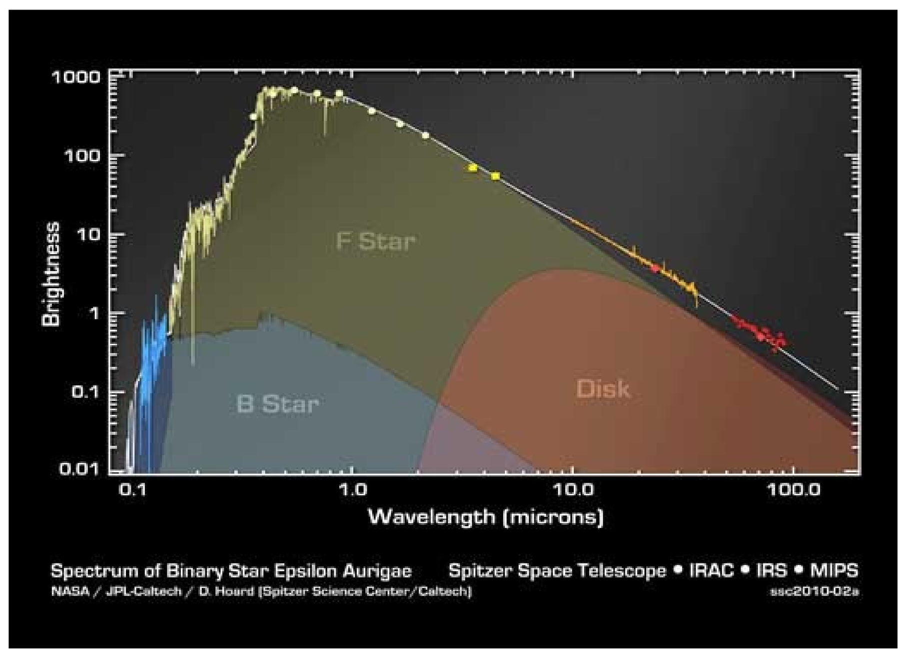

Infrared Studies of Epsilon Aurigae In Eclipse 2010

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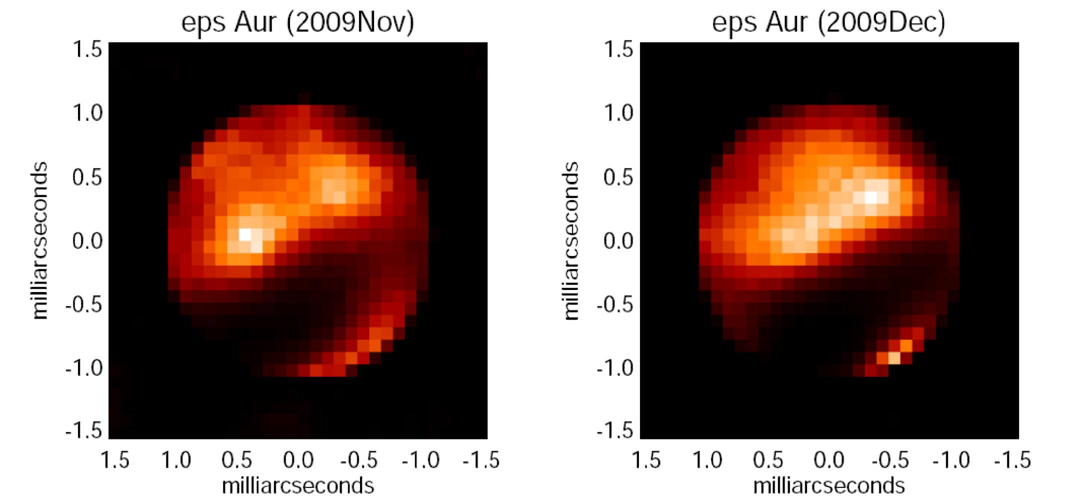


CHARA+MIRC H-band imaging of eclipse/disk ingress, 2009

Abstract:

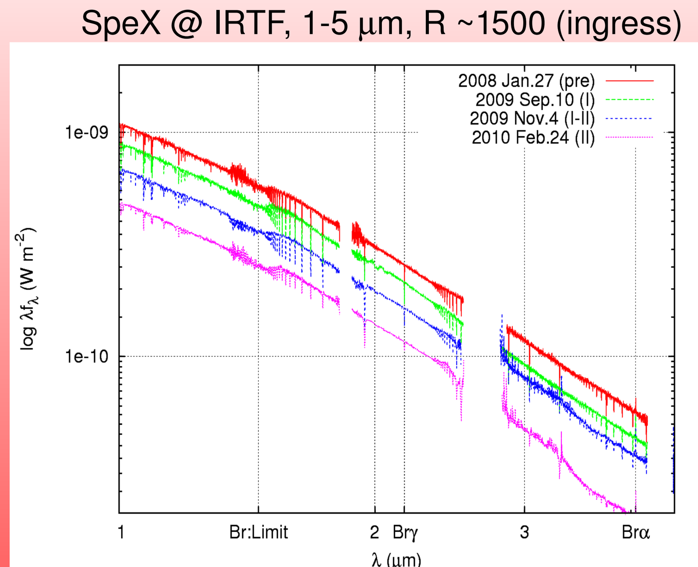
The goals for these observations include: (1) compare eclipse depths with prior eclipse data and disk SED/thermal structure expectations, (2) confirm the re-appearance of CO absorption bands at and after mid-eclipse, associated with the disk, and (3) seek evidence for any mid-infrared solid state spectral features from particles in the disk, seen during different portions of total eclipse. The results to date show that the infrared eclipse is less deep than the optical one, and the implied disk temperature has begun to increase from 550K toward 1100K as eclipse progresses past midpoint and heated portions of the disk come into view. Material properties of the disk are consistent with large particles.

Context/methods:

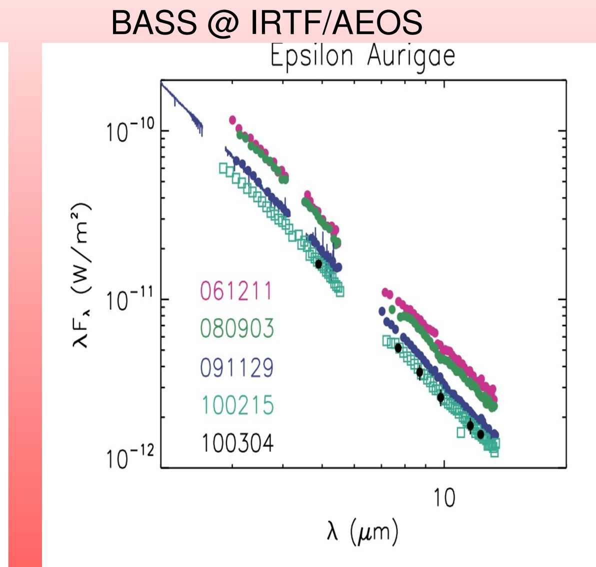
We report here on a series of observations of the enigmatic long period eclipsing binary ε Aurigae during the transit of its companion's DISK during the eclipse interval 2009-2011, with near-IR spectra & photometry obtained with SpeX/IRTF, Spitzer/IRAC, mid-IR data: BASS/IRTF & at AEOS, MIRSI on IRTF and MIRAC4 on MMT, along with archival data with Denver's TNTCAM2 at WIRO, plus recent J&H photometry at Mt.Evans Observatory.

Results: (1) IR eclipse depths appear similar to that observed during the most recent (1983) eclipse, although evidence for post-mid-eclipse temperature increase is present; (2) CO absorption returned 57 days after nominal mid-eclipse, but was not present at mid-eclipse +34 days – narrowing the association with disk regions; (3) the **lack of solid-state features** in 2006 Spitzer IRS and 2009 MIRAC spectra suggests large particles in the disk. MIRAC observations on 22Dec2010 did not detect any signs of classic 10 μm silicates, thus far.

SpeX @ IRTF, 1-5 μm, R ~1500 (ingress)



BASS @ IRTF/AEOS

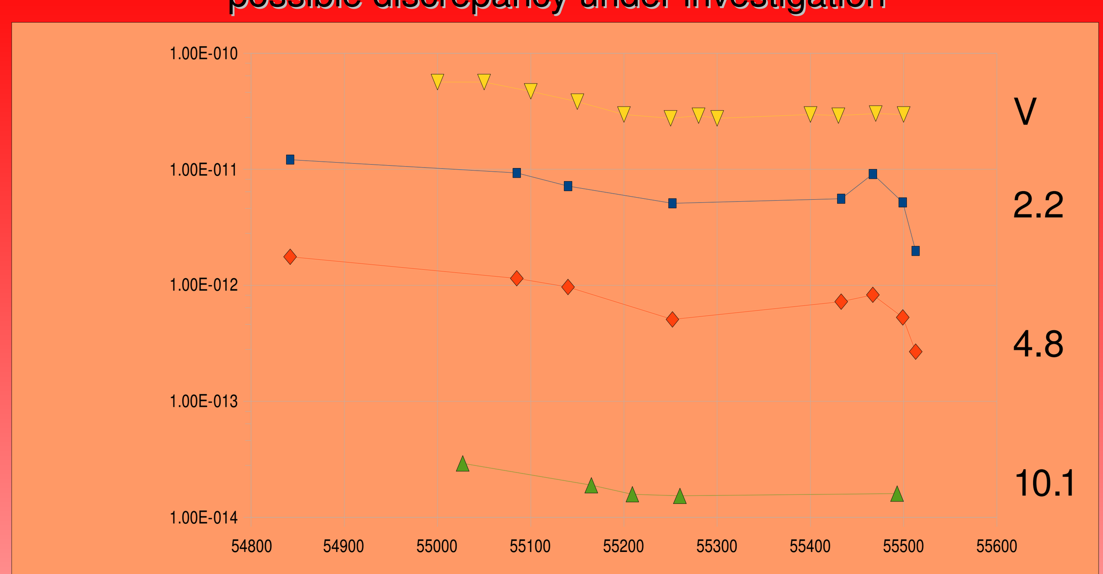


Result #1: comparison with prior eclipse depths:

Wavelength	Backman'84	Current Eclipse
0.55 μ (V)	0.75 ± 0.02	0.78 ± 0.02*
2.2 (K)	0.71 ± 0.02	0.66 ± 0.02
4.8 (M)	0.66 ± 0.03	0.89 ± 0.02**
10.1 (N)	0.61 ± 0.03	0.70 ± 0.03
20 (Q)	0.32 ± 0.06	- - -

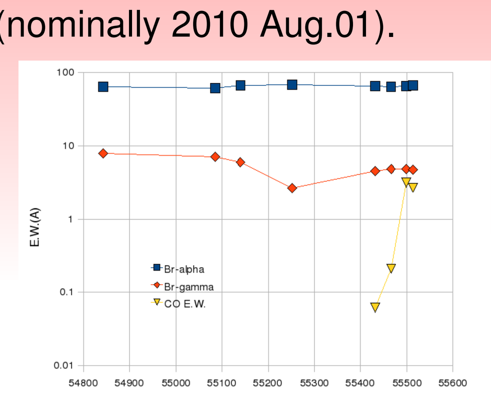
*http://www.hposoft.com/Plots09/VBand.JPG

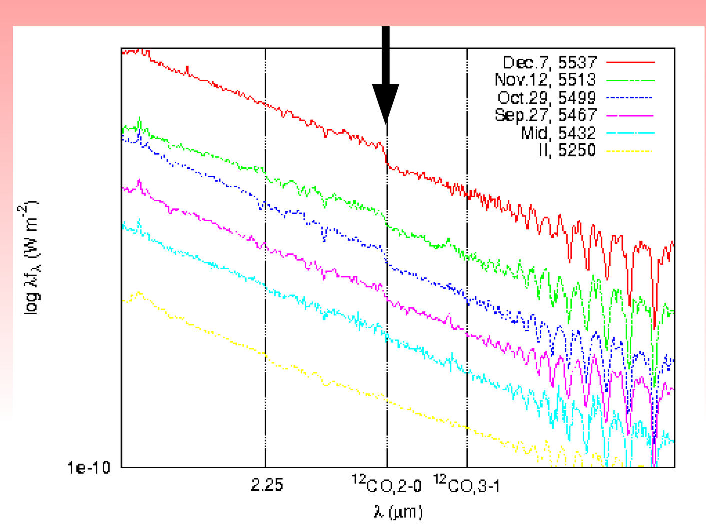
** possible discrepancy under investigation



Result #2: Re-appearance of CO bands at 2.29 μm.

Evidence for the CO 2-0 band re-appearance in ε Aur at 2.29 μm since mid eclipse (nominally 2010 Aug.01).





Equivalent width trends for 3 lines in SpeX data: Brackett α emission remains approximately constant, while Brackett γ absorption strength declined, especially during early totality (RJD55092), and CO 2-0 bands reappeared within 2 months of nominal mid-eclipse (2010 Aug. 01, RJD 55410).

FACTOIDS: ***Totality predicted to end April 2011***

- Epsilon Aurigae: SB1 eclipsing binary, P=27.1 years
- Eclipse duration: nearly 2 years (2009-2011)
- SED + interferometric imaging → system params:
  - * primary is an over-luminous F star [135R_o & 3 to 4 M_o]
  - * dark secondary = B5V [5.9M_o]+ earth-mass disk, R=3.8AU *Hoard, Howell & Stencel, 2010 HHS; Kloppenborg et al. 2010 Nature*
- Disk IR excess → 550 ± 50 K (unheated side)
- Featureless continuum → large particles (>1 micron).
- Pre-eclipse Spitzer IRS and MIPS data → 550 ± 50 K

  Backman et al. (1984); Backman & Gillett (1985); HHS
- Overtone CO 2.3 μm appeared during 2nd half during this one (2010) and the prior (1983) eclipse

  → sublimation of icy particles after exposure to the hotter F star (7500K, ~12AU dist.) during transit, subsequently rotating into view (disk exterior orbital period ~ 3 years).

  Takeuti (1986, 2011)Hinkle & Simon (1987) & this work.
- Expect disk SED to show signs of heating for years after mid-eclipse.

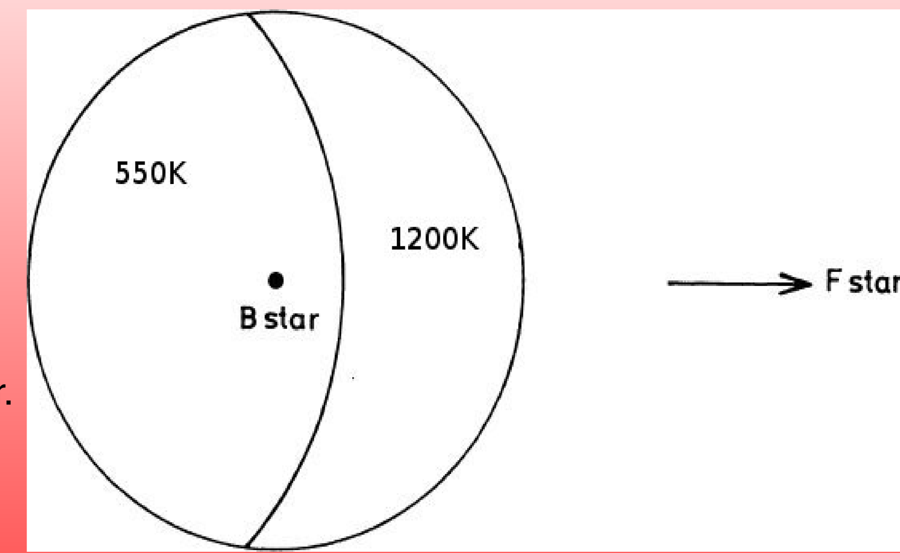
  → near/mid-IR photometry & spectra.

NEW IR DATA:

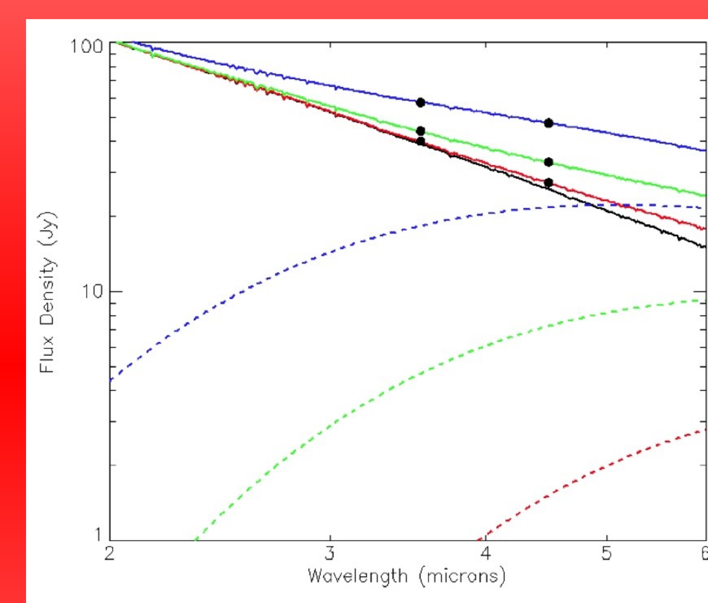
- IRTF + SpeX, 1-5 μm, R ~ 2000
- Spitzer IRAC, ch.1,2
- BASS (IRTF & AEOS), 3-13 μm, R ~500
- MIRAC (MMTO), 8-13 μm, R ~ 500
- In the queue: Gemini North IR Spectr., HSO

The fine print: Confirmation of the disk signatures during eclipse with improved, modern IR technology remains the key experiment as part of the ongoing Epsilon Aurigae 2009 -2011 eclipse campaign [http://www.hposoft.com/Campaign09.html]. Takeuti (1986) argued that the rotating dark disk ($\sim$3 year orbital period) should bring newly heated material into view after mid-eclipse. The predicted disk temperature rises from 550K to 1100K or more, which optimally is seen in the near-infrared bands. Thus, we seek to measure the photometric and spectroscopic facets of the disk with SpeX and MIRSI during egress semester 2011A to sample the thermal changes, the appearance of sublimation fragments and continue to map disk structure asymmetry (bow to wake), that is clearly indicated by prior spectroscopic studies of CO (Hinkle and Simon 1987 and hopefully starting in semester 2010B) and neutral potassium (Lambert and Sawyer 1986; Leadbeater and Stencel 2010). In this way, modern model-making methods (e.g. Whitney et al. 2004) can be applied to the excellent disk transect data being assembled during this rare eclipse.

Schematic of the doubly irradiated disk (Takeuti 1986). During total eclipse, earth is to the far left in this drawing (625 pc). The disk is 8 AU diameter and the F star is 18AU from the B5V central star.



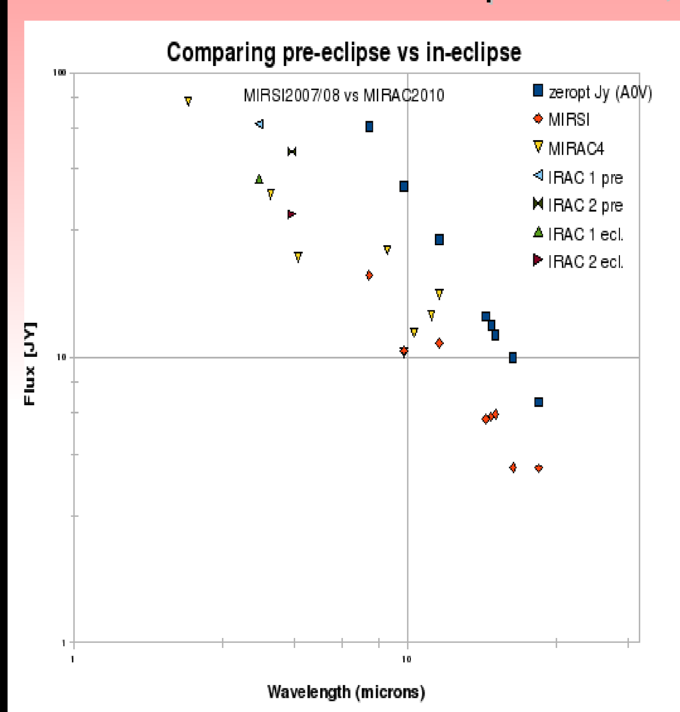
Spitzer IRAC monitoring → semi-annually since 2009 spring, appears to be showing signs of temperature increase in the disk SED: black line is the F star (7500K), red is 550K, green is 750K, blue is 1000K.

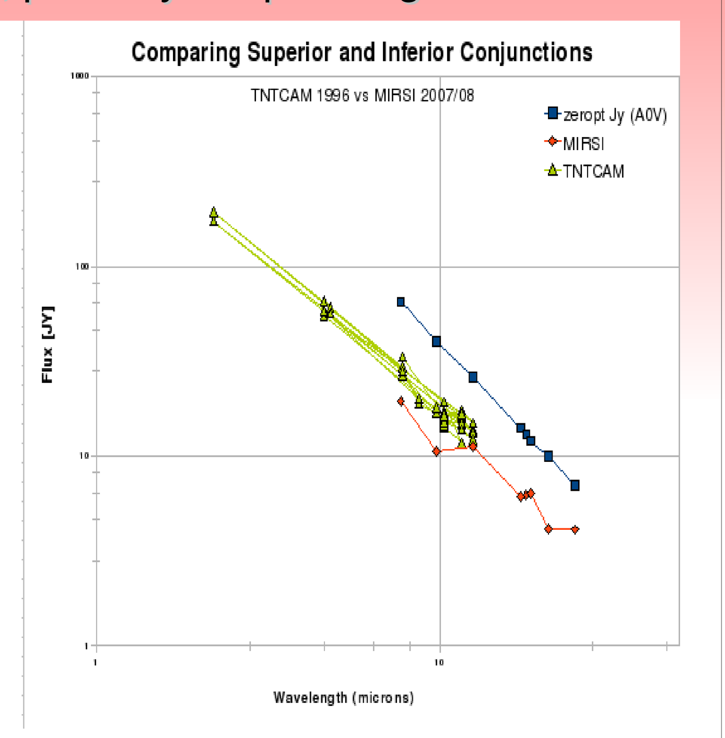


IRAC data to date:	*f[3.6]*	*Jy*	*f[4.5]*
pre-eclipse (2009 Apr 26)	*66.3*	*+/- <1%*	*52.9*
2010 March/April	*42.4*	*pre-mid-eclipse*	*31.8*
2010 Oct 29	*46.1*	*post-mid-eclipse*	*33.5*

3. Mid-IR & solid state features:

Archival TNTCAM data from the mid-1990s and newer MIRAC and MIRSI photometry are being used to check the hypothesis that the disk has a higher temperature on the side facing the F star, certainly in view during the 1990s and again coming back into view after mid-eclipse 2010, possibly evaporating solids.





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