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NPOI Current Status and Recent Science

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Navy Precision Optical Interferometer

- Joint project between NRL, Lowell Observatory, and USNO
- Observes in visible wavelengths (550 to 860 nm)
- Consists of two nested arrays:
  - 4 astrometric stations
  - 10 imaging array stations distributed among 30 piers
- Combines up to 6 beams
- Apertures are 12-cm
- Current magnitude limit: 6.0
- Baselines span 9 to 98 m
- Soon will have 432 m baseline
- Beam combiners:
  - Classic
  - New Classic
  - VISION

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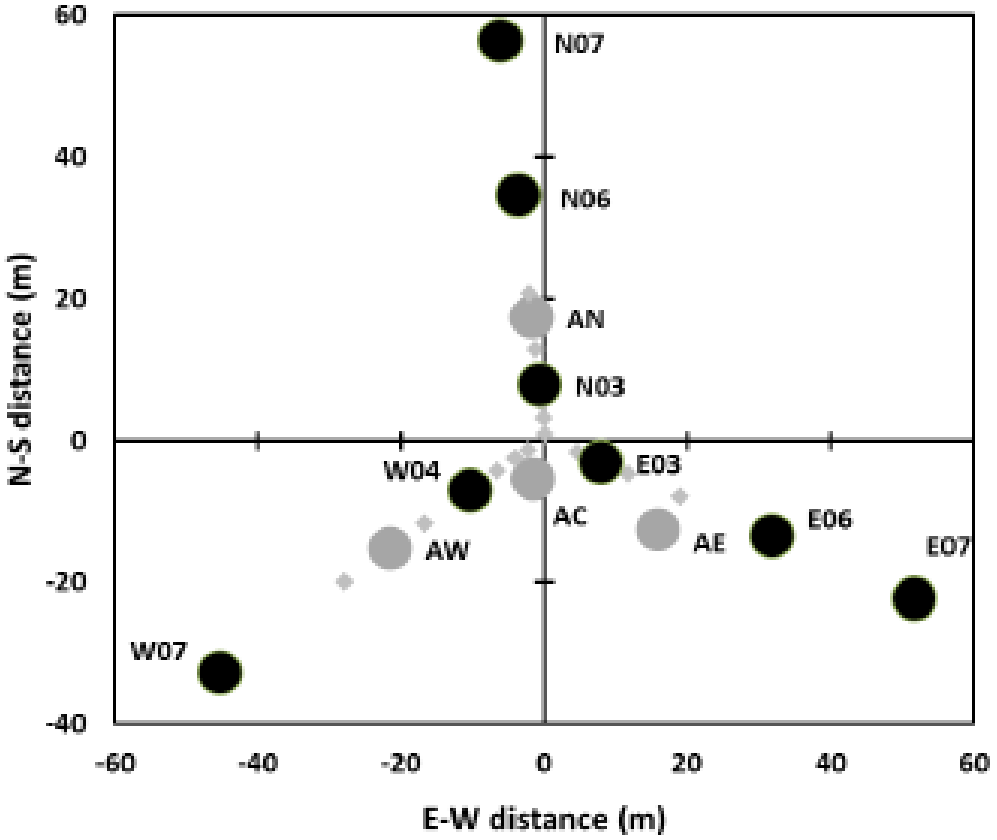
Inner Array



black circles: available stations for the imaging siderostats

grey circles: astrometric stations

grey diamonds: piers available for commissioning

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NPOI Bright Star Multiplicity Survey

Hutter et al. 2016, ApJSS, 227, 4

- Project born from past and current speckle programs
- Goal: test the contention that speckle and RV surveys have closed the gap in orbital period coverage
- Interferometry offers a single technique for multiplicity detection over separations/periods spanning classic visual doubles to interacting binaries.

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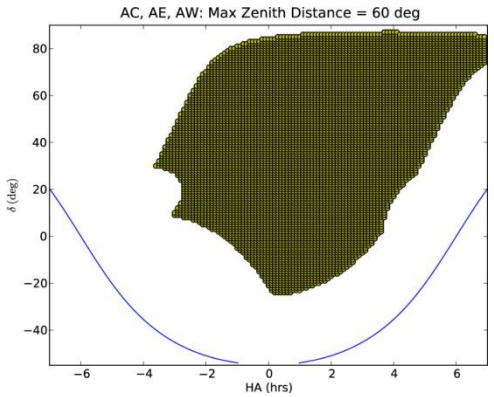
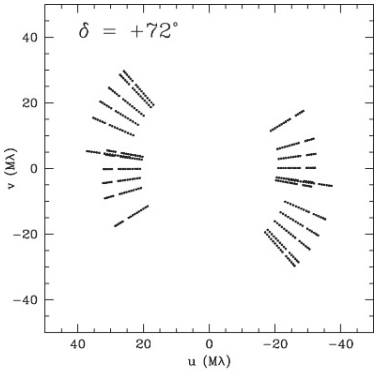
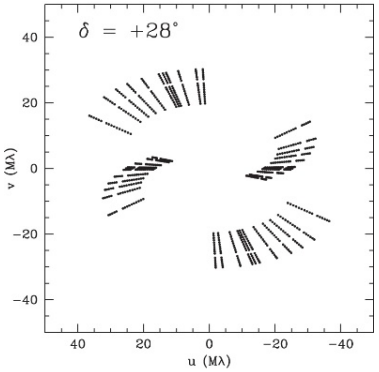
Observations

- Used AC, AE, AW stations
  - Best sky coverage
  - Good UV coverage
- Sample derived from TPF list:
  - Stars within 30 pc
  - $m_V \leq 4.30$ (limit c. 2004)
  - $0.3 \leq B\text{-}V \leq 1.2$ (F0 to mid K)
  - Dec ≥ -20°
  - Captured 90%/28% of III/V stars relative to Hipparcos completeness
  - 59 sources







- 1389 multi-baseline observations of 41 of 59 stars on 46 nights
- 705 observations of 15 non-program binaries

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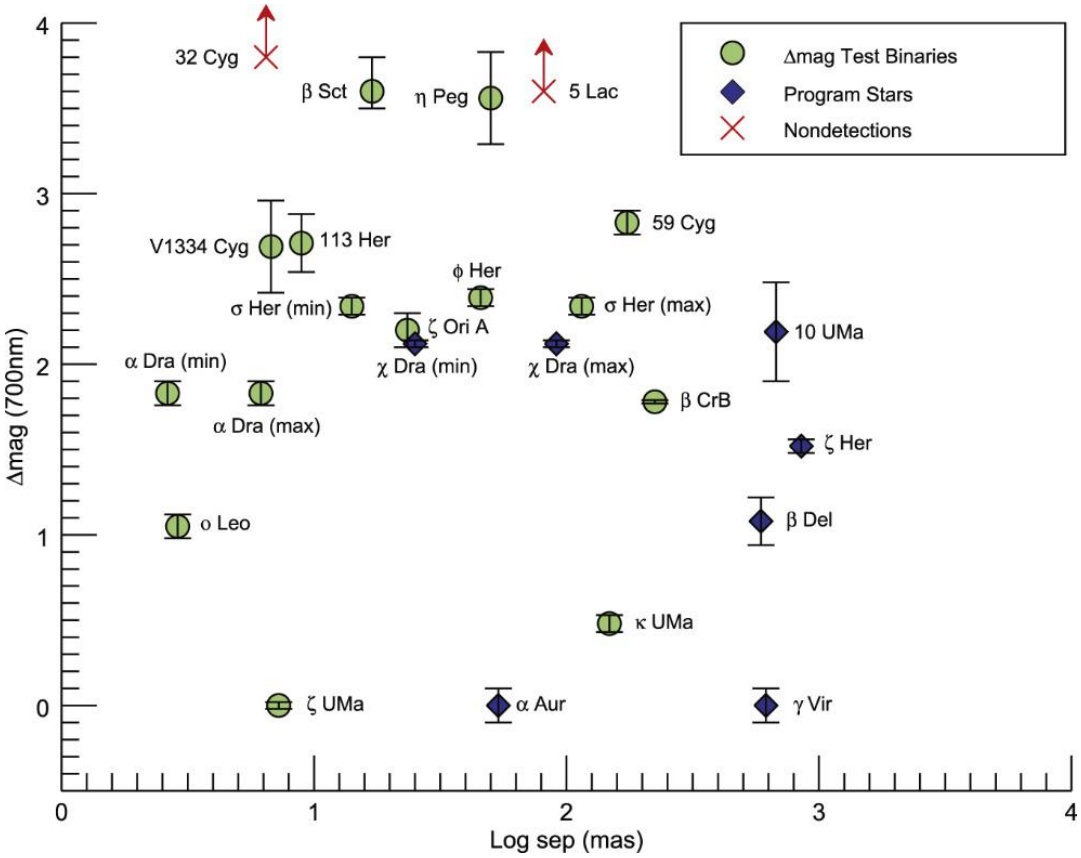
Binary Results



Model fits to data:
– 13 of 15 test binaries
– 6 program stars

NPOI can detect binaries at $\Delta m \leq 3.0$ for separations 3 – 860 mas

First detection of secondary of β Scuti with precisely measured ρ and θ (8 nights)

Inner angular separation limit set by resolution of modest baselines
Outer limit set by bandwidth smearing, up to 90% reduction in V^2 at 860 nm

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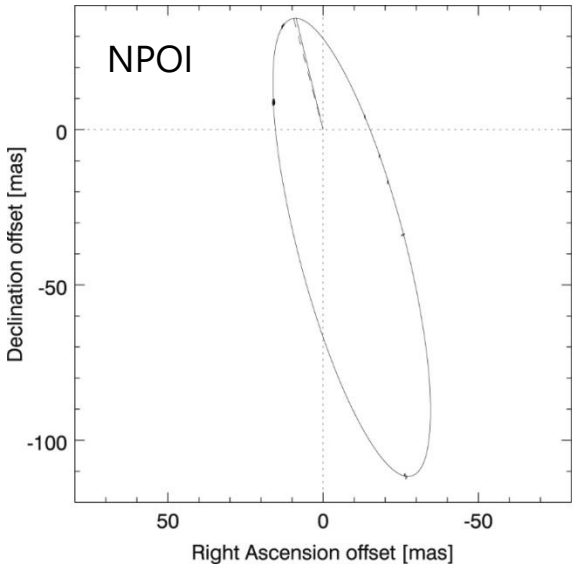
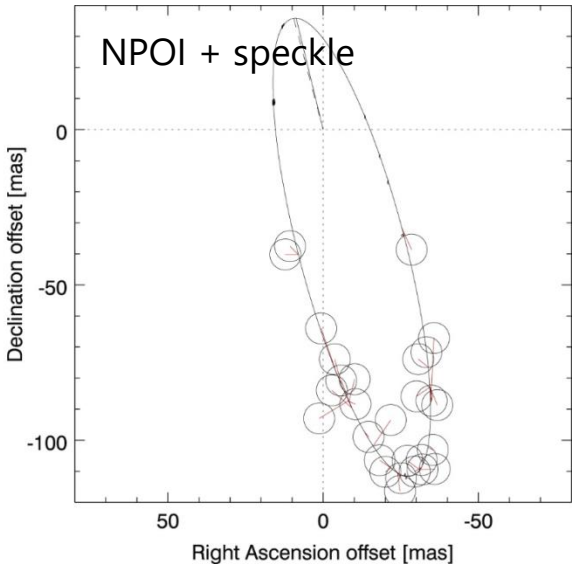
Results: σ Herculis





16 nights of data

New orbit fit

NPOI error ellipses ≤ 0.5 mas

Other binaries:
– Position measurements of secondary for 19 systems
– First accurate measurements for β Scuti
– Limiting magnitude went from 4.3 (2004) to 6.0 (now), which would increase sample to 51 stars within 17 pc

Table 10
σ Her—Orbital Elements

Parameter	Value
a (mas)	76.21 ± 0.27[a]
e	0.5135 ± 0.0028
i (deg)	105.25 ± 0.51
ω (deg)	184.97 ± 0.40
Ω (deg) (J2000.0)	14.95 ± 0.47
P (days)	2706.19 ± 4.89
T (JD— −2440000.0)	10665.4 ± 2.68
χ^2_ν	1.34

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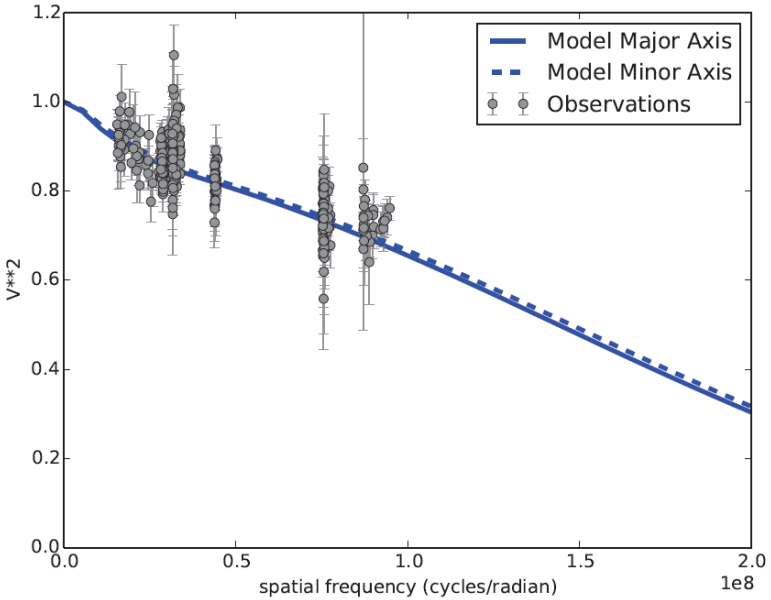
Disks of 48 Per and ψ Per

Grzenia et al. 2016, ASPC, 119

- Be disk stars
- 377 observations in the Hα band
- Used the non-LTE code BEDISK, BERAY , and 2dDFT

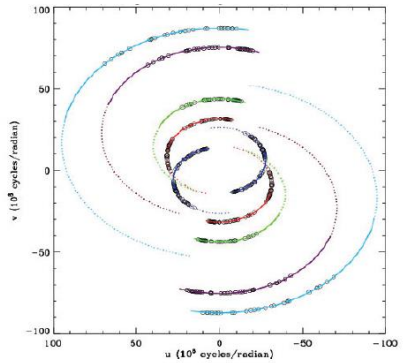


48 Per fit for:

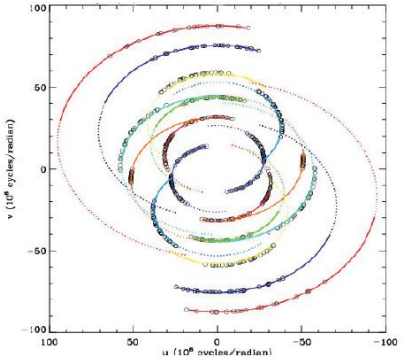
ρ_0 = density at stellar surface

n = power law exponent

i = inclination



48 Per (5 baselines)



ψ Per (9 baselines)

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β Lyrae's Accretion Disk

Nemravová et al. 2017, A&A, in press

- β Lyr A: rapid mass transfer via an accretion disk

- Observed using 3 beam combiners on 2 instruments:
  - NPOI Classic, 562 – 861 nm, two 3-station triangles
  - CHARA MIRC, *H*-band, 6 telescopes
  - CHARA VEGA, R=5,000, 2 or 3 telescopes

- Used 4 calibrators

- Photometry was monitored for 3 years.

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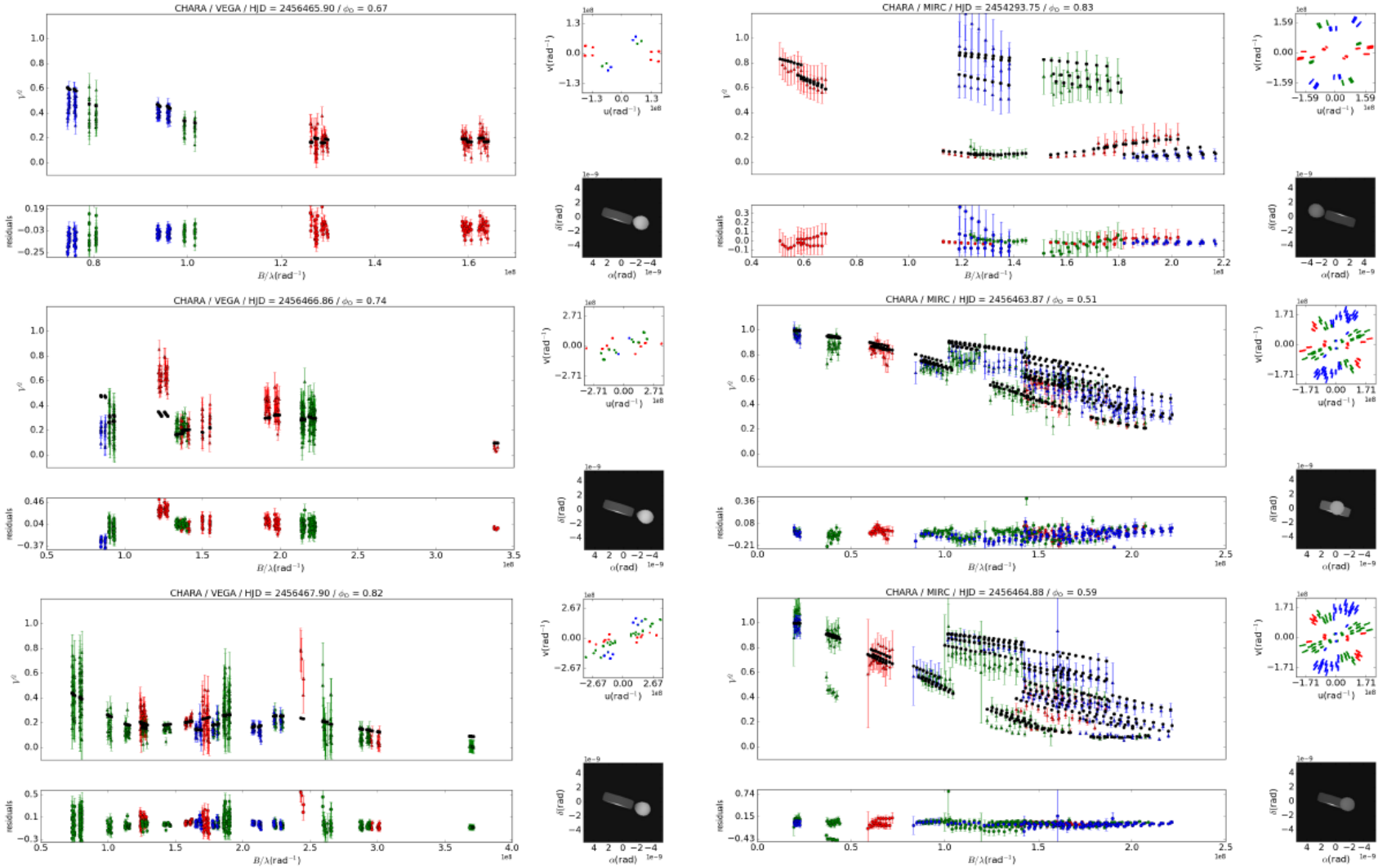
Example CHARA Data



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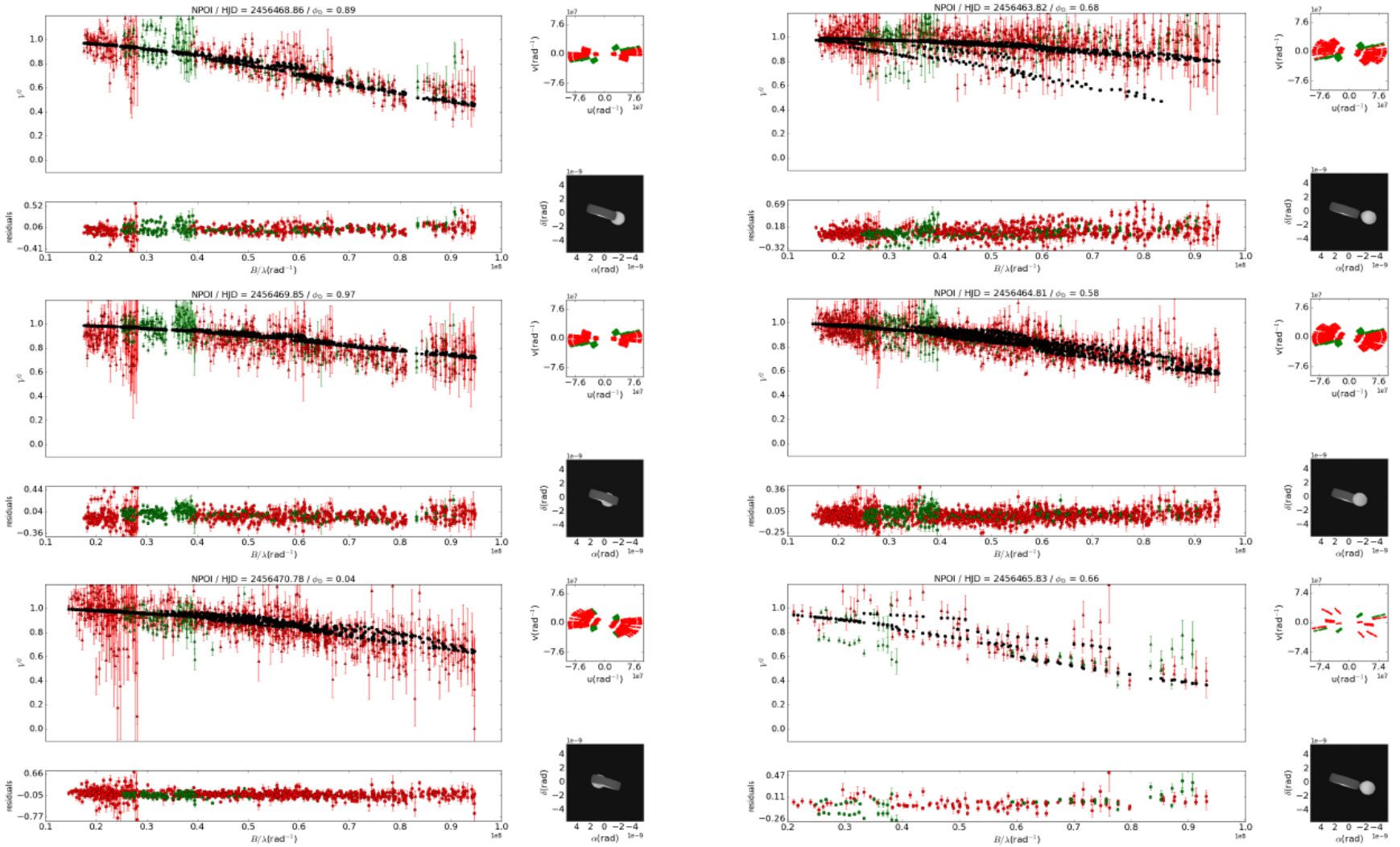
Example NPOI Data



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Disk Configuration

- Models were fitted for:
  - Shape, size, radial density, *T* profile
  - A possible hot spot
  - Orientation on the sky
  - Distance

Param.	Unit	Min	Max	Disk shape / Radial temperature profile: slab/pl	slab/sd	wedge/pl	wedge/sd
i	(deg)	91	95	$92.59\pm^{0.24}_{0.86}$	$92.55\pm^{0.74}_{0.17}$	$94.53\pm^{0.43}_{0.57}$	$94.53\pm^{0.43}_{0.57}$
Ω	(deg)	251	255	$252.71\pm^{0.65}_{1.82}$	$252.88\pm^{1.66}_{0.92}$	$253.40\pm^{0.86}_{1.27}$	$253.40\pm^{0.86}_{1.27}$
T_0	(K)	23 000	32 000	$31\,250\pm^{740}_{3\,340}$	$26\,740\pm^{1\,450}_{1\,460}$	$24\,720\pm^{2\,180}_{650}$	$24\,720\pm^{2\,180}_{650}$
ρ_0	($g\,cm^{-3}$)	5.10^{-8}	5.10^{-6}	$7.38\pm^{1.73}_{3.48}\times10^{-7}$	$19.50\pm^{8.43}_{15.74}\times10^{-7}$	$7.38\pm^{2.59}_{4.89}\times10^{-7}$	$7.26\pm^{1.48}_{22.87}\times10^{-7}$
α_T		-1.1	-0.75	$-0.939\pm^{0.022}_{0.085}$	–	$-0.939\pm^{0.022}_{0.085}$	–
α_D		-3.5	-0.80	$-2.06\pm^{0.26}_{0.16}$	$-2.72\pm^{0.49}_{0.17}$	$-2.72\pm^{0.27}_{0.41}$	$-2.81\pm^{0.27}_{0.41}$
R_{out}	($R_\odot$)	26	33	$32.04\pm^{0.85}_{1.33}$	$31.17\pm^{1.22}_{1.02}$	$31.17\pm^{1.22}_{1.02}$	$32.40\pm^{0.52}_{1.96}$
H	($R_\odot$)	7.5	12	$8.979\pm^{0.021}_{1.034}$	$8.513\pm^{0.972}_{0.851}$	$8.513\pm^{0.972}_{0.851}$	$13.16\pm^{0.52}_{1.38}$
d	(pc)	305	335	$325.0\pm^{4.5}_{7.0}$	$324.0\pm^{6.4}_{5.3}$	$324.0\pm^{6.4}_{5.3}$	$326.6\pm^{4.3}_{4.3}$
$\chi^2_{R,LC}$				1.78	1.31	1.31	1.81
χ^2_{R,V^2}				4.06	4.08	4.08	4.08
$\chi^2_{R,CP}$				2.90	2.88	2.88	2.87
χ^2_R				3.60	3.58	3.58	3.60
N_{LC}				1 434			
N_{V^2}				15 936			
N_{CP}				6 869			

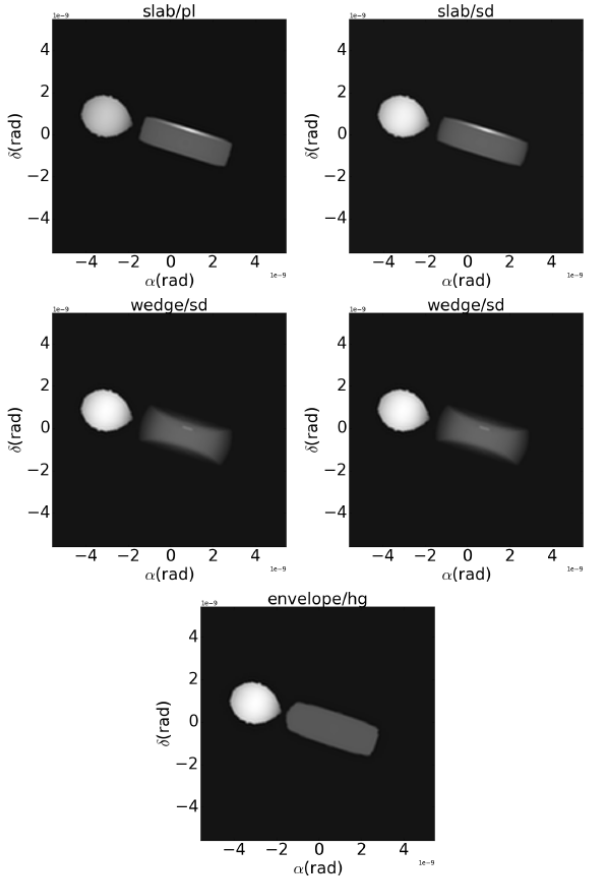

Fig. 3. Images of β Lyr for the different models of the accretion disk surrounding the gainer for wavelength 1000 mn and orbital phase 0.25. δ goes along north-south direction, and α along east-west direction. Above each panel shape of the accretion disk (see Fig. 2 for notation), and radial temperature profile. "pl" stands for power-law given by Eq. (8), "sd" for steady disk given by Eq. (7), and "hg" for isothermal profile.

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Observing Exoplanet Candidates

Baines et al. 2016, SPIE, 9907, 3T

- Sample comes from the Penn State-Torun Planet Search (PTPS) survey
- Full sample is 744 giant stars; 455 with spectroscopic analysis completed
- Goal: provide more precise, model-independent radius
- Stellar parameters: T_{eff}, L, F_{BOL}, mass, age
- Planetary parameters: P, mass, $T_{surface}$

- NPOI can observe 25 of the stars – have data on 6 so far
- CHARA will get more. (Hopefully.)

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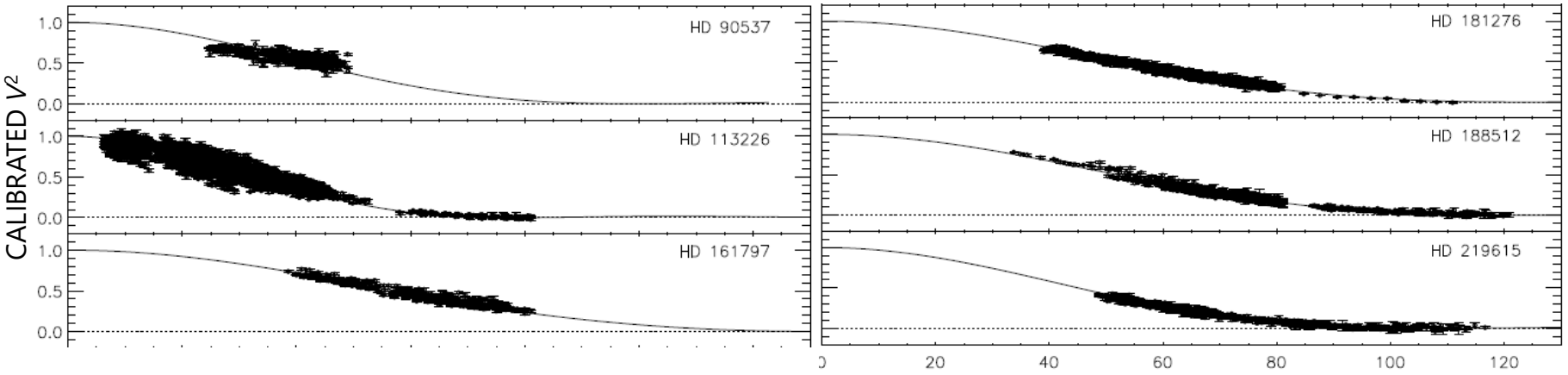
Results



Name	# nights	# data points	θ_{LD} (mas)	R (R_{sol})	T_{eff} (K)
β LMi	7	281	2.618±0.044	13.28±0.38	4149±41
ε Vir	22	3954	3.321±0.023	11.99±0.10	5018±26
μ Her	23	328	1.952±0.012	1.74±0.01	5324±17
κ Cyg	11	1420	2.172±0.005	8.89±0.04	5022±22
β Aql	6	133	2.166±0.009	3.19±0.02	4992±11
γ Psc	8	627	2.481±0.011	11.28±0.10	4834±24

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Fundamental Properties for 90 Stars

Baines et al. in prep

- Data from the NPOI archive → 2004 to 2016
- Spectral classes span B to M
- Luminosity classes: I (7), II (3), III (71), IV (3), V (6)
- Mostly a paper of long tables
- Determined the regular stuff: θ, R, T_{eff}, F_{BOL}, L, M, age

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Example Data