Review of Interferometric Measurements and Prospects: *Speckle Studies of Binary Stars*

H.A. McAlister

Center for High Angular Resolution Astronomy
Georgia State University
Atlanta, Georgia 30303

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Labeyrie "Invents" Speckle Interferometry - 1970

Astron. & Astrophys. 6, 85—87 (1970)

Attainment of Diffraction Limited Resolution in Large Telescopes by Fourier Analysing Speckle Patterns in Star Images*

A. Labeyrie
Observatoire de Meudon

Received January 23, 1970

Resolution in excess of the limitation set by seeing, and reaching the diffraction value, can be obtained on star features by laser processing the speckle pattern observed in short exposures made with a large telescope. The technique may be considered as an extension of the Michelson stellar interferometry; it is applicable to star diameter measurements and stellar system studies.

Key words: speckle interferometry — Michelson interferometry — image processing — aperture synthesis

It has been known since the work of Fizeau and Michelson that the resolution loss of large telescopes due to atmospheric seeing can be retrieved in some cases by analysing interference effects in the image. Such techniques give direct diameter measurements for several stars, but their possible applications are restricted since small pupils must be used for reasons of phase uniformity. It seems possible to extend interferometer methods in such a way as to use the full aperture of a large telescope, with a corresponding increase in information sensitivity.

visual observation and long focus photography. It is rarely seen on star photographs because both a high magnification and a short exposure time are required, but it can be observed visually in telescopes using a strong eye-piece. The minimum grain size of the speckle thus observed is equal to the size of the Airy disk given by the telescope in the absence of seeing and aberrations.

It is therefore conceivable that speckle-affected images contain more information on smaller features than long exposure images with a blurred speckle

First Speckle Measurements - 1972

THE ASTROPHYSICAL JOURNAL, 173:L1–L5, 1972 April 1
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SPECKLE INTERFEROMETRY: DIFFRACTION-LIMITED MEASUREMENTS OF NINE STARS WITH THE 200-INCH TELESCOPE*

D. Y. GEZARI, A. LABEYRIE,† AND R. V. STACHNIK
Department of Earth and Space Sciences, State University of New York at Stony Brook
Received 1972 February 7

ABSTRACT

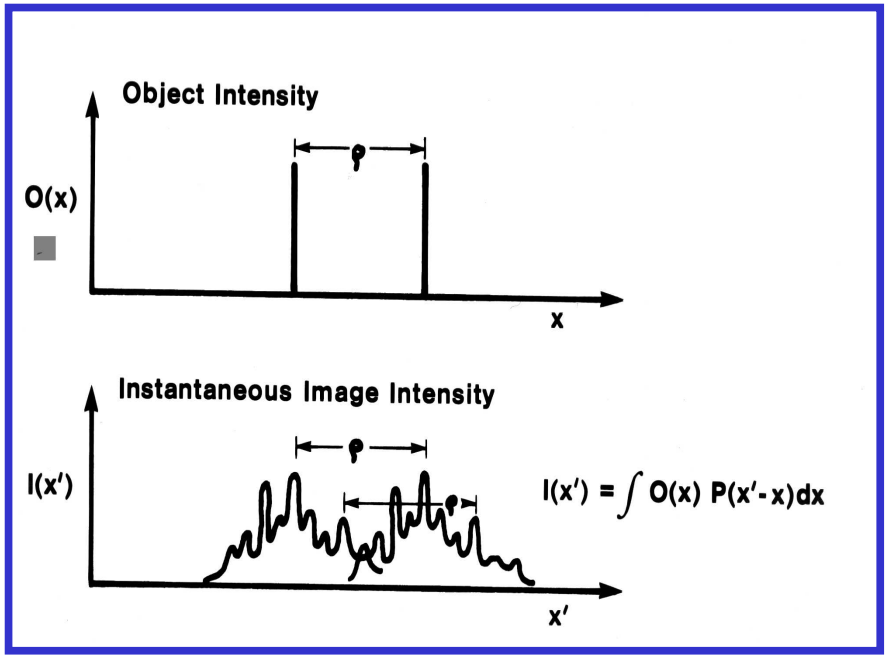
A new method has enabled us to repeat most of the classical Michelson-Pease measurements of stellar diameters. Stellar images are photographed "coherently" with a special camera. They contain a fine structure from which diffraction-limited information is extracted by optical processing. Nine of the stars observed were resolved, showing angular dimensions as small as 0".016. Limb darkening is evidenced in α Ori, and a faint companion is found for β Cep.

I. INTRODUCTION

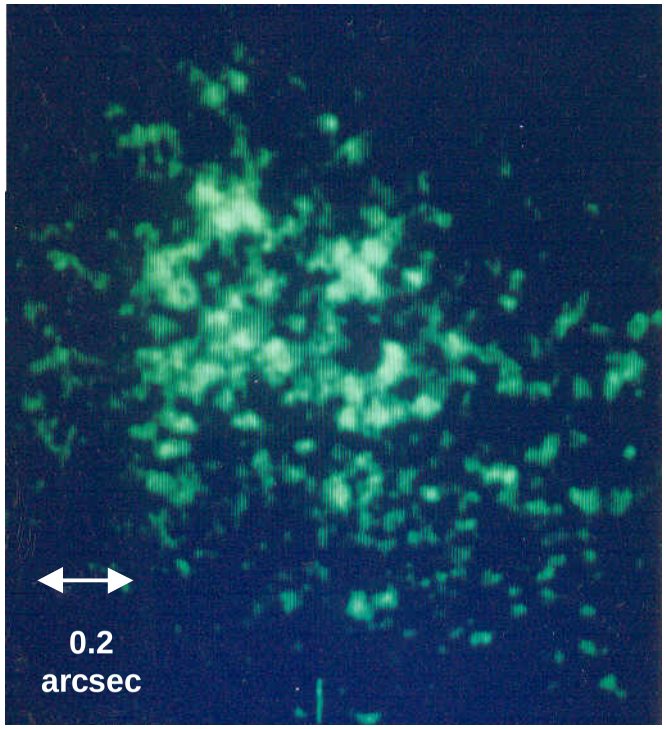
Stellar dimensions have previously been measured by using classical double-aperture interferometry (Michelson and Pease 1921; Anderson 1920), lunar occultation (Evans 1955), and intensity interferometry (Hanbury Brown and Twiss 1958). Each of these methods has been successfully applied to a particular class of objects. An excellent review was presented by Hanbury Brown (1968). We report here on our observations

The Speckle Process I.

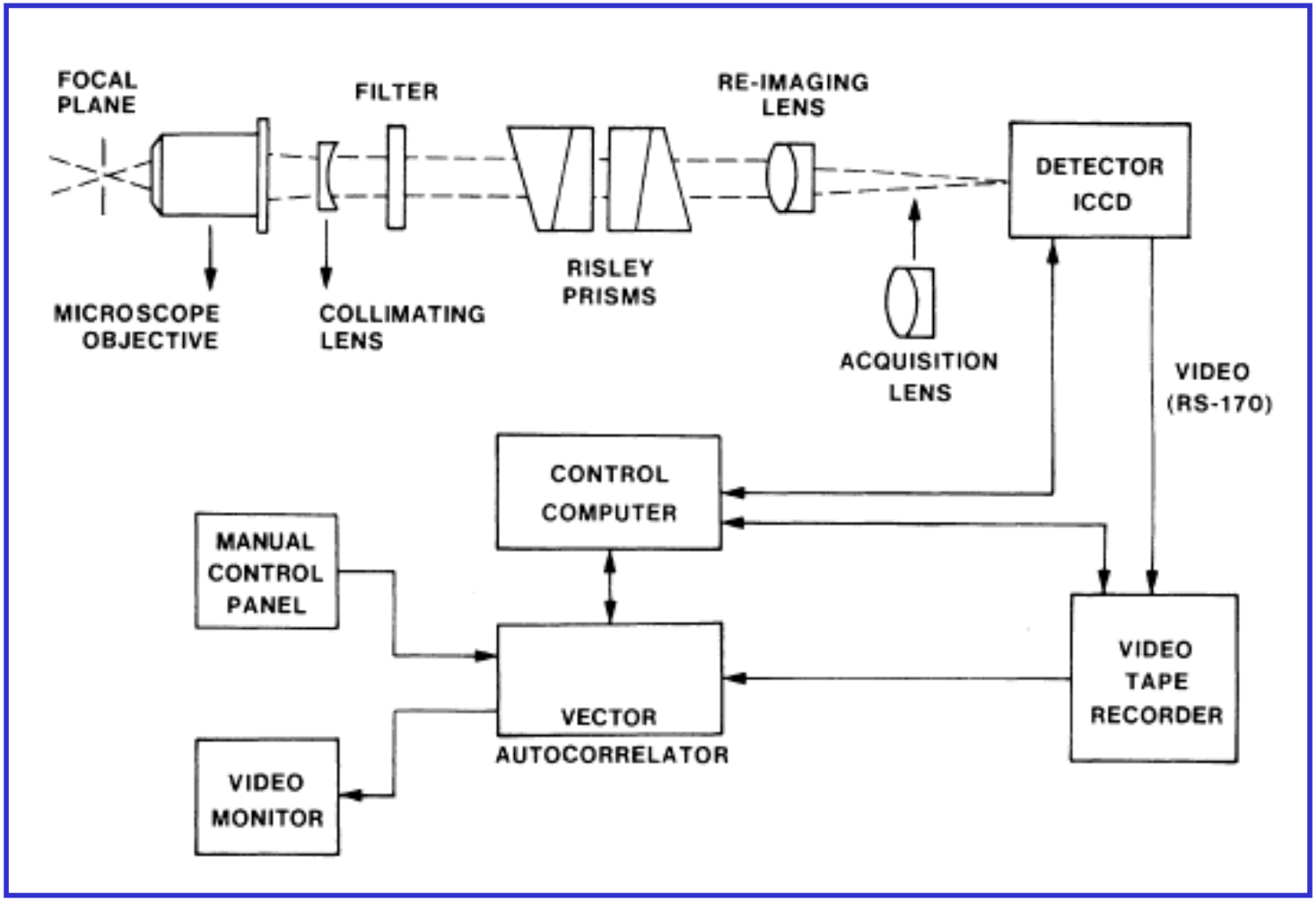
Formation



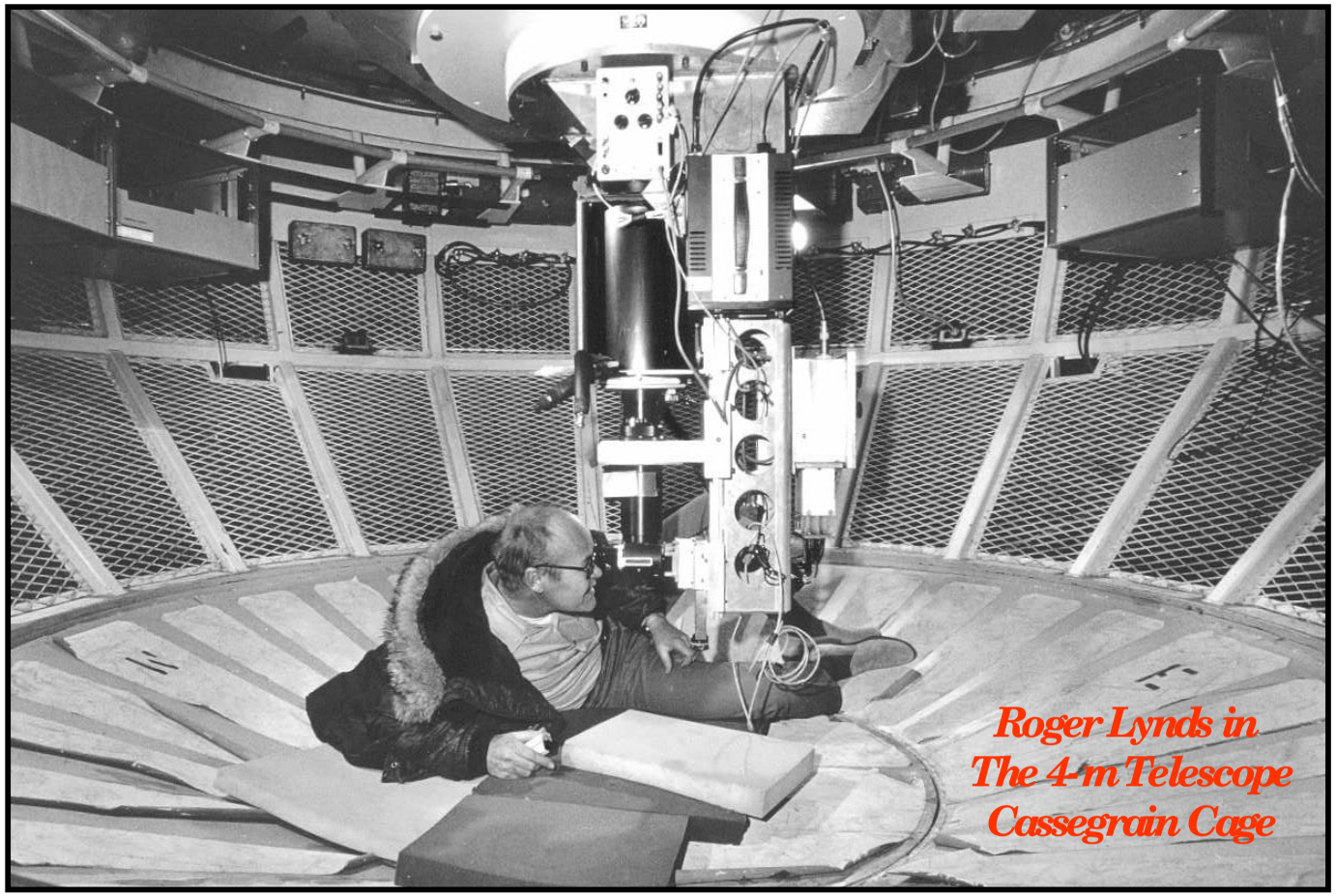
Speckle Image



Georgia State Speckle Camera System
(McAlister *et al.* AJ, 93, 688,1987)

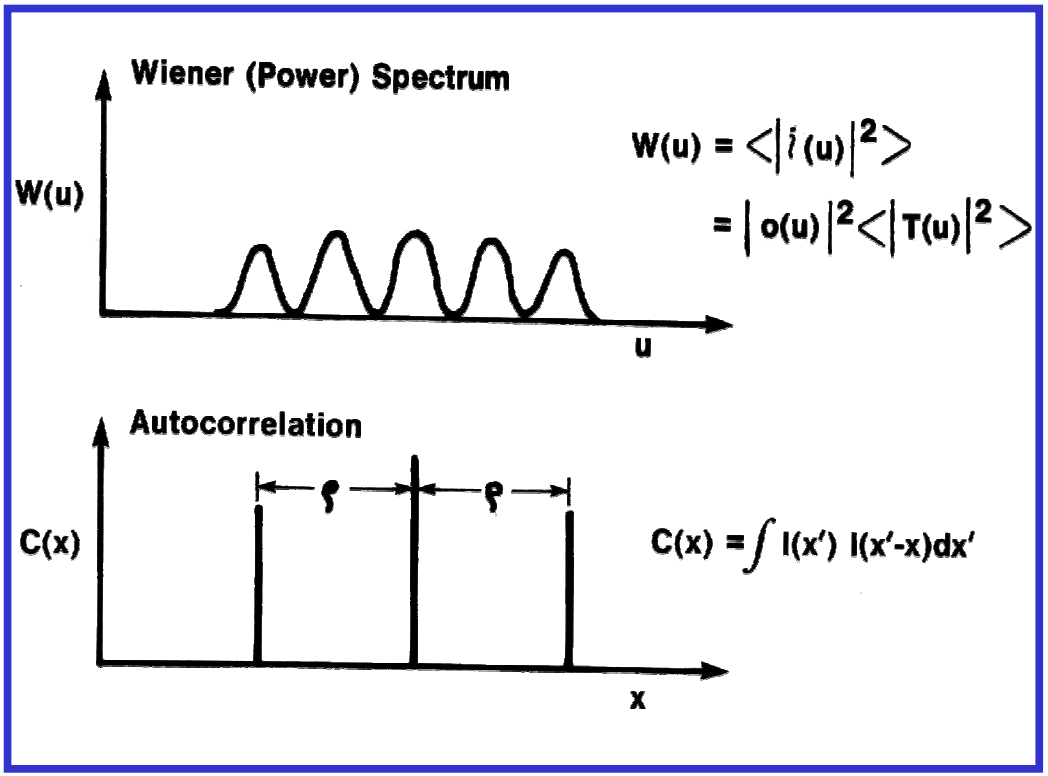


Speckle Interferometry at Kitt Peak c. 1975

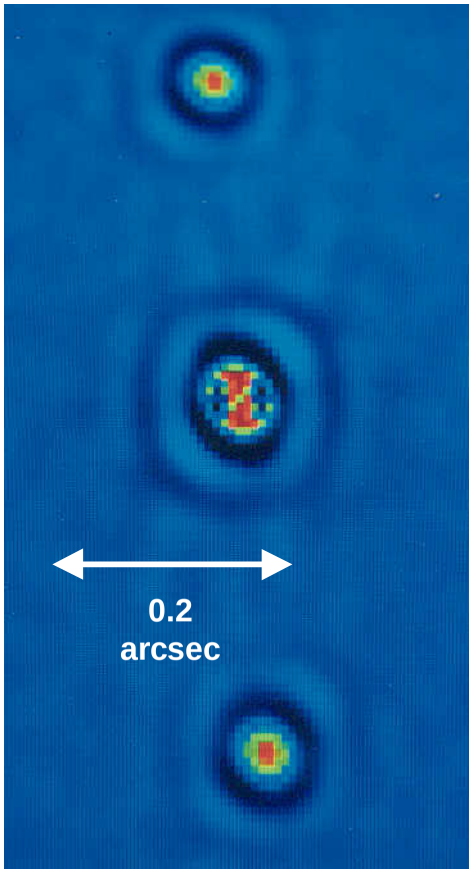


The Speckle Process II.

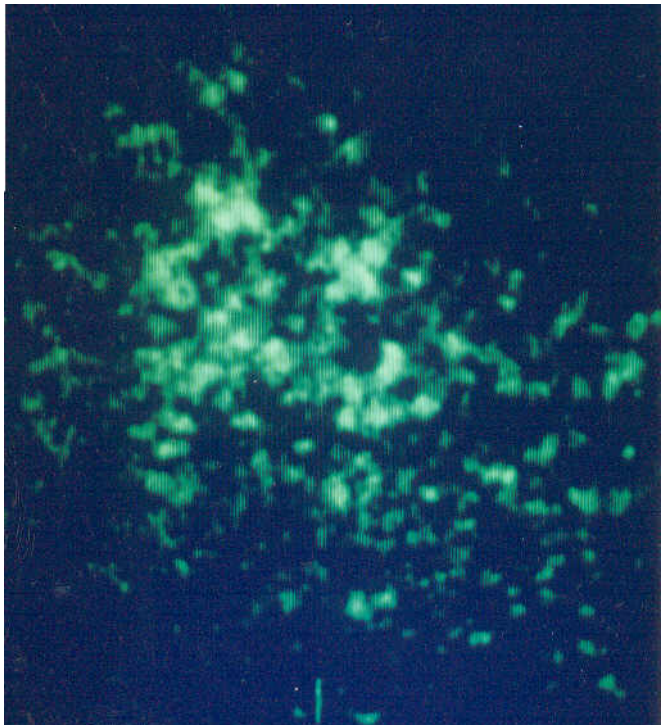
Analysis

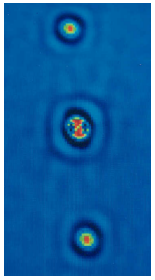


Vector Autocorrelogram



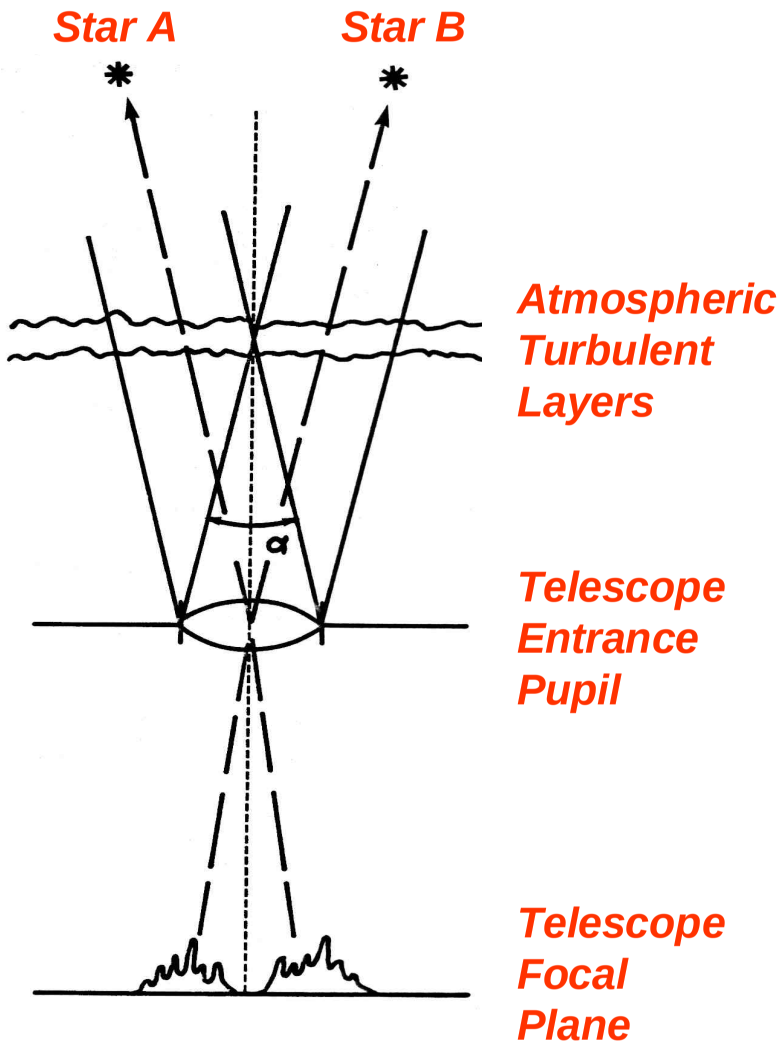
Before & After Processing

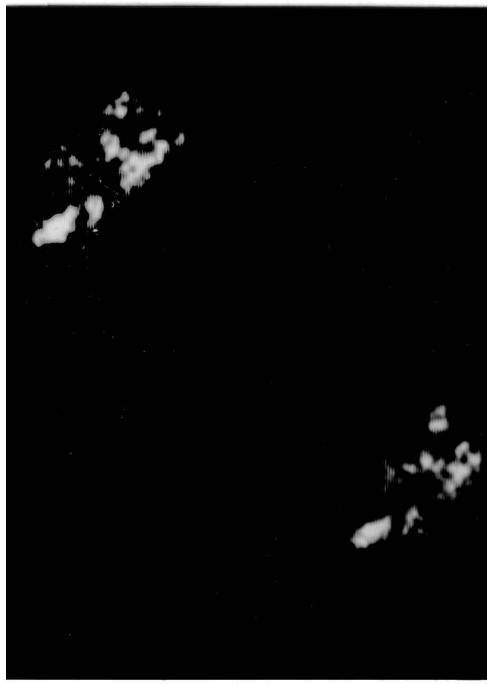




Pretty obvious which can be measured most accurately, huh?

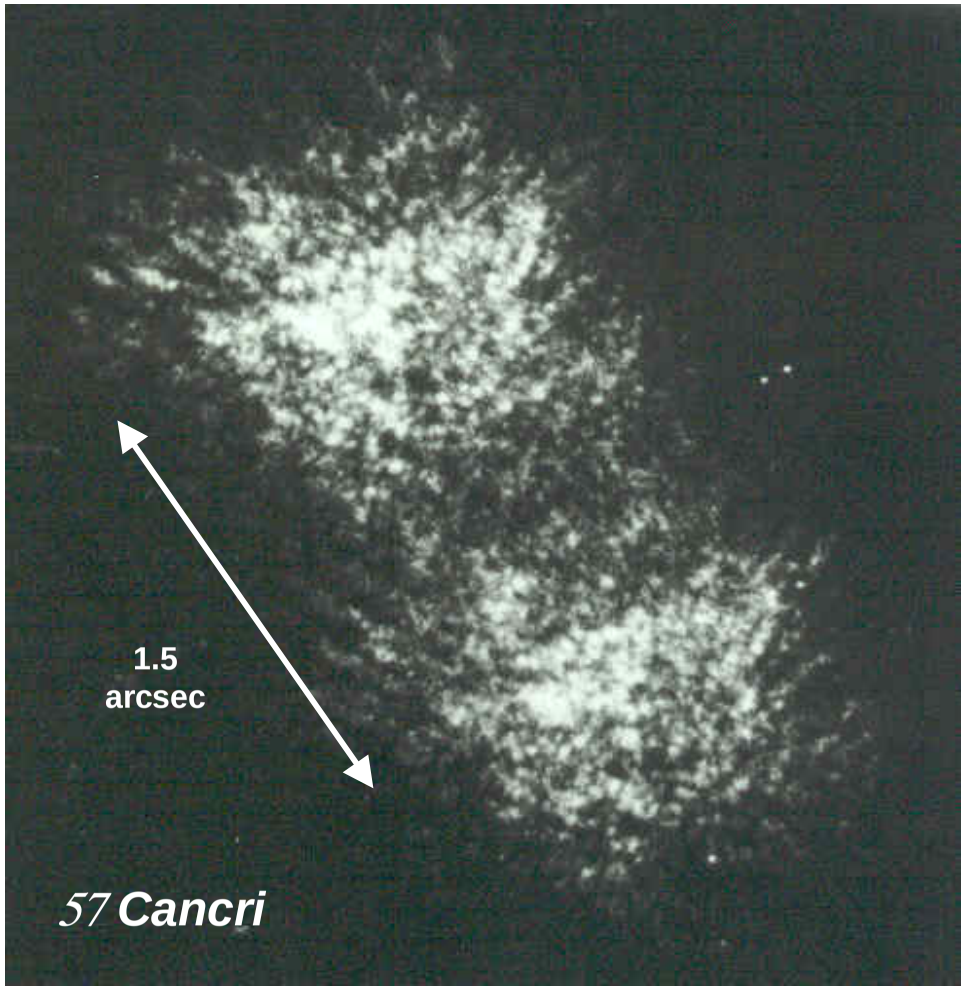
Speckle Isoplanicity



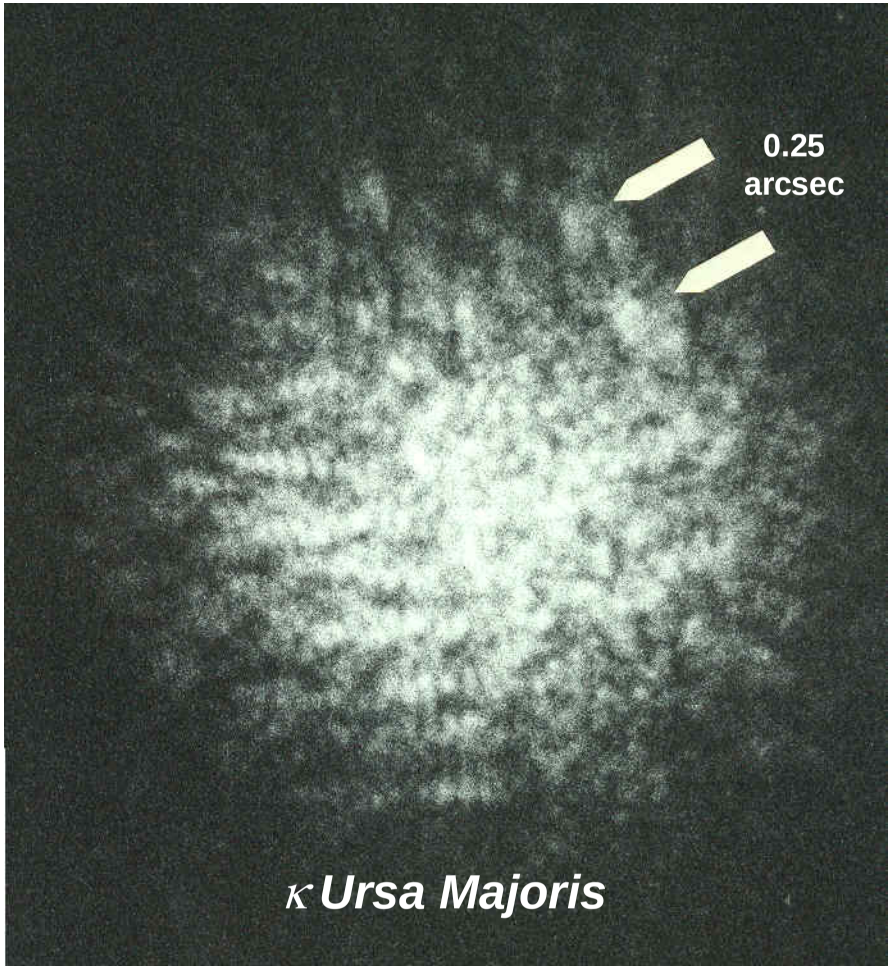


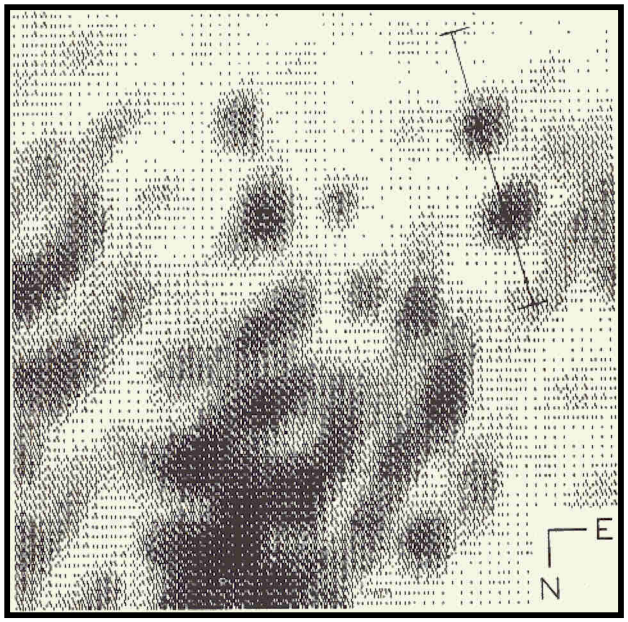
ADS 11483
G2V+G2V, 1985.51, Sep = 1.74 arcsec
GSU Speckle Camera @ CFH Telescope

Speckle Images of a "Wide" Binary



Speckle Images of "Close Binaries"





Capella – 0.05 arcsec

Why Apply Speckle Interferometry to Binary Stars?

Speckle methods possess higher resolution than classical methods

Discovers new binaries

Resolves spectroscopic binaries

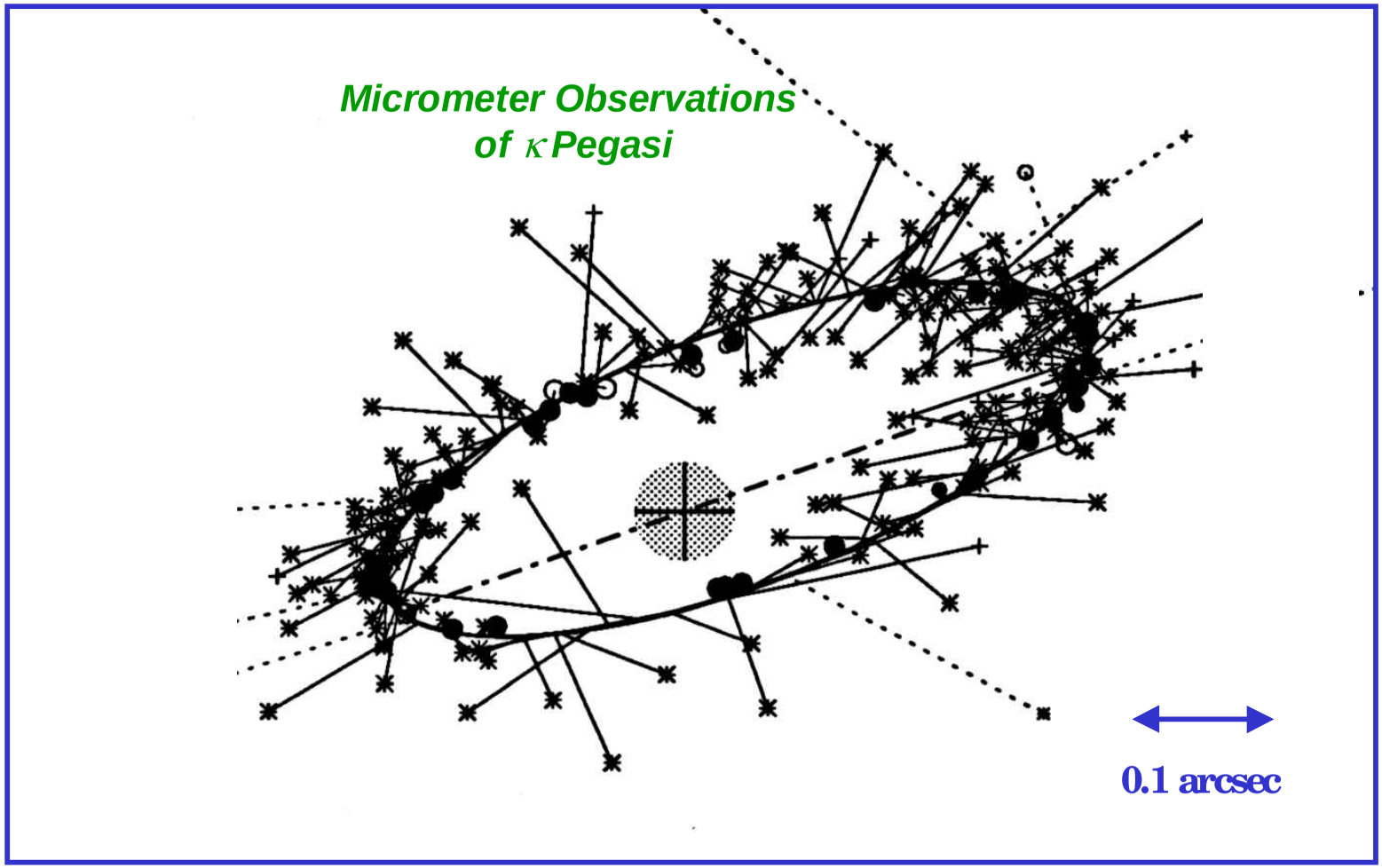
Provides better orbital coverage

Speckle methods possess higher accuracy than classical methods

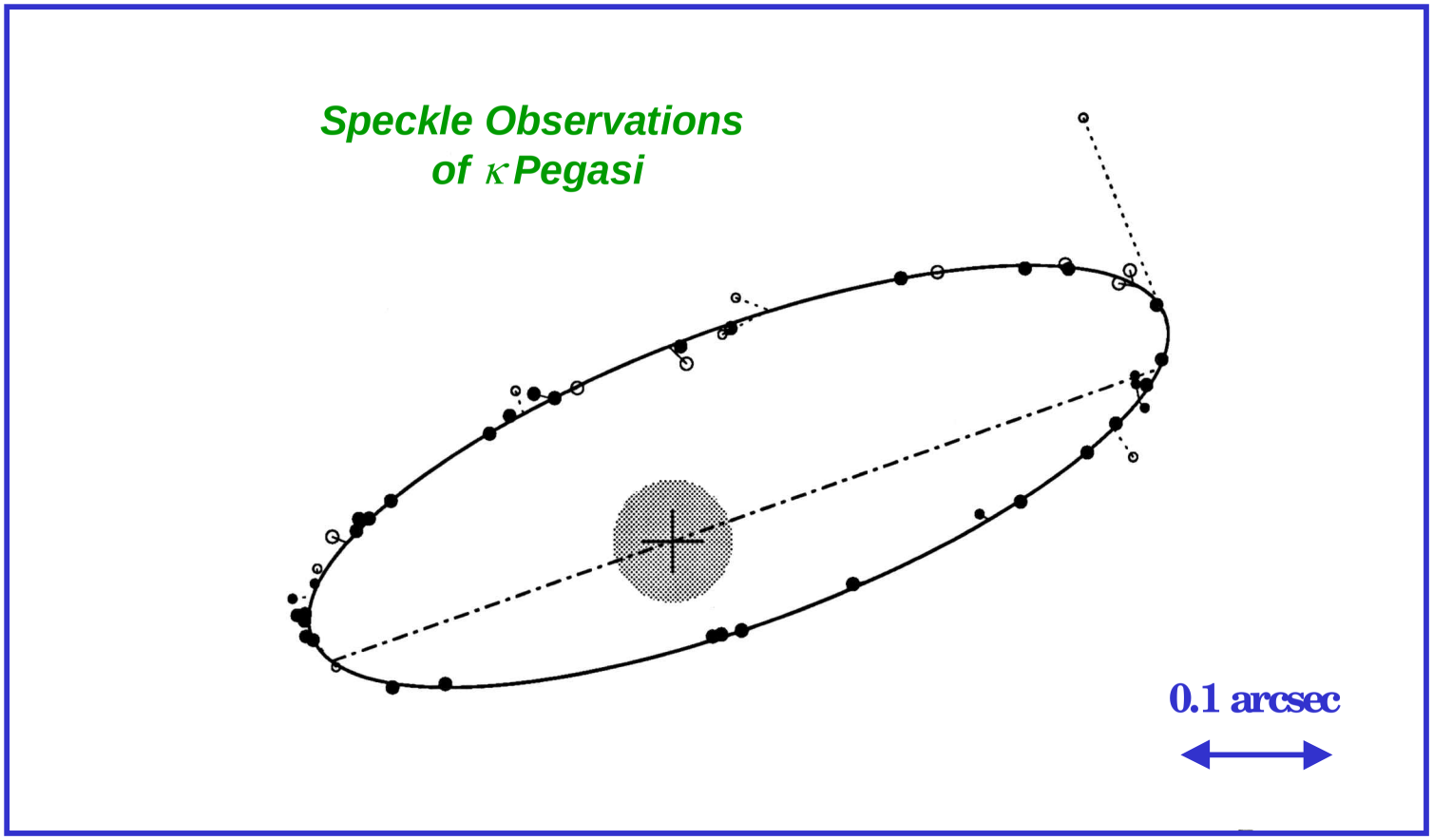
Leads to more accurately determined masses

Can detect submotions from unseen companions

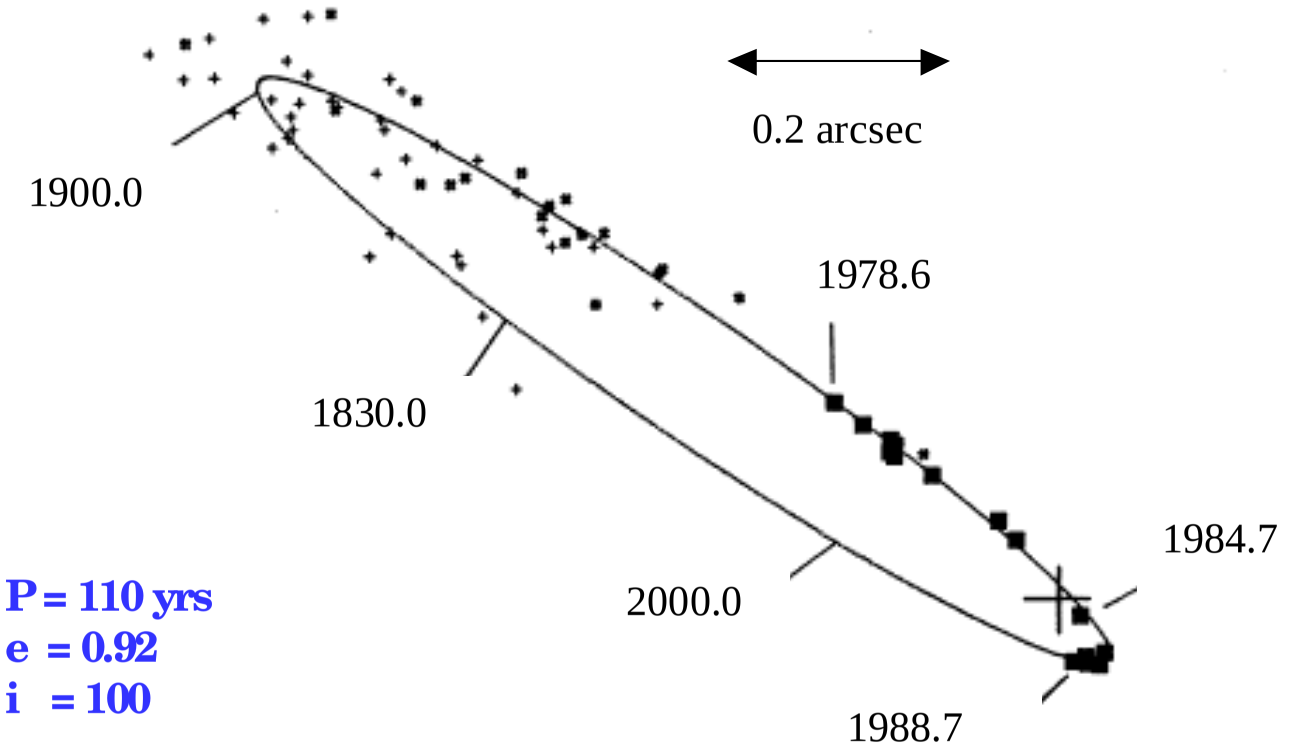
Enhanced Measurement Accuracy I.



Enhanced Measurement Accuracy II.

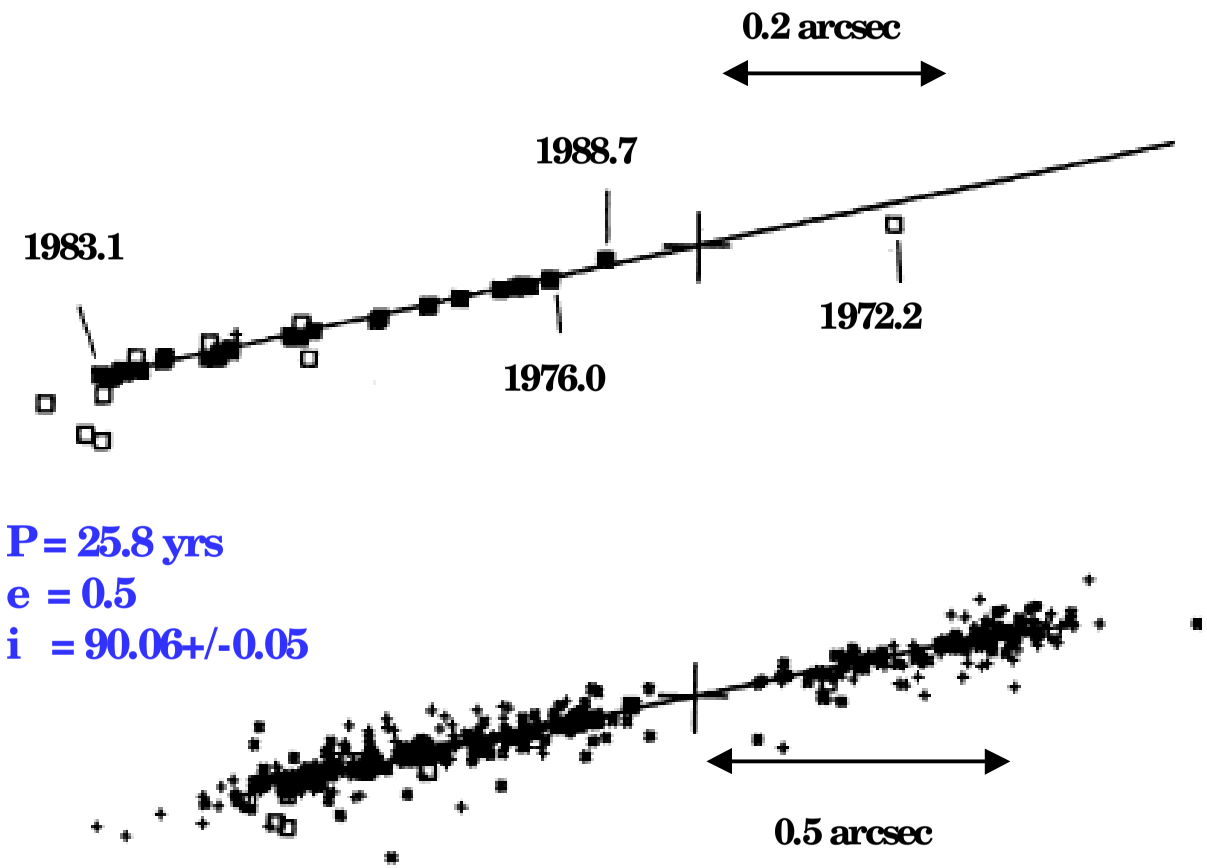


ADS 1105 – 1984 Periastron Passage
(Hartkopf *et al.* AJ, 98, 1014, 1989)

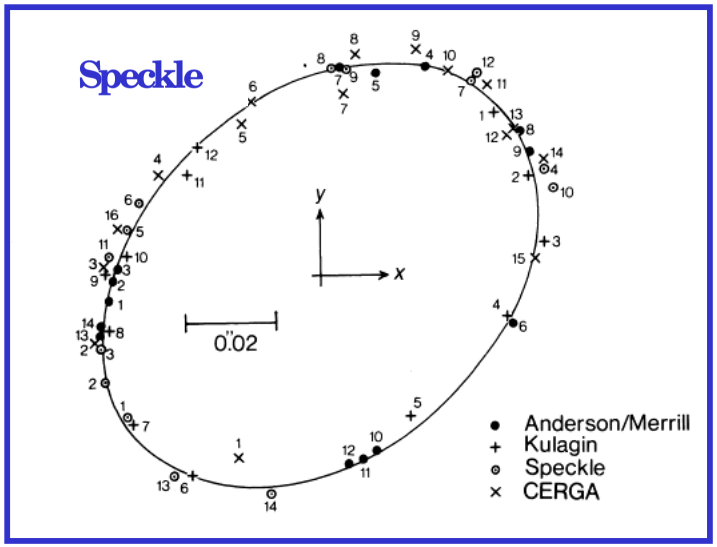


P = 110 yrs
e = 0.92
i = 100

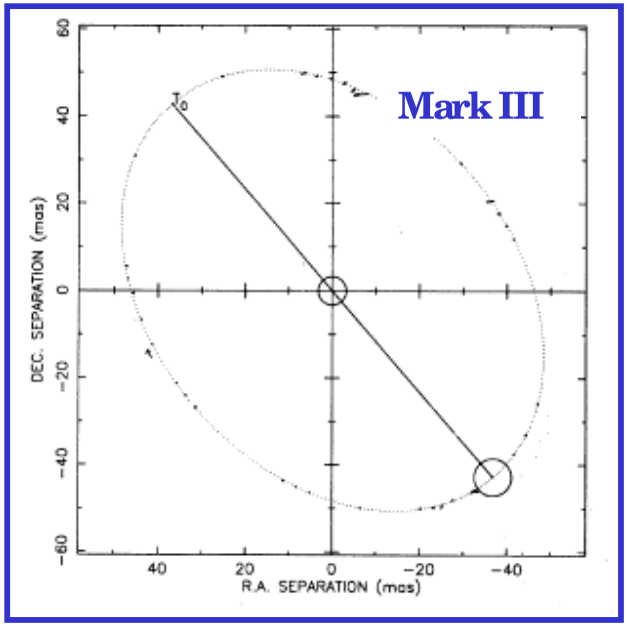
ADS 8804 – Edge-on Orbit
(Hartkopf *et al.* AJ, 98, 1014, 1989)



Capella – God's Gift to Interferometrists



McAlister, AJ, 86, 795, 1981

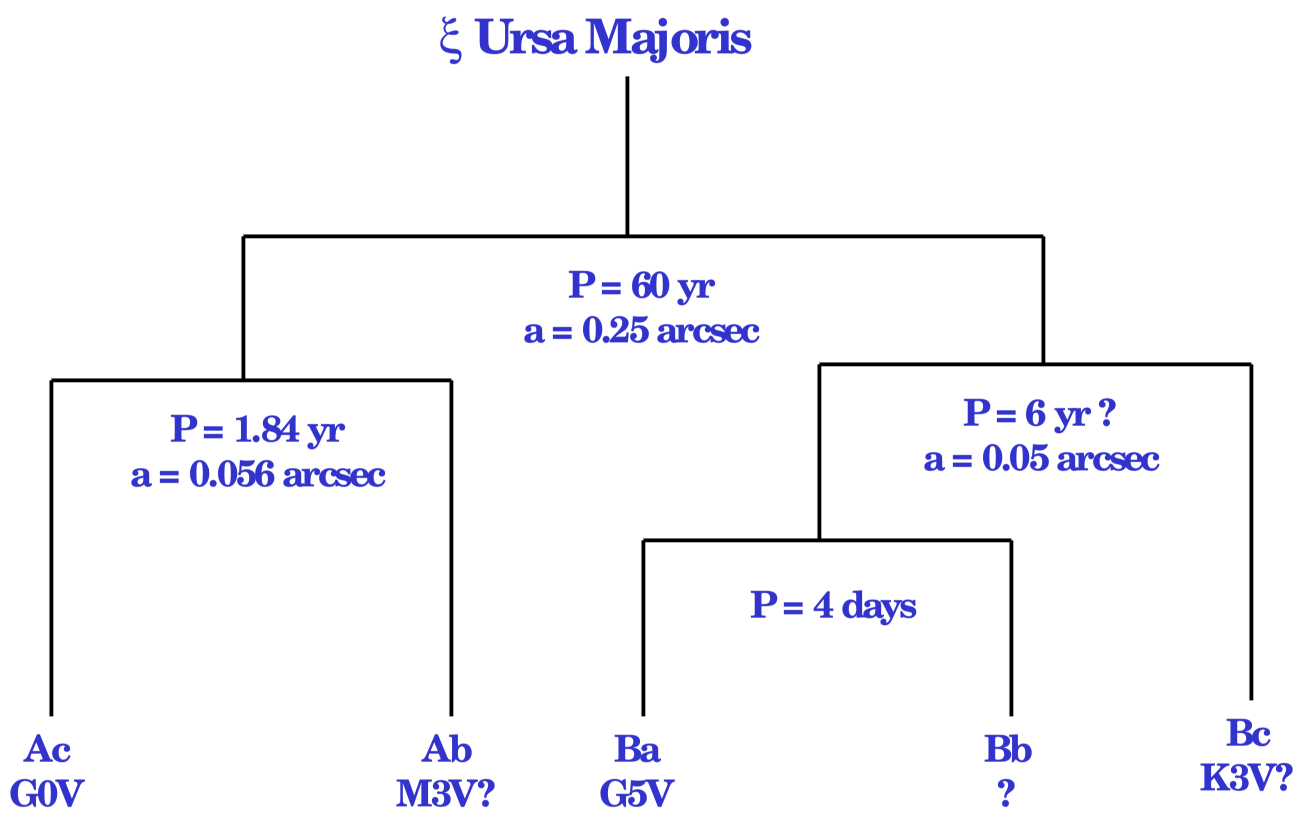


Hummel *et al.*, AJ, 107, 1859, 1994

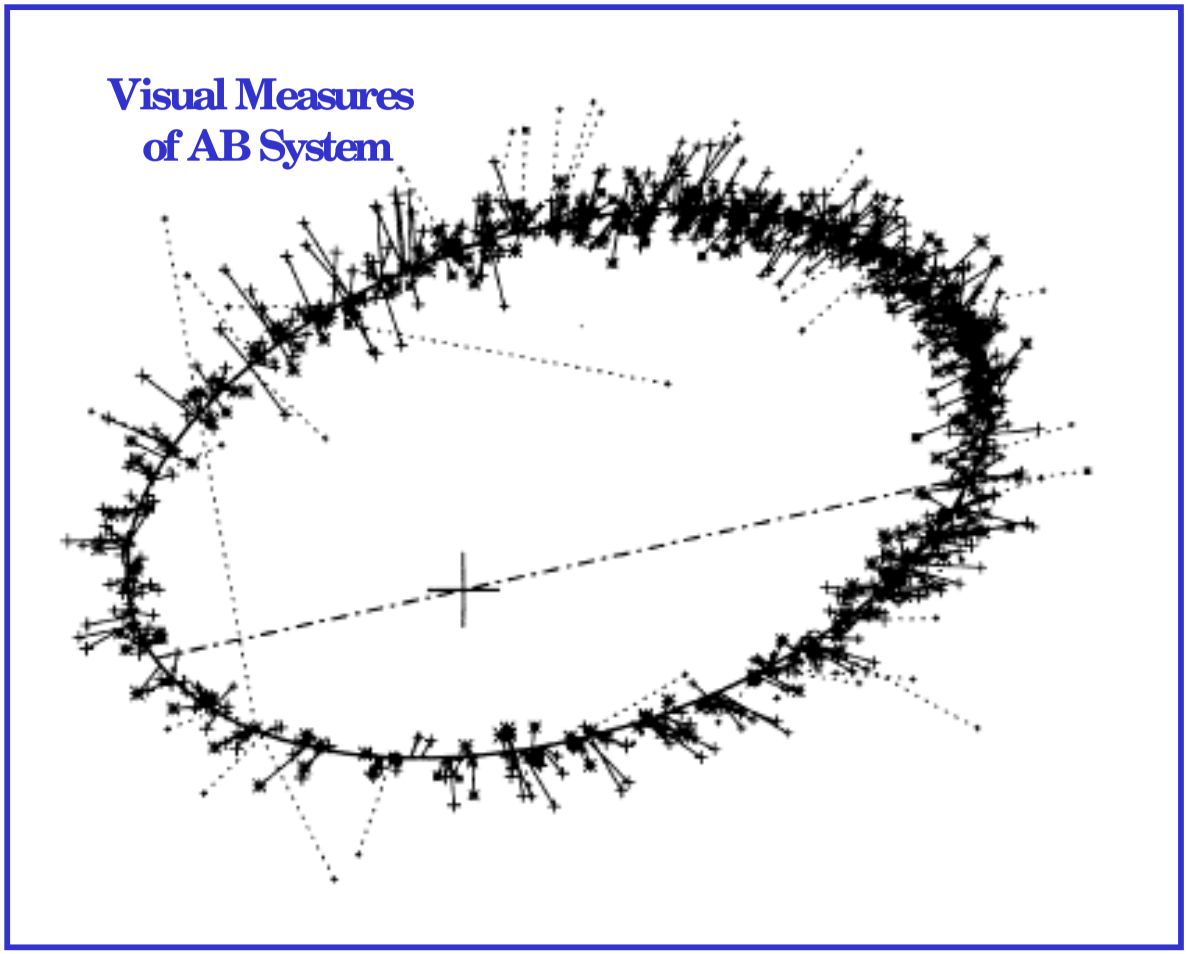
	Speckle	Mark III
P:	104.024+/-0.002	104.022+/-0.002
e:	0	0+/-0.0007
i:	136.64+/-0.10	137.18+/-0.05
a:	54.7+/-0.1	56.47+/-0.05

ξ Ursa Majoris – A Hierarchical Quintuple System I.

(Mason *et al.* AJ, 109, 332, 1995)

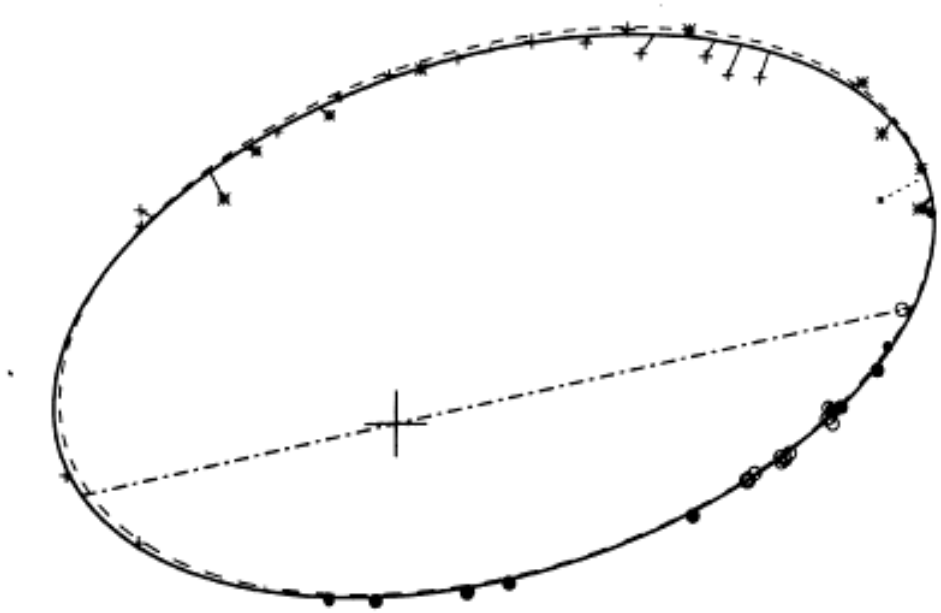


ξ Ursa Majoris – A Hierarchical Quintuple System II.

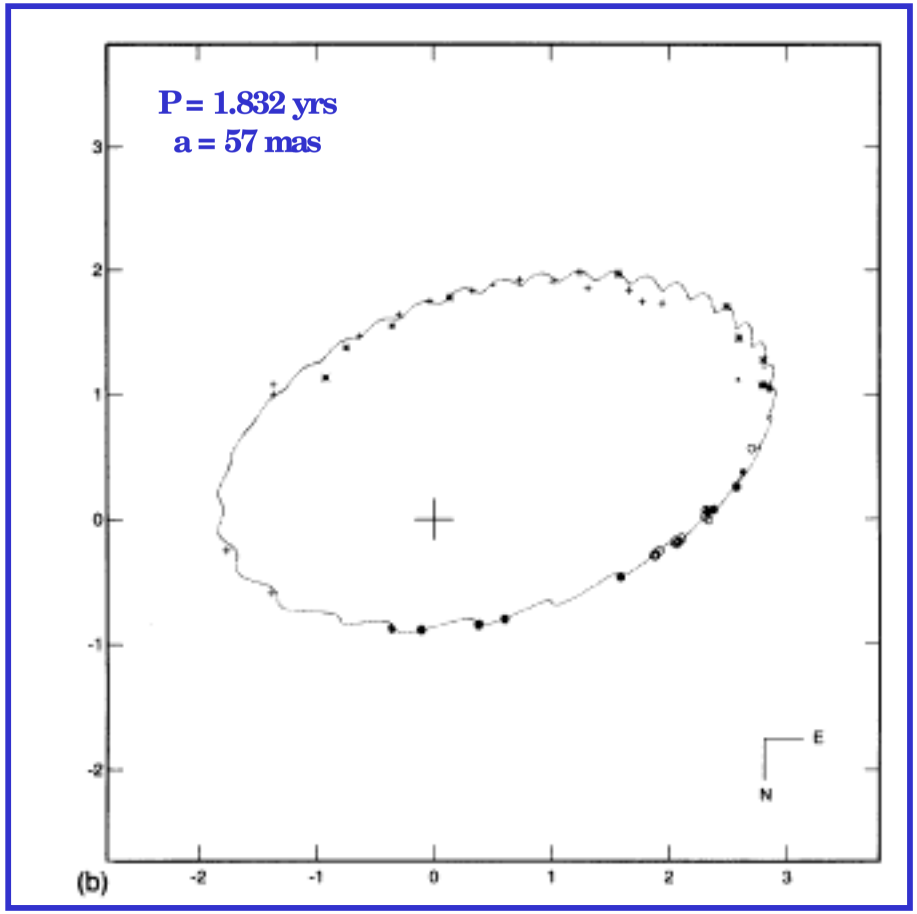


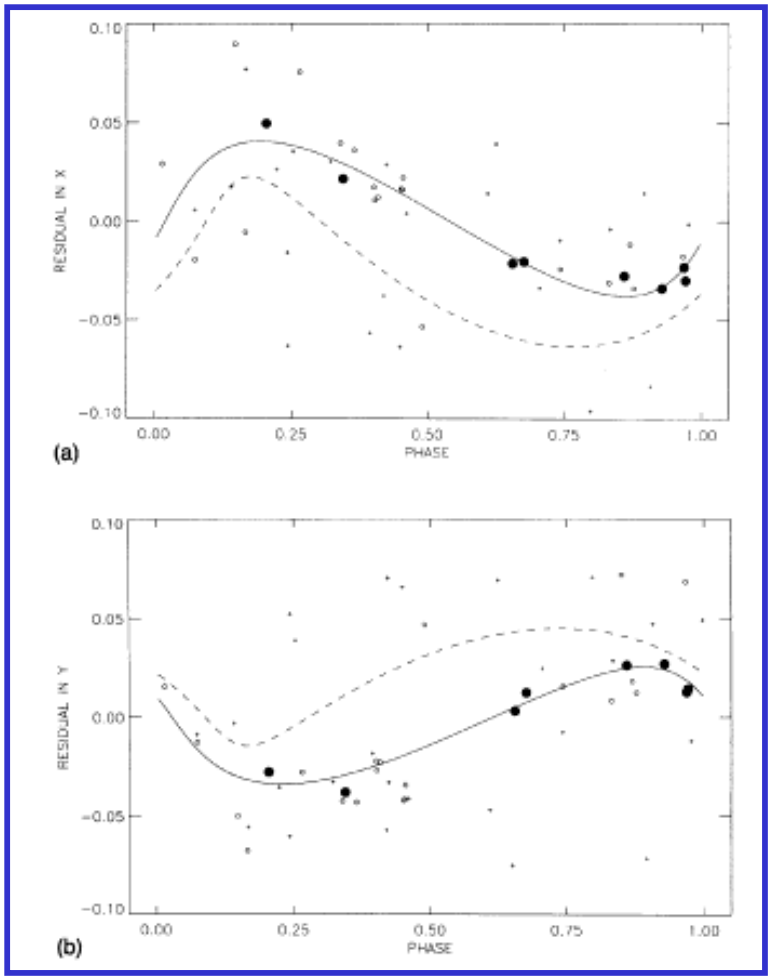
ξ Ursa Majoris – A Hierarchical Quintuple System II.

Speckle Measures of AB System

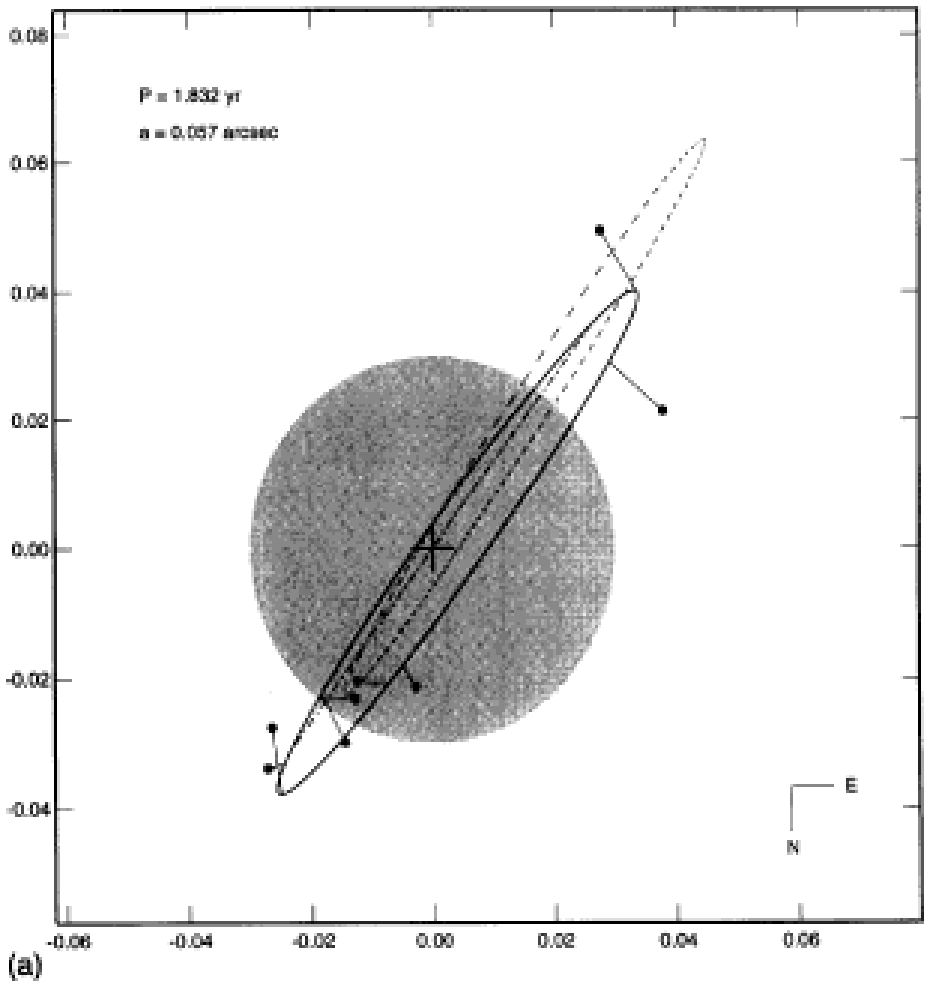


ξ Ursa Majoris – A Hierarchical Quintuple System III.
Astrometric Companion



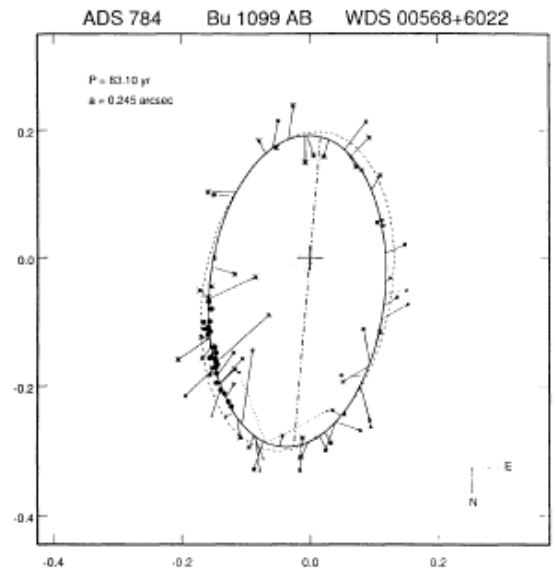


ξ Ursa Majoris – A Hierarchical Quintuple System III.
Speckle Orbit for Astrometric Companion



HR 266: A Visual/Spectroscopic/Astrometric Quadruple
(Cole *et al.* AJ, 103, 1357,1992)

FIG. 2. Mobile diagram of HR 266 and some of its properties.



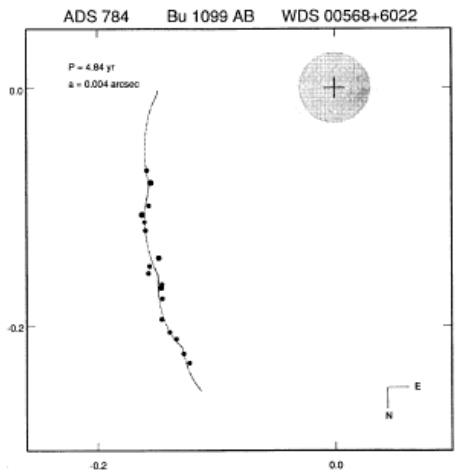


TABLE 8. Assumed properties of HR 266 = ADS 784.

Component	Spectral type	M_V	Mass ($\mathscr{M}_\odot$)	$v \sin i$ (km s^{-1})
A	B7 IV	−1.0	5.0	270
Ba	B9 IV	−0.3	3.4	⩽5
Bb	A1 V	1.2	2.25	⩽5
Bc			2.8	
Parallax		0".0038	0".0054	
Distance		263 pc	185 pc	

Separation Histogram of Interferometric Measures (from the "Third Catalogue…")

Table 1. Third Interferometric Catalogue Statistics
(as of April 2000)

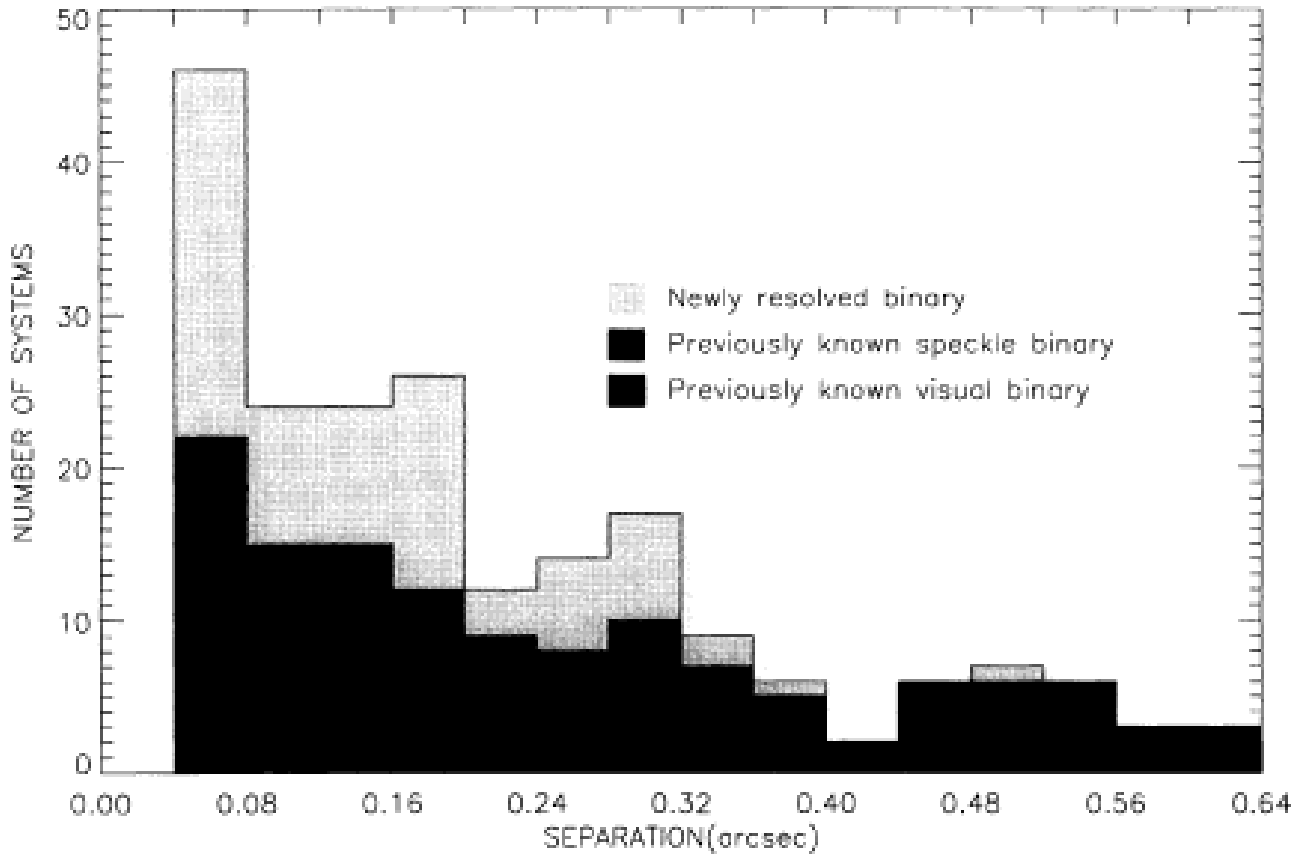
Number of stars: 28,777
Number of interferometric binaries: ~3,500
(excluding occultation pairs)

Number of observations:	Resolved	Unresolved	Total	Median Separation
CHARA Speckle	18,746	6,477	25,223	0.27
Hipparcos	13,140	0	13,140	1.40
Tycho	12,745	0	12,745	2.27
USNO Speckle	10,986	196	11,182	1.45
Other interferometry	3,801	2,126	5,917	0.22
Eyepiece interferometry	2,820	981	3,801	0.13
Occultation	721	156	877	0.06
Arrays	472	3	475	0.01
HST	356	50	406	0.22
All sources	63,787	9,989	73,776	0.81

Number of papers included in catalogue: 320

See the USNO "Double Star Library" at ad.usno.navy.mil/dsl/

Duplicity Survey of Bright Stars
(McAlister *et al.* AJ, 92, 183, 1987 & AJ, 106, 1639, 1993)



Other Speckle Surveys for Binaries

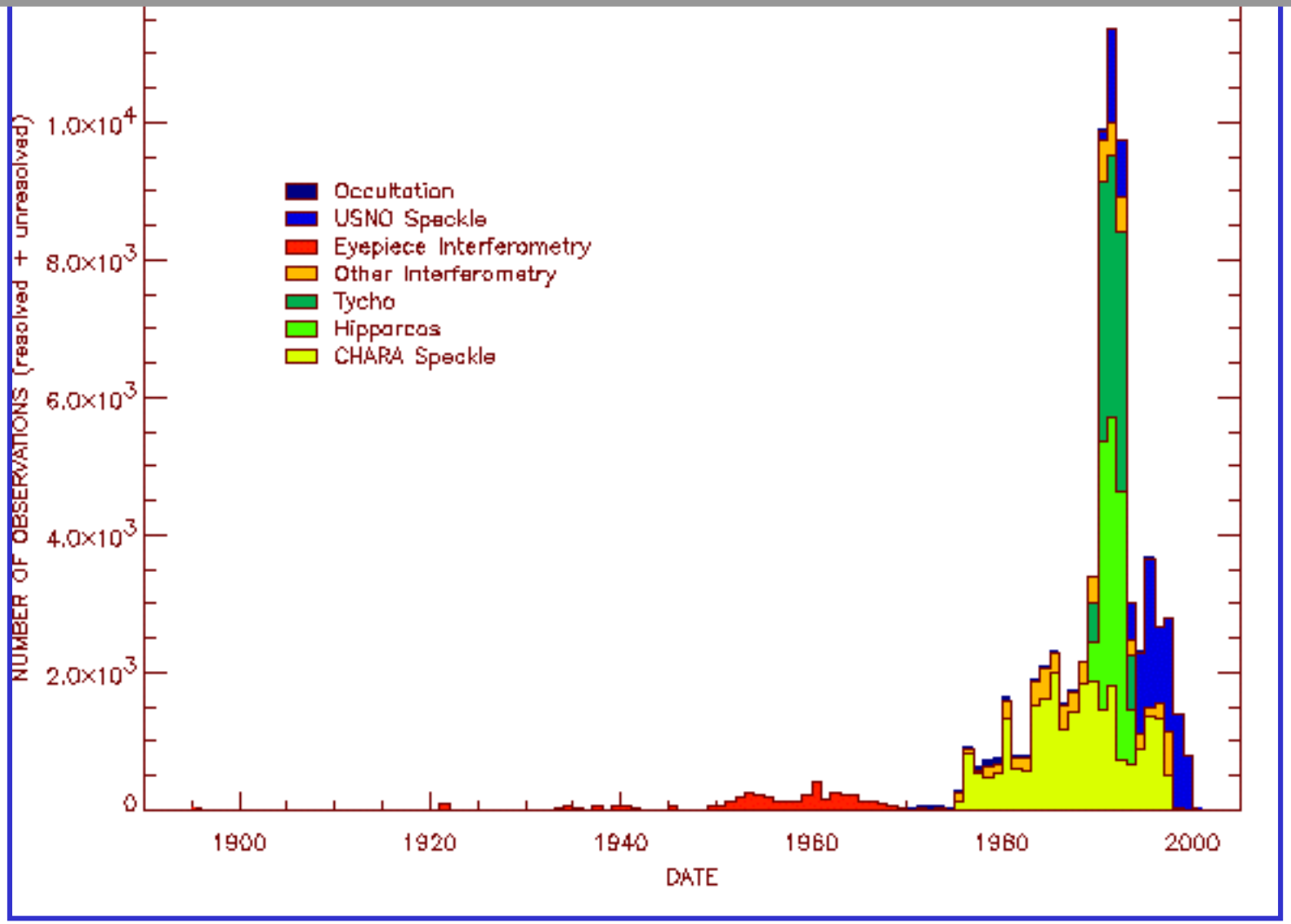
Asteroids **– Roberts *et al.* AJ, 110, 2463, 1995.**

White Dwarfs **– McAlister *et al.* AJ, 112, 1180, 1996.**

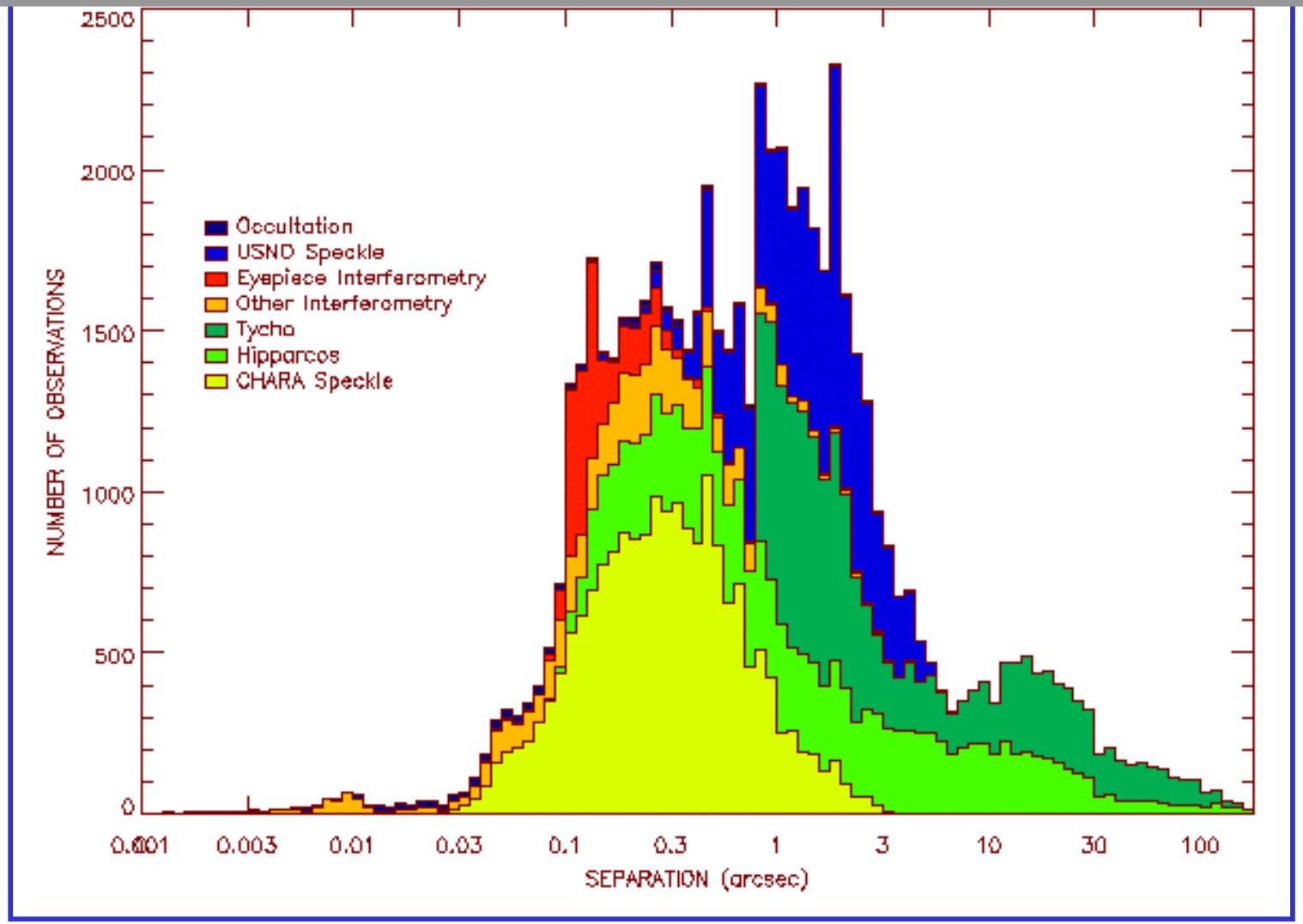
O Stars **– Mason *et al.* AJ, 115, 821, 1998.**

Wolf-Rayet Stars **– Hartkopf *et al.* AJ, 118, 509, 1999.**

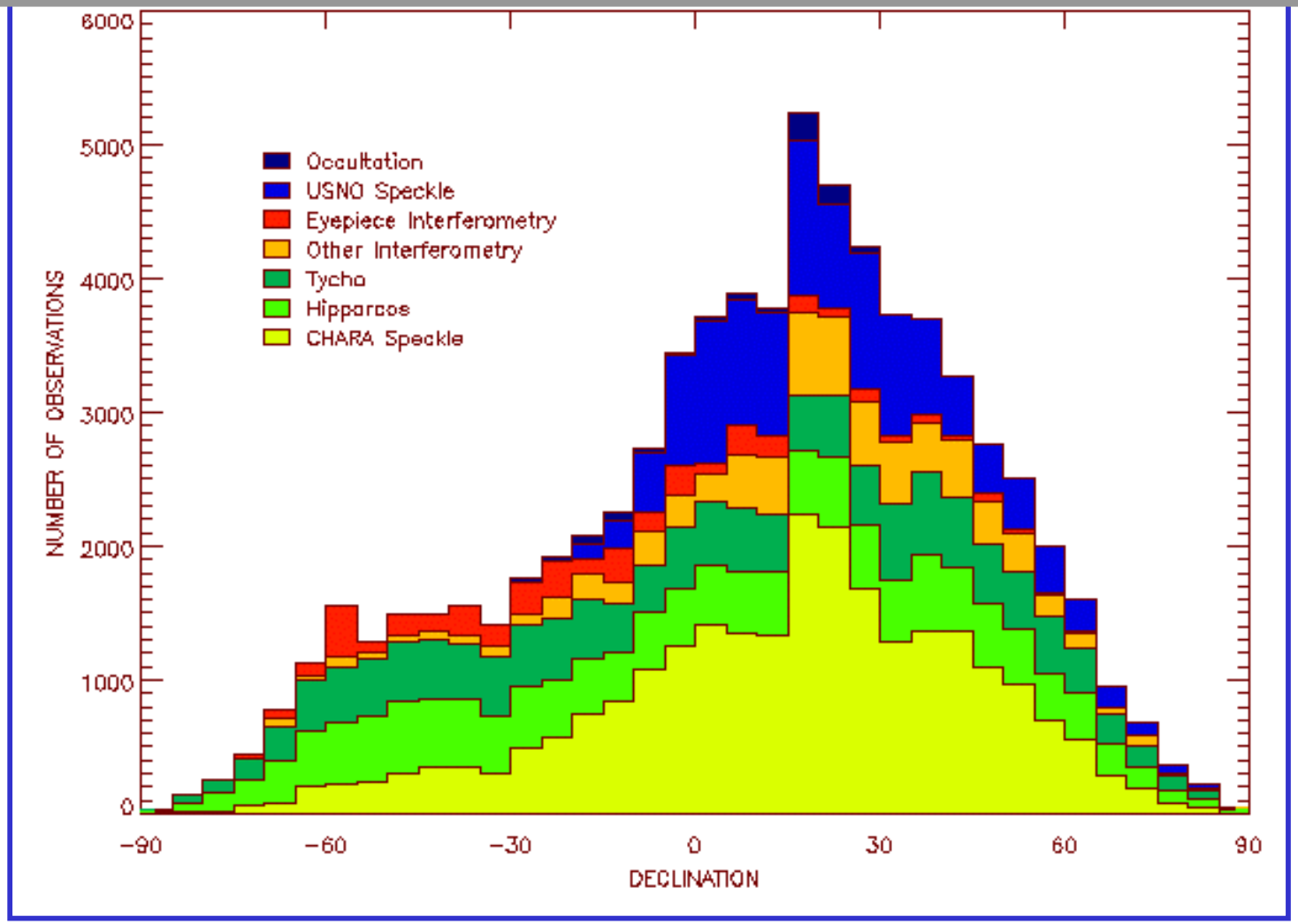
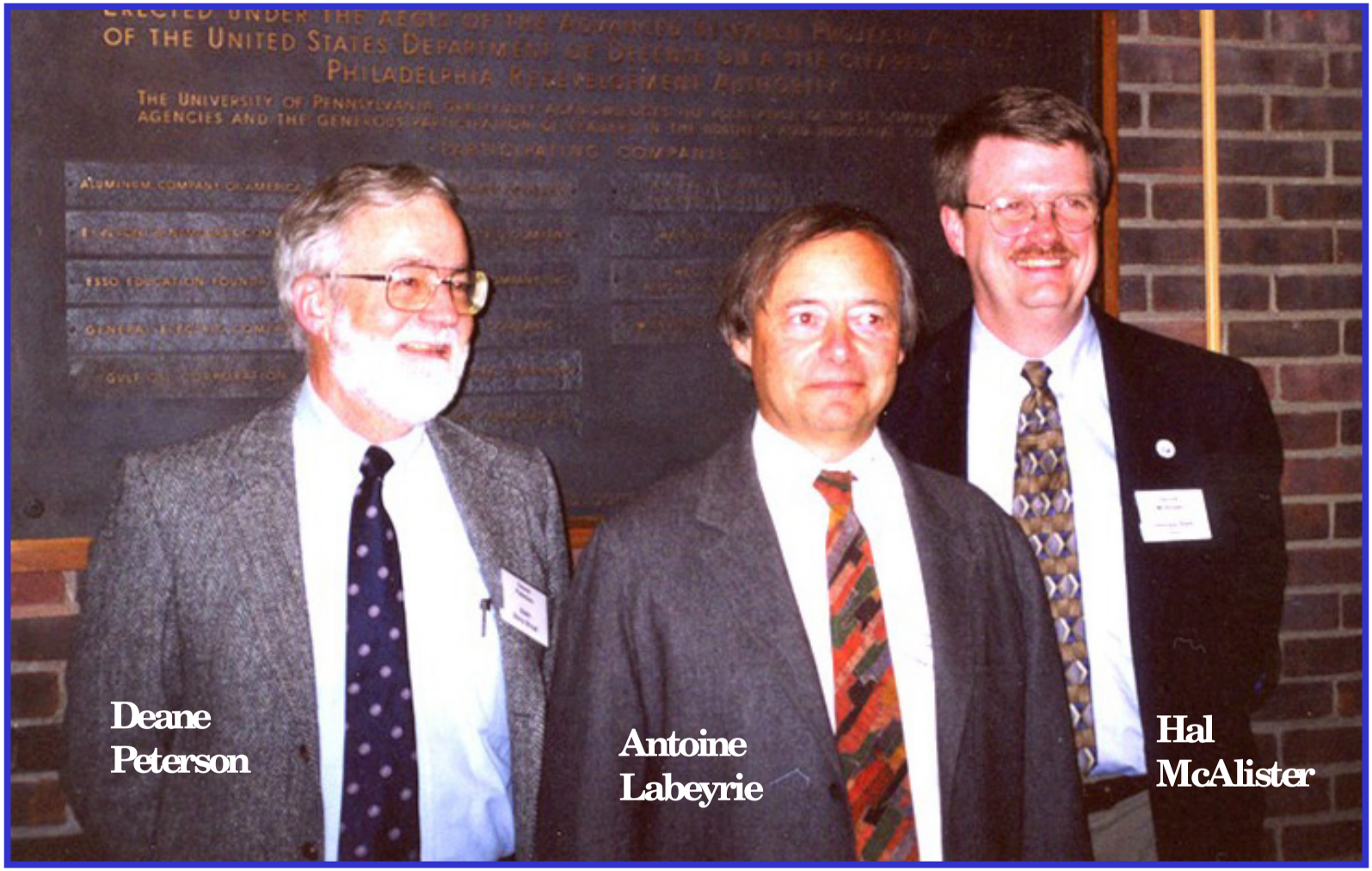
Growth of Interferometric Measures of Binaries (from the "Third Catalogue…")



Separation Histogram of Interferometric Measures (from the "Third Catalogue…")



Declination Histogram of Interferometric Measures (from the "Third Catalogue…")



Antoine Labeyrie – Franklin Medal Winner
28 April 2000