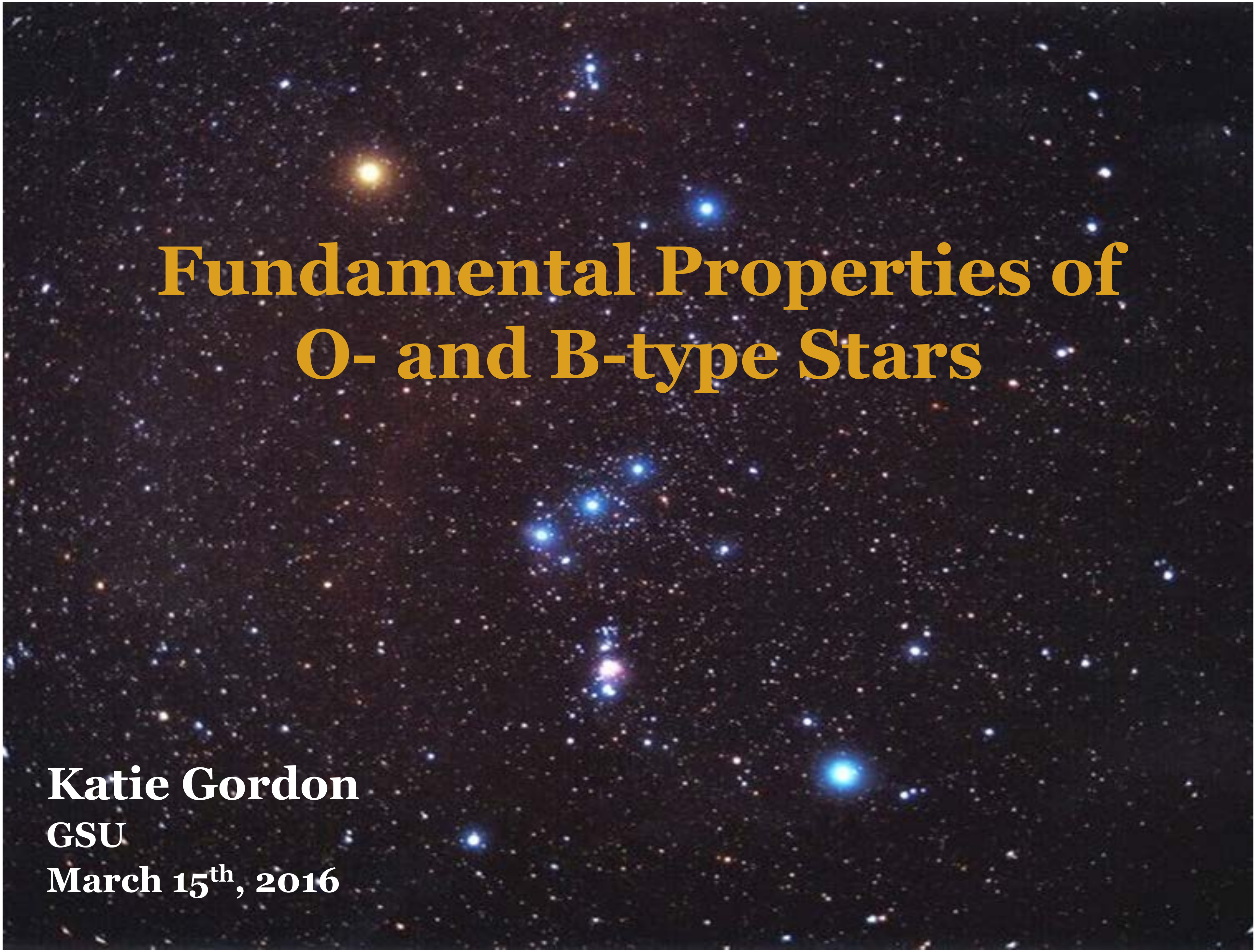
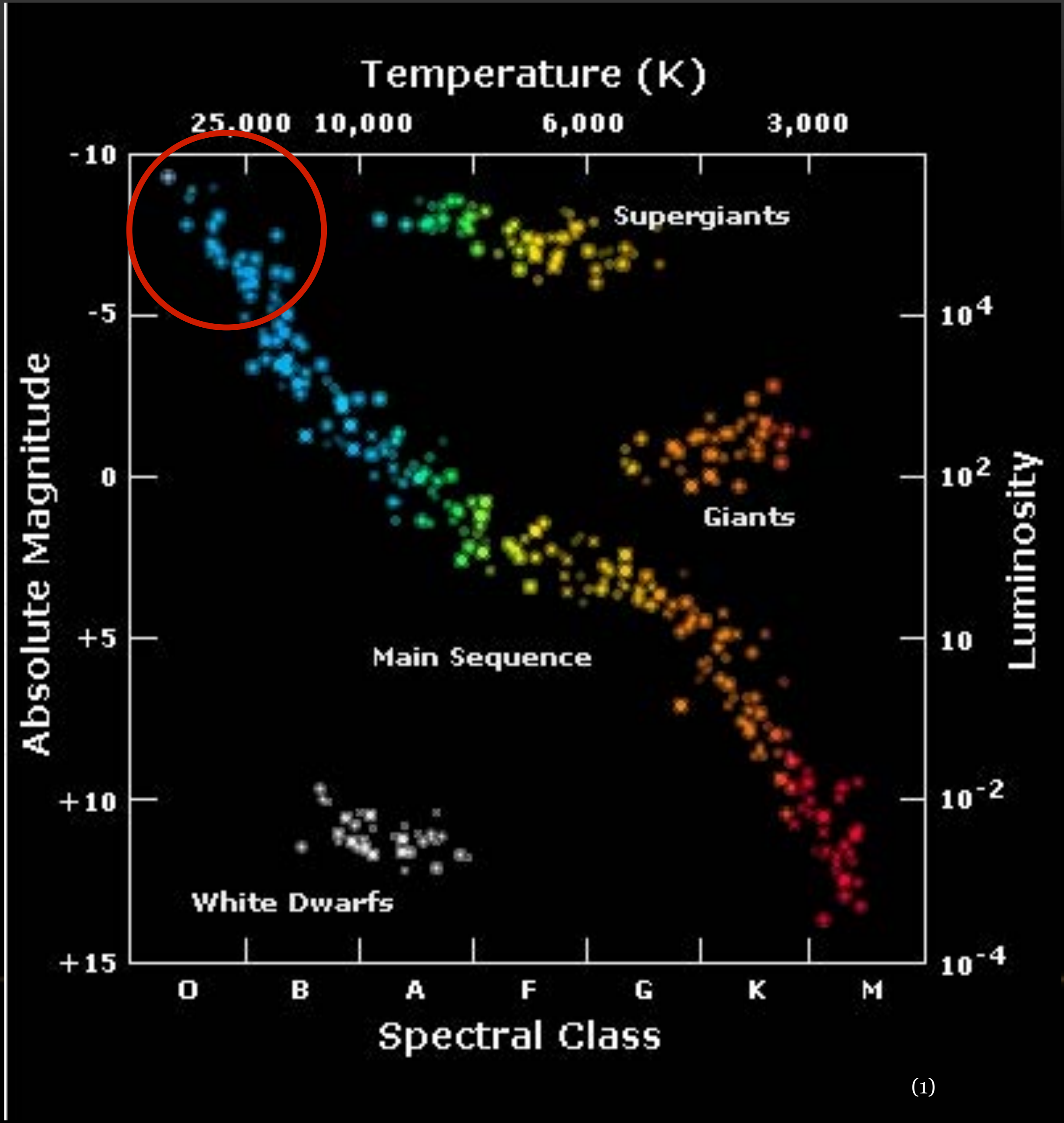


Fundamental Properties of O- and B-type Stars

Katie Gordon
GSU
March 15th, 2016

WHY DO WE CARE?



(1)

OUR SAMPLE

- Started with: 10 O stars, 189 B stars
  - ~0 to 5 mag
  - In or near galactic plane

- Narrowed down to: 10 O stars, 67 B stars
  - Use all O stars
  - B stars with Hipparcos parallax errors < 10%
  - Cluster member
  - No Be stars

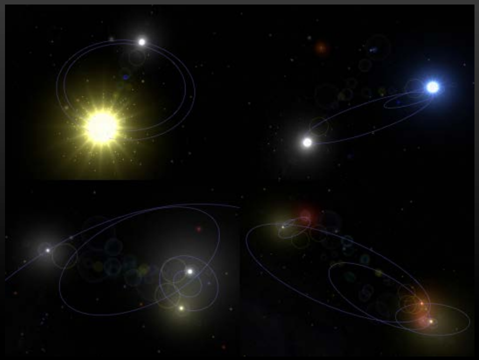
Closest O star: zeta Oph (HD 149757) - 140±14 pc
Farthest O star: alpha Cam (HD 30614) - 1900±700 pc

Closest B star: alpha And (HD 358) – 29.8±0.6 pc
Farthest B star: gamma Lyr (HD 176437) - 195±19 pc

8 B stars within 50 pc
37 B stars within 100 pc
30 B stars > 100 pc

Expected sizes: 0.2 – 1.4 mas

V: 48% IV: 17% III: 27% II: 5% I: 3%



- **Many massive stars are in binary or multiple star systems! (opportunity?)**

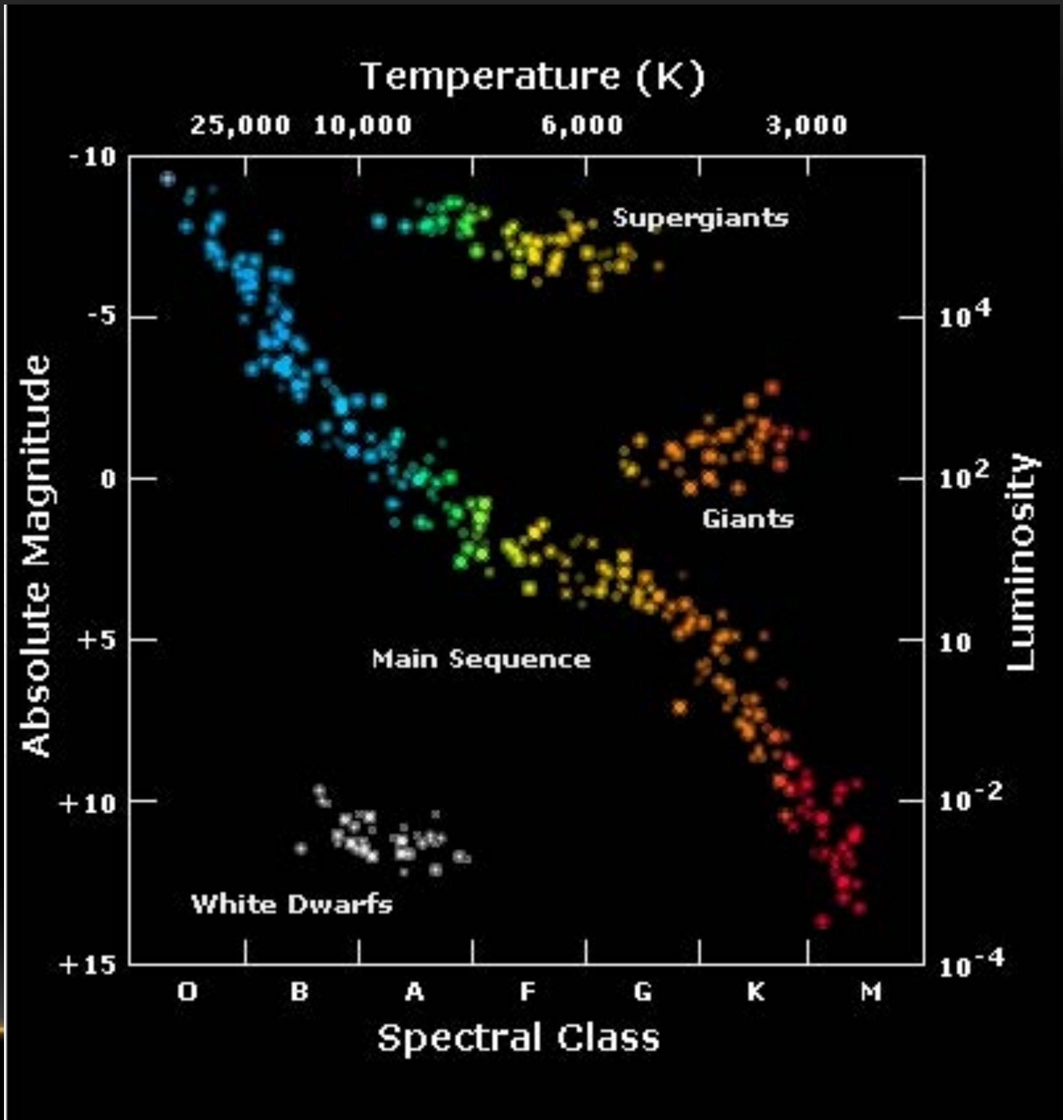
- **Not many stars nearby → smaller angular sizes**

- **Working close to resolution limits of CHARA**

- **Good calibrators harder to find**

OUR GOALS

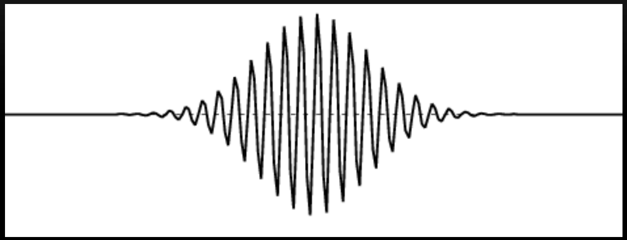
- **Radius, temperature, mass, age**
- **Model dependent!**
  - **Color and spectra**
  - **Large errors in luminosity**



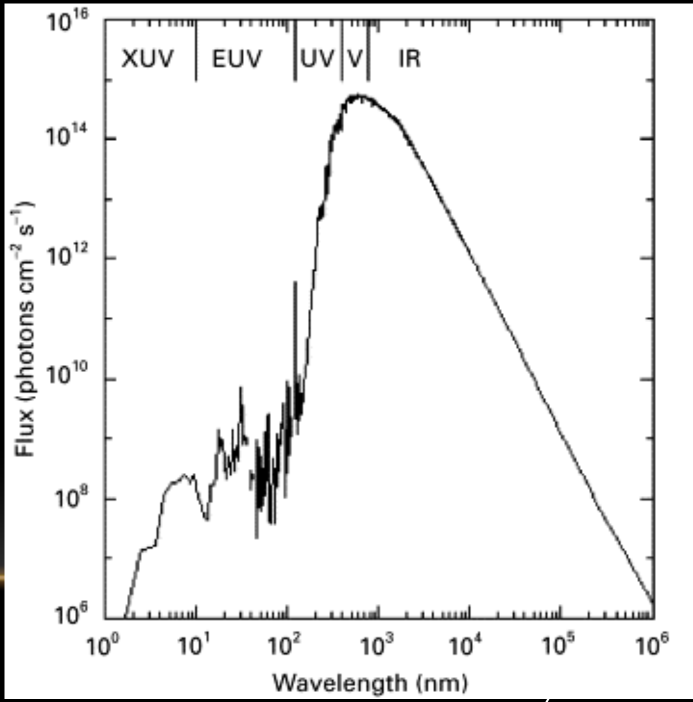
 (1)

Observationally determined properties

- Angular size + distance → Radius
  - » Interferometry



- Integrated flux + angular size → Effective Temperature
  - » Spectrophotometry



$$F_{obs} = \frac{1}{4}\alpha^2 F_{em} \qquad F_{em} = \sigma T_{eff}^4$$

(2)

Hot stars with PAVO

Optical Interferometry of early-type stars with PAVO@CHARA
I. Fundamental stellar properties

V. Maestro[1*], X. Che[2], D. Huber[1,3], M. J. Ireland[1,4,5], J. D. Monnier[2], T. R. White[1], Y. Kok[1], J. G. Robertson[1], G. H. Schaefer[6], T. A. Ten Brummelaar[6], P. G. Tuthill[1]
[1]Sydney Institute for Astronomy, School of Physics, University of Sydney, NSW 2006, Australia
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[3]NASA Ames Research Center, Moffett Field, CA 94035, USA
[4]Department of Physics and Astronomy, Macquarie University, NSW 2109, Australia
[5]Australian Astronomical Observatory, PO Box 915, North Ryde, NSW 1670, Australia
[6]Center for High Angular Resolution Astronomy, Georgia State University, PO Box 3969, Atlanta, GA 30302, USA

26 June 2013

4 stars in our sample overlap

DATA AND RESULTS SO FAR

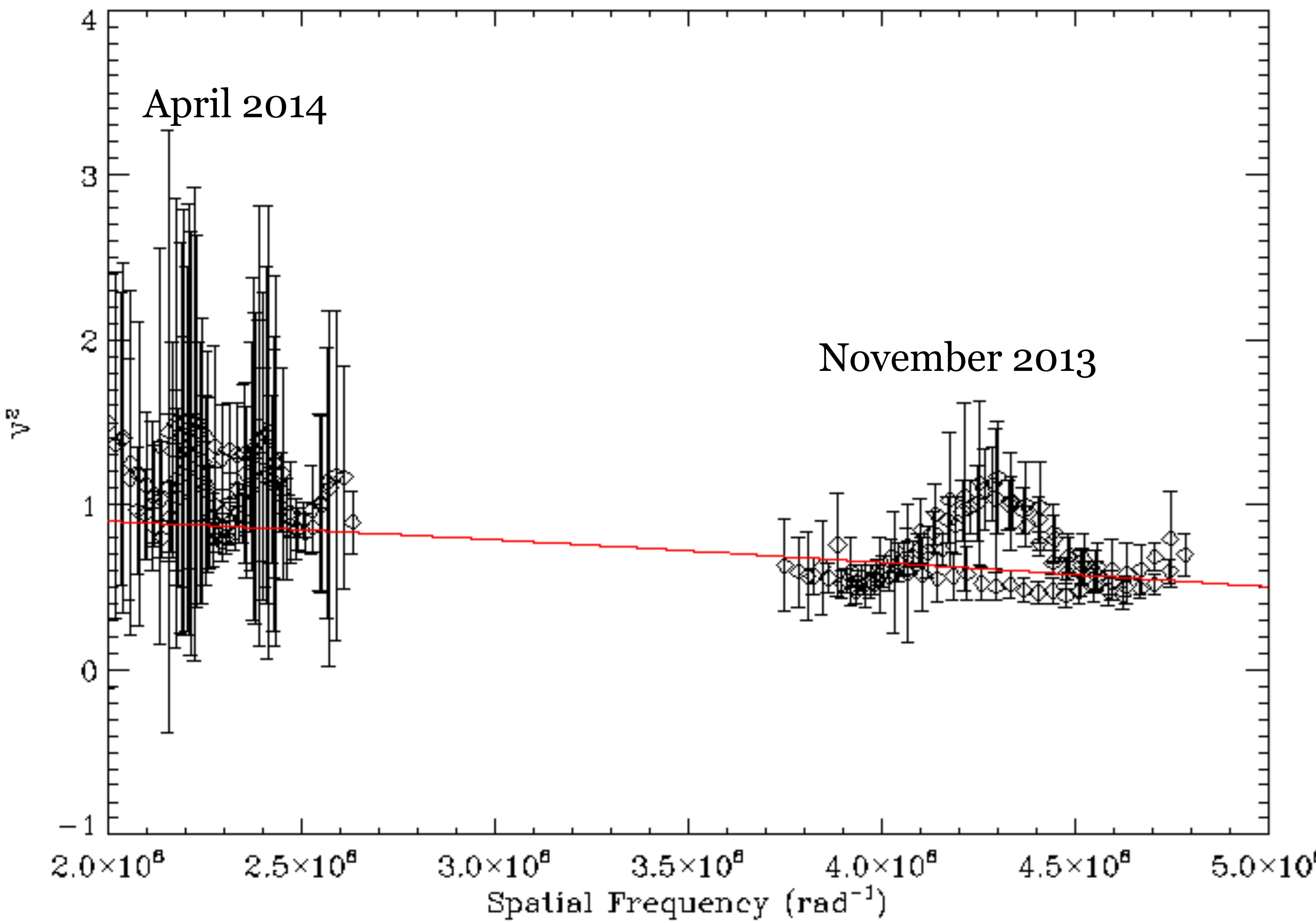
Nights scheduled: 66
(from 2012-2015)

Nights with data: 22

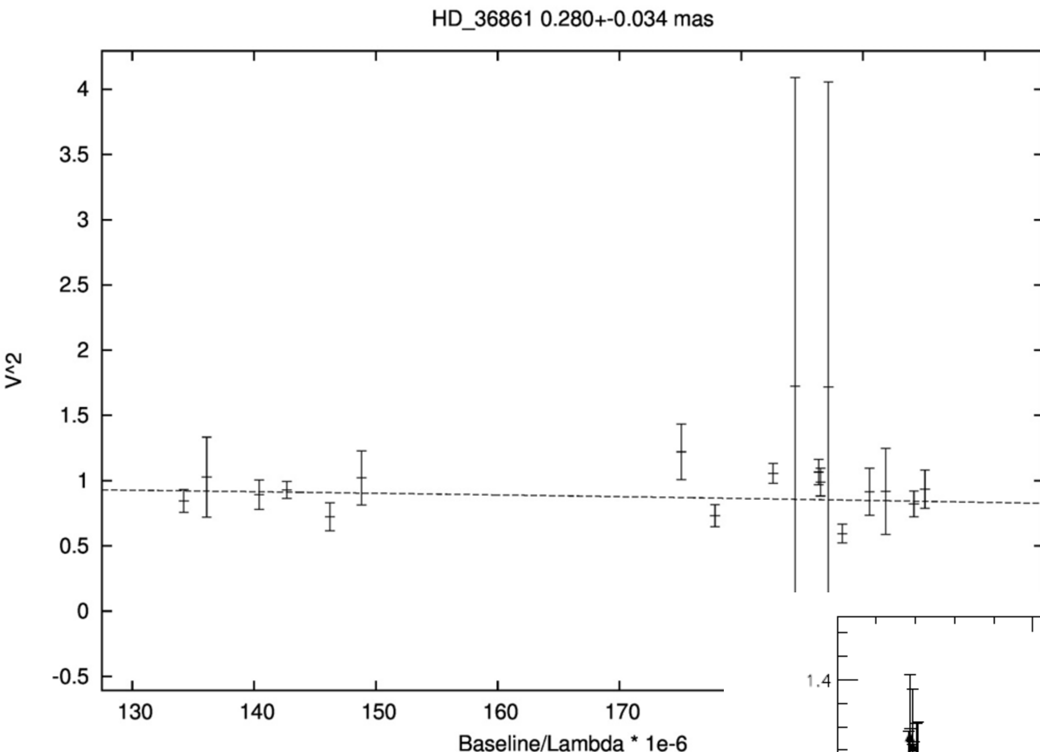
Data on 33 stars

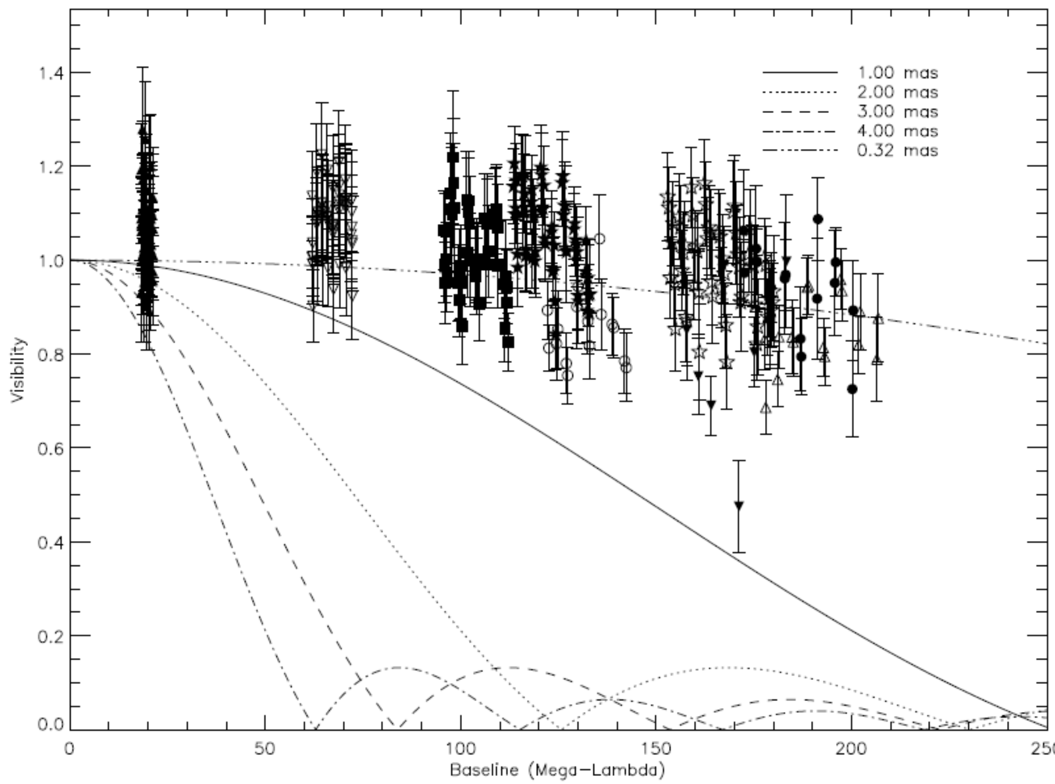
Diameters for 27 stars (2 O stars – alpha Cam and HD 214680)

λ Ori

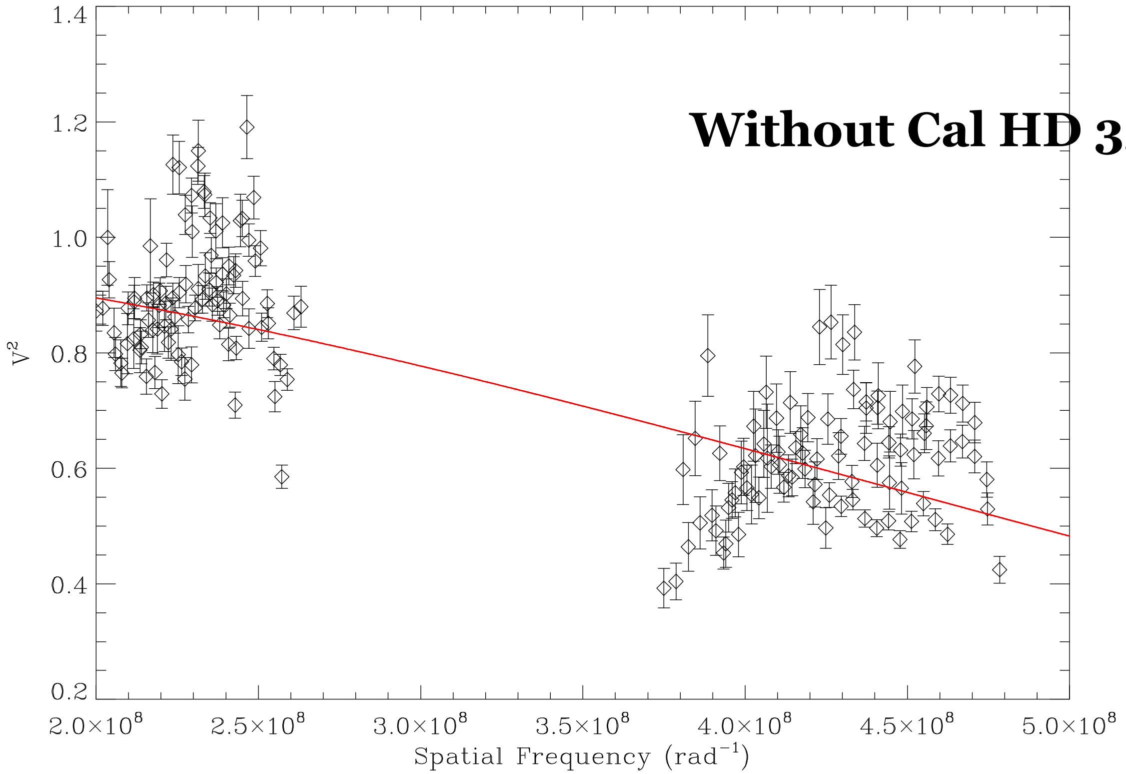


April 2014
November 2013
4
3
2
1
0
−1
V^2
2.0×10⁶
2.5×10⁶
3.0×10⁶
3.5×10⁶
4.0×10⁶
4.5×10⁶
5.0×10⁶
Spatial Frequency (rad⁻¹)

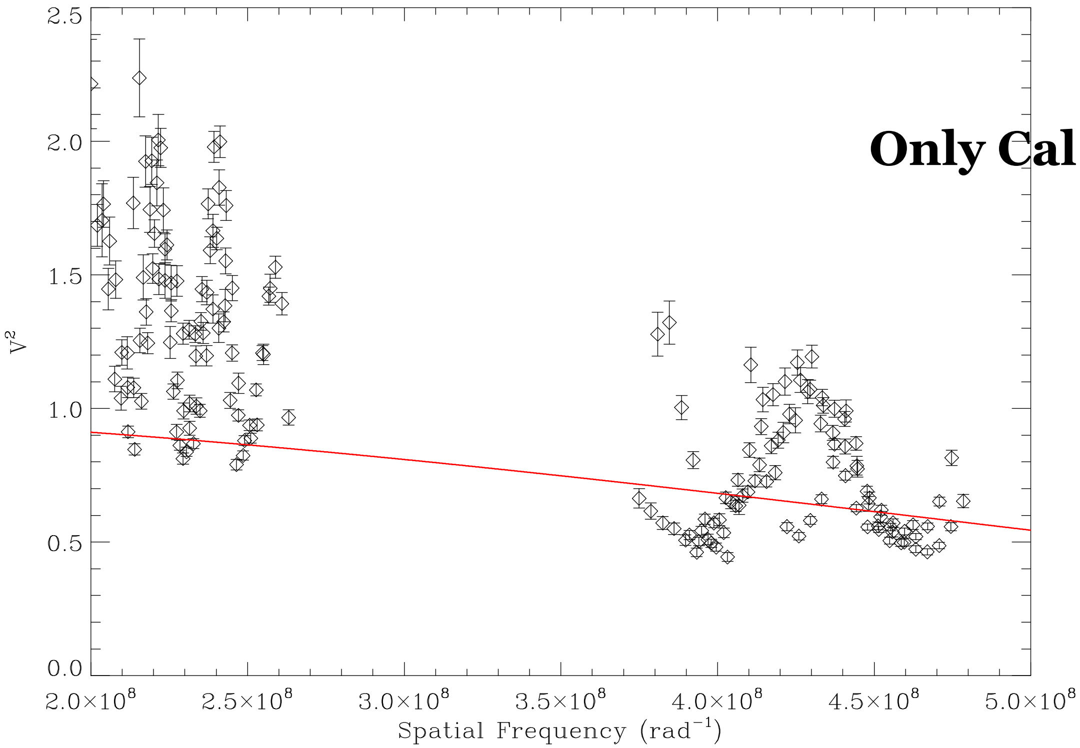

HD_36861 0.280+-0.034 mas
V^2
Baseline/Lambda * 1e-6

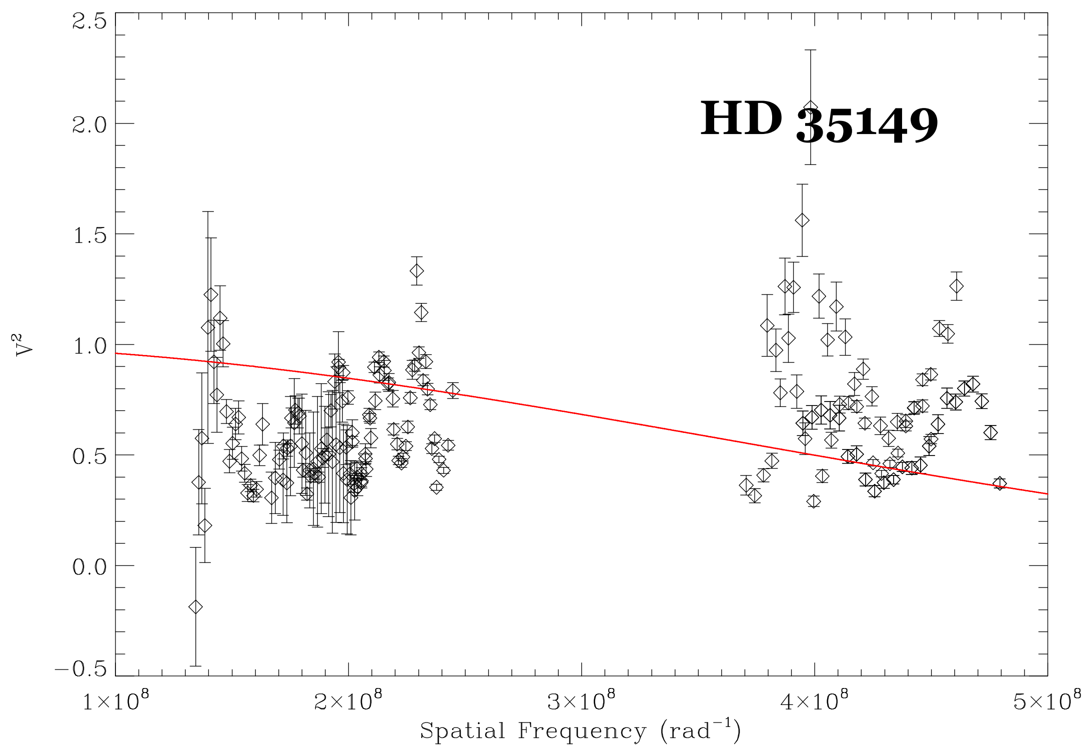

1.00 mas
2.00 mas
3.00 mas
4.00 mas
0.32 mas
Visibility
Baseline (Mega-Lambda)

Without Cal HD 35149



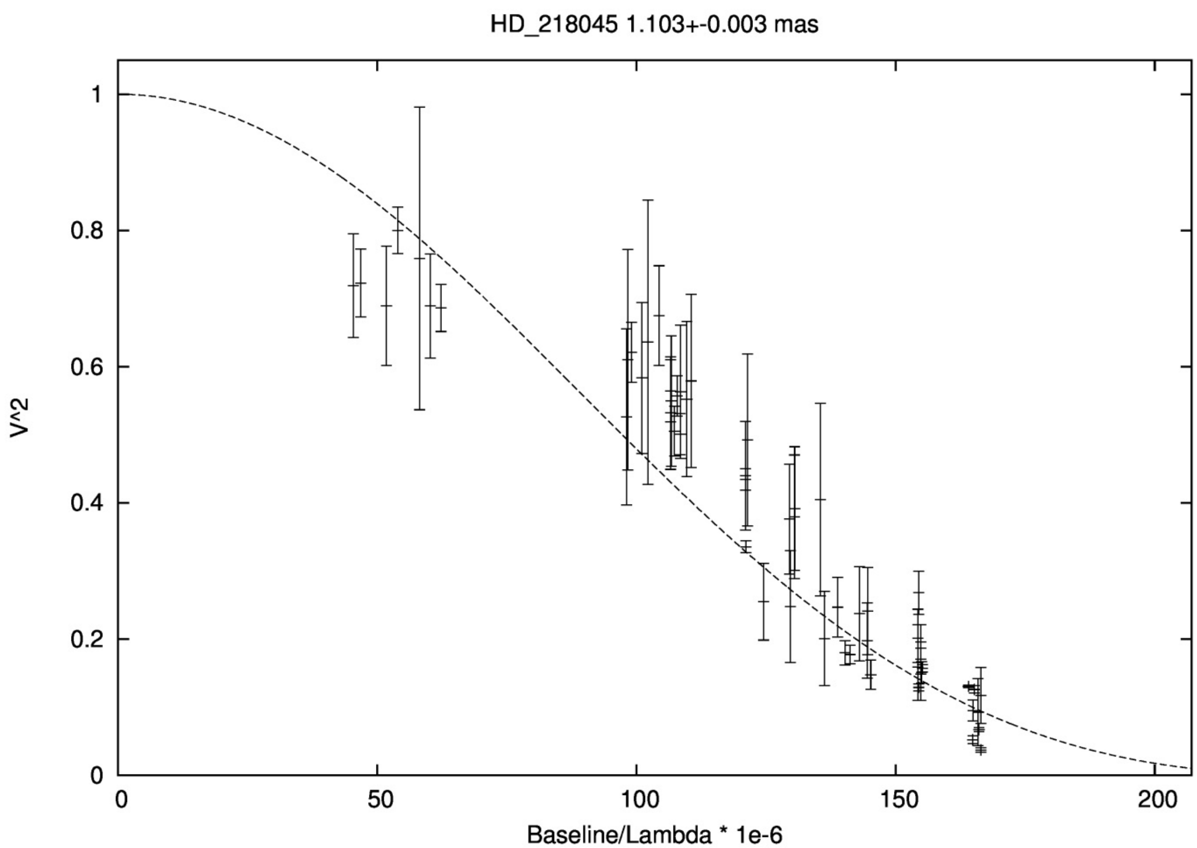
Only Cal HD 35149



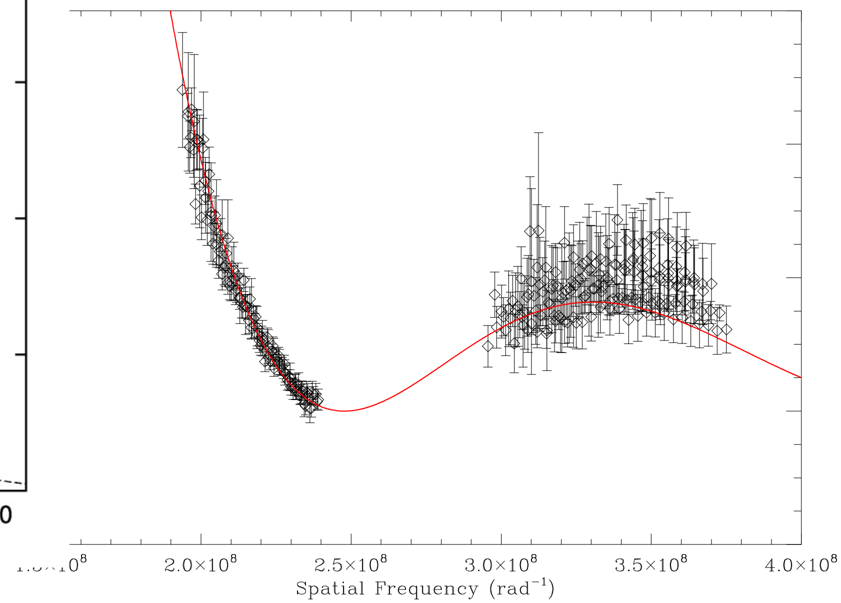


HD 35149
V²
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
1×10⁸
2×10⁸
3×10⁸
4×10⁸
5×10⁸
Spatial Frequency (rad⁻¹)

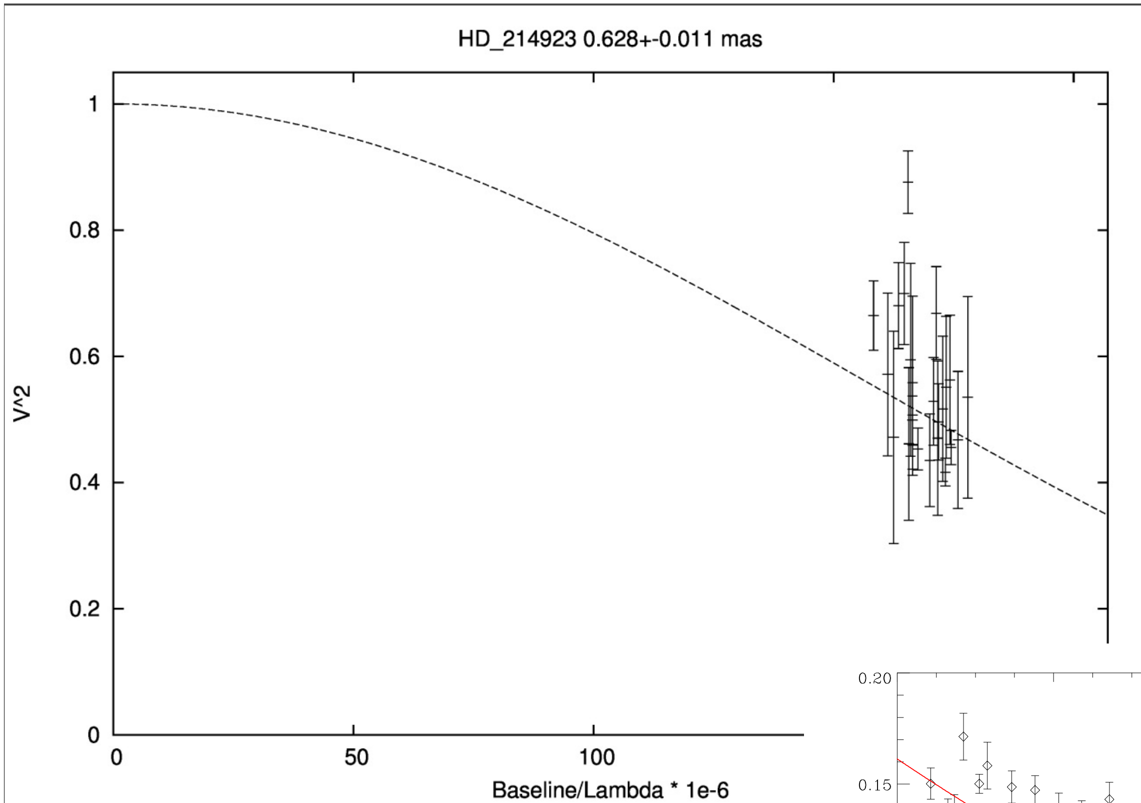
COMPARING CLIMB AND PAVO



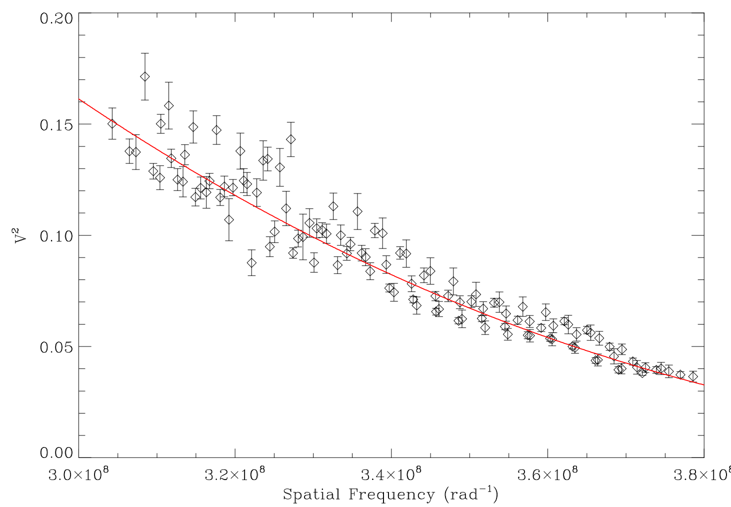
7%



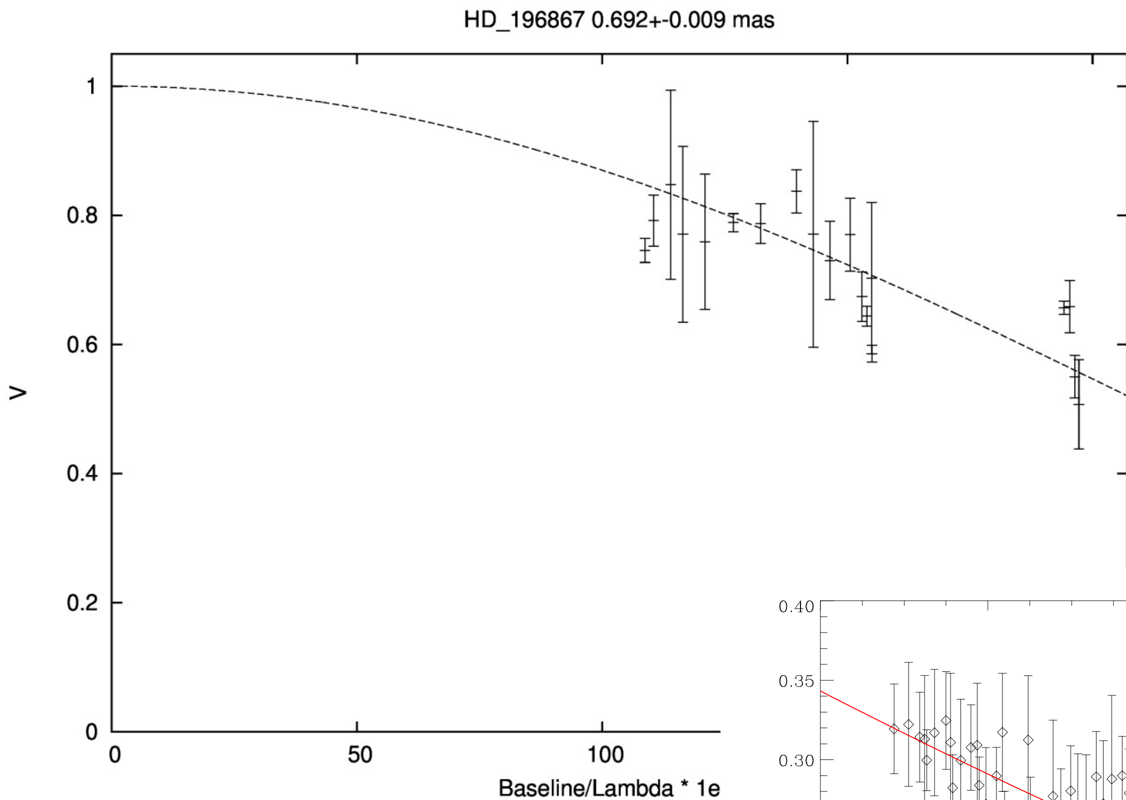
1.028 ± 0.003


HD_214923 0.628+-0.011 mas
V^2
1
0.8
0.6
0.4
0.2
0
0
50
100
Baseline/Lambda * 1e-6

12%

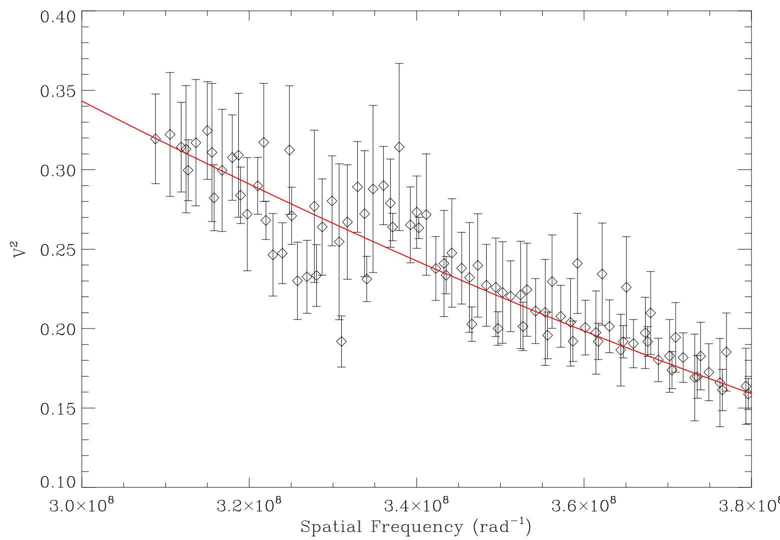

0.20
0.15
0.10
0.05
0.00
V^2
3.0×10^8
3.2×10^8
3.4×10^8
3.6×10^8
3.8×10^8
Spatial Frequency (rad^{-1})

0.560 ± 0.008



Companion adding extra light to visibility curve

54%



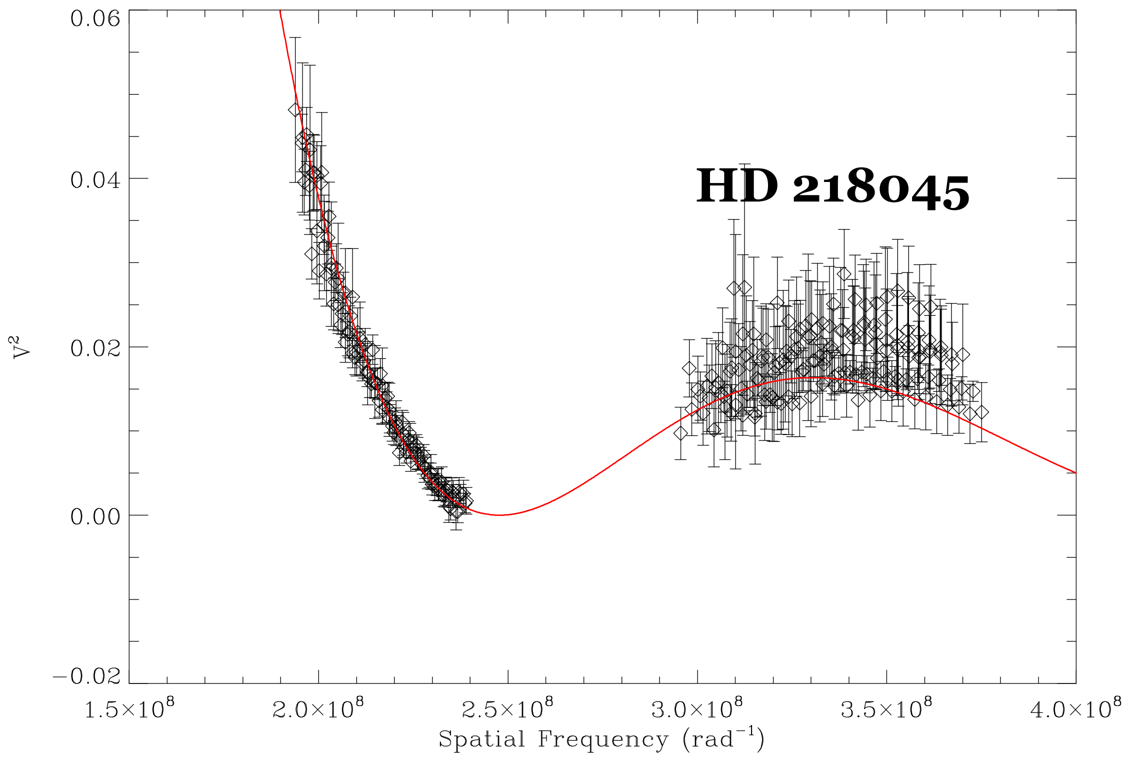
0.445 ± 0.010

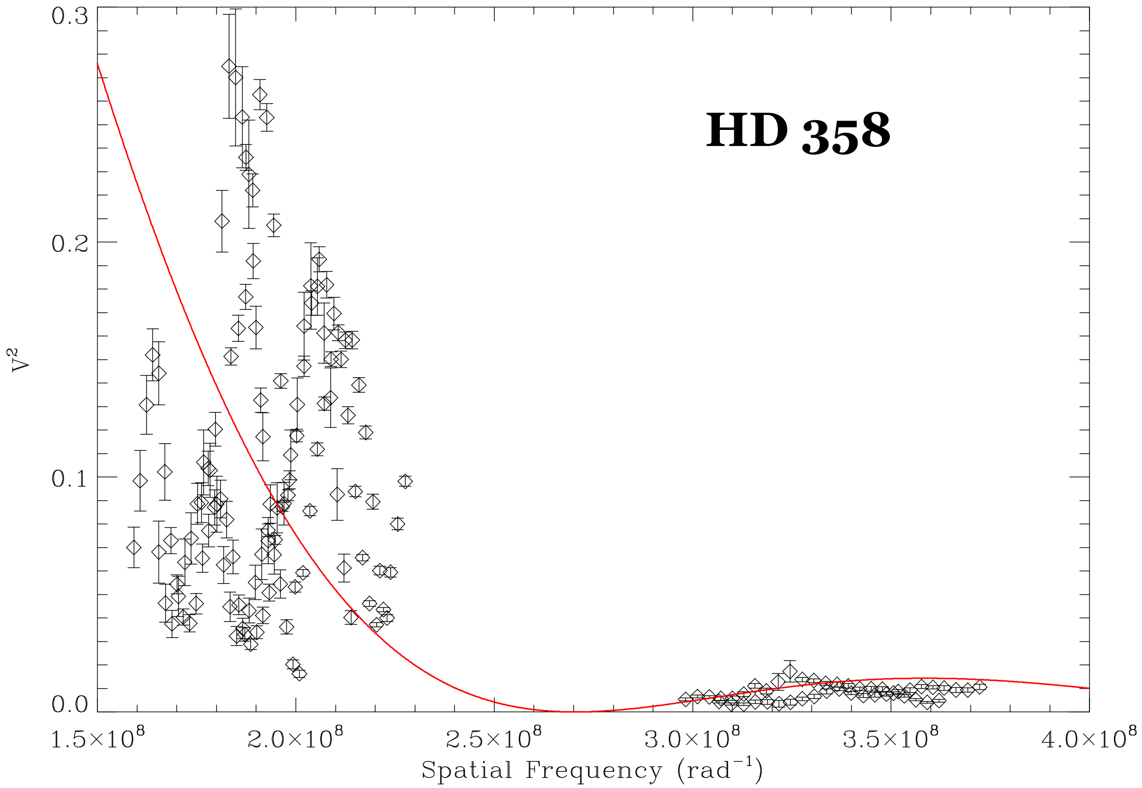
Table 4. Measured angular diameters and fundamental properties.

Star	Combiner	μ	θ_{UD} (mas)	θ_{LD} (mas)	R ($R_\odot$)	M ($M_\odot$)	T_{eff} (K)
θ Cyg	PAVO	0.47 ± 0.04	0.720 ± 0.004	0.754 ± 0.009	1.49 ± 0.02	1.37 ± 0.04	6745 ± 44
	MIRC	0.21 ± 0.03	0.726 ± 0.014	0.739 ± 0.015	1.46 ± 0.03	1.31 ± 0.06	6813 ± 72
	PAVO+MIRC	–	–	0.753 ± 0.009	1.48 ± 0.02	1.37 ± 0.04	6749 ± 44
16 Cyg A	PAVO	0.54 ± 0.04	0.513 ± 0.004	0.539 ± 0.006	1.22 ± 0.02	1.07 ± 0.04	5839 ± 37
	Classic	0.26 ± 0.04	0.542 ± 0.015	0.554 ± 0.016	1.26 ± 0.04	1.16 ± 0.10	5759 ± 85
	PAVO+Classic	–	–	0.539 ± 0.007	1.22 ± 0.02	1.07 ± 0.05	5839 ± 42
16 Cyg B	PAVO	0.56 ± 0.04	0.467 ± 0.004	0.490 ± 0.006	1.12 ± 0.02	1.05 ± 0.04	5809 ± 39
	Classic	0.27 ± 0.04	0.502 ± 0.020	0.513 ± 0.020	1.17 ± 0.05	1.20 ± 0.14	5680 ± 112
	PAVO+Classic	–	–	0.490 ± 0.006	1.12 ± 0.02	1.05 ± 0.04	5809 ± 39

White et al., 2013

LIMB DARKENING DATA




HD 358
V²
Spatial Frequency (rad⁻¹)
0.0
0.1
0.2
0.3
1.5×10⁸
2.0×10⁸
2.5×10⁸
3.0×10⁸
3.5×10⁸
4.0×10⁸

FUTURE WORK

- **Finish observations this year**
- **Combine spectrophotometry with interferometric sizes**
- **Fit binaries well and still get star sizes**
- **Fit data with one routine to help normalize and understand errors**
- **Place stars on evolutionary tracks and compare with models**

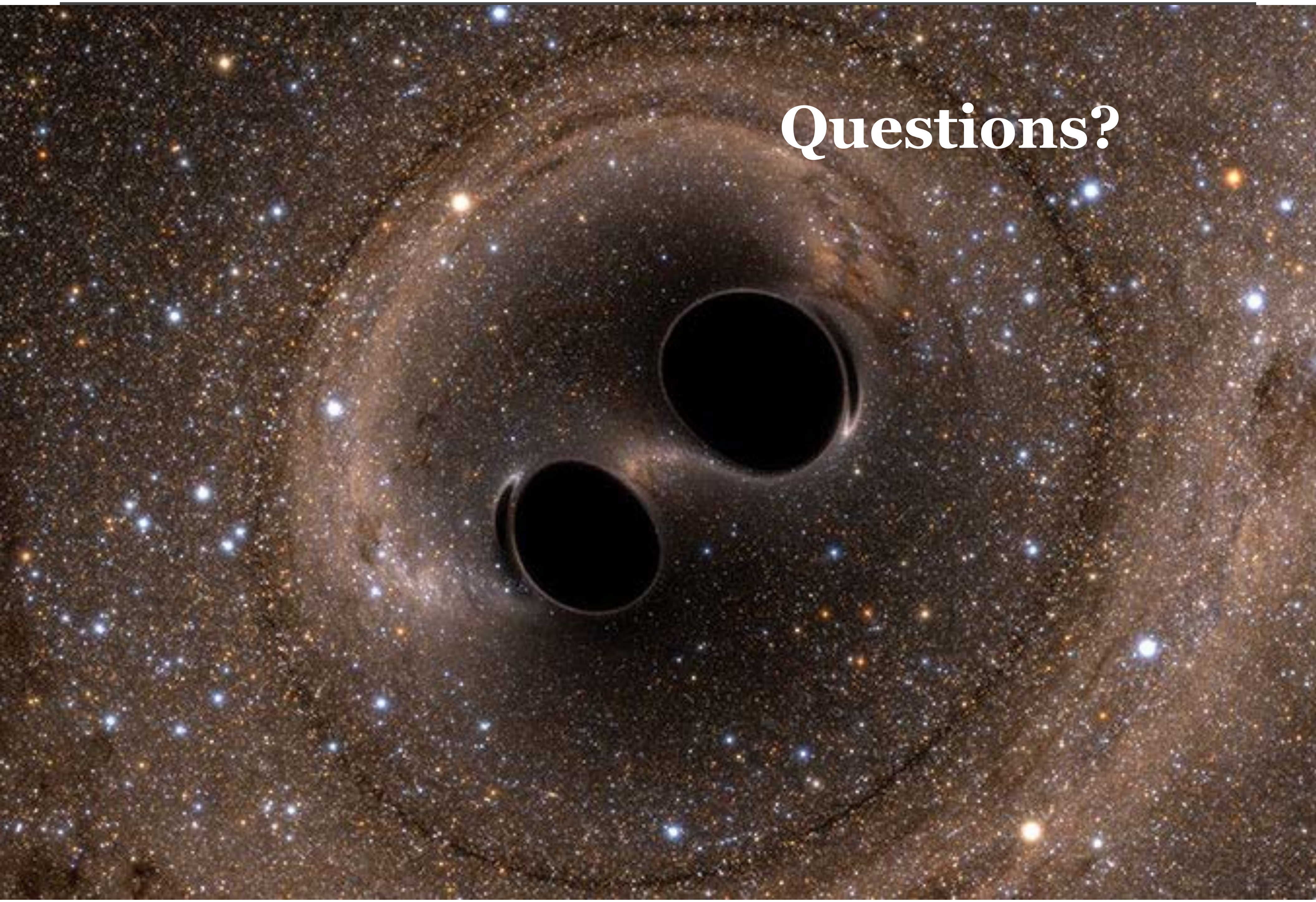

Questions?

IMAGE CREDITS

- http://sci.esa.int
- Tobiska, W.K. et al., 2000. Journal of Atmospheric and Solar-Terrestrial Physics 62, 1233.
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