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New rotation periods in the open cluster NGC 1039 (M 34), and a derivation of its gyrochronology age *,**

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Abstract

Aims. Employing photometric rotation periods for solar-type stars in NGC 1039 [M 34], a young, nearby open cluster, we use its mass-dependent rotation period distribution to derive the cluster's age in a distance independent way, i.e., the so-called gyrochronology method.

Methods. We present an analysis of 55 new rotation periods, using light curves derived from differential photometry, for solar type stars in the open cluster NGC 1039 [M 34]. We also exploit the results of a recently-completed, standardized, homogeneous *BVI*c CCD survey of the cluster, performed by the Indiana Group of the WIYN open cluster survey, in order to establish photometric cluster membership and assign $B-V$ colours to each photometric variable. We describe a methodology for establishing the gyrochronology age for an ensemble of solar-type stars. Empirical relations between rotation period, photometric colour and stellar age (gyrochronology) are used to determine the age of M 34. Based on its position in a colour-period diagram, each M 34 member is designated as being either a solid-body rotator (*interface or I-star*), a differentially rotating star (*convective or C-star*) or an object which is in some transitory state in between the two (*gap or g-star*). Fitting the period

and photometric colour of each I-sequence star in the cluster, we derive the cluster's mean gyrochronology age.

Results. Of the photometric variable stars in the cluster field, for which we derive a period, 47 out of 55 of them lie along the loci of the cluster main sequence in $V/B-V$ and $V/V-I$ space. We are further able to confirm kinematic membership of the cluster for half of the periodic variables [21/55], employing results from an on-going radial velocity survey of the cluster. For each cluster member identified as an I-sequence object in the colour-period diagram, we derive its individual gyrochronology age, where the mean gyro age of M 34 is found to be 193 $\pm$ 9 Myr.

Conclusions. Using differential photometry, members of a young open cluster can be easily identified in a colour–magnitude diagram from their periodic photometric variability alone. Such periodicity can be used to establish a period-colour distribution for the cluster, which for M 34, we have used to derive its gyrochronology age of 193 $\pm$ 9 Myr. Formally, our gyro age of M 34 is consistent (within the errors) with that derived using several *distance-dependent*, photometric isochrone methods (*250* $\pm$ *67* Myr).

Key words: methods: data analysis / starspots / stars: fundamental parameters / globular clusters: individual: NGC 1039 (M 34)

* Appendices A–C are only available in electronic form at http://www.aanda.org

** Data of Appendices A–C are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/515/A100

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