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ON Ca II EMISSION AS AN INDICATOR OF THE AGE OF YOUNG STARS

Inseok Song[1,2] and B. Zuckerman[1]
Department of Physics and Astronomy, University of California, Los Angeles, CA 90095; song@astro.ucla.edu, ben@astro.ucla.edu
and
M. S. Bessell
Research School of Astronomy and Astrophysics Institute of Advanced Studies, Australian National University, ACT 2611, Australia; bessell@mso.anu.edu.au
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ABSTRACT

Chromospheric emission in the Ca II H and K lines has often been used as an age diagnostic for solar mass stars. For 20 such stars with ages less than a few hundred megayears, we compare Ca II ages derived by Wright et al. with ages we derive based on a combination of lithium abundance, X-ray activity, and Galactic space motion. Typically, the Ca II ages are noticeably older than the lithium/X-ray ages, suggesting that a recalibration of the Ca II ages may be necessary.

Subject headings: stars: activity — stars: fundamental parameters

1. INTRODUCTION

Stellar age determination is difficult. On the main sequence, stellar activity generally declines with age. Ca II chromospheric H and K line emission is often used as a measure of stellar activity and, thus, of age (e.g., Henry et al. 1996; Lachaume et al. 1999). Wright et al. (2004) present chromospheric Ca II activity measurements, rotation periods, and ages for ~1200 F-, G-, K-, and M-type main-sequence stars based on ~18,000 spectra from Keck and Lick Observatories.

We have been carrying out a multiyear project to identify young stars near the Sun (Song et al. 2003; I. Song, M. Bessell, & B. Zuckerman 2004, in preparation). Our age determinations for ~1000 stars are based on a variety of indicators that are described in § 3 of Zuckerman & Song (2004b). Typically, the oldest stars we are interested in have ages comparable to that of the Pleiades (~100 Myr). Because Wright et al. (2004) were primarily interested in stars that are substantially older than 100 Myr, the overlap between our two large samples is small.

Nonetheless, there are 20, mostly young, stars for which Wright et al. and we have derived ages. These are presented in Table 1 and Figure 1 and discussed below.

2. DISCUSSION

Song et al. (2003) and Zuckerman & Song (2004b) consider various methods for the determination of stellar ages. Methods that relate to stellar activity (e.g., Hα emission, Ca II H and K emission, X-ray luminosity) are not mutually exclusive being a function, ultimately, of the stellar rotation rate. For our age estimates given in column (6) of Table 1, we combine three techniques—X-ray luminosity, lithium abundance, and Galactic space motion—only one of which is directly activity related. Absolute ages are derived using trace-back of 12 Myr old β Pictoris moving group members (Ortega et al. 2002; Song et al. 2003) to calibrate theoretical pre–main-sequence tracks. Relative lithium and X-ray ages are fixed by comparison with the Hyades, Pleiades, and IC 2602 clusters (see, e.g., Figs. 2–4 in Zuckerman & Song 2004b). As a result, we expect that for stars $\lesssim$100 Myr old both relative and absolute ages derived from these three methods in concert should be quite reliable. (Below we call ages so derived "lithium ages" for short.)

Of the 20 late F- to early K-type stars listed in Table 1, about one-half have Ca II ages (col. [5]) that are clearly older than the lithium ages in column (6). In no case is a Ca age clearly younger than a lithium age. (As only one star in Table 2 of Wright et al. 2004 has an age in the range between 10^7 and 10^8 yr, whereas four have listed ages $<10^7$ yr, we regard all Ca ages in the vicinity of 10^7 yr to be essentially equivalent. Thus, we regard the Ca and lithium ages for HD 129333 and 202917 to be in agreement.)

As noted by Henry et al. (1996) and Wright et al. (2004), because of stellar activity cycles, Ca II activity should be measured through a complete cycle to determine the age of an individual star. Indeed, because of the possibility of a Maunder minimum phase, for an individual star monitoring for a very long period is desirable. But for an ensemble of stars, the age/activity calibration, which is presumably pegged to stars in open clusters, should be reliable, and therefore one might expect as many stars with Ca ages less than lithium ages as vice versa. (The Ca emission/age relation used by Henry et al. and Wright et al. originates in an unpublished Ph.D. thesis [Donahue 1993], and we do not know how this relationship was calibrated.)

In any event, 13 stars in Figure 1 with estimated rotation periods (see below) in the range 3–7 days have Ca ages in the relatively narrow range 100–500 Myr, independent of rotation period. Thus, we regard this age spread to be representative of the putative error in Ca-derived ages. Errors in the Table 1 lithium ages may be estimated by noting that seven stars are likely members of the Tucana, AB Dor, or β Pic associations. Ages for these moving groups are derived in the references listed in Table 1 or in references therein. The β Pic, Tucana, and AB Dor stars are unlikely to be older than 20, 40, and 70 Myr, respectively. Lithium ages for Table 1 stars not in known moving groups are less secure, but we expect these stars to be not more than twice as old as listed. We anticipate that some of these stars will eventually be placed into yet to be identified moving groups, which will tighten up the age error estimates.

While Table 1 suggests that Ca ages are suspect for stars $\lesssim$200 Myr old, the questionable reliability of Ca ages may pertain to older stars as well. For example, based in large part

[1] Center for Astrobiology, University of California, Los Angeles, CA 90095.
[2] Association of Universities for Research in Astronomy/Gemini Observatory, 670 North A'ohoku Place, Hilo, HI 96720.

TABLE 1
SAMPLE STARS

HD (1)	HIP (2)	$B-V$ (3)	P_{rot} (days) (4)	Age: Ca II (10^8 yr) (5)	Age: Li/X-ray/*UVW* (10^8 yr) (6)	Association (7)	References (8)
105	490	0.59	5	4.3	0.3	Tucana	1, 2
377	682	0.63	4	2.4	1.0		1
984	1134	0.52	3	4.9	0.3		
...	6276	0.79	6	1.0	0.5	AB Dor	2, 3
13507	10321	0.67	10	8.5	2.0	[a]	4
13531	10339	0.70	7	3.9	2.0	[a]	4
14082B	10679	0.62	4	2.7	0.1	β Pic	2
14082A	10680	0.52	3	4.7	0.1	β Pic	2
25457	18859	0.50	2	3.5	0.5	AB Dor	2, 3
35850	25486	0.55	1.1	0.1	0.1	β Pic	1, 2
77407	44458	0.61	3	1.5	0.5		1, 5
90905	51386	0.56	4	5.6	0.5		1
92945	52462	0.87	7	1.0	1.0		1, 6, 7
107146	60074	0.60	3	1.5	1.0		1, 6
122652	68593	0.56	11	25	3.0?		6
129333	71631	0.63	1.2	0.1	0.3		1
152555	82688	0.59	4	4.5	0.6		1
202917	105388	0.69	2	0.1	0.3	Tucana	1, 2, 6
206387	107107	0.72	7	2.4	1.0		
218739	114385	0.66	10	10	2.0		

NOTE.—In addition to the references listed below, the stars in this table are considered in I. Song, M. Bessell, & B. Zuckerman 2004, in preparation.

[a] HD 13507 and 13531 are components of a binary system with a separation of 10′15″.

REFERENCES.—(1) Wichmann et al. (2003); (2) Zuckerman & Song (2004b); (3) Zuckerman et al. (2004); (4) Montes et al. (2001); (5) Mugrauer et al. (2004); (6) Zuckerman & Song (2004a); (7) Song et al. (2002).

on Ca emission, Lachaume et al. (1999) and Jourdain de Muizon et al. (1999) considered HD 207129 to be about as old as the Sun. But, on the basis of multiple considerations, Song et al. (2003) derived a much younger age (~600 Myr).

In Figure 1, we plot age versus rotation period as listed in column (4) of Table 1. These periods taken from Wright et al. (2004) were originally derived by Noyes et al. (1984) and are based on a relationship between period, convective turnover time, and Ca H and K emission strength (R'_{HK}) for an ensemble of stars. Because of this coupling between the listed periods and R'_{HK}, one should not make too much of the figure beyond noting that (1) the Ca ages are clearly older than the lithium ages and (2) the lithium ages are correlated with the rotation period derived from the calcium data.

A potentially more illuminating application of the calcium lines would be to use the autocorrelation function in an individual star to derive a rotation period that is not dependent on absolute intensity (R'_{HK}). To quote from Baliunas et al. (1983): "With time series measurements of chromospheric Ca II H and K emission fluxes, it is possible to measure the rotation period directly, independent of axial inclination." They observed 47 stars daily during a few month period. Either calcium or broadband photometric monitoring of young stars listed in Zuckerman & Song (2004b) should provide a measure of the correlation between lithium ages and rotation period for a range of spectral types.

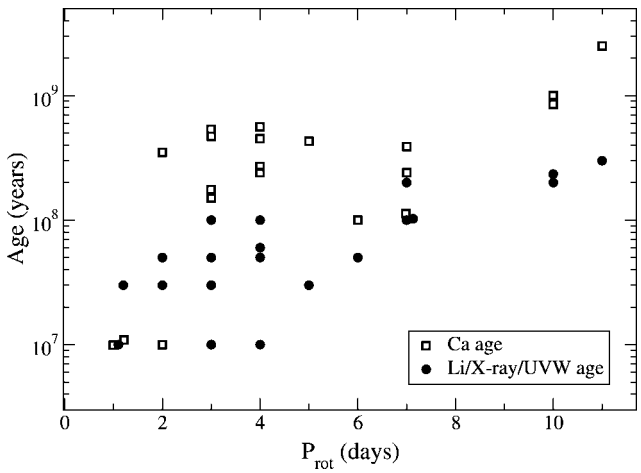


FIG. 1.—Calcium and lithium ages vs. rotational period. Indicated rotational periods are not directly measured but are estimated values based on a relation given in Noyes et al. (1984). See text for additional details.

3. CONCLUSIONS

Multiple methods now exist to reasonably reliably date stars with ages comparable to and younger than the Pleiades. We deduce that, more often than not, stellar ages derived from the strength of chromospheric Ca II H and K line emission are likely to be in error for such young stars and may be in error for older main-sequence stars as well. Because Ca-derived ages are systematically older than those derived in other ways, recalibration of the Ca/age relationship may be needed.

Autocorrelation analysis of extensive time series measurements of either calcium or broadband fluxes can establish quantitative relationships between rotation period and age for nearby young stars.

Conclusions in this Letter are based on 21 stars (Table 1 plus HD 207129). A much larger sample of nearby young stars is available (Zuckerman & Song 2004b; I. Song, M. Bessell, & B. Zuckerman 2004, in preparation) for future Ca line measurements and comparative analysis.

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