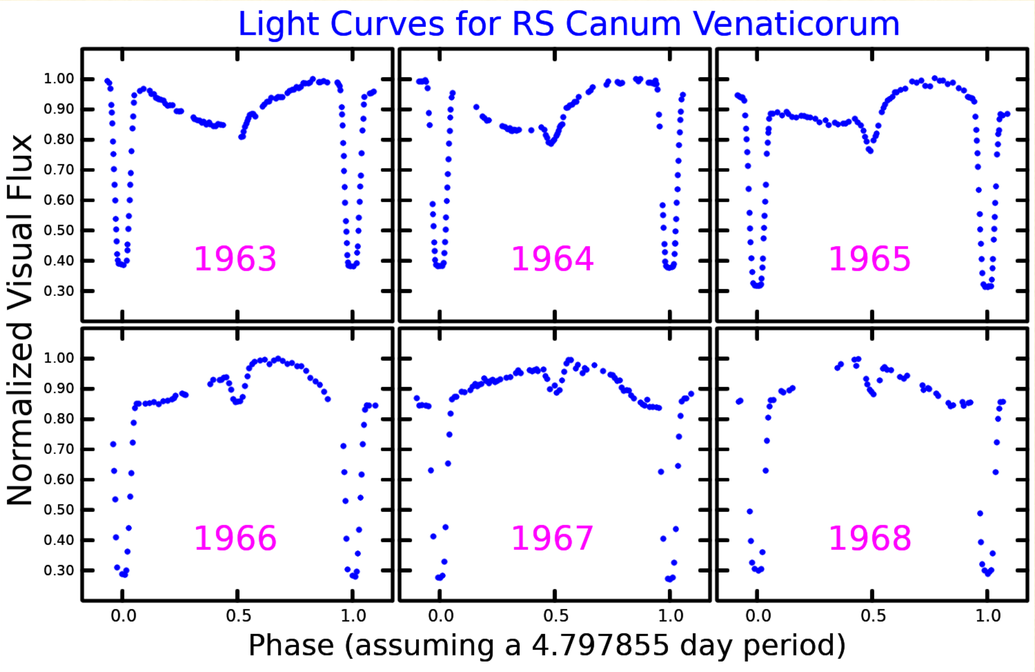
CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

TIME-LAPSE VERY LONG BASELINE INTERFEROMETRY IMAGING OF THE CLOSE ACTIVE BINARY HR 1099

Walter W. Golay (CfA & formerly U of Iowa),
Robert L. Mutel (U of Iowa), & Evan E. Abbuhl (U of Iowa)

GETTING ACQUAINTED WITH HR 1099



Rodonò+95

- "Chromospherically active binary" = at least one late-type star w/ enhanced magnetic activity
- RS CVn: extremely active, characterized by cool spots in the photosphere, little or no evidence for mass transfer
- Emission across the spectrum (notably X-ray and radio)
- Zeeman Doppler Imaging target reveals 10 G mean B-field on secondary and large photospheric spots on the primary

0.86 mas binary separation

Table 1
Fixed Parameters

Parameter	Symbol	Value	Uncertainty[a]	References
Spectral type	…	K1 IV + G5 IV–V[b]	…	(1)
Primary radius	r_1	3.74 $R_\odot$ (0.59 mas)	0.08 $R_\odot$ (0.01 mas)	(2)
Secondary radius	r_2	1.14 $R_\odot$ (0.18 mas)	0.08 $R_\odot$ (0.01 mas)	(2)
Primary mass	$m_1 \sin^3 i$	0.2256 $M_\odot$	0.0016 $M_\odot$	(3)
Secondary mass	$m_2 \sin^3 i$	0.1752 $M_\odot$	0.0011 $M_\odot$	(3)
Primary semimajor axis	$a_1 \sin i$	1.8915×10^6 km (0.0126 au)	0.0050×10^6 km	(3)
Secondary semimajor axis	$a_2 \sin i$	2.4335×10^6 km (0.0163 au)	0.0078×10^6 km	(3)
Eccentricity	e	0.0	…	(3)
Reference epoch[c]	$T_{\rm ephem}$	HJD − 2457729.7084	0.0017	(3)
Orbital period	P	2.837711 days	0.000066 day	(3)
R.A. proper motion	$\mu_\alpha \cos\delta$	−32.2484 mas yr	0.036 mas yr^{-1}	(3)
decl. proper motion	μ_δ	−162.0732 mas yr^{-1}	0.032 mas yr^{-1}	(4)
Parallax	Π	33.9783 mas	0.0349 mas	(4)

2.837711 days

READ HERE

THE HISTORY OF HR 1099

StarGlass

Discoverer: F. G.W. Struve (1827) in Catalogus Novus Stellarum Duplicium et Multiplicium

NUMER. CATAL.	N O M E N.	MOTUS IN AR.	N. O.	MOTUS IN DECL.	N. O.	D E S C R I P T I O.
311	♯ Arietis	+ 5″,4	5	— 3″,1	5	I. et V. (4) (9) (9) H. I. 64.
327	Rangiferi 26 . . .					IV. (6) (11).
318	20 Persei	+ 2,4	5	— 2,5	5	III. (5) (10) H. III. 60.
320	Cephei 47 Hev. . .	— 5,9	1	— 1,8	2	II. (6) (9).
323	AR = 39° 55′ 2) .	— 7,3	1			I. (8) (8).
333	♯ Arietis	+ 0,5	5	+ 2,1	5	I. (7) (7).
346	52 Arietis	— 6,8	5	+ 0,2	4	III. (4) (10).
422	P. III. 98 = 51° 3′ 2)	+ 8,8	2	— 9,5	2	II. (6) (8) H. III. 45.
453	27Pleiad. Atlas . .	— 2,1	5	— 2,4	5	I. (5) (8).
452	30 Tauri	— 6,9	4	— 0,6	5	II. (4) (10) H. III. 66.
464	ζ Persei	+ 1,2	5	— 3,2	4	III. (3) (9).
470	32 Eridani . . .	+ 4,2	5	+ 0,6	5	II. (4) (6) H. II. 36.
471	♯ Persei	— 0,7	5	— 0,7	4	III. (3) (9) H. II. 22.

READ HERE

Catalog

THE ASTRONOMICAL JOURNAL, 122:3466–3471, 2001 December

THE 2001 US NAVAL OBSERVATORY DOUBLE STAR CD-ROM. I. THE WASHINGTON DOUBLE STAR CATALOG

BRIAN D. MASON, GARY L. WYCOFF, WILLIAM I. HARTKOPF, GEOFFREY G. DOUGLASS,[1] AND CHARLES E. WORLEY[2]
US Naval Observatory, 3450 Massachusetts Avenue, NW, Washington, DC 20392-5420; bdm@usno.navy.mil, glw@usno.navy.mil, wih@usno.navy.mil
Received 2001 July 6; accepted 2001 August 10

ABSTRACT

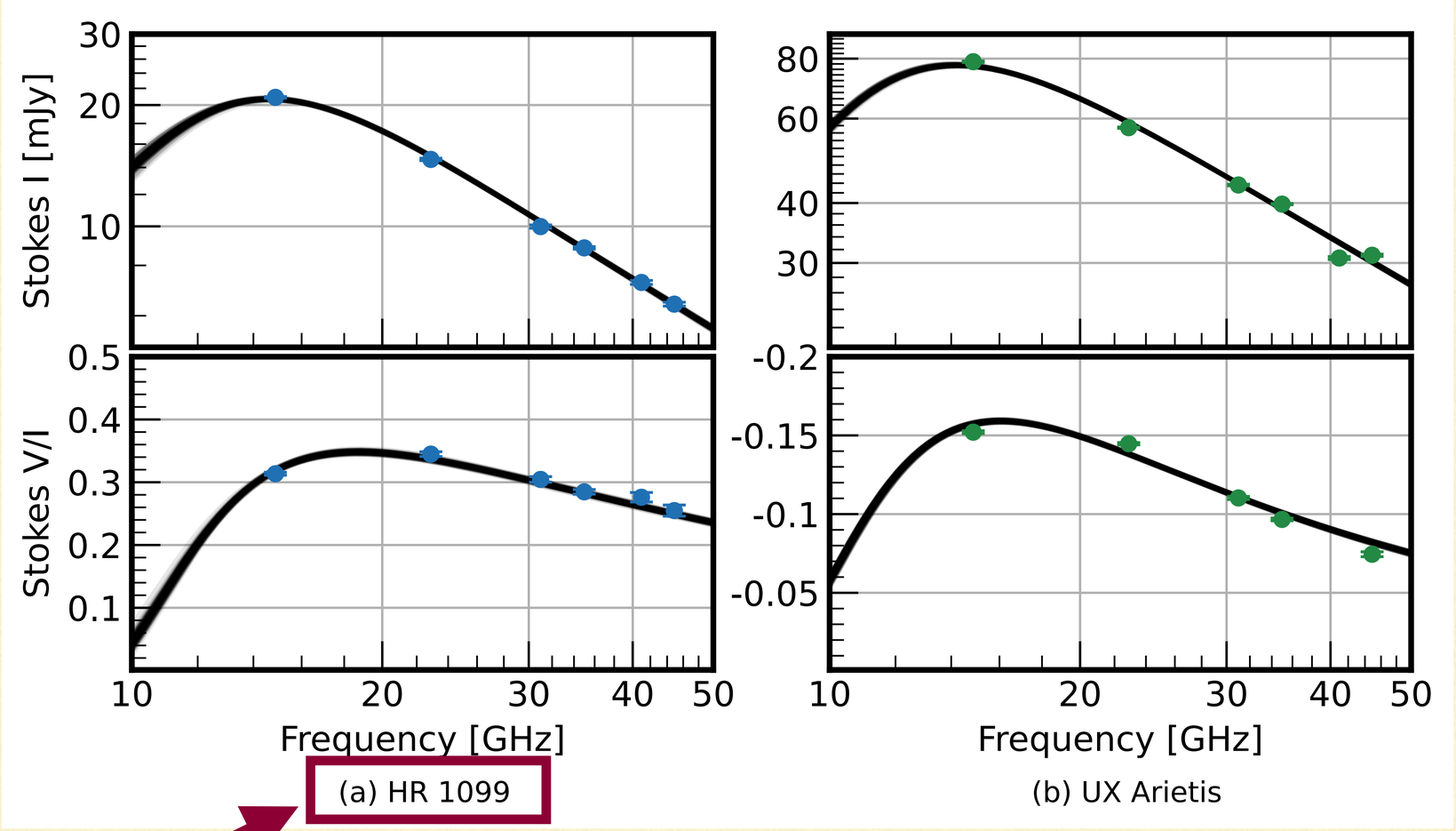
The Washington Double Star Catalog (WDS), maintained by the US Naval Observatory, is the world's principal database of astrometric double and multiple star information. The WDS contains positions (J2000), discoverer designations, epochs, position angles, separations, magnitudes, spectral types, proper motions, and, when available, Durchmusterung numbers and notes for the components of 84,486 systems based on 563,326 means. The current version, available on-line, is updated nightly. This catalog is one of four USNO double star catalogs to be included on a new CD-ROM. A brief summary and statistical analysis of the contents of the catalog are presented.

Key words: binaries: general — binaries: visual — catalogs

RADIO EMISSION FROM RS CVN SYSTEMS

- Radio emission from RS CVn binaries is non-thermal
- Low-frequency emission often present, well modeled by ECMI
- Modest (10-100 Gauss) magnetic fields filling ~R_{star}
- Gyro frequency means GHz emission is well-described by semi-relativistic cyclotron (called "gyro-synchrotron")

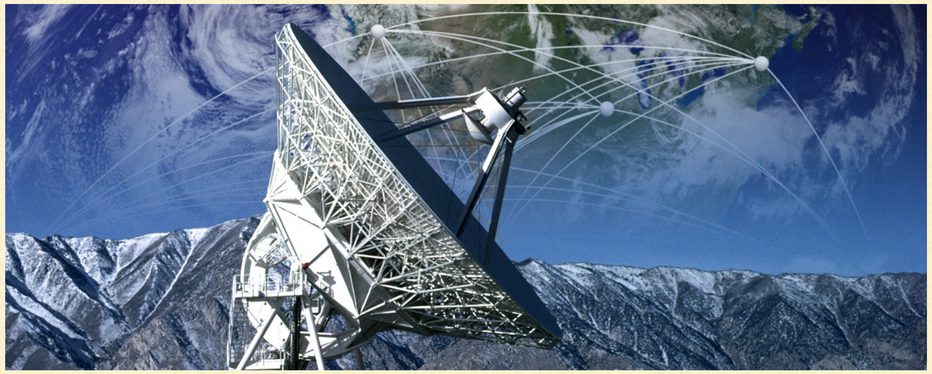
- Spectral energy distribution (SED) modeling of HR1099 uncovers:
  - 2.6 R_{sun} plasma volume
  - 240 +/- 50 Gauss B-field
- But where in the binary is the radio emission coming from?



Golay+23 (MNRAS):"A search for thermal gyro-synchrotron emission from hot stellar coronae"

READ HERE

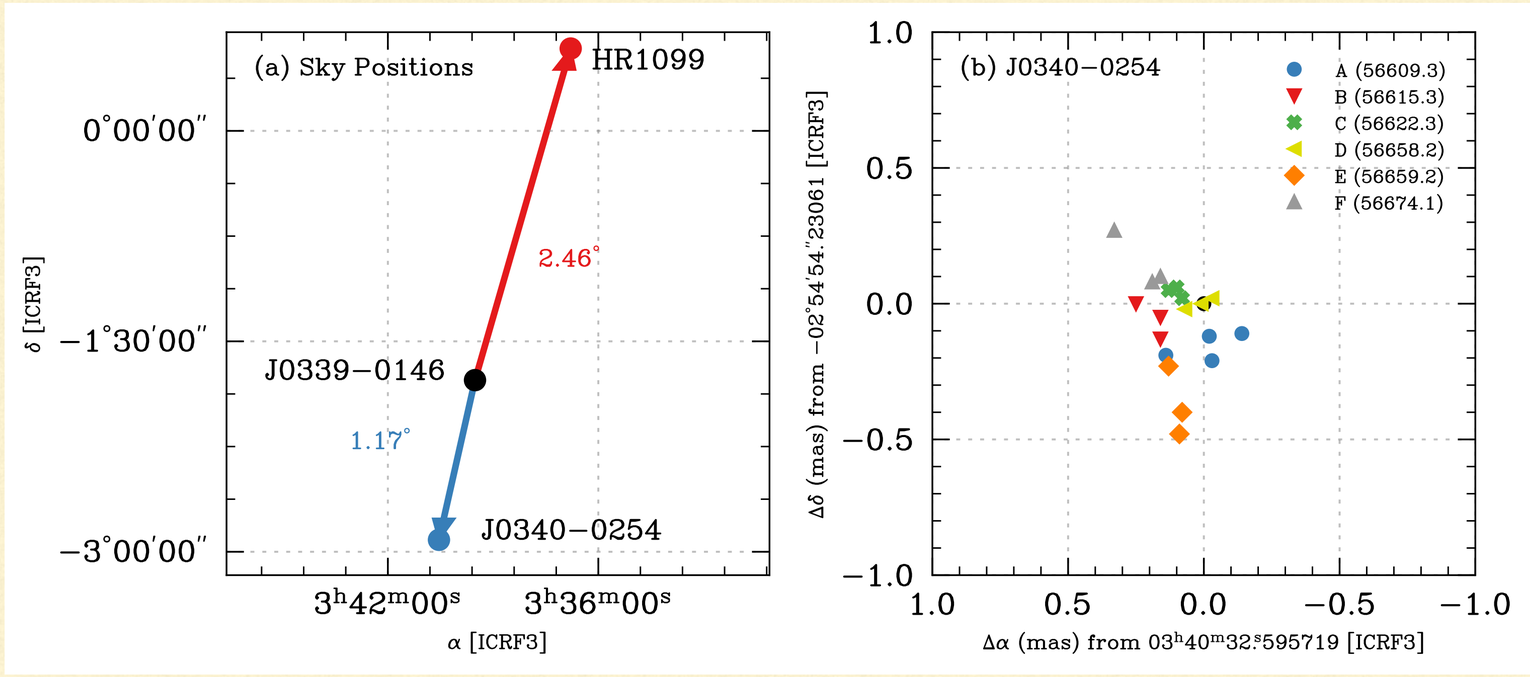
EXPERIMENTAL SETUP: ASTROMETRIC PHASE REFERENCING



- Collected Nov 2013 through Jan 2014 in 6 individual 10-hour epochs

- K-band (22.2 GHz) w/ polyphase filter bank
- Phase-referenced to primary calibrator CTA26 (J0339-0146) on 3-minute cycle

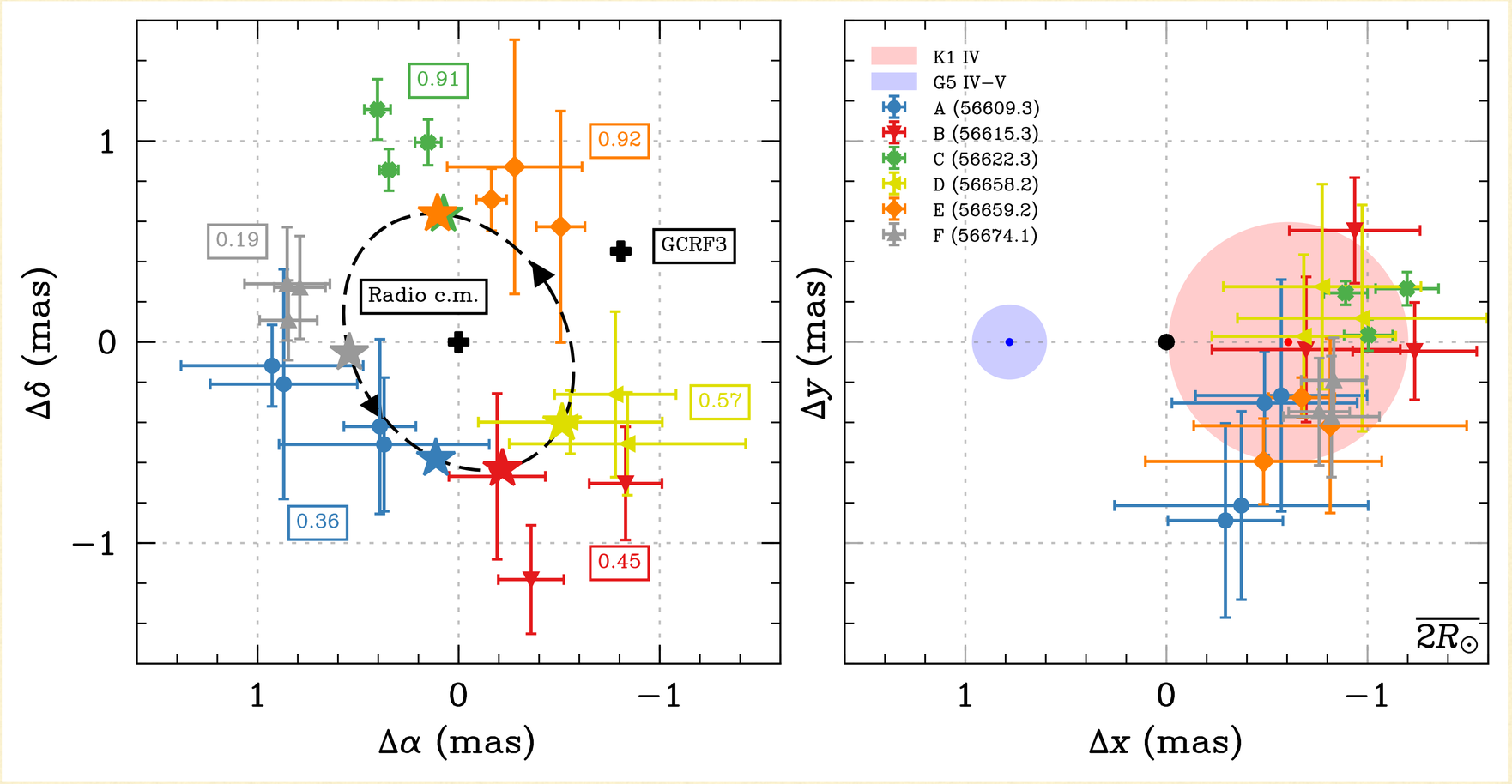
- Secondary calibrator J0340-0254 observed every ~15min to check stability



READ HERE

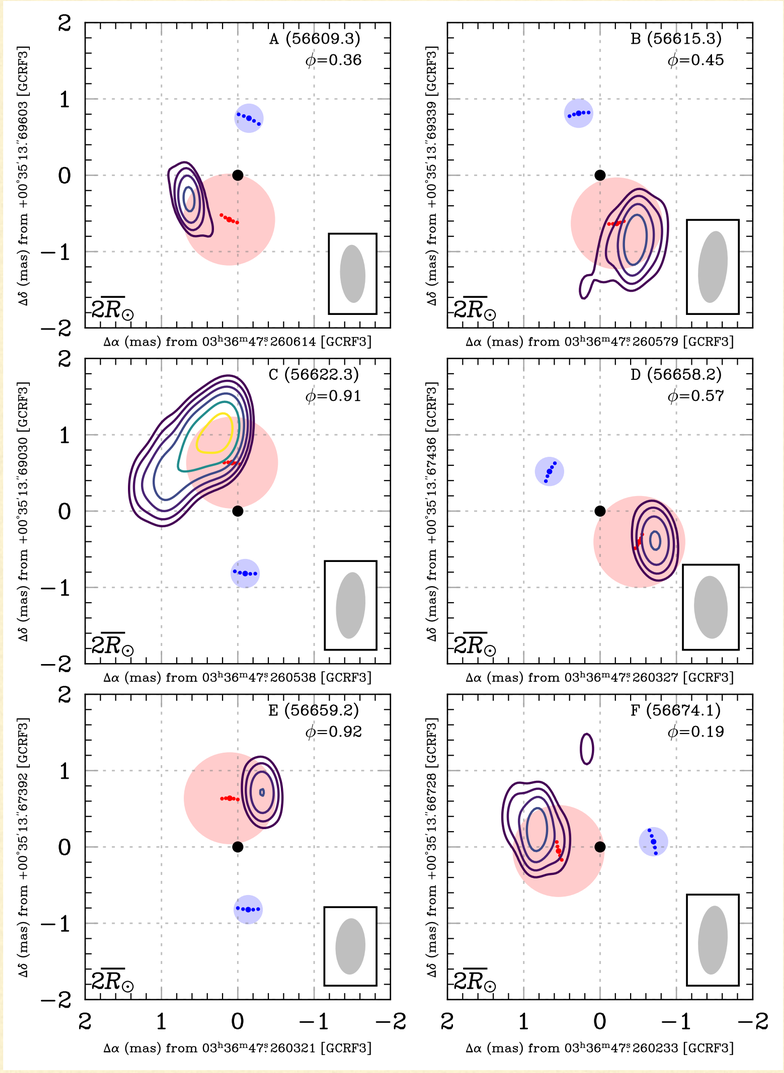
TRACKING THE ORBITAL MOTION

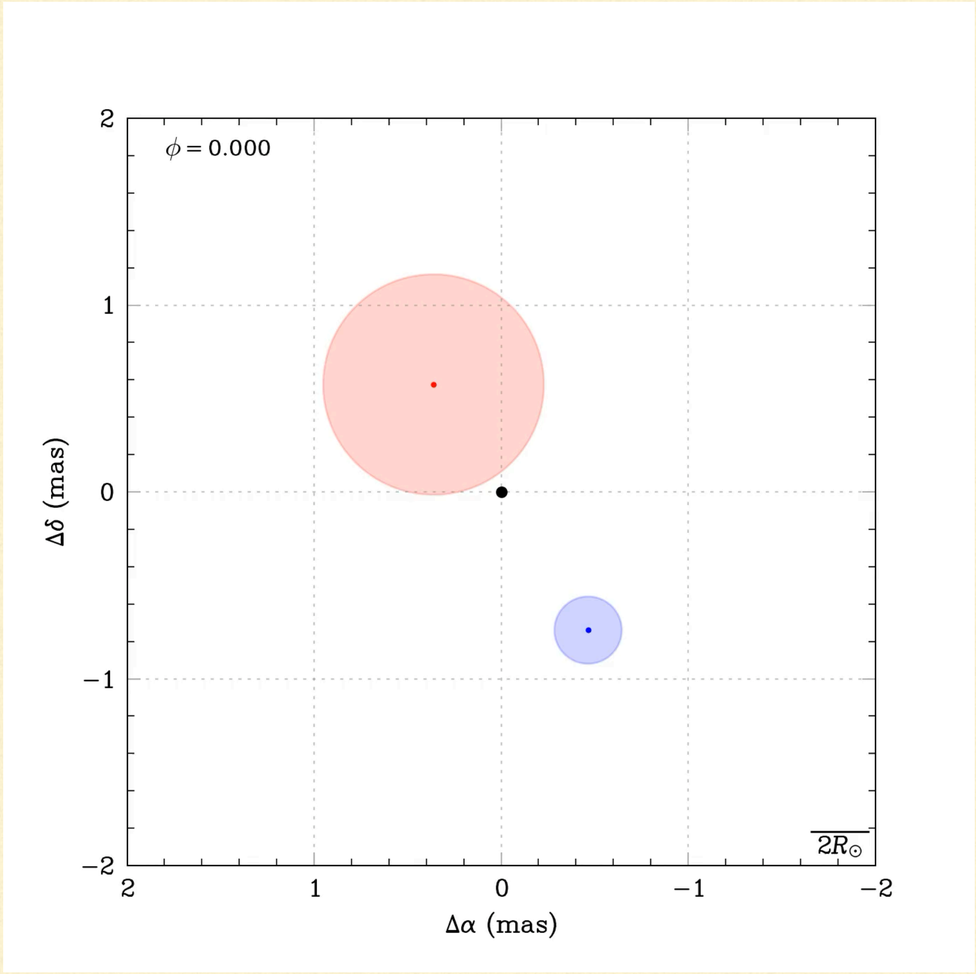
- "Phase wrap" has a whole new meaning here
- The radio positions over ~3 months are very well-fit by an ellipse on the sky
- This ellipse is **offset** from the Gaia DR3 position
- In the co-rotating frame, it is clear the radio emission is **not** in the inter-binary region
- Ask me which star (ZDI)



READ HERE

TIMELAPSE VLBI IMAGING

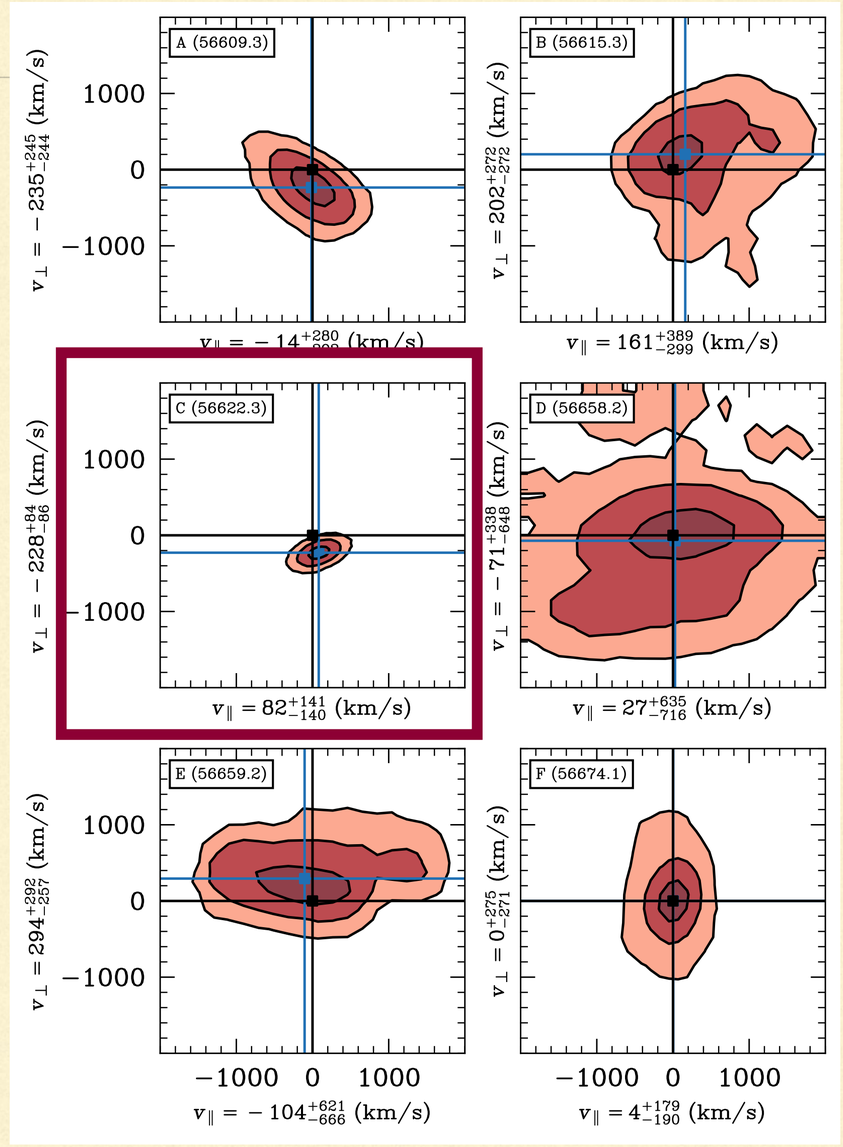




READ HERE

THE SEARCH FOR A CME

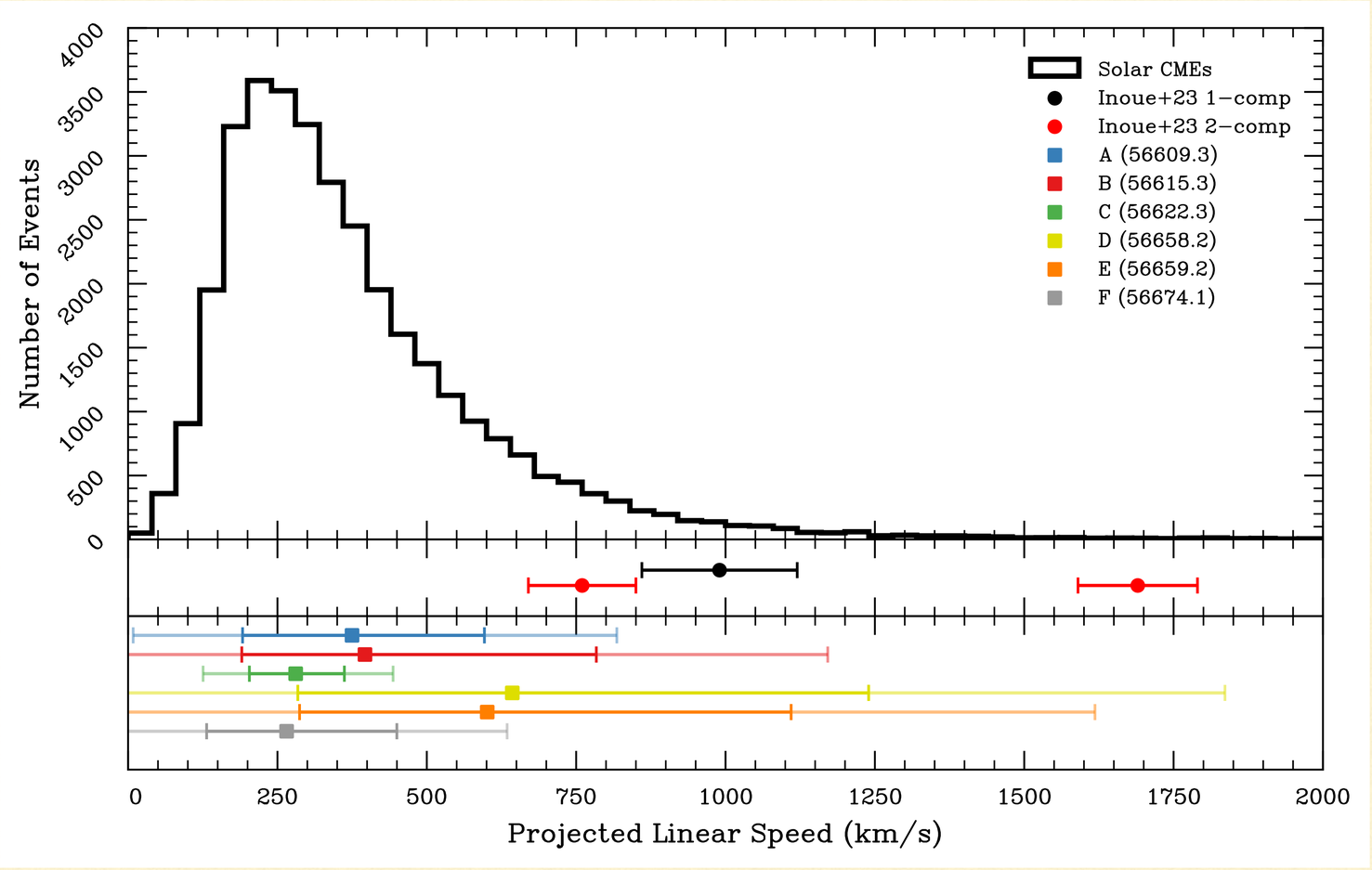
- We fit directly to visibilities, providing the signal-to-noise necessary to slice our observations into individual hours
- Custom visibility-fitting routine that uses multiple clean components (novel from existing AIPS & CASA routines)
- We place limits on the motion within each individual epoch by fitting a linear model
- But what about the flare?



READ HERE

COMPARISON TO THE SOLAR ANALOGUE

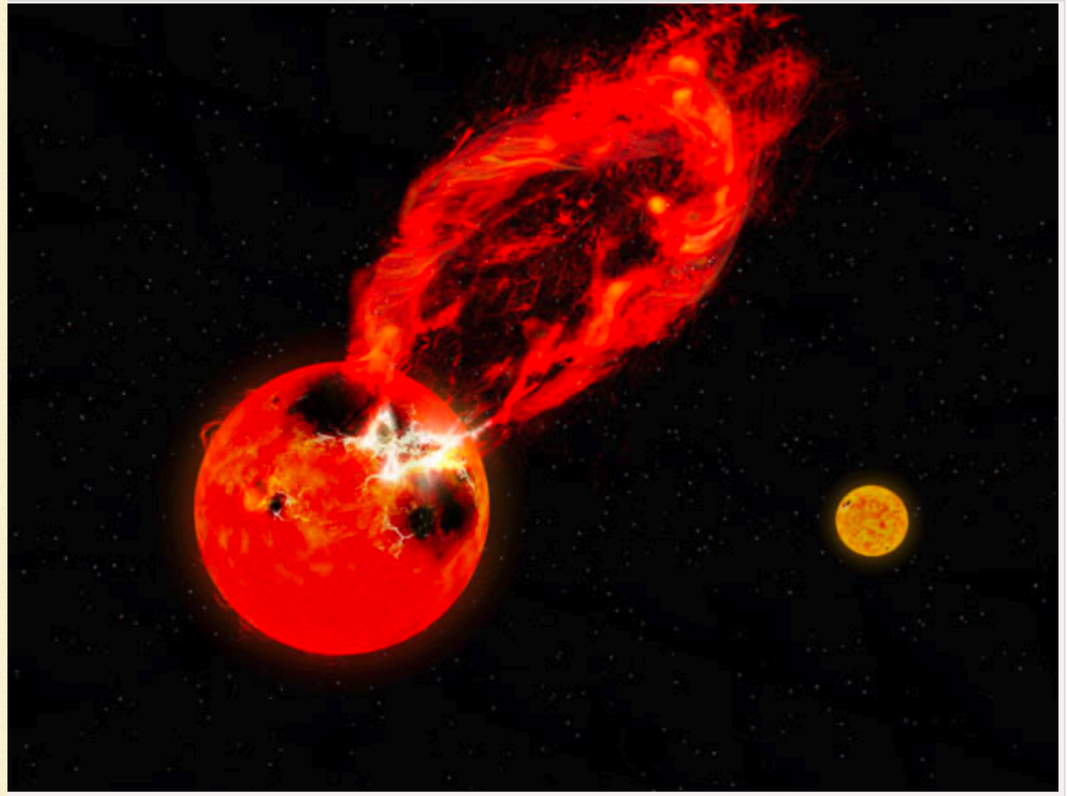
- Challenging to compare: the analogous emission mechanism on the Sun peaks in the MHz-regime
- Cm-wave Type IV radio bursts have been compared to white-light emission (see e.g. Bastian et al. 2001)
- Our tenuous detection of motion is comparable speeds to the median solar CME speed
- V1355 Ori (another RS CVn) with a recent H-alpha flare allowed Inoue+23 to infer much higher ejecta velocities
- TL;DR - stellar CMEs remain elusive



READ HERE

THE NEW PICTURE OF HR 1099

- We can define an orbit from the offset ellipse
- In all epochs, the GHz-emitting region is **NOT** in the inter-binary region
- The offset is a new (independent and unique) constraint on the frame transfer parameters between ICRF3 (radio) and GCRF3 (Gaia/optical)
- No intra-epoch motion, except for a very weak (3 sigma) motion signal during the flaring epoch
- We do not resolve two oppositely circularly polarized regions (unlike, e.g., Algol)



An artist's impression of the superflare from the main member of the V1355 Orionis binary system. Image credit: NAOJ.

READ HERE

THE ASTROPHYSICAL JOURNAL

OPEN ACCESS

Time-lapse Very Long Baseline Interferometry Imaging of the Close Active Binary HR 1099

Walter W. Golay[1,2], Robert L. Mutel[1], and Evan E. Abbuhl[1]

Published 2024 April 9

The Astrophysical Journal, Volume 965, Number 1

Citation Walter W. Golay *et al* 2024 *ApJ* **965** 86

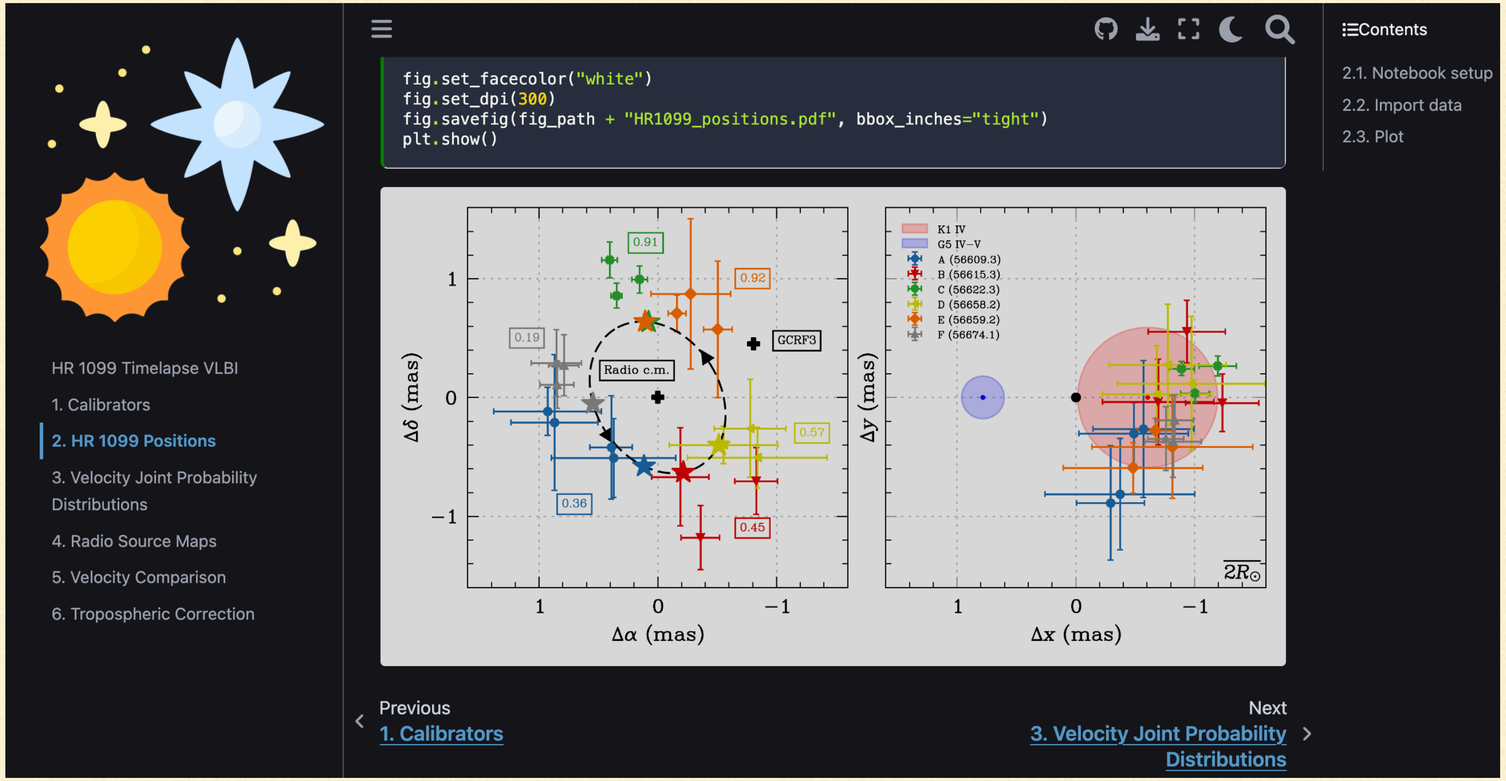
DOI 10.3847/1538-4357/ad29fb

Article PDF Article ePub

Figures Tables References Article data

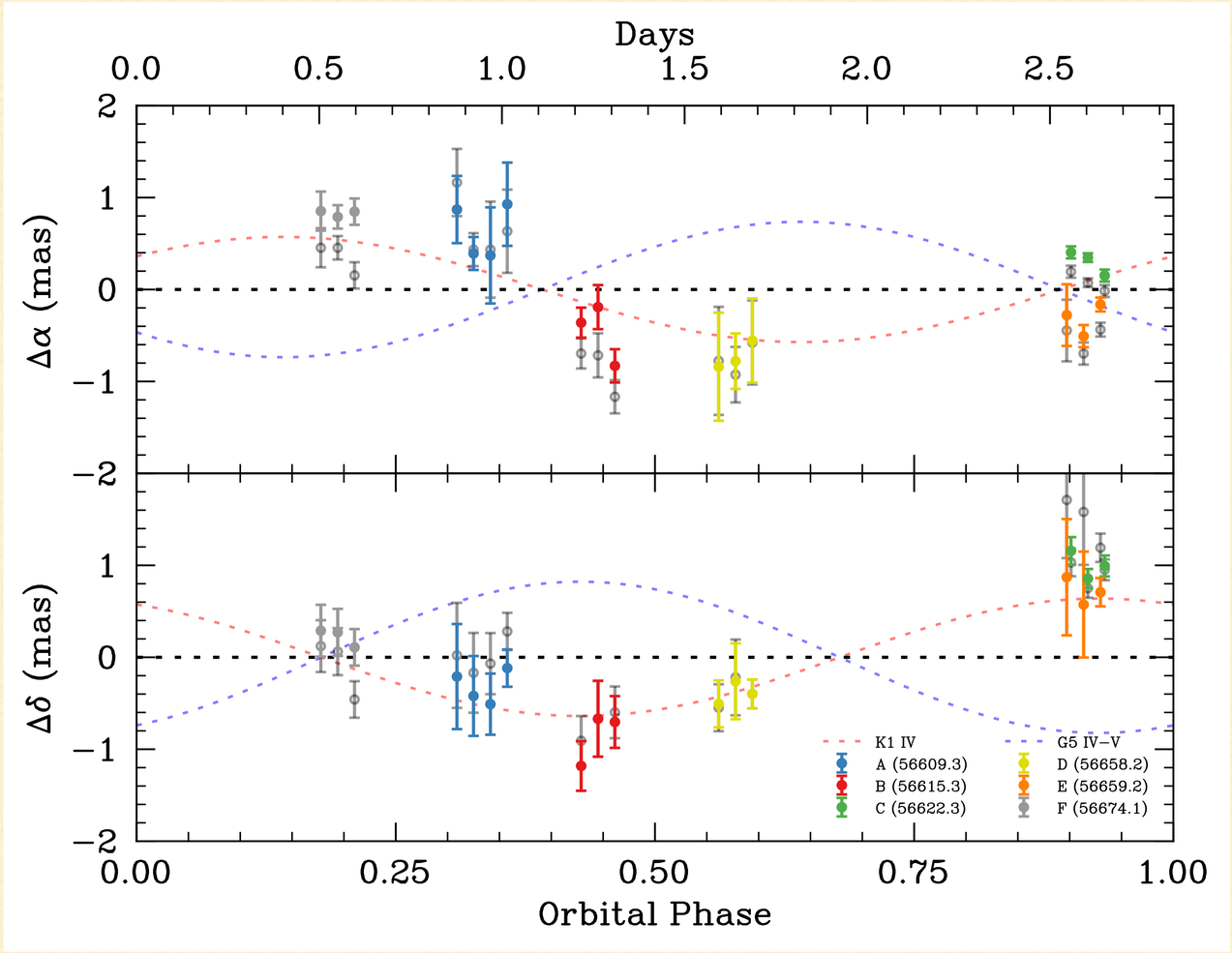
READ HERE

ACCOMPANYING PAPER WEBSITE



READ HERE

TROPOSPHERIC CORRECTION (CONT.)



READ HERE