Precise stellar properties via Bayesian analysis

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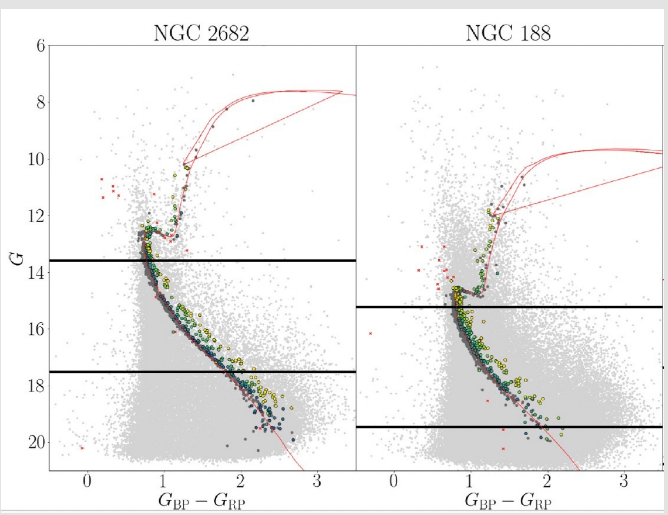
Introduction

Bayesian Analysis of Stellar Evolution (BASE-9) is a Bayesian software suite (von Hippel et al. 2006; van Dyk et al. 2009; Stenning et al. 2016) that recovers star cluster and stellar parameters from photometry via comparison to stellar evolution models, with priors defined from existing literature and databases, including Gaia astrometry. BASE-9 has been used to analyze two-component globular clusters, single-component star clusters, binaries, and single stars, and to simulate such systems. BASE-9 uses Markov chain Monte Carlo and brute-force numerical integration techniques to estimate the posterior probability distributions for the age, metallicity, helium abundance, distance, and line-of-sight absorption for a cluster, and the mass, binary mass ratio, and cluster membership probability for every stellar object. BASE-9 is open-source code available on GitHub at https://github.com/BayesianStellarEvolution/.

BASE-9 example #1: Cluster properties and binary mass ratios

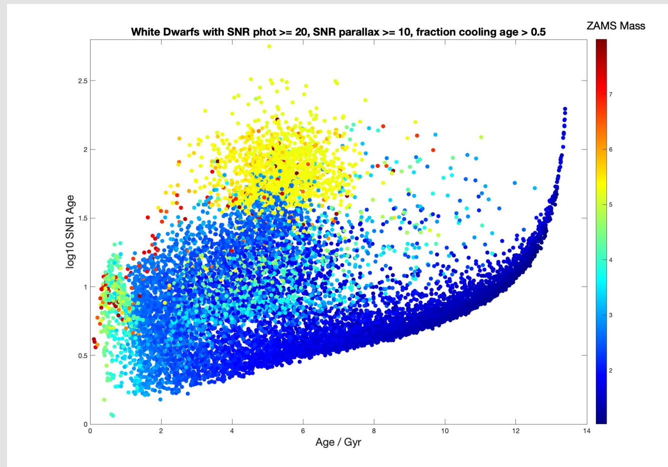


Derived from Figure 1 of Childs et al (2024). Single star BASE-9 members are marked in dark gray and BASE-9 binary members are colored according to their mass ratio. Field stars are marked in light gray and stars classified as members using Gaia kinematics and distances but rejected by BASE-9 are marked in red. The black horizontal bars indicate the G magnitudes for primary masses of 0.6 $M_\odot$ and 1 $M_\odot$. The red line shows a PARSEC isochrone created from the median cluster parameters.

	NGC 2682	NGC 188
Age (Gyr)	$4.407^{+0.0310}_{-0.0408}$	$6.167^{+0.0124}_{-0.0185}$
Distance (kpc)	$0.814^{+0.0016}_{-0.0012}$	$1.816^{+0.0014}_{-0.0010}$
[Fe/H]	$-0.150^{+0.0048}_{-0.0044}$	$0.018^{+0.0060}_{-0.0046}$
A_V (mmag)	$211.77^{+2.292}_{-2.166}$	$144.10^{+2.755}_{-2.939}$

The very high internal precision for derived cluster parameters (Childs et al. 2024). For example, relative age uncertainties, are about 0.1% to 1%.

BASE-9 example #2: Precise ages for individual white dwarfs



Log SNR age versus total age for 11,057 white dwarfs with photometric precision better than 5% and Gaia parallax precision better than 10%. The color bar represents the precursor masses for each star. For 4639 (42%) of these stars, BASE-9 yields SNR age > 10, or relative age precision better than 10%.

Next: Mass-transferring binaries

Many Gaia cluster members in Fig. 1 marked in red are located above and to the left of the main sequence turn-off. These are rejected as cluster members by BASE-9 because they are inconsistent with single-star evolution. These so-called Blue Stragglers stars (BSS) are cluster members (Sandage 1953) that are thought to be the result of binary star evolution with mass transfer resulting in a higher mass primary and typically a white dwarf secondary. We will incorporate BSS models (Hurley, Tout, Pols 2002) into BASE-9. The goals of this work are:

- constrain precursor binary star separation and masses that form BSS;
- study BSS properties as a function of cluster age, metallicity, and dynamics;
- create a pathway for incorporating other types of mass-losing or mass-transferring binaries into BASE-9.

References

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