Infrared Companions to T Tauri Stars:

Clues to the Formation and Evolution of Low-Mass Binaries

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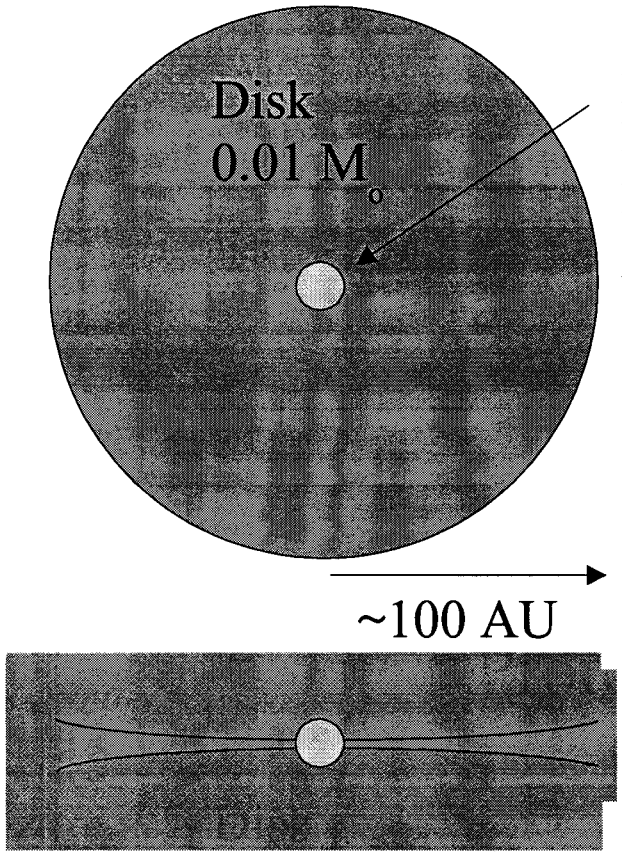
T Tauri Stars: Young Sun–Like Stars with Protoplanetary Disks



Formed in cloud cores

Disks are sites of planet formation

Excess of Binaries (compared to main–sequence counterparts)

"Classical":

- Strong H_α emission
- IR and UV Excesses
- Submillimeter Excess

Properties of the Infrared Companions

ompanions to "normal" TTS

eparation ~Disk Radius

arge IR excess
- Evidence for strong dust extinction

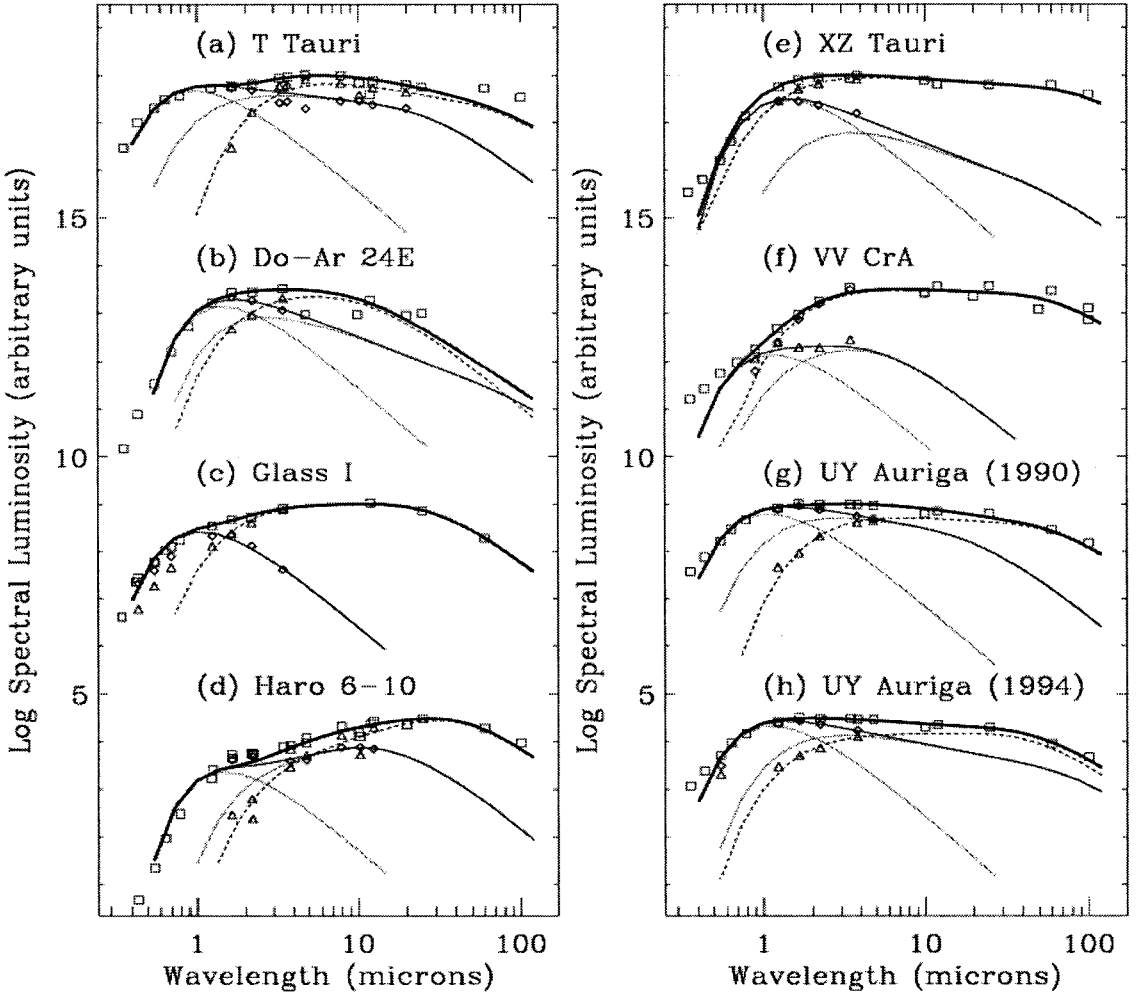
loderate dust masses
- (from submillimeter fluxes)

aint in visible light

arge luminosity

arge variability

lagnetic accretion?
- H_2 emission
- Nonthermal Radio

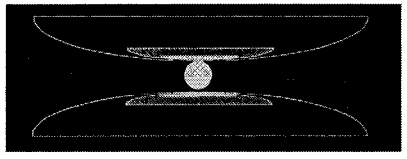


Infrared Companions: A Brief History

IRC Discoveries

UY Aur	1944 *(Joy & van Biesbroek)*	*Visible Image*
T Tauri	1982 *(Dyck, Simon, & Zuckerman)*	*IR speckle*
VV CrA	1985 *(Frogel)*	*IR offset*
DoAr 24e	1988 *(Chelli et al.)*	*IR speckle*
Glass I	1988 *(Chelli et al.)*	*IR speckle*
Haro 6−10	1989 *(Leinert & Haas)*	*IR speckle*
XZ Tauri	1990 *(Haas, Leinert, & Zinnecker)*	*IR speckle*
WSB 4	1993 *(Reipurth & Zinnecker)*	*IR Image*

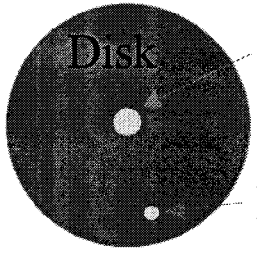
Models for the IRCs



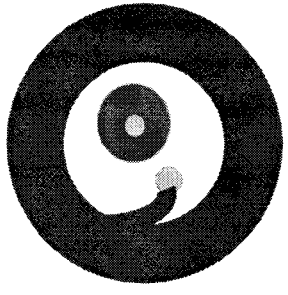
IRC has an Edge–On Disk

Variability due to changing extinction?

Testable via high–resolution imaging



IRC is a TTS hidden by primary's disk

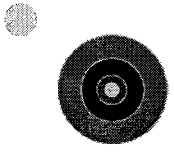


IRC accretes from circumbinary disk

Variability due to changing extinction and/or accretion rate

Accretion streams preferentially onto IRC because of eccentricity and mass ratio

IRC characteristics episodic and tied to binary orbit



IRC is active accretion disk ("mini–FUor")

Luminosity powered by disk accretion

Variability due to changing accretion rate

Models for the IRCs (continued)

IRC is Younger than the Primary (Protostar!?)

Formation or evolution delayed wrt Primary

Formed from disk around Primary?

Accretion a "Fountain of Youth"?

Explains low color temperature and infrared excess

Spatially Resolving IRCs with Speckle Holography

)iffraction–limited
maging technique

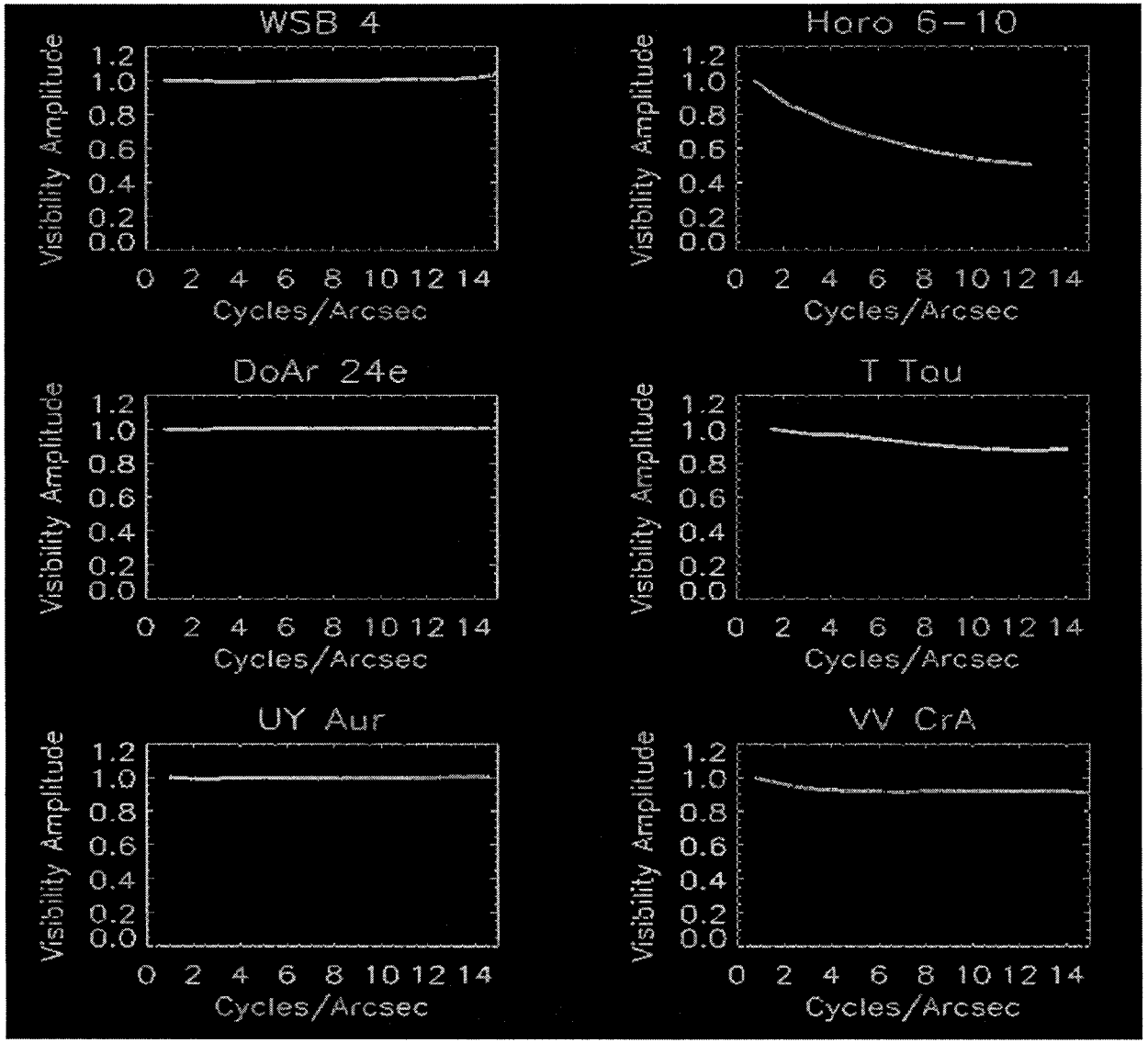
0 m Keck I telescope

'SF Self–Calibration

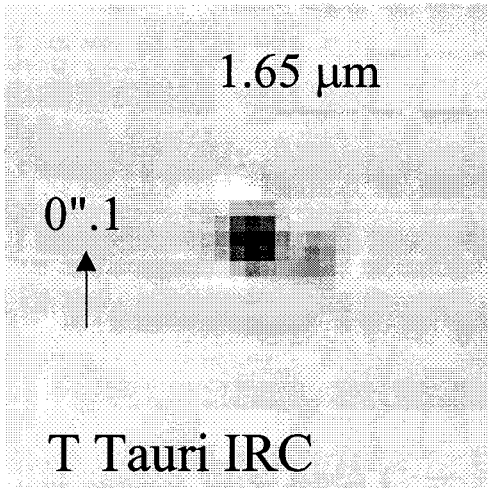
\zimuthally Averaged
/isibility Amplitude

:onstant ⇨ Unresolved
- WSB 4
- DoAr 24e
- UY Aur

'alling ⇨ Resolved
- Haro 6–10
- T Tauri
- VV CrA



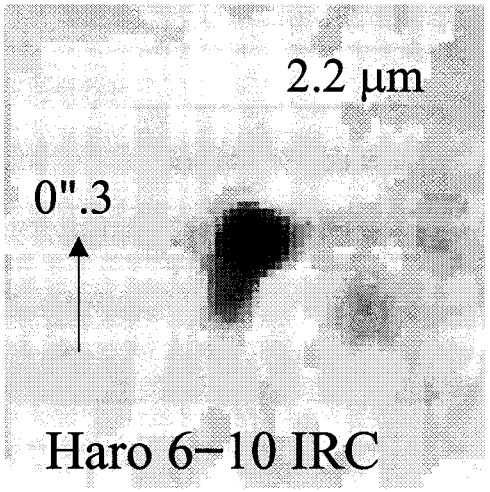
Near–Infrared Images of the Three Resolved IRCs



T Tauri is a triple!

Both objects are highly reddened

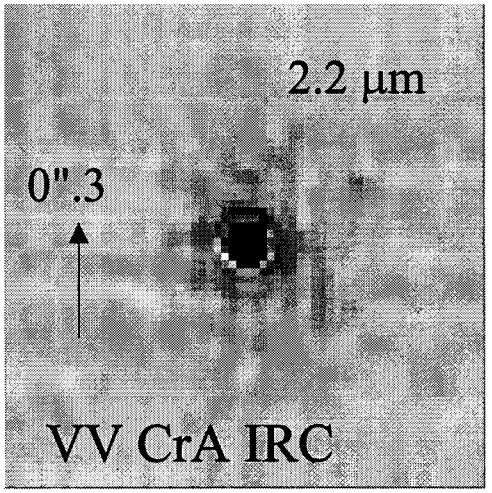
Orbital motion seen in IRC pair



Nebular "tail"

Fainter structures

Heavily embedded



Faint nebulosity (core+halo source)

No clear sign of deviation from circular symmetry

UY Aur B: An IRC that Wasn't

1944: The UY Aur IRC was discovered. It was a bright visible object! (Δ mag 0.4−0.5)

1995: Δ mag > 5 (Herbst, Koresko, & Leinert 1995)

FIVE NEW DOUBLE STARS AMONG VARIABLES OF THE T TAURI CLASS

A. H. Joy and G. van Biesbroeck

Five of the eleven known T Tauri variable stars were found to be double by Joy while observing them with the spectrograph at the 100-inch telescope on Mount Wilson.

Micrometer measures by van Biesbroeck at the McDonald Observatory for four of the pairs give the position angles and distances in Table I. The measures were made at unfavorable hour angles where the maximum accuracy would not be expected. The estimated magnitude differences are in the last column.

TABLE I

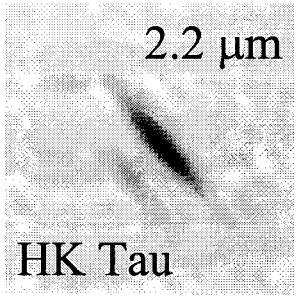
Micrometer Measures of T Tauri Stars

Star	Date	P	d	Δ mag
RW Aur	1944.246	253°8	1".17	1.5
	.248	254.9	1.28	...
	(Mean) .25	254.3	1.22	
UY Aur	1944.246	212.6	0.72	0.5
	.248	211.8	0.92	0.4 ◄■
	(Mean) .25	212.2	0.82	
UX Tau	1944.246	269.8	5.66	...
	.248	270.2	5.66	...
	.251	270.2	5.89	...
	(Mean) .25	270.1	5.74	
UZ Tau	1944.237	271.4	3.70	0.4
	.246	272.4	3.72	0.3
	.248	270.9	3.60	0.2
	.251	91.3	3.68	0.2
	(Mean) .25	271.5	3.68	

Variability of the Haro 6−10 IRC

Christoph Leinert's section goes here...

Discussion



IRCs don't look like edge–on disk systems (such as HK Tauri B)

No consistent morphology

Are the IRCs really a consistent class?

Existence of IRCs indicates that significant *non–disk* circumstellar material can exist in a binary system

Conclusions

Companions to Young (Pre−Main Sequence) Solar−Mass stars

Infrared excess, silicate absorption, and nebulosity indicate diffuse dusty circumstellar material

Diverse Morphology (pointlike, binary, core+halo, and "tail")

⇨ Probably not just special viewing geometry