Photometric systems and classification techniques

Teresa Aparicio Villegas
Observatório Nacional (RJ)
WHAT IS A PHOTOMETRIC SYSTEM?

Set of **filters** at different **wavelength ranges** with a known **sensitivity** to incident radiation

- Measure absolute fluxes
- Inferring particular properties of the emitter objects

At least 3 **spectral bands** → 2 **colors** to be able to derive the main deviations of the stellar radiation from a Black Body
UBV system (Johnson & Morgan, 1953)

B → photographic magnitude
V → visual magnitude
U → ultraviolet magnitude

<table>
<thead>
<tr>
<th>Filter</th>
<th>$\lambda_c$ (nm)</th>
<th>FWHM (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>358</td>
<td>55</td>
</tr>
<tr>
<td>B</td>
<td>439</td>
<td>99</td>
</tr>
<tr>
<td>V</td>
<td>545</td>
<td>85</td>
</tr>
</tbody>
</table>
RGU system (Becker 1946)

- RGU system offers a better separation of the cold giants than the UBV system.
- It is a purely photographic system, so its application was subordinated to the existence of a sequence of standard stars measured in a photoelectric system, which was usually the UBV system.

<table>
<thead>
<tr>
<th>Filter</th>
<th>$\lambda_c$ (nm)</th>
<th>FWHM (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>360</td>
<td>53.5</td>
</tr>
<tr>
<td>G</td>
<td>467</td>
<td>50</td>
</tr>
<tr>
<td>R</td>
<td>641.8</td>
<td>43</td>
</tr>
</tbody>
</table>
**uvby system (Strömgren 1951)**

- Filters for characterizing B, A, and F stars: Balmer lines, metallicity and effective temperature.

- Non-overlapping, intermediate bands → better measure of Paschen slope, Balmer jump and metal-line blanketing.

<table>
<thead>
<tr>
<th>Filter</th>
<th>$\lambda_c$ (nm)</th>
<th>FWHM (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>u</td>
<td>350</td>
<td>30</td>
</tr>
<tr>
<td>v</td>
<td>411</td>
<td>19</td>
</tr>
<tr>
<td>b</td>
<td>467</td>
<td>18</td>
</tr>
<tr>
<td>y</td>
<td>547</td>
<td>23</td>
</tr>
</tbody>
</table>
Photoelectric Photometer $\rightarrow$ Charge-coupled device (CCD)

Multiband photometry + Wide-field two-dimensional detectors $\rightarrow$ SED of many celestial objects

$\rightarrow$ Redshifts ($z$) of QSOs or galaxies

$\rightarrow$ Classification of galaxies or more exotic objects

Photometric systems have become a very powerful tool for dealing with a great quantity of astrophysical problems

Large observational projects $\rightarrow$ band selection criteria:

- Obtaining accurate estimations of redshifts
- Getting precise classifications of galaxies

$\rightarrow$ Study the large-scale structure of the Universe
Sky Surveys

- **Sloan Digital Sky Survey** (SDSS, Fukugita et al. 1996; Smith et al. 2002)

- **COMBO-17** (Wolf et al. 2003):
  - ~ 50,000 galaxies; $\sigma_{z,\text{gal}} \approx 0.03$
  - $\leq$ 1000 QSOs; $\sigma_{z,\text{QSO}} \leq 0.1$

But.....

- To obtain deeper photo-zs ($z > 0.9$) the near-infrared is needed
- The survey imaged 1 square degree of the sky

- **ALHAMBRA Survey** (Moles et al. 2008)
- Future : **J-PAS Survey** (Benitez et al. 2009)
The ALHAMBRA System
The ALHAMBRA project: SCIENTIFIC OBJECTIVE

Perform a tomography of the universe in some selected areas conforming almost $4 \text{ deg}^2$ in 8 non-contiguous regions of the sky, with enough precision to draw an evolutionary track of its content and properties (Moles et al. 2008)

- Obtain spectral energy distributions (SED) with spectral resolution and depth good enough to do a physical classification of the objects.
- Estimate the redshift ($z$) for the largest possible number of objects and with the best possible accuracy.
- Spectral range covering from $3500\text{Å}$ to $9700\text{Å}$ in the optical plus the standard JHKs near-infrared bands.

The best filter system fitting these conditions is formed by 20 constant-width, non-overlapping medium-band filters and with uniform transmission, in the optical range plus the three classical bands in the near-infrared (JHKs) (Benítez et al. 2008).
The ALHAMBRA System: CHARACTERIZATION

The definition of the system is given by the response curve defined by the product of three different transmission curves: the **filter** set, **detector** and **atmospheric extinction** at 1.2 airmasses, based on the CAHA monochromatic extinction tables.
### The ALHAMBRA System: CHARACTERIZATION

<table>
<thead>
<tr>
<th>Filter</th>
<th>$\lambda_{iso}$ (nm)</th>
<th>$F_{\lambda}$ (erg/s/cm²/Å)</th>
<th>$Vega AB$ Magnitude</th>
<th>$\lambda_{m}$ (nm)</th>
<th>$\nu_{m}^{-1}$ (nm)</th>
<th>$\lambda_{eff}$ (nm)</th>
<th>$\sigma$</th>
<th>$Q$</th>
<th>FWHM (nm)</th>
<th>$\delta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A366M</td>
<td>373.8</td>
<td>3.354e-09</td>
<td>0.96</td>
<td>366.4</td>
<td>366.0</td>
<td>366.1</td>
<td>0.0216</td>
<td>0.0211</td>
<td>27.9</td>
<td>186.2</td>
</tr>
<tr>
<td>A394M</td>
<td>398.5</td>
<td>6.851e-09</td>
<td>0.02</td>
<td>394.4</td>
<td>393.9</td>
<td>394.1</td>
<td>0.0239</td>
<td>0.0414</td>
<td>33.0</td>
<td>222.2</td>
</tr>
<tr>
<td>A425M</td>
<td>430.9</td>
<td>6.782e-09</td>
<td>-0.13</td>
<td>425.3</td>
<td>424.9</td>
<td>424.9</td>
<td>0.0229</td>
<td>0.0419</td>
<td>34.2</td>
<td>229.8</td>
</tr>
<tr>
<td>A457M</td>
<td>456.8</td>
<td>6.117e-09</td>
<td>-0.18</td>
<td>457.8</td>
<td>457.4</td>
<td>457.5</td>
<td>0.0209</td>
<td>0.0412</td>
<td>33.2</td>
<td>224.9</td>
</tr>
<tr>
<td>A491M</td>
<td>500.8</td>
<td>4.726e-09</td>
<td>-0.05</td>
<td>491.7</td>
<td>491.2</td>
<td>491.3</td>
<td>0.0208</td>
<td>0.0426</td>
<td>35.6</td>
<td>241.2</td>
</tr>
<tr>
<td>A522M</td>
<td>522.4</td>
<td>4.145e-09</td>
<td>-0.04</td>
<td>522.6</td>
<td>522.3</td>
<td>522.4</td>
<td>0.0178</td>
<td>0.0395</td>
<td>32.6</td>
<td>218.9</td>
</tr>
<tr>
<td>A551M</td>
<td>551.0</td>
<td>3.547e-09</td>
<td>0.01</td>
<td>551.2</td>
<td>550.9</td>
<td>551.0</td>
<td>0.0156</td>
<td>0.0385</td>
<td>29.7</td>
<td>202.1</td>
</tr>
<tr>
<td>A581M</td>
<td>581.1</td>
<td>3.031e-09</td>
<td>0.07</td>
<td>581.2</td>
<td>580.9</td>
<td>580.9</td>
<td>0.0161</td>
<td>0.0407</td>
<td>32.4</td>
<td>221.1</td>
</tr>
<tr>
<td>A613M</td>
<td>613.4</td>
<td>2.573e-09</td>
<td>0.13</td>
<td>613.6</td>
<td>613.4</td>
<td>613.4</td>
<td>0.0149</td>
<td>0.0364</td>
<td>32.0</td>
<td>216.2</td>
</tr>
<tr>
<td>A646M</td>
<td>650.8</td>
<td>2.119e-09</td>
<td>0.23</td>
<td>646.4</td>
<td>646.0</td>
<td>646.1</td>
<td>0.0159</td>
<td>0.0419</td>
<td>35.7</td>
<td>241.5</td>
</tr>
<tr>
<td>A678M</td>
<td>678.1</td>
<td>1.896e-09</td>
<td>0.24</td>
<td>678.2</td>
<td>678.0</td>
<td>678.1</td>
<td>0.0133</td>
<td>0.0355</td>
<td>31.4</td>
<td>211.9</td>
</tr>
<tr>
<td>A708M</td>
<td>707.9</td>
<td>1.661e-09</td>
<td>0.29</td>
<td>707.9</td>
<td>707.7</td>
<td>707.8</td>
<td>0.0135</td>
<td>0.0347</td>
<td>33.2</td>
<td>225.3</td>
</tr>
<tr>
<td>A739M</td>
<td>739.1</td>
<td>1.453e-09</td>
<td>0.34</td>
<td>739.3</td>
<td>739.1</td>
<td>739.2</td>
<td>0.0117</td>
<td>0.0302</td>
<td>30.4</td>
<td>203.3</td>
</tr>
<tr>
<td>A770M</td>
<td>770.1</td>
<td>1.277e-09</td>
<td>0.39</td>
<td>770.2</td>
<td>769.9</td>
<td>769.9</td>
<td>0.0132</td>
<td>0.0329</td>
<td>35.4</td>
<td>239.2</td>
</tr>
<tr>
<td>A802M</td>
<td>802.4</td>
<td>1.123e-09</td>
<td>0.44</td>
<td>802.2</td>
<td>801.9</td>
<td>802.0</td>
<td>0.0111</td>
<td>0.0263</td>
<td>31.2</td>
<td>210.5</td>
</tr>
<tr>
<td>A829M</td>
<td>830.2</td>
<td>1.012e-09</td>
<td>0.48</td>
<td>829.5</td>
<td>829.3</td>
<td>829.4</td>
<td>0.0103</td>
<td>0.0226</td>
<td>29.6</td>
<td>202.1</td>
</tr>
<tr>
<td>A861M</td>
<td>861.5</td>
<td>8.943e-10</td>
<td>0.54</td>
<td>861.6</td>
<td>861.3</td>
<td>861.4</td>
<td>0.0121</td>
<td>0.0233</td>
<td>36.9</td>
<td>246.4</td>
</tr>
<tr>
<td>A892M</td>
<td>884.3</td>
<td>8.703e-10</td>
<td>0.50</td>
<td>891.9</td>
<td>891.7</td>
<td>891.8</td>
<td>0.0095</td>
<td>0.0162</td>
<td>30.3</td>
<td>200.2</td>
</tr>
<tr>
<td>A921M</td>
<td>936.2</td>
<td>8.197e-10</td>
<td>0.48</td>
<td>920.9</td>
<td>920.7</td>
<td>920.8</td>
<td>0.0096</td>
<td>0.0143</td>
<td>30.8</td>
<td>207.8</td>
</tr>
<tr>
<td>A948M</td>
<td>950.4</td>
<td>7.502e-10</td>
<td>0.52</td>
<td>948.3</td>
<td>948.2</td>
<td>948.2</td>
<td>0.0093</td>
<td>0.0109</td>
<td>31.9</td>
<td>208.1</td>
</tr>
</tbody>
</table>

Aparicio Villegas et al. 2010
Classification techniques with photometry
Classification techniques with photometry

- Classification diagrams

- Functional relations (analytical or non-analytical) between colors or color combinations and the physical properties

- The direct comparison of “photometrical spectra”: photometric system are more and more a low resolution spectroscopy
Stellar Physics and the ALHAMBRA system

Main stellar physical properties

Internal properties
- Effective Temperature
- Log(g)
- [Fe/H]

External properties
- Color excess (E(B-V))

Training data set
- BaSeL 2.2
  (Lejeune, Cuisiner & Buser 1998)
  Theoretical spectral library

Testing data set
- Next Generation Spectral Library
  (NGSL, Gregg et al. 2004)
  288 spectrophotometric stars
  - Standards in the ALHAMBRA calibration
  - Wide spectral type range
  - Good spectral resolution
  - Homogeneity in the flux calibration
Stellar Physics and the ALHAMBRA system:

**Stellar classification diagram**

Look for a **diagram formed by two reddening-free Q-parameters**, that enables an approximation to the spectral type of the stars, similar to the \([m_1], [c_1]\) diagram in the “uvby” system (Strömgren, 1966)

**Reddening-free Q-parameters**

\[
Q_{ijkl} = (m_i - m_j) - \frac{E_{ij}}{E_{kl}} (m_k - m_l)
\]

**DATA**

✓ BaSeL 2.2. Models with log(g)=4.5.

✓ Observed spectral energy distribution with synthetic ALHAMBRA colors: 288 stars from Next Generation Spectral Library (NGSL, Gregg et al. 2004)

Stellar Physics and the ALHAMBRA system:
Stellar classification diagram

Fitzpatrick (1999)

Nandy et al. (1975)
Stellar Physics and the ALHAMBRA system: Stellar classification diagram

Aparicio Villegas et al. 2013 (submitted)

This Q,Q diagram is not discriminating for all the point-like objects that can be found in the ALHAMBRA survey, but if we just consider the stars, this diagram provides us a first evaluation of their spectral types.

Fig. 7. — Same Q,Q diagram with QSO models, where type-1 QSOs are represented with black circles, Mrk 231 QSO with an asterisk, the type-2 QSO with plus symbol, the two Seyferts with squares and the Seyfert 2 IRAS 19254-7245 South is shown with a cross.
Stellar Physics and the ALHAMBRA system:
Stellar classification diagram

Color-color diagram (Sesar et al. 2007)

![Stellar classification diagram](image)

- I. White Dwarf
- II. Low redshift QSO
- III. dM/WD pair
- IV. RR Lyrae
- V. Stellar Locus star
- VI. High redshift QSO
Parametric approaches

- Backward Stepwise Regression – BIC
- Classification a priori of the data (temperature ranges)

Effective Temperature

Color parametric approaches

Q-parameter parametric approaches

Two ranges of temperature
Stellar Physics and the ALHAMBRA system: Effective Temperature estimation

**Color parametric approximation**

1. For stars with \((A522M - A948M) \leq -0.29:\)

   \[
   \log(T_{\text{eff}}) = 1.71(A522M - A829M)^2_0 + 1.04(A522M - A829M)_0 + 4.07
   \]

   \(R^2 = 0.99\), Residual Standard Error = 0.02

2. For stars with \((A522M - A948M) > -0.29:\)

   \[
   \log(T_{\text{eff}}) = 0.02(A457M - A646M)^2_0 - 0.18(A457M - A646M)_0 + 3.84
   \]

   \(R^2 = 0.97\), Residual Standard Error = 0.02

Valid for the range of spectral classes and luminosity classes of BaSeL 2.2
Stellar Physics and the ALHAMBRA system: Effective Temperature estimation

Color parametric approach

216 NGSL stars

\[
\overline{ab(\delta(T_{\text{eff}}))} = 574.54 \pm 151
\]

\[
\overline{\delta(T_{\text{eff}})} = -265.80 \pm 155
\]

\[
\overline{ab(\delta(T_{\text{eff}})/T_{\text{eff}})} = 0.054 \pm 0.007
\]

- The temperatures are overestimated on average
- Most residuals are within a 5%
- There are not differences between the residuals of cold and hot stars
Stellar Physics and the ALHAMBRA system:
Effective Temperature estimation

Q parametric approximation

1. For stars with $\log(T_{eff}) \geq 3.9$:

$$\log(T_{eff}) = -1.09 \cdot Q_{1,5,6} + 0.44 \cdot Q_{1,5,6}^2 - 0.09 \cdot Q_{2,17,19} + 4.55$$

$R^2=0.98$, Residual Standard Error = 0.03

2. For stars with $\log(T_{eff}) < 3.9$:

$$\log(T_{eff}) = -0.14 \cdot Q_{6,16,18} + 0.01 \cdot Q_{6,16,18}^2 - 0.02 \cdot Q_{1,7,8} + 3.81$$

$R^2=0.91$, Residual Standard Error = 0.04

Valid for the range of spectral classes and luminosity classes of BaSeL 2.2
Stellar Physics and the ALHAMBRA system: Effective Temperature estimation

Q parametric approximation

281 NGSL stars

\[ ab(\delta(T_{\text{eff}})) = 695.26 \pm 120 \]

\[ \delta(T_{\text{eff}}) = -23.60 \pm 127 \]

\[ ab(\delta(T_{\text{eff}})/T_{\text{eff}}) = 0.084 \pm 0.005 \]

- The Q,Q diagram is used to classify the stars in the two temperature ranges.
- More dispersion
- Most residuals are within a 8%
- No overestimation in average
- Bias in the residuals in the stars with \( 3.65 < \log(T_{\text{eff}}) < 3.8 \) which depend on the temperature

Aparicio Villegas et al. 2013 (submitted)
Support Vector Machine (SVM)

- Recently more **automatic algorithms** have been proposed to extract the physical information of the objects from photometry.
- SVM is a useful technic for data classification based on the Statistical Learning Theory.

![Diagram of SVM process]

- Don't need classification a priori of the data.

**PROBLEM**: overtraining, black box effect.
Stellar Physics and the ALHAMBRA system: Effective Temperature estimation

**SVM $T_{\text{eff}}$ estimations**

**216 NGSL stars**

\[
ab(\delta(T_{\text{eff}})) = 541.61 \pm 107
\]

\[
\delta(T_{\text{eff}}) = -273.28 \pm 112
\]

\[
ab(\delta(T_{\text{eff}})/T_{\text{eff}}) = 0.052 \pm 0.006
\]

- Results statistically equivalent to the color equations approximations
- Residuals are within a 5%
- Temperatures overestimated in about 300K
- Residuals higher in the hottest stars
Stellar Physics and the ALHAMBRA system:
Q Fit Algorithm

Q Fit Algorithm

(Aparicio Villegas et al. 2011)

ALHAMBRA optical photometry

↓

Low-resolution spectroscopy
Stellar Physics and the ALHAMBRA system : Q Fit Algorithm

1. Generation of 18 independent Q parameters from ALHAMBRA photometry: theoretical and observed spectra:

\[ Q_{ijk} = (Alh_i - Alh_j) - \frac{E_{ij}}{E_{jk}} (Alh_j - Alh_k), j = i+1, k = i+2 \]

MODELS

BaSeL 2.2
(Lejeune et al. 1998)

White Dwarfs Templates
(Holberg & Bergeron, 2006)

Next Generation Spectral Library
(Gregg et al. 2004)

288 observed spectra with synthetic photometry from NGSL::

\[ 3440 K \leq T_{eff} \leq 44500 K \]
\[ 0.45 \leq \log(g) \leq 7.5 \]
\[ -2.9 \leq [Fe/H] \leq 0.7 \]
2. Estimation of physical parameters: Teff, log(g) and [Fe/H] directly from the models

- Considering the 18 dimensional euclidean space formed by 18 independent Q-parameters for each object, then, we look for the model which minimizes the euclidean distance between the star and the model.

- Weighted fitted including some weights for the different Q-values, in particular, giving less weight to the QA366MA394MA425M, QA394MA425MA457M, QA861MA892MA921M and QA892MA921MA948M

- No interpolation in the model grid → the accuracy of the estimations depends very much on the grid resolution.

An example: HD117880
Stellar Physics and the ALHAMBRA system:
Q Fit Algorithm

HD117880
Teff NGSL: 9431(K)  Teff BaSeL: 9250(K)
Logg NGSL: 3.5  Logg BaSeL: 3.5
Met NGSL: -1.4  Met BaSeL: -1.5

RMSE: 0.009

An example: HD117880
From the synthetic photometry of the model, we have 19 unreddened ALHAMBRA colors:

$$Alh_{0i} - Alh_{0(i+1)}, i=1:19$$

With the reddened colors of the star, we can determine the color excess in each band:

$$E(Alh_i - Alh_{i+1}) = (Alh_{1i} - Alh_{1(i+1)}) - (Alh_{0i} - Alh_{0(i+1)}), i=1:19$$

And so, we can generate 19 E(B-V) from each different color excess adopting an extinction law...the E(B-V) associated to the star would be the median of these 19 values:

$$E(B-V) = median_{i}[\alpha_i \cdot E(Alh_i - Alh_{i+1})], i=1:19$$
Stellar Physics and the ALHAMBRA system:
Q Fit Algorithm

From the synthetic photometry of the model, we have 19 unreddened ALHAMBRA colors:
With the reddened colors of the star, we can determine the color excess in each band:
And so, we can generate 19 E(B-V) from each different color excess adopting an extinction law...the E(B-V) associated to the star would be the median of these 19 values:

\[ E(\text{B} - \text{V}) = \text{median} \left[ \alpha \cdot E(\text{Alh}_i - \text{Alh}_{i+1}) \right], i=1:19 \]

HD 117880
E(B−V) NGSL: 0.08 E(B−V) BaSeL: 0.04 (+/− 0.008)

RMSE: 0.008
Stellar Physics and the ALHAMBRA system: Q Fit Algorithm

\[
\frac{ab}{\delta (T_{\text{eff}})} = 564.51 \pm 81 \quad \delta (T_{\text{eff}}) = -434.18 \pm 84
\]

\[
\frac{ab}{\delta (\log (g))} = 0.50 \pm 0.03 \quad \delta (\log (g)) = 0.007 \pm 0.04
\]

\[
\frac{ab}{\delta ([Fe/H])} = 0.49 \pm 0.03 \quad \delta ([Fe/H]) = -0.14 \pm 0.04
\]

\[
\frac{ab}{\delta (E_{B-V})} = 0.052 \pm 0.004 \quad \delta (E_{B-V}) = -0.024 \pm 0.005
\]
Stellar Physics and the ALHAMBRA system: 
Q Fit Algorithm

BD442051
Teff NGSL: 3943(K)  Teff BaSeL: 3750(K)
Logg NGSL: 4.9  Logg BaSeL: 1.5
Met NGSL: −0.6  Met BaSeL:−0.3
E(B−V) NGSL: 0.002  E(B−V) fit:0(+− 0.08)

RMSE: 0.1305

RMSE: 0.0872
Stellar Physics and the ALHAMBRA system: Q Fit Algorithm

- $\delta(T_{\text{eff}}) = 564.51 \pm 81$
- $\delta(T_{\text{eff}}) = -434.18 \pm 84$
- $\delta(\log(g)) = 0.50 \pm 0.03$
- $\delta([\text{Fe/H}]) = 0.49 \pm 0.03$
- $\delta(E_B - V) = 0.052 \pm 0.004$

Diagram showing the relationship between Q values and various stellar parameters.
Stellar Physics and the ALHAMBRA system:
Q Fit Algorithm

ALHAMBRA point-like objects: $E<0.1$ mag. in 20 bands

Molino et al. (2013), 1st ALHAMBRA data release

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median($E_{B-V}$)</td>
<td>$0.037 \pm 0.004^1$</td>
</tr>
<tr>
<td>Mean($E_{B-V}$)</td>
<td>$0.142 \pm 0.005^2$</td>
</tr>
<tr>
<td>Median($T_{eff}$)</td>
<td>$5316 \pm 84^1$</td>
</tr>
<tr>
<td>Mean($T_{eff}$)</td>
<td>$7440 \pm 139^2$</td>
</tr>
<tr>
<td>Median($\log(g)$)</td>
<td>$4.5 \pm 0.04^1$</td>
</tr>
<tr>
<td>Mean($\log(g)$)</td>
<td>$4.12 \pm 0.05^2$</td>
</tr>
<tr>
<td>Median([$Fe/H]$)</td>
<td>$-0.64 \pm 0.02^1$</td>
</tr>
<tr>
<td>Mean([$Fe/H]$)</td>
<td>$-0.79 \pm 0.02^2$</td>
</tr>
</tbody>
</table>

1. MAD divided by the square root of the number of elements
2. Standard deviation divided by the square root of the number of elements

2477 objects:
288 White Dwarfs
(156 with $T_{eff}<10,000$K)
165 QSOs
Stellar Physics and the ALHAMBRA system:
Q Fit Algorithm

Besancon Models (Robin et al. 2003)

\( l=140^\circ \quad b=49^\circ \)

\( V = 19 \)

Distance interval from 0 to 50 Kpc

<table>
<thead>
<tr>
<th>Median((E_{B-V}))</th>
<th>0.026</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median((T_{eff}))</td>
<td>5012</td>
</tr>
<tr>
<td>Median((\log(g)))</td>
<td>4.61</td>
</tr>
<tr>
<td>Median([\text{Fe/H}])</td>
<td>-0.38</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>0.037</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5316</td>
</tr>
<tr>
<td></td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>-0.63</td>
</tr>
</tbody>
</table>
New tasks

Population II stars in the ALHAMBRA survey
New tasks

Population II stars in the ALHAMBRA survey
New tasks

Population II stars in the ALHAMBRA survey
New tasks

Population II stars in the ALHAMBRA survey

![Graph showing ALH colors vs. another parameter with data points for HD094028 and SDSS 2047+00]
New tasks

Planetary Nebulae in the ALHAMBRA survey

Viironem et al. (2009)
J-PAS photometric system
The J-PAS project: mapping the observable Universe in 59 bands (starting in 2014 during 5-6 years).

Will observe all the objects brighter than mag~22.5 over an area of more than 8000 square degrees, with a 2.5m telescope at the OAJ (Observatorio Astronómico de Javalambre, Teruel, Spain).

J-PAs photometric system

56 overlapping band filters, in the optical range (3500A – 10,000 A).
2 broad-band filters, one in the ultraviolet (50 nm) and one in the near-infrared (180 nm)
54 narrow band filters (~15nm) overlapped and with uniform transmission.
3 SDSS bands: u, g, r
Javalambre
Physical of the Accelerating Universe
Astrophysical
Survey
(http://j-pas.org/)

J-PAS Filter Transmission

Filter Transmission

Wavelength (Angstroms)
The J-PLUS survey

Observations stars this year!!!
New tasks

Planetary Nebulae in the JPLUS survey

Viironen et al. (2009)
HD064412
Teff ngs: 5742   Teff basel: 6000
Logg ngs: 4.1   Logg basel: 4
Met ngs: -0.6   Met basel: -0.3
E(B-V) ngs: 0.003 E(B-V) basel: 0(+/- 0.002)

χ²: 0.01076

RMSE: 0.0071692
OBRIGADA!!!