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ANALYSING STELLAR POPULATIONS USING ISOCHRONES

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We present methods for analysing colour-magnitude diagrams, with particular emphasis on studies of the field halo stellar populations of nearby galaxies. Special consideration is made to the analysis of stars on the Red Giant Branch (RGB), and methods of obtaining metallicity distributions for old populations based on analysis of evolved sections of the Colour Magnitude Diagram (CMD).

The isochrones used in this study are those by Girardi et al (2000). Though we consider only V vs. $V - I$ CMDs here, the methods described apply equally well to any suitable choice of filters.

The first step in our method is to generate a fine grid of isochrones, with age and metallicity steps significantly smaller than the observational error. This becomes the basis for the simulated stellar population.

In order to interpolate accurately between two isochrones, it is necessary to identify important stages in the isochrone tracks which should be faithfully reproduced in all interpolated isochrones.

To do this we parse through each isochrone and follow the tangent vector to the parametric curve traced by the isochrone points in the colour magnitude plane. A critical point is one in which the gradient of this tangent vector changes by more than a certain critical angle between one point and the next. Once all the critical points have been highlighted we must pair them up as accurately as possible and then interpolate between them.

In order to analyse any CMD data it is necessary to compare the loci of stars detected in the given CMD to the positions of theoretical isochrones. This is the principle of 'isochrone fitting'. We then determine which linear combination of isochrones best describes the CMD under study.

Bayes' theorem allows one to calculate the probability that a certain model created an observed data set. This probability can be maximised in order to discover the most likely model or formation scenario for those data.

First we build a **Probability matrix**, P_{ij}, which relates the chance of each star, i coming from each isochrone, j. From this we can calculate the probability that any star, given its coordinates in colour-magnitude space, came from any linear combination of isochrones with weightings α_j;

$$P_i = \sum_j \alpha_j P_{ij} \quad (1)$$

and this thus leads to the probability that any set of stars, i, came from a given linear combination of isochrones with weightings α_j;

$$L = \prod_i \left(\sum_j \alpha_j P_{ij} \right) \quad (2)$$

The next step is to optimise the coefficients α_j, to maximise the likelihood. This is a constrained maximisation in a space with dimensionality determined by the number of isochrones available.

We used the simulated annealing method to optimise the coefficient weightings (Kirkpatrick et al. 1983a). This algorithm is designed to simulate stochastically the cooling of a physical system. However, it is sufficiently general that it may be applied to many other optimisation problems where the global minimum or maximum of a function is required.

Random steps are generated, and are accepted depending on the relative value of the likelihood at the new point compared to the old point. Any step which increases the likelihood is automatically accepted. However, any step which decreases the likelihood is accepted with a certain probability given by;

$$P(step) = e^{\frac{\Delta log(L)}{T}} \quad (3)$$

Further details of our methods and extensive testing process, together with preliminary results to be published in MNRAS.

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