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Building the Panchromatic Stellar Atlas

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Abstract. The Panchromatic Stellar Atlas (PaStA) is a catalog joining data from Gaia, AllWISE, and GALEX, with objects chosen for optimal astrometric measurements and photometry in twelve bands. Applications of PaStA are shown through colour-colour and colour-magnitude diagramas to illustrate statistical behaviour from chosen objects. We sampled objects with full range of photometric bands to acquire atmospheric parameters from literature. Such objects are input into VOSA to generate synthetic SED from libraries of models and derived parameters are compared with the reference for evaluation, where we can see good behavior of the models.

Resumo. O Atlas Estelar Pancromático (PaStA) é um catálogo que une os dados dos levantamentos Gaia, AllWISE, e GALEX, com objetos escolhidos para medidas astrométicas ótima e fotometria em 12 bandas. Mostramos aplicações do catálogo através de diagramas cor-magnitude e cor-cor, para mostrar comportamentos estatísticos. Amostramos objetos com dados em todas as 12 bandas para obter parâmetros atmosféricos observados da literatura. Esses objetos foram inseridos no VOSA para gerar SEDs sintéticas a partir de bibliotecas de modelos, os parâmetros derivados foram então comparados com a referência dos observados para poderem ser avaliados, o que mostrou bom comportamento dos modelos.

Keywords. Atlases – Catalogs – Astronomical Databases: miscellanous

1. Introduction: Sky Surveys and Catalogues

Surveys are astronomical observations that require the collection of a relatively large amount of data to fulfil their scientific goals. Photometric surveys either observe a specific region of the sky in extraordinary depth ("pencil beam" surveys, e.g. the Hubble Deep Field, Williams et al. 1996) or a wide area ("wide field" surveys, e.g. the Sloan Digital Sky Survey, Abazajian et al. 2009). Observations can be done in one or more bands of the electromagnetic spectrum. Data gathered in surveys are normally published in catalogues, containing tables organised to be accessible to the scientific community.

The Panchromatic Stellar Atlas aims to build a catalogue collecting information from surveys covering more than 60% of the sky, photometry data in bands across the electromagnetic spectrum, and optimal astrometry measurements. This catalogue is expected to be a great tool for a large variety of studies. Initial applications are the search for exotic objects in a large and robust database, and improving libraries of stellar models.

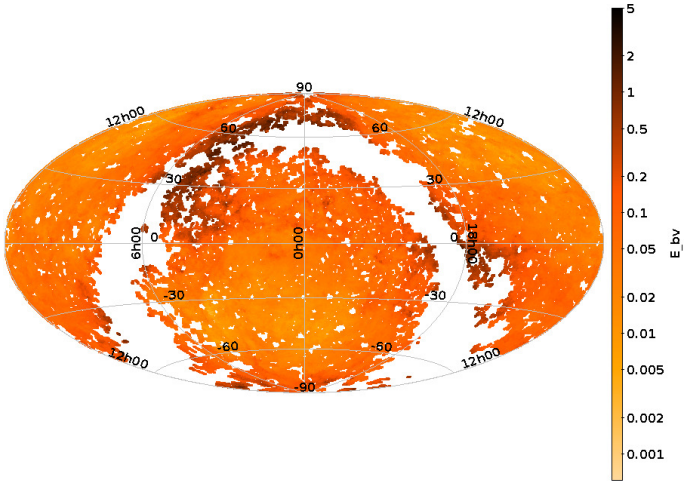

Figure 1. PaStA sky coverage in Aitoff projection, coordinates α and δ, epoch J2000. The heatmap illustrates the extinction from Schlegel, Finkbeiner & Davis (1997), increasing towards the galactic plane, where the lack of data is due to the survey area of GALEX.

2. Querying and exploring the data

PaStA is built upon three prominent sky surveys: Gaia EDR3 (Gaia Collaboration et al. 2021) was chosen to be the main catalogue due to the amount of objects, as faint as 21 mag, and astrometric precision; AllWISE (Cutri et al. 2021) and GALEX (Martin et al. 2005) sources were matched to add further photometric bands.

The resulting catalogue contains 8,709,742 objects, with 146 columns of data. The sky coverage is illustrated in Figure 1. Twelve photometric bands are available covering the spectrum from 154.5 *nm* to 22.08 μm, the plots between each and magnitude distributions are shown in Figure 2.

A first colour-magnitude diagram was built plotting Gaia G absolute magnitude against colour $Bp - Rp$. On this diagram the areas corresponding to each stellar evolutionary sequence were marked, to see their behaviour in different colour-magnitude or colour-colour combinations. This exploratory data analysis is illustrated in Figure 3. Overall, the sequences seen in diagrams respect an order: White Dwarves, Main Sequence with Subgiants in its middle, Horizontal Branch, and Giants. Sometimes unexpected groups can be found, e.g. for Giants and Horizontal Branches appearing in two distinct groups. In diagrams based on bluer magnitudes the sequences are mixed up, which may be reflection of the dispersion seen in the scatter plots in Figure 2. A hypothesis for this behaviour could be the presence coronal emissions or hot components. The diagrams built with redder magnitudes are disperse, and its hard to separate the sequences.

Figure 2. Magnitudes measured in each band plotted in pairwise scatter fashion, with distributions in the main diagonal. UV bands shows greater variance, possibly due to lack of previous corrections or excess emissions present in this region. W3 and W4 bands data becomes quickly dispersed going to fainter magnitudes, due to a far lower signal-to-noise ratio. Above: Logos of surveys used in PaStA.

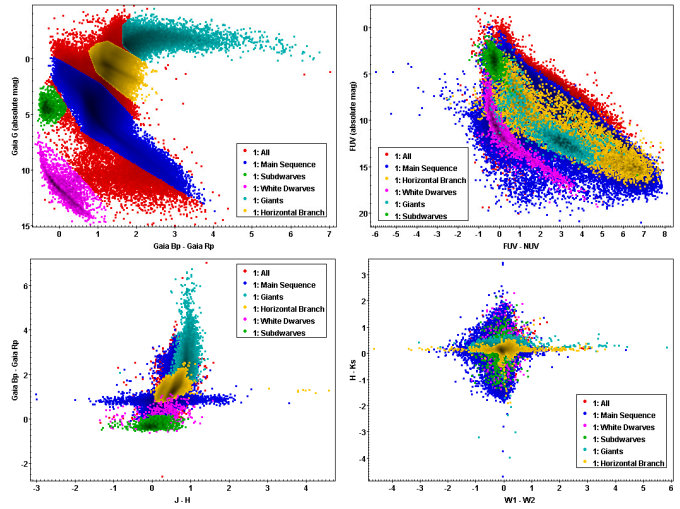

Figure 3. Colour-magnitude and colour-colour diagrams. Evolutionary sequences were marked in the first (upper-left) to be seen how they would behave in different bands or colours. Sequences tend to be obey an order in colours close to optical wavelength. Bluer colours clump sequences together inside the Main Sequence still maintaining some ordering, while redder sequences show greater dispersion of the data with less patterns to be identified.

3. Applications: Evaluating SED models

Stars were sampled from PaStA, looking for objects with information available in all bands. These objects were cross-matched with Gilmore (1997) resulting in a table of 9 objects. Their measured 12 photometric bands were input to the Virtual Observatory SED Analyser (Bayo et al 2008), to be fitted with Spectral Energy Distribution stellar libraries from Coelho (2014). The atmospheric parameters derived from the models were compared to the reference from Gaia-ESO, as can be seen in Figure 4. Overall a good behaviour was seen, except a few anomalous objects, which are incompatible with the models.

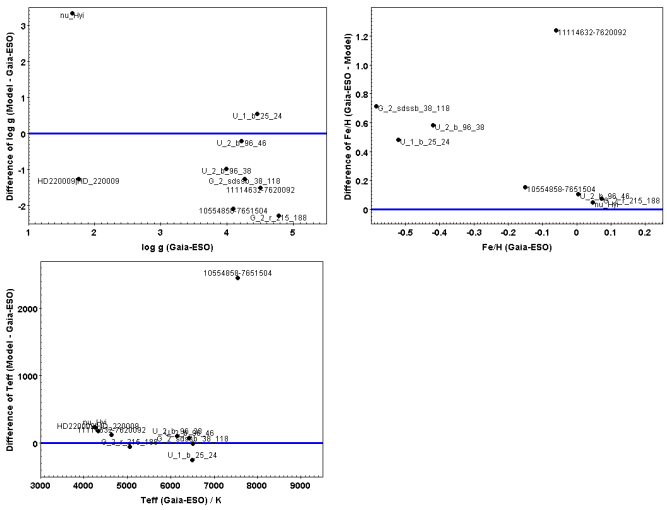

Figure 4. Difference of atmospheric parameters from model to reference, the blue line indicating the zero mark. The data shows good behaviour overall, with small number of outliers due to objects not well fit to the models. Metalicity may indicate a tendency, but due to the small amount of the data it can't be confirmed.

Most of the divergences were identified in the bands FUV, NUV, W3 and/or W4.

4. Conclusion

PaStA is available in the form of a catalogue containing almost 9 million objects, as a 5.5GB FITS file. Gaia is the basis of the atlas, providing objects as faint as 21 mag in Gaia G band and further info populated using AllWISE and GALEX, with high precision astrometry.

PaStA data was initially used in exploratory analysis based on its magnitudes, building colour-magnitude and colour-colour diagrams, and applied to evaluate libraries of SED models. Further studies on these same lines of work are planned.

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