2017

Testing the Stellar Rotation vs. Age Paradigm Using Wide Binaries in the Kepler & K2 Fields

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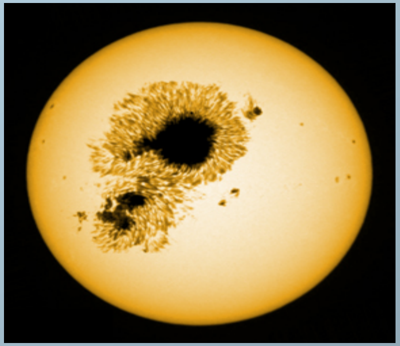

https://subarutelescope.org/Pressrelease/2015/05/11/index.html

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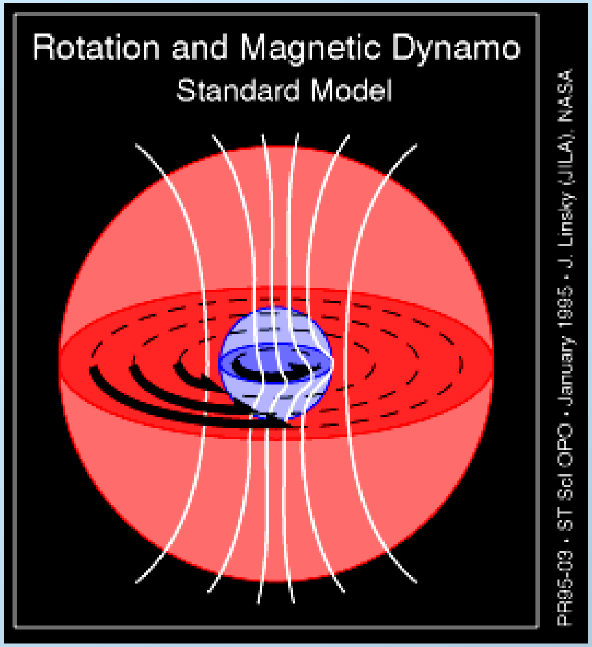
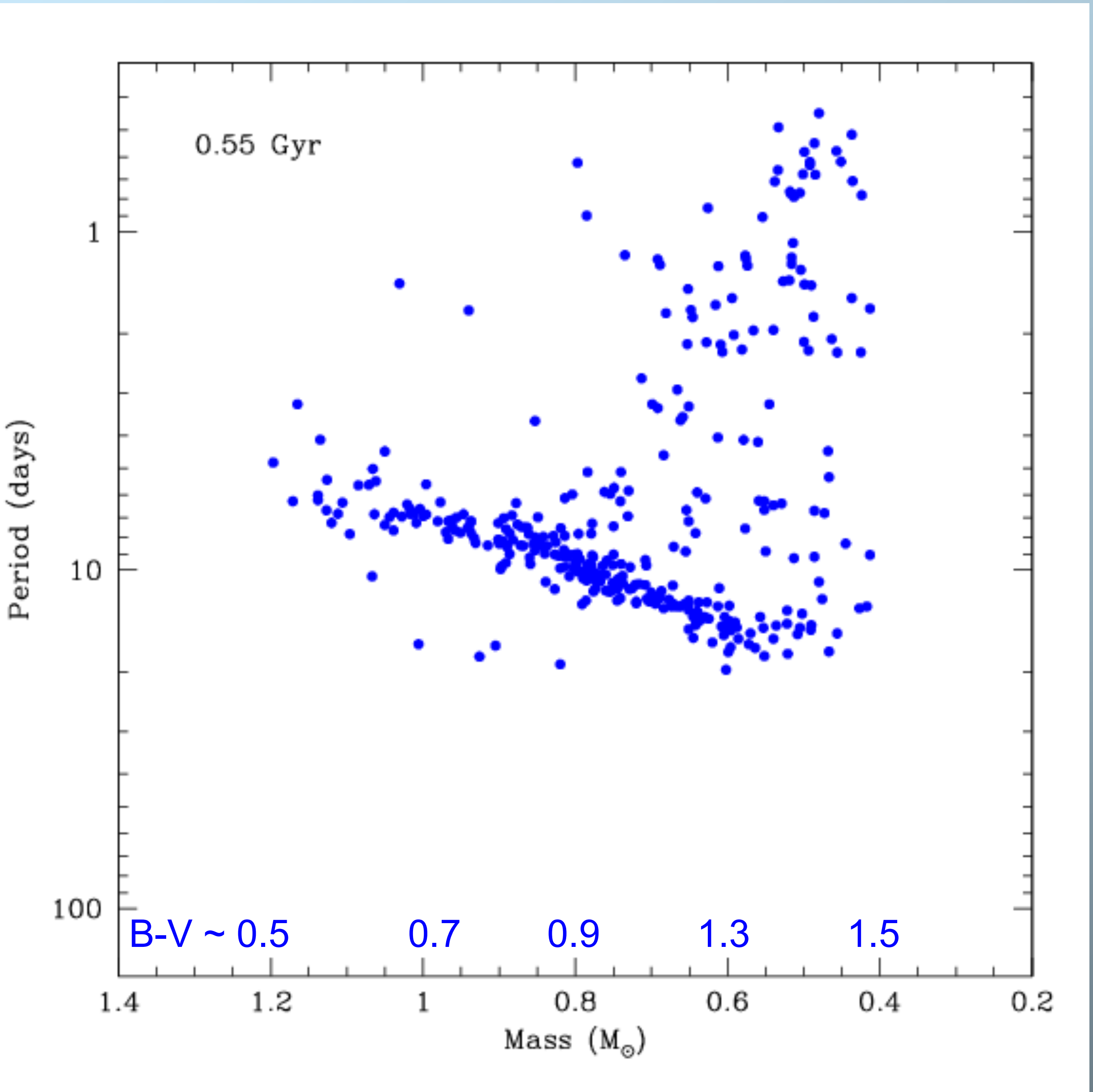
EMBRY-RIDDLE Aeronautical University DAYTONA BEACH, FLORIDA

Gyrochronology

Fast Rotators
(young)

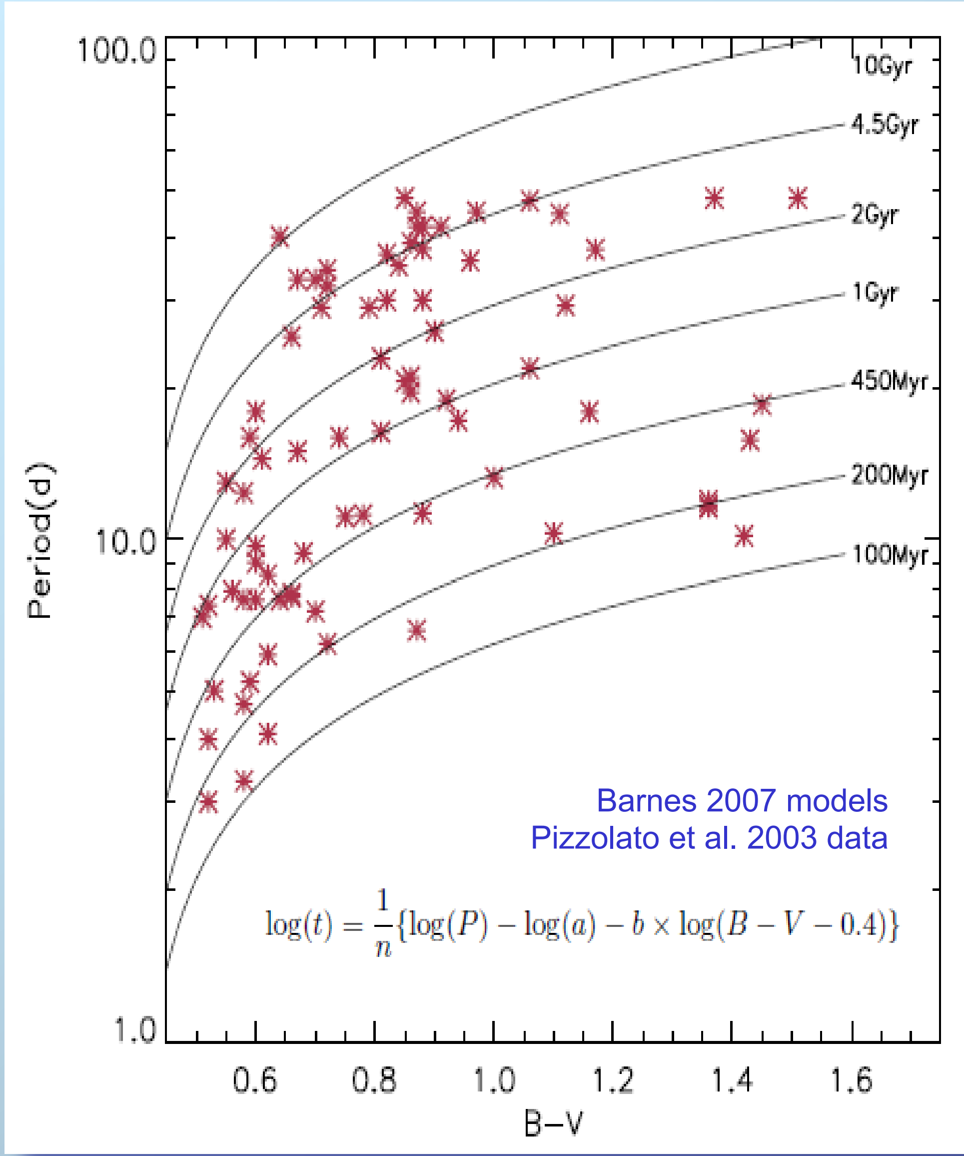


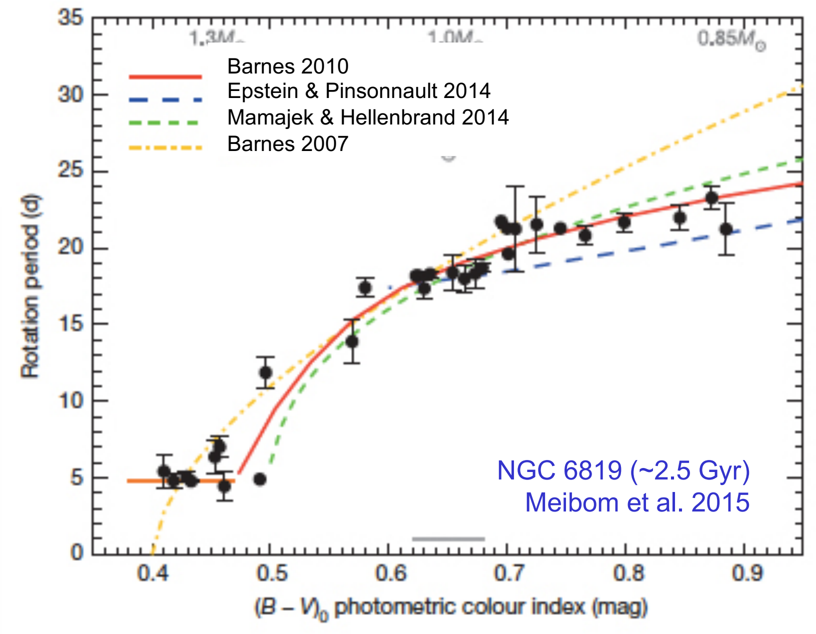
Slow Rotators
(old)

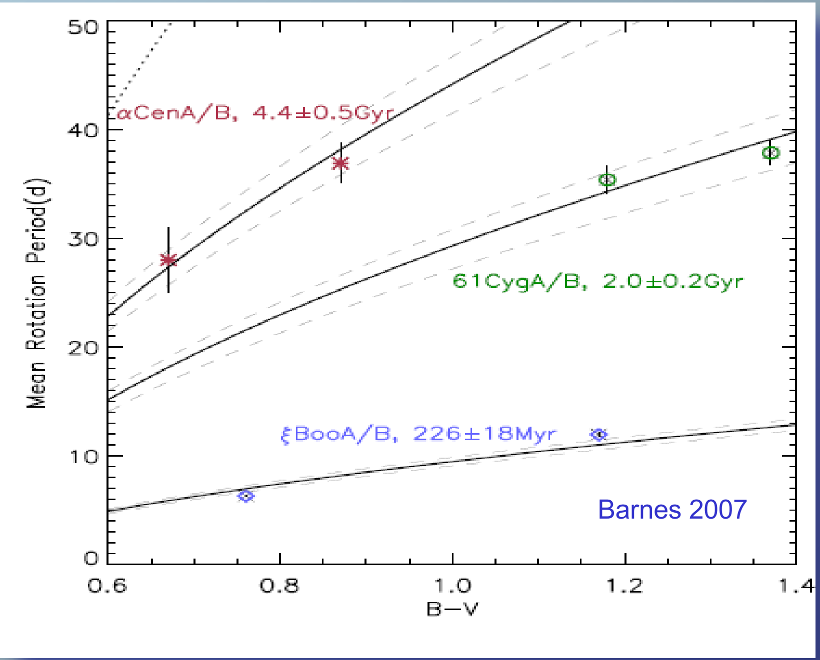


Animation courtesy of
Courtney Epstein
(see Epstein & Pinsonneault 2012)

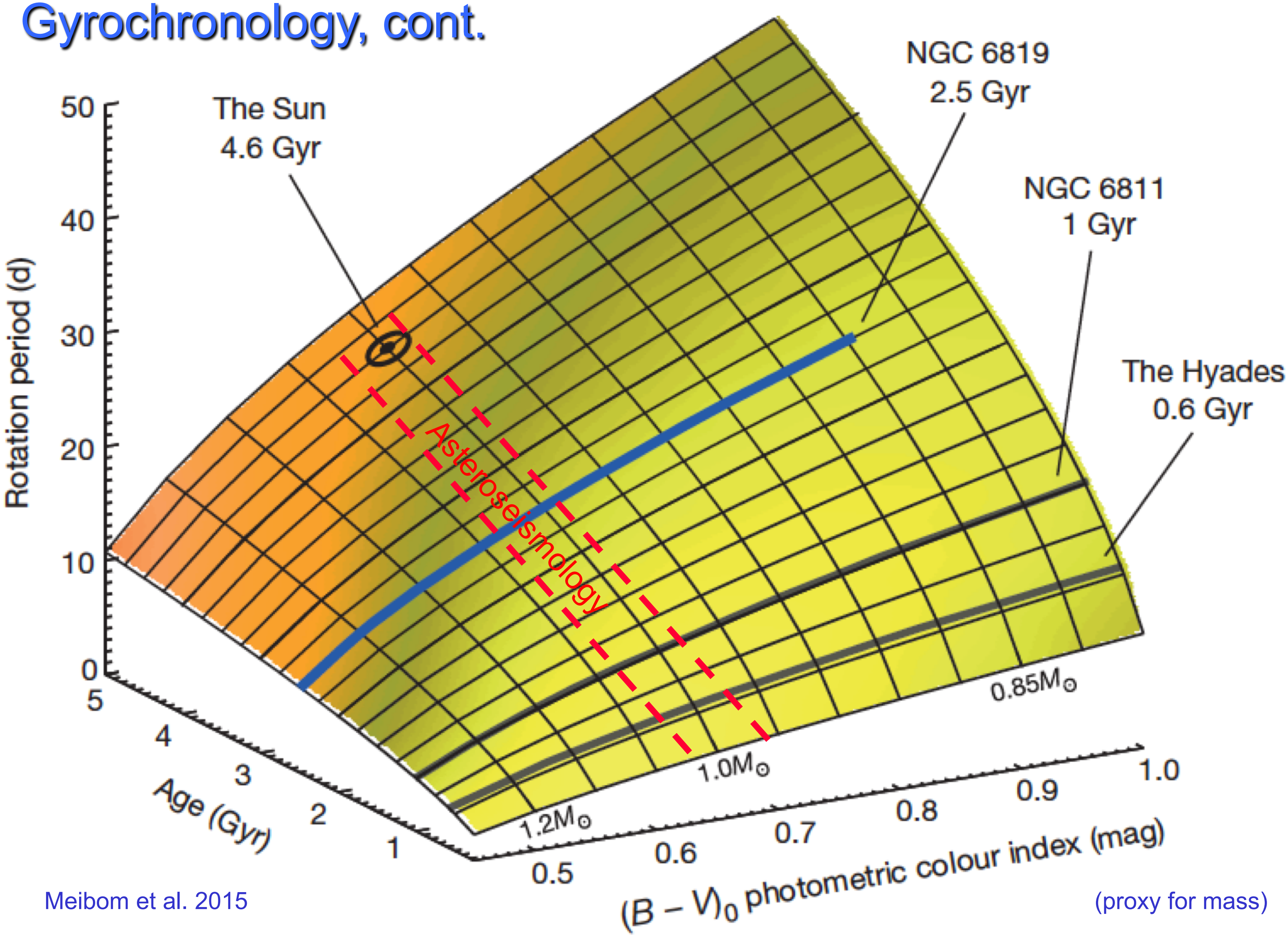
Gyrochronology







Gyrochronology, cont.

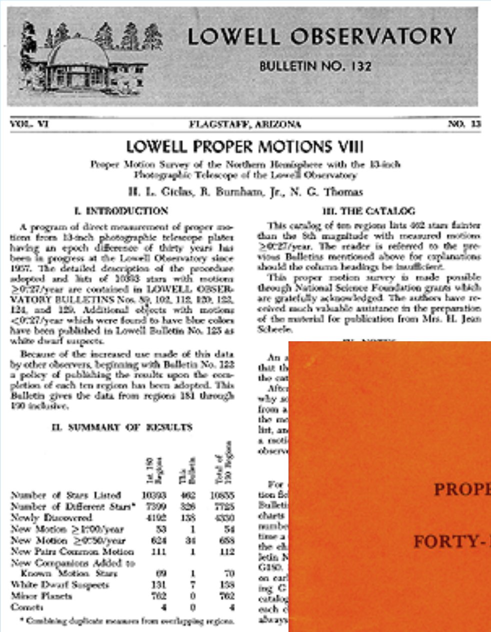


Meibom et al. 2015

(proxy for mass)

“Fragile” Binaries: Definition

“…small galactic clusters containing stars of the same age and composition.” –Greenstein 1986


LOWELL OBSERVATORY
BULLETIN NO. 132

VOL. VI | FLAGSTAFF, ARIZONA | NO. 13

LOWELL PROPER MOTIONS VIII

Proper Motion Survey of the Northern Hemisphere with the 13-inch Photographic Telescope of the Lowell Observatory

H. L. Giclas, R. Burnham, Jr., N. G. Thomas

I. INTRODUCTION

A program of direct measurement of proper motions from 13-inch photographic telescope plates having an epoch difference of thirty years has been in progress at the Lowell Observatory since 1957. The detailed description of the procedure adopted and lists of 10393 stars with motions ≥0″27/year are contained in LOWELL OBSERVATORY BULLETINS Nos. 89, 102, 112, 120, 122, 124, and 129. Additional objects with motions <0″27/year which were found to have blue colors have been published in Lowell Bulletin No. 125 as white dwarf suspects.

Because of the increased use made of this data by other observers, beginning with Bulletin No. 122 a policy of publishing the results upon the completion of each ten regions has been adopted. This Bulletin gives the data from regions 181 through 190 inclusive.

II. SUMMARY OF RESULTS

	1st 180 Regions	This Bulletin	Total of 190 Regions
Number of Stars Listed	10393	462	10855
Number of Different Stars*	7399	326	7725
Newly Discovered	4192	138	4330
New Motion ≥1″00/year	53	1	54
New Motion ≥0″50/year	624	34	658
New Pairs Common Motion	111	1	112
New Companions Added to Known Motion Stars	69	1	70
White Dwarf Suspects	131	7	138
Minor Planets	762	0	762
Comets	4	0	4

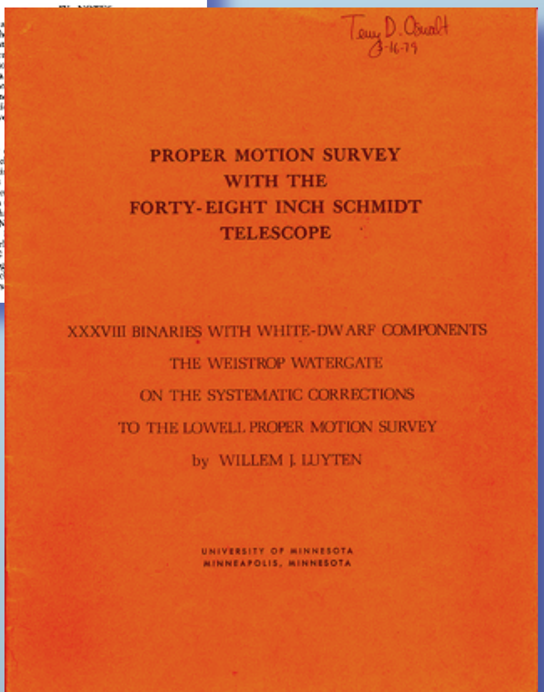
* Combining duplicate measures from overlapping regions.

III. THE CATALOG

This catalog of ten regions lists 462 stars fainter than the 8th magnitude with measured motions ≥0″27/year. The reader is referred to the previous Bulletins mentioned above for explanations should the column headings be insufficient.

This proper motion survey is made possible through National Science Foundation grants which are gratefully acknowledged. The authors have received much valuable assistance in the preparation of the material for publication from Mrs. H. Jean Scheele.

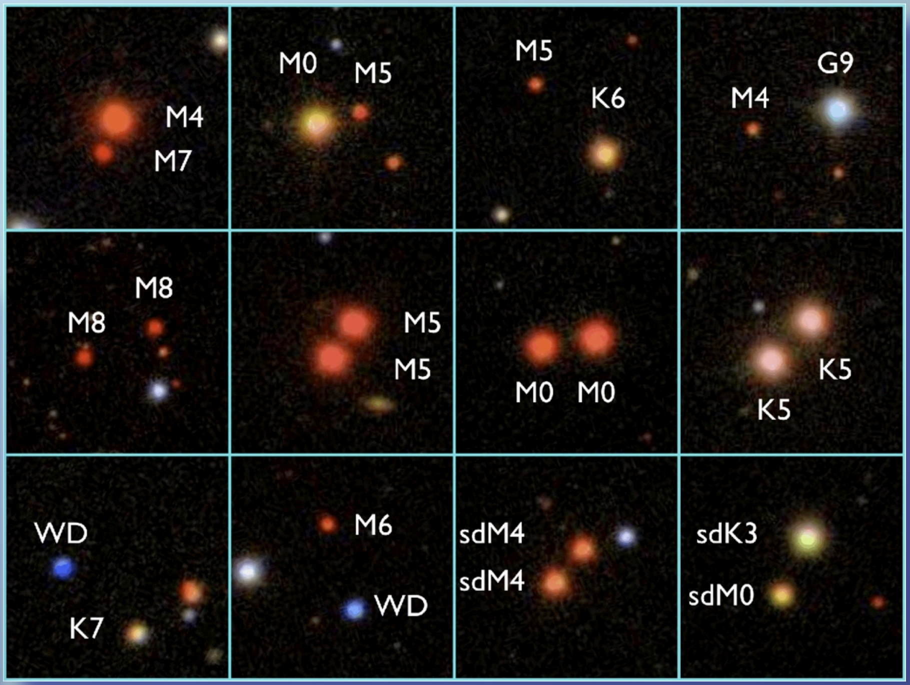
Giclas et al.
1971-8


PROPER MOTION SURVEY
WITH THE
FORTY-EIGHT INCH SCHMIDT
TELESCOPE

XXXVIII BINARIES WITH WHITE-DWARF COMPONENTS
THE WEISTROP WATERGATE
ON THE SYSTEMATIC CORRECTIONS
TO THE LOWELL PROPER MOTION SURVEY
by WILLEM J. LUYTEN

UNIVERSITY OF MINNESOTA
MINNEAPOLIS, MINNESOTA

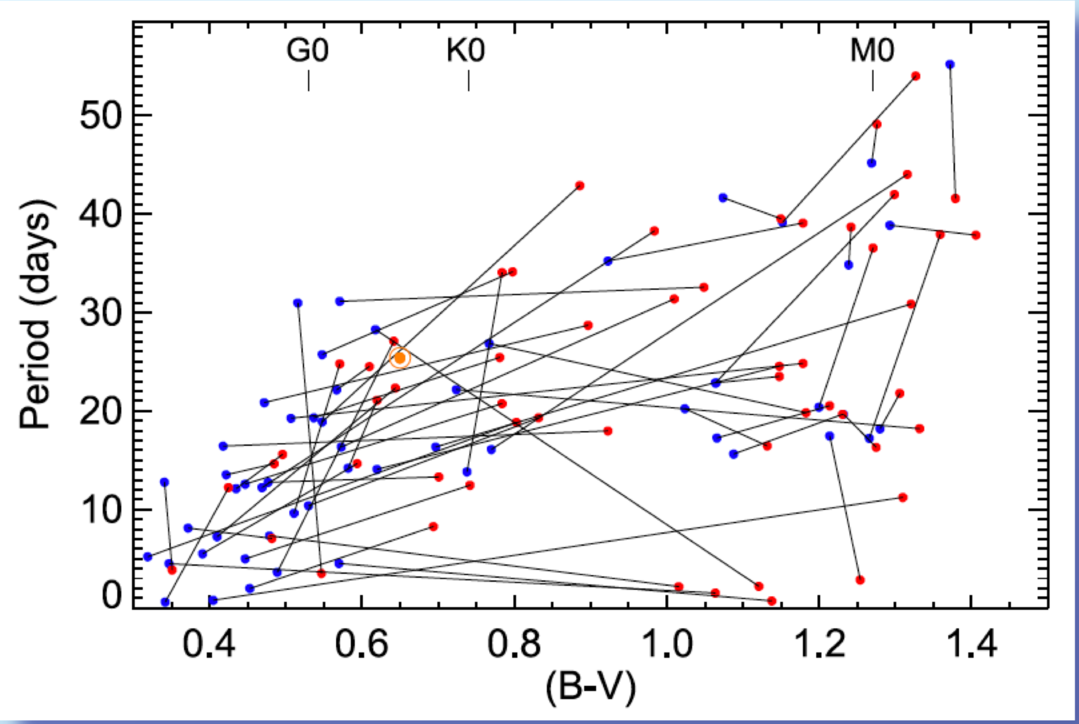
Luyten
1969 et seq.

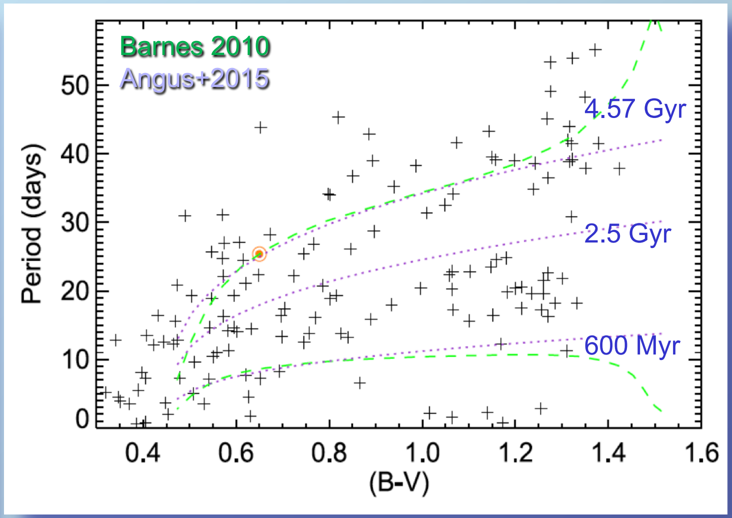


SLoWPoKES Catalog
http://slowpokes.vanderbilt.edu

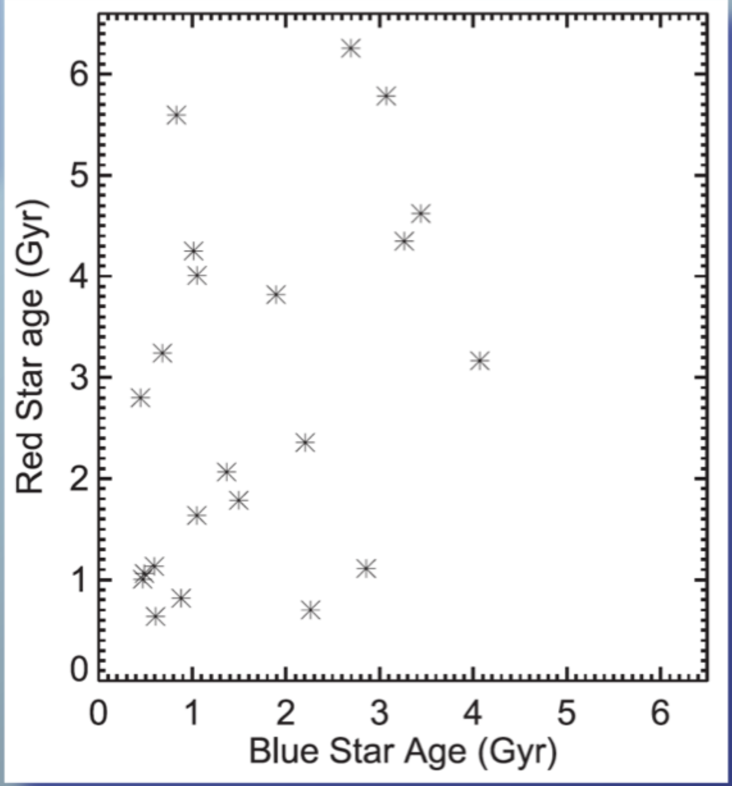
Washington Double Star Catalog
http://ad.usno.navy.mil/wds/

Fragile Binaries in the Kepler Field (Janes 2017)





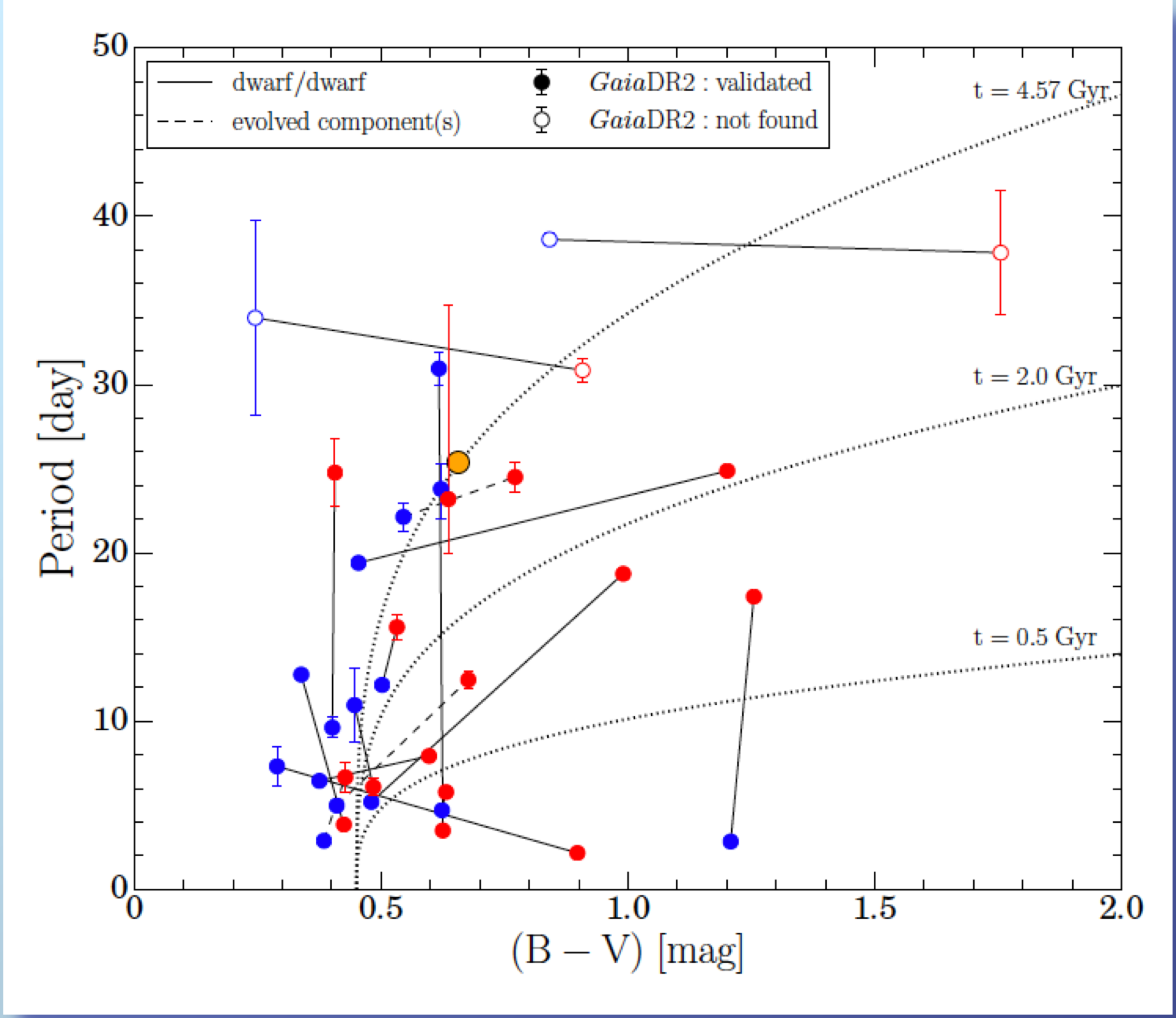
93 – 37 = 56 pairs w/ modulation in both stars &
B-V colors estimated from:
B-V = a + b (g-K) + c (g-K)²



22 "best" pairs with B-V > 0.6 colors and P_{rot} > 5 d
Barnes 2010 ages

No correlation

Fragile Binaries in Kepler Field (Godoy-Rivera & Chaname 2018)



17 pairs total
15 pairs vetted by Gaia
2 pairs w/UACA4 data
-3 pairs w/evolved stars

7/14= 50% "consistent" age slopes

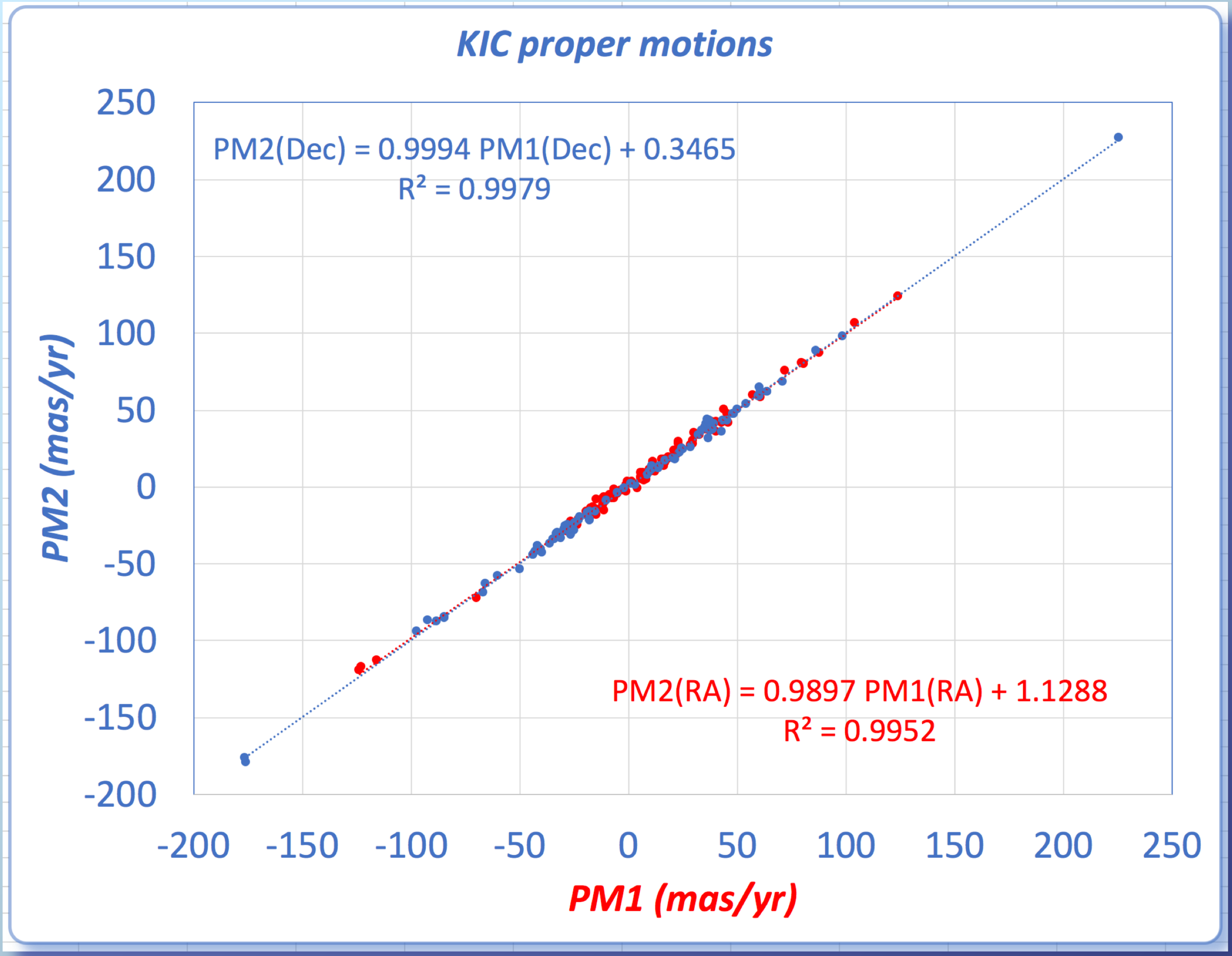
(Angus+15 ages)

Why such poor agreement with gyrochronology?

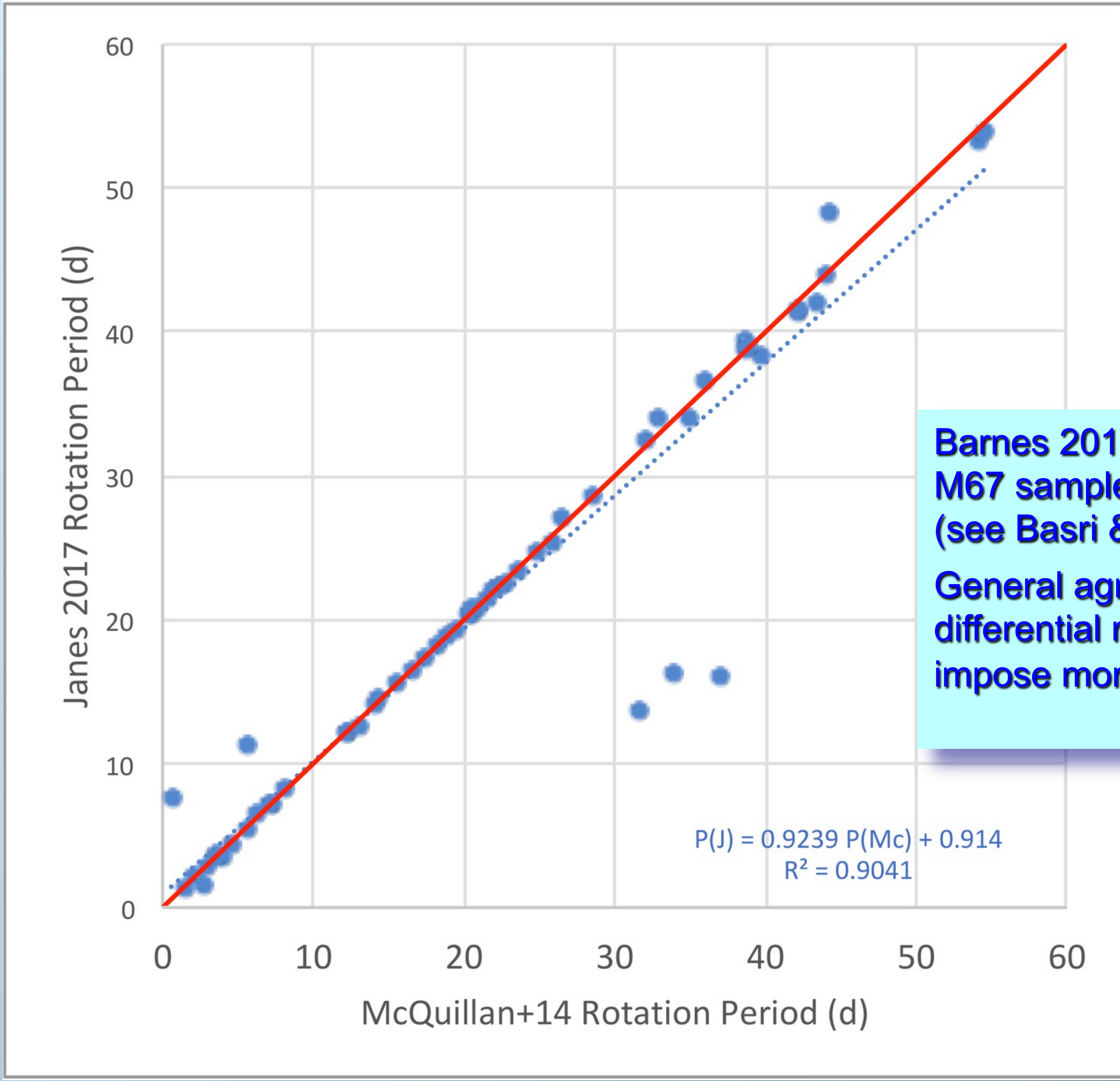
1. Some may be nonphysical pairs
2. Many components near B-V ~ 0.5 degeneracy in gyrochrones
3. Few B-V values available; estimated B-V values are poor ($\sigma = \pm$ 0.12!)
4. Unresolved tertiary components can affect colors and/or rotation rate
5. Unrecognized evolved components do not follow dwarf gyro paradigm
6. Periods may be incorrect
7. Scatter due to differential rotation, multiple spots and/or cycles
8. Current models may not yet be fully mature—which are best?

Use the Janes (2017) Kepler sample of 93 binaries to assess the above

Does the Kepler sample contain any non-physical pairs?

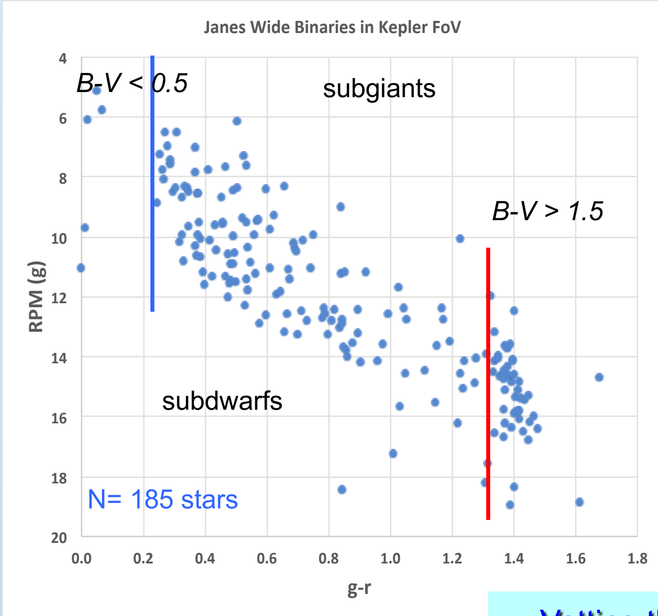


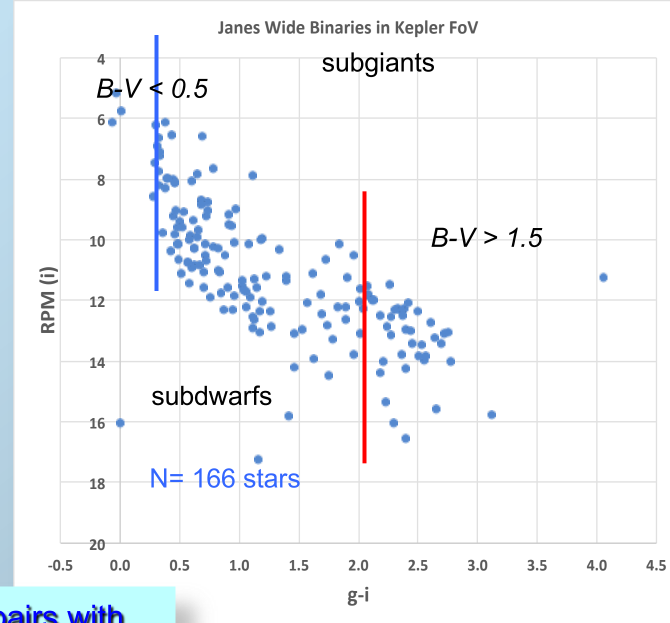
Does the Kepler sample contain incorrect rotation periods?



Barnes 2018 says 70% of his M67 sample are "double dippers" (see Basri & Nguyen 2018)

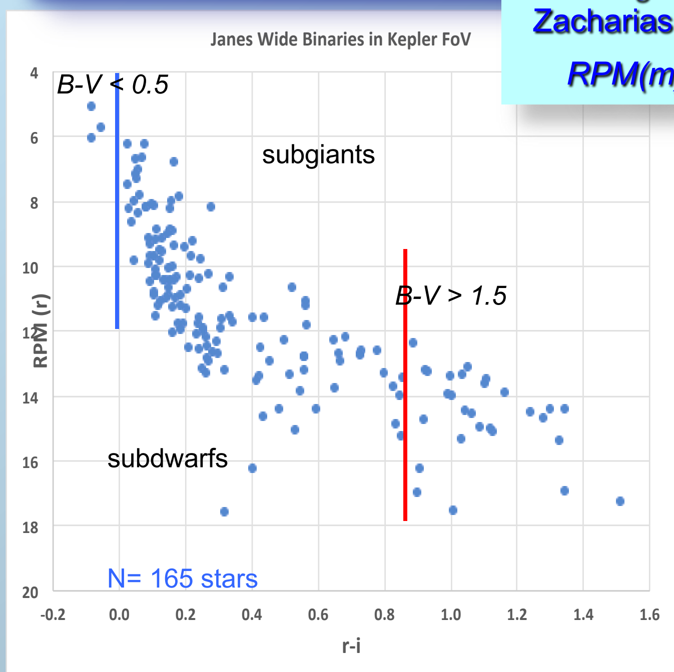
General agreement suggests differential rotation & cycles don't impose more than ~10% scatter

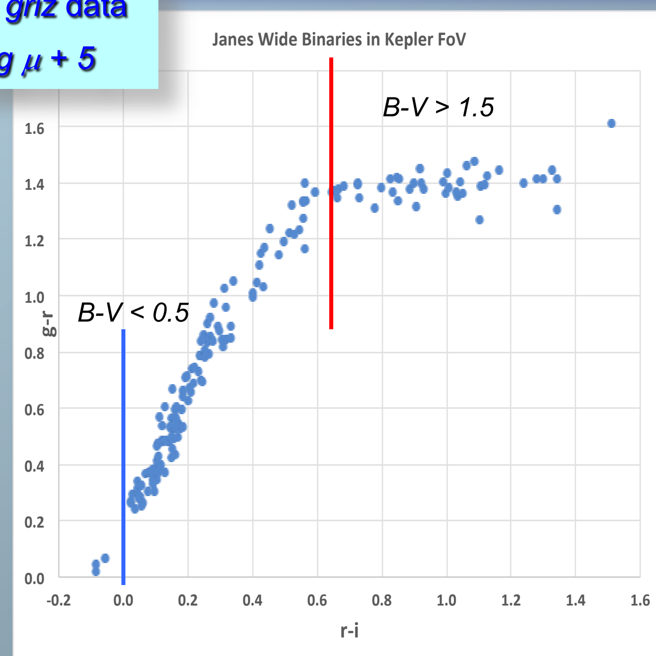




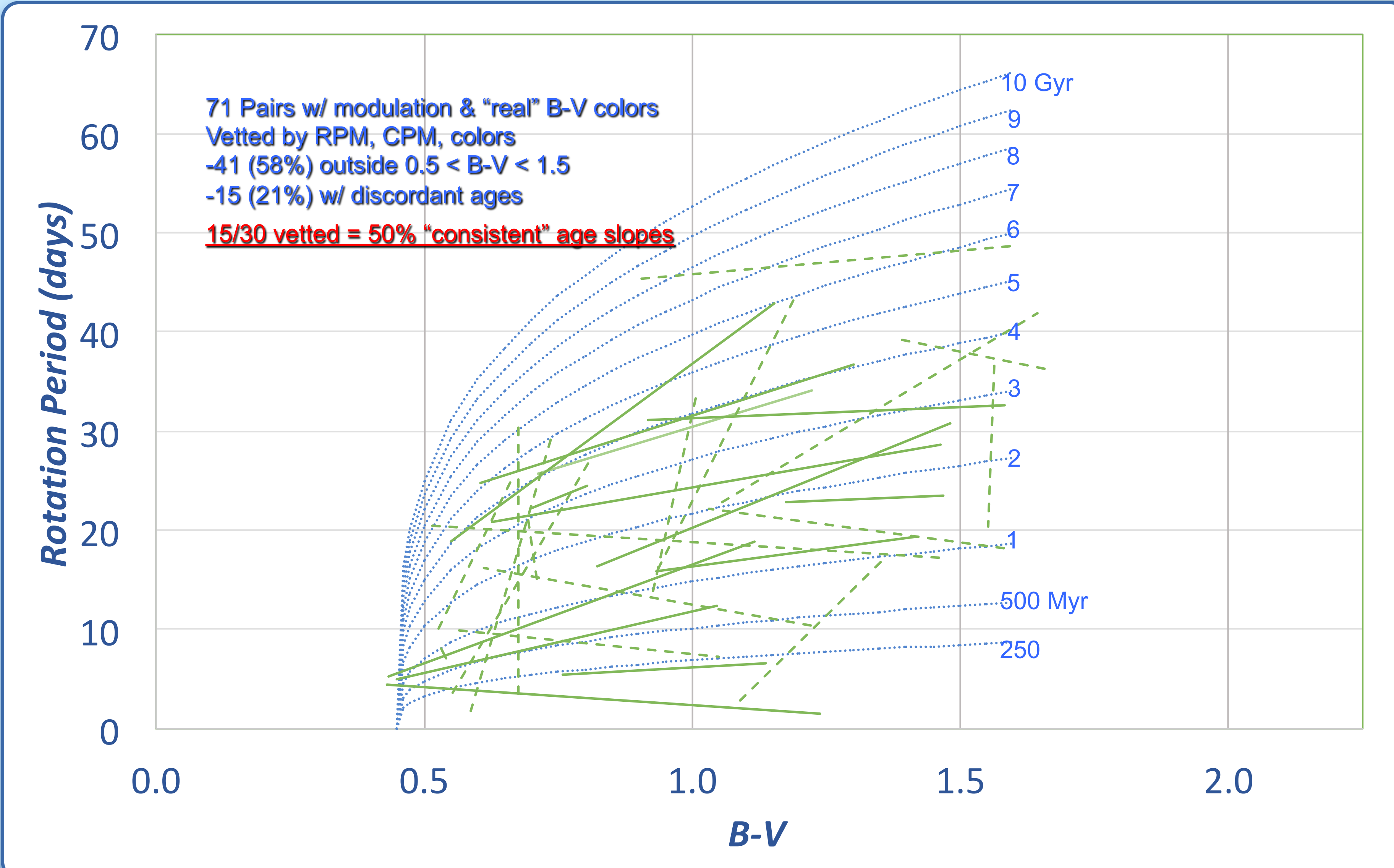
Vetting the Kepler pairs with Zacharias+15 URAT1 *griz* data

RPM(m) = m + 5 log μ + 5

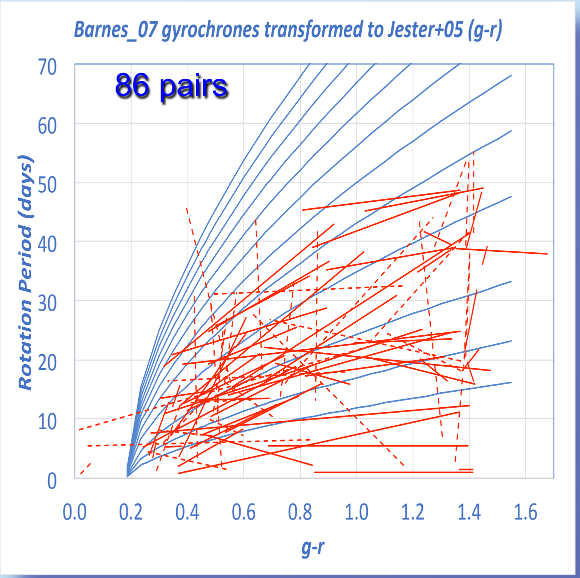


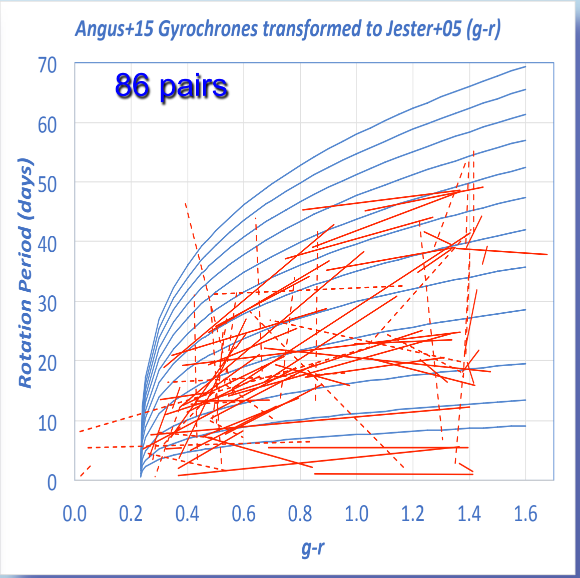


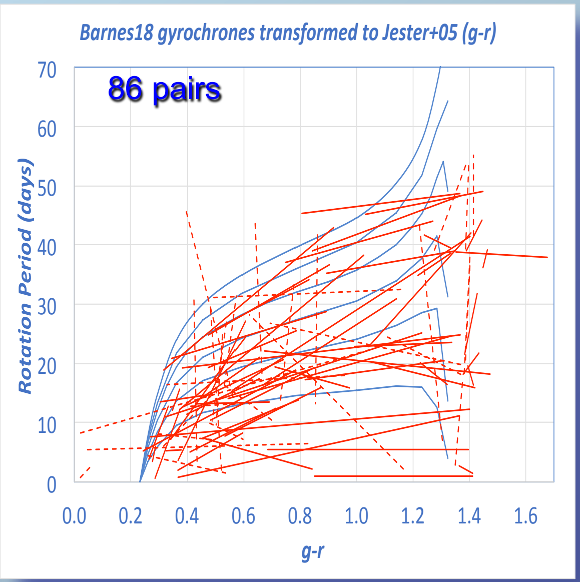
Vetting Fragile Binaries in the Kepler Field (data from Janes 2017; Angus+2015 models)

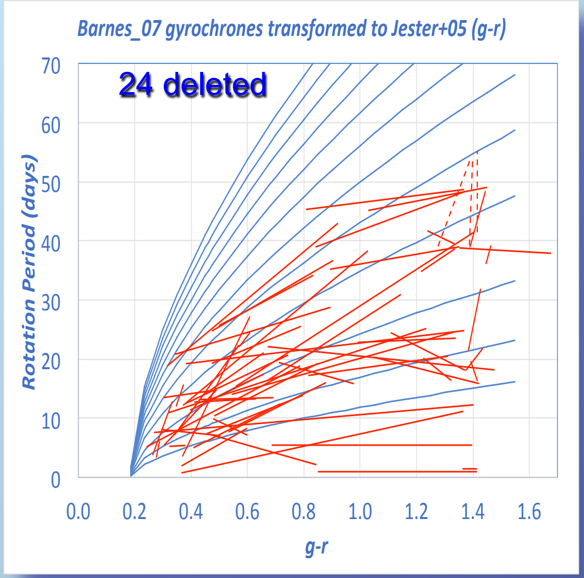


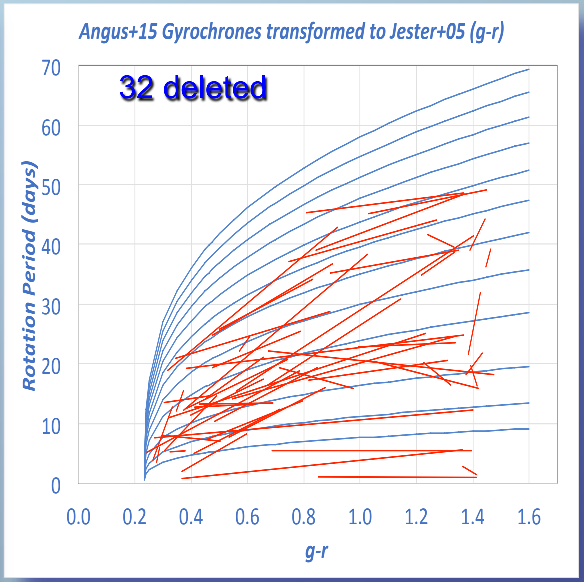
Which models are best (subjectively)?

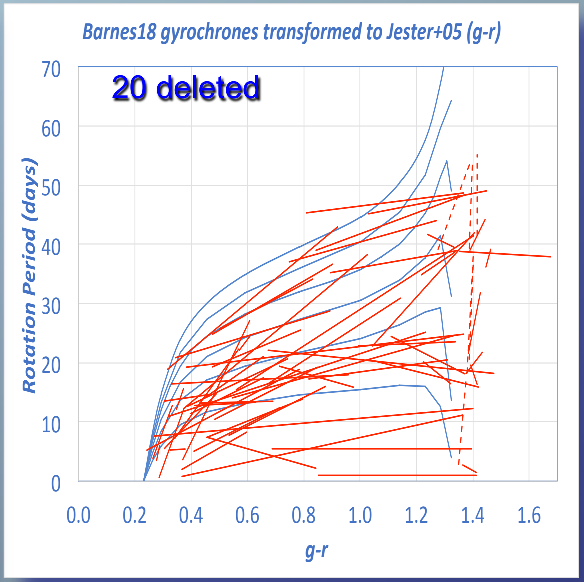




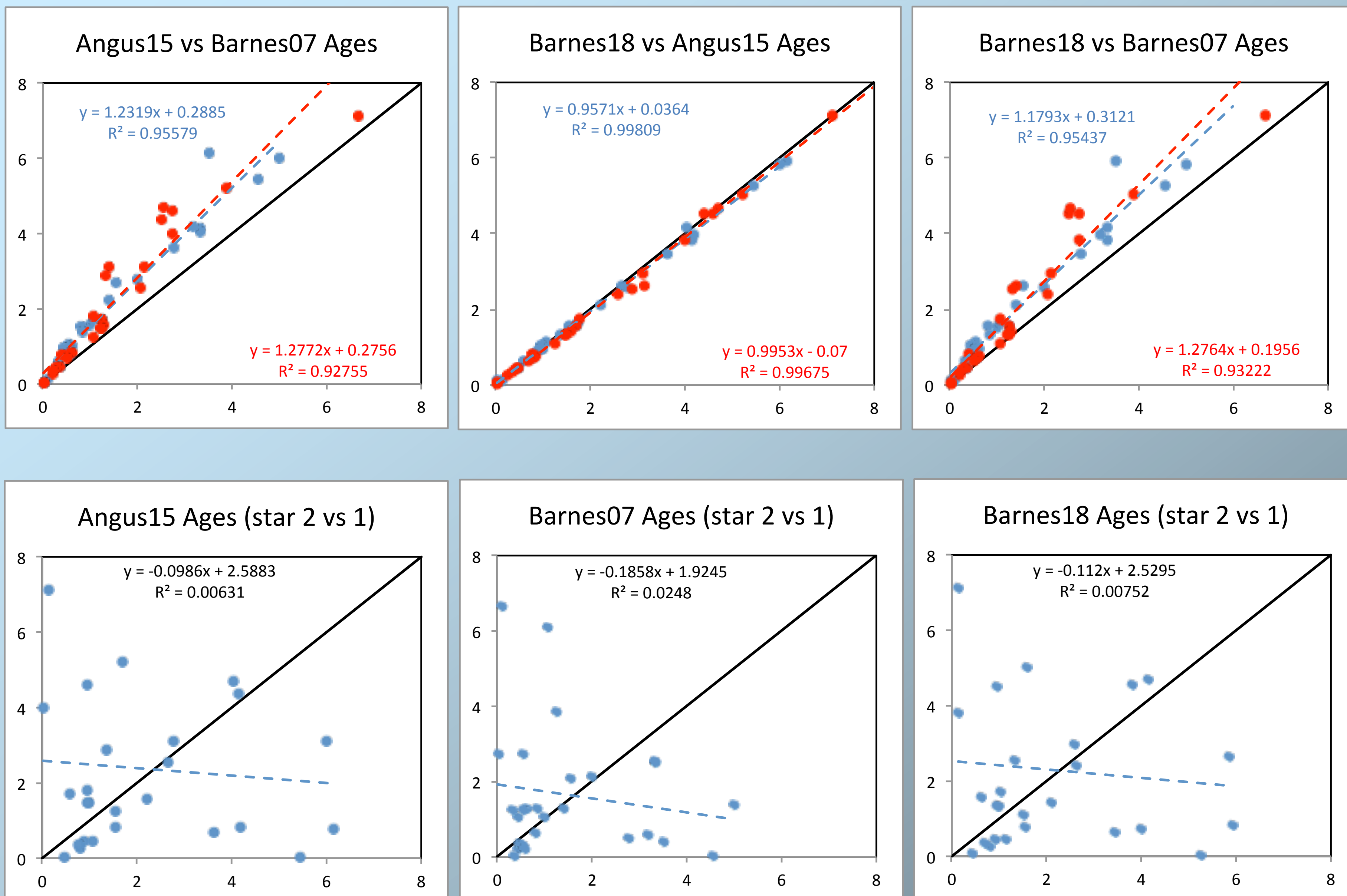


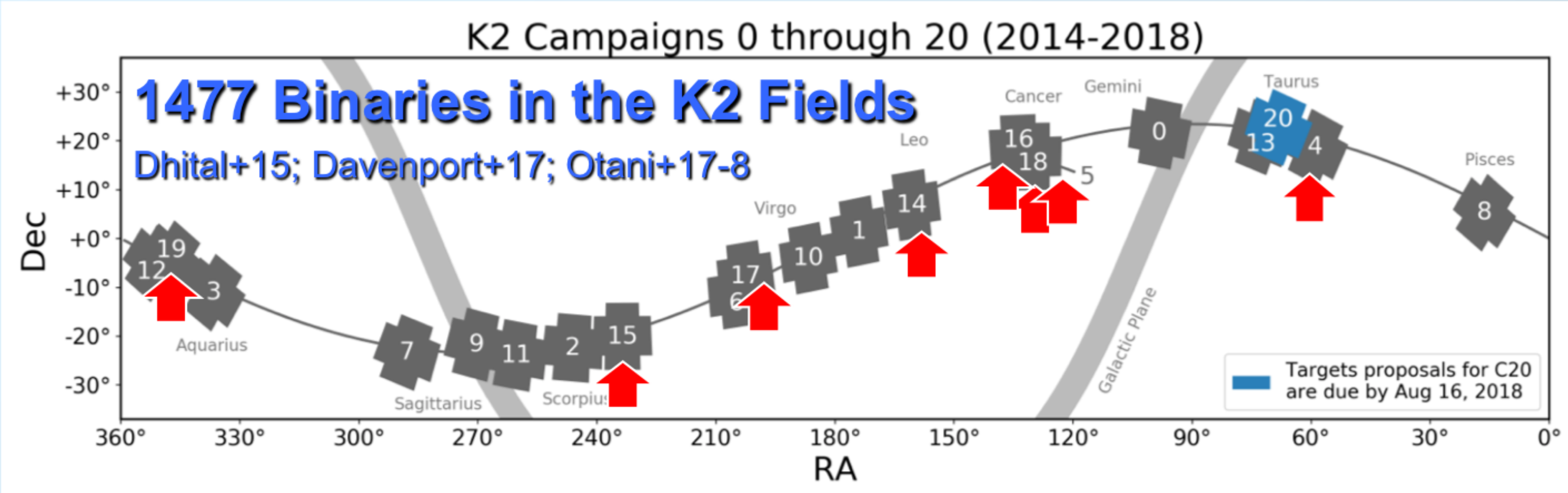




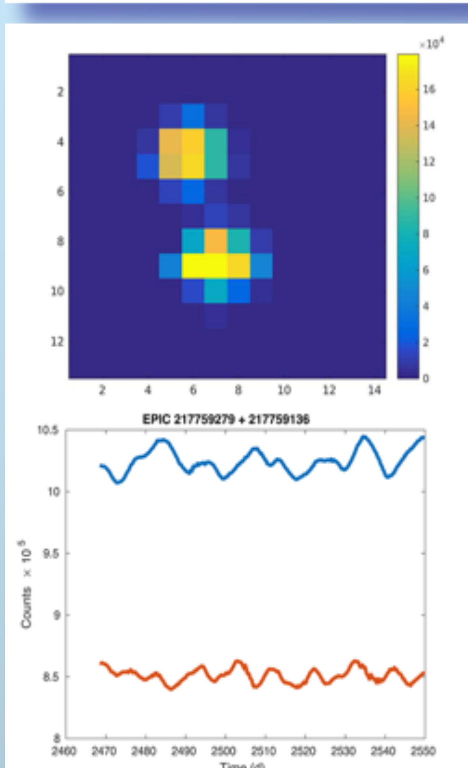


Which models are best (objectively)?

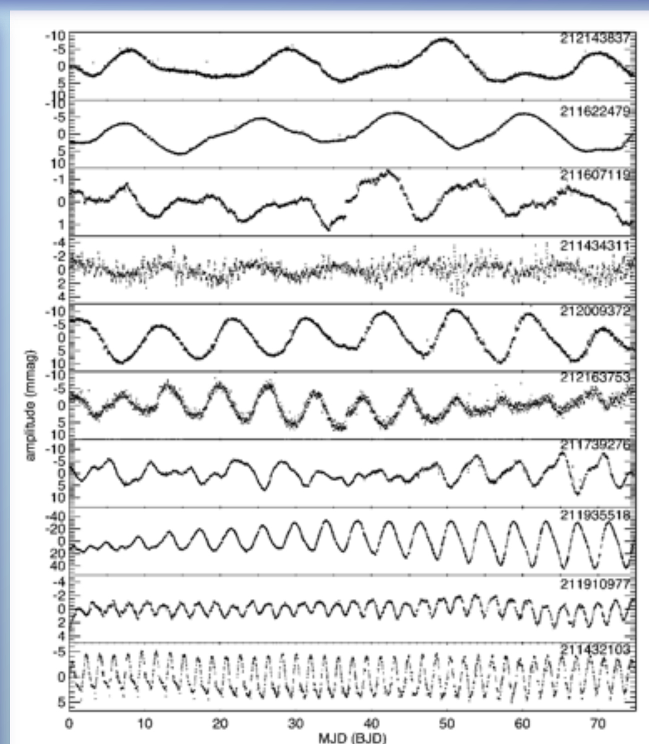




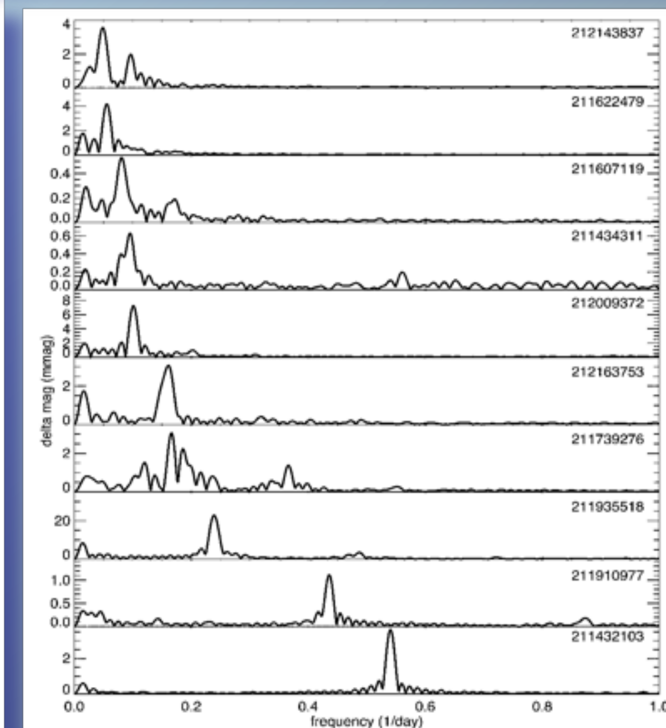
K2 Campaigns 0 through 20 (2014-2018)
1477 Binaries in the K2 Fields
Dhital+15; Davenport+17; Otani+17-8
Targets proposals for C20 are due by Aug 16, 2018
Aquarius
Sagittarius
Scorpius
Virgo
Leo
Cancer
Gemini
Taurus
Pisces
Galactic Plane
Dec
RA



EPIC 217759279 + 217759136
Counts × 10^5
Time (d)



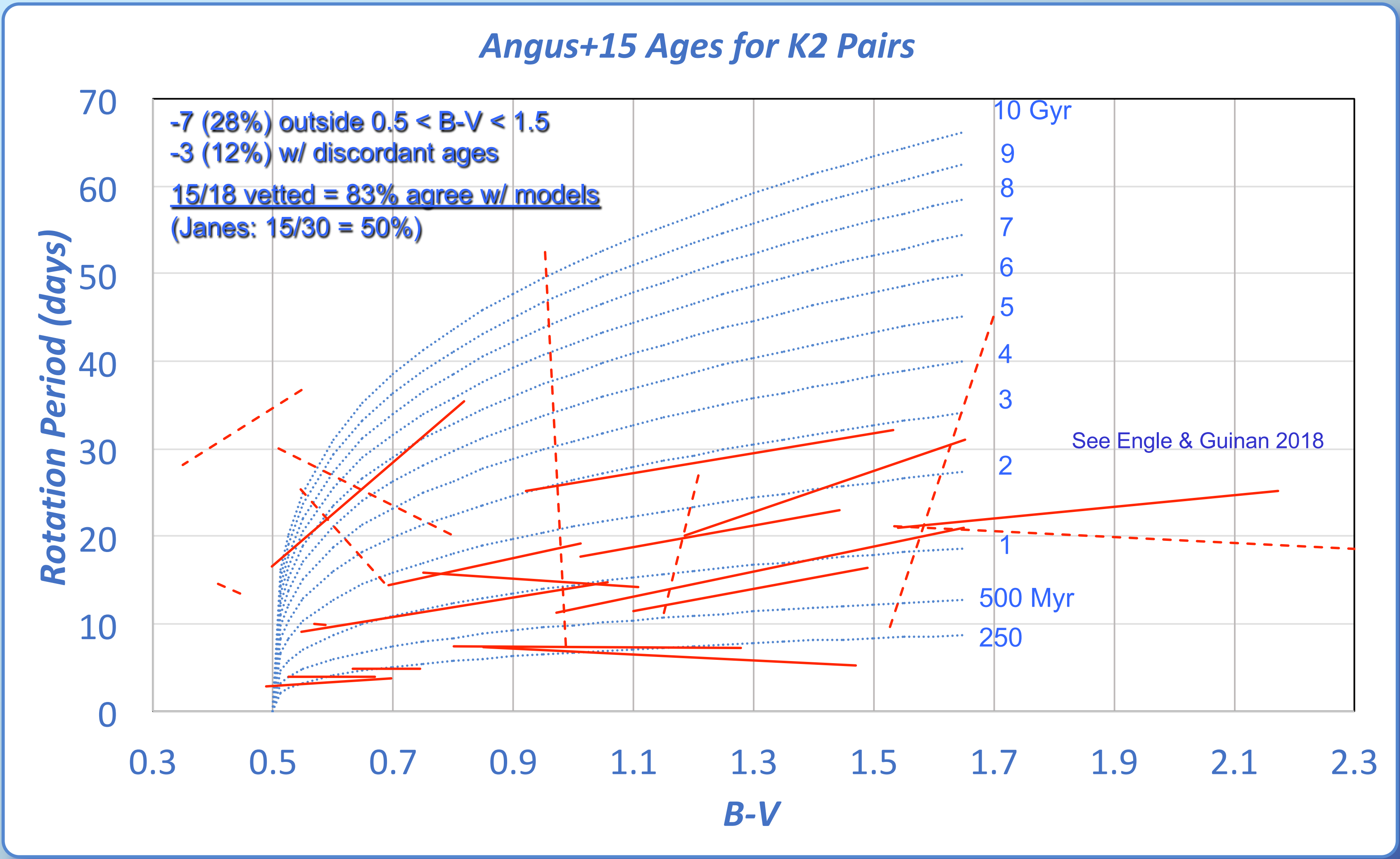
212143837
211622479
211607119
211434311
212009372
212163753
211739276
211935518
211910977
211432103
amplitude (mmag)
MJD (BJD)



212143837
211622479
211607119
211434311
212009372
212163753
211739276
211935518
211910977
211432103
delta mag (mmag)
frequency (1/day)

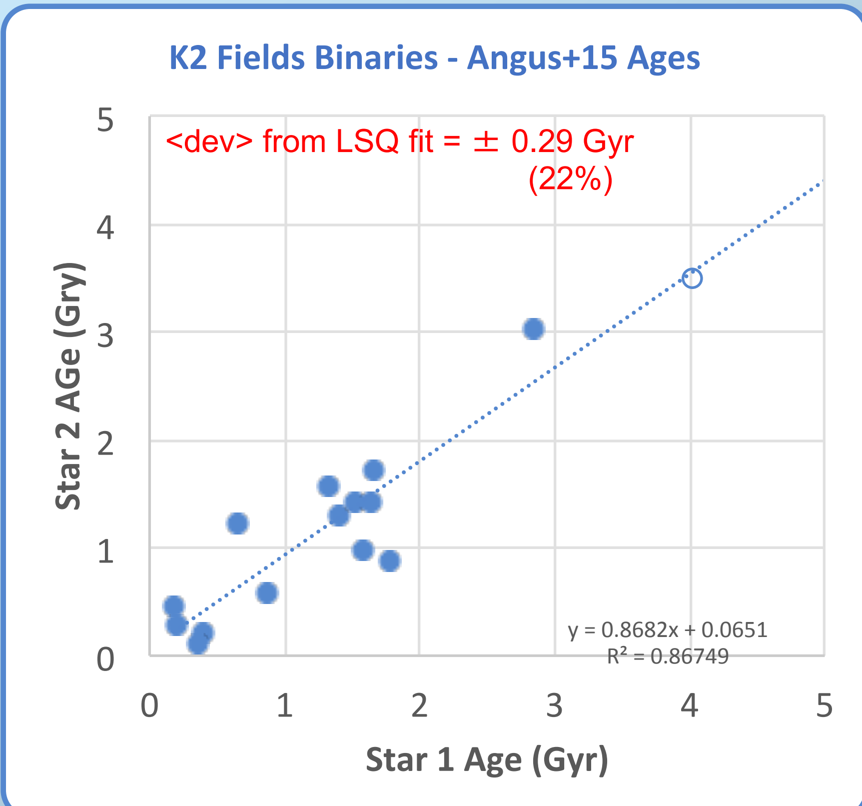
Fragile Binaries in the K2 C5, C6, C7, C12 Fields

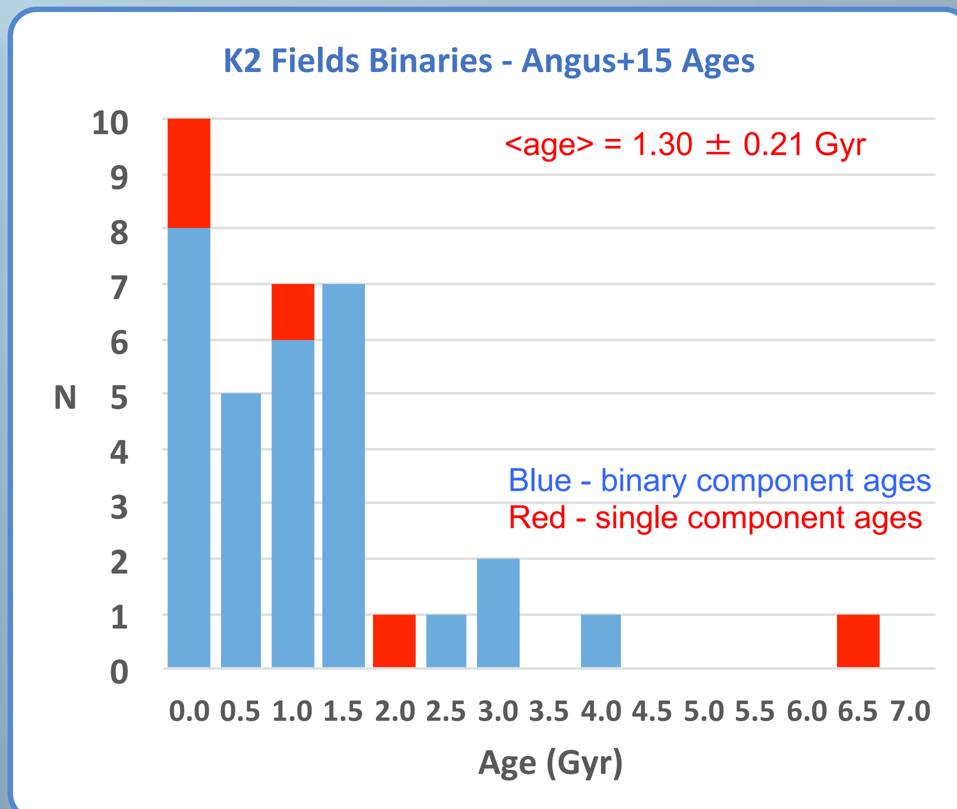
~340 pairs; 99 w/ rotational modulation in at least one component BUT
Only 25 pairs w/ rotational modulation in both components and B-V data



Vetted Fragile Binaries in the K2 C5, C6, C7, C12 Fields
Angus+15 models

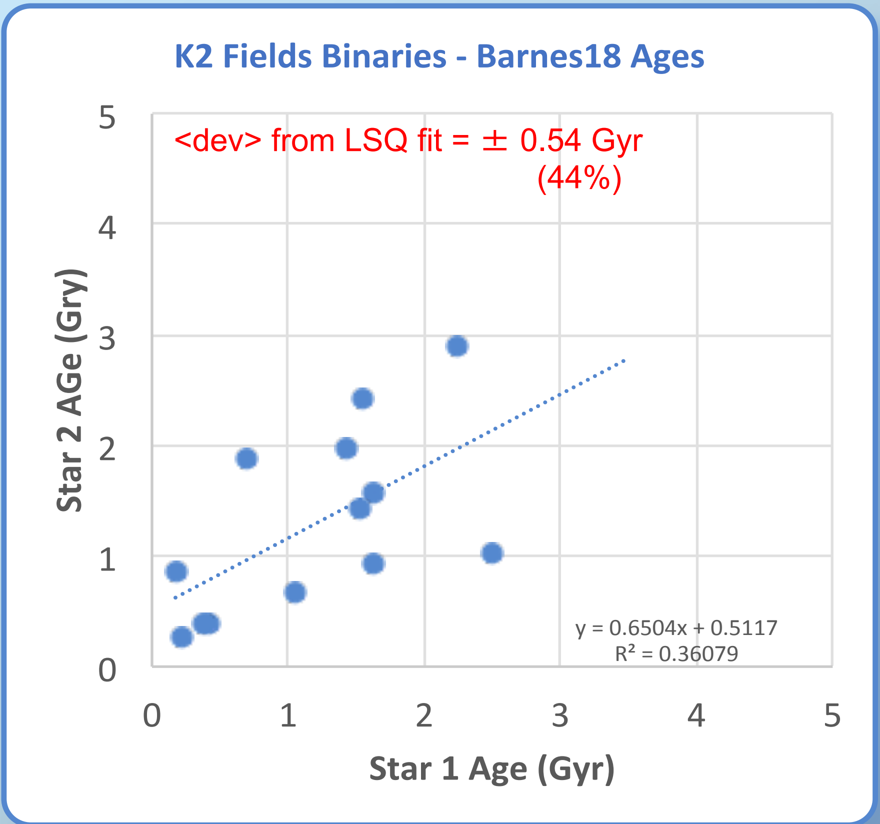
Consistent proper motions
B-V, *g-r*, *r-i* colors from MAST archive
No evolved components (checked via colors & RPM diagram)
No color index anomalies (i.e. unresolved tertiary components)
Expect a "young" sample due to K2 time window of ~80 days
Yield: 18 "vetted" pairs with *0.5 < B-V < 1.5*
15/18 = 83% with consistent ages

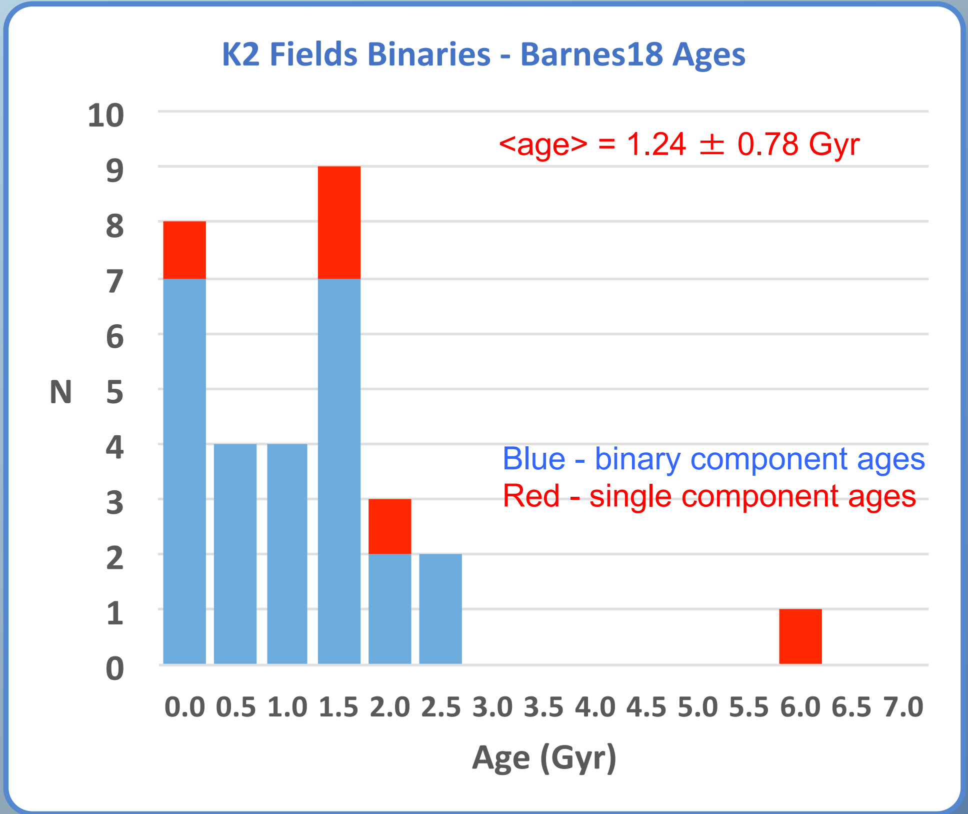




Vetted Fragile Binaries in the K2 C5, C6, C7, C12 Fields Barnes18 models

Consistent proper motions
B-V, g-r, r-i colors from MAST archive
No evolved components (checked via colors & RPM diagram)
No color index anomalies (i.e. unresolved tertiary components)
Expect a “young” sample due to K2 time window of ~80 days
Yield: 18 “vetted” pairs with *0.5 < B-V < 1.5*
<u>12/18 = 67% with consistent ages</u>





CONCLUSIONS

1. The Janes (2017) Kepler binary sample has provided very useful insight on how such pairs can be used to test gyrochonology theory
2. It is very important to fully vet any prospective sample of binaries; many stars are outside the color/temperature/mass range where gyrochronology applies
3. If the K2 yield of the 4 fields searched so far (25/340 ≈ 7%) is typical, the remaining 16 fields, which contain >3300 pairs, should yield ~250 vetted pairs
4. The current work on the K2 sample suggests that carefully vetted samples of binaries can achieve ~20% precision in age estimates.
5. All the dispersion seen in the plots of secondary vs. primary ages cannot be resolved by the approaches described here: current models may need to incorporate additional variables in the period-age-mass relation

Gaia and TESS will be hugely helpful in all the above efforts!

TBD (on the observational side):

1. Rotation periods drift with spot evolution (differential rotation, latitude, size, number, cycle) – need extended ground-based and/or TESS data
2. Spectra needed for RV, [Fe/H], etc.

Thank you for listening!
Questions?

Support from NSF AST-0807919, AST-1358787, PHY-1358879 (CUR REU) and NASA NNX15AV60G, NASA/FSGC NNX15_005 is gratefully acknowledged