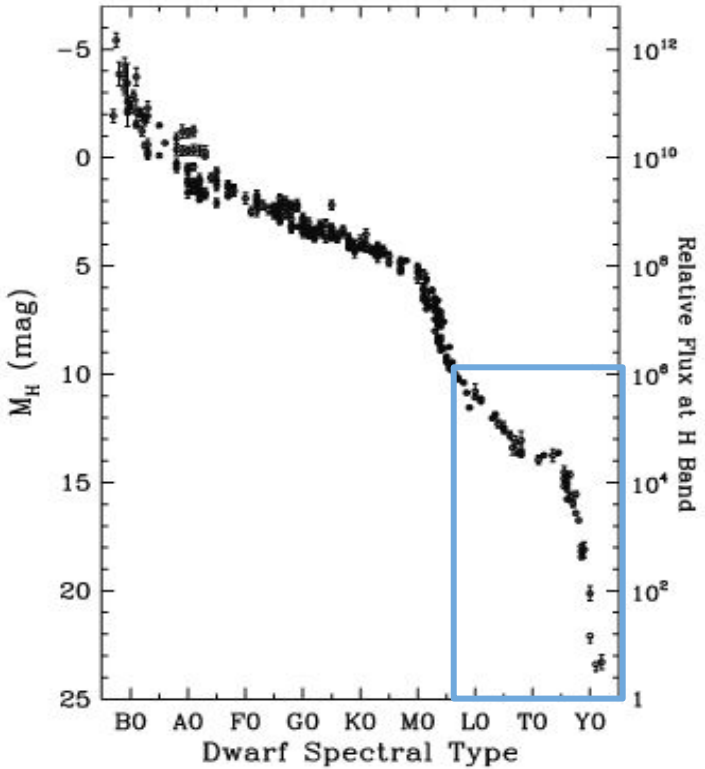
Kirkpatrick et al (2012)

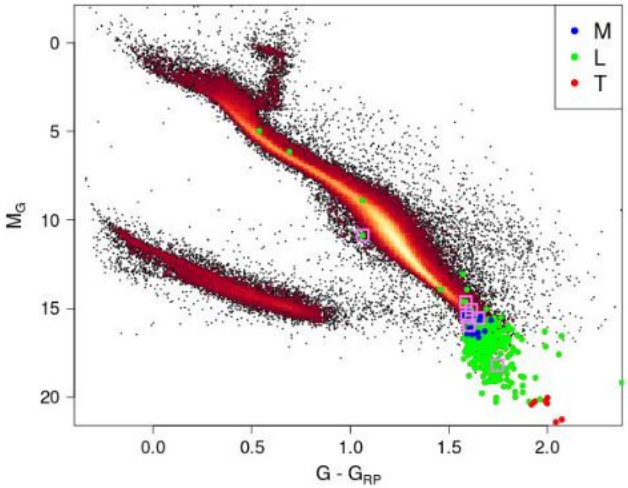


ESP_UCD Objective: detect and characterize ultracool dwarfs, introduced in 1997 by J. Davy Kirkpatrick, Todd J. Henry, and Michael J. Irwin as stellar sources with spectral type M7 or later.

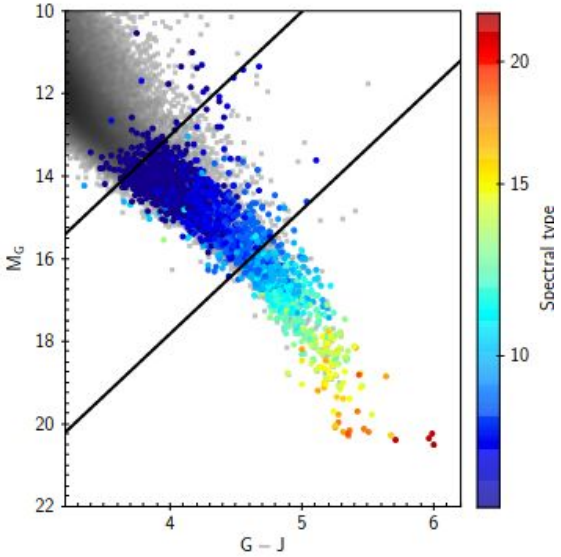
- L dwarfs show absorption features due to hydrides and neutral alkali elements (grain formation and sedimentation)
- L/T transition marked by cloud clearing and methane opacity (colour trend reversal)
- Disequilibrium chemistry and vertical transport of species
- Model mismatches in several wavelength ranges -> non-adiabatic P-T profiles

Precedents in Gaia

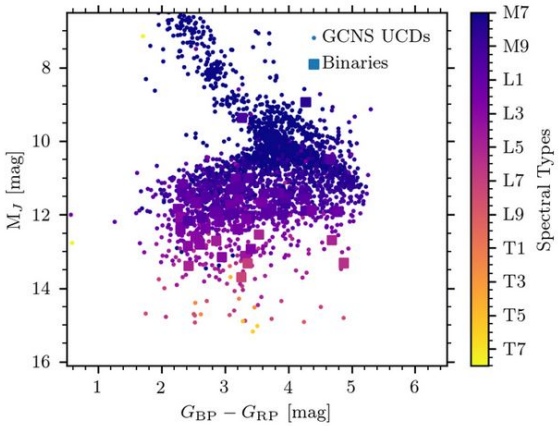
GUCDS (Smart et al, 2017) in the GDR2 CAMD by Babusiaux et al (2018)



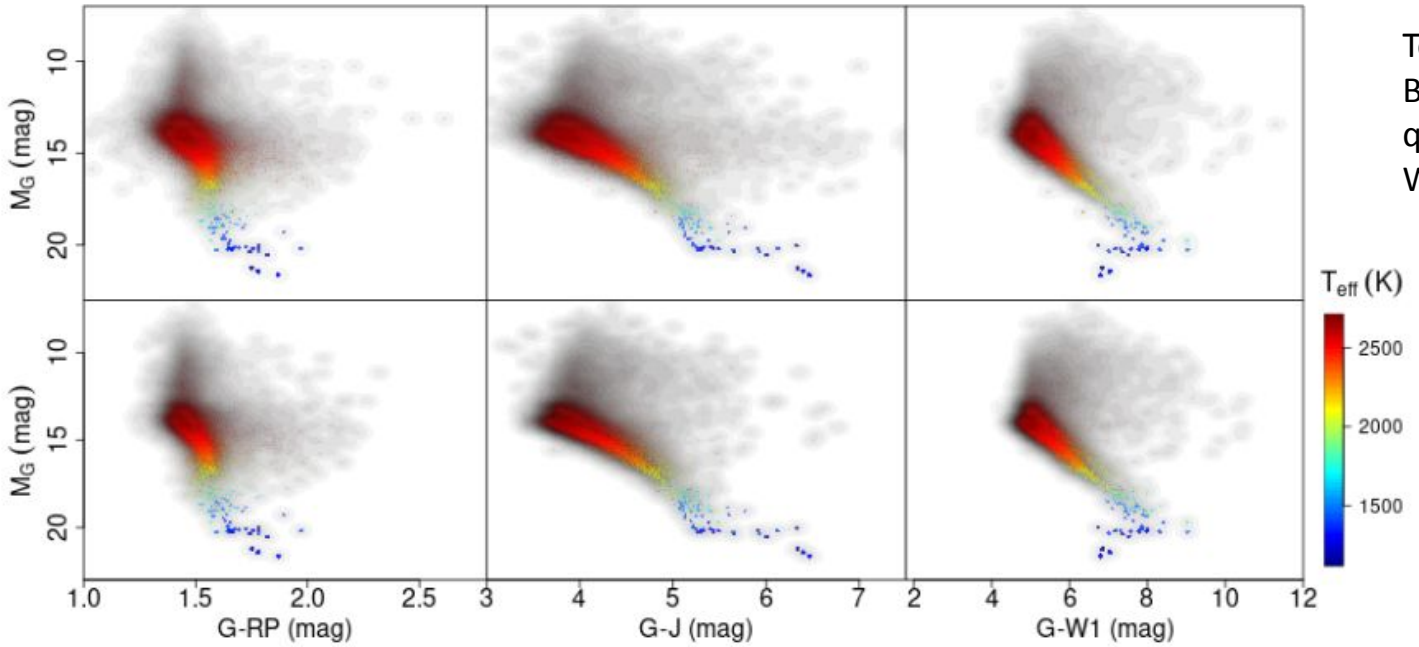
[DR2] 13 000 ≥M7 (631 new L) candidates from Reyle (2018)



[GDR3] GCNS contains 2879 additional candidates compared to *Gaia* DR2



Gaia DR3: ~ 94000 UCD candidates



Top row: all sources
Bottom row: only A & B quality in 2MASS and WISE

Selection for Processing

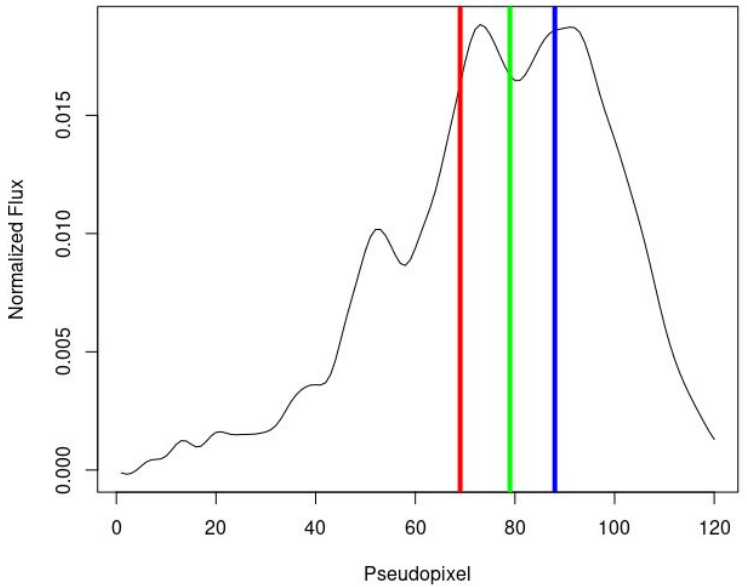
Inputs

The inputs to the ESP-UCD module are fields in the Gaia source table (the field names are links to the data model):

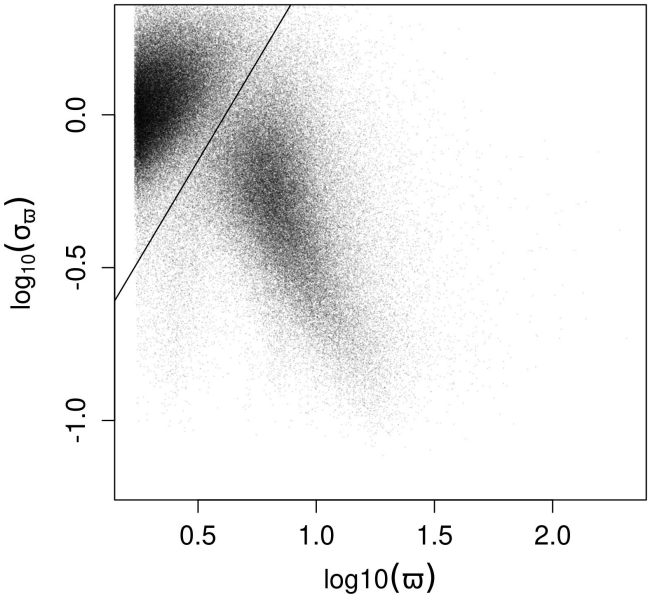
- parallax, `parallax`
- *G* band magnitude, `phot_g_mean_mag`
- RP band magnitude, `phot_rp_mean_mag`
- the continuous representation of internally calibrated BP/RP spectra in terms of coefficients.

Selection for Processing

- Parallax $\varpi > 1.7$ mas
- Colour index $G - G_{\mathrm{RP}} > 1.0$ mag
- $q_{33} > 60$
- $q_{50} > 71$
- $q_{67} > 83$



Selection for AP publication



Euclidean distance to closest training template

- $\log(d_{TS}) > -2.05$ (sources outside the quality criteria defined above);
- the number of transits used to construct the RP spectrum was less than 15;
- $T_{\rm eff}$ estimates outside the $(500, 2700)$ K range;
- the normalized RP spectrum median curvature $\tau \geq 2.0 \cdot 10^{-5}$;
- the sum of normalized RP spectrum fluxes below the zero flux level is smaller than -0.1;
- the reddest flux corresponding to the 120-th pixel of the (normalized) RP spectrum is greater than or equal to 0.015.
- sources with $\log(\texttt{varpi_error}) \geq -0.8 + 1.3 \cdot \log(\texttt{varpi})$

Postprocessing:

Teff calibration in the hot regime

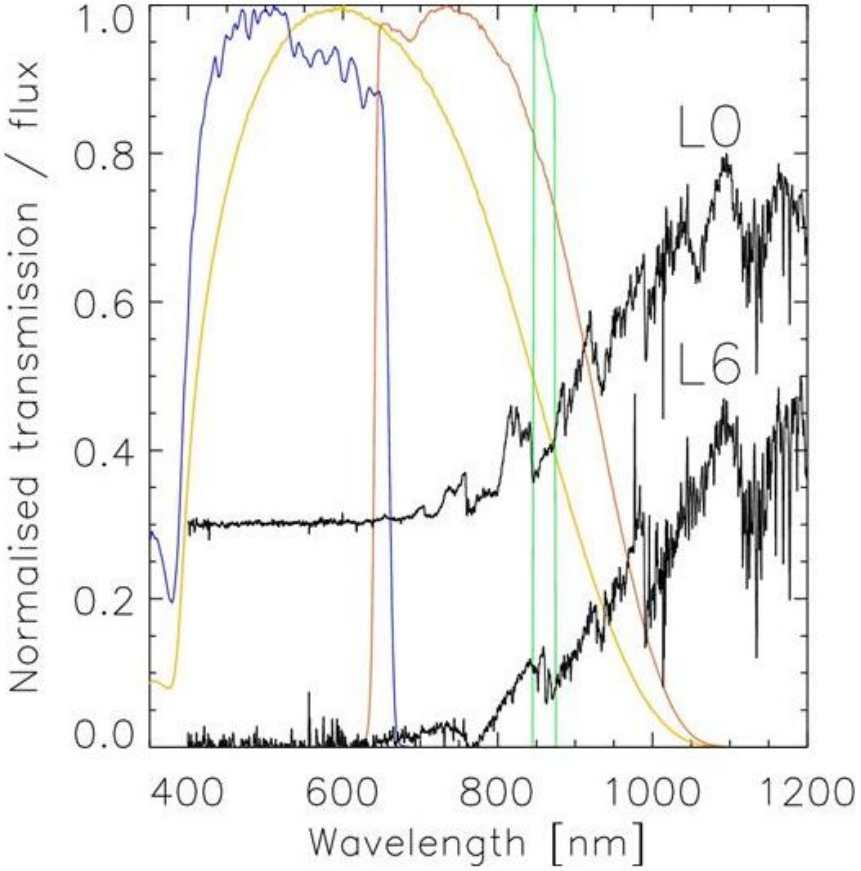
$$T_{\rm eff}^{new} = T_{\rm eff}^{old} - \kappa \cdot \sigma \left(\frac{T_{\rm eff}^{old} - T_{ref}}{\eta} \right) \quad (11.35)$$

where $\kappa = 150.0$ K, $T_{ref} = 2575$ K, $\eta = 150$ K and

$$\sigma(x) = \frac{1}{1 + \exp(-x)}. \quad (11.36)$$

Plus uncertainty inflation by a factor 7 derived from comparisons with predictions for the GUCDS

RP spectra

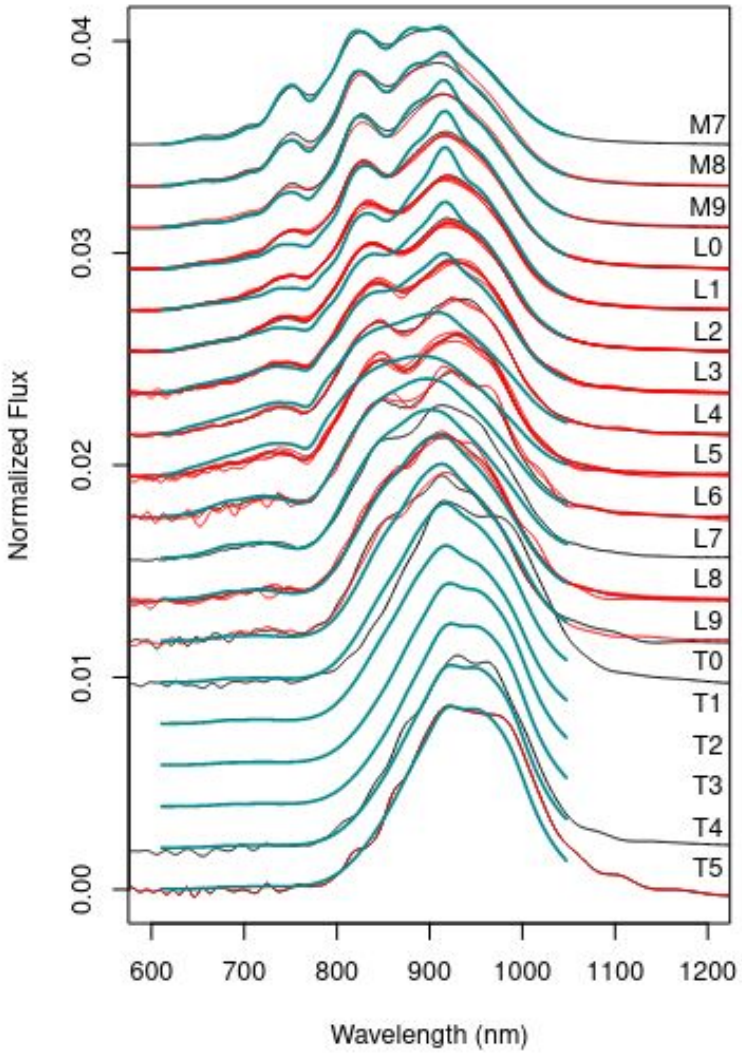

Normalised transmission / flux
1.0
0.8
0.6
0.4
0.2
0.0
400
600
800
1000
1200
Wavelength [nm]
L0
L6

RP spectra

Red lines are spectral standards

Turquoise lines are BT Settl simulations

Black line is the median spectrum



RP spectra: truncation

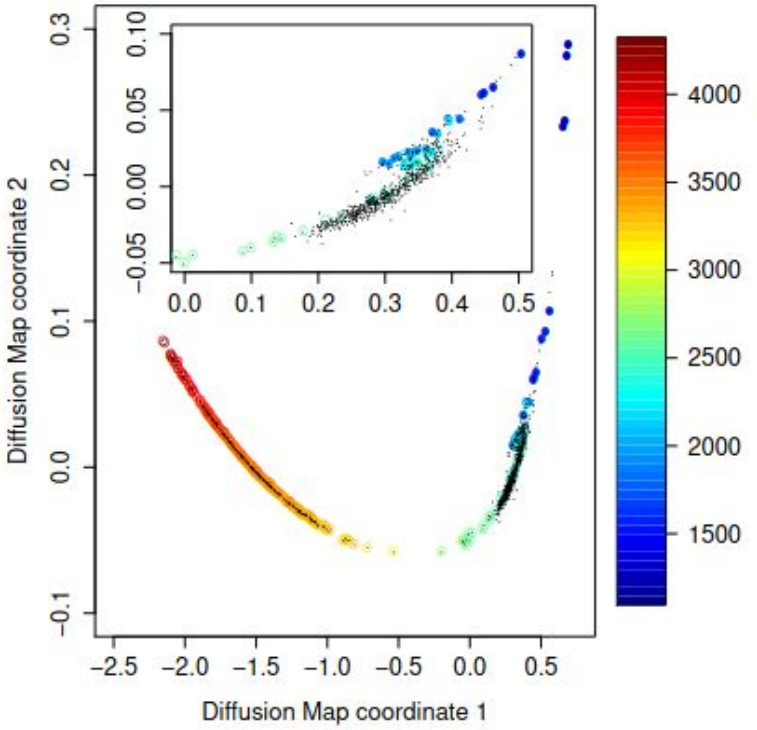
Given the faintness of the UCD sources, the ESP-UCD module introduces a coefficient truncation stage in the reconstruction of the sampled mean RP spectrum from the continuous representation coefficients (see Section 11.3.1 for details). The truncation stage reduces the number of basis functions used in the reconstruction of the spectrum by setting to zero coefficients that are not significantly larger than their uncertainties. Details about the truncation procedure can be found in Carrasco et al. (2021). We use a=3 where a is the threshold coefficient in Equation 27 of Carrasco et al. (2021). After this coefficient truncation step, the reconstruction is carried out in the same way as

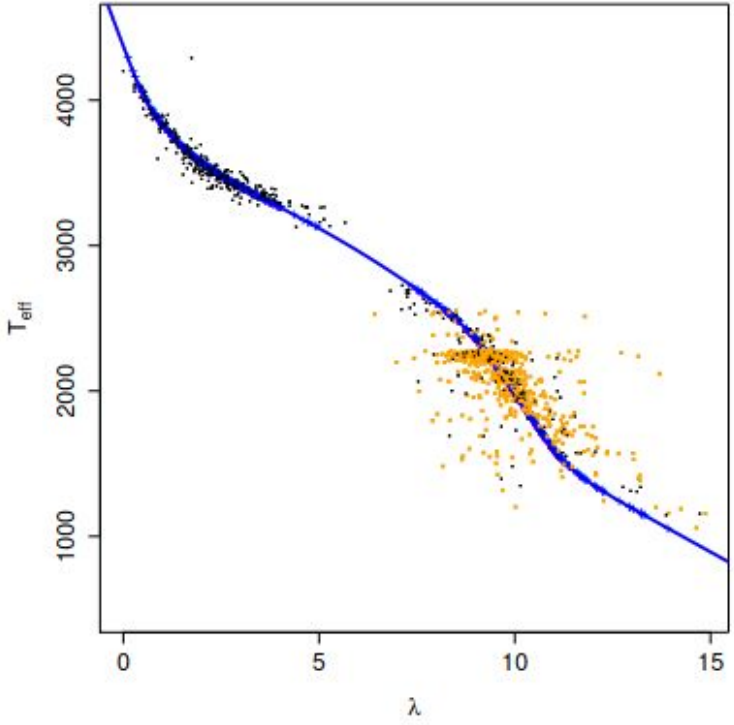
RP spectra: publication criteria

- Curvature < 2 times 10^{-5}; a negative fraction of the spectrum below 10%; normalized reddest flux below 0.015.
- More than 15 observations of the RP spectrum
- The RP relative uncertainty (sigma over flux) less than 0.05
- Minimum Euclidean distance to the set of templates less than 0.05
- The Teff estimate by the empirical module differs from absolute magnitude bin median by less than 400 K.

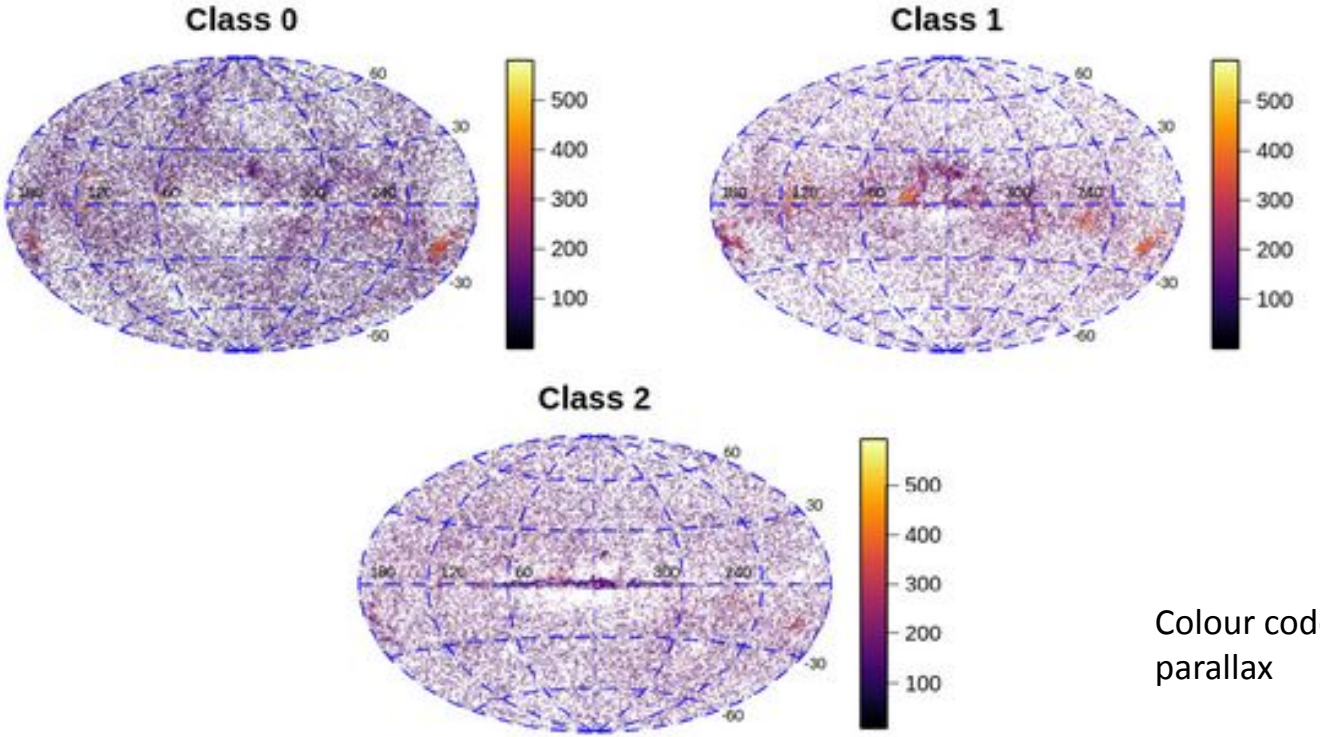
• The criteria above are defined based only on the RP spectra. No quality check or assessment has been carried out on the BP spectra.

The empirical training set



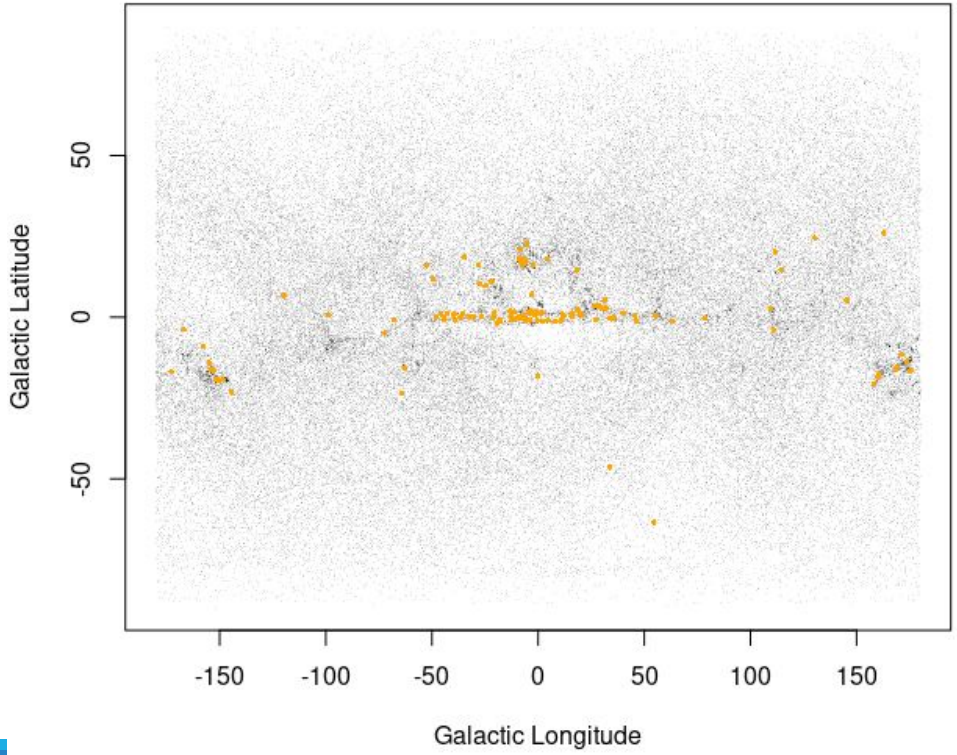


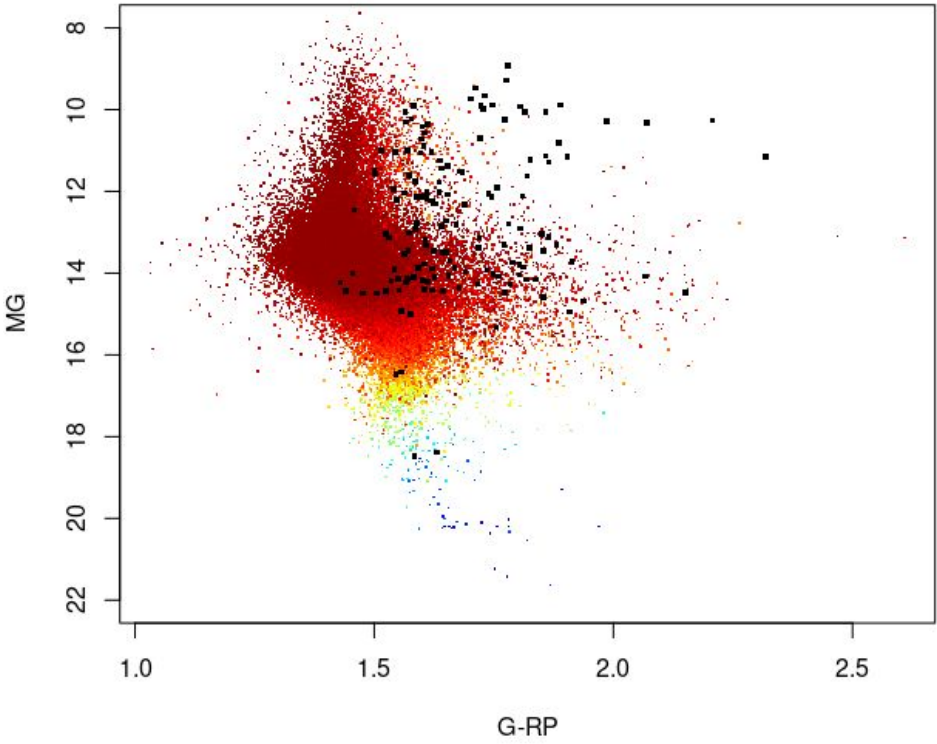
Flag 1: quality class



Colour code reflects reciprocal of the parallax

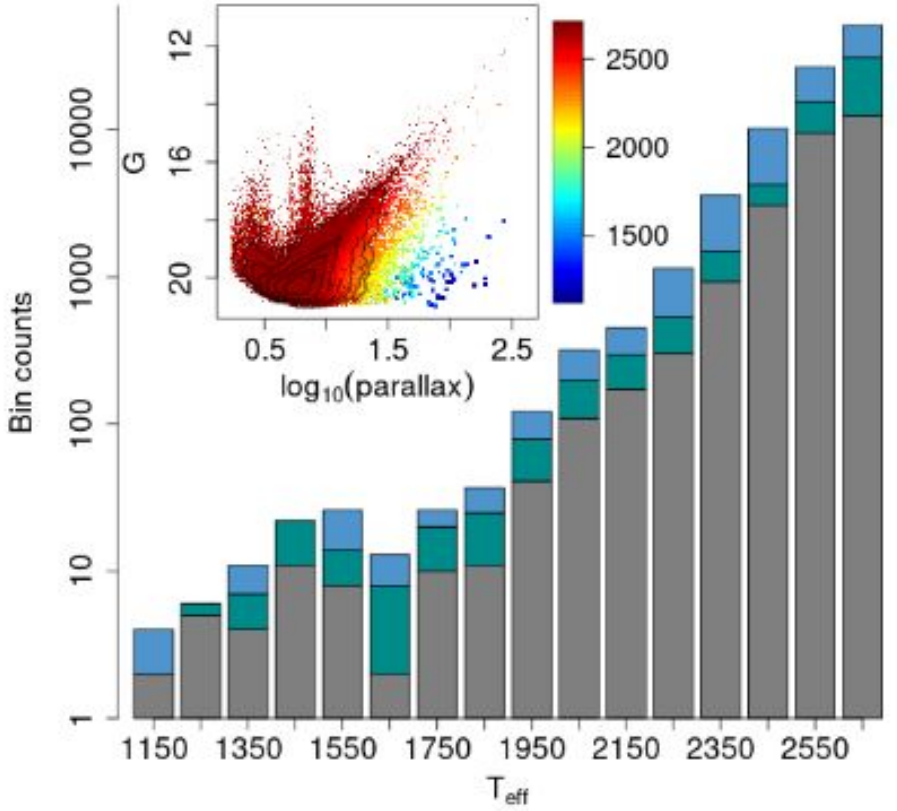
Flag 2: inconsistent CAMD positions



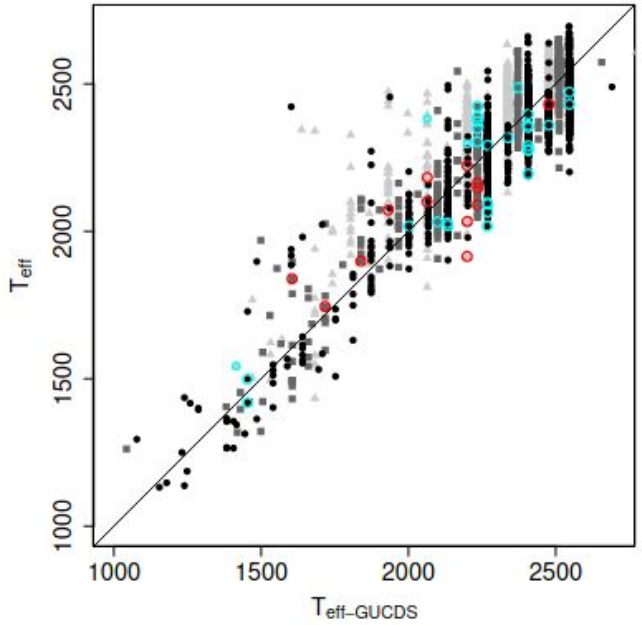


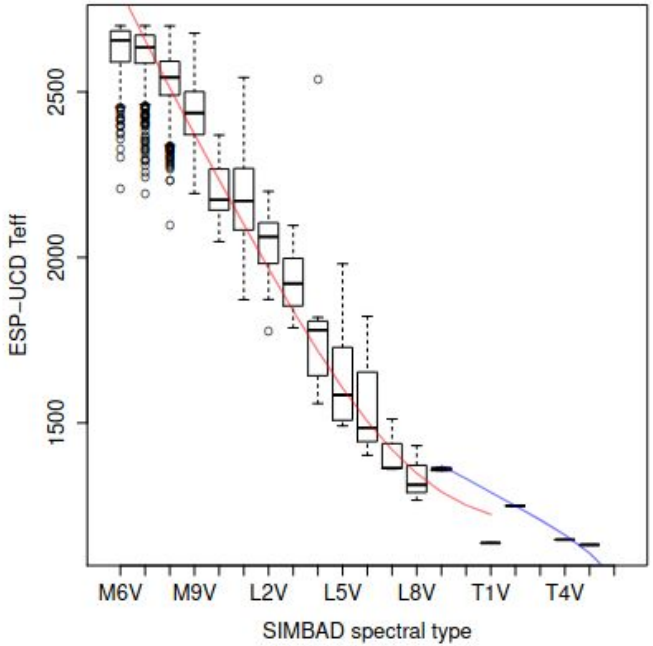
The UCD catalogue

Counts in the three quality classes



Validation

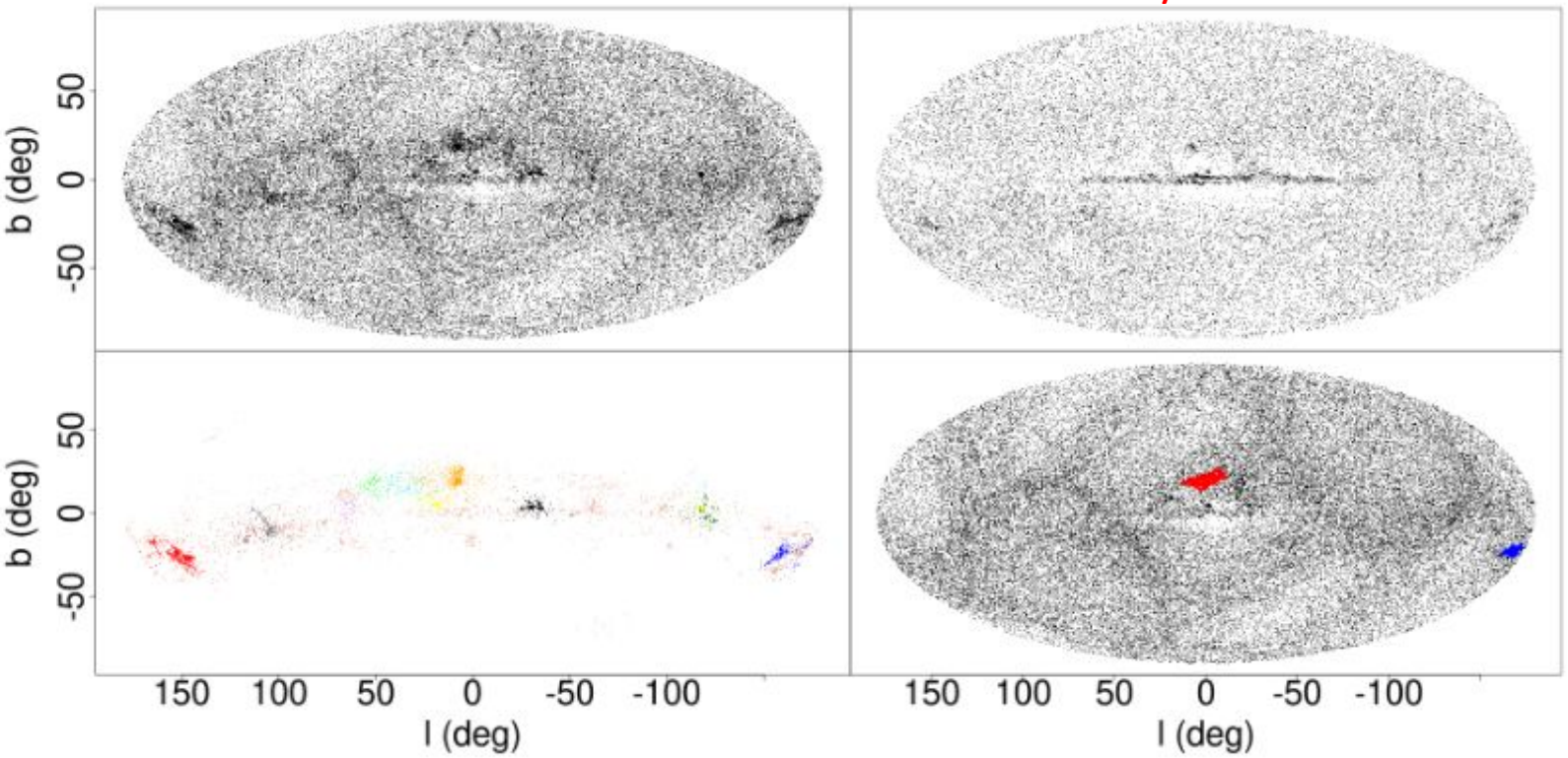

T_{eff}
1000
1500
2000
2500
$T_{eff-GUCDS}$


ESP-UCD Teff
1500
2000
2500
M6V
M9V
L2V
L5V
L8V
T1V
T4V
SIMBAD spectral type

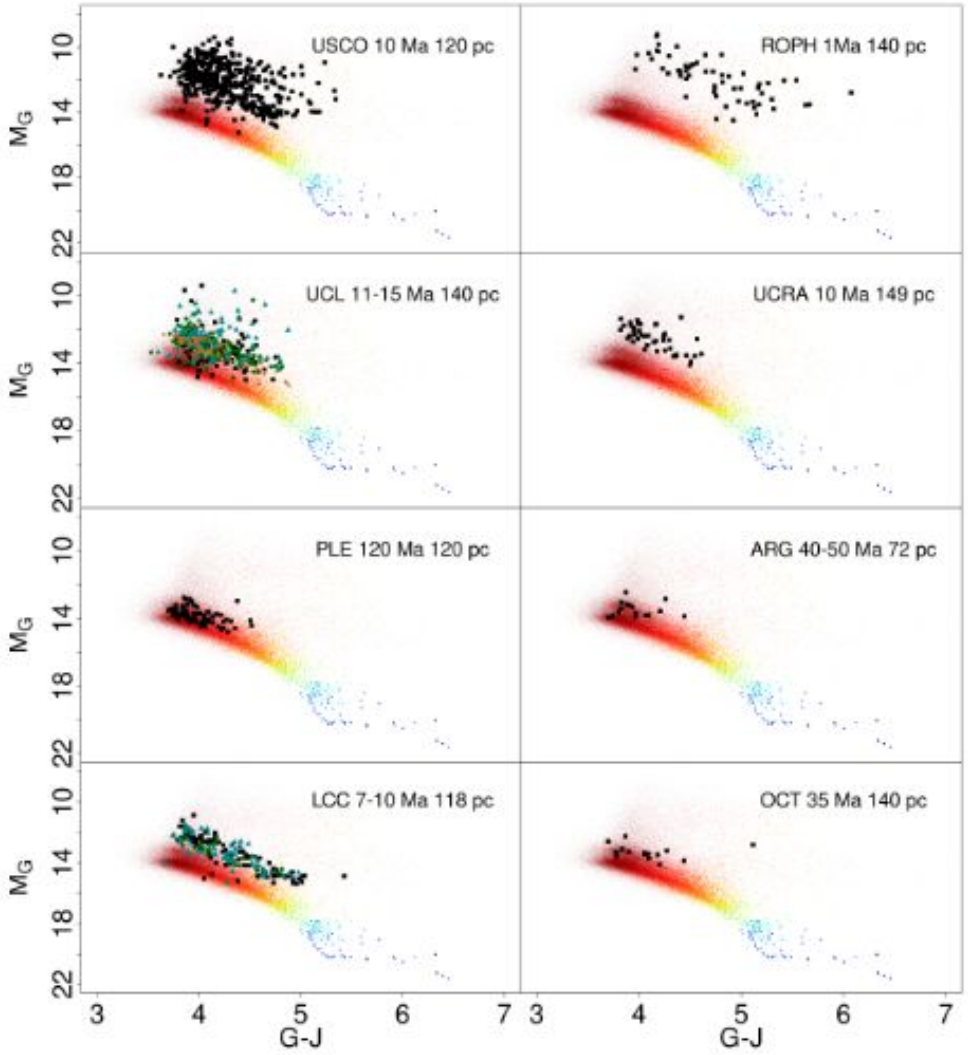
UCDs in star forming regions and clusters

Quality classes 0 & 1

Quality class 2

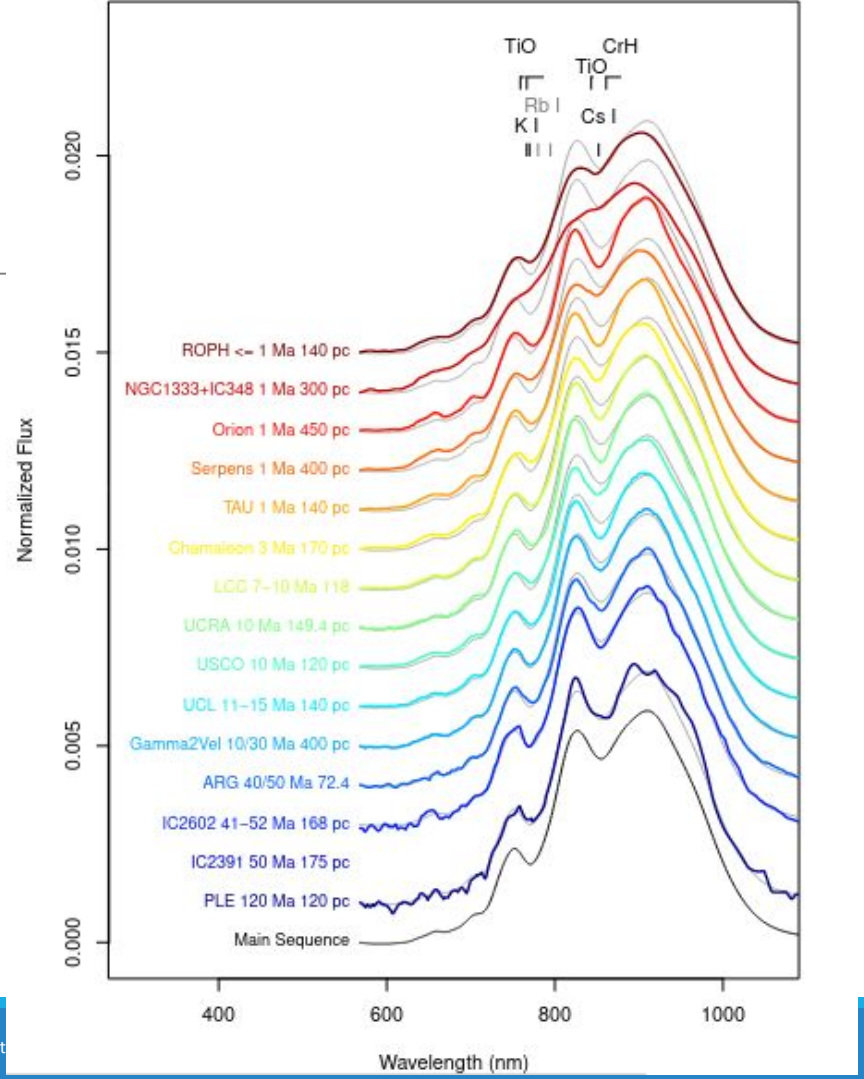


CAMD of overdensities



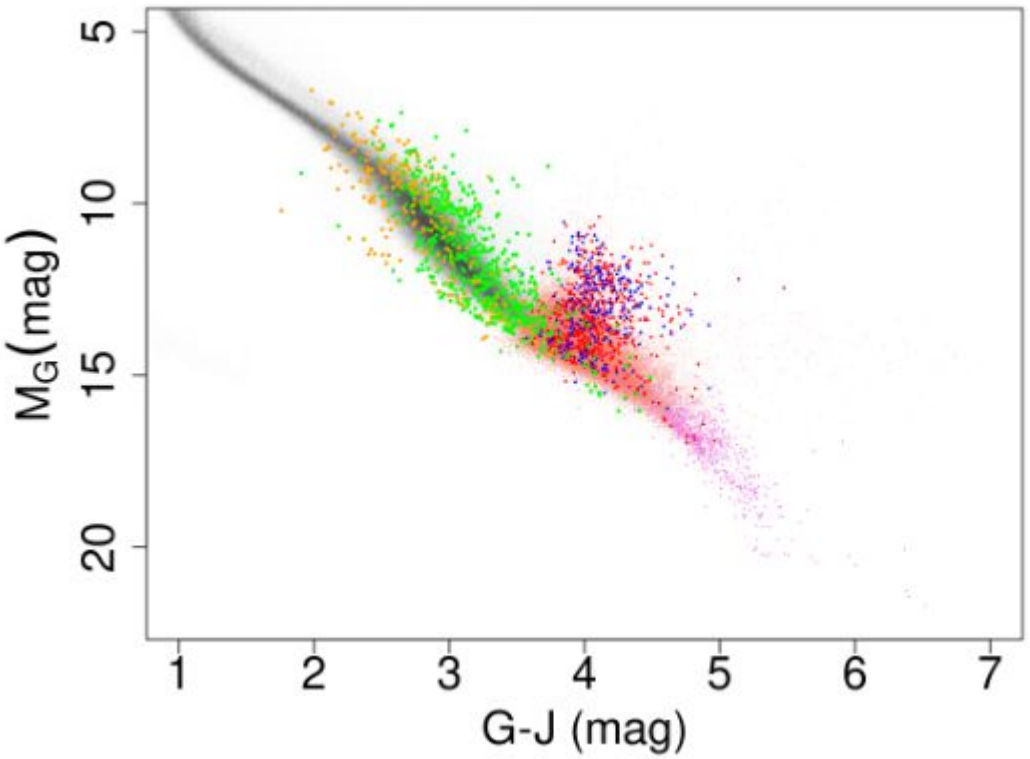
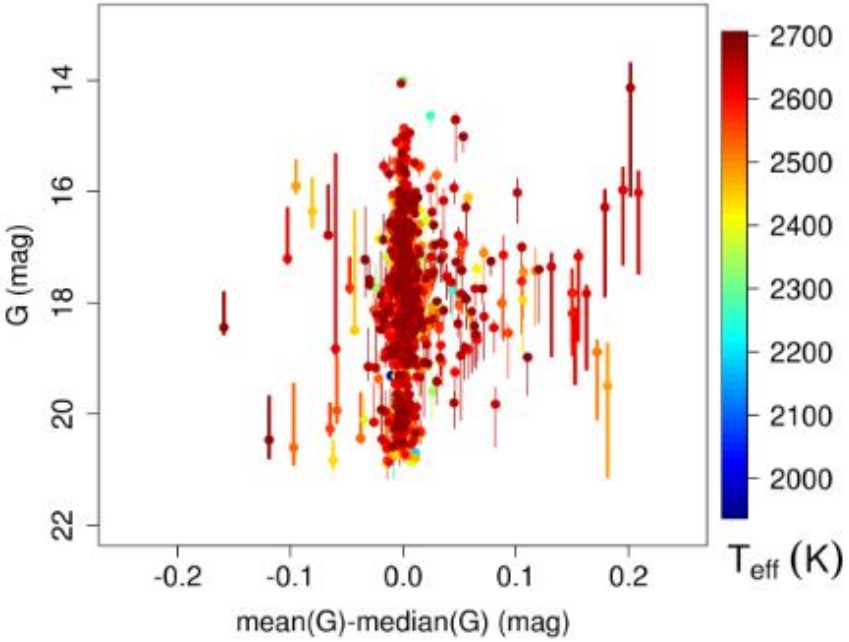
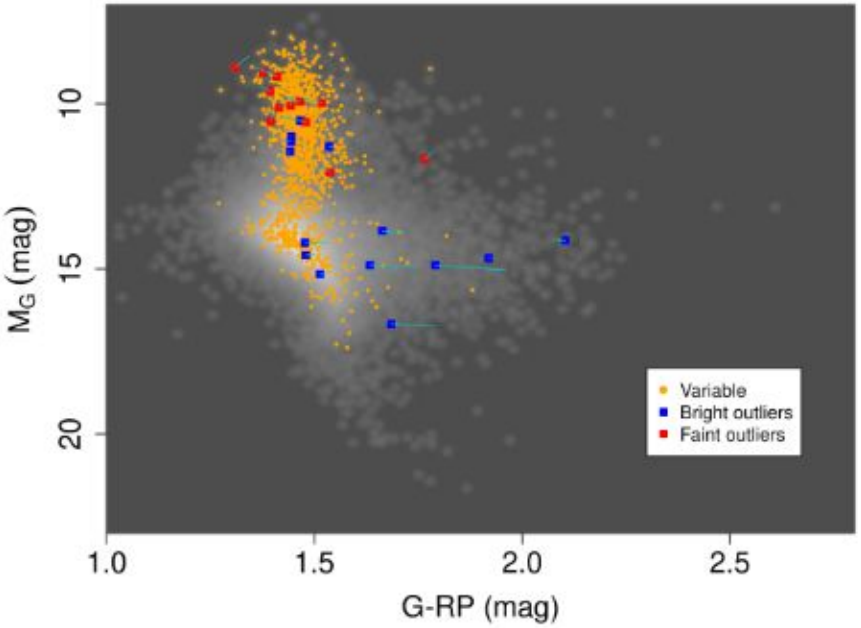
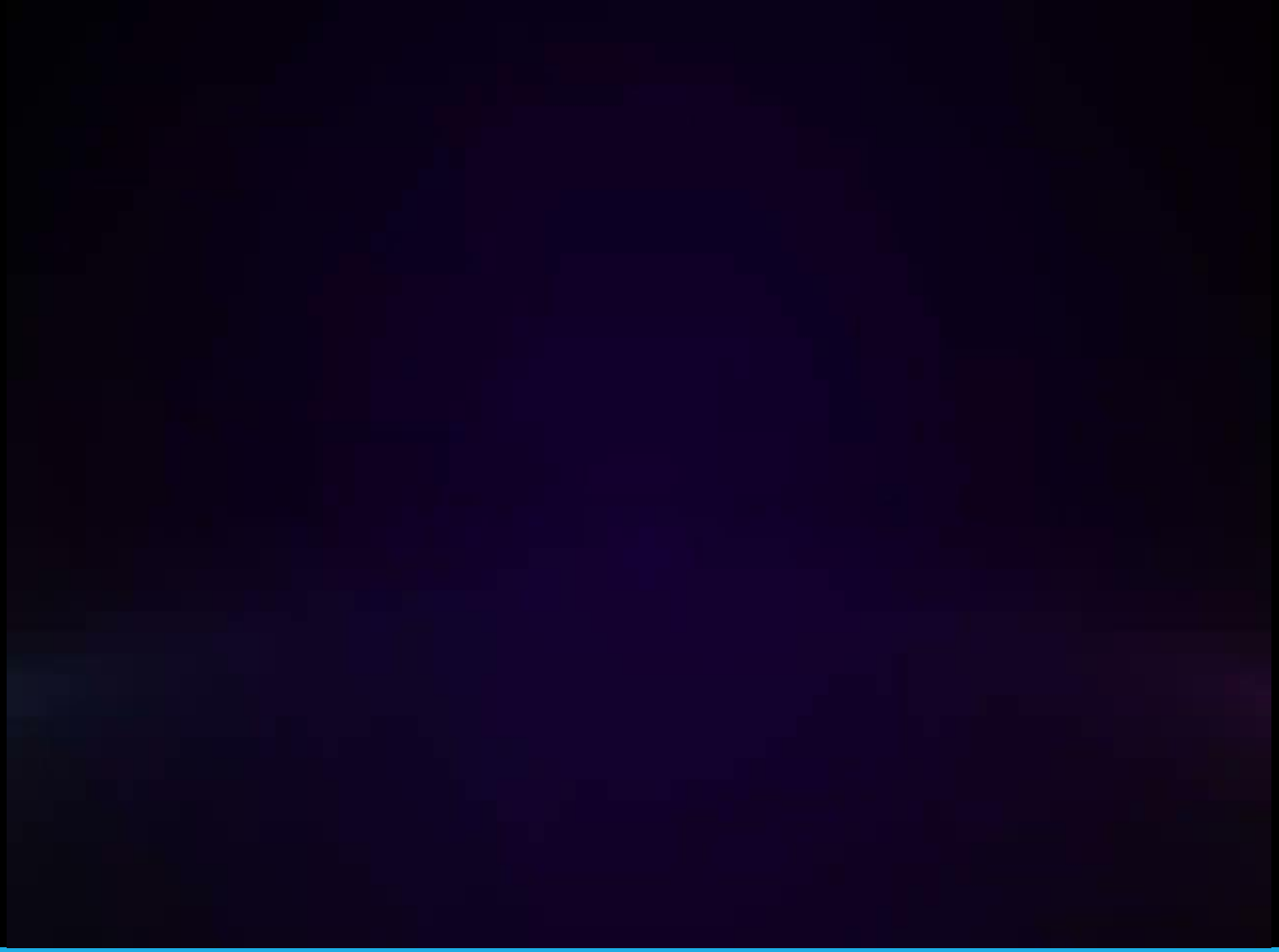
RP spectra of young UCDs

2500 K



Contamination by background objects

Black dots: main sequence derived from the GCNS
Violet dots; GUCDS
Red and Blue: residual overdensities
Orange and green dots: residual overdensities after de-reddening



Variable UCDs