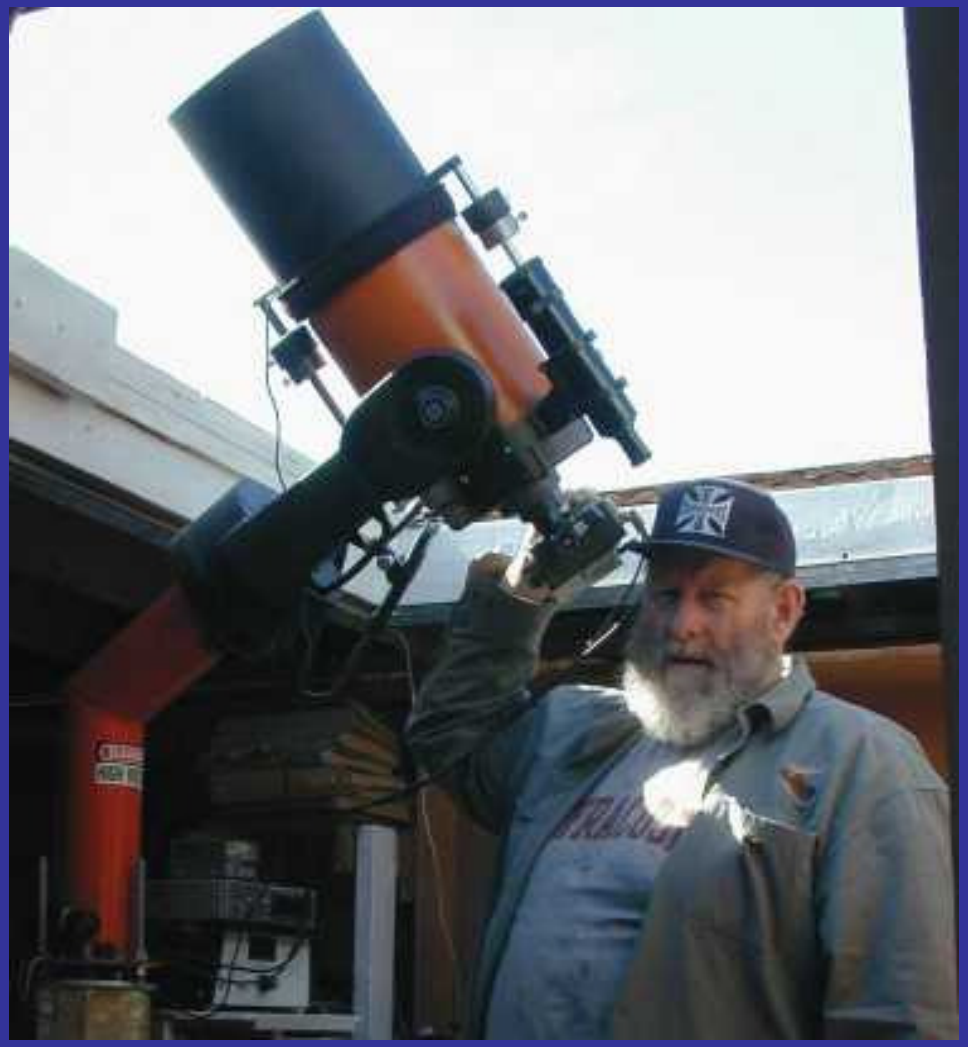
epsilon Aurigae

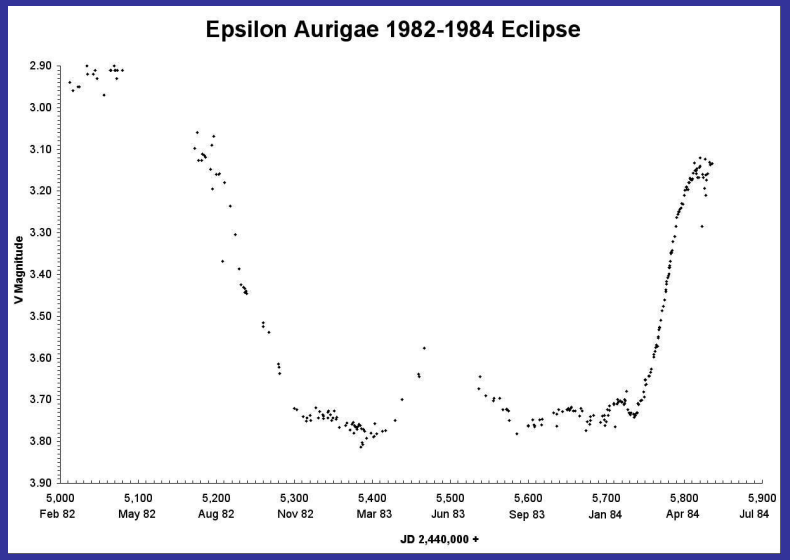
Overview & the 2009-2011 eclipse

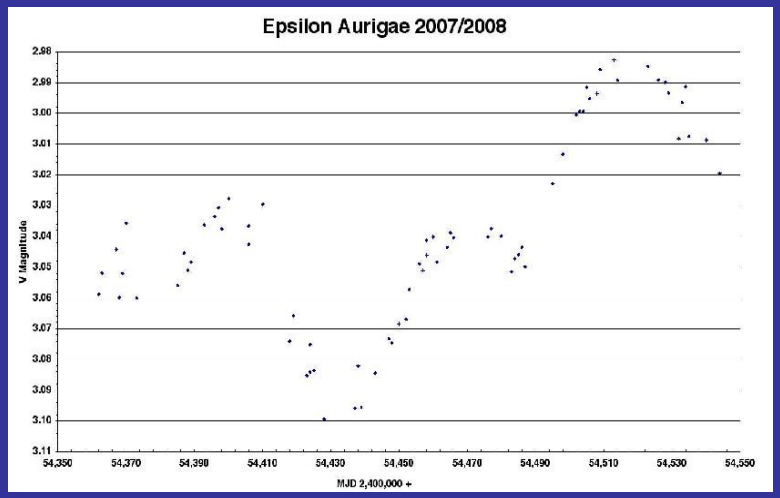
Dr. Bob Stencel
Univ. Denver &
twitter.com/epsilon_Aurigae

CITIZEN SKY workshop
Adler Planetarium
August 5, 2009
http://www.citizensky.org

My partner in this crime: Jeff Hopkins







Hopkins - Phoenix Observatory

http://www.hposoft.com/Astro/astro.html

Homage

Some of the observers and theorists who have contributed to this multi-generational effort include:

J. Fritsch
J. Schmidt
Otto Struve
Robert Kraft
C.M. Huffer
Harlow Shapley
K.Aa. Strand
Robert Wilson
Su-Shu Huang
L.W. Fredrick
Jack Kemp
P. Eggleton
Dana Backman
I.S. Nha
Mary Barsony
Ed Guinan
D.M. Harrington
Robert Stefanik
Jeffrey Hopkins
Philip Bennett

H.C. Vogel
Hans Ludendorff
Bengt Stromgren
Zdenek Kopal
W.S. Adams
Margherita Hack
K.O. Wright
A.G.W. Cameron
Richard Mitchell
Mamoru Saito
A. Arellano-Ferro
J. Pringle
C. Boehm
R. Canavaggia
Guangwie Cha
Ken Hinkle
J.R. Kuhn
Lothar Schanne
Thomas Ake
Nicholas Long

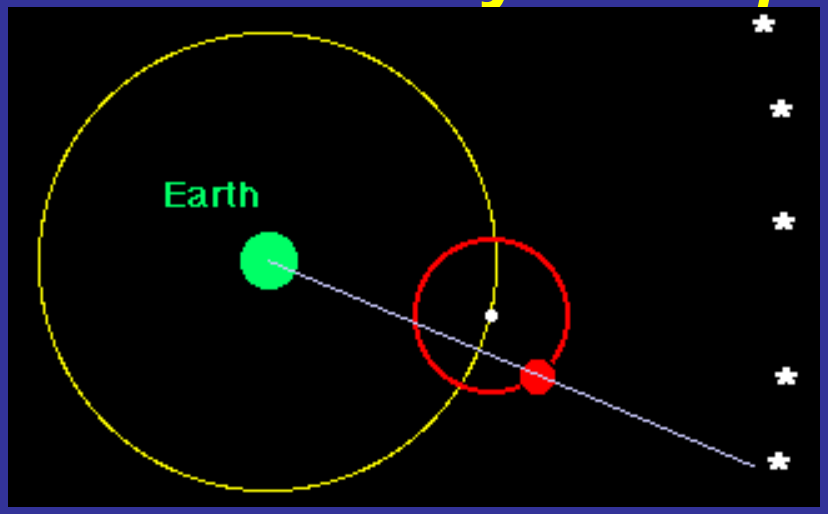
F.W.A. Argelander
E. Schönfeld
Gerald Kuiper
M. Güssow
R.F. Sanford
G. Larsson-Leander
R.S. Kushwaha
K. Gyldenkerne
Stephen C. Morris
David Lambert
R.E. Stencel
Jack Lissauer
S. Ferluga
F. Castelli
Sean Carroll
Richard Miles
Paul Beckmann
Des Loughney
Brian McCandless
Brian Kloppenborg

… *and you!*

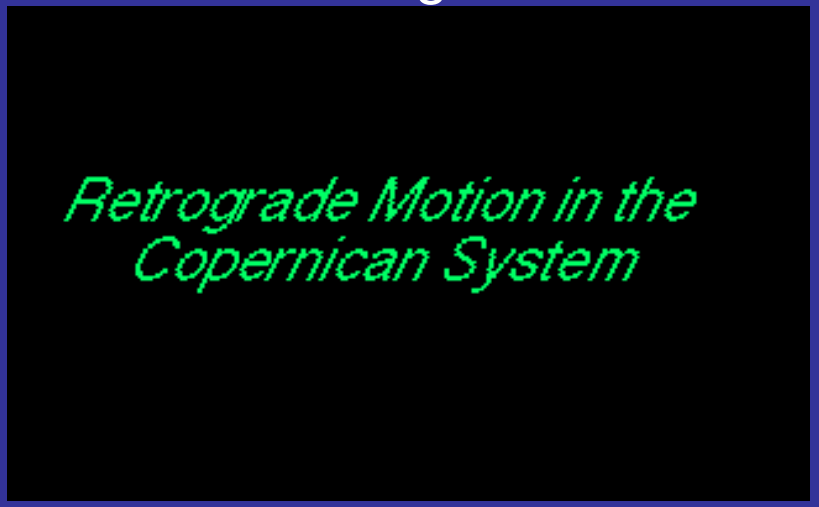
Why do we care about ε Aurigae?

- Eclipses are rare (27.1 year period)
- Where is the second star???
  - *Mass ratio ~ 1 from F star orbital velocity*
  - *Mid-eclipse, only see the primary (F) star*
  - *Totality is flat and wavelength-independent*
- "something dark" rotates through during eclipse…
- It's peculiar and defies interpretation

First, some theory -- *Epicycles?*



Epicycles seemed like a perfectly reasonable way to explain solar system motions – like Mars in retrograde… at least, until Copernicus:



http://csep10.phys.utk.edu/astr161/lect/retrograde/aristotle.html

epsilon—i-cycles?

Normal eclipsing binary star analysis suggests that the secondary is massive, about 10AU across – but it does not emit much light!

Struve (1937): "Infrared (I)-component"

…seemed like a perfectly reasonable way to explain the eclipse until...

Ludendorff / Kopal / Huang: A dark (and stormy) disk…

…seemed like a perfectly reasonable way to explain the eclipse until...

Hack (1961) : add an Ultraviolet hot source

…seemed like a perfectly reasonable way to explain the eclipse until...

Lissauer & Backman (1985): Embedded companions…

…seemed like a perfectly reasonable way to explain the eclipse until...

Saito; Lambert: It's a low mass binary…

…seemed like a perfectly reasonable way to explain the eclipse until...

Senay (2009): Refractive lensing… & ???

Models for the system…

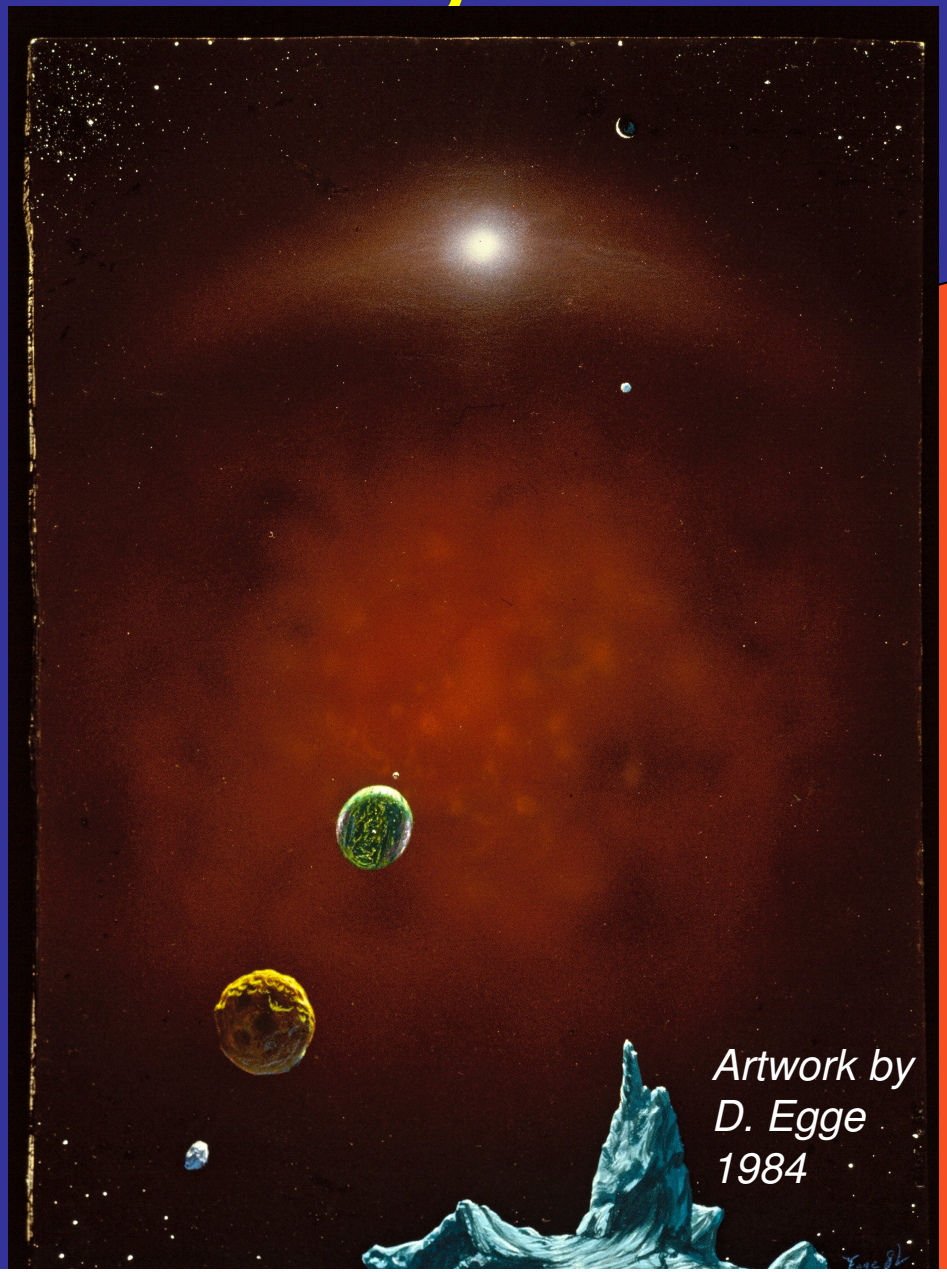
The “I” component…

1937 –

Struve, Stromgren,

& Kuiper

F star heats the side of the I component, seen doubling the F star spectrum during grazing eclipse…



Key observations I: 1930 – *Struve & Elvey…*

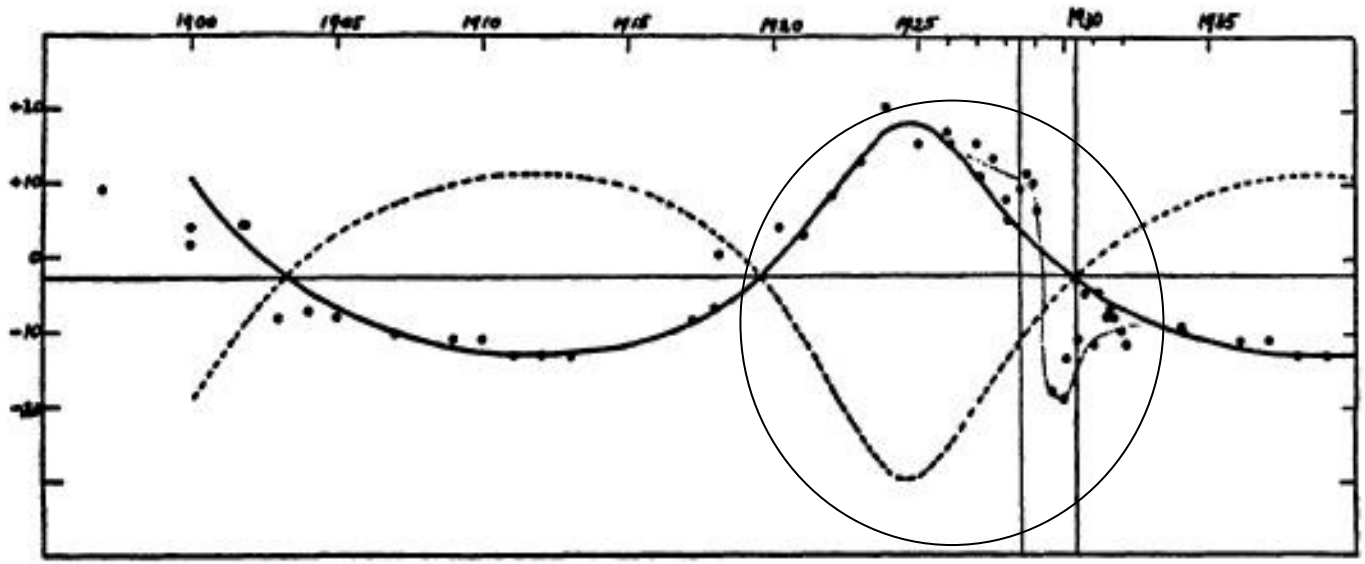
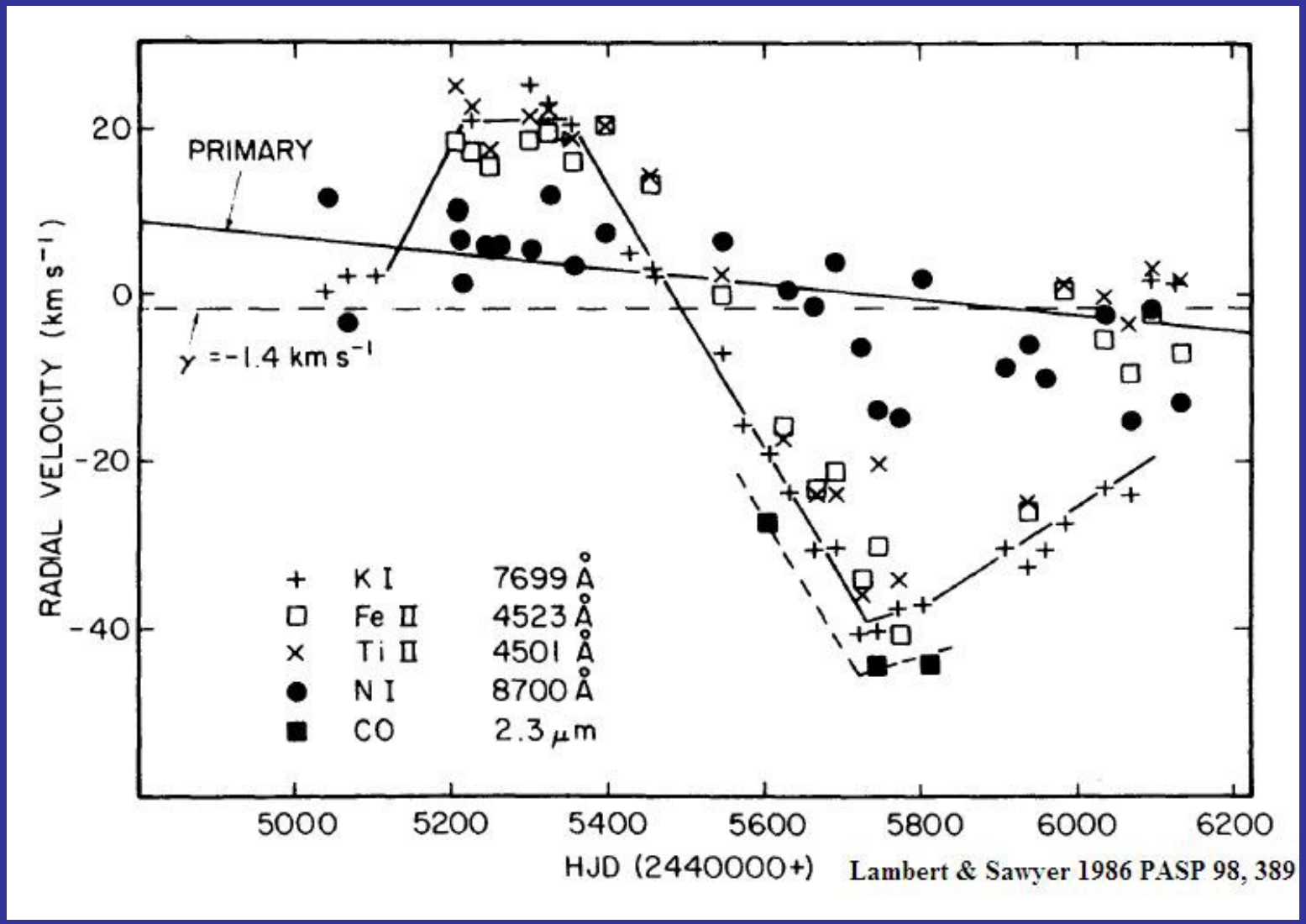


FIG. 3.—Velocity curve of ε Aurigae. The abscissas are years and the ordinates are radial velocities in kilometers per second. Only one component can be measured and the full line shows the representation of the observations by means of an elliptical orbit having an eccentricity of 0.33. The dotted curve shows the corresponding velocities of the invisible component of ε Aurigae which have not been observed but which may be inferred from the ratio of the masses. The departures of the observations during the time of the eclipse 1928–30 are caused by the blending of the absorption lines of the F2 star with spectral lines which are produced during the passage of its light through the ionized layers of the I star.

STRUVE, O. 1956 PASP 68: 27.

SB1, mass ratio ~ 1 → massive companion to an F supergiant

Key observations II: evidence of the secondary

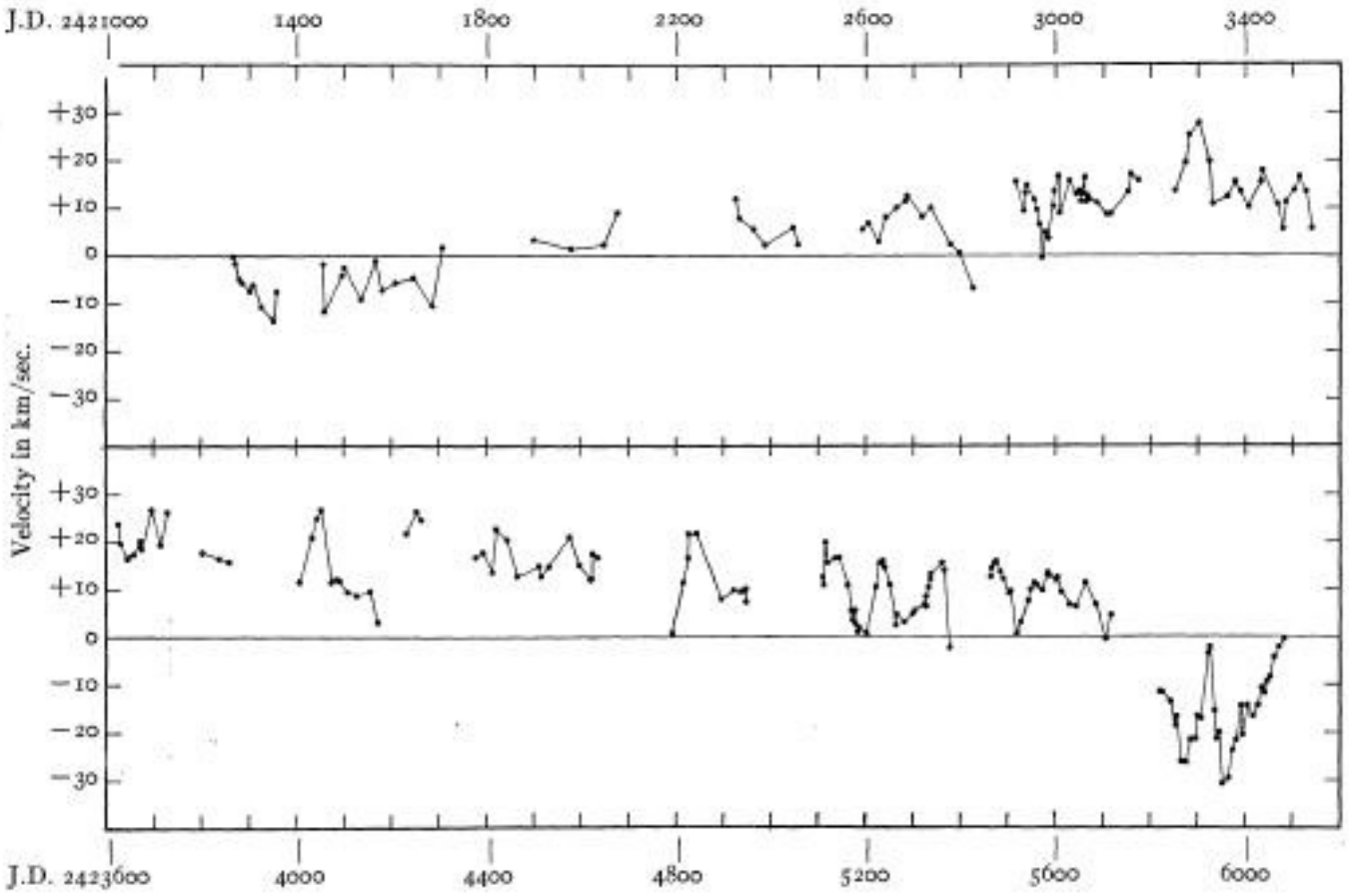


Something rotates past during eclipse with about 30 km/sec spin…

Key observations III: 1930 – *Adams & Sandford*

- Ingress: redshifted component appears, grows in strength
- Egress: blueshift component present, persists then fades away
- MID-ECLIPSE: lines are *DOUBLED*

Key observations IV: 1930 – *Struve & Elvey…*
Erratic radial velocity variations follow primary



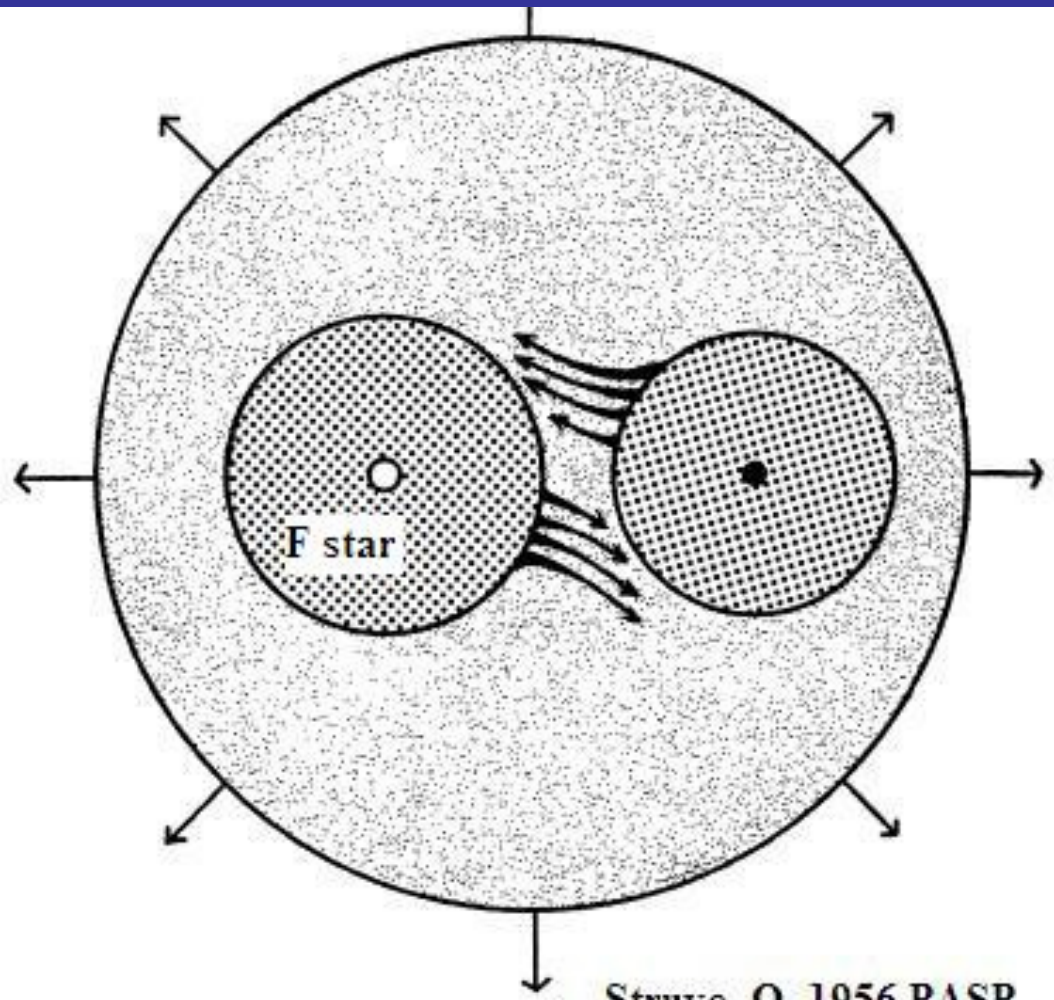
SPECTROGRAPHIC OBSERVATIONS OF ε AURIGAE 145

FIG. 4.—Observed radial velocities of 7 ε Aurigae. The upper portion of the curve covers the period from 1917 to 1923; the lower from 1923 to 1930. The values are chiefly based upon measures by Struve. In a later publication all available measures by various persons will be discussed, including spectrograms taken in 1899 and in 1901.

Struve & Elvey 1930 ApJ 71:136

1956 – *Struve, amended model.*

Add interaction… Circumstellar material surrounding both objects to account for variations during and outside of eclipse…



Struve, O. 1956 PASP

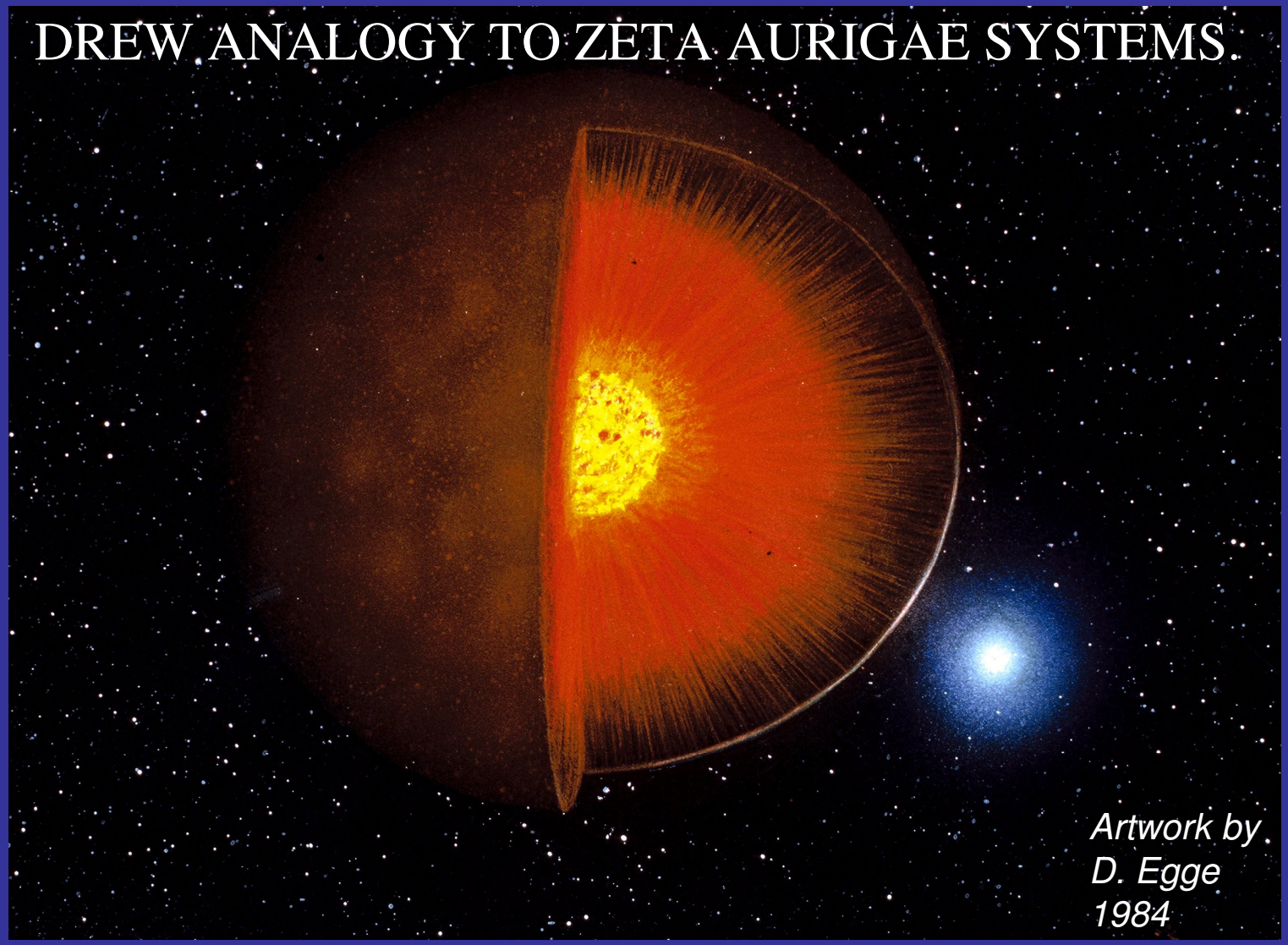
FIG. 5.—Schematic model of ε Aurigae. The white spot represents the F2 star. The black spot represents a hypothetical cool star in the center of a nebulosity which fills the entire loop of the critical zero-velocity surface. The F2 star is believed to be surrounded by a similar nebulosity which fills its own loop. Both nebulosities are unstable, and gaseous streams flow in opposite directions through the bottleneck near the inner Lagrangian point, L_1. An expanding nebulosity surrounds the entire system.

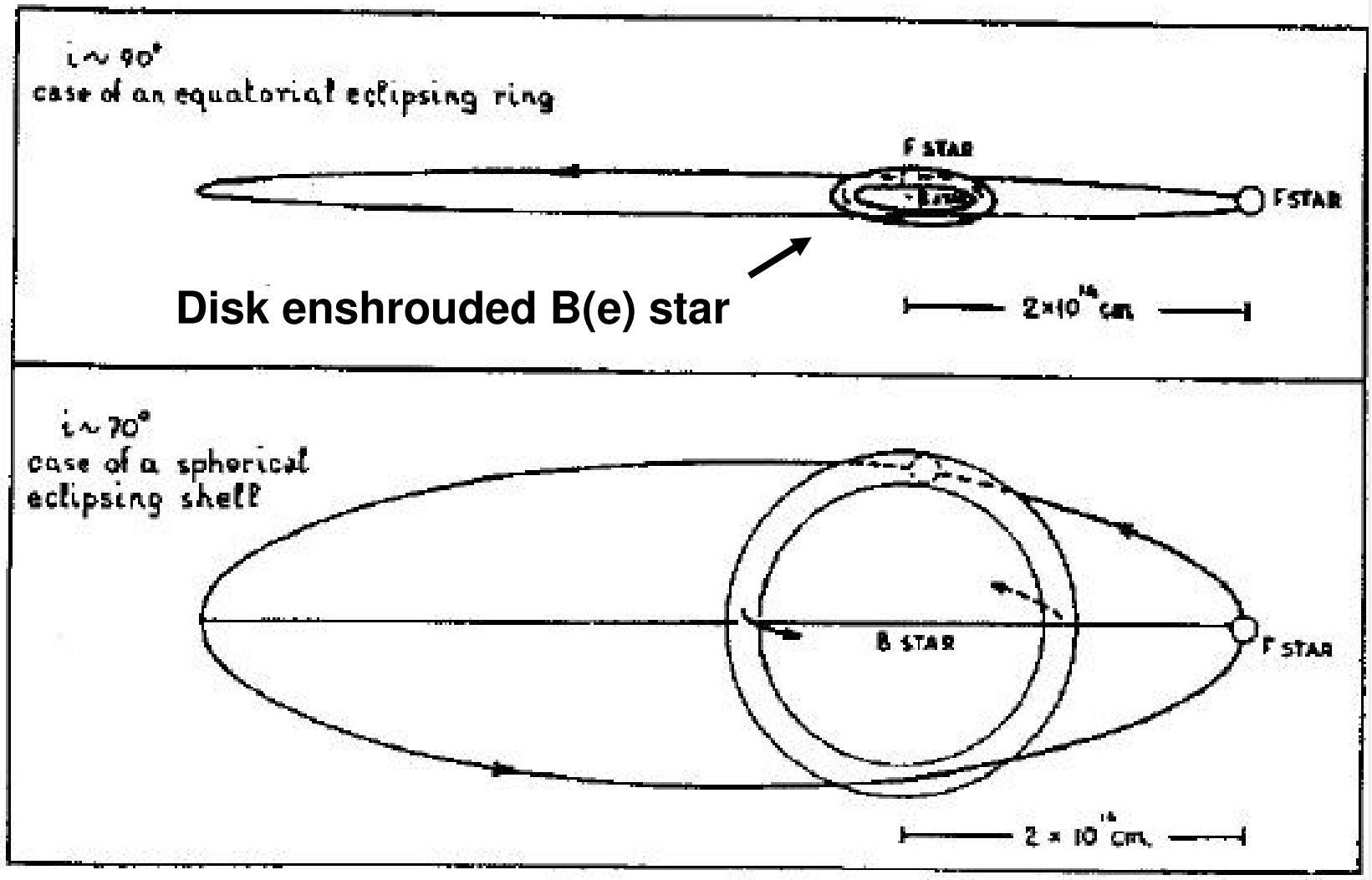
Problems with the Struve models

Kopal, 1954:

- *Cannot reproduce flat-bottom eclipse light curve*
- *Densities for sufficient amount of electron scattering are unreasonably large*
- *Interior structure of secondary would not match any reasonable stellar evolutionary state known…*

1961 – Hack: Add a hot component… To account for out of eclipse variations, allow the core of the cool component to shine through… IUE, HST & FUSE confirmed strong UV excess





Contrasting models. Relative orbit as seen from secondary's point of view…

The “disk” model…

1924, Ludendorff

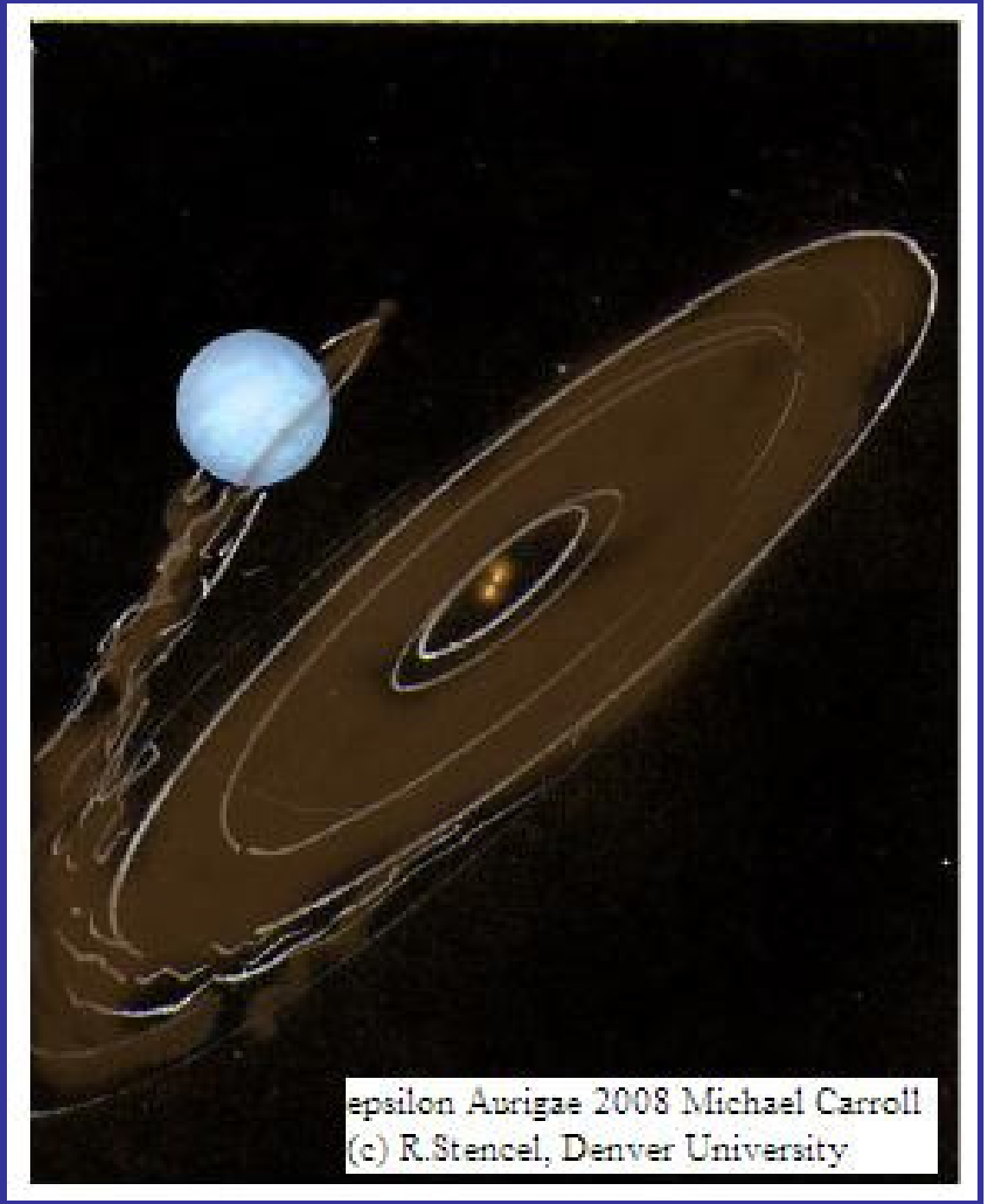
An elongated swarm of meteorites…

1954, Kopal

A 40AU flat disk like planet forming ones…

+Dims the light without changing the spectrum.
+Matches rotational observations.

“Party line” model.

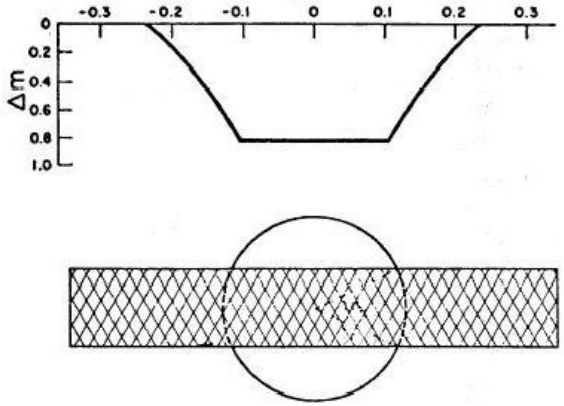


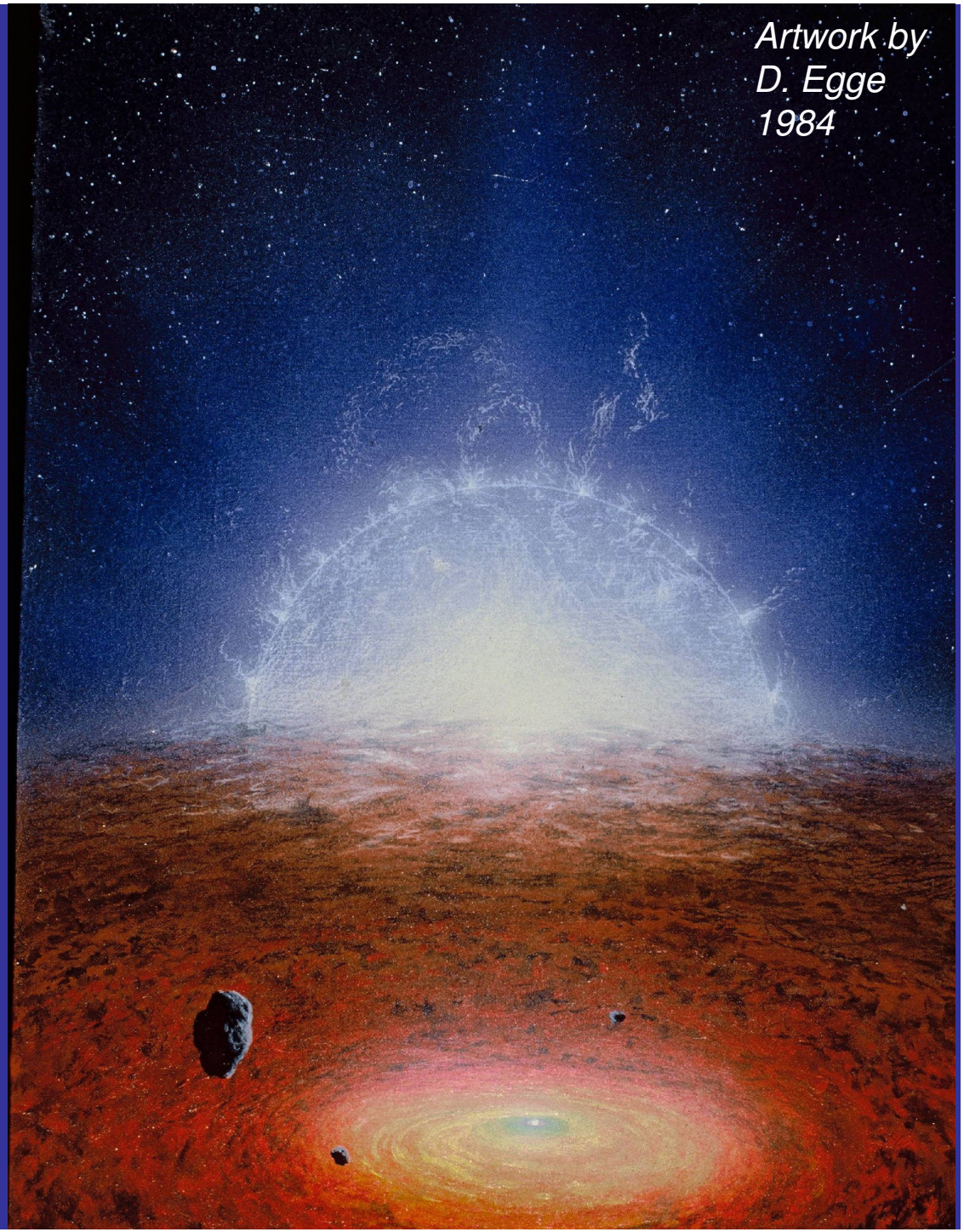
The “disk” model…

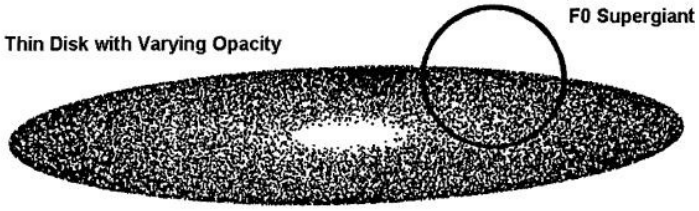
1965 – *Huang*
Northwestern Univ. prof

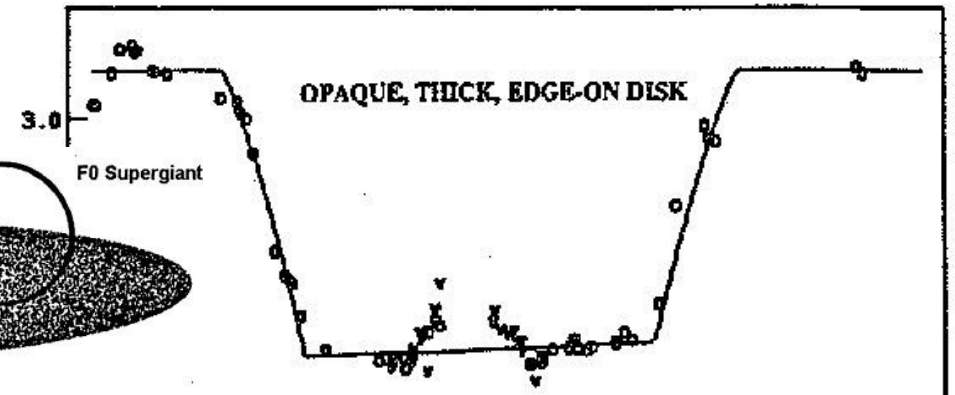
An opaque thin disk causes eclipses… source of irregular variations unclear…

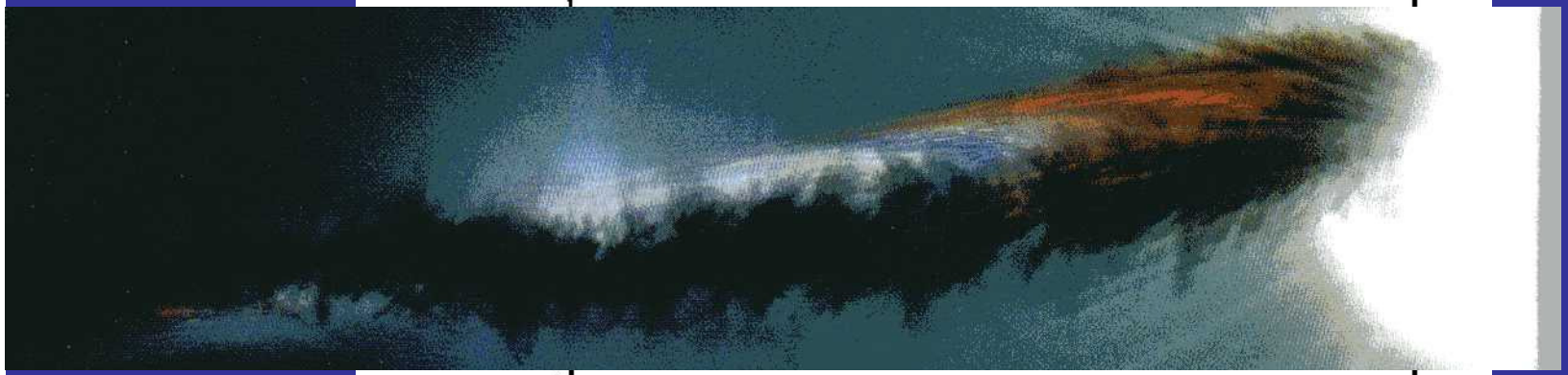
Lissauer & Backman: Add binary B dwarf stars inside, to stabilize disk

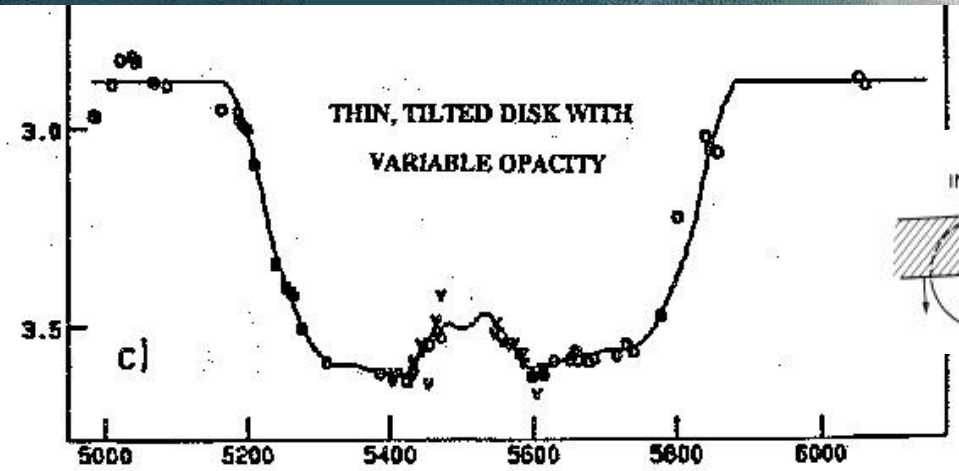


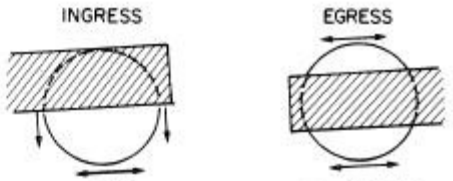



Thin Disk with Varying Opacity
Central Hole


OPAQUE, THICK, EDGE-ON DISK
3.0
F0 Supergiant




THIN, TILTED DISK WITH
VARIABLE OPACITY
3.0
3.5
c)
5000
5200
5400
5600
5800
6000
Julian Day 2440000+

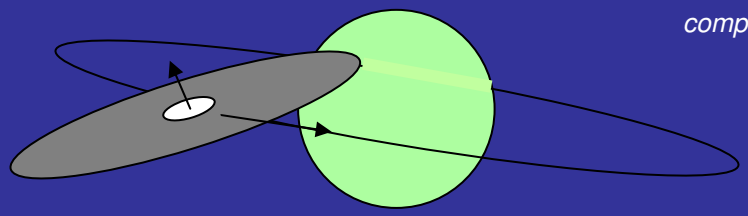

INGRESS
EGRESS

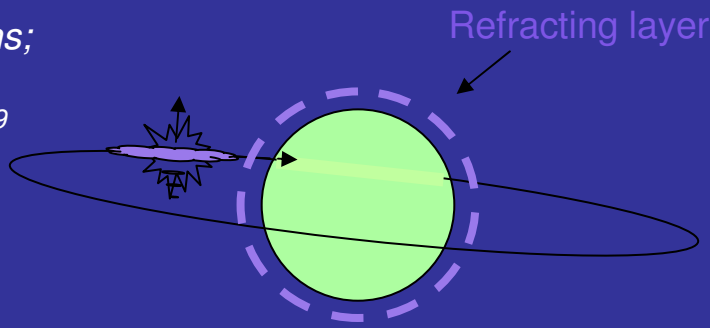
Epsilon Aurigae – eclipse ingress 2009 – Earth views:

Huang/Wilson model – dark disk in front

Hack/Senay model – bright UV source behind

schematic inclinations;
not to scale
compiled by R.Stencel 6/09





Right handed rotation – redshifted motion of disk appears in absorption first

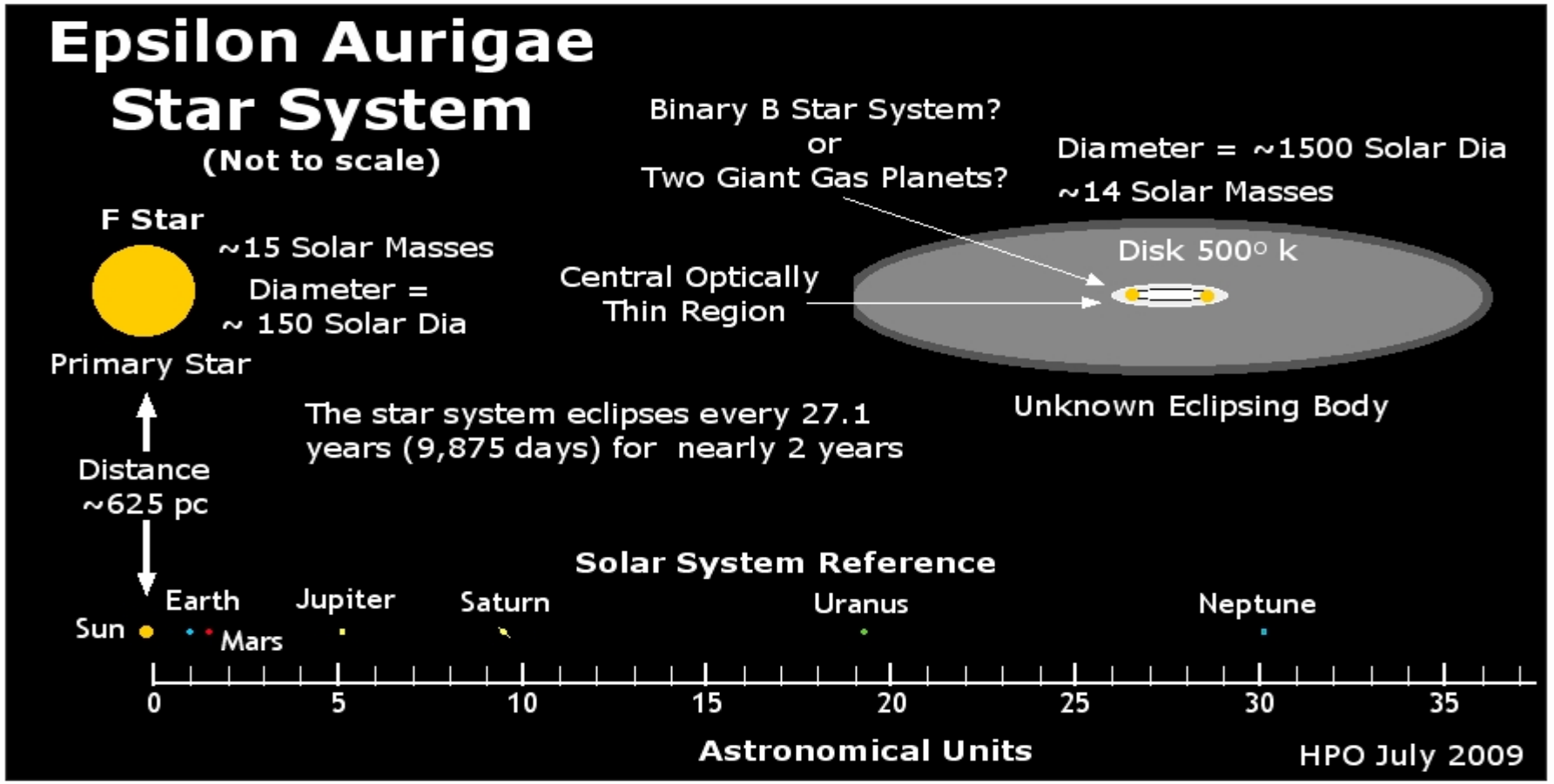
requires central hole to explain mid-eclipse brightening.

Retrograde rotation – blueshifted absorption against UV source disappears first

UV source light variation refracted by F * layers

Current Epsilon Aurigae Star System Model *[the party line]*

Carroll et al. 1991 Ap.J. 367: 278; updated by Jeff Hopkins…



Key questions for this eclipse:

…is this correct? …has the disk changed?

What's next?

- Observations needed
  - Visual and Photometric monitoring
  - Spectroscopy
  - Polarimetry
  - Interferometry
- Theory needed
  - Binary star evolution
  - Interaction & disk physics

Photometry

Some key papers:

Hans Ludendorff, 1912, Astron. Nachrichten

Analysis of visual observations, 1874, 1902 eclipses

K. Gyldenkerne, 1970 Vistas Astron.

Analysis of photometric observations, 1956 eclipse

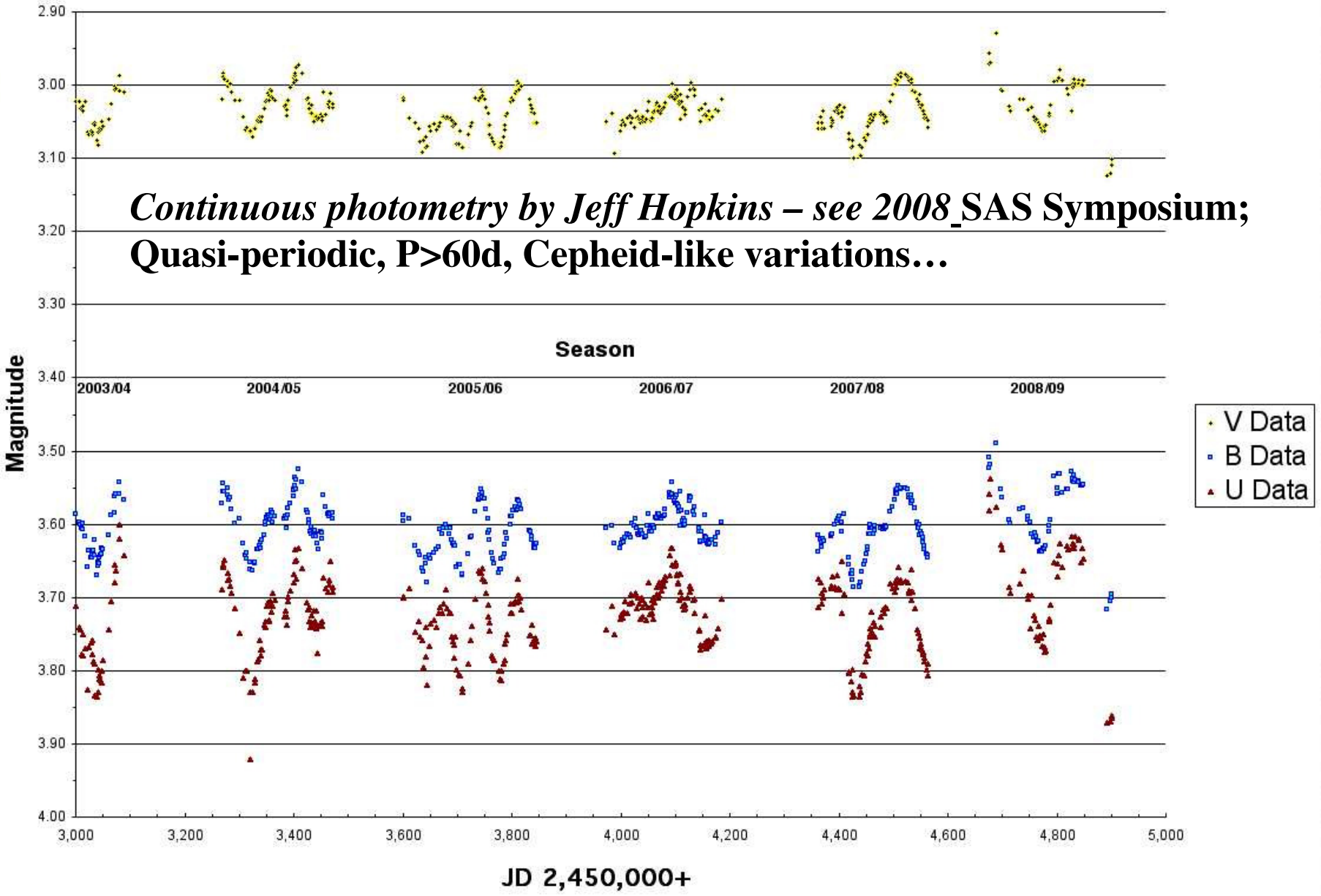
Jeff Hopkins, 1985 NASA Conf. Proc. 2384

Photometric observations, 1983 eclipse

Jeff Hopkins et al. 2008 SAS Symposium

Gearing up for Epsilon Aurigae's First Eclipse of the Millennium

Epsilon Aurigae 2003 - 2009



Continuous photometry by Jeff Hopkins – see 2008 **SAS Symposium;**
Quasi-periodic, P>60d, Cepheid-like variations…

SOME of the ACTIVE CAMPAIGN OBSERVERS

Excellent photometric data have been reported by:

David Trowbridge

(Tinyblue Observatory, Greenbank, Washington, USA)

Dr. Tiziano Colombo

(S. Giovanni Gatano al Observatory, Pisa, Italy)

Richard Miles

(Golden Hills Observatory, Stourton Caundle Dorset, England)

Paul Beckmann

(Jim Beckmann Observatory, Mendota Heights, Minnesota, USA)

Des Loughney

(Edinburg, Scotland),

Brian McCandless

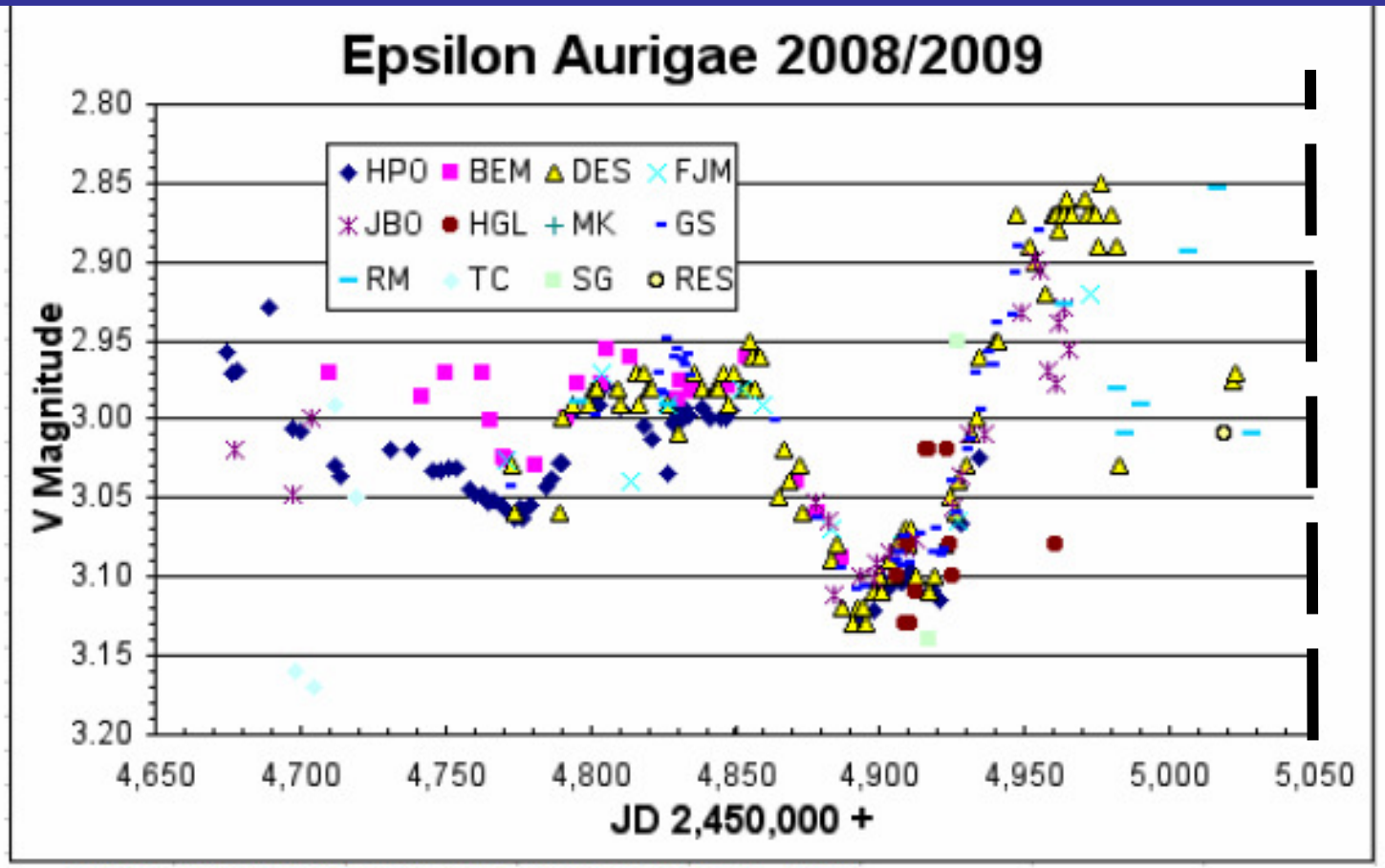
(Grand View Observatory, Elkton, Maryland, USA),

Frank J. Melillo

(Holtsville, New York, USA)

& you!

VISUAL & DSLR & PHOTOMETRIC

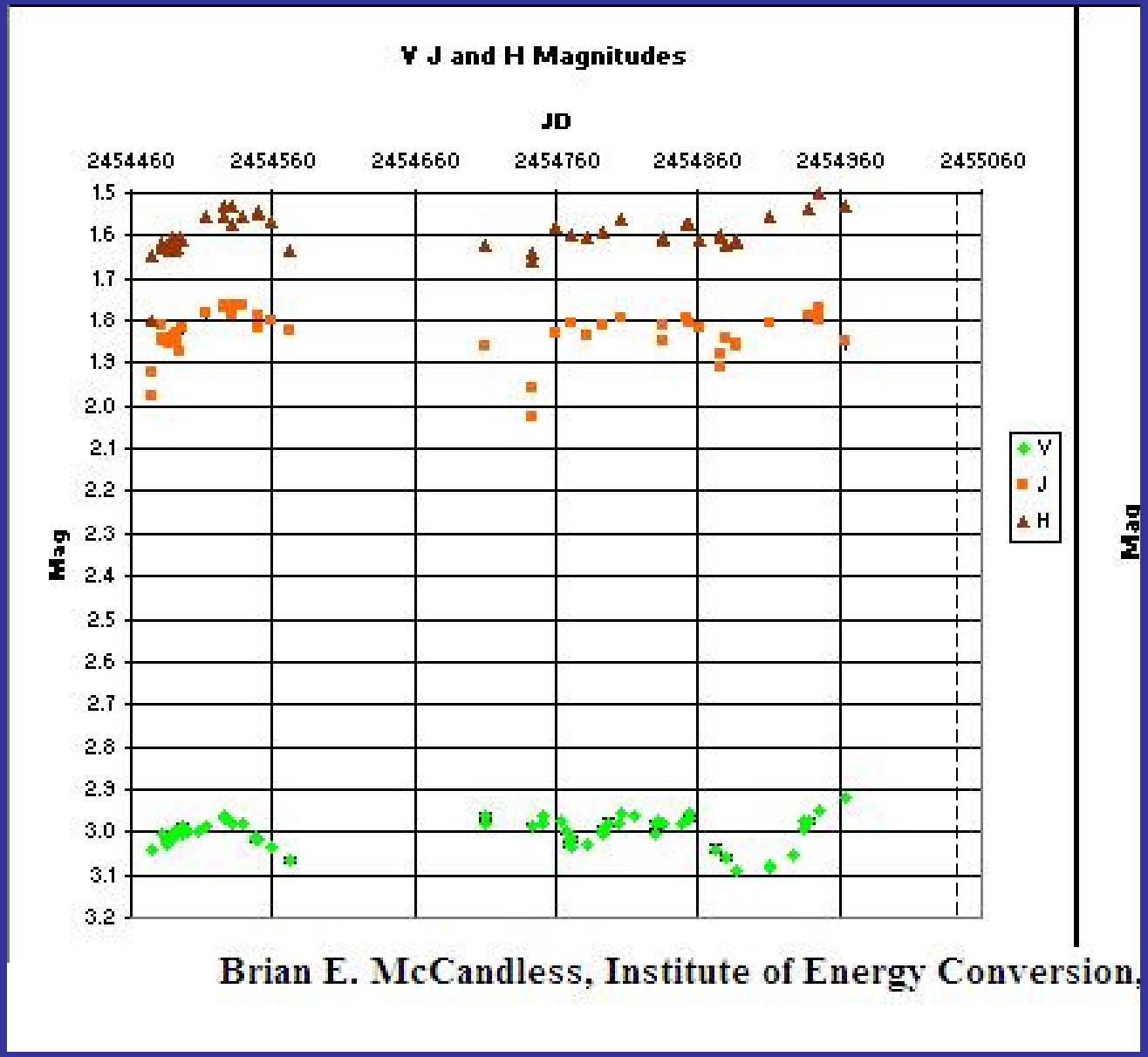


HPO - Hopkins Phoenix Observatory, Arizona, USA
JBO - Jim Beckmann Observatory, Minnesota, USA
RM - Richard Miles, England
BEM - Brian McCandless, Maryland, USA
HGL - Hans-Goran Lindberg, Sweden
TC - Dr. Tiziano Colombo, Italy
DES - Des Loughney (Scotland)
MK - Dr. Mukund Kurtadikar, India
SG - Snaevarr Gudmundsson, Iceland
FJM - Frank J. Melillo, New York, USA
GS - Gerald Samolyk, Wisconsin, USA
RES - Robert E. Stencel/Nicholas Long, Denver USA

^

Eclipse starts?

Near infrared photometry (SSP4)



J = 1.8
H = 1.6

Some variations

Expect 0.8 mag decline into eclipse.

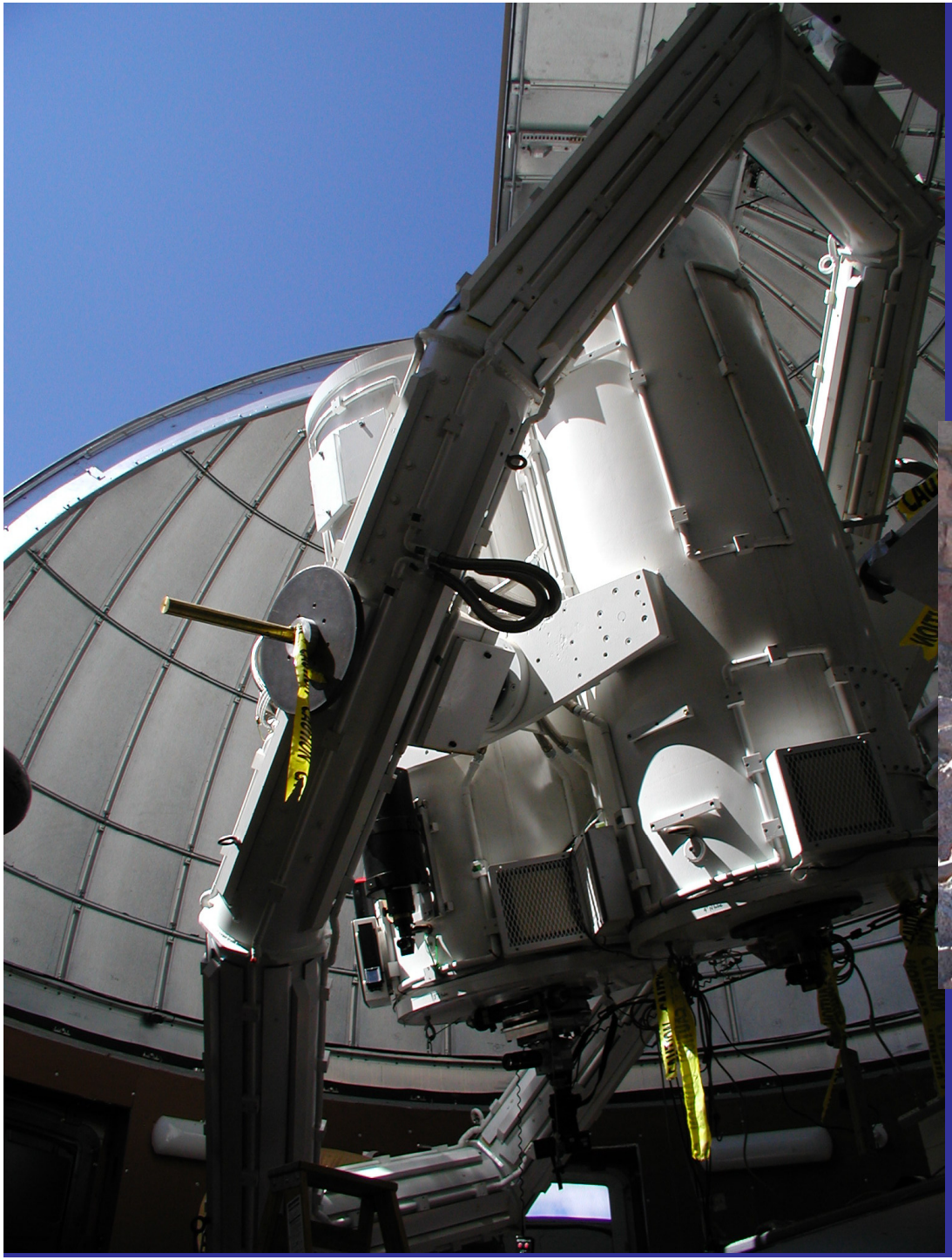
SSP4 observations from Meyer-Womble Observatory, summer 2009

The instrument: Optecinc Solid State Photometer 4

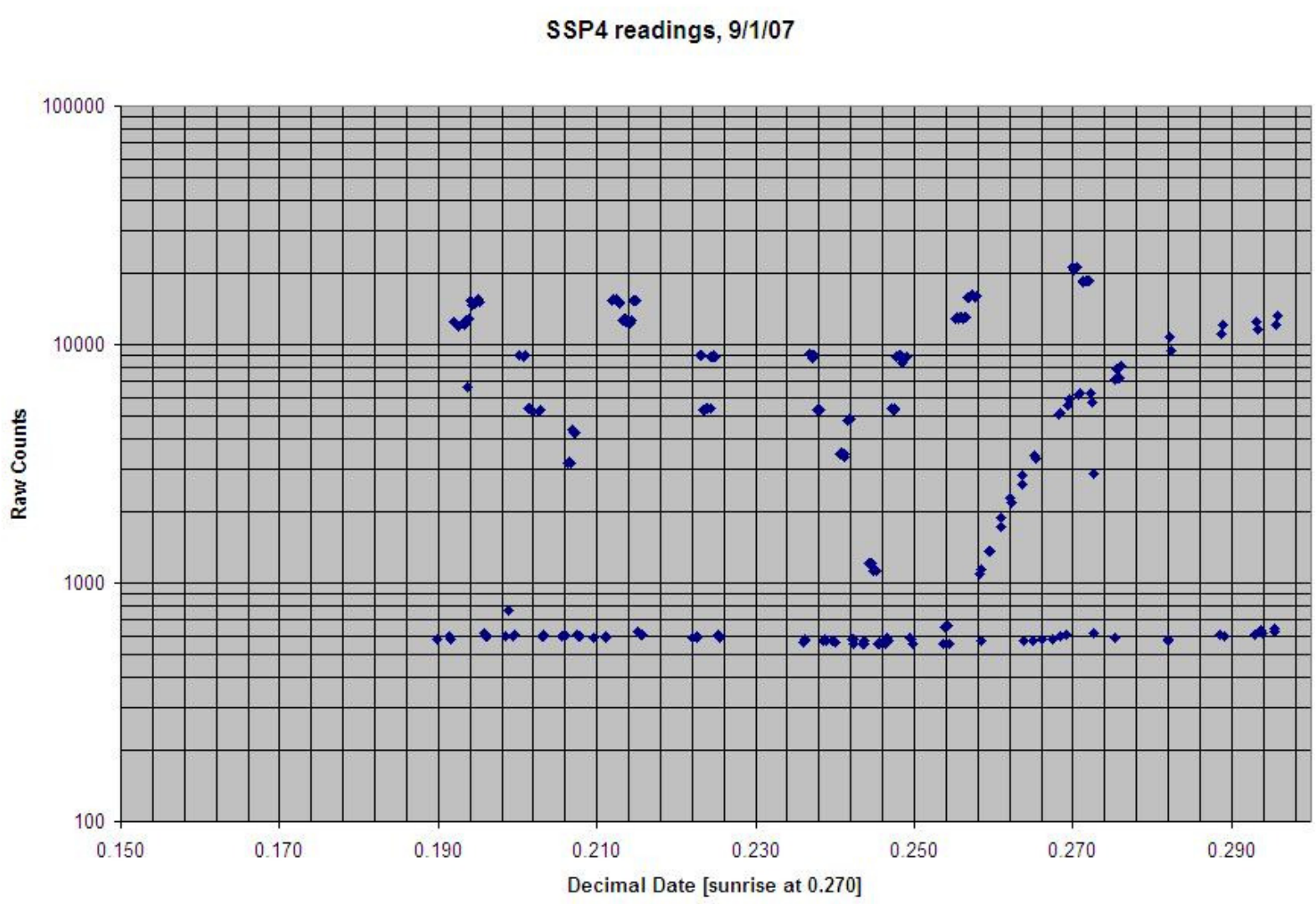
A near-IR photometer, which allows a great many stars to be observed accurately in the J (1250nm) and H (1650nm) photometric bands, using custom J-band and H-band filters.

The AAVSO has assisted Optec in the development of this instrument and they have an active users group and much information concerning data reduction and program stars.

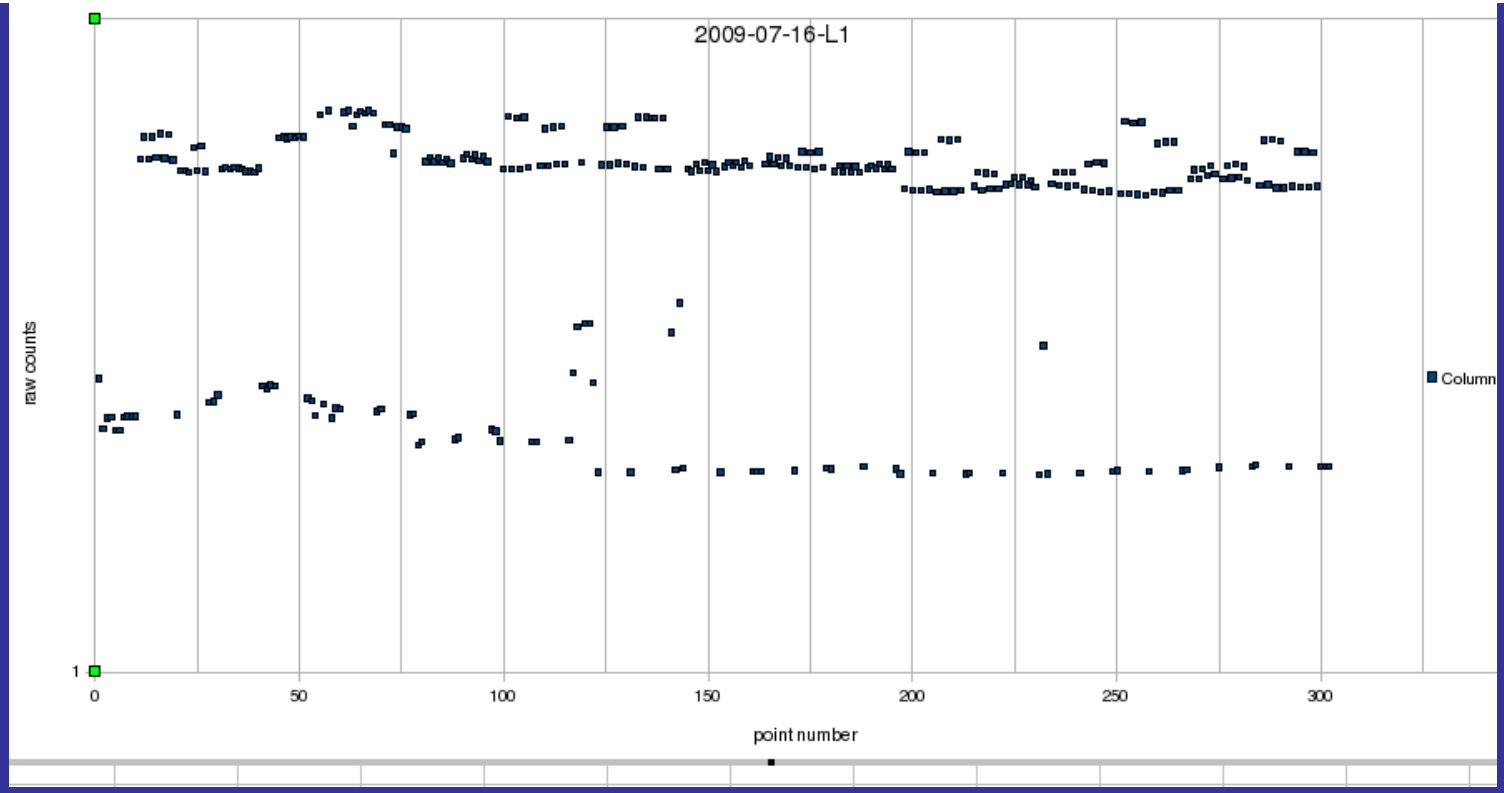
Alternate Software for Optec's SSP-4 – by Brian Kloppenborg, for Windows Linux and Mac OS X. Features: select exposure times between 0.01 and 65.53 seconds in 0.01 second increments; preserves data in case of accidental camera disconnects or power cycles; thoroughly tested over the last five weeks at DU's Mt. Evans observatory and improved during that time; available for download from the "Software" tab at (http://portfolio.du.edu/bkloppen); officially announced at the Citizen Sky Workshop at the Adler Planetarium in August.



Capella and the kids...



Daytime observing – possible but not trivial…


2009-07-16-L1
raw counts
1
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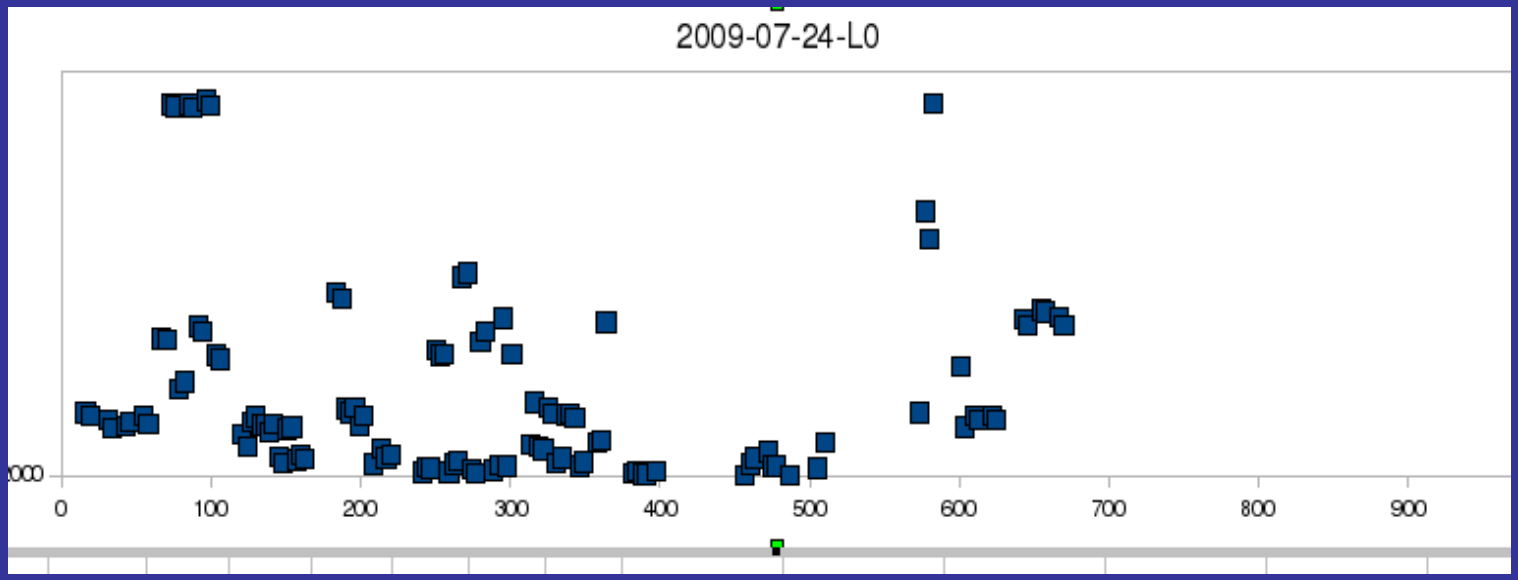
50
100
150
200
250
300
point number
Column


2009-07-24-L0
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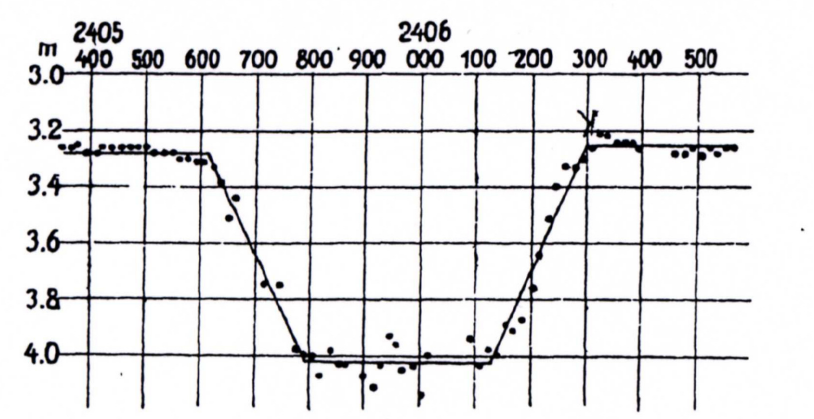
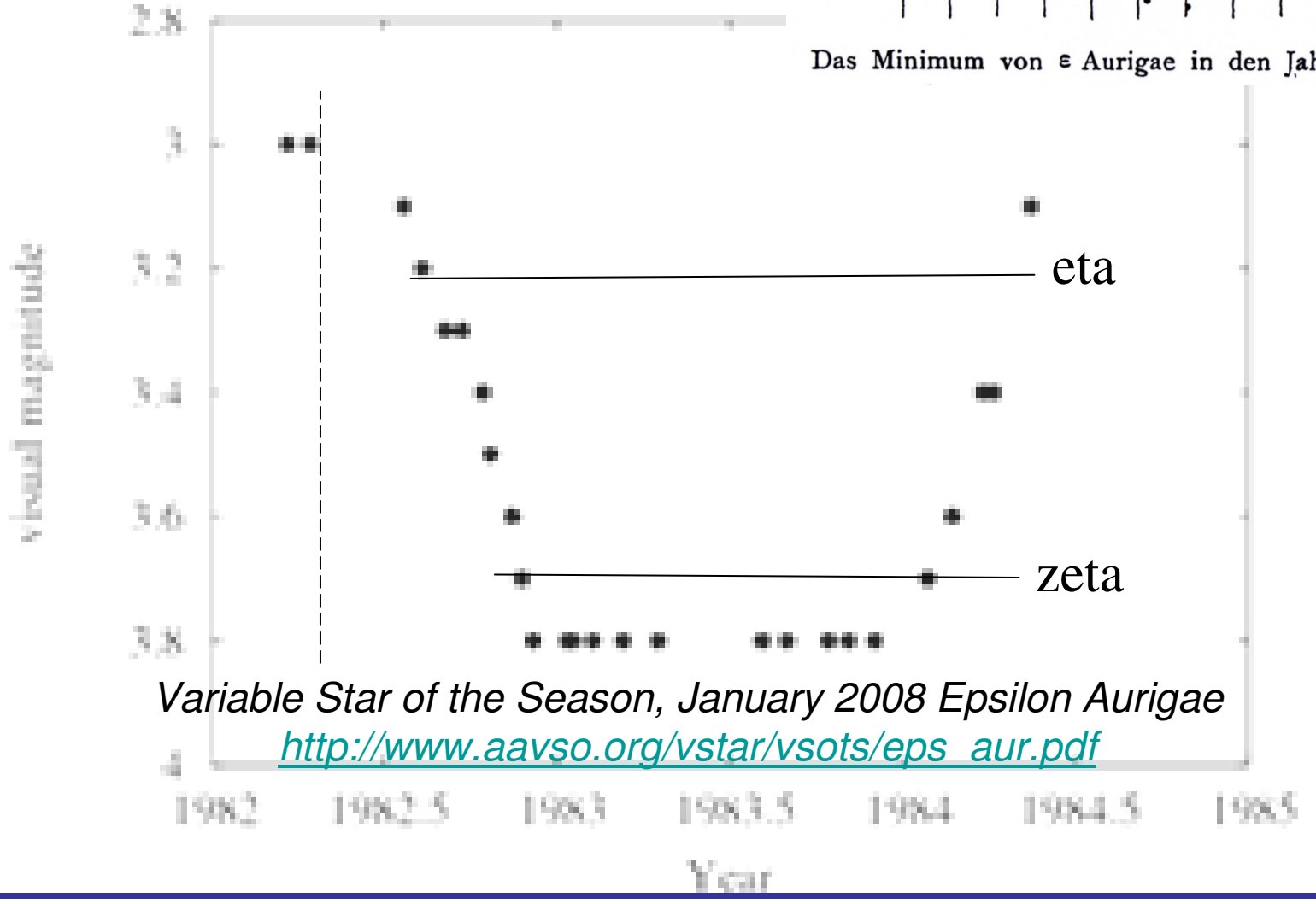
What to expect during eclipse…

Visually:



Das Minimum von ε Aurigae in den Jahren 1874–75.



Variable Star of the Season, January 2008 Epsilon Aurigae

http://www.aavso.org/vstar/vsots/eps_aur.pdf

Predicted times of contact:

http://www.citizensky.org/forum/contest-predict-first-contact

1st Contact: JD= 2,455,043 = 30 July 2009*

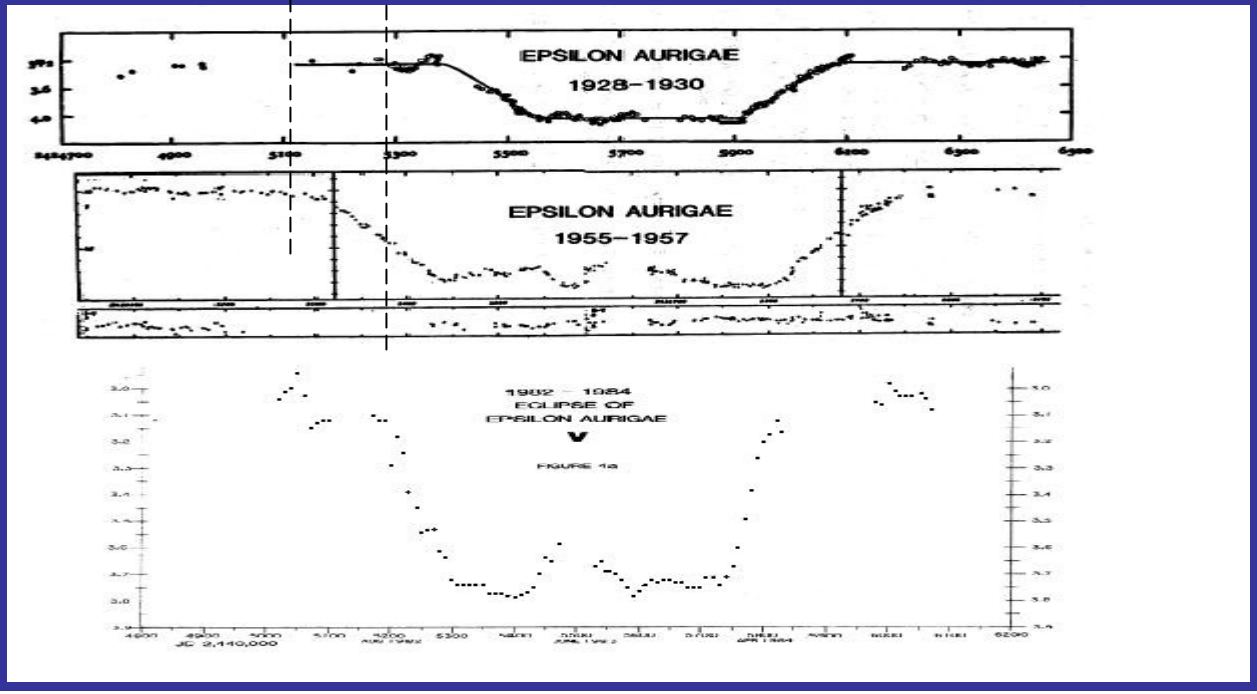
2nd Contact: JD= 2,455,185 = 19 Dec. 2009

Mid Eclipse: JD= 2,455,413 = 04 August 2010

3rd Contact: JD= 2,455,640 = 19 March 2011

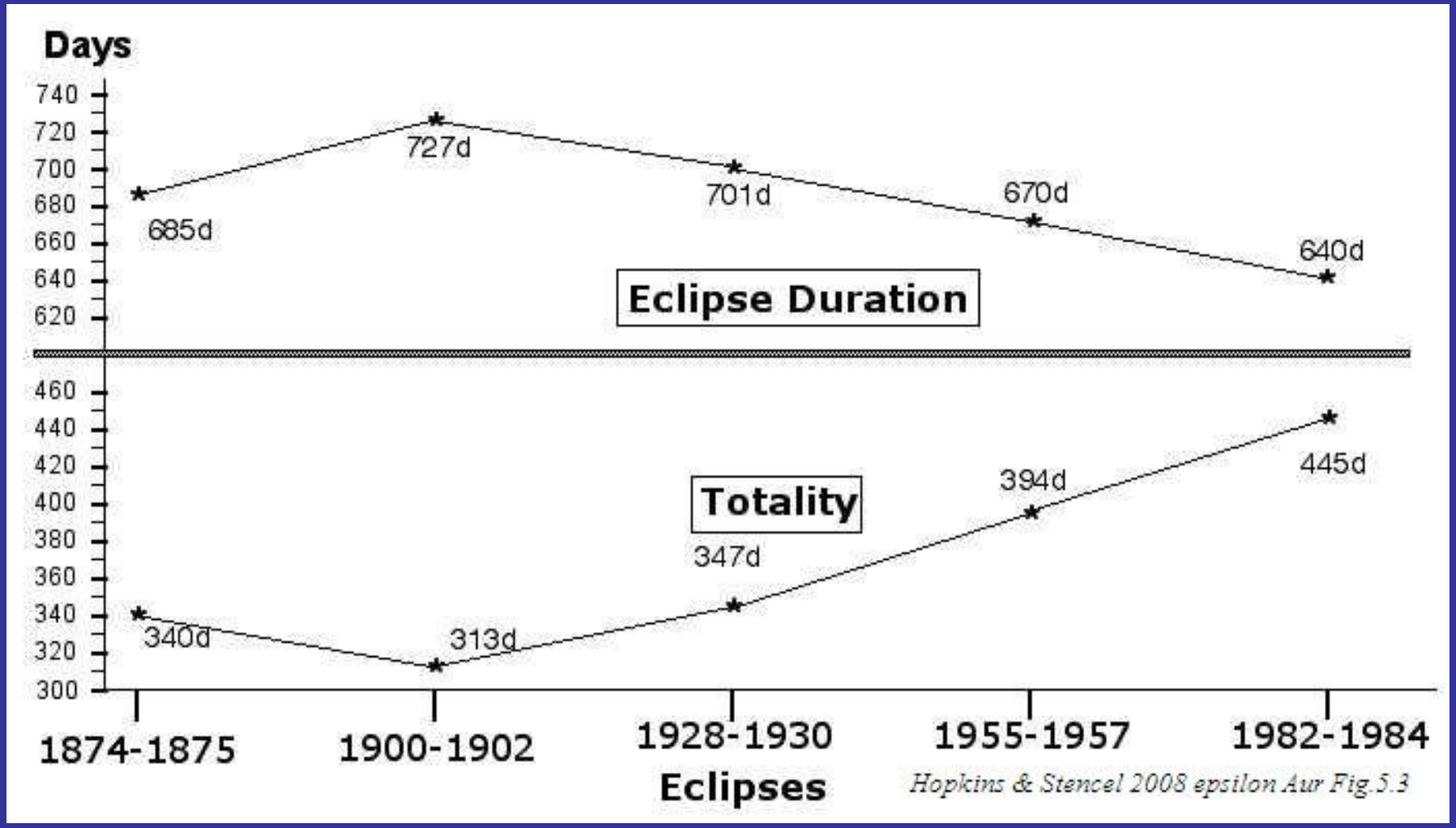
4th Contact: JD= 2,455,695 = 13 May 2011

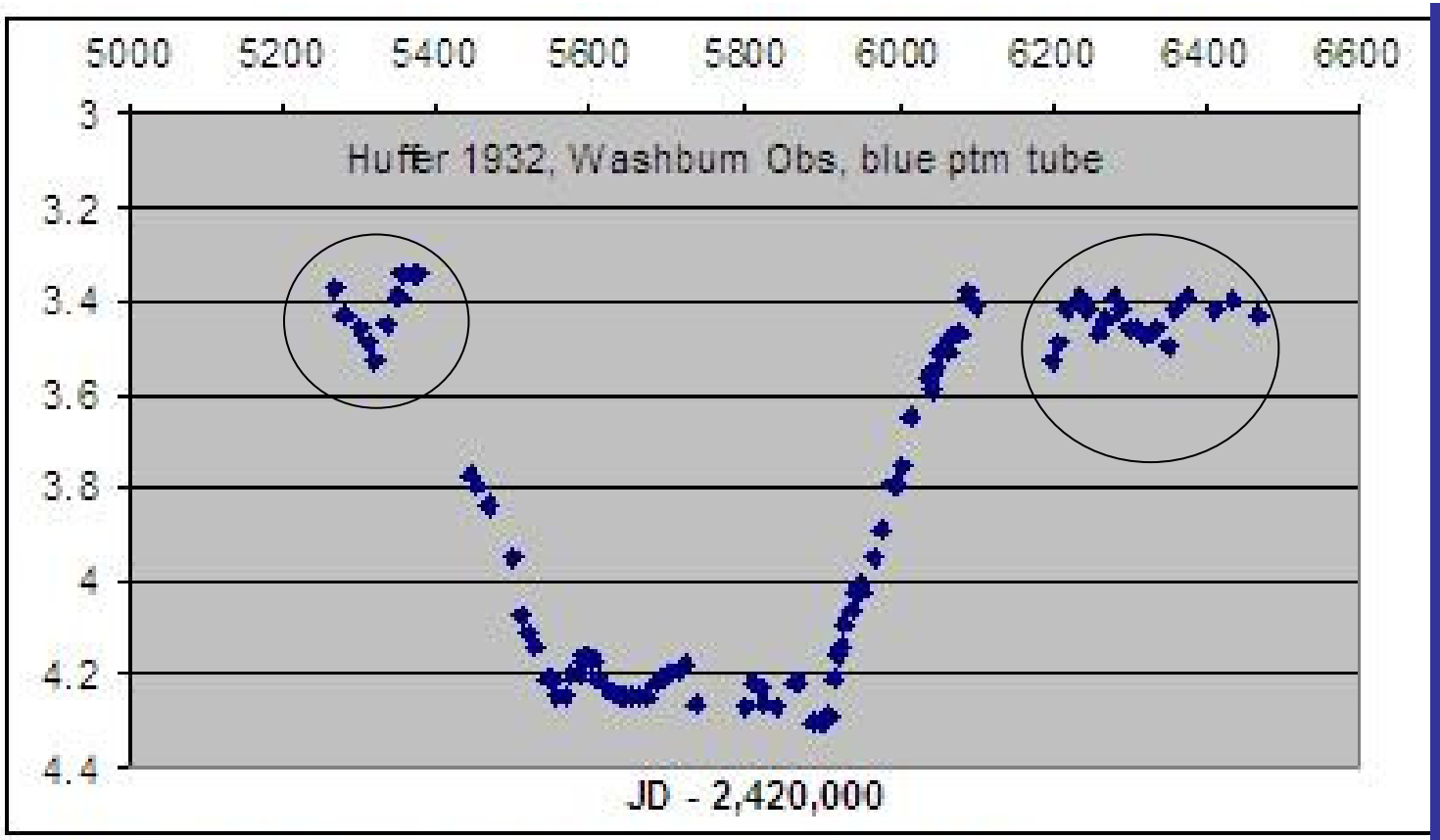
Will mid-eclipse brightening RECUR?



Prediction caveats:

Combining with prior eclipse light curves → changes abound!





http://adsabs.harvard.edu/abs/1932ApJ....76....1H

Out of eclipse light variations, too?

H. Shapley, 1928 Harvard Obs Bulletin:

Although few in number, the observations indicate a period of 355 days, with an uncertainty of possibly ten days. Variability in a period of less than a day is not absolutely excluded, but successive observations on the same night make it improbable. The comparison star used by Wendell is B.D. +44° 1077, spectral class A2, magnitude 7.21. It is not impossible that a seasonal error may have affected Wendell's observations since there is a considerable interval of brightness between

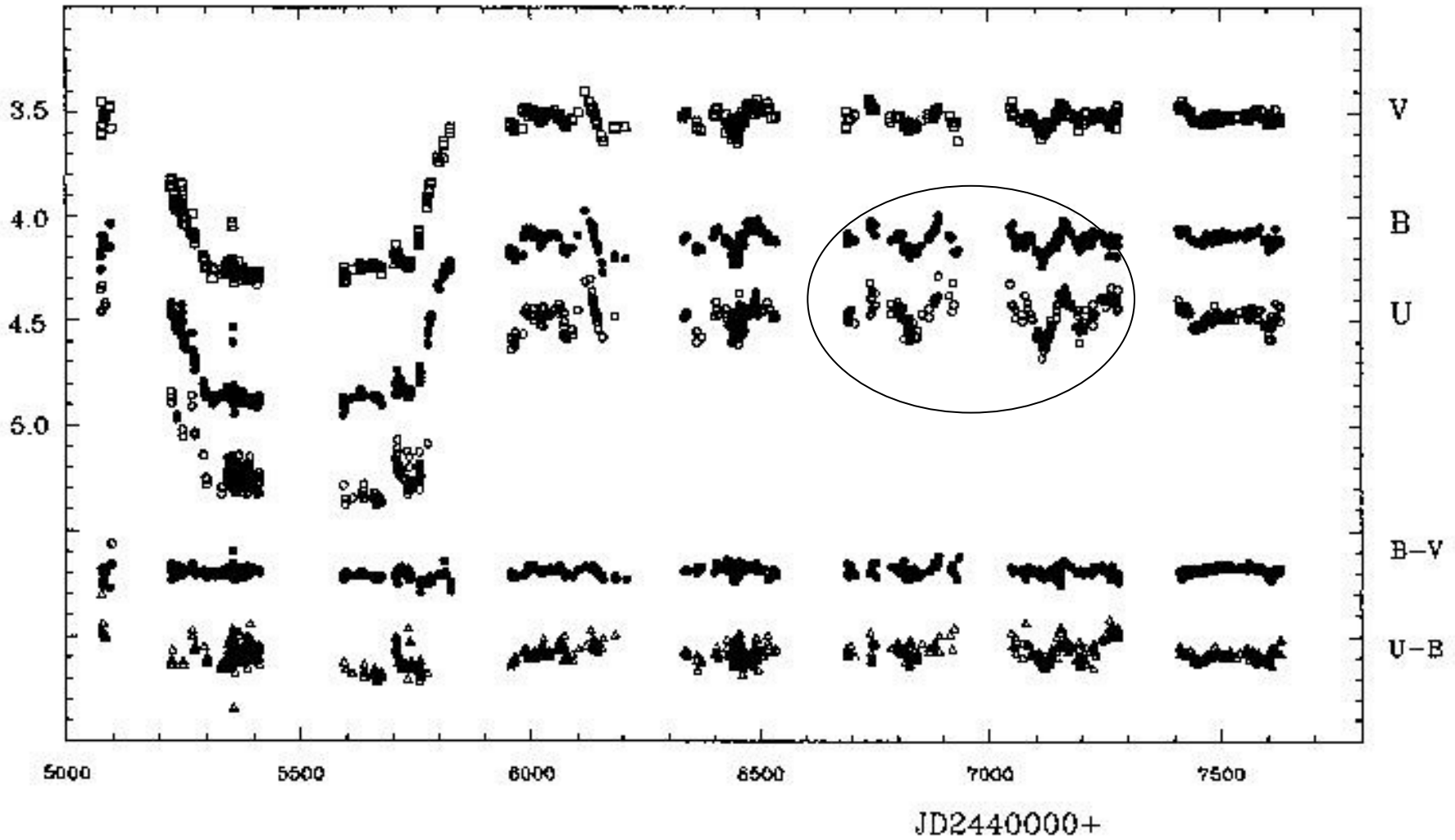


Figure 1. *U*, *B*, *V*, *B-V* and *U-B* curves of ϵ Aur made with YUO data for seven years (1982-1989).

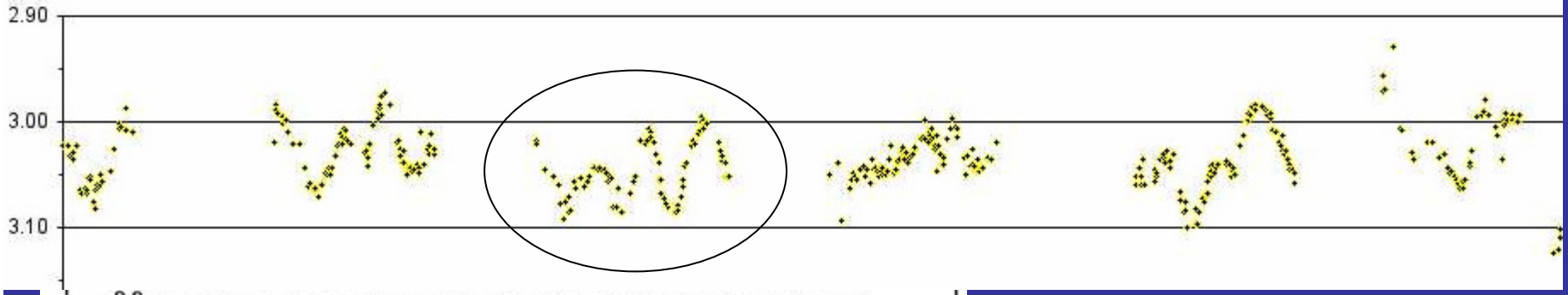
Nha et al. 1993 http://adsabs.harvard.edu/abs/1993ASPC...38..291N

Nha et al. 1993:

A period of 95.5 days satisfies *U*, *B*, *V* observations outside eclipse phases in 1984-1989. Increase of the amplitude of light variation with shorter wavelength is confirmed.

HPO

Epsilon Aurigae 2003 - 2009



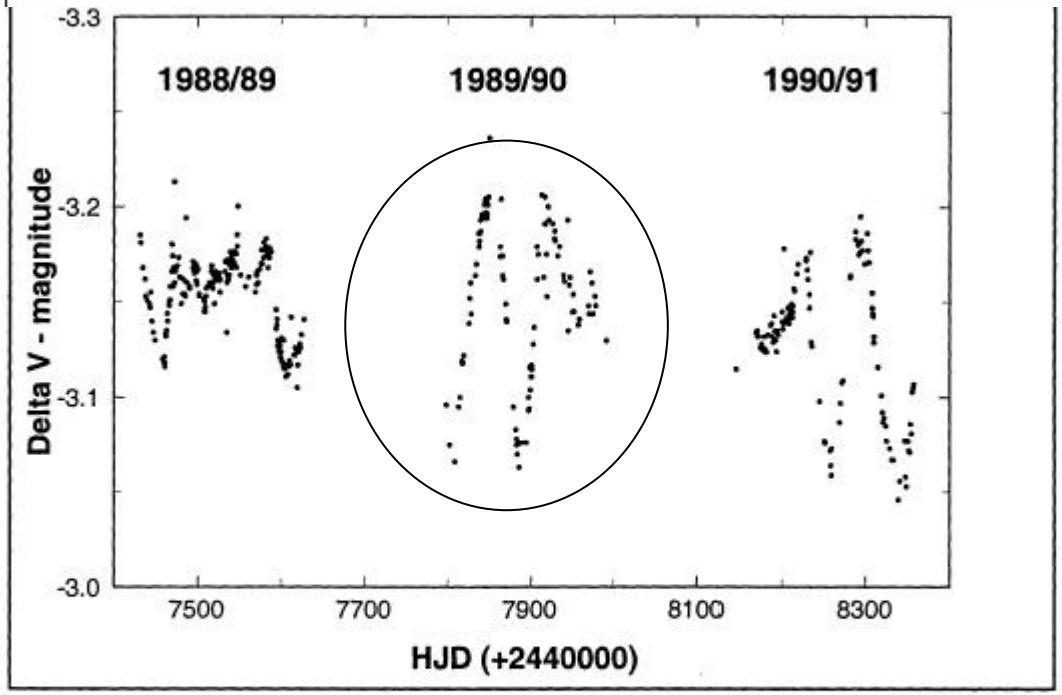


Figure 4. Plot of the differential *V*-mag measures of ϵ Aurigae obtained by L. Boyd from 1988-1991 at Fairborn Observatory. The changing low-amplitude light variations arising from the F-supergiant are shown. from Guinan & Dewarf 2002 ASP Conf. 279

Peranso period analysis shows characteristic period has decreased from ~95 days (Nha; Boyd) to ~65 days (HPO) since last eclipse…

…at least until recently & subject to re-analysis.

?Cause of quasi-period changes?

Spectroscopy

Some key papers:

Otto Struve & C. Elvey 1930 Astrophys Journal

Spectrographic observations of 7 epsilon Aurigae.

Otto Struve 1956 Publ. Astron. Society Pacific

epsilon Aurigae.

David Lambert 1986 Publ. Astron. Soc. Pacific

Epsilon Aurigae in eclipse. II - Optical absorption lines from the secondary

Steno Ferluga 1991 Astron. Astrophys.

Epsilon Aurigae. II - The shell spectrum

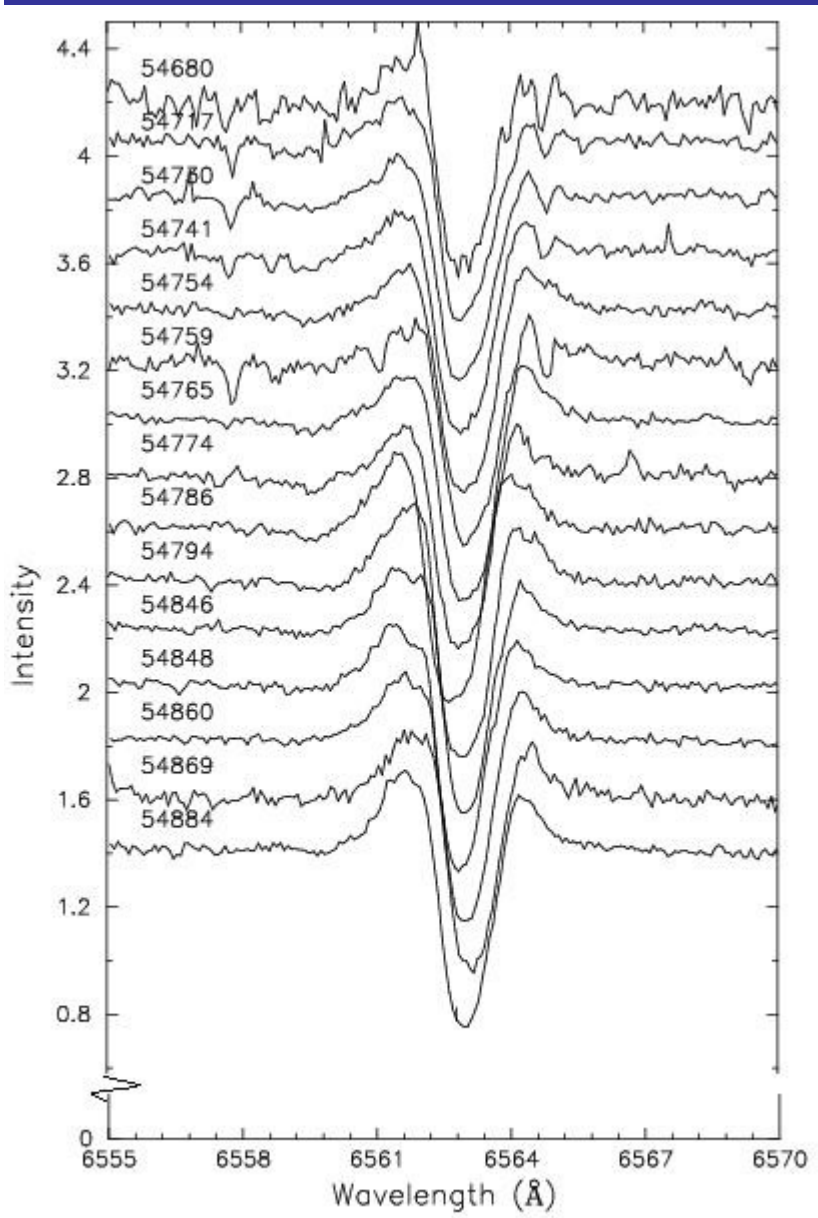
Yaron Sheffer & David Lambert 1999 Publ.Astron.Soc.Pacific

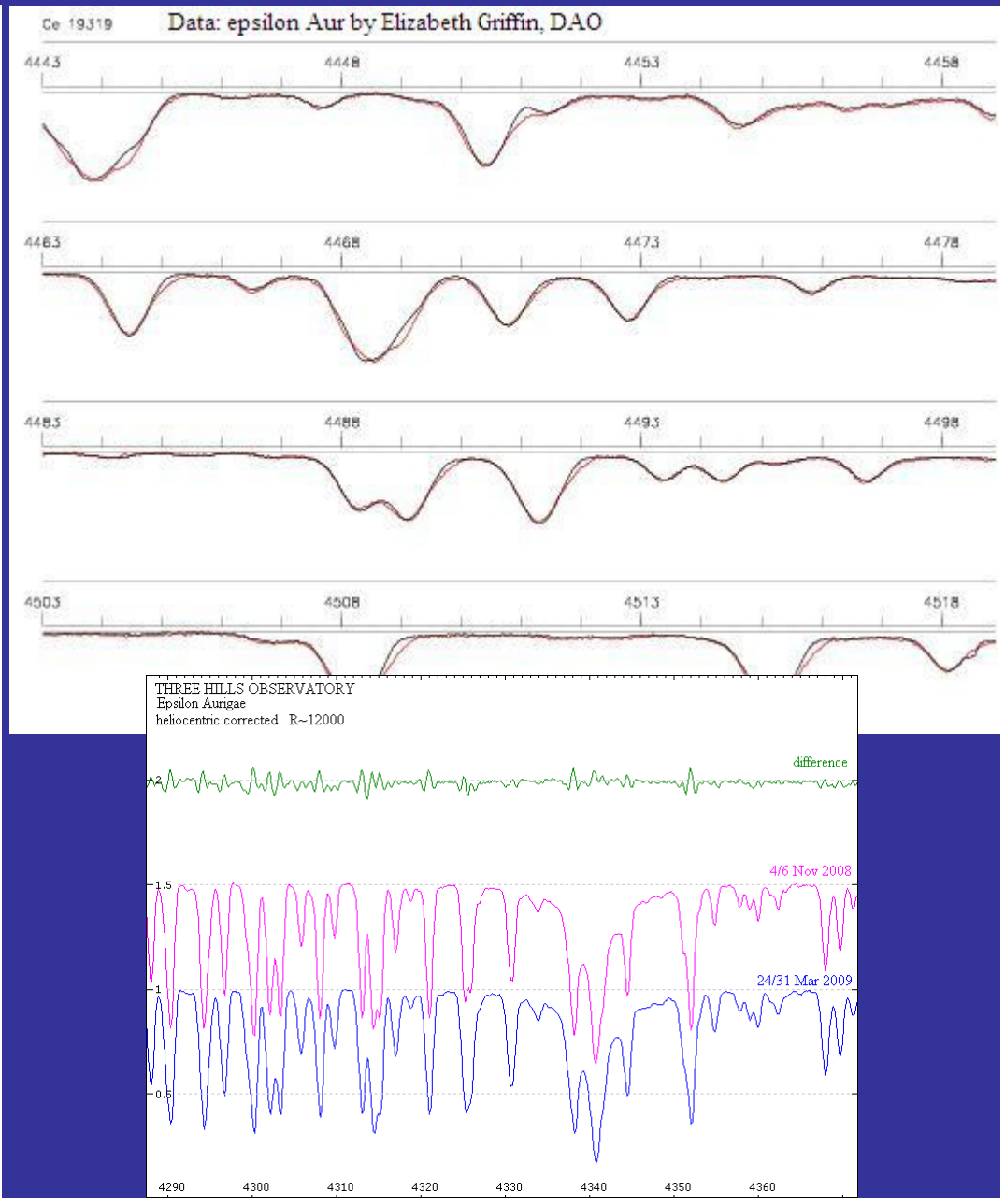
Intereclipse Spectroscopic Snapshot of epsilon Aurigae with the Hubble Space Telescope

Some campaign observers

- Elizabeth Griffin, DAO, Canada
- Des Loughney, 3Hills Obs, UK
- Jeff Hopkins, HPO
- Joel Eaton, Tenn. State
- Steve Howell et al., NOAO
- Mike Sitko, U.Cincinnati
- And more…

Recent results





What to expect during eclipse

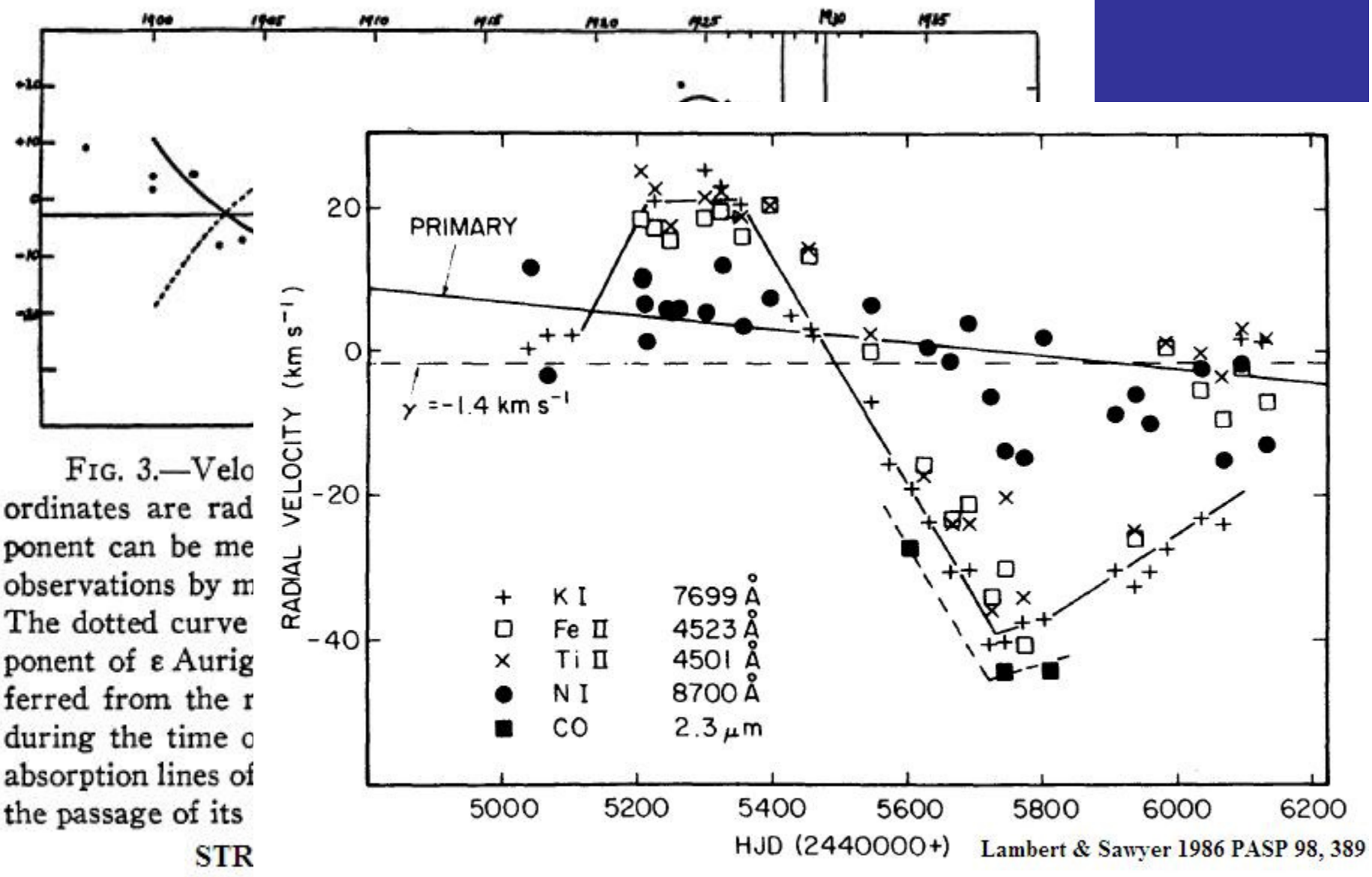
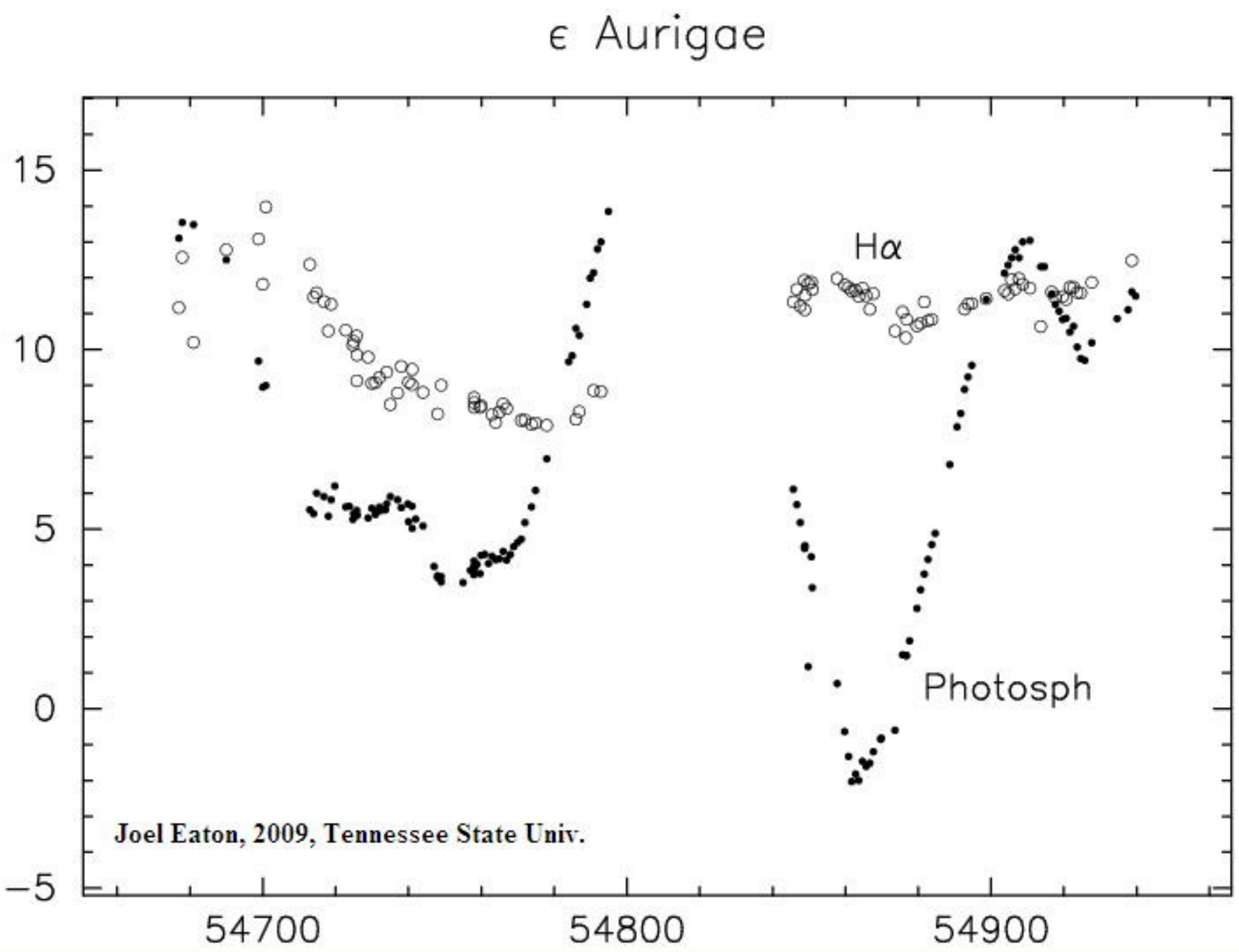


FIG. 3.—Velo
ordinates are rad
ponent can be me
observations by m
The dotted curve
ponent of ε Aurig
ferred from the r
during the time o
absorption lines of
the passage of its

STR

Lambert & Sawyer 1986 PASP 98, 389


ϵ Aurigae
15
10
5
0
−5
54700
54800
54900
Hα
Photosph
Joel Eaton, 2009, Tennessee State Univ.

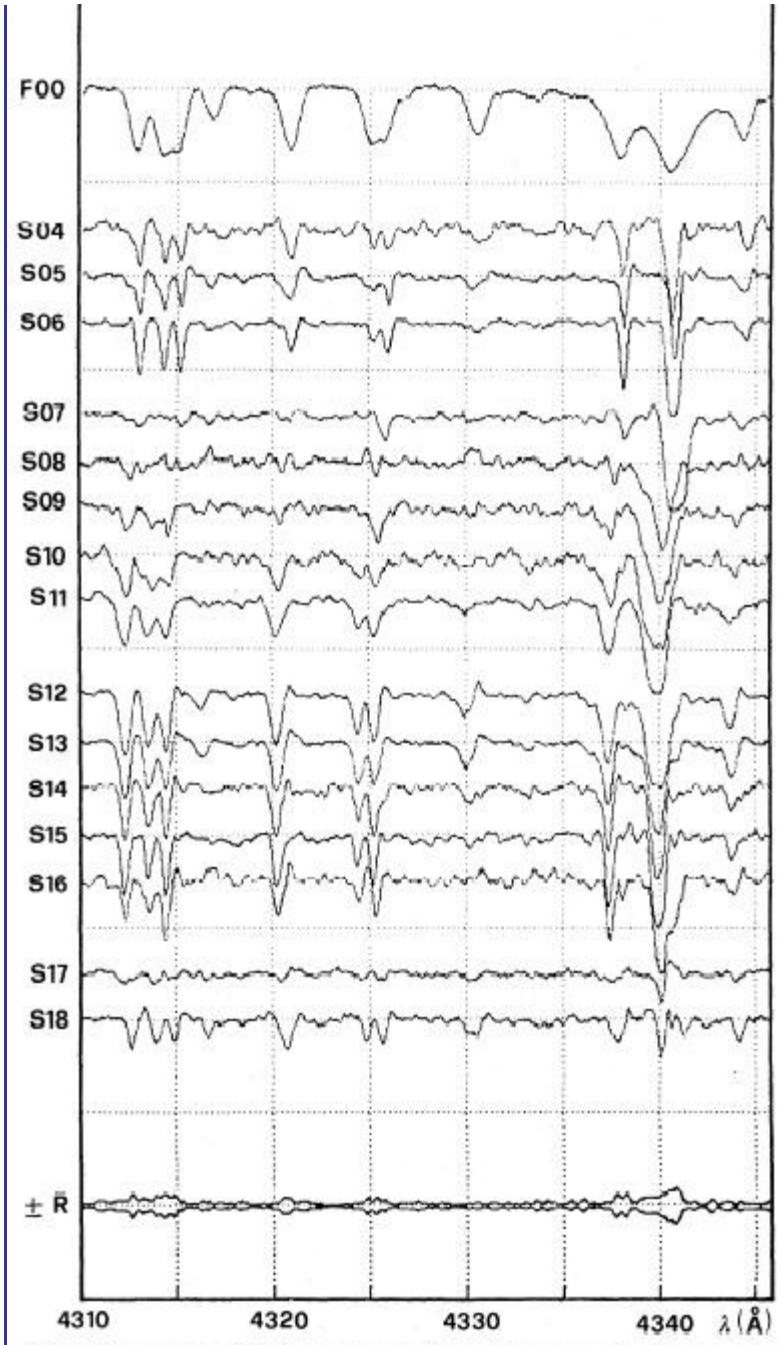


Fig. 2. The extracted shell spectra in linear-intensity scale (spectra 5, 8, 14, 15 are not yet optimized). The upper tracing is the reference stellar spectrum F_0. At bottom the uncertainty band is reported. One may note:

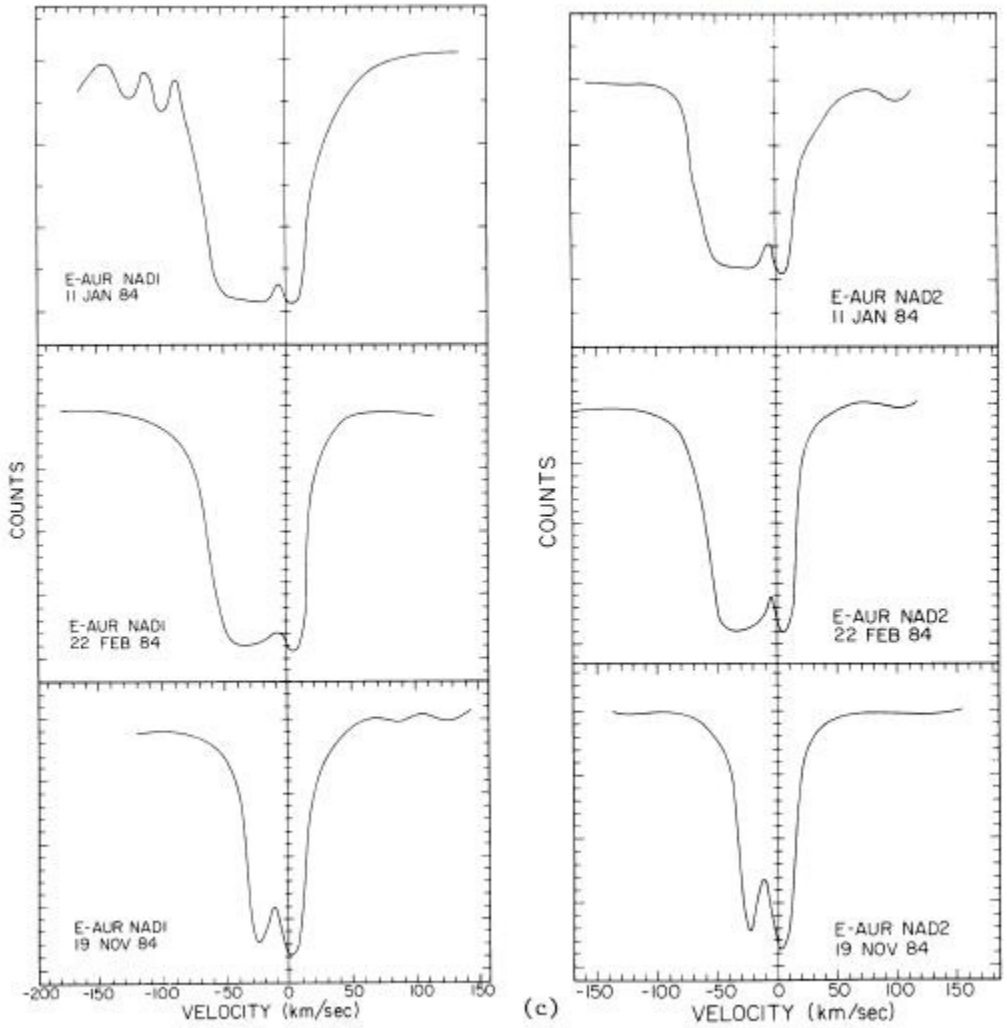
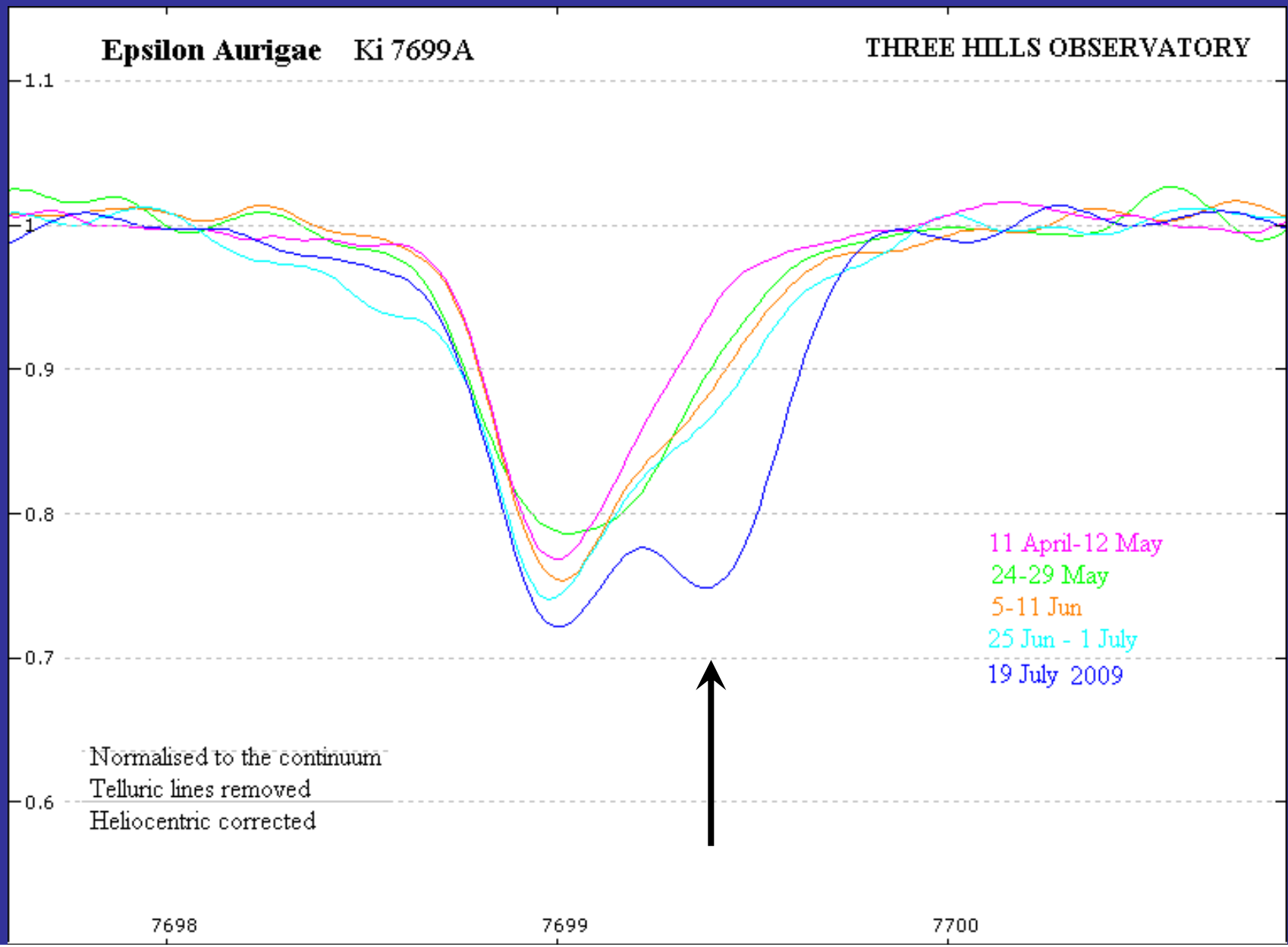
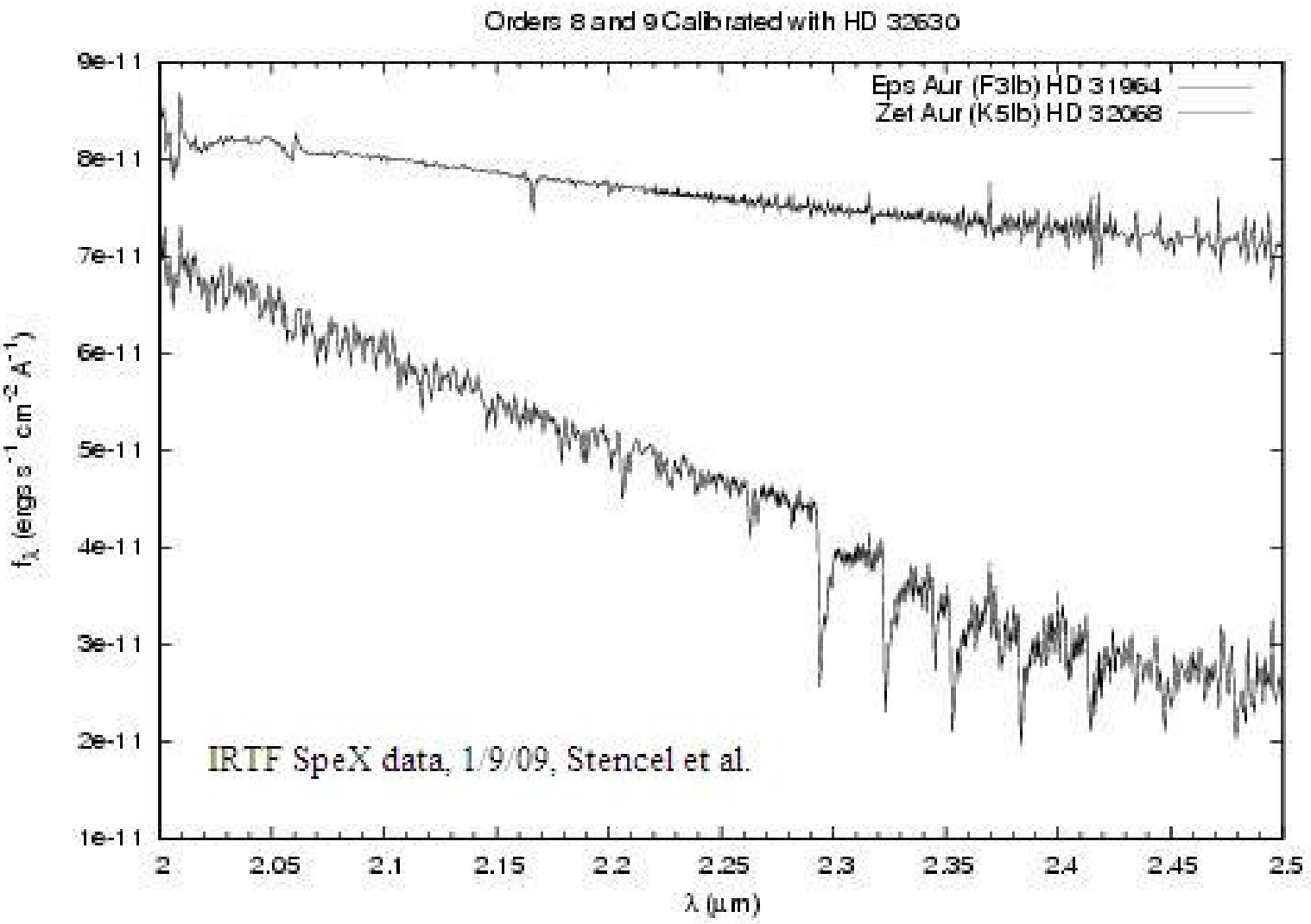


FIG. 3(c)–The Na D1 (laboratory wavelength = 5889.953 Å) and Na D2 (laboratory wavelength = 5895.923 Å) lines of ε Aur as they evolved (1 January 11 to November 19) during the 1982–84 eclipse of the system.

Lines to watch:
Ca K, Balmer lines, Na D, He I, K I, O I (7774)
& CO 2.3 microns…

Ingress begins(?)…IAUC1885





With thanks to Brian Kloppenborg and Bobby Buss

Polarimetry

- Some key papers (very few to choose from)
- Jack Kemp et al. 1986 Astrophys. Journal

  Epsilon Aurigae - Polarization, light curves, and geometry of the 1982-1984 eclipse (& 1989 G.Henson thesis)
- David Harrington & Jeff Kuhn *(CFHT survey incl. eps Aur)*

  Ubiquitous Hα-Polarized Line Profiles
- N. M. Elias II, R.Koch & R.Pfeiffer *(survey incl. eps Aur)*

  Polarimetric measures of selected variable stars
- Sloane Wiktorowicz & Keith Matthews *(Palomar 5 meter)*

  A High-Precision Optical Polarimeter to Measure Inclinations of High-Mass X-Ray Binaries

& Possibles: N.Manset, CFHT spectro-polarimeter

G.Cole; B.McCandless: instruments planned

K.Bjorkmann et al: HPOL redux

What is Polarimetry?

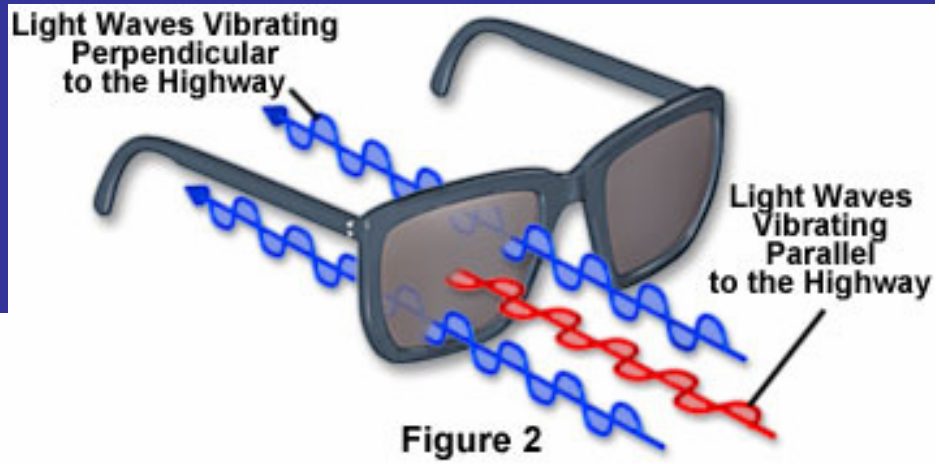
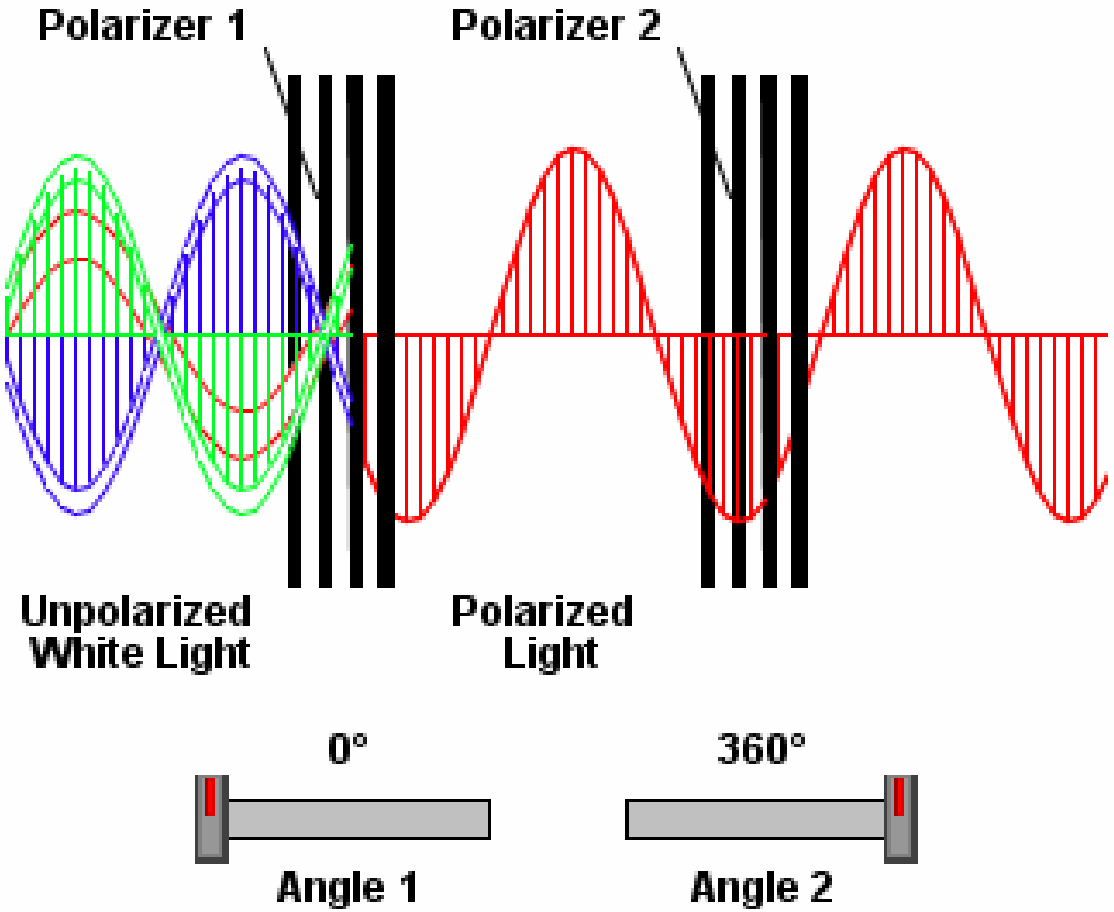


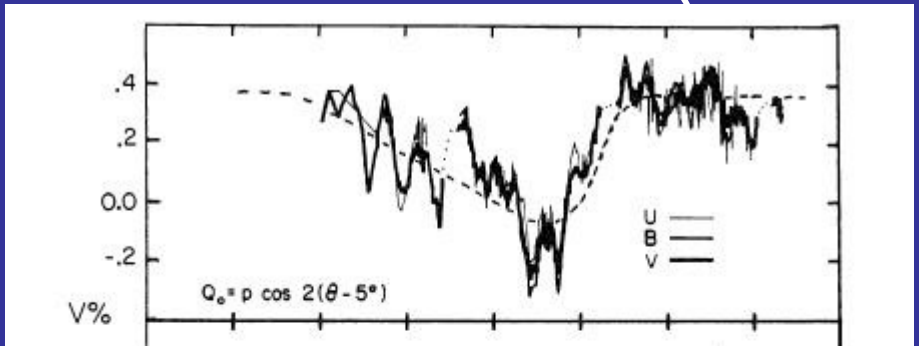
Figure 2



Crossed polarizers

http://micro.magnet.fsu.edu/primer/java/scienceopticsu/polarizedlight/filters/index.html

“Recent” (i.e. the only) results



Kemp, 1986

Polarimetry can reveal source GEOMETRY

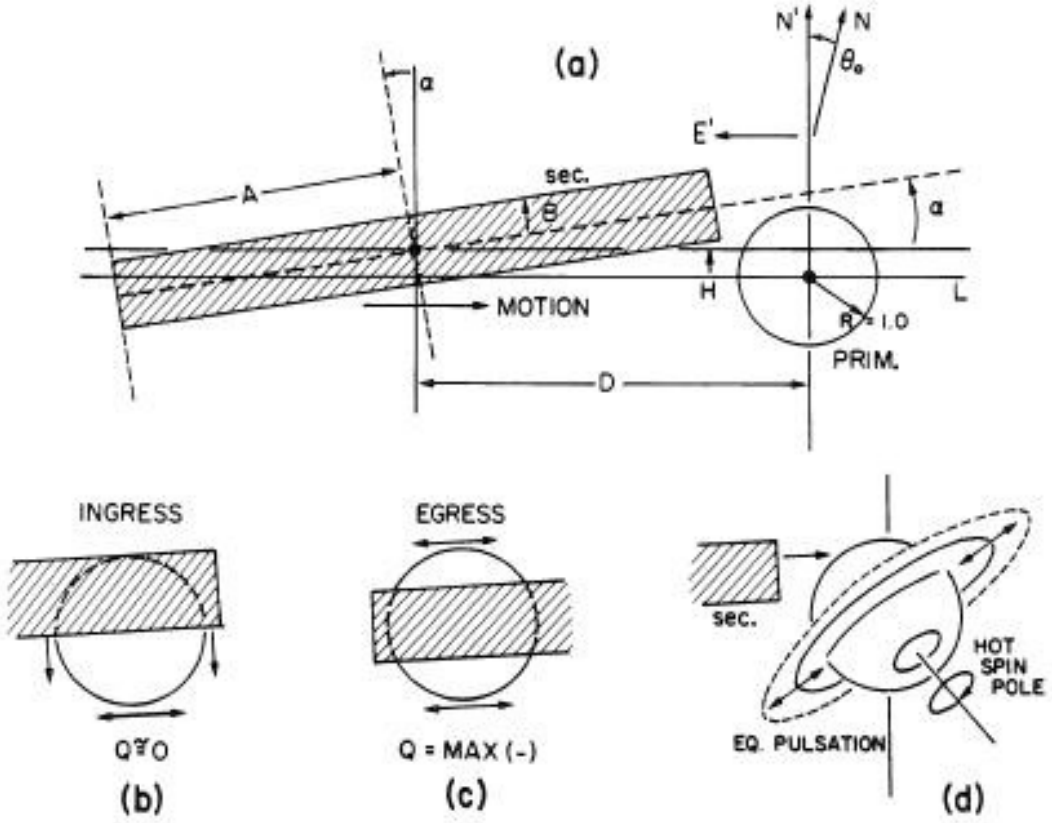


FIG. 2.—Model geometry of the eclipse, showing in Fig. 2*a* the model parameters. In Fig. 2*d* is a hypothetical geometry for future modeling involving a tilted, rotating primary star with nonspherical pulsations possibly correlated with the spin axis. J.Kemp et al. 1986 Astrophys.J. 300,L11.

What to expect during eclipse?

Spectropolarimetric Surveys: HAeBe, Be and Other Emission-Line Stars
Harrington, D. & Kuhn, J. 2009 ApJS ***180*** *138-181*

Nadine Manset has proposed CFHT monitoring 2009…

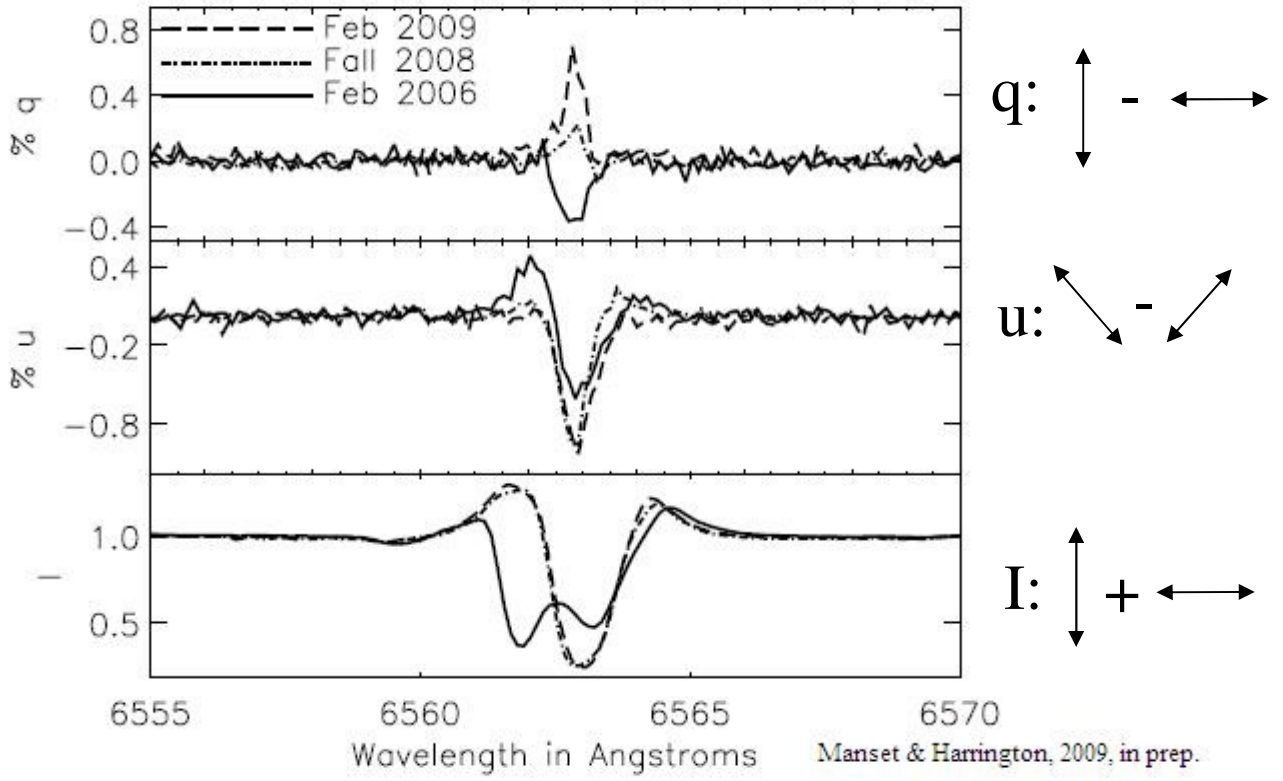


Figure 3: ESPaDOnS observations of Eps Aur that show the QUI variability between 2006 and 2009 in Hα. Polarization at a level of 0.5-1.0 % is clearly detected. Between 2006 and 2008, the intensity line profile has significantly changed, and the Stokes Q profile has been inverted. Between late 2008 and early 2009, the polarization changed again. Not shown are small absorption features seen in Stokes I moving along the redward emission bump, and disappearing in Feb 2009.

Interferometry

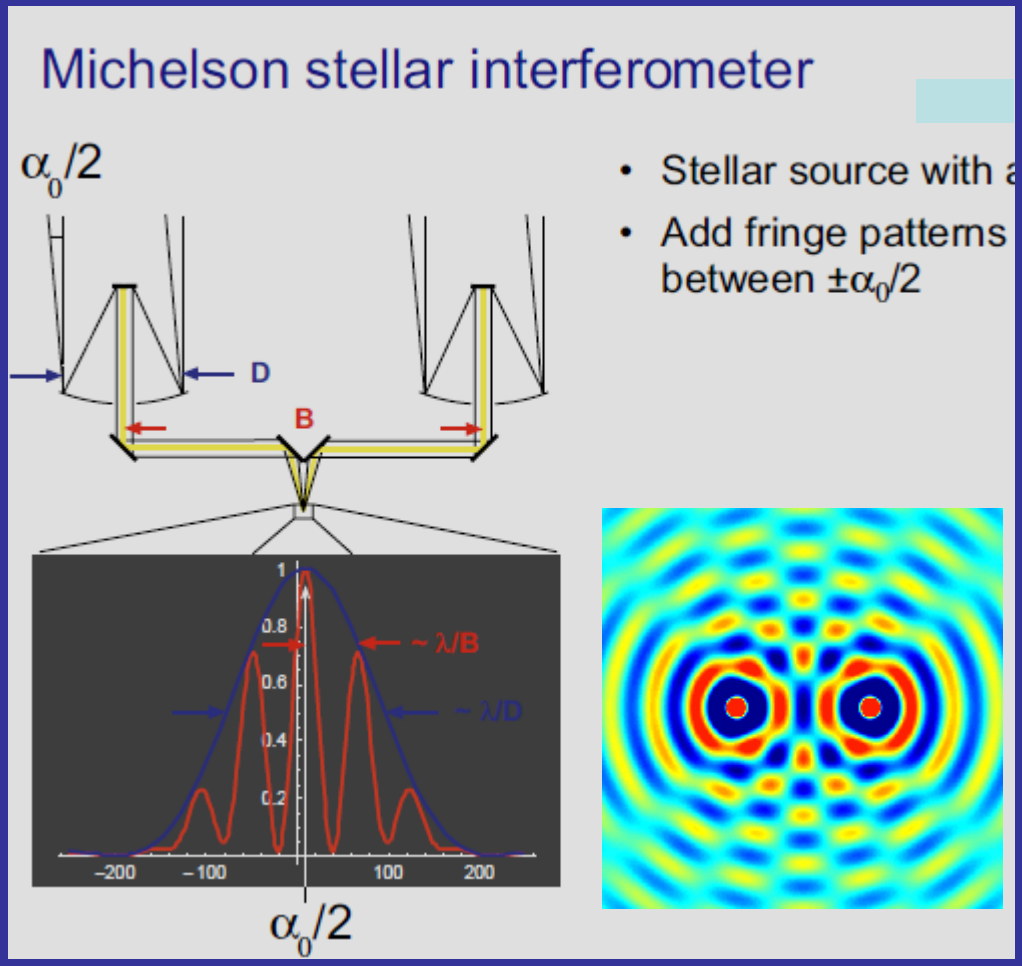
- Technique rapidly developing in the 21st century

- The only papers, so far:

  --Robert Stencel et al. 2009 Astrophys. Journal *Interferometric Studies of the Extreme Binary epsilon Aurigae: Pre-Eclipse Observations*

  --Tyler Nordgren et al. 2001 Astronomical Journal *(survey) Comparison of Stellar Angular Diameters from the NPOI, the Mark III Optical Interferometer*

How does it work? By combining telescopes:



Each pair of telescopes produces an antenna pattern on the sky, perpendicular to the baseline, and resolves lambda / baseline.

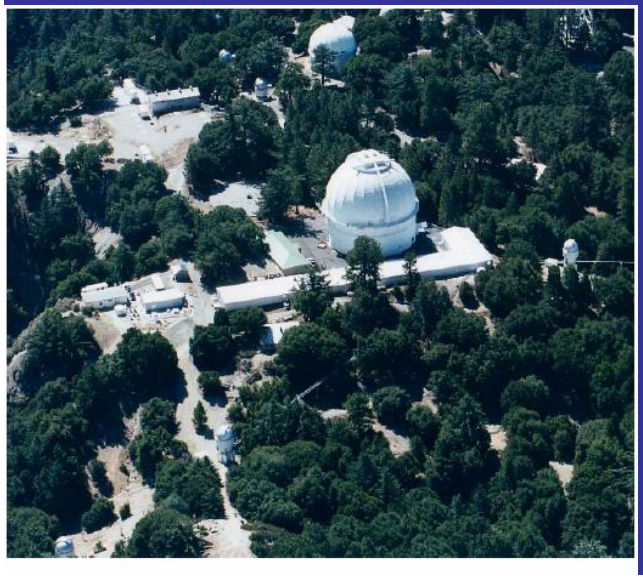
Baseline	Resolution*
1 meter	0.1 arcsec
10 m	0.01”
100 m	0.001”
	=1 milli-arcsec

**at 550 nm (V band)*

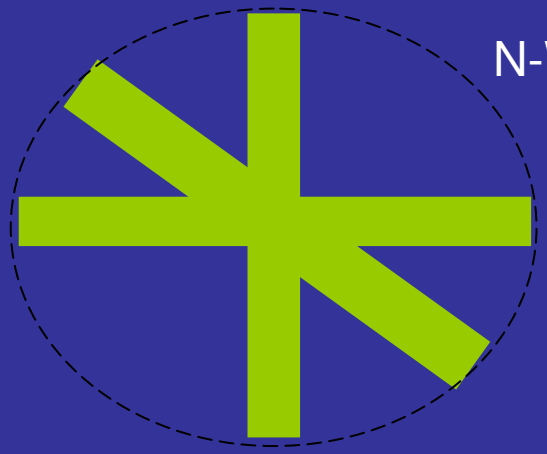
Recent results

Interferometric snapshots of epsilon Aur using PTI (1997- 2008) & CHARA (2008-)

Aerial View of PTI and the 200" Palomar Telescope
(Gerald van Belle)



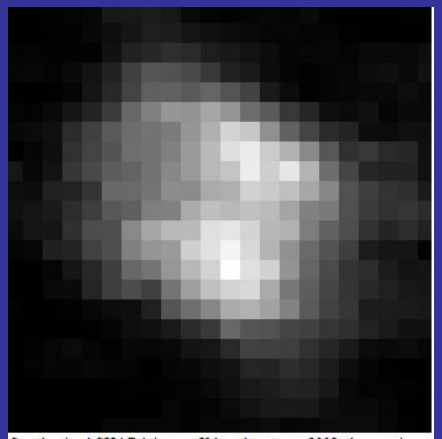
N-S baselines, 2.2 mas



N-W baselines, 2.5 mas

E-W baselines, 2.6 mas

Preliminary result:
model-dependent
image synthesis,
< CHARA Nov'08 data
(first look)
Revisits planned

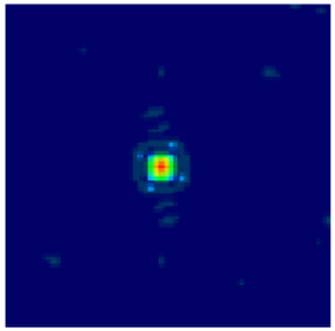


Synthesized CHARA image, K band, autumn 2008 observation
epsilon Aurigae.

What to expect during eclipse?

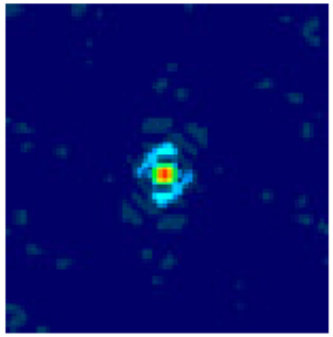
Image space →
Scale is
Milli-arcsec
(nano-radians)

Image 1, July 2009



2D FFT 1

Image 2, Oct.2009



2D FFT 2

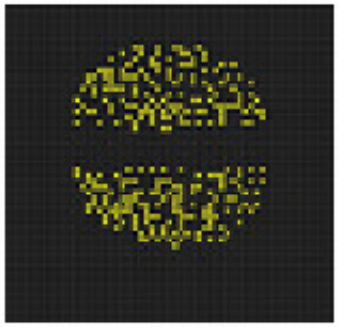
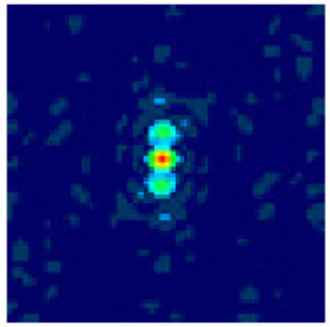


Image 3, 2010



2D FFT

← Interferometric
view with fringes

Direct test of the
Huang disk model

A worthy task
for modern
interferometers
like CHARA,
NPOI, (MROI)

Theory

- Some key papers:

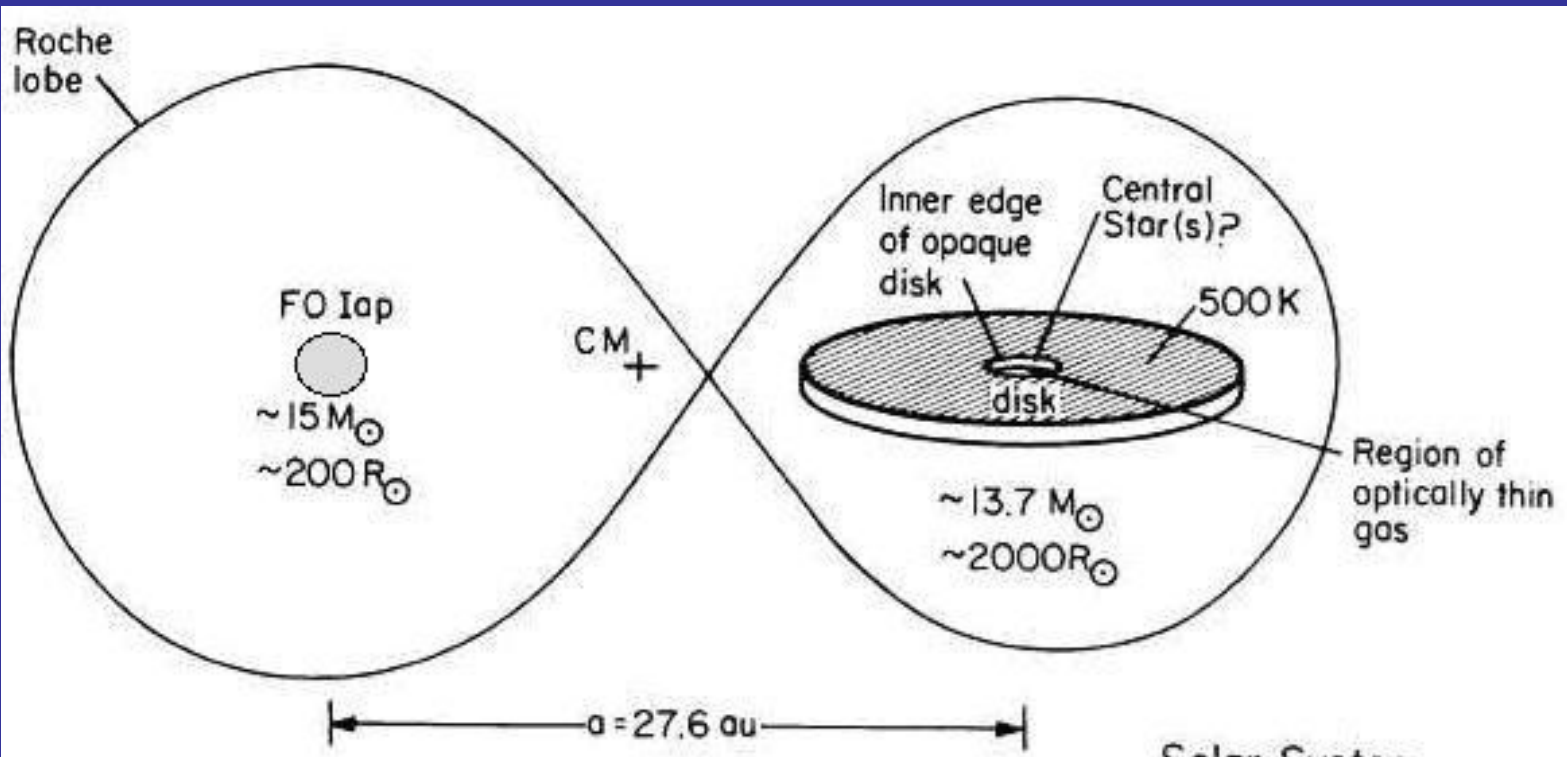
Gerard Kuiper, Otto Struve, Bengt Strömgren 1937
Astrophys Journal - *The Interpretation of epsilon Aurigae*

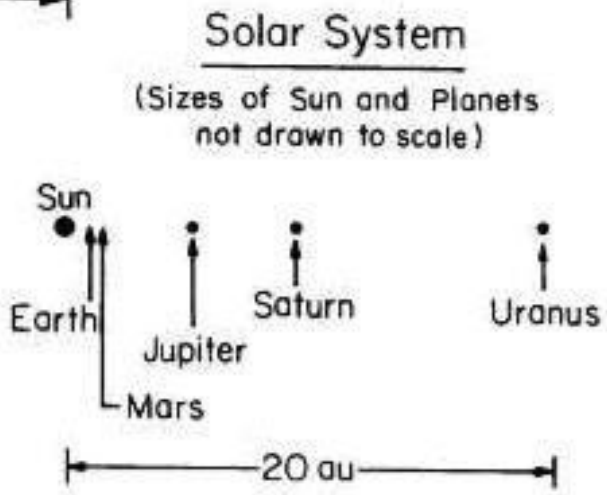
Huang, Su-Shu 1965 Astrophys. Journal
An Interpretation of epsilon Aurigae

Eggleton, P. P.; Pringle, J. E.1985 Astrophys. Journal
Possible evolution of a triple system into epsilon Aurigae

Ron Webbink, 1985 NASA Conf. Proc. 2384
Binary Evolutionary scenarios for epsilon Aurigae

Sean Carroll, et al. 1991 Astrophys. Journal
Interpreting epsilon Aurigae





Standard model
Carroll et al. 1991

Evolutionary status of ε Aur?

- Ron Webbink, 1985 NASA Conf.Publ.2384
  - Massive post-main sequence star in shell He burning state, OR,
  - Lower mass post-AGB star contracting toward white dwarf star, having transferred mass to companion, OR,
  - Triple system: F star plus binary embedded in disk…

IN SUMMARY - some testable predictions:

#1: will spectroscopy indicate CHANGES since 1983?

#2: will 2010 mid-eclipse brightening recur as in 1983?

#3: will interferometry reveal the disk silhouette?

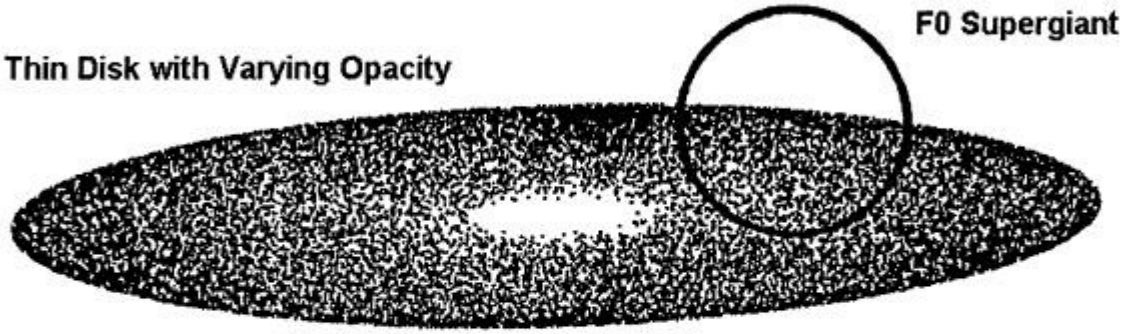
Some additional questions:

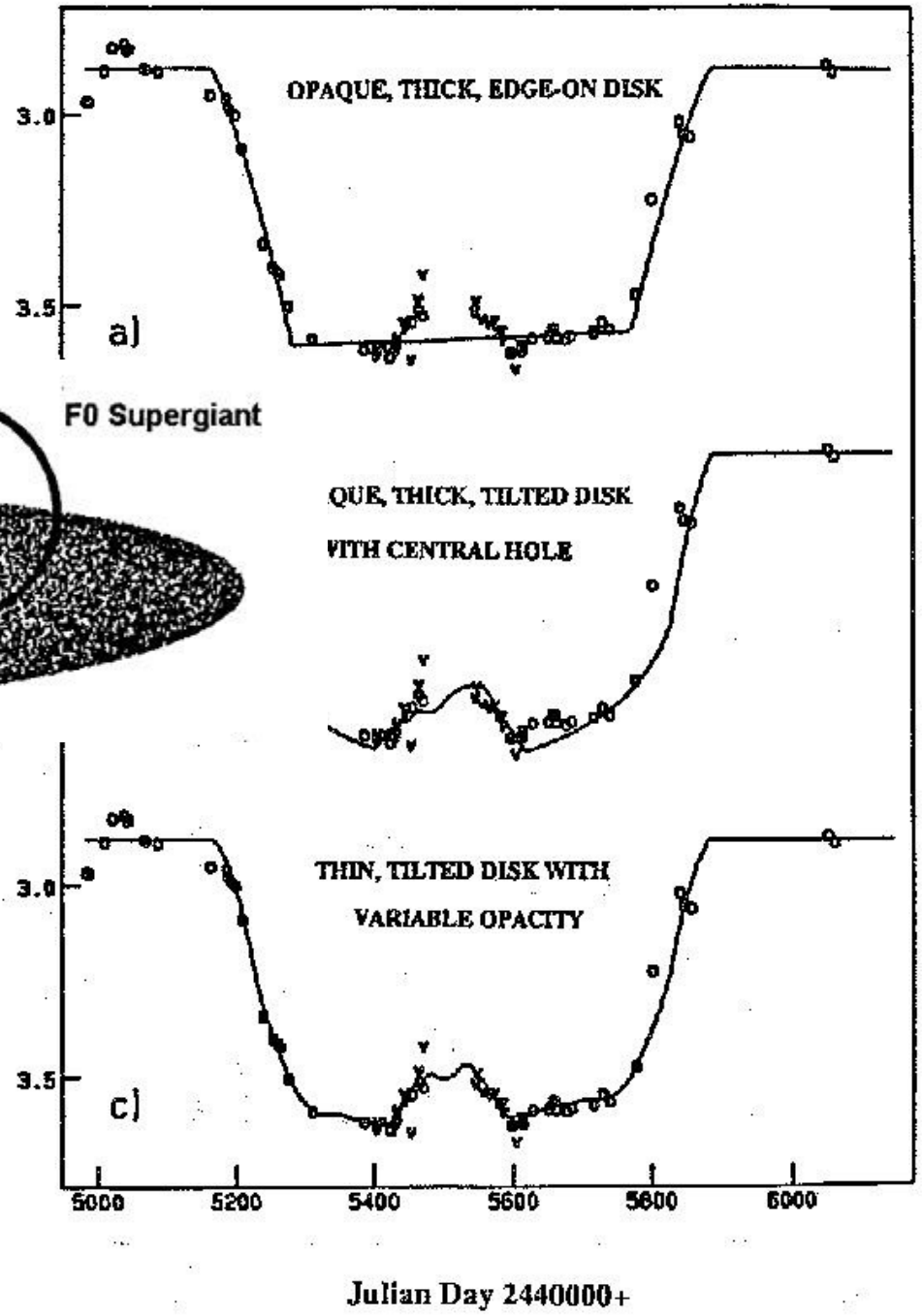
Why is transient emission present during first and third contacts?

Why is the nebular sodium 1000X solar abundance (Castelli ’78)?

etc.

Mid eclipse brightening, summer 2010 of course, requires central clearing
But why don't we see the interior beasties?

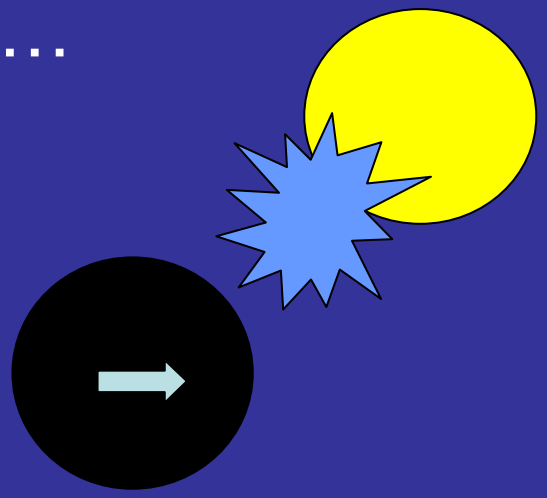


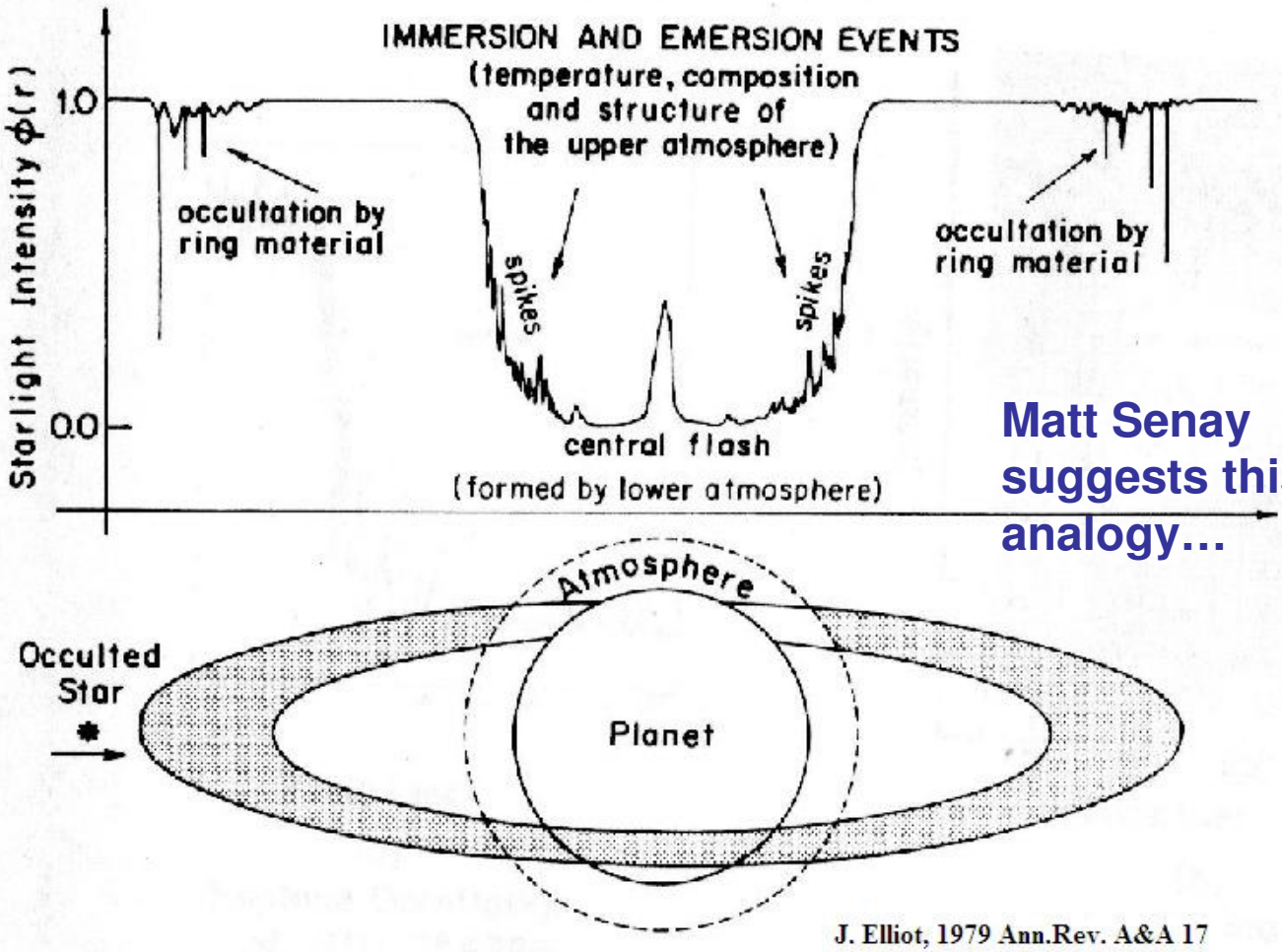


Guinan & Carroll, 1990/91

Ingress phase flaring?

- 1928 Autumn - H-beta core emission seen
  (1930 Struve & Elvey)
- 0.4 mag blue light flare, Nha 1983 IBVS
- UV ‘flares’ - ingress and egress (Ake 1985)
- 2009 April - helium line emission reported
  (McCandless, 6678A, recombination singlet)
- ? 50,000K source? atypical of F supergiant stars
  mass transfer or sub-disk point longitudinal flaring?
- Likely to recur during this ingress…





Matt Senay suggests this analogy…

J. Elliot, 1979 Ann.Rev. A&A 17

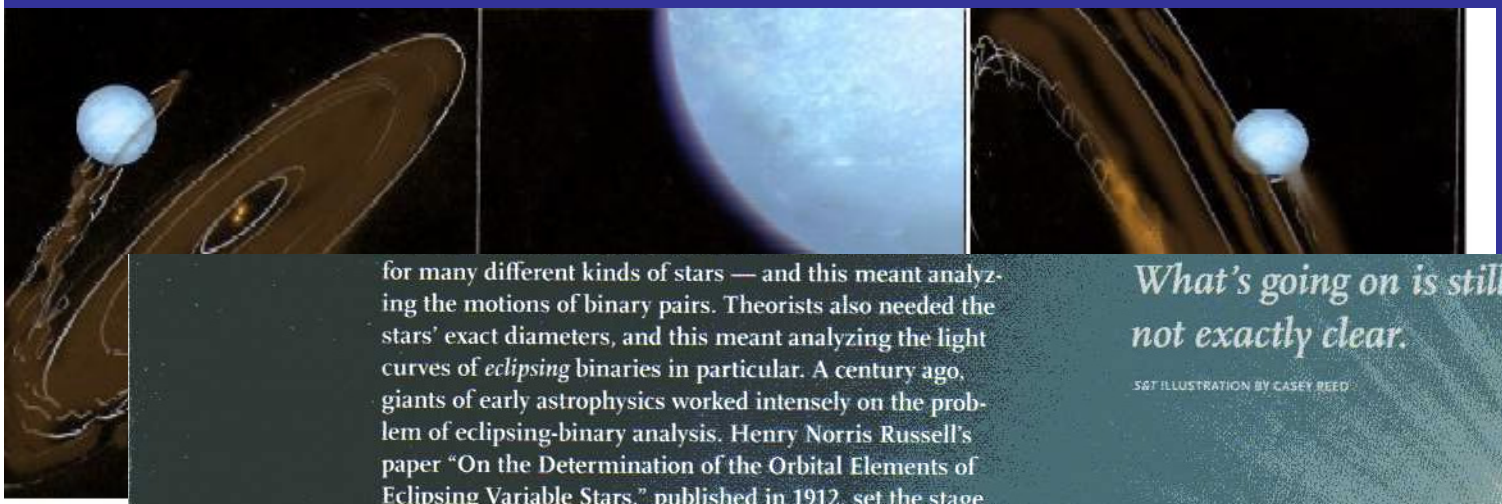
Figure 1 Schematic light curve for a central occultation by a ringed planet. The upper portion of the figure shows the light intensity of the star that would be observed from Earth as a function of the position of the star behind the planet. The first attenuation of starlight is due to the extinction by the ring material. The occultation of the star by the atmosphere occurs through the process of differential refraction (see Figure 2), with irregular variations (spikes) caused by atmospheric structure that deviates from being isothermal. The central flash is observed when the star is directly behind the center of the planet and can yield information about the extinction of the lower atmosphere.

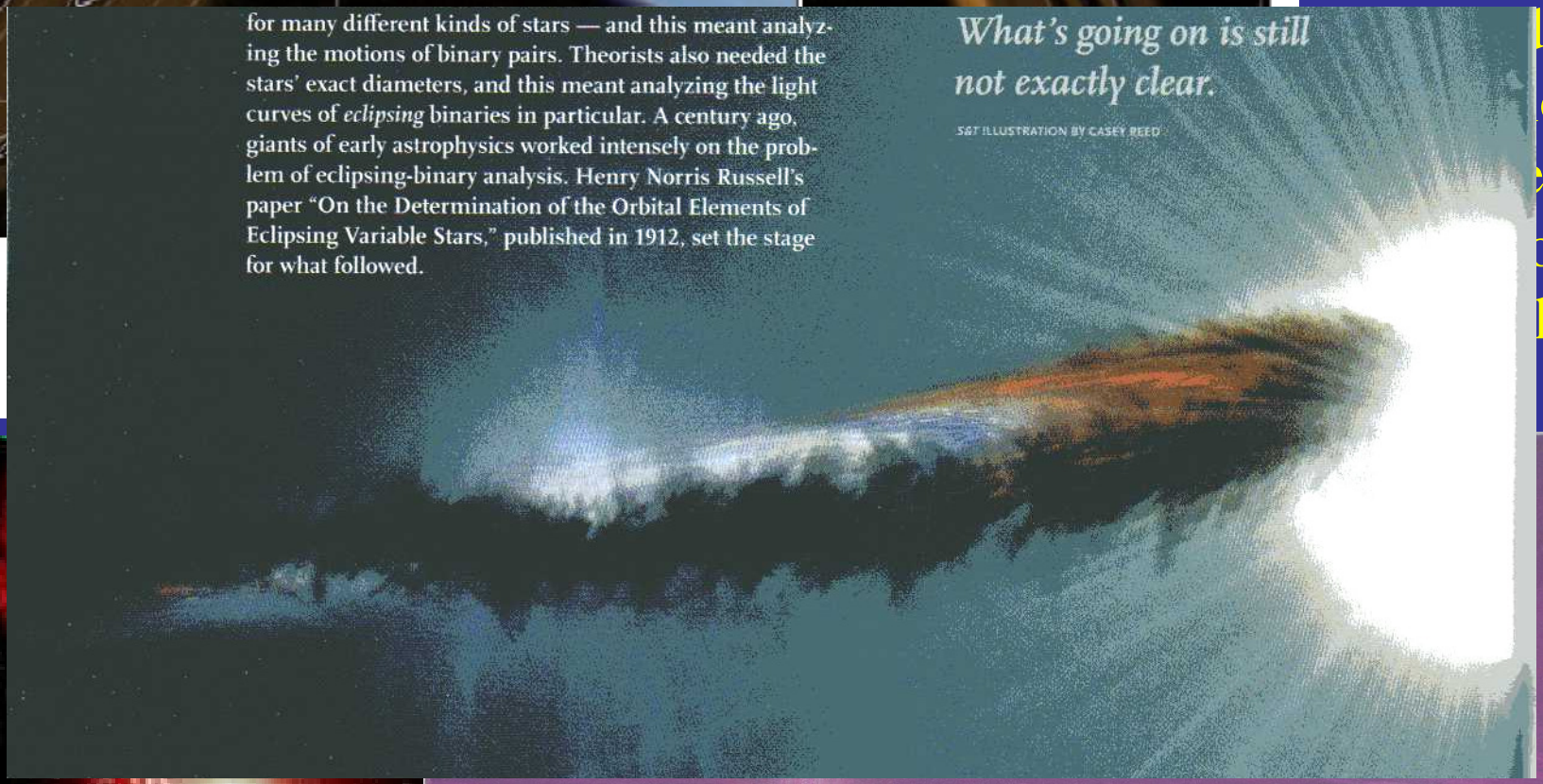
High quality observations needed

- Photometry – especially during summer seasons
- Spectroscopy –
  - Ca K, the Balmer lines, Na D, He I, K I, O I (7774)
- Polarimetry – observers/instruments still needed!
- Interferometry – in the queue at CHARA, NPOI
- Cadence? Things change on fortnightly timescale,
  - or faster…

- All reasonable reports will be printed in the Campaign Newsletters & compiled by AAVSO:
  http://www.hposoft.com/Campaign09.html
  & co-authorship on science papers is a strong possibility

Art imitates life…

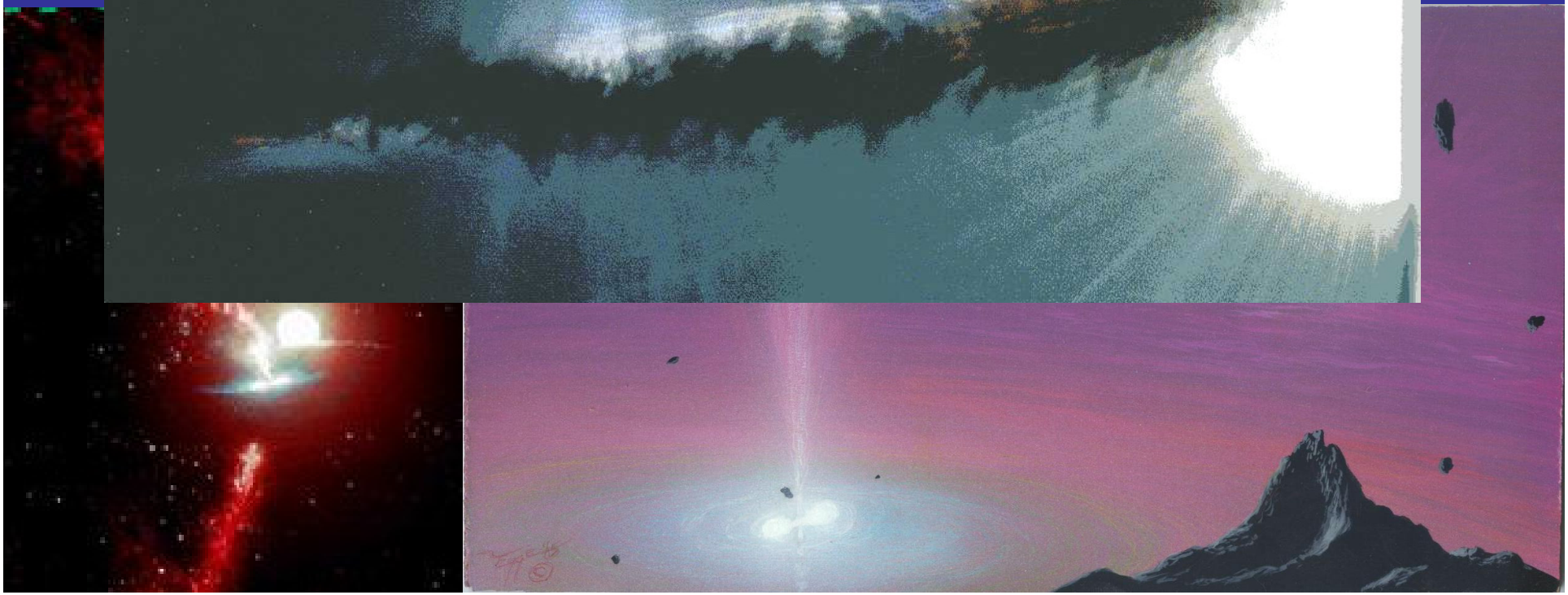




for many different kinds of stars — and this meant analyzing the motions of binary pairs. Theorists also needed the stars' exact diameters, and this meant analyzing the light curves of *eclipsing* binaries in particular. A century ago, giants of early astrophysics worked intensely on the problem of eclipsing-binary analysis. Henry Norris Russell's paper "On the Determination of the Orbital Elements of Eclipsing Variable Stars," published in 1912, set the stage for what followed.

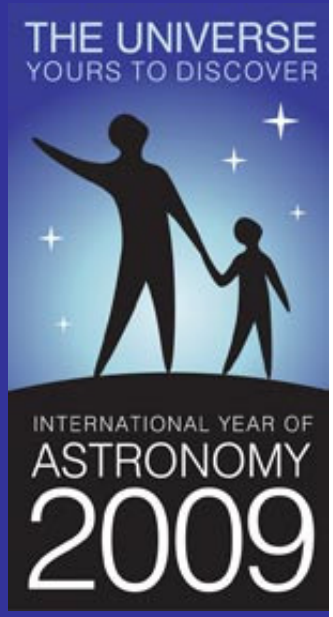
What's going on is still not exactly clear.

S&T ILLUSTRATION BY CASEY REED



Thank you for listening!

- Eclipse schedule:
  - Aug. 2009, partial phase begins
  - Dec. 2009, enters totality
  - Summer 2010, mid-eclipse brightening?
  - Mar. 2011, totality ends?
  - May 2011, partial phase ends?
  - “Lagging indicators” may persist ‘til 2012+
- **Your help needed**
- **Any questions?**
- **www.*twitter.com/epsilon_Aurigae***

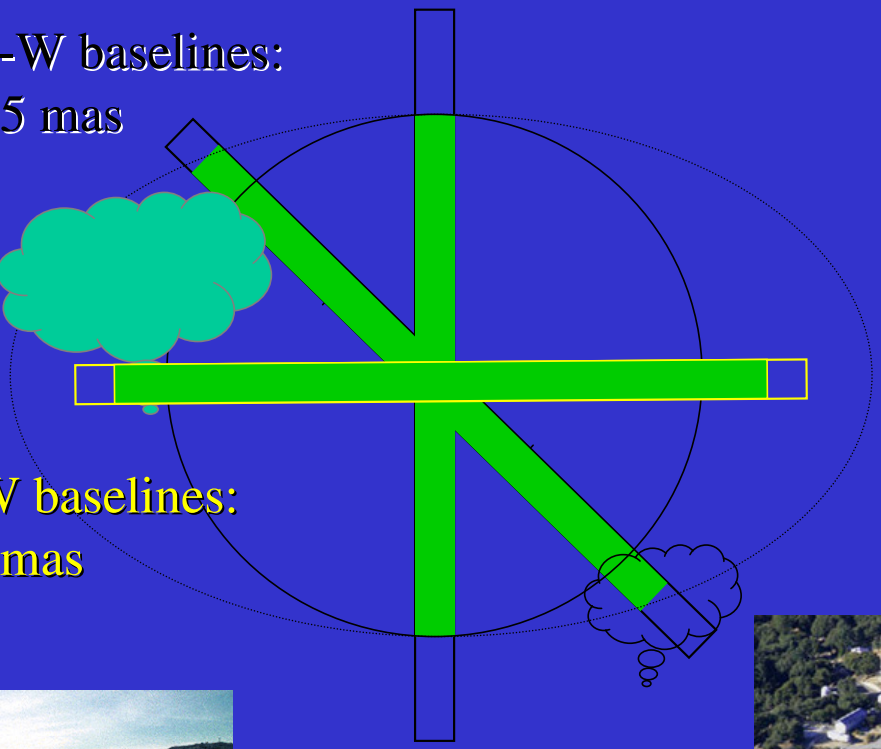


CHARA – recent imaging interferometry: Nov&Dec'08

Interferometric snapshots of epsilon Aurigae, 2008: PTI, CHARA

N-S baselines: 2.2 mas

N-W baselines:
2.5 mas



E-W baselines:
2.6 mas