CHARA's Origins & MWO's Interferometry Heritage

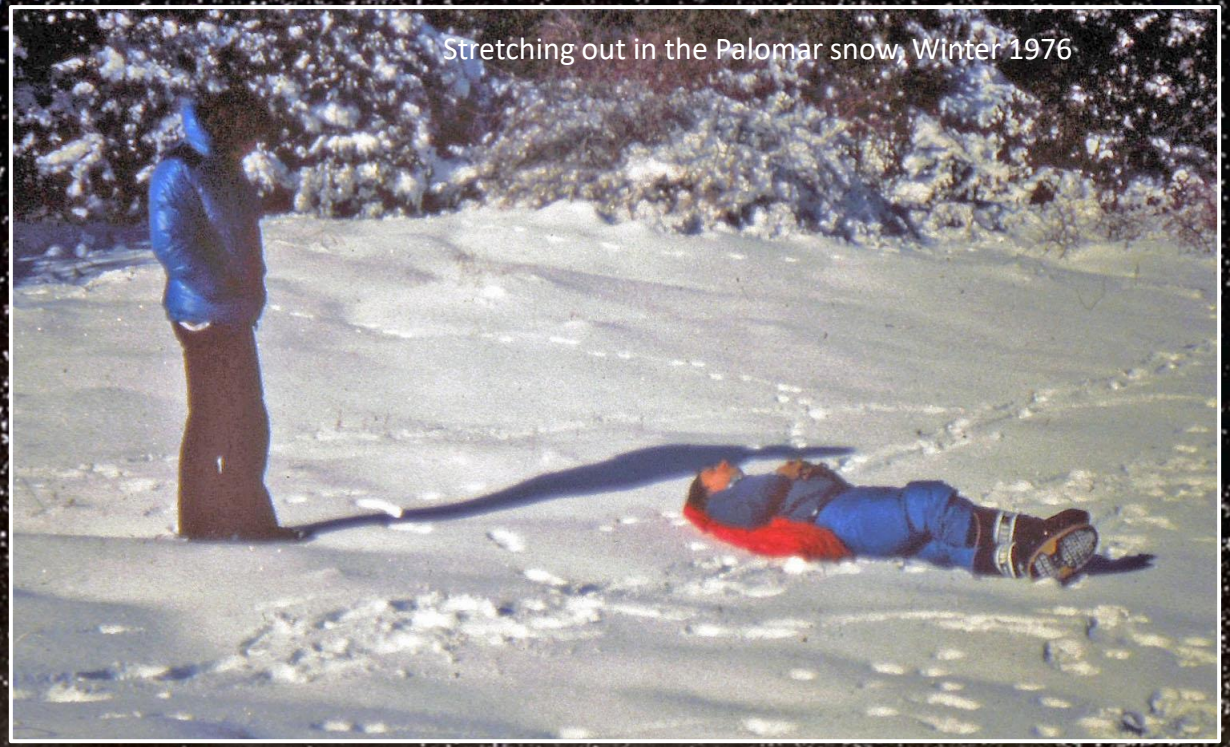
Harold A. McAlister

Regents Professor Emeritus of Astronomy
Georgia State University

A Presentation to the 2023 CHARA Science Meeting
Atlanta, Georgia
13 March 2023


CHARA's Origins
It's All About the People…

CHARA's Origins



Stretching out in the Palomar snow, Winter 1976

Author's Photo

Binary Star Speckle Interferometry

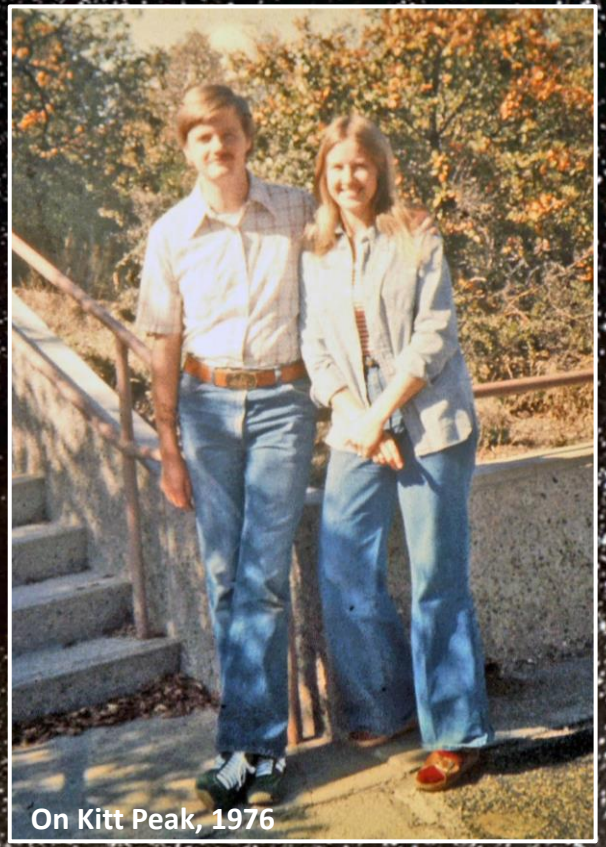
CHARA's Origins

Upon finishing my PhD in 1975 at the Univ. of Virginia, I lucked into a post-doc at Kitt Peak Nat. Obs.

Roger Lynds experimented in Labeyrie's new technique of speckle interferometry and felt it would be worthy of time on the brand-new KPNO 4-m telescope.

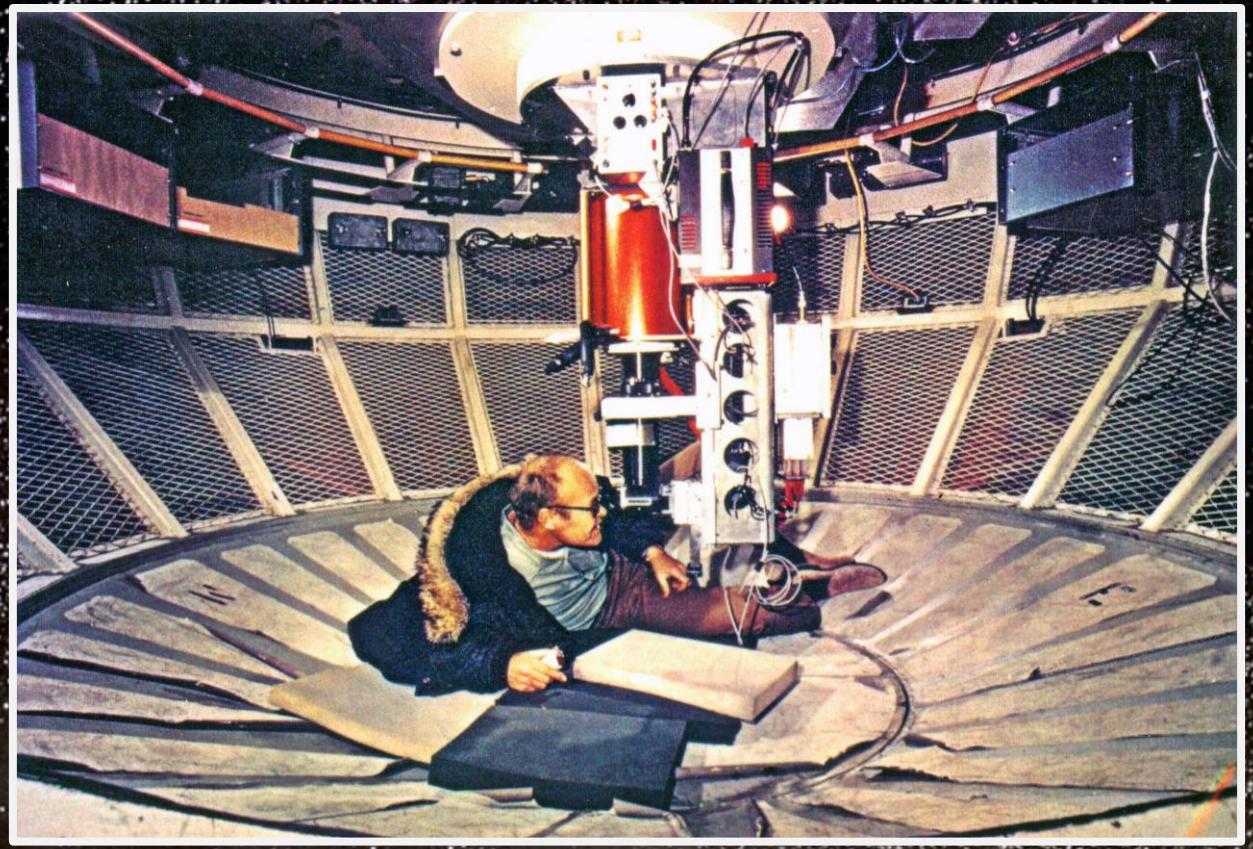
A decision was made to hire a new PhD with experience in astrometry. I fit into that model and went to Tucson for two years.

Steve Ridgway's office was adjacent to the one I shared with another postdoc….



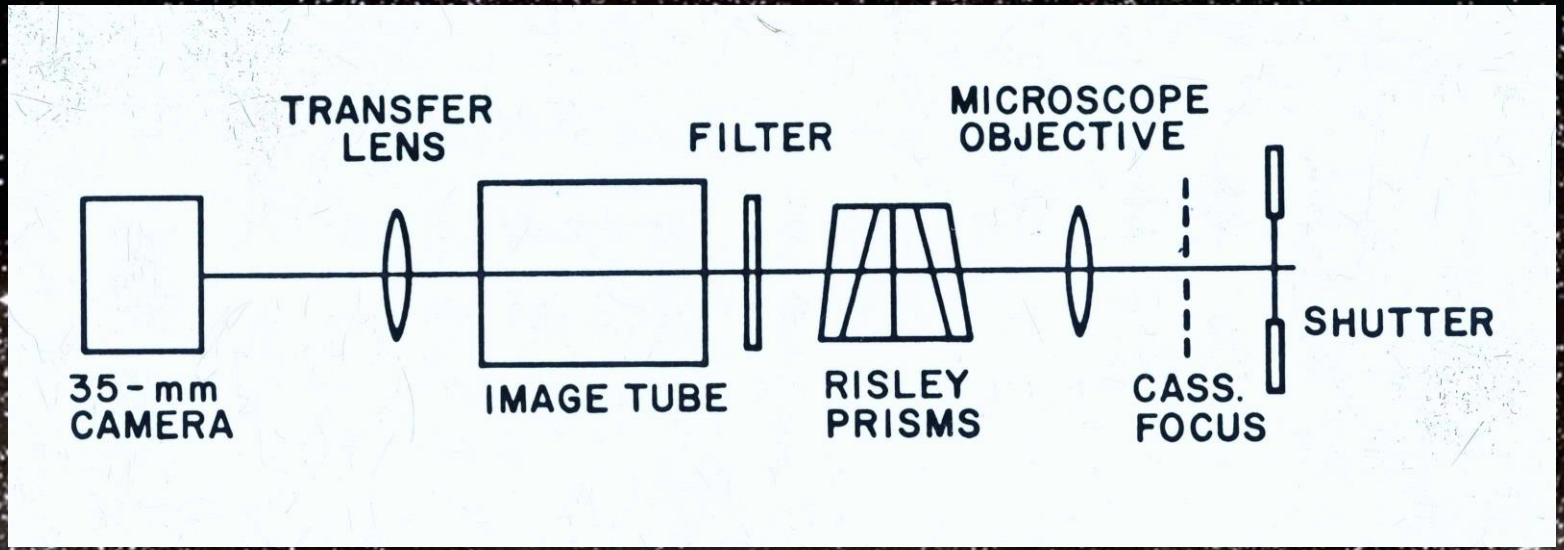
On Kitt Peak, 1976

Lynds' Film-Based Speckle Camera

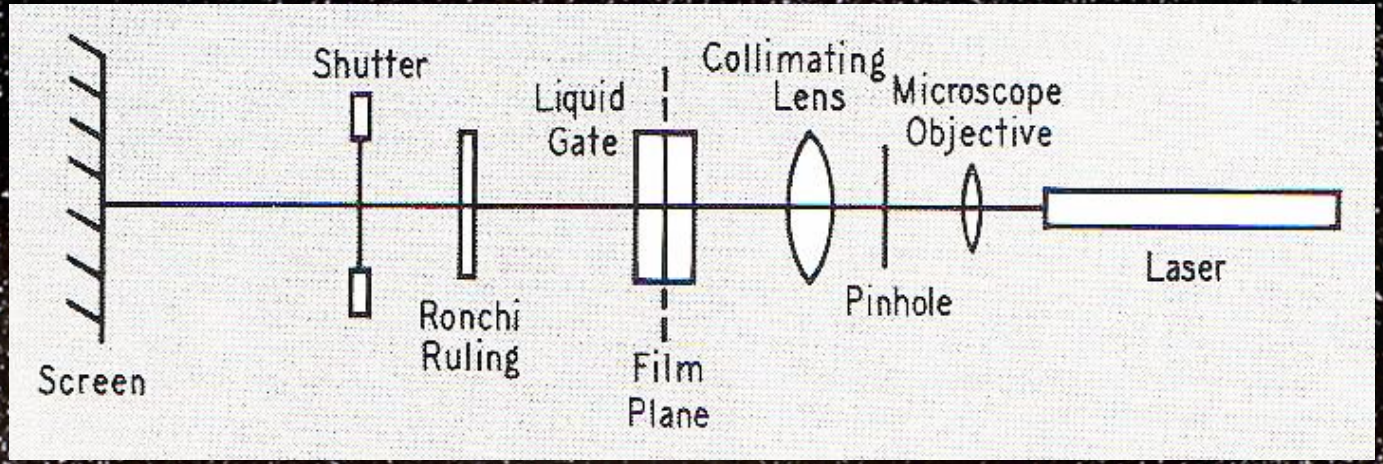


Courtesy AURA, Inc.

Lynds' Film-Based Speckle Camera

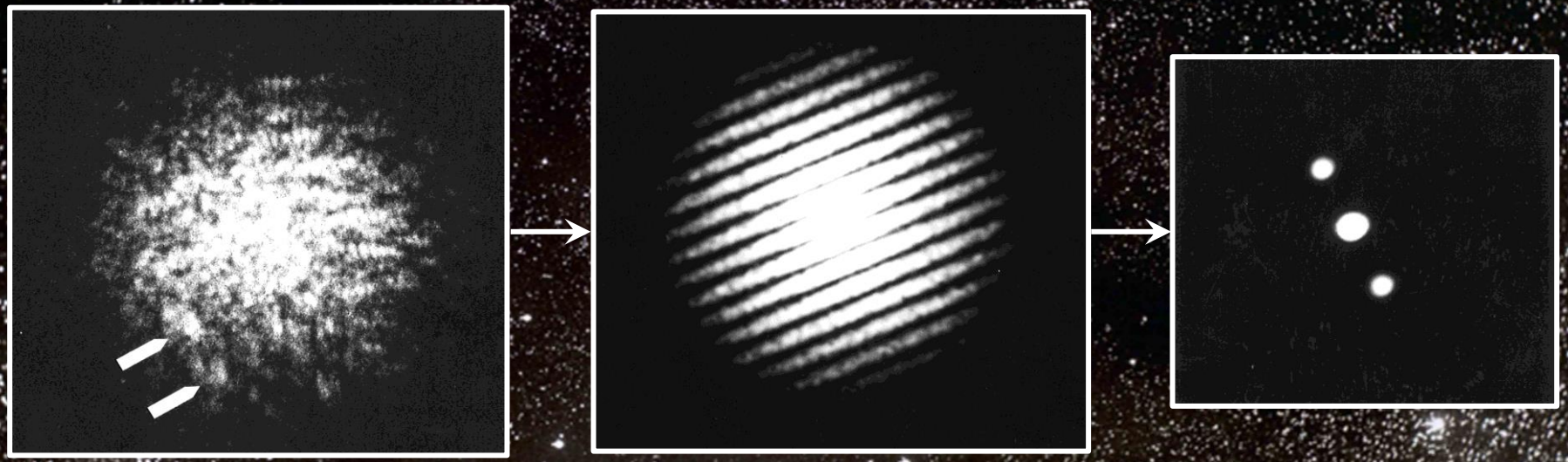


Author's Diagram.



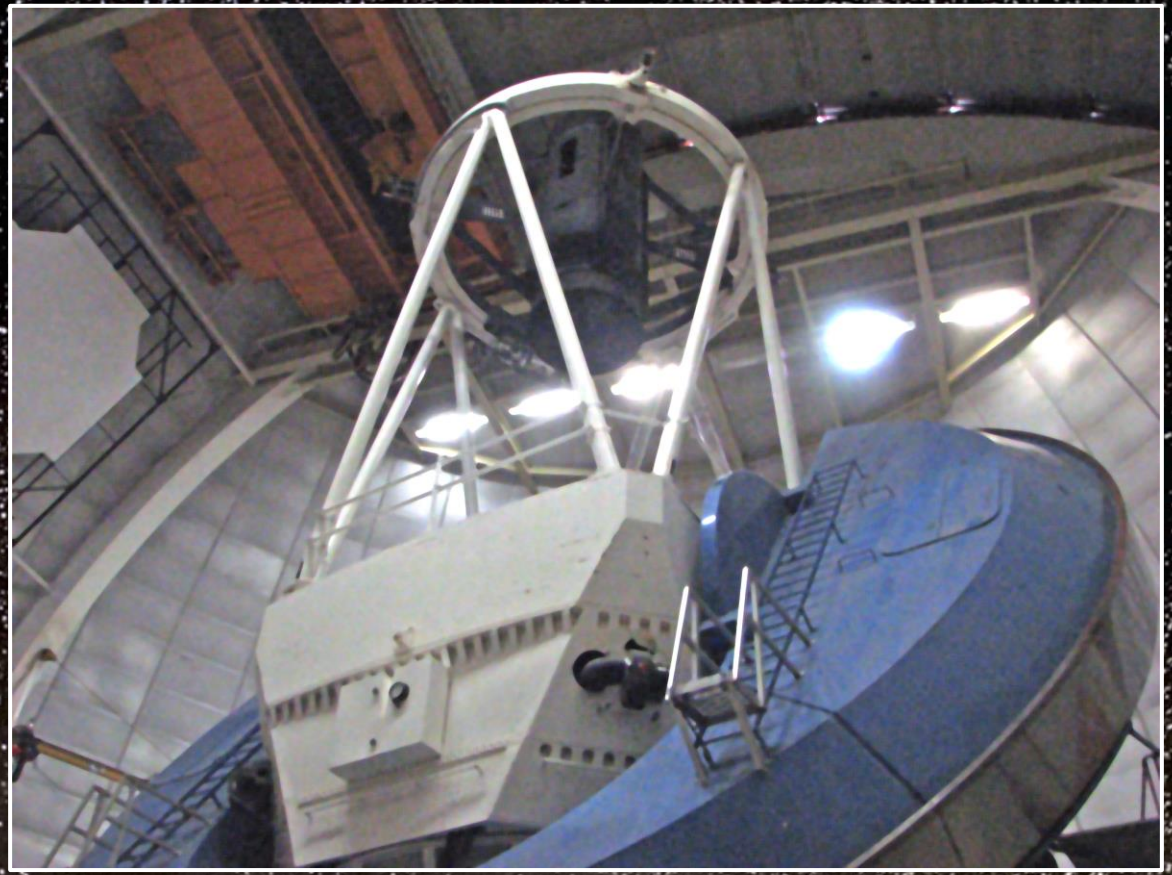
Author's Diagram

Primitive but Lovely Results



Author's Photo

Emphasis was on Calibration

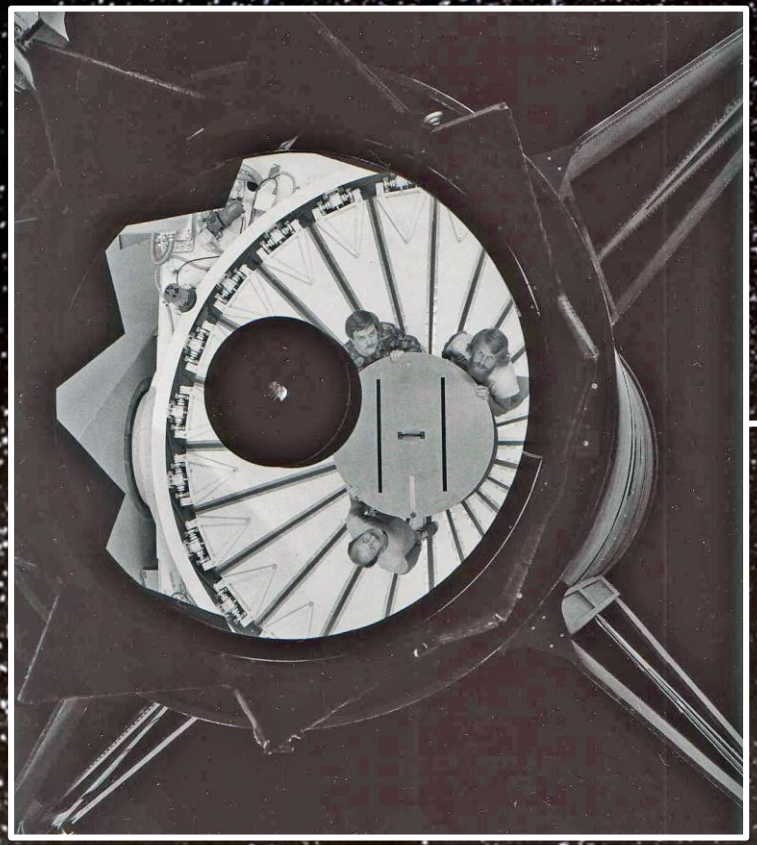


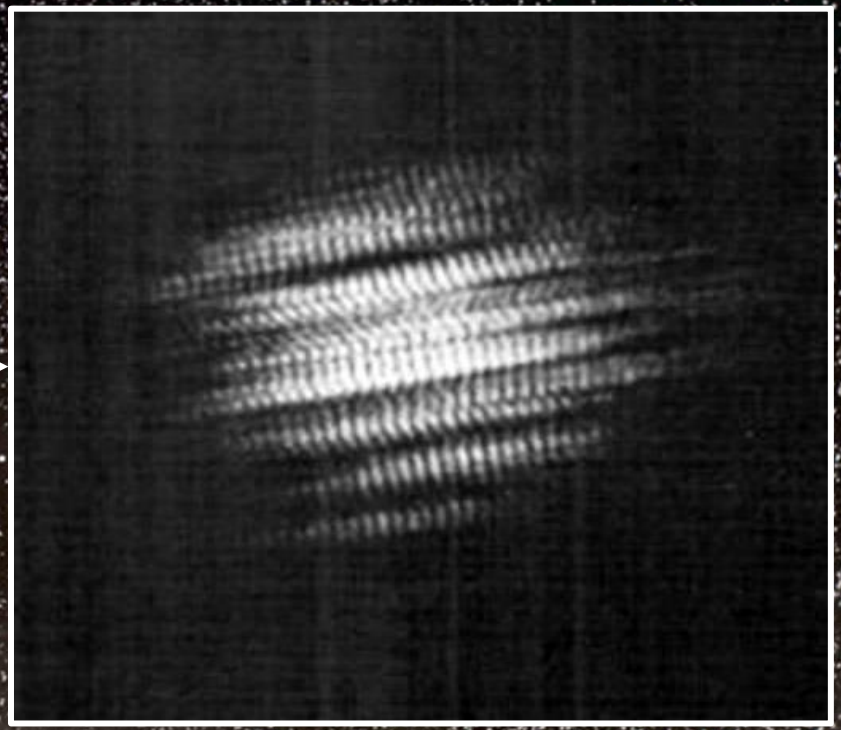
Author's Photo

Emphasis was on Calibration

Author's Photo

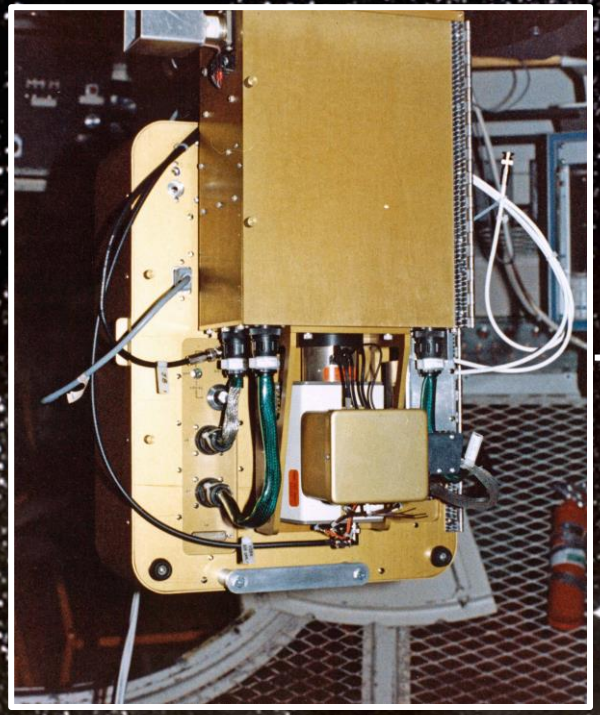
Emphasis was on Calibration

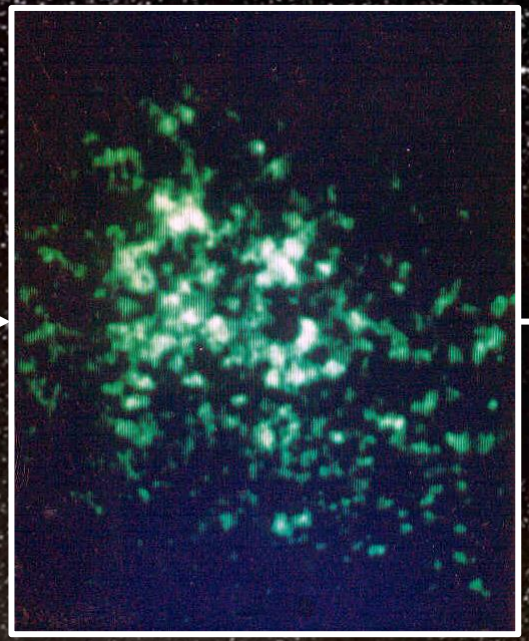


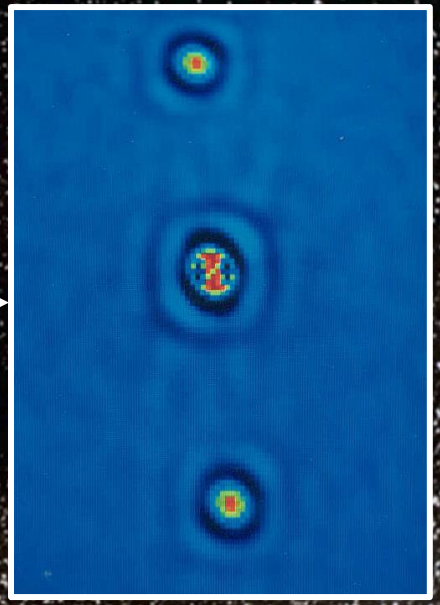


Author's Photos

NSF Funded an ICCD Camera in 1982







Author's Photos

PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC
88:317-322, June 1976

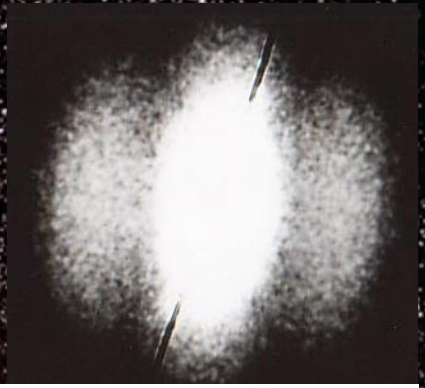
SPECTROSCOPIC BINARIES AS A SOURCE FOR ASTROMETRIC AND SPECKLE INTERFEROMETRIC STUDIES

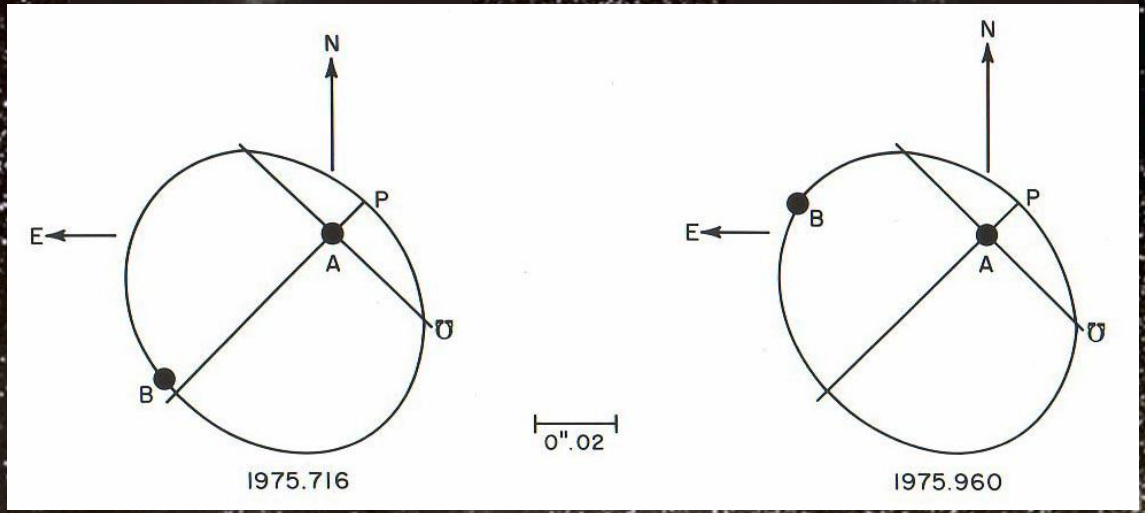
HAROLD A. McALISTER
Kitt Peak National Observatory,* Tucson

Received 1976 February 9

Published orbital elements of spectroscopic binaries are systematically examined to provide lists of systems which might profitably be observed by astrometric and speckle interferometric techniques. The importance of observing these spectroscopic systems with other techniques is emphasized. Consideration is given to image blending effects on astrometric amplitude predictions. Angular separation predictions for

12 Per Orbital Motion in 89 days





12 Persei: ApJ 223, 526, 1978.

CHARA's Origins

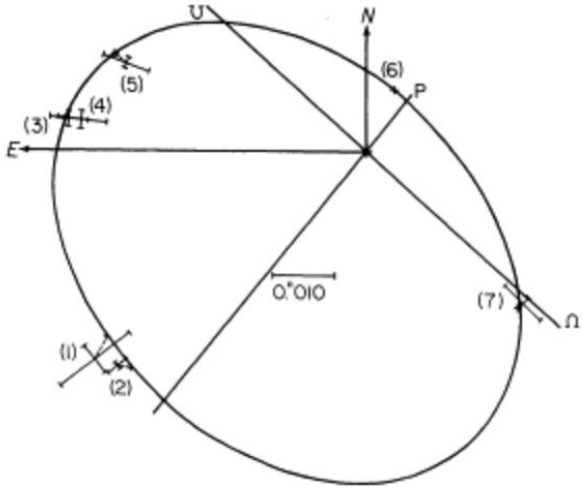


FIG. 1.—The six speckle observations and their error bars are shown on the deduced relative visual orbit for 12 Per. Expected positions calculated for the seven epochs in Table 2 are shown as crosses.

TABLE 3

NEWLY DETERMINED PARAMETERS FOR 12 PERSEI

d	$= 21.9 \pm 1.1$ (s.e.) pc
i	$= 123°.0 \pm 2°.0$
a	$= 0".057 \pm 0".003$
Ω	$= 227°.9 \pm 1°.5$
$\mathfrak{M}_1$	$= (1.25 \pm 0.20)\,\mathfrak{M}_\odot$
$\mathfrak{M}_2$	$= (1.08 \pm 0.17)\,\mathfrak{M}_\odot$
M_{v1}	$= 3.8 \pm 0.1$
M_{v2}	$= 4.1 \pm 0.1$

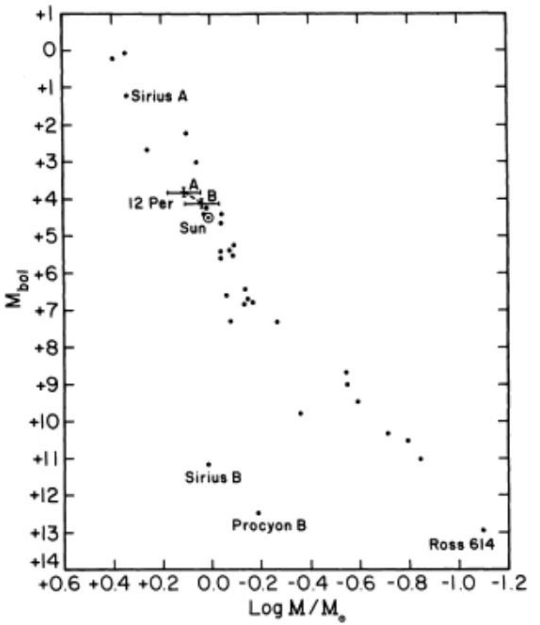


FIG. 2.—The locations on the empirical mass-luminosity diagram as adapted from Harris, Strand, and Worley (1963) are shown for the components of 12 Per.

The Beauty of Resolving DSBs

CHARA's Origins

Angular resolution of a double-lined spectroscopic binary provides masses, distance, and hence luminosities.

Speckle resolution of 0.035 arcsec can penetrate into the sample of candidate DSBs.

100 x more resolution is required to substantially exploit DSBs.

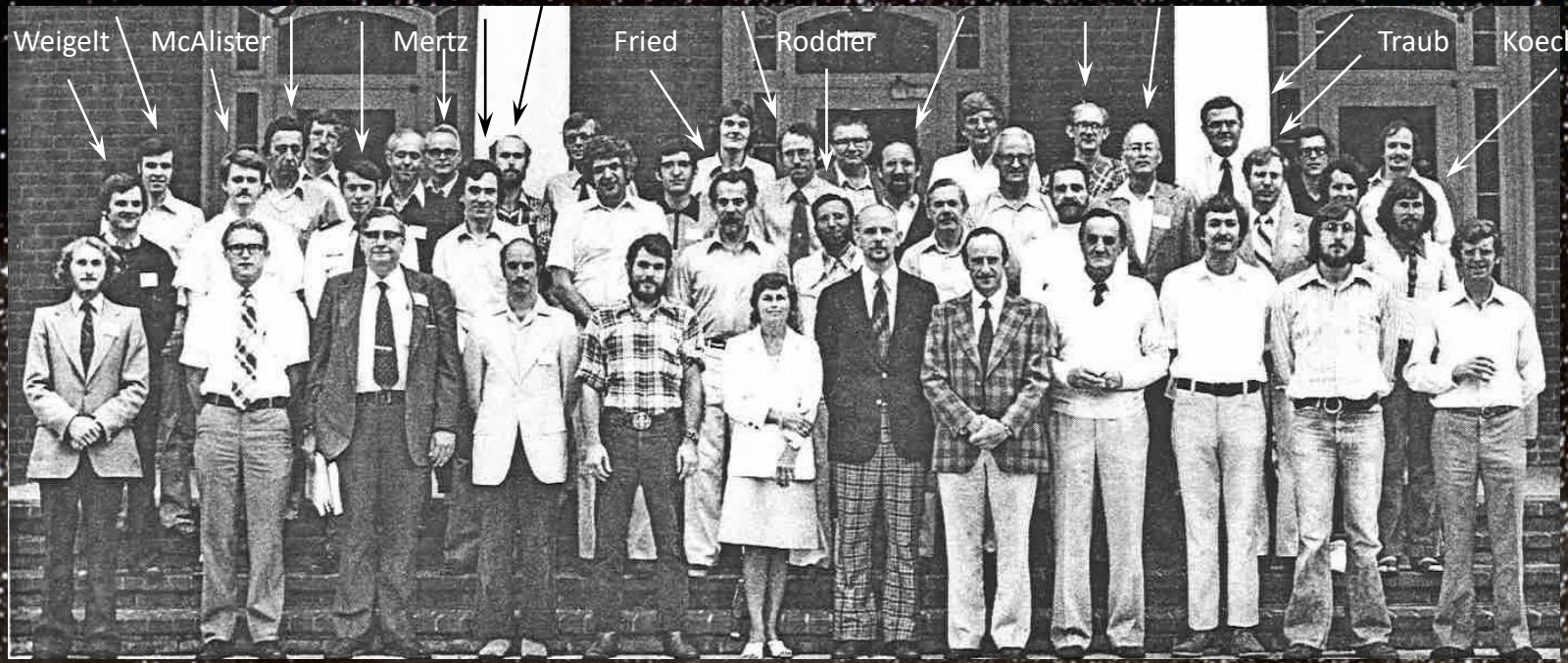
In the late 1970s, particularly as a result of Labeyrie's efforts, LBOI was reawakening.

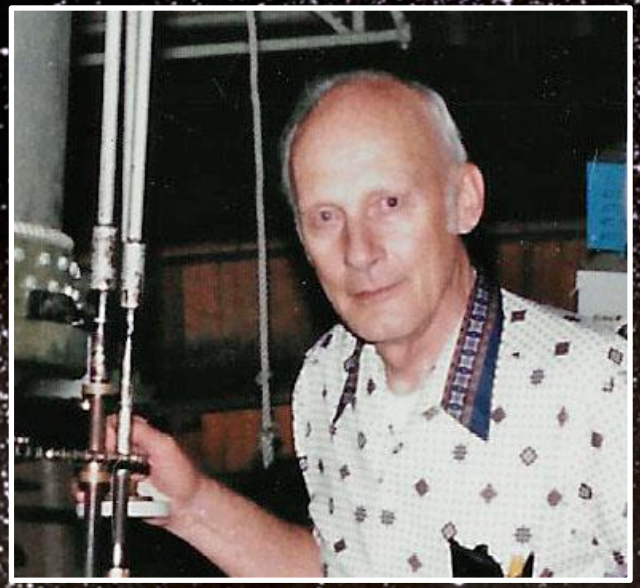
This is when I first became excited by the potential of LBOIs.

A Significant Early Meeting

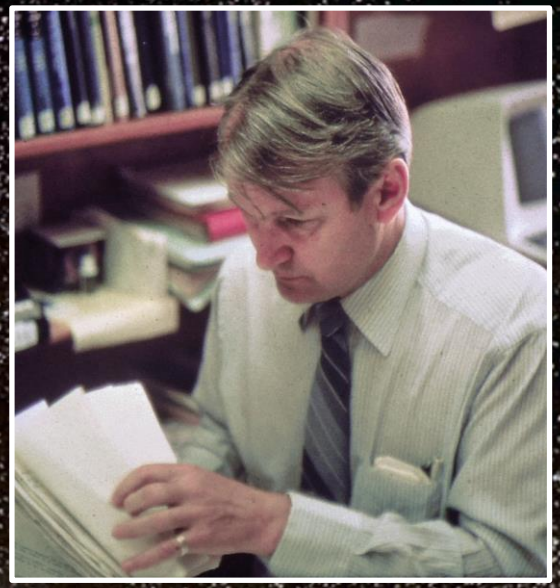
CHARA's Origins

IAU Colloquium No. 50 – High Angular resolution Stellar Interferometry
College Park, Maryland – 30 Aug - 1 Sep 1978





Art Hoag



Ingemar Furenlid

Author's Photos

Speckle Work Gave Us Credibility

The program was carried out from 1975 – late 1990s.

By 1997, CHARA's speckle program had produced:

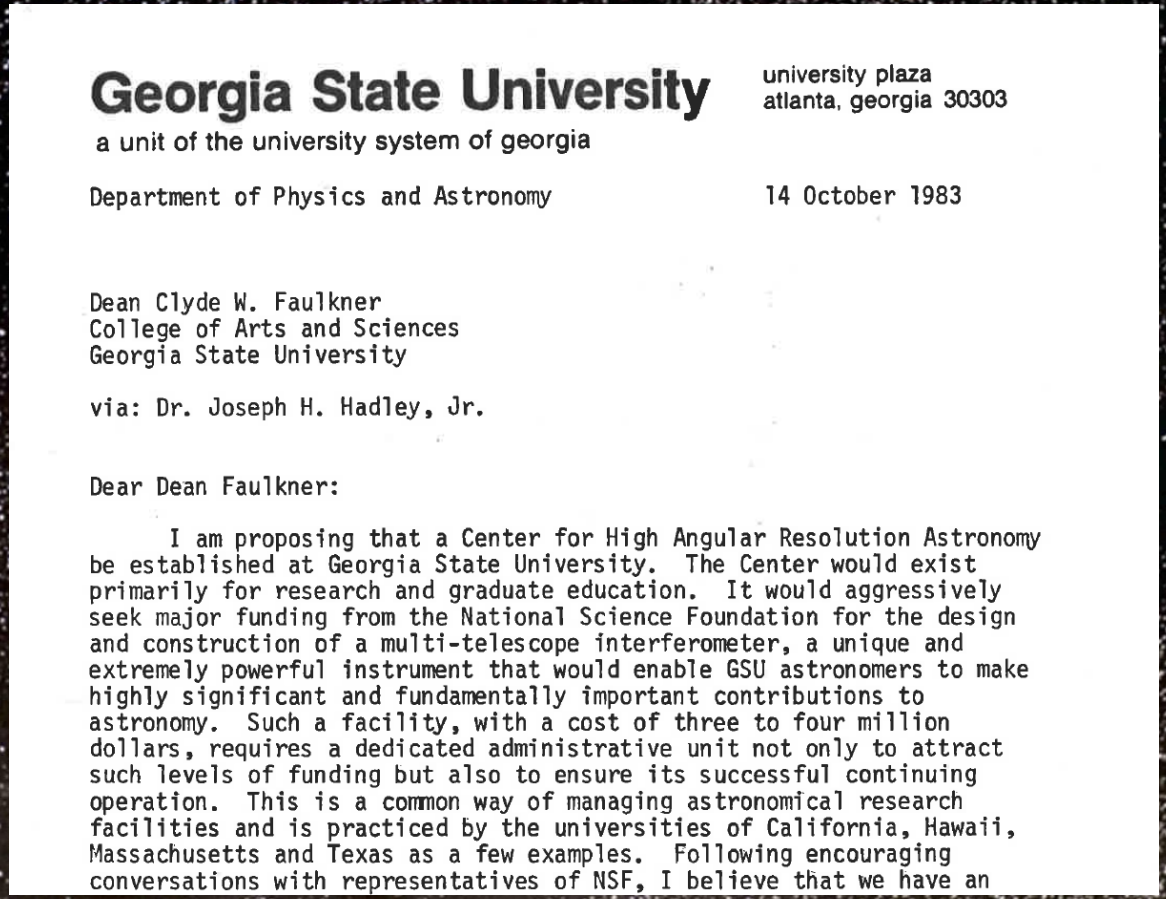
- *12,300 accurate measurements of 3,200 binaries including 230 new binaries, representing ~85% of all speckle results.*
- *We surveyed ~one-third of the stars in the Yale Bright Star Catalogue*
- *85 refereed papers with ~3700 citations*
- *63 unrefereed conference proceedings, popular articles, etc.*
- *Inspired new programs elsewhere, e.g., the USNO abandoned its venerable micrometry program in favor of speckle interferometry.*

Program funded by 9 NSF grants & 3 AFOSR grants totaling $1.9M.

<u>The Array could never have been funded without this track record</u>.

CHARA's Founding 40 Years Ago

CHARA's Origins



Georgia State University
a unit of the university system of georgia

university plaza
atlanta, georgia 30303

Department of Physics and Astronomy

14 October 1983

Dean Clyde W. Faulkner
College of Arts and Sciences
Georgia State University

via: Dr. Joseph H. Hadley, Jr.

Dear Dean Faulkner:

I am proposing that a Center for High Angular Resolution Astronomy be established at Georgia State University. The Center would exist primarily for research and graduate education. It would aggressively seek major funding from the National Science Foundation for the design and construction of a multi-telescope interferometer, a unique and extremely powerful instrument that would enable GSU astronomers to make highly significant and fundamentally important contributions to astronomy. Such a facility, with a cost of three to four million dollars, requires a dedicated administrative unit not only to attract such levels of funding but also to ensure its successful continuing operation. This is a common way of managing astronomical research facilities and is practiced by the universities of California, Hawaii, Massachusetts and Texas as a few examples. Following encouraging conversations with representatives of NSF, I believe that we have an

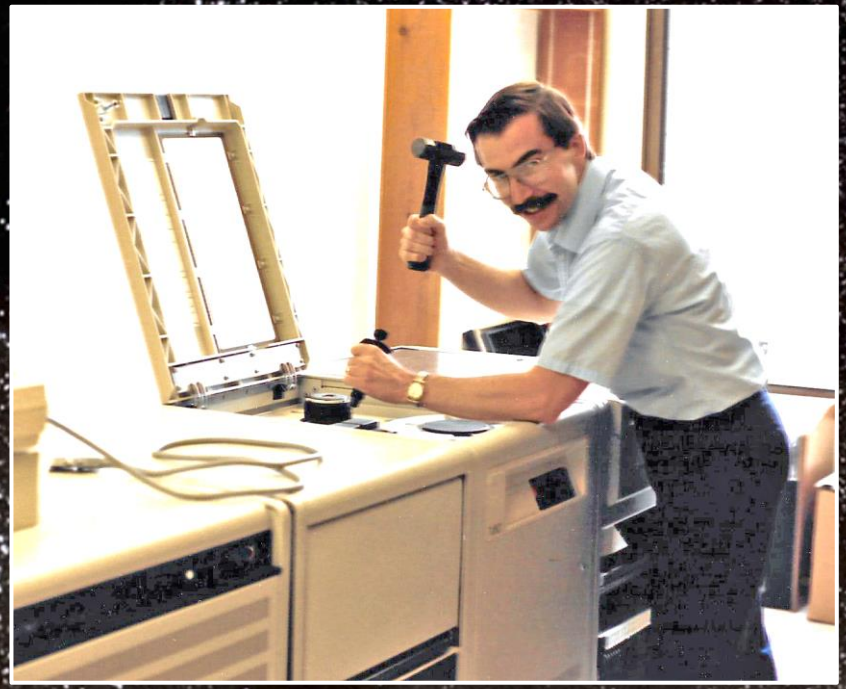
CHARA's Original Team

Bill Hartkopf

- *PhD - U. Illinois*
- *Arrived in 1981*
- *Largely responsible for our speckle productivity*
- *Left for USNO in 1999*

Author's Photo

CHARA's Origins



Bill could do anything

– even repair computers

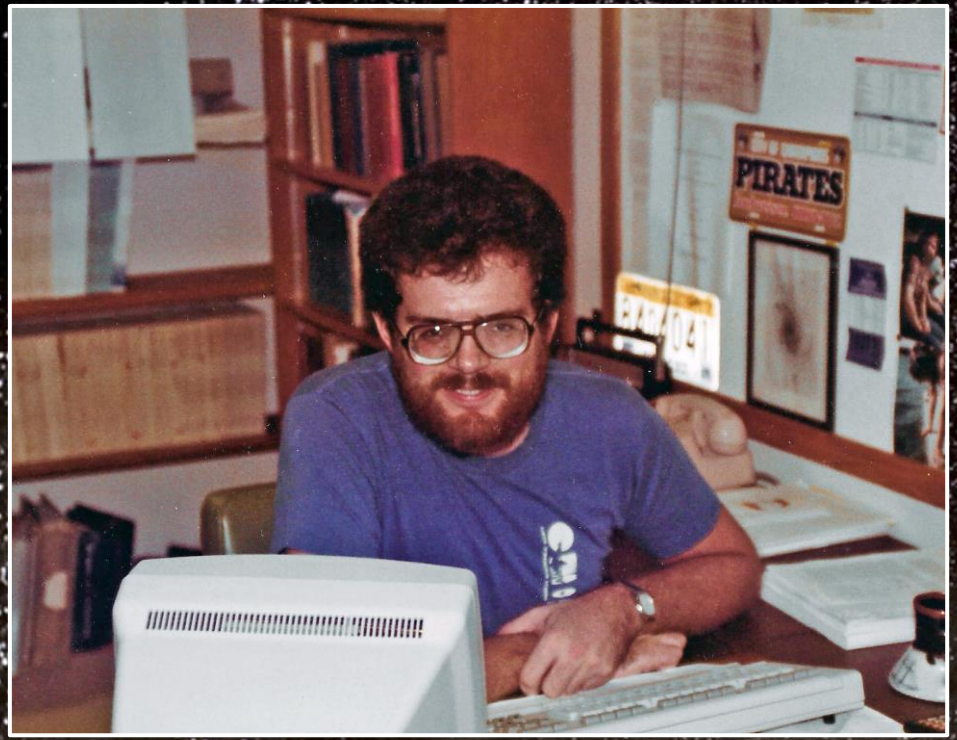
Author's Photo

Bill & Deborah in 2004

– Happy denizens of Maryland & Northern Virginia

– and now the Gulf Coast of Florida!

Author's Photo



Don Hutter

- ***With CHARA during 1984–1985 when he joined the Mark III staff on Mount Wilson.***
- ***He did a lot of speckle observing during his 18 months with us.***

Don Hutter

- *Now retired from the USNO after heading up NPOI.*
- *Like me, he's taken up astrophotography as a retirement hobby, except he's better at it than I am.*

M81 Photo by Don Hutter

Bill Bagnuolo

- *PhD – Caltech*
- *Arrived in 1985*
- *Major role in array design*
- *His study of imaging requirements led to Keck gift of sixth telescope*
- *Left GSU ca. 2008*

Author's Photo

Wean–Shun Tsay

- *PhD - GSU*
- *GSU's first astro PhD – 1989*
- *Performed site analysis of Anderson Mesa*
- *Returned to Taiwan*

Author's Photo

Brian Mason

- ***PhD – GSU 1994***
- ***Stayed on as a postdoc until 1997 when he took over the USNO speckle program***
- ***Bill & Brian were the dynamic duo of CHARA Speckle***

Author's Photo

NSF-Funded Feasibility Study

CHARA's Origins

PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION
Cover Page

FOR CONSIDERATION BY NSF ORGANIZATIONAL UNIT (list only the most specific unit known, i.e. program, division, etc.)
Astronomical Instrumentation & Development
Division of Astronomical Sciences

IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? Yes ___ No X . IF YES, LIST ACRONYM(S)

PROGRAM ANNOUNCEMENT/SOLICITATION NO.
None

CLOSING DATE (IF ANY)

NAME OF SUBMITTING ORGANIZATION TO WHICH AWARD SHOULD BE MADE (INCLUDE BRANCH/CAMPUS/OTHER COMPONENTS)
Georgia State University

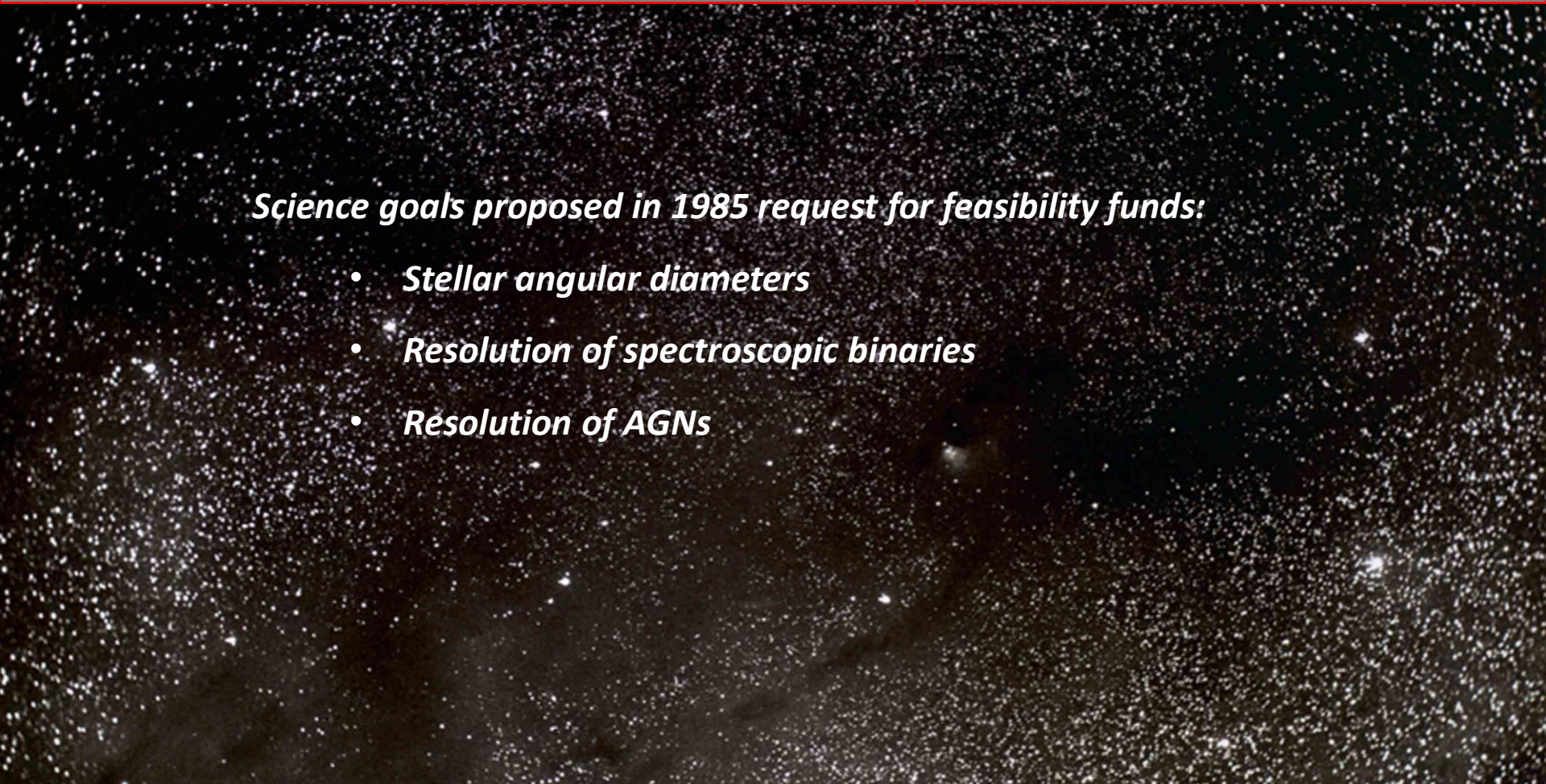
ADDRESS OF ORGANIZATION (INCLUDE ZIP CODE)
Atlanta, Georgia 30303

TITLE OF PROPOSED PROJECT
A Feasibility Study for Long-Baseline Optical Interferometry

REQUESTED AMOUNT	PROPOSED DURATION	DESIRED STARTING DATE
$199,920	12 Months	1 April 1985

PI/PD DEPARTMENT	PI/PD ORGANIZATION	PI/PD PHONE NO.
Dept. of Physics and Astronomy	Georgia State University	(404)658-2279

PI/PD NAME	SOCIAL SECURITY NO.*	DATE OF HIGHEST DEGREE ACHIEVED	MALE*	FEMALE*
Harold A. McAlister	[redacted]	July 1975	X	
ADDITIONAL PI/PD				



Science goals proposed in 1985 request for feasibility funds:

- *Stellar angular diameters*
- *Resolution of spectroscopic binaries*
- *Resolution of AGNs*

1985 Concept

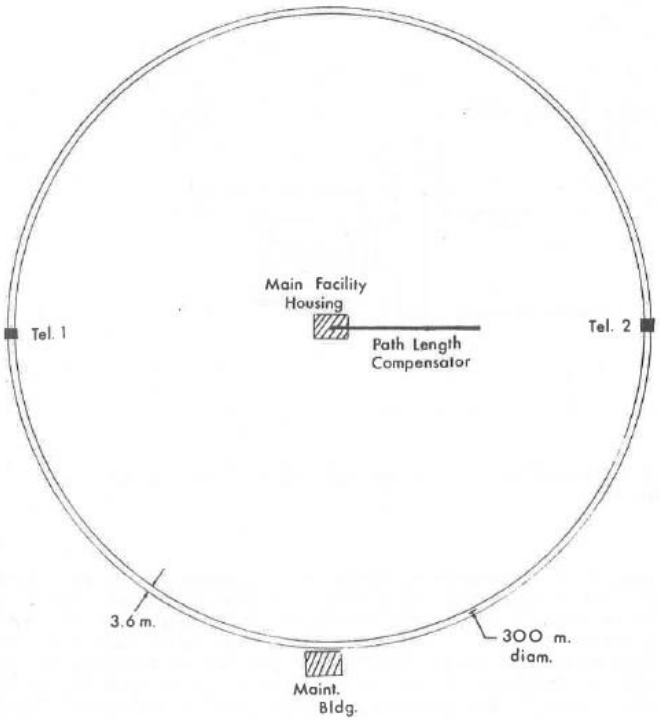


FIGURE 4.2 - The interferometer facility with its 300-meter diameter track is shown. This Narrabri-type configuration permits any combination of baseline orientations and lengths up to 300 meters.

NSF-Funded Feasibility Study

CHARA's Origins

Painting by Bill Pounds

Science goals proposed in 1989 feasibility study final report:

- *Stellar angular diameters*
- *Pulsating variable stars*
- *Extended atmospheres and emission regions*
- *Resolution of spectroscopic binaries*
- *Surveys for new binaries*
- *Close, interacting binary features*
- *Detection of low mass companions (including planets)*
- *Resolution of nuclei of active galaxies*

Contributors to CHARA's Feasibility Study Proposal

- *Hal McAlister – GSU Professor PI*
- *Bill Bagnuolo– GSU Research Scientist*
- *Bill Hartkopf – GSU Research Scientist*
- *Ingemar Furenlid – GSU Associate Professor*
- *Allen Garrison – GTRI Senior Research Scientist*
- *Morris Hetzler – GTRI Research Scientist*
- *Davis Roberts – GTRI Research Scientist*
- *Don Barry – GSU Graduate Research Assistant*
- *Wean Shun Tsay – GSU Graduate Research Assistant*
- *John Laudo – GTRI Graduate Research Assistant*
- *Kenneth Whitesett – GTRI Graduate Research Assistant*

CHARA's Science Advisory Committee:

- *Pierre Demarque – Yale University*
- *Jay Gallagher – Lowell Observatory Director*
- *Dan Popp[er – UCLA*

Dan Popper's prophetic contribution to our construction proposal:

"While it is often attractive to invoke serendipity as a justification for a new scientific endeavor, history has indeed taught us that whenever a new technique enters a new realm of observational phase space, the most striking and productive results tend to be those not anticipated by even the most prescient thinkers

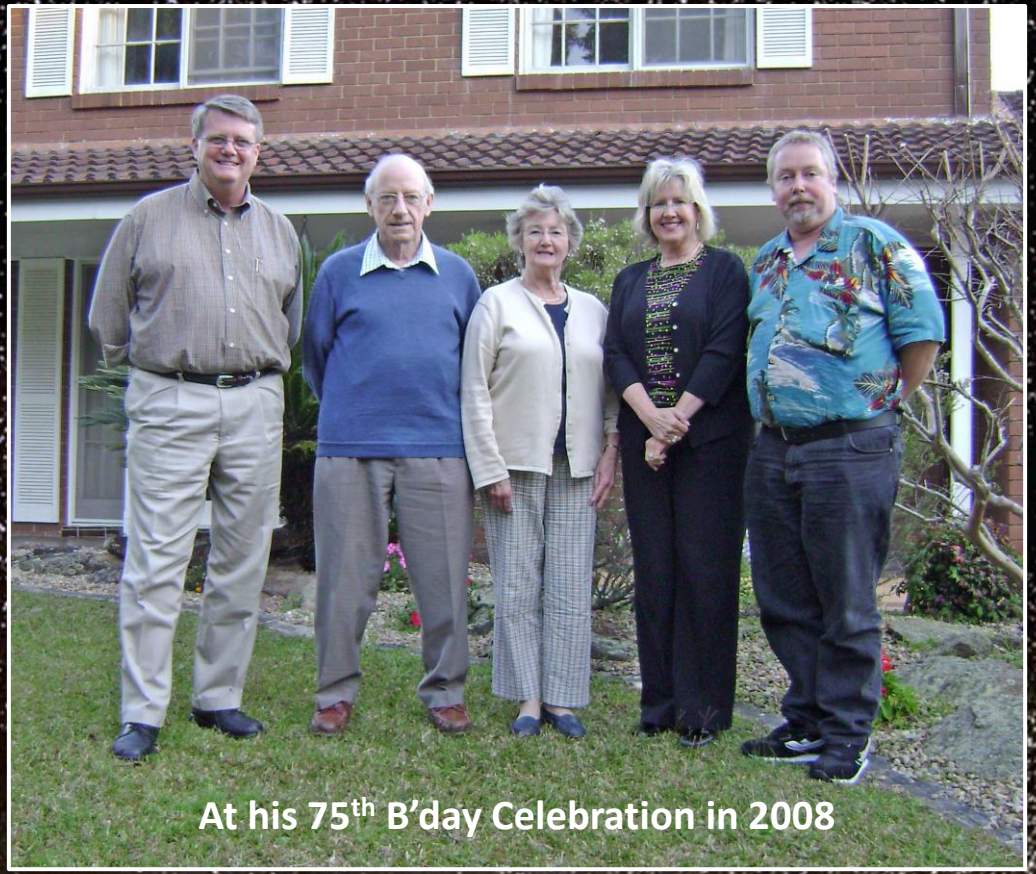
In his home – IAU Symposium 1089, 1997

Author's photo

On Anderson Mesa, Arizona ca. 1988

Author's photo

Remembering John Davis



At his 75th B'day Celebration in 2008

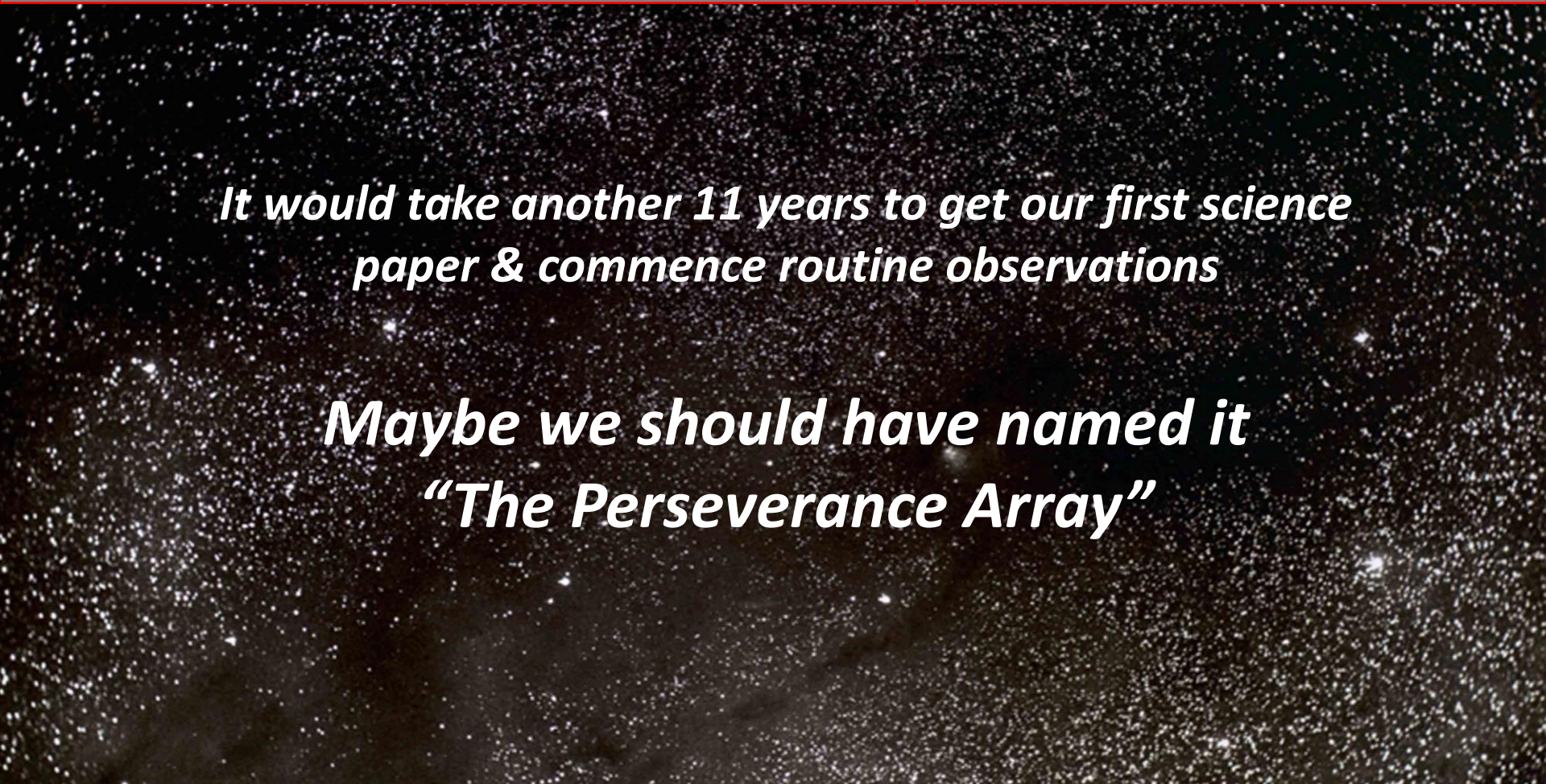
Author's photo

The Phase A Feasibility Study grant of $262K was completed in May 1989.

At the NSF's suggestion, we submitted a Phase B Preliminary Design Study proposal that received $485 and was completed during 1992 – May 1994.

The time then became ripe for our construction proposal, which was awarded $6.25M effective 1 Oct 1994.

That culmination was 2 weeks short of 11 years since I first proposed a Center for High Angular Resolution Astronomy at GSU.

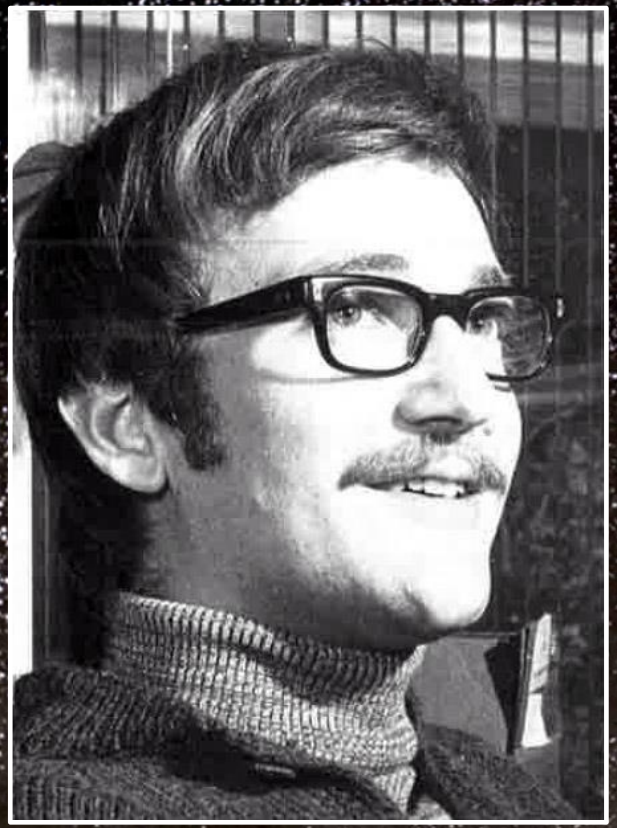


It would take another 11 years to get our first science paper & commence routine observations

Maybe we should have named it "The Perseverance Array"

Theo ten Brummelaar

- ***Arrived in 1993***
- ***His contributions are worthy of an entire talk…***
- ***Retired in May 2022***



Steve Ridgway

- ***Joined as adjunct in 1993***
- ***Here again, another talk is required…***
- ***Steve will never retire!***

On an Amsterdam houseboat, July 2012

Mark Shure

- *Arrived in 1996*
- *Designed & Built CHARA Science Camera*
- *Left for industry in 2002*

Nils Turner

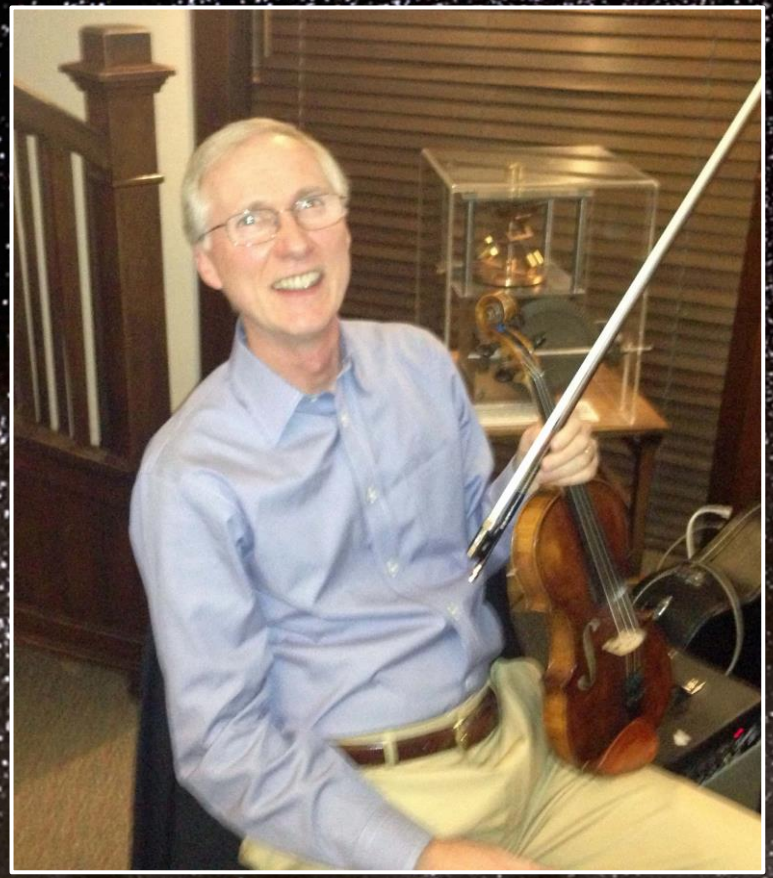
- ***GSU PhD Dec 1997***
- ***Never left!***

The Sturmanns

- ***Arrived in 1996***
- ***Two more talks…***
- ***Retired 2021***

Larry Webster

- *The Mayor of Mount Wilson*
- *With CHARA 2009–2021*



Doug Gies

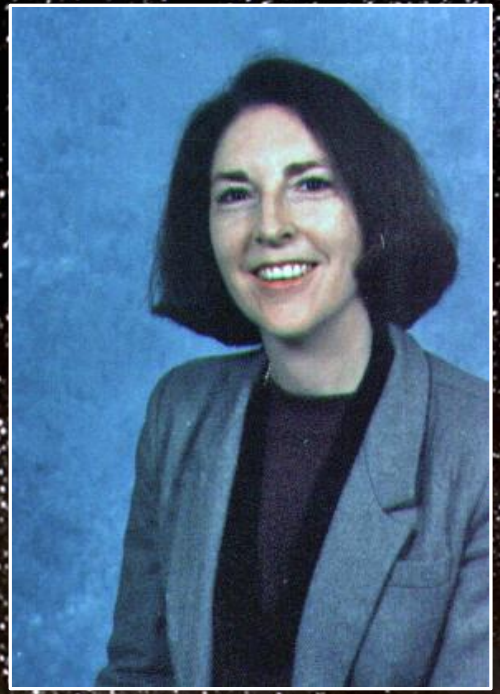
- ***Joined P&A Faculty 1988***
- ***Regents Professor 2011***
- ***CHARA Director 2015***

Gail Schaeffer

- ***Joined GSU 2007***
- ***CHARA Array Director 2015***

CHARA's Business Managers

CHARA's Origins



Sandy Land
(1995–2012)

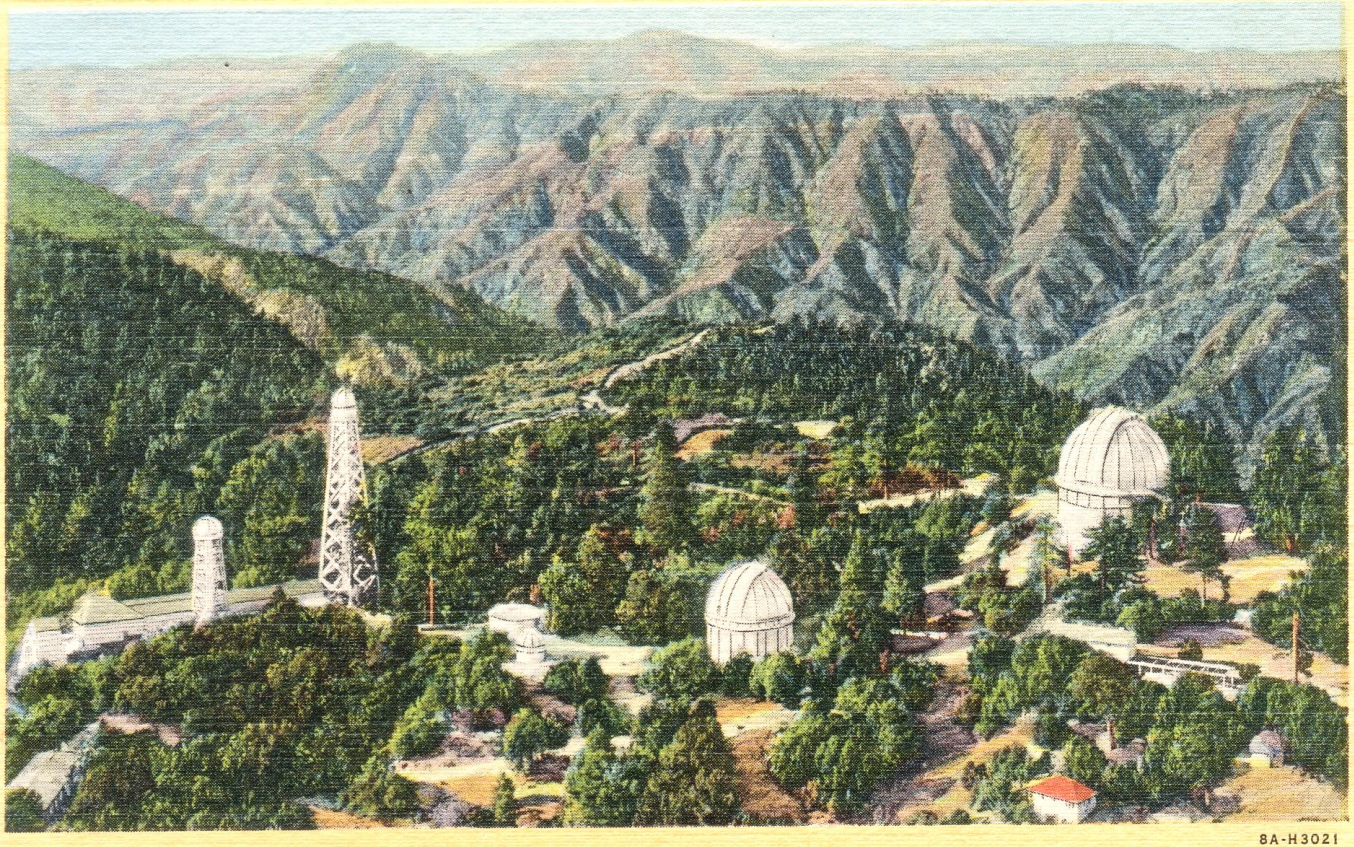
Brenda Stith
(2012–2017)

Alicia Rice
(2017–Present)

I've focused here on the CHARA staff who conceived, designed and built an incredibly powerful and durable facility, but the success we enjoy 40 years after CHARA's founding is also the direct result of the creation of the greater CHARA collaboration. The CHARA Array would today be a far lesser scientific entity without these partnerships.

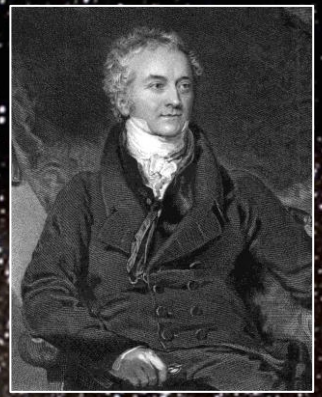
Credit for this goes to Steve Ridgway's vision and Theo's enthusiastic support for and efforts toward its realization.

P-69 Mount Wilson Observatory, California

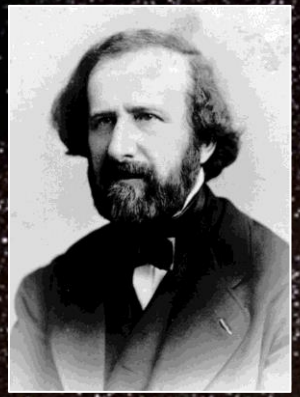


8A-H3021

From author's collection

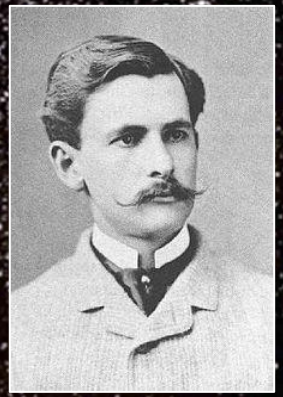


Thomas Young
(1773 – 1829)



A.H.L. Fizeau
(1819 – 1896)

Édouard Stephan
(1837 – 1923)

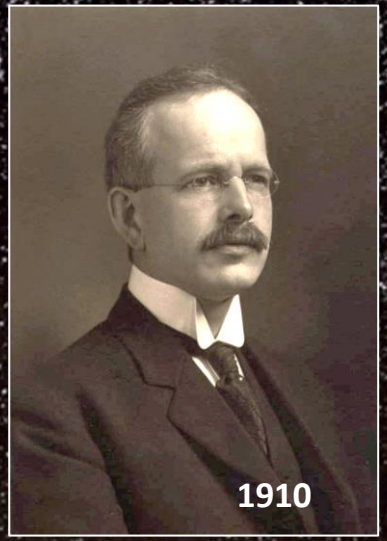


A.A. Michelson
(1852–1931)

Karl Schwarzschild
(1873 – 1916)

Left: Image courtesy of the Smithsonian Institution. *Right:* Author's diagram

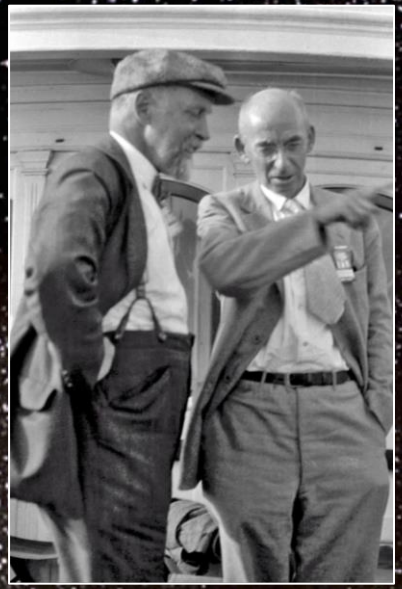
Mount Wilson's Role was Predestined by George Ellery Hale



The fact that no astronomical applications of the method have since been made is not easily explained.

— *George Ellery* Hale commenting on interferometry in the *Carnegie Year Book* for 1920

Three major proponents for resolving purported giant stars



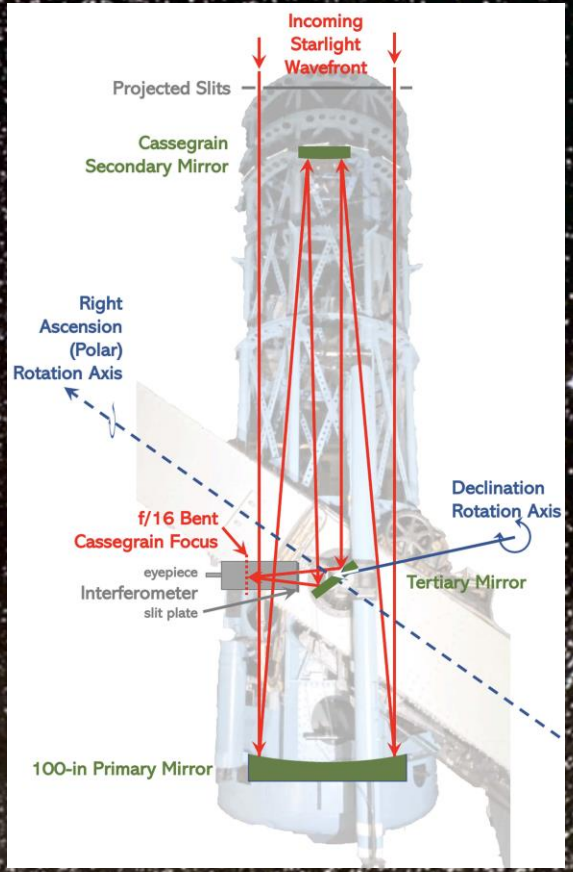
Ejnar Hertzsprung
with
Raymond S. Dugan

Henry Norris Russell
with binoculars next to
Walter S. Adams

Arthur Stanley Eddington
with Annie Jump Cannon

Anderson's Double Star Interferometer

John August Anderson
(1876–1959)



Left: Image courtesy of the Carnegie Institution for Science & the Huntington Library; *Right:* Author's diagram.

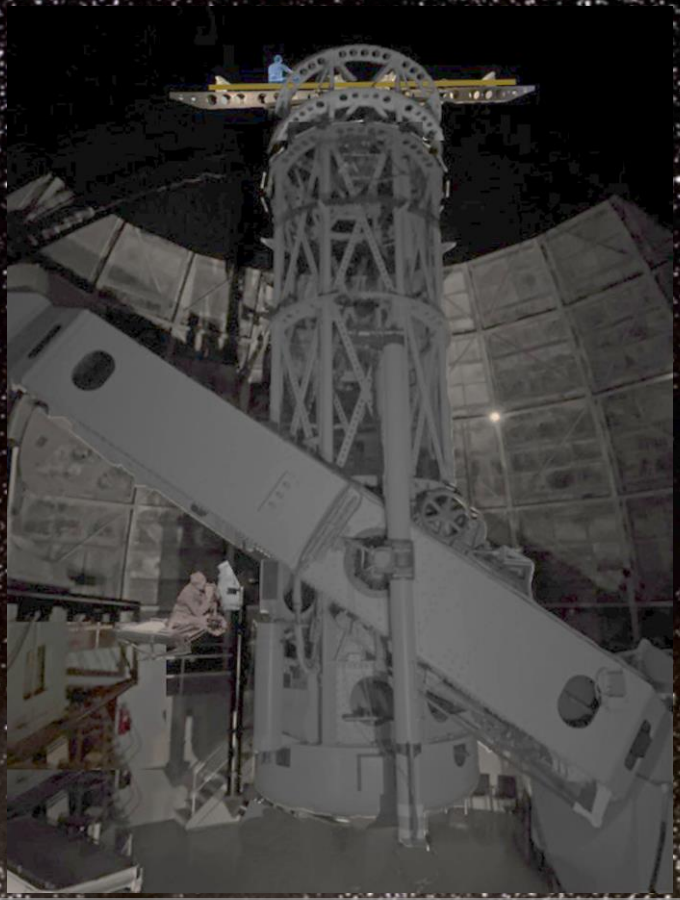
A Moonlit Fantasy – 13 Dec 1920

Seeing the Unseen

Author's imagery. Orion by Akira Fujii.

A Moonlit Fantasy – 13 Dec 1920

Seeing the Unseen



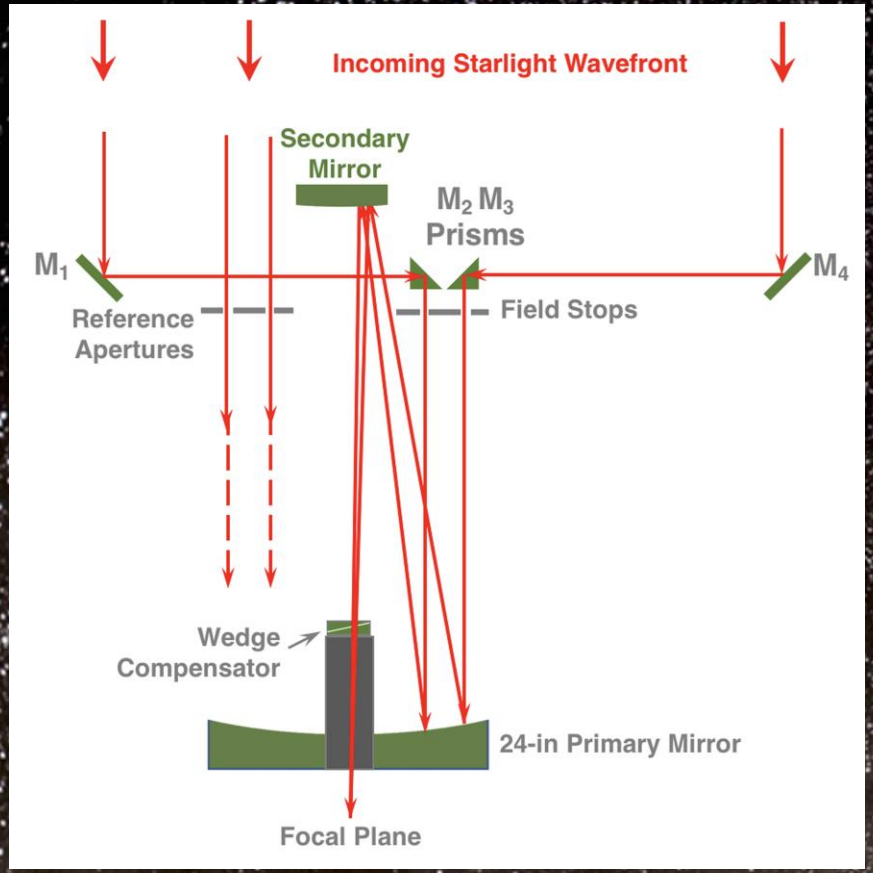
Author's imagery. Orion by Akira Fujii.

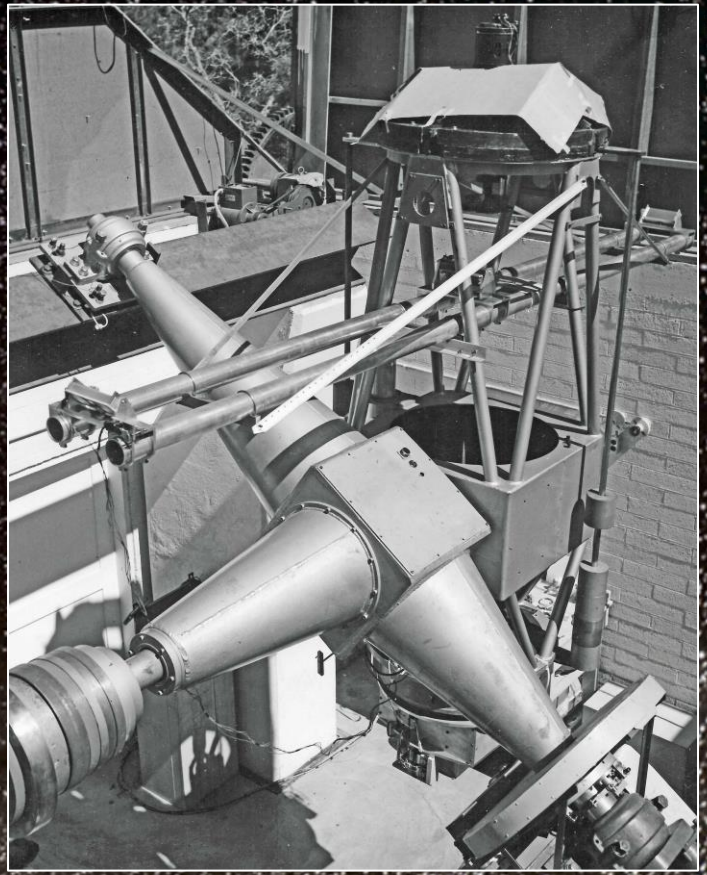
A Bridge Too Far – Pease's 50-ft

Image courtesy of the Carnegie Institution for Science & the Huntington Library.

Willet Beavers' 12-ft Beam Interferometer

Seeing the Unseen

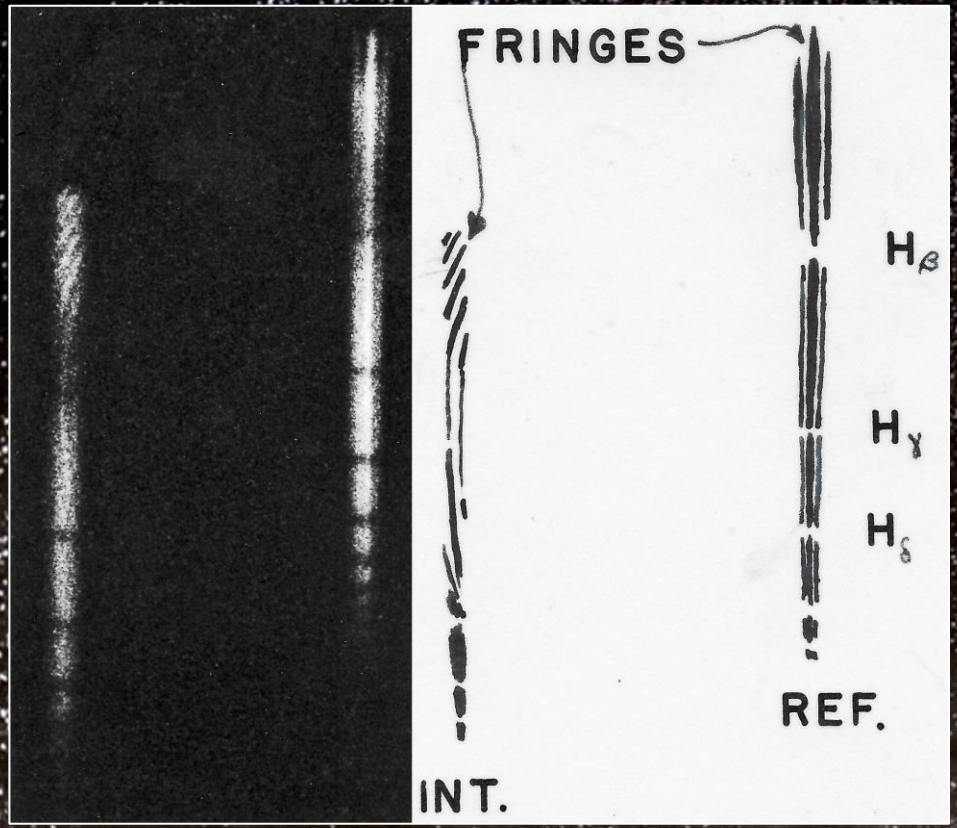


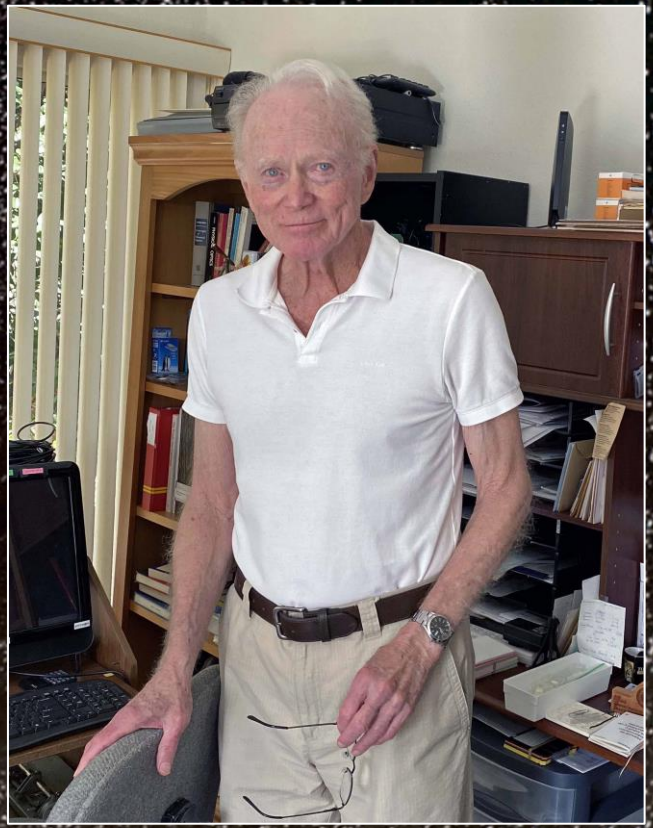


Left: Author's diagram, Right: Photograph by Willet Beavers.

Willet Beavers' 12-ft Beam Interferometer

Seeing the Unseen

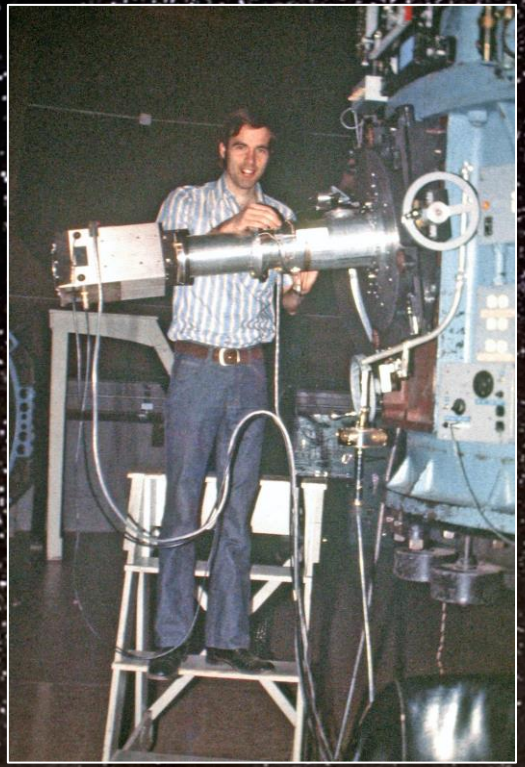


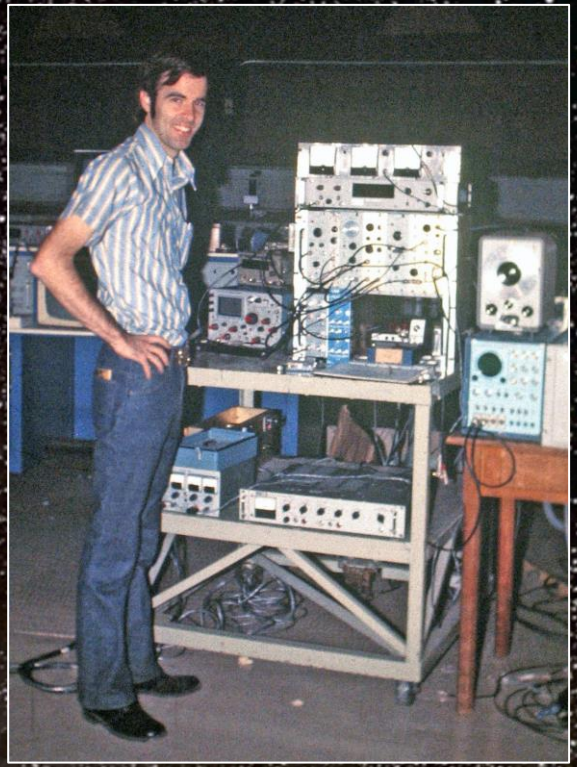


Left: Courtesy of Willet Beavers, *Right*: Author's photograph

William Wickes' Automatic Interferometer

Seeing the Unseen



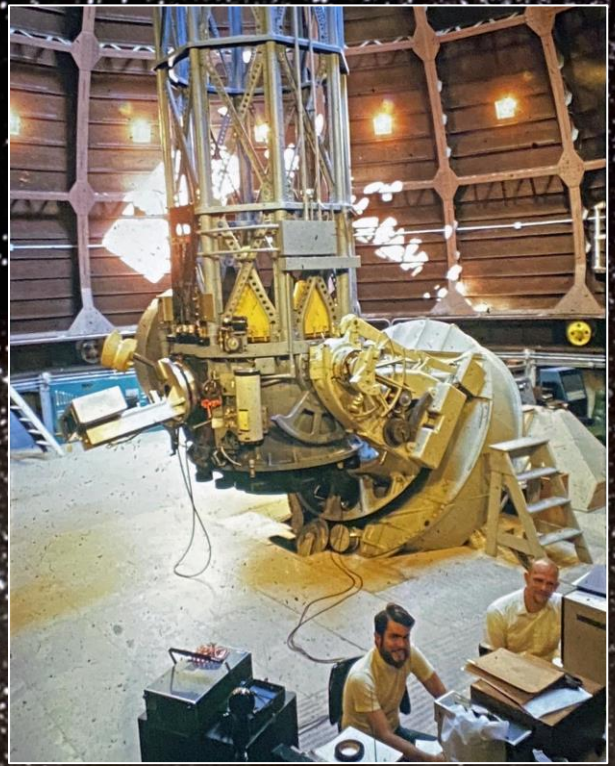


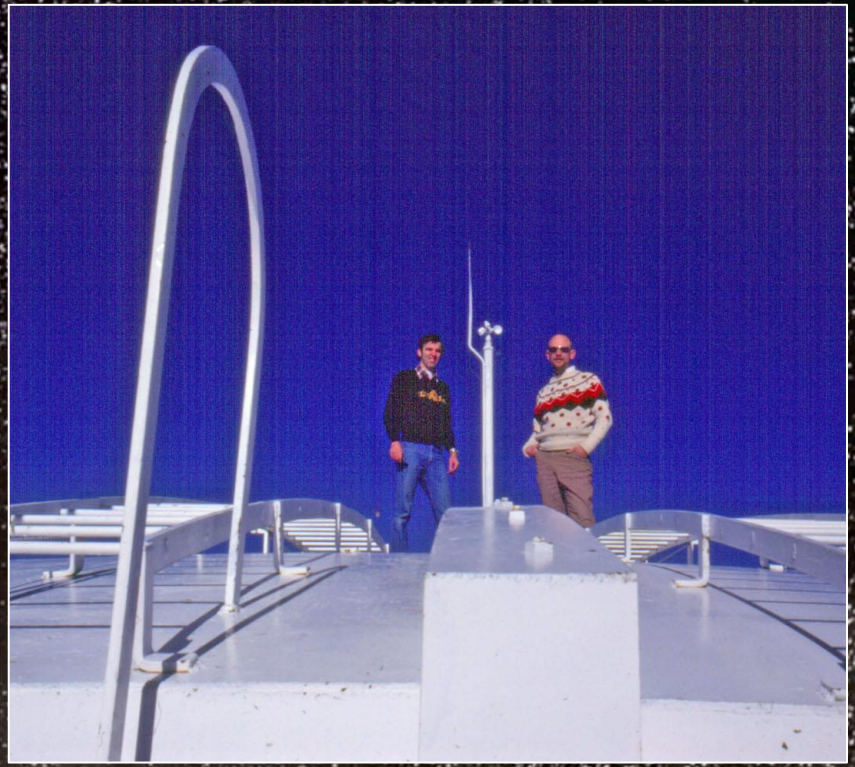
Courtesy of Bill Wickes

Susan and Bill Wickes with their Grandsons

Courtesy of Bill Wickes

Douglas G. Currie's Amplitude Interferometer





Courtesy of Bill Wickes & Doug Currie

An Unknown Genius

Seeing the Unseen

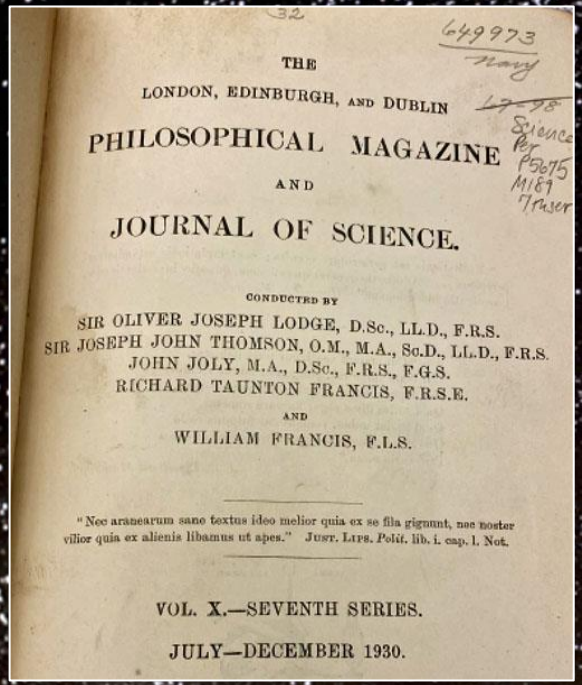
During 1928 – 1932, contributed nine papers to *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science.*

Edward Hutchinson Synge
(1890–1957)

These papers laid out concepts for near-field scanning microscopy, LiDAR, and multi-mirror telescopes. Half a century later, his priority was acknowledged.

An Unfortunate Evaluation

Seeing the Unseen



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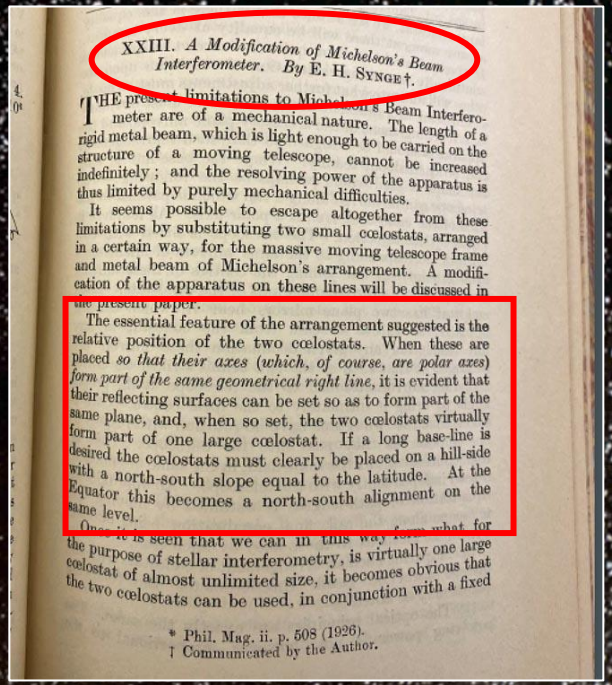
"Nec aranearum sane textus ideo melior quia ex se fila gignunt, nec noster vilior quia ex alienis libamus ut apes." Just. Lips. Polit. lib. i. cap. 1. Not.

VOL. X.—SEVENTH SERIES.

JULY—DECEMBER 1930.



XXIII. *A Modification of Michelson's Beam Interferometer.* By E. H. Synge†.

THE present limitations to Michelson's Beam Interferometer are of a mechanical nature. The length of a rigid metal beam, which is light enough to be carried on the structure of a moving telescope, cannot be increased indefinitely; and the resolving power of the apparatus is thus limited by purely mechanical difficulties.

It seems possible to escape altogether from these limitations by substituting two small cœlostats, arranged in a certain way, for the massive moving telescope frame and metal beam of Michelson's arrangement. A modification of the apparatus on these lines will be discussed in the present paper.

The essential feature of the arrangement suggested is the relative position of the two cœlostats. When these are placed *so that their axes (which, of course, are polar axes) form part of the same geometrical right line*, it is evident that their reflecting surfaces can be set so as to form part of the same plane, and, when so set, the two cœlostats virtually form part of one large cœlostat. If a long base-line is desired the cœlostats must clearly be placed on a hill-side with a north-south slope equal to the latitude. At the Equator this becomes a north-south alignment on the same level.

Once it is seen that we can in this way form what for the purpose of stellar interferometry, is virtually one large cœlostat of almost unlimited size, it becomes obvious that the two cœlostats can be used, in conjunction with a fixed

* Phil. Mag. ii. p. 508 (1926).
† Communicated by the Author.

This was an inaccurate and disparaging evaluation of this paper by a graduate student of Harlow Shapley: "*It also raises doubt as to the worth of various ingenious proposals for increasing enormously the dimensions and effectiveness of stellar interferometers*." W.A. Calder, Harvard Obs. Bull. 885, 8, 1931.

the present paper.

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One [illegible] for

An Unknown Genius

See:

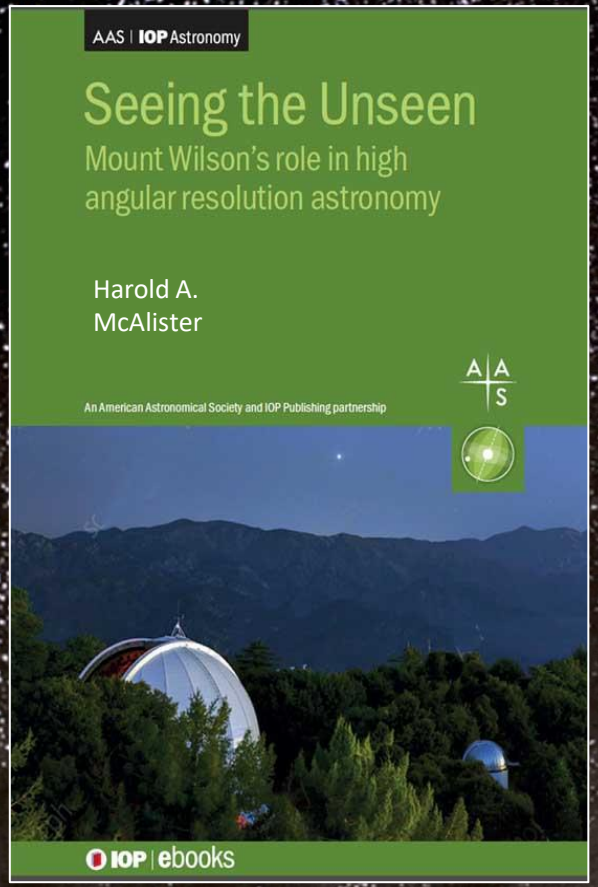
Hutchie: The Life and Works of Edward Hutchinson Synge, ed by J.F. Donegan, D. Weaire, and P. Florides (Pöllauberg, Austria: Living Edition)

Unknown Genius, above authors, *Physics World,* Dec 2012.

Courtesy of Living Edition

For Considerably More on This

Seeing the Unseen



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Background from E.E.Barnard's *Atlas of the Northern Milky Way*