A New Sample for Testing Stellar Evolution: Wide Binaries

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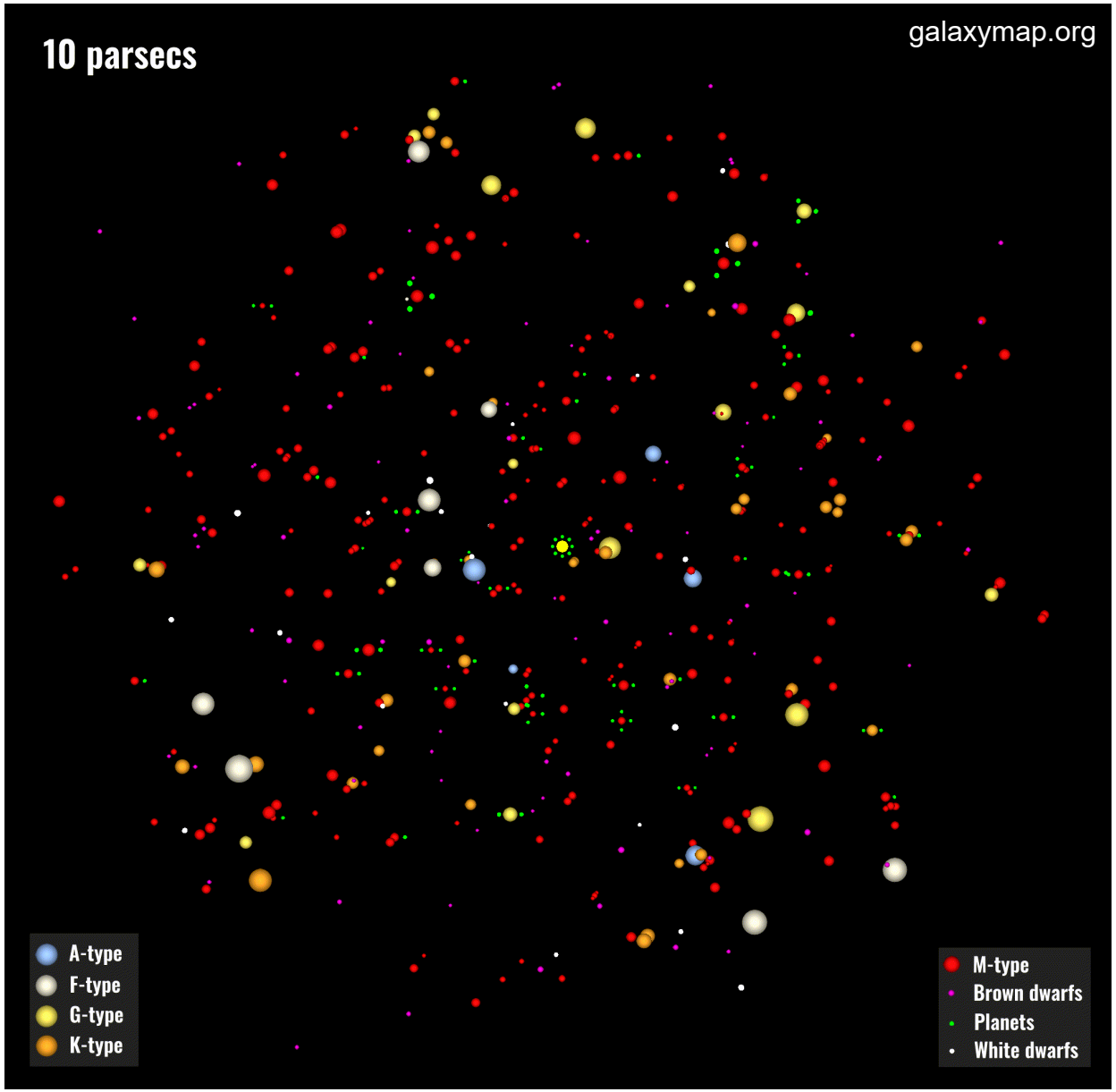
The Solar Neighborhood

10 pc Gaia Sample (Reylé et al. 2021)

- 15% FGK stars
- 61% M dwarfs
- 77 confirmed planets

Properties of stars needed:
M, R, T, Fe/H, A

- Empirical relations
- Exoplanets



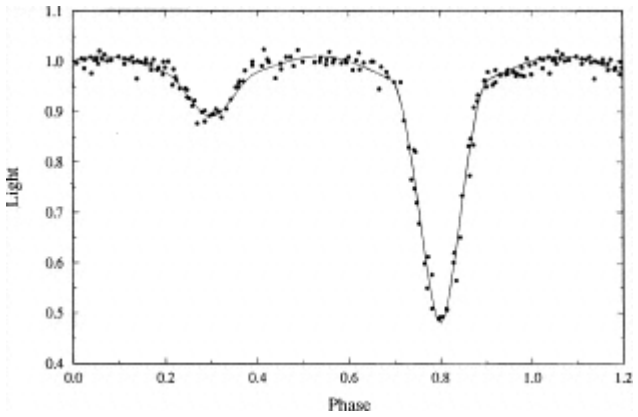
M & R from Binaries

Only way to get masses directly

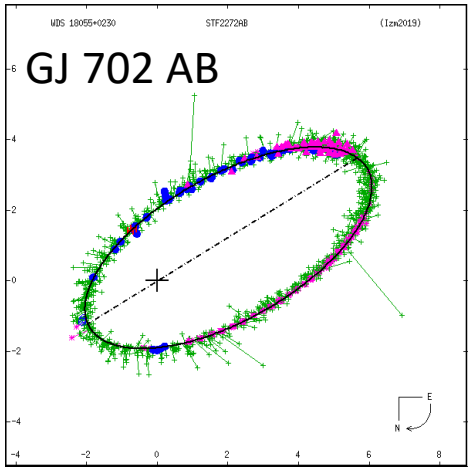
Eclipsing systems & SB2

- detached & short-period
- Precise M&R (1-2%)
- Benchmark systems

Light Curve

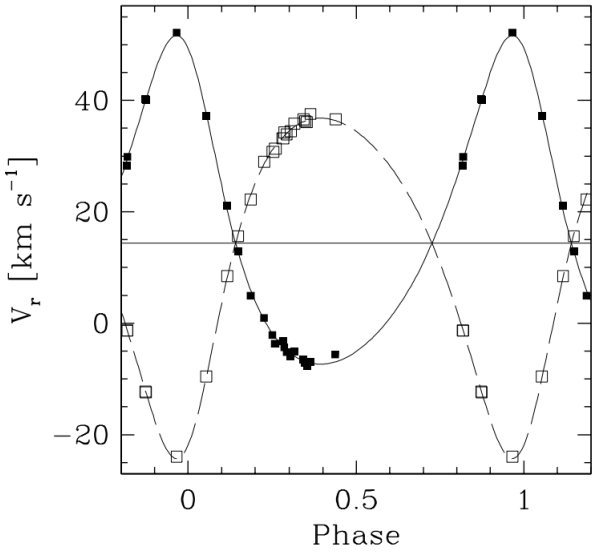


~ or ~



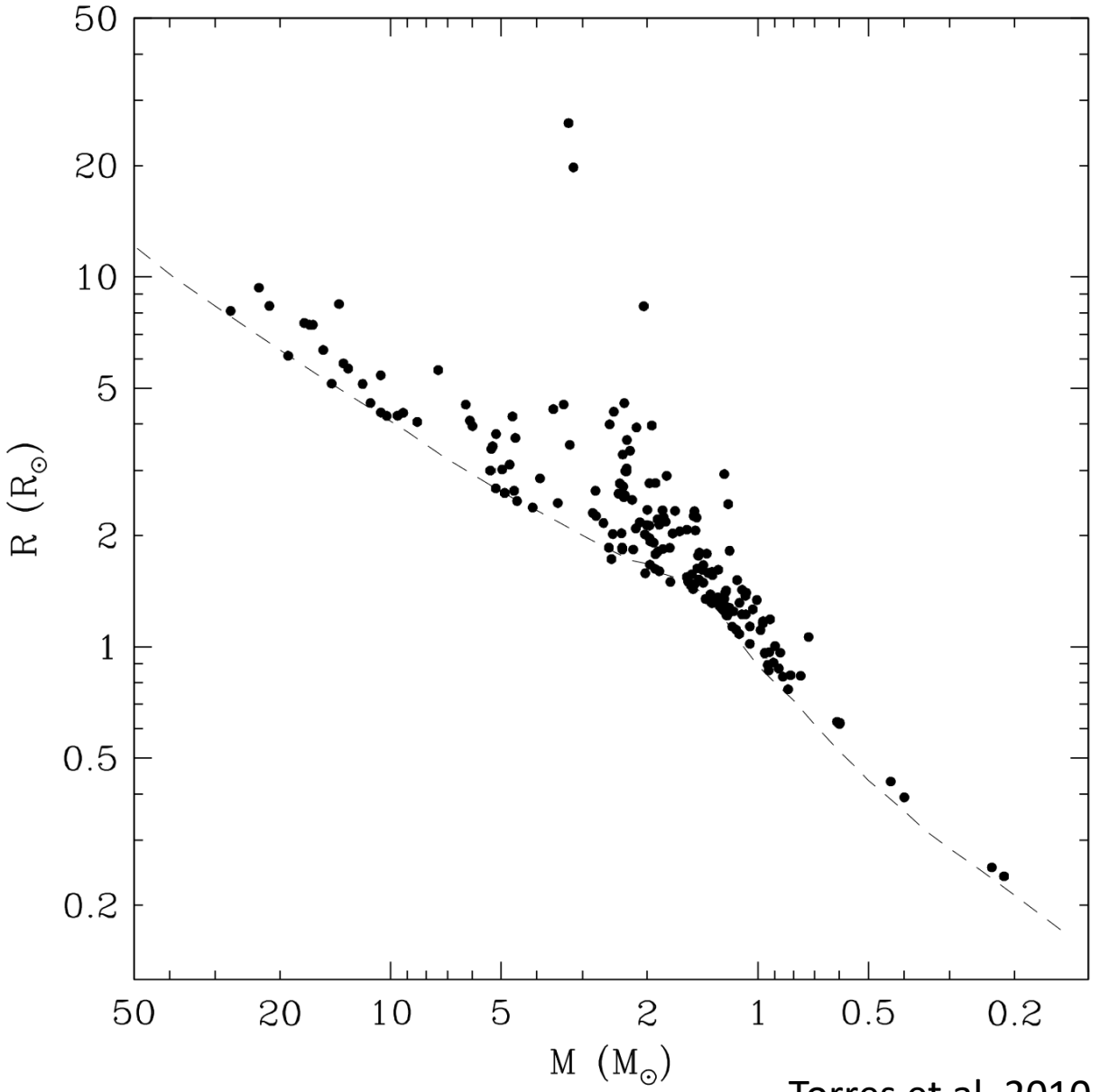
Astrometric Orbit

Radial Velocities



Samples of Fundamental Parameters

- 94 eclipsing systems + α Centauri
- M & R better than 3%
- Stellar evolution tests
- Empirical relations for MS stars > 0.6 $M_\odot$

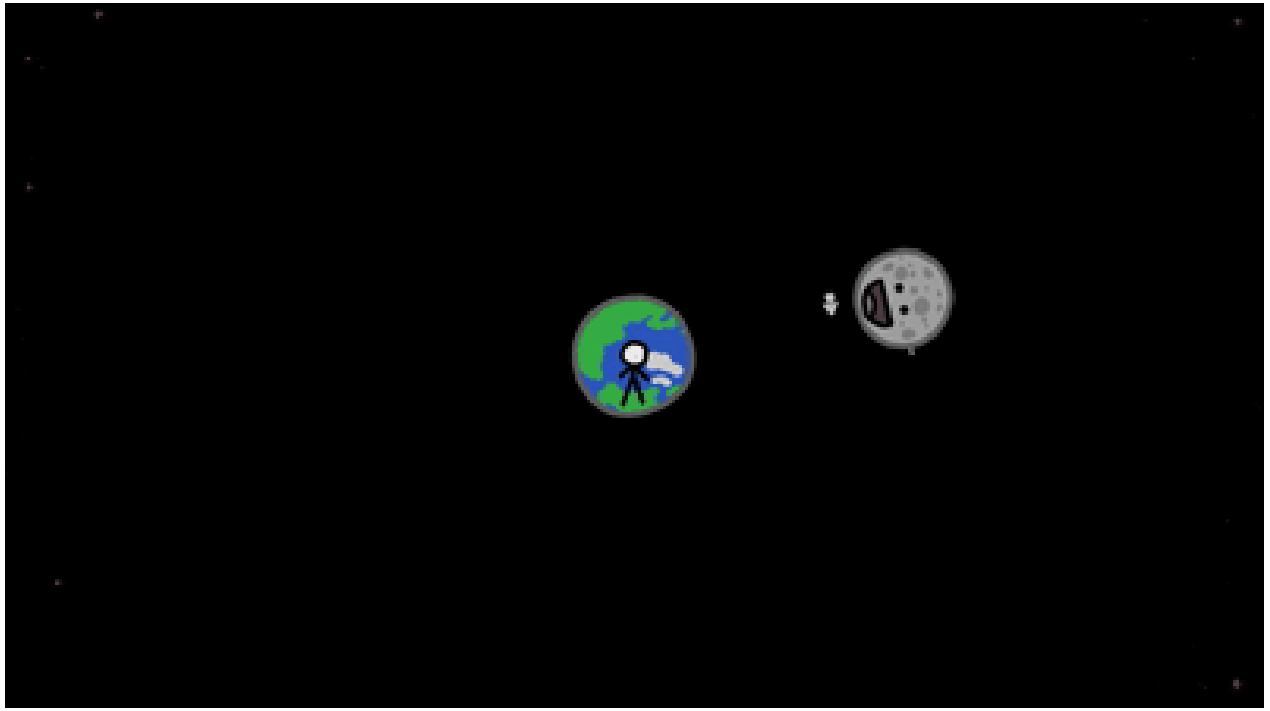


Torres et al. 2010

Radius Inflation - Tidal Interactions

- Short period
- Increased magnetic activity
- Decreased efficiency in convective energy transport
- Inflated radius

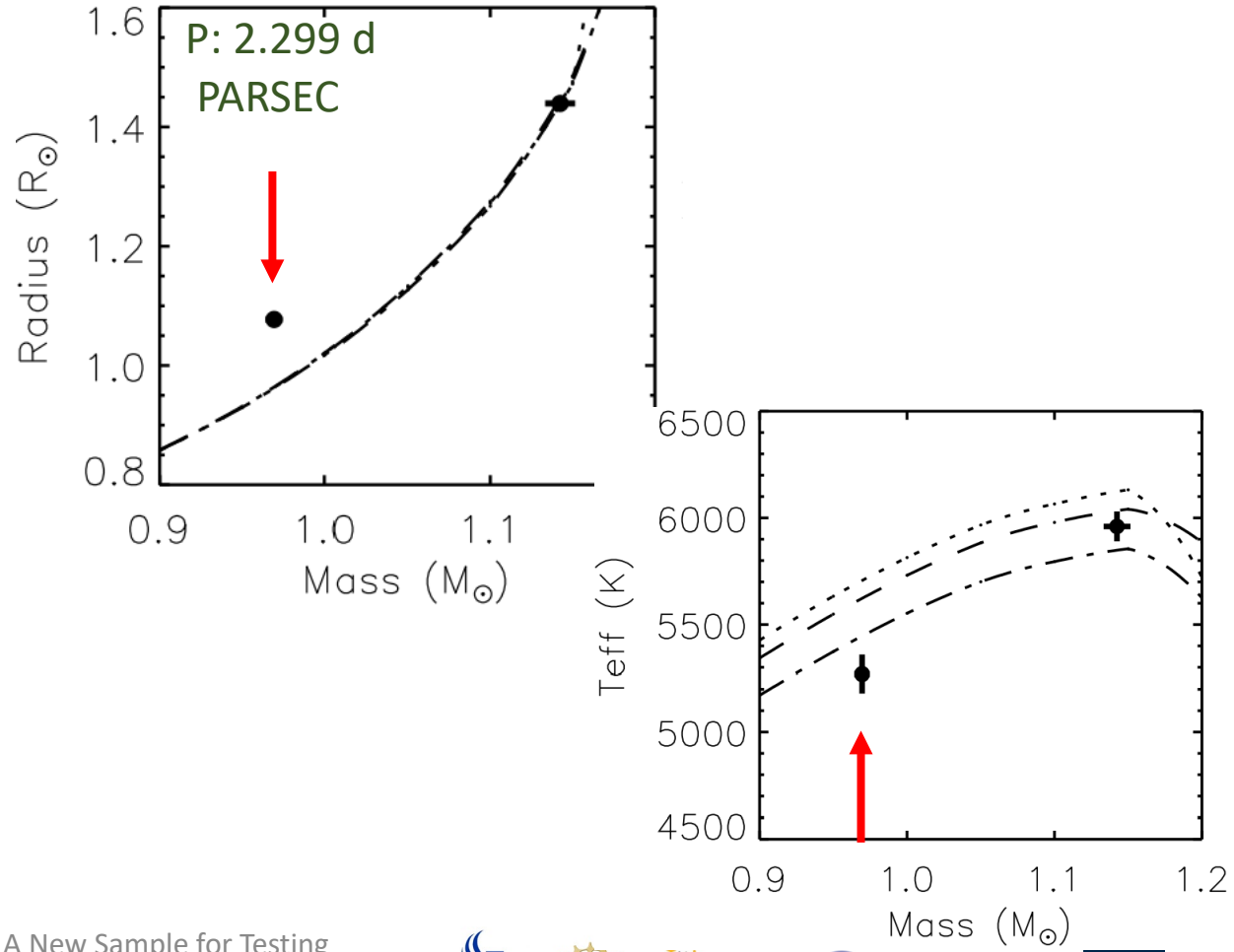
❖ Torres & Ribas 2006; Torres et. 2006, López-Morales 2007b, Kraus et al. 2011, Birkby et al. 2012, Garrido et al. 2018



Solar-like Binaries

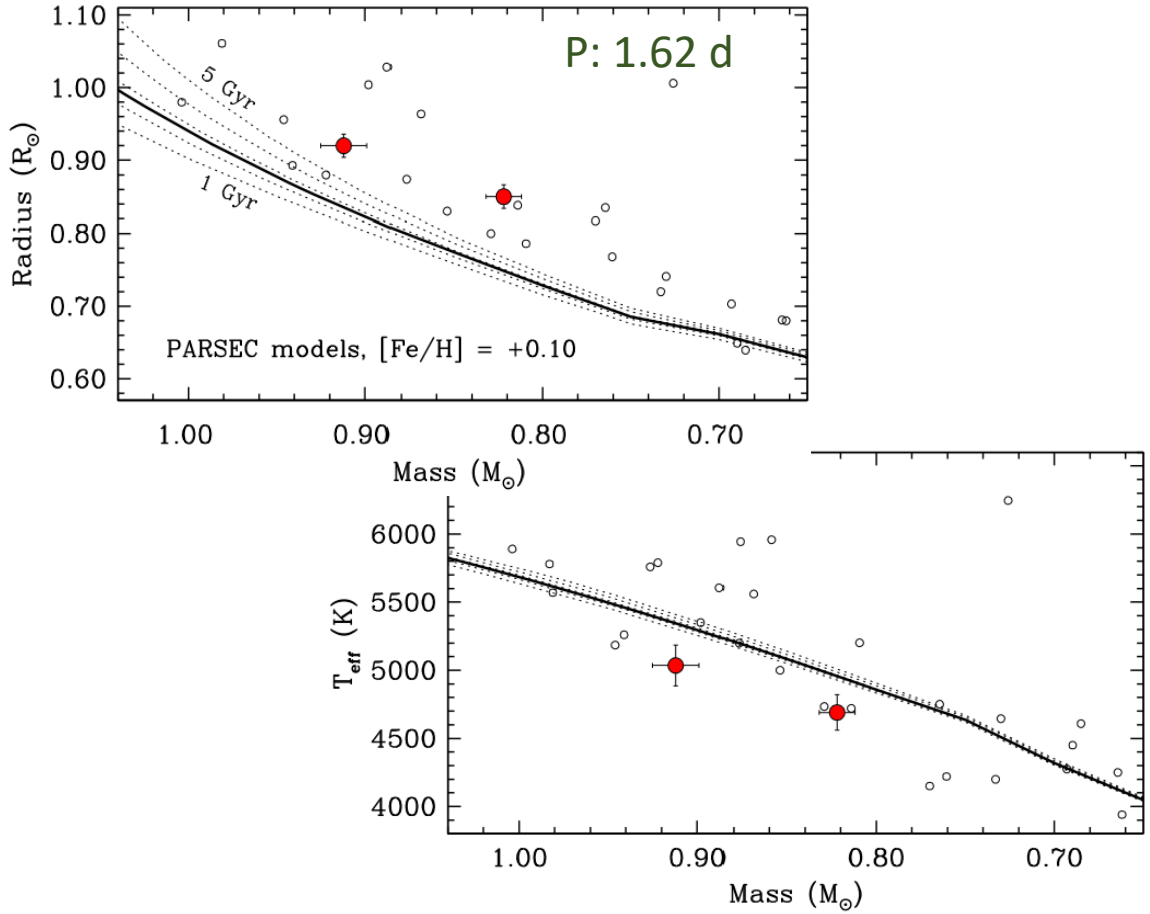
ZZ Uma (G0 + G8):

Southworth 2022



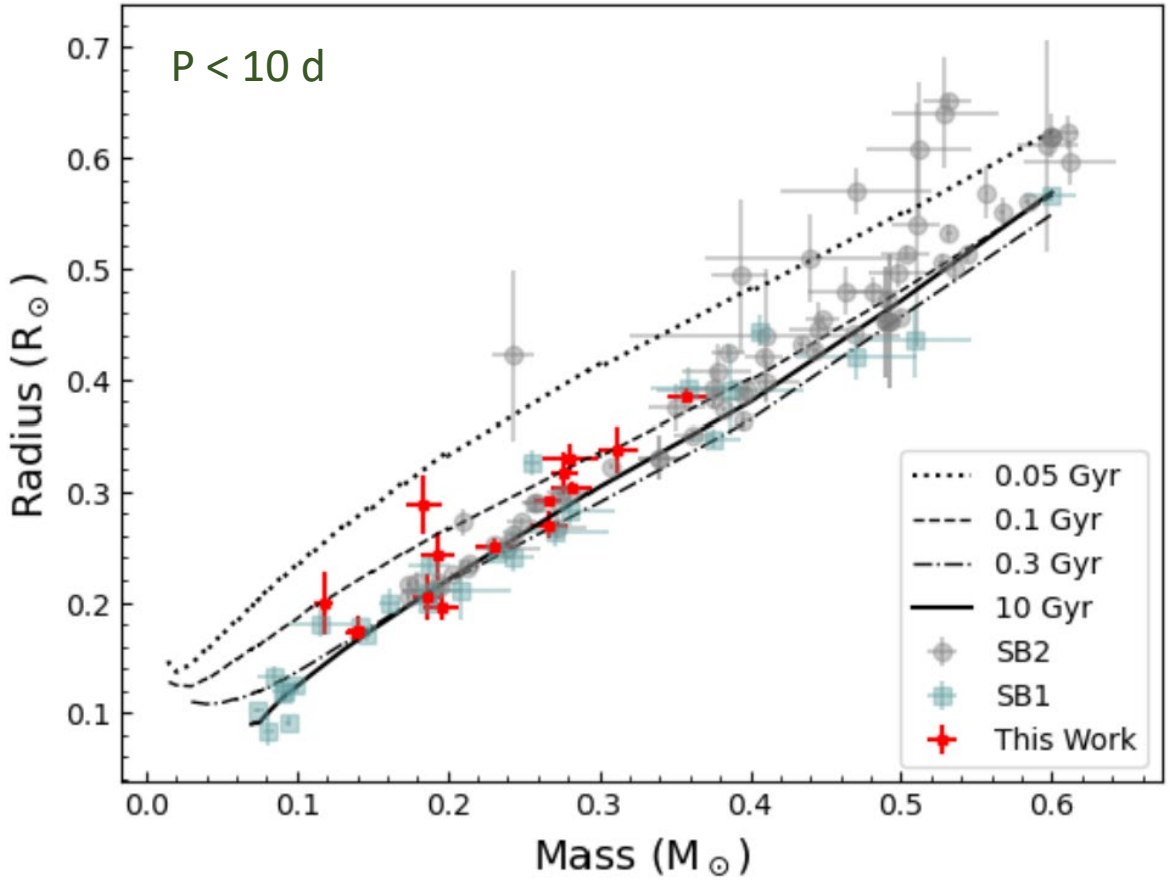
EPIC 219511354 (K type)

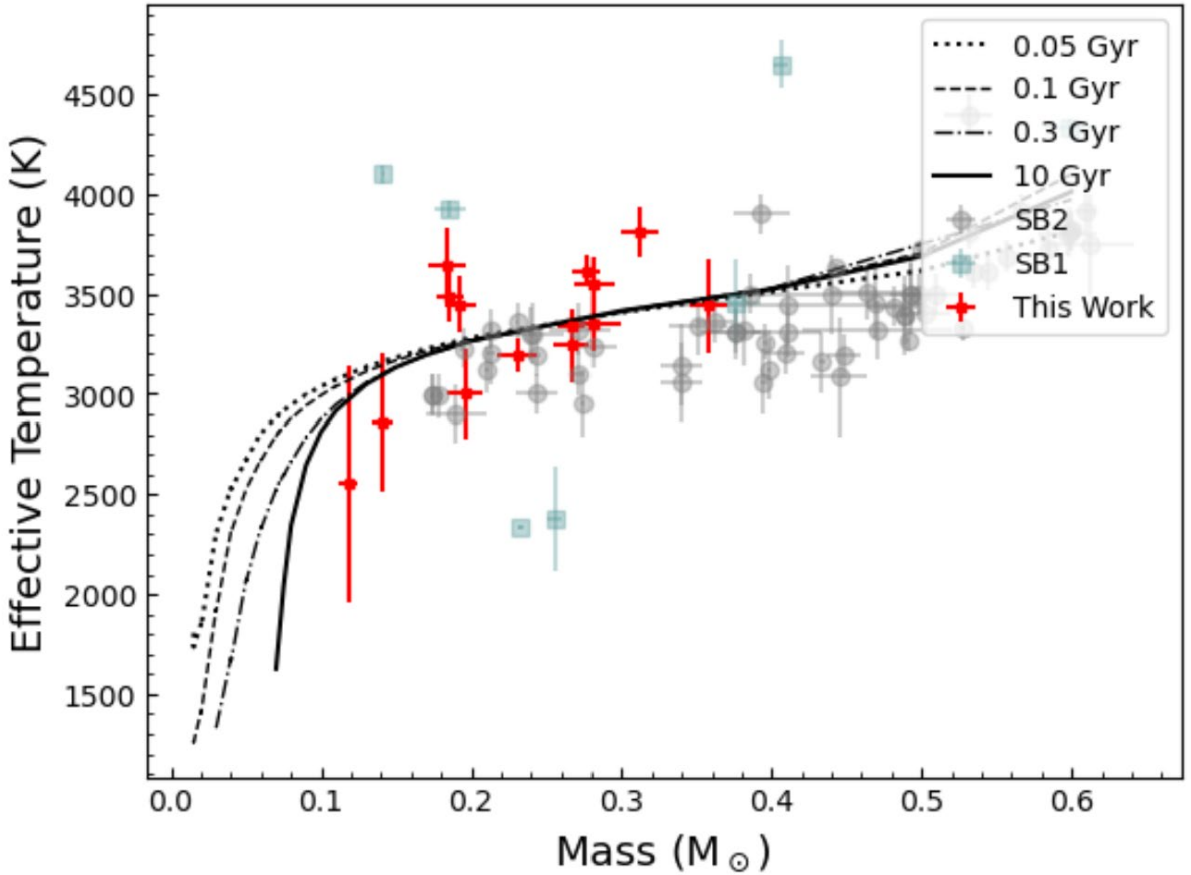
Torres et al. 2021



M dwarf Binaries

Jennings et al. 2023





All but 3 are inflated

Motivation & Research Plan

Provide a **new** sample of non-eclipsing systems

- wide systems to represent single stars & free from tidal interactions
  - wide = large separations & periods
- Remove bias of tidal interactions eclipsing systems are susceptible to

1. Use interferometry for precise angular diameters
2. Masses* from the literature
3. Test against evolution models

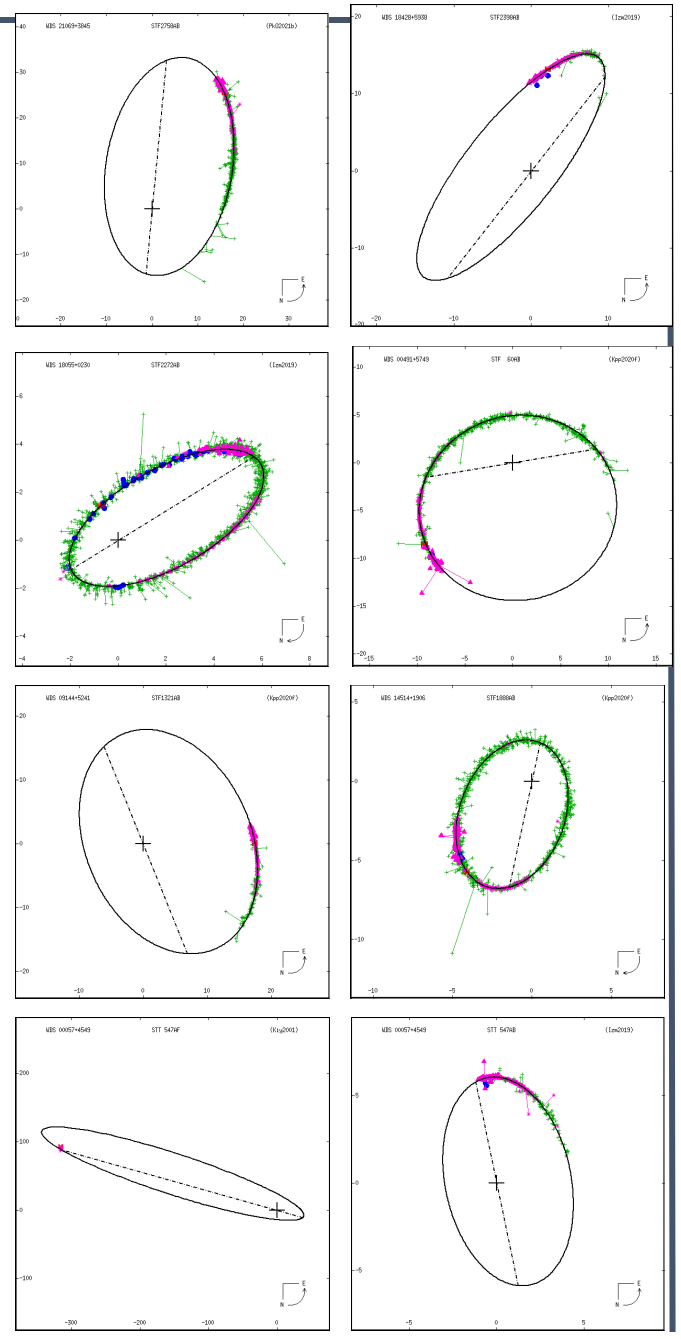
➢Sample of new, precise M&R grids for testing stellar evolution models

Sample of Wide Binaries from WDS

Washington Double Star Catalog

- δ > -20˚
- D < 12.5 pc
- V_{mag} (primary) < 10

- ρ (last meas.) ≥ 4.5“
- SpT cooler than F5



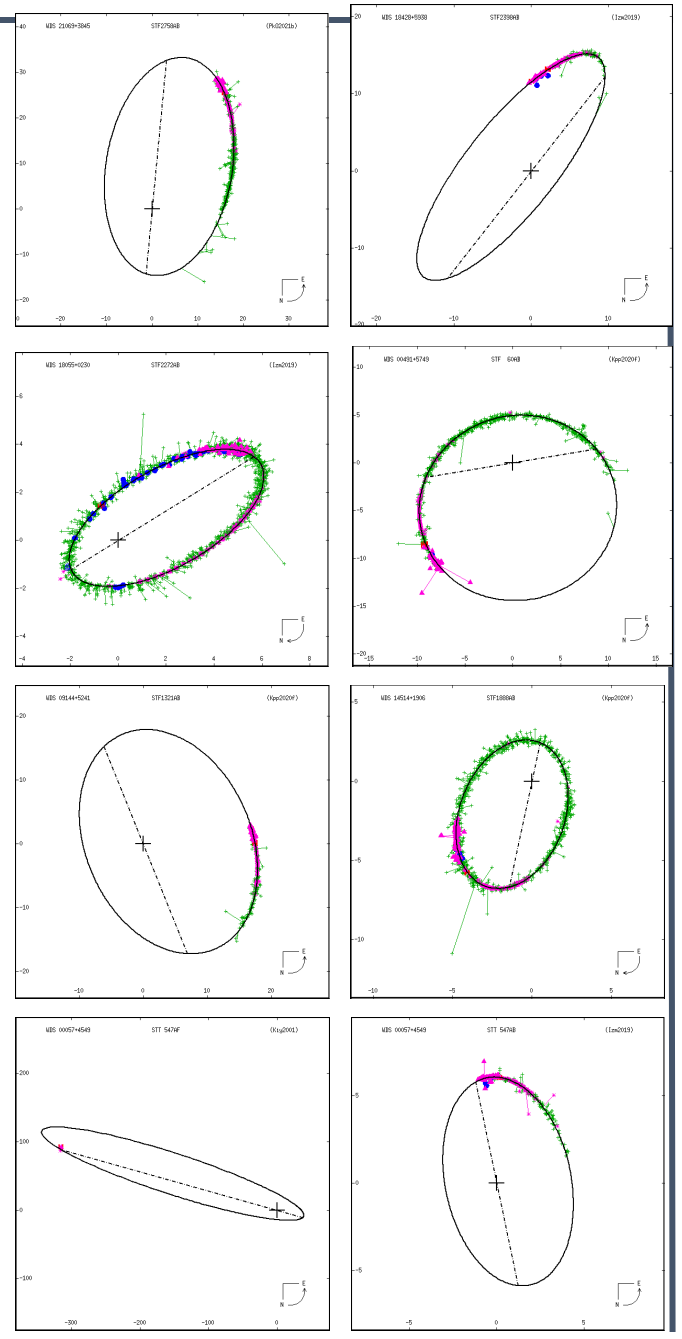
Sample of Wide Binaries from WDS

14 systems, 30 stars total

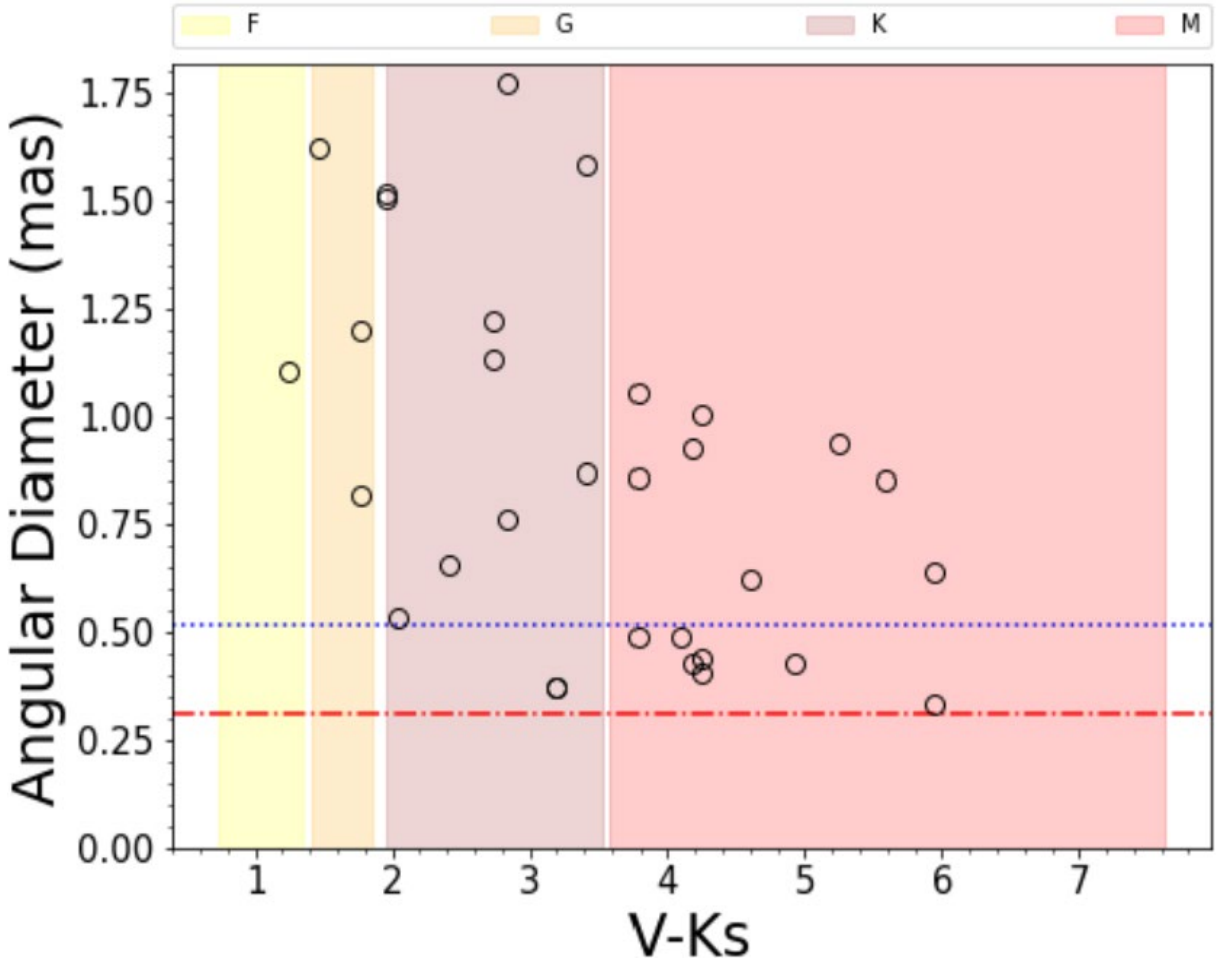
- 11 binaries, 2 triples, 1 quadruple
- exclude WD GJ 166 B and BD GJ 570 D

P: 309 days to several hundred years

H = 2.0-6.9 mag



Angular Diameters of Stars with Mass Information

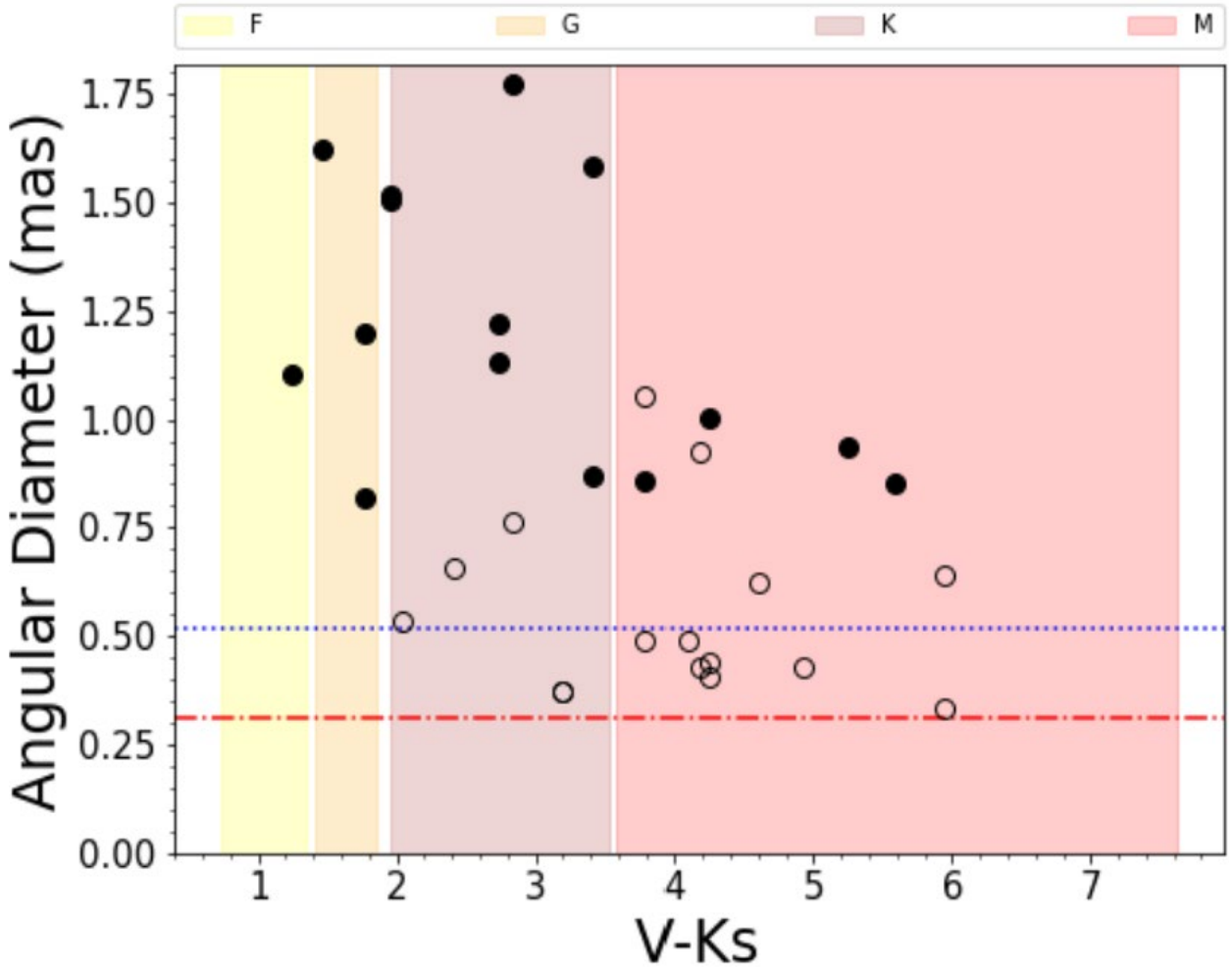


Angular Diameters of Stars with Mass Information

14 have measured angular diameters

Use relations to predict angular diameters

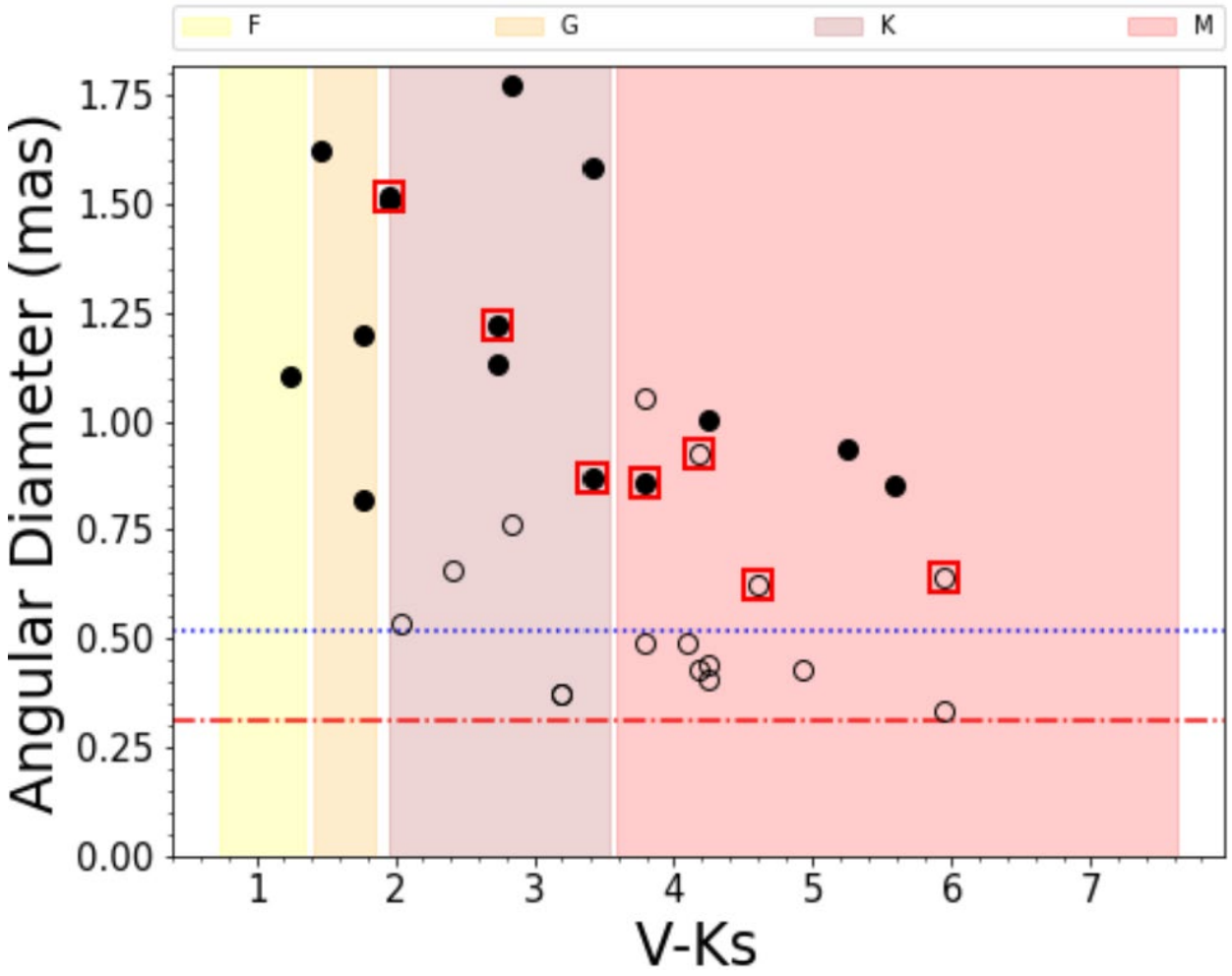
- FGK: Adams et al. 2018
- M: Mann et al. 2015



Angular Diameters of Stars with Mass Information

16 stars have mass info

- individual masses: 8
- mass ratios: 6
- total mass: 2



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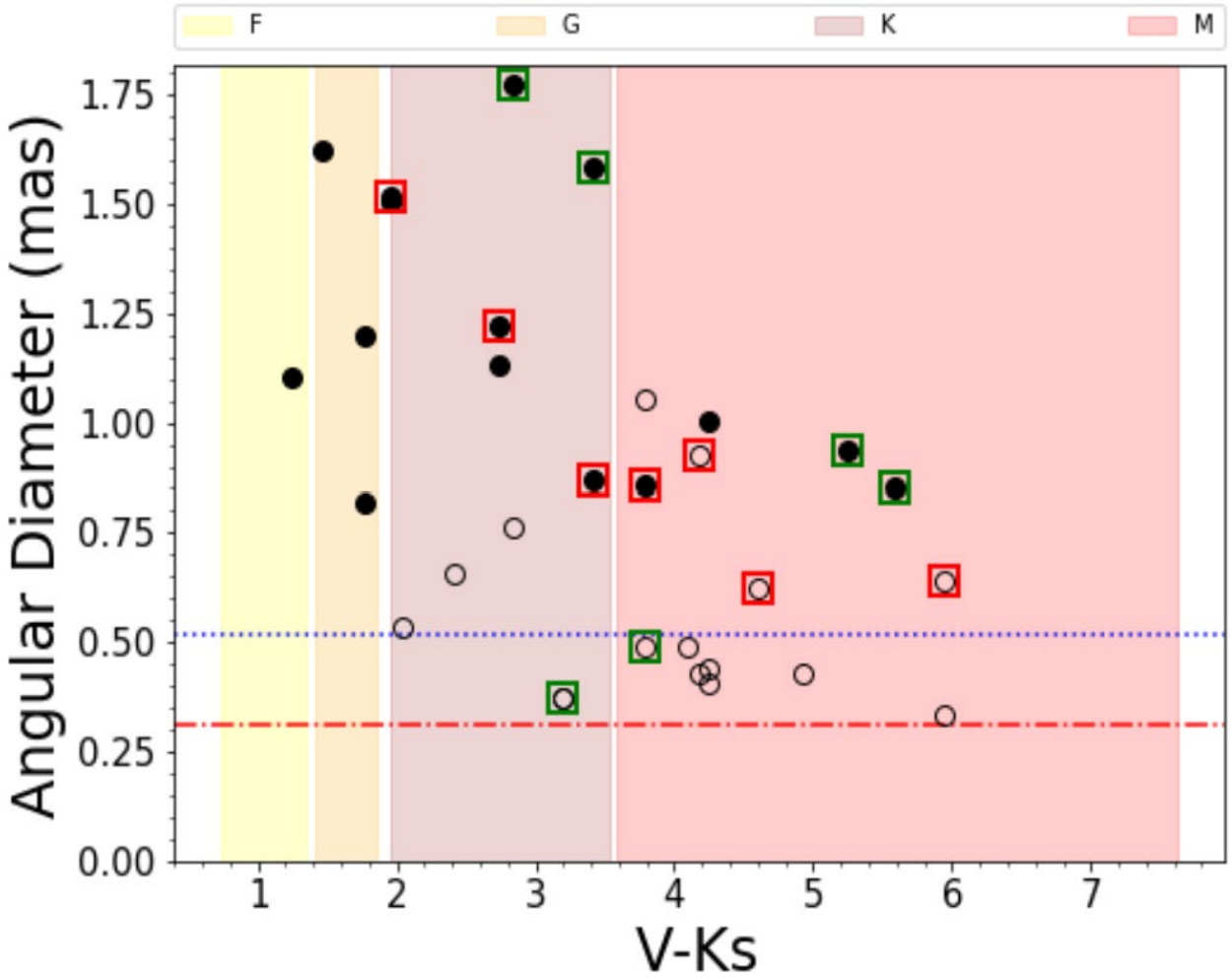

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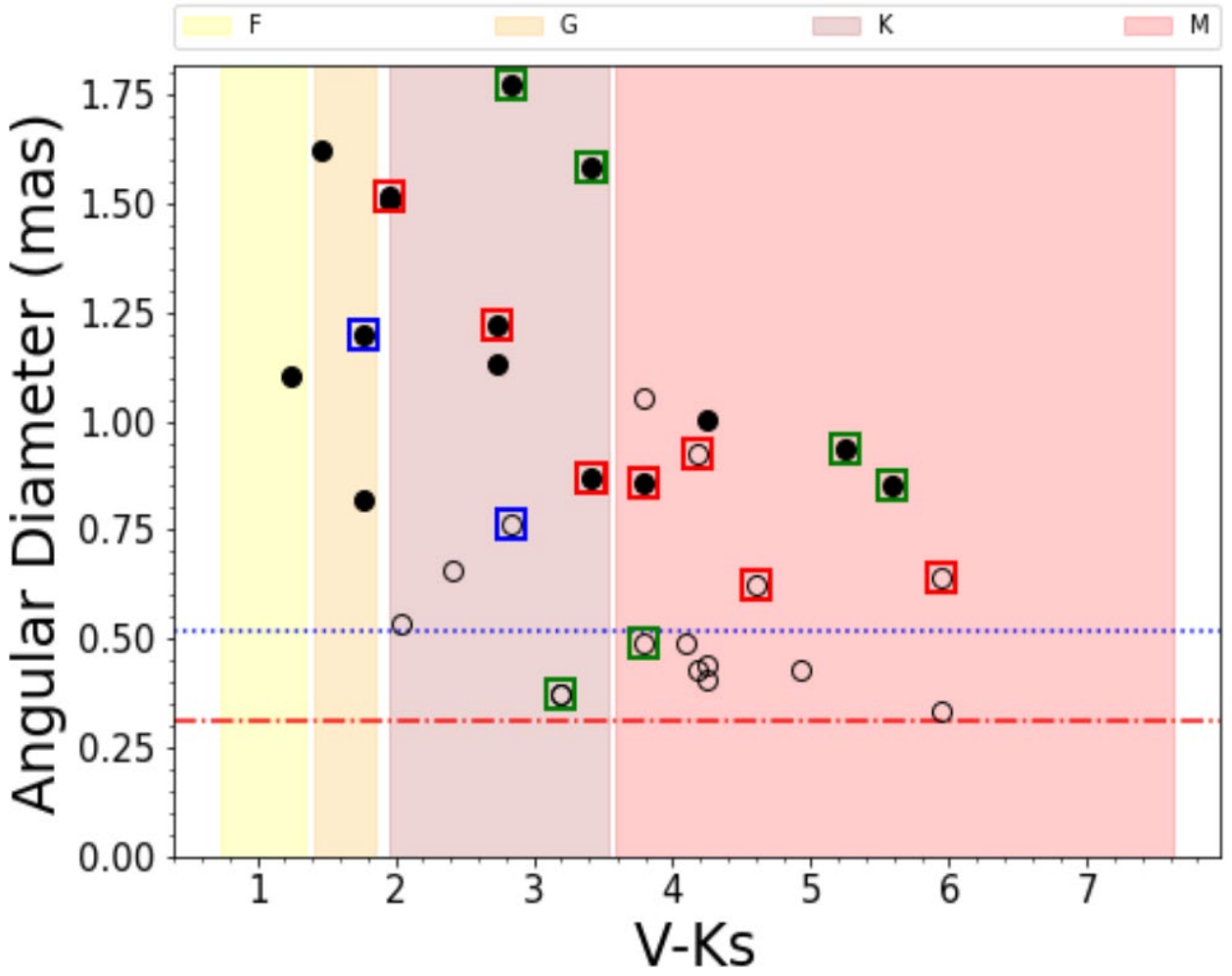
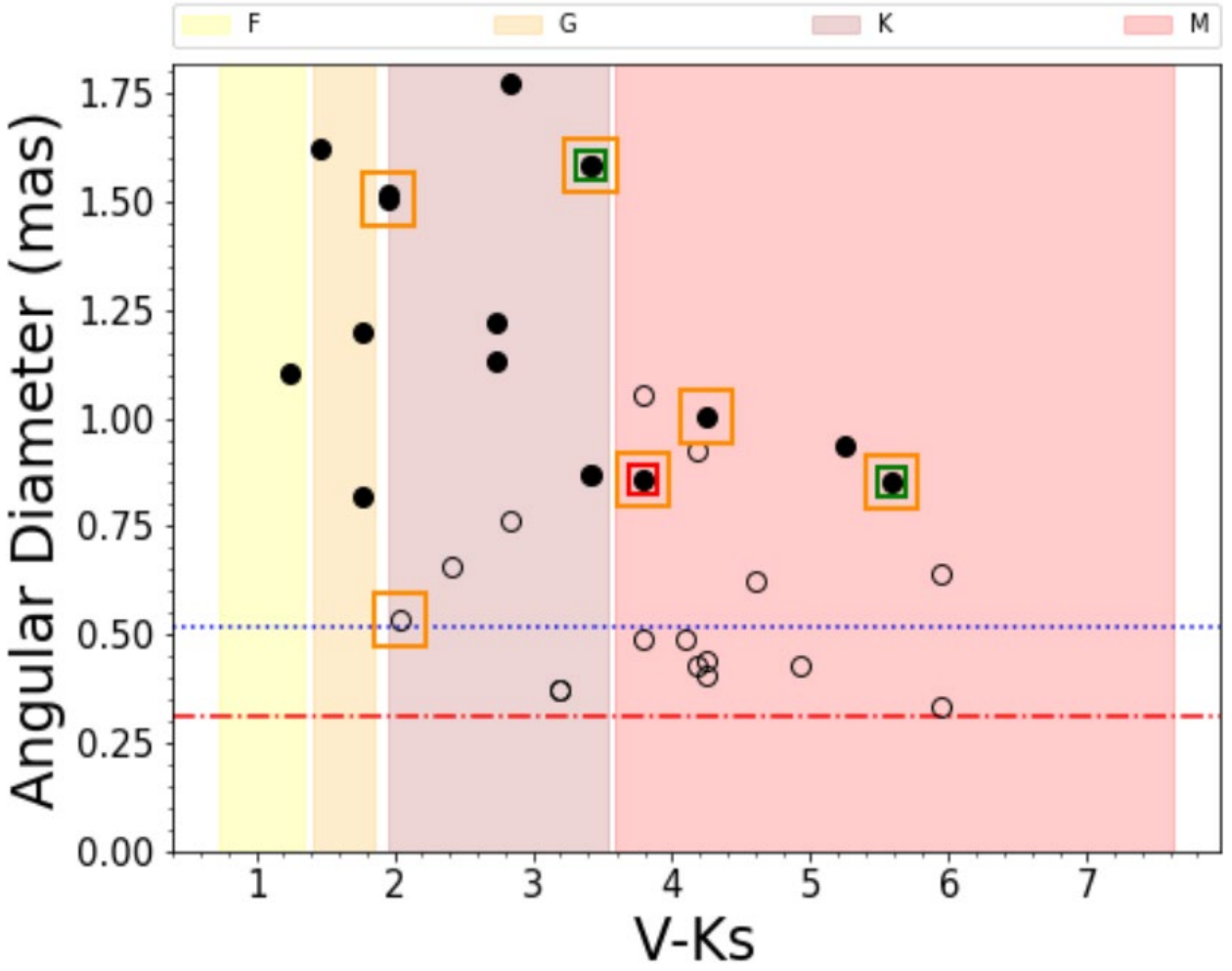


Angular Diameters of Stars with Mass Information

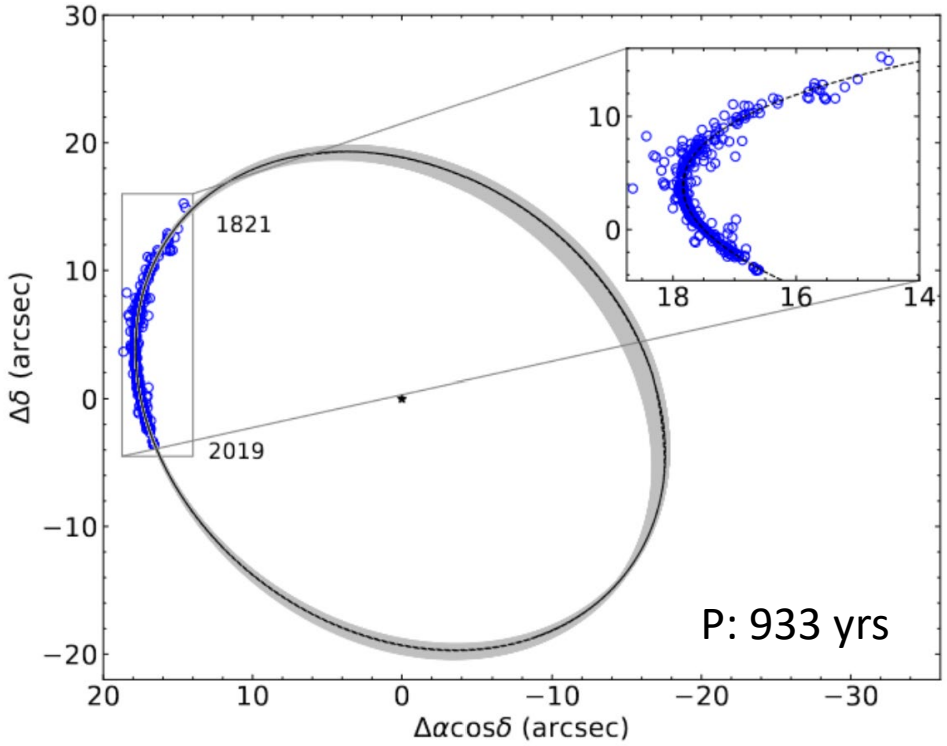
6 stars have exoplanets

- 7 planets + 1 unconfirmed

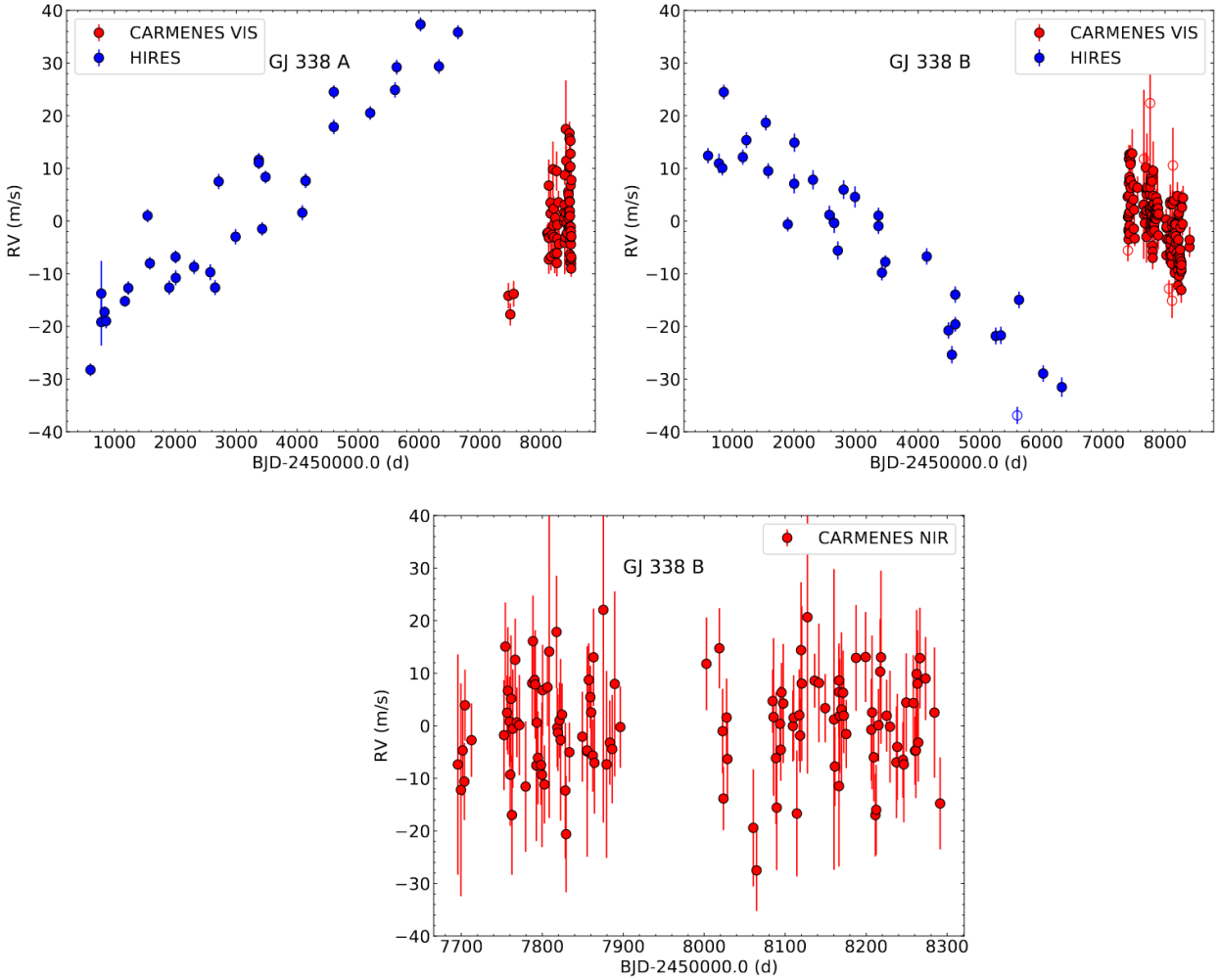


GJ 388 AB

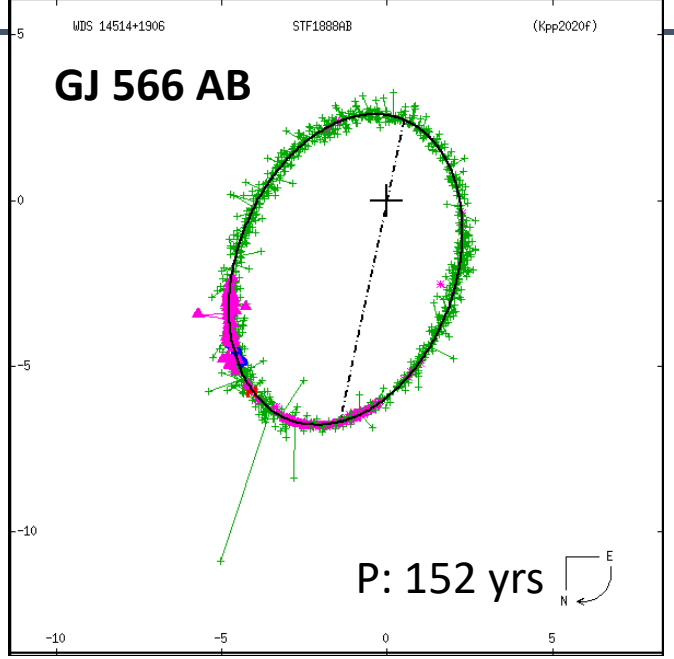
- 0.69 ± 0.07 $M_\odot$
- 0.64 ± 0.07 $M_\odot$
- 10% precision…?

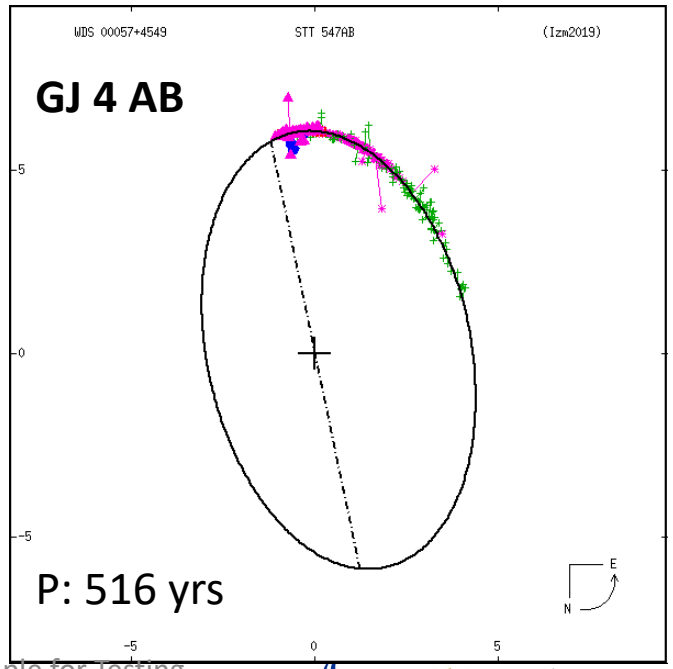


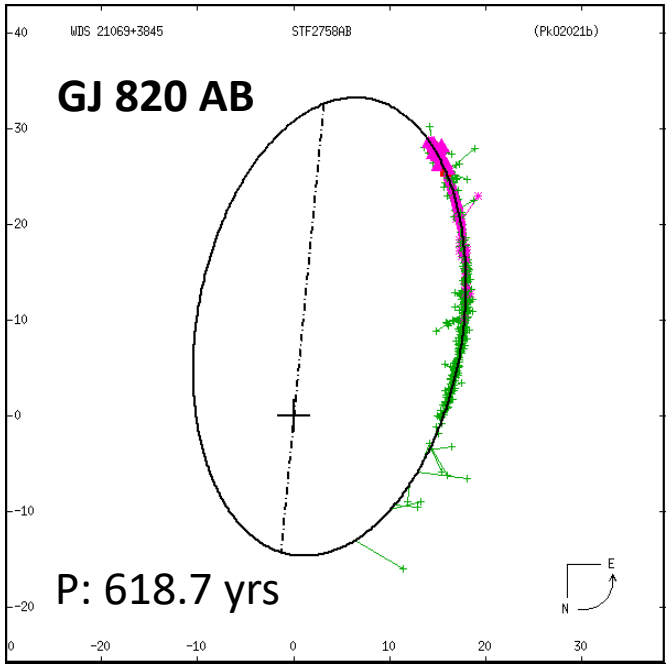
Gonzalez-Alvarez et al. 2020

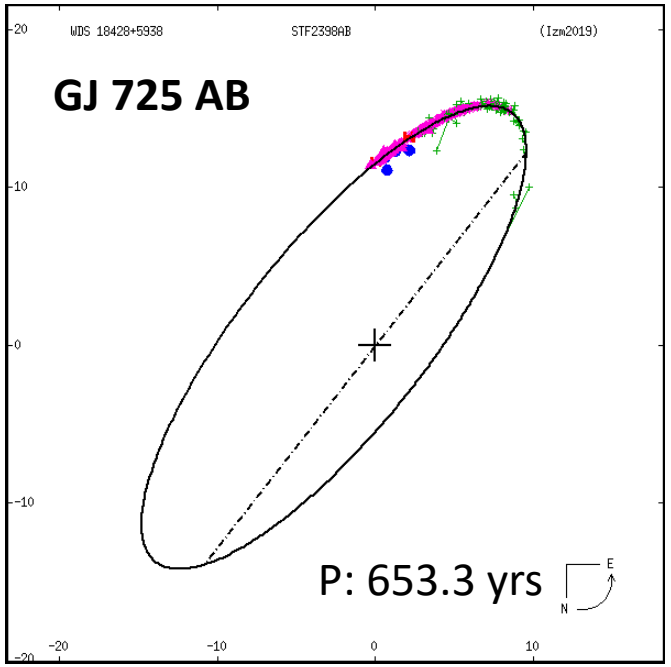


Orbits with mass information

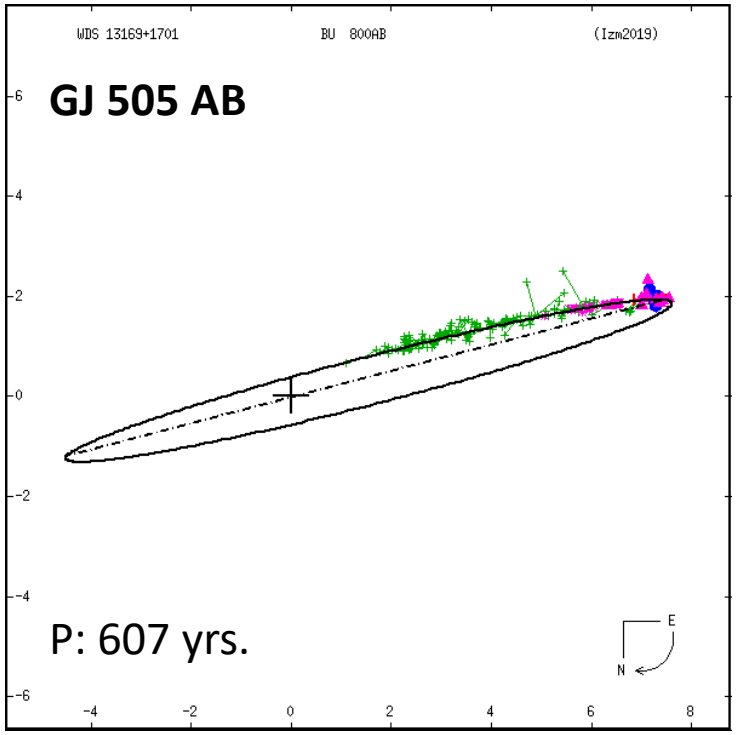


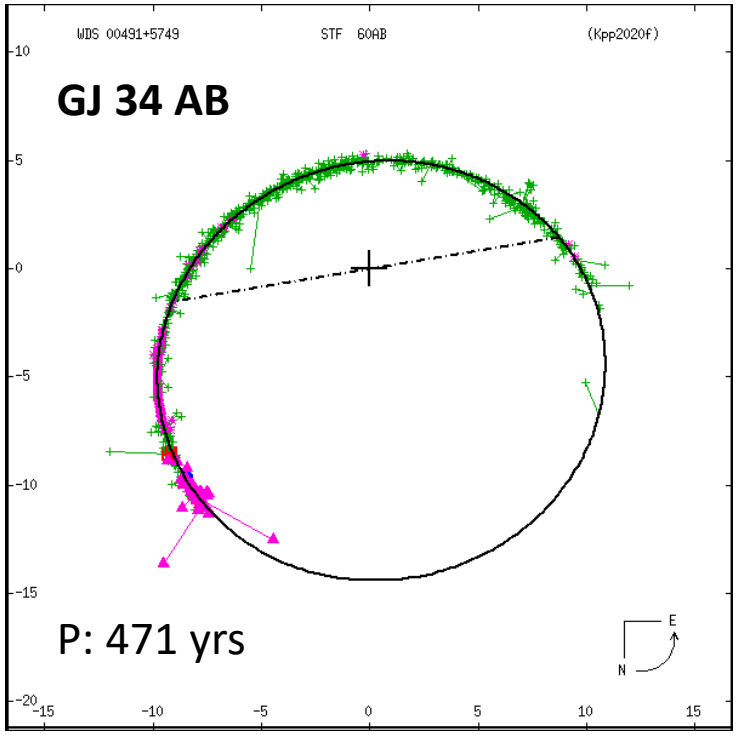


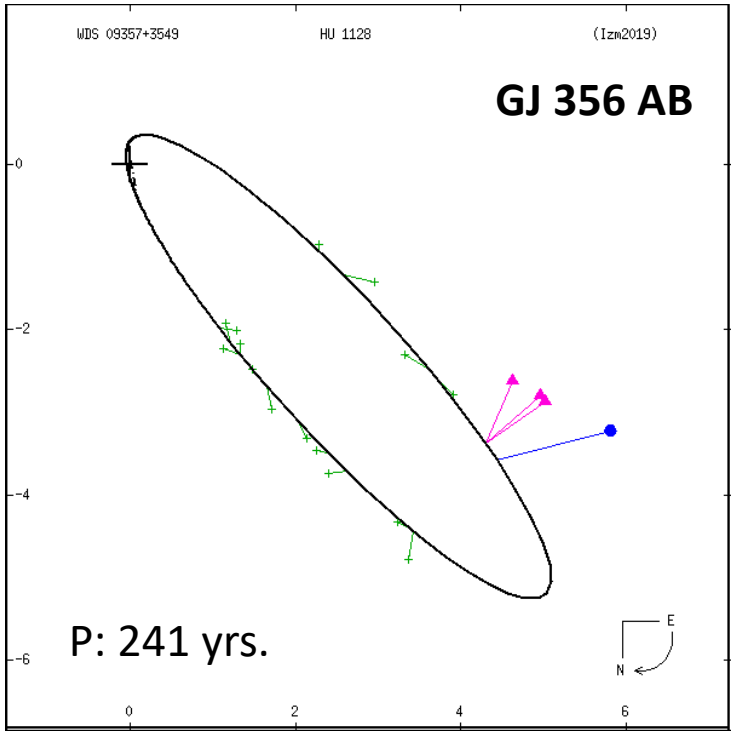




Orbits with no mass information…*yet*







Observing Plan

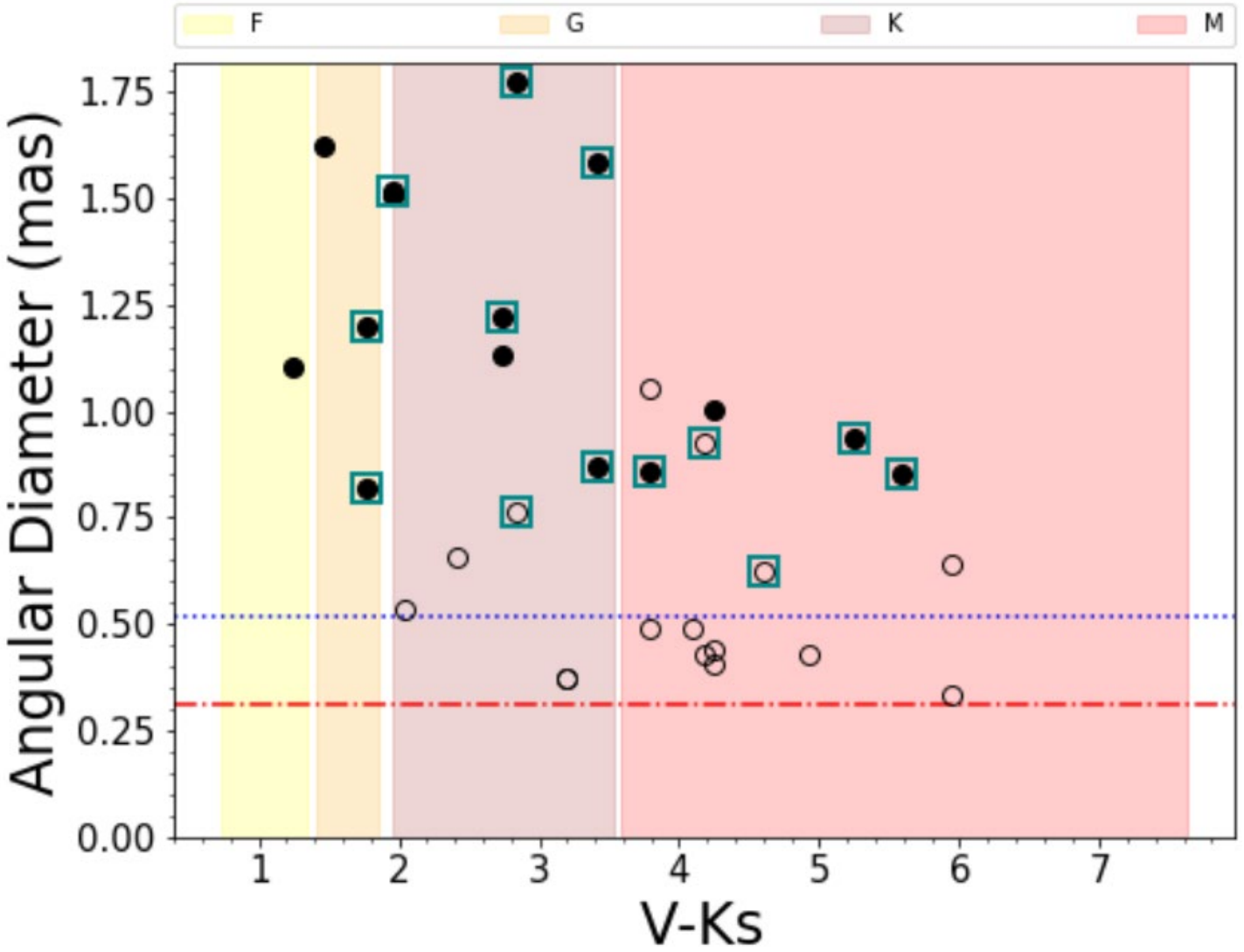
Above resolution limit:

- Use Classic &/or Mirc-X/MYSTIC
- ~19 nights

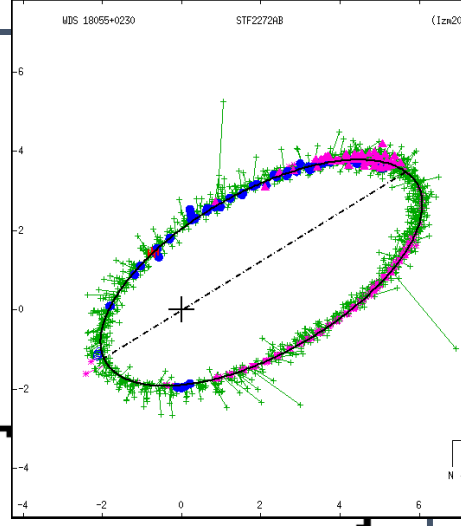
Below Resolution limit:

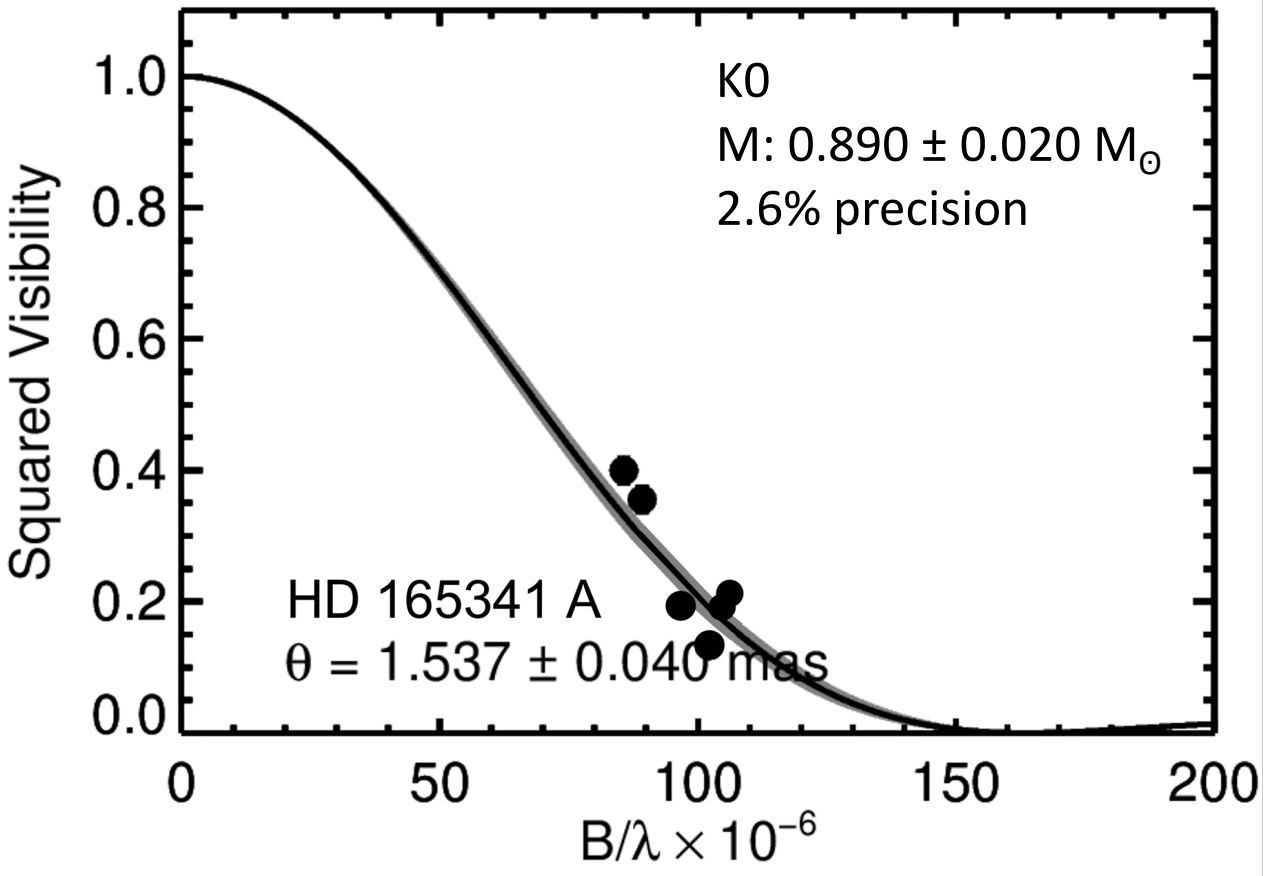
- 8 with Silmaril & Pathfinder

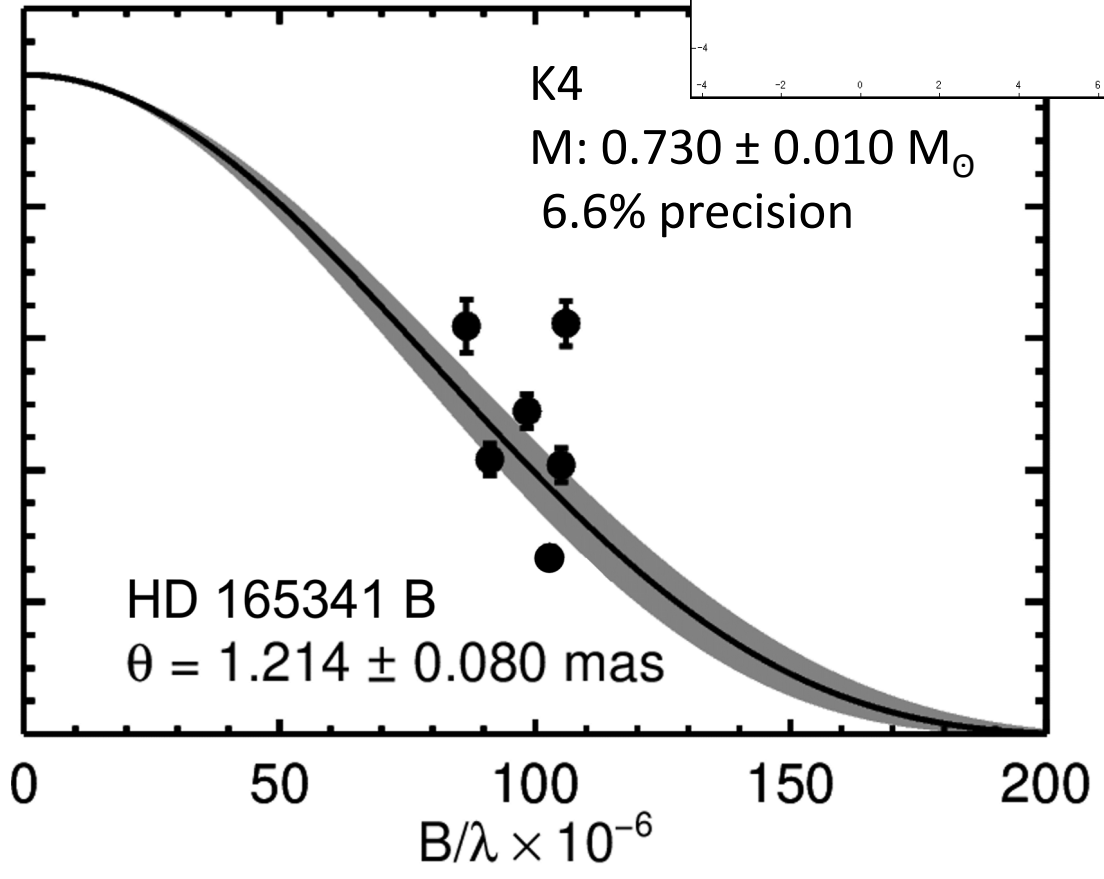
➢ Observed 6 out of 13 spring targets so far



Preliminary Result: GJ 702 AB

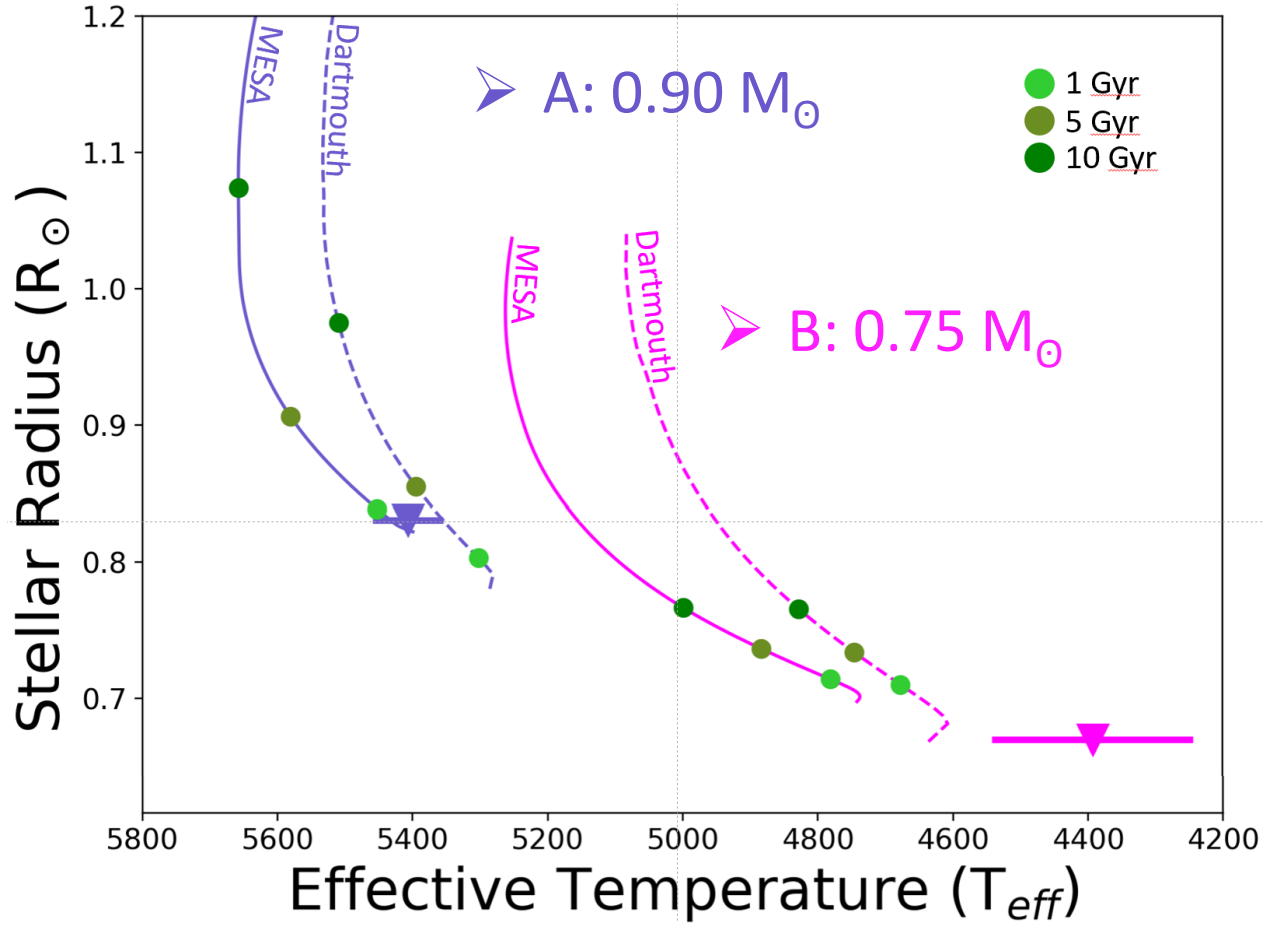






GJ 702 AB Model Comparisons

Triangles: CHARA
Boyajian et al. 2012b



- Could use a smaller mixing length parameter

(Torres et al. 2006)

Summary

- Want precise fundamental properties (M&R)
- Short period EB – tidal interactions – radius inflation
- Provide sample of ‘wide’ separation binaries to test evolution models
  - ✓ Sample created
  - ○ Measure angular diameters
    - ✓ Started observing / plan to observe
  - ○ Test against models

Sample of Wide Binaries

#	GJ	D (pc)	SpT	P (yrs) a (")	M_{sun}	θ (mas)
1	820 A	3.497	K5V	618.7	M_b/M_a =	1.78*
	820 B		K7V	25.25	0.758 ± 0.049	1.58*
2	725 A	3.523	M4V	653.3	M_b/M_a =	0.94*
	725 B		M4.5V	19.84	0.544 ± 0.030	0.85*
3	15 A	3.562	M1V	1226	[0.59]	1.01*
	15 B		M3.5V	26.95		0.43
4	166 A	5.008	K0V	[84.00]	Und.	1.504*
	166 B		DA2.9	233.2	0.573 ± 0.018	<0.1
	166 C		M4.5V	6.888	0.204 ± 0.006	0.64
5	702 A	5.113	K0V	88.40	0.89 ± 0.02	1.52*
	702 B		K4V	4.550	0.73 ± 0.01	1.22*
6	34 A	5.923	G1V	471.3	[1.58}	1.62*
	34 B		M0V	11.90		1.05
7	570 A	5.886	K4V	[86.80]	Und.	1.13*
	570 B		M1.5V	169.3	0.586 ± 0.007	0.93
	570 C		M3V	0.151	0.390 ± 0.005	0.63
	570 D		T8	[258.0]	Und.	<0.1
8	338 A	6.334	M0V	933.0	0.69 ± 0.07	0.87*
	338 B		M0V	19.20	0.64 ± 0.07	0.86*
9	566 A	6.754	G8V	152.0	M_{tot} =	1.20*
	566 B		K5V	4.920	1.59 ± 0.011	0.76
10	250 A	8.747	K3V	Und.	Und.	0.66
	250 B		M2V	[65.20]		0.44
11	505 A	10.99	K1V	607.0	[0.93]	0.54
	505 B		M1V	6.360		0.49
12	107 A	11.15	F7V	3327	[1.71]	1.10*
	107 B		M1.5V	23.90		0.43
13	356 A	11.23	G8V	241.0	[0.90]	0.82*
	356 B		M5V	7.180		0.33
14	4 A	11.52	K6V	516.0	M_b/M_a =	0.43
	4 B		M0V	6.170	0.996 ±	0.49
	2		M2V	..		0.41