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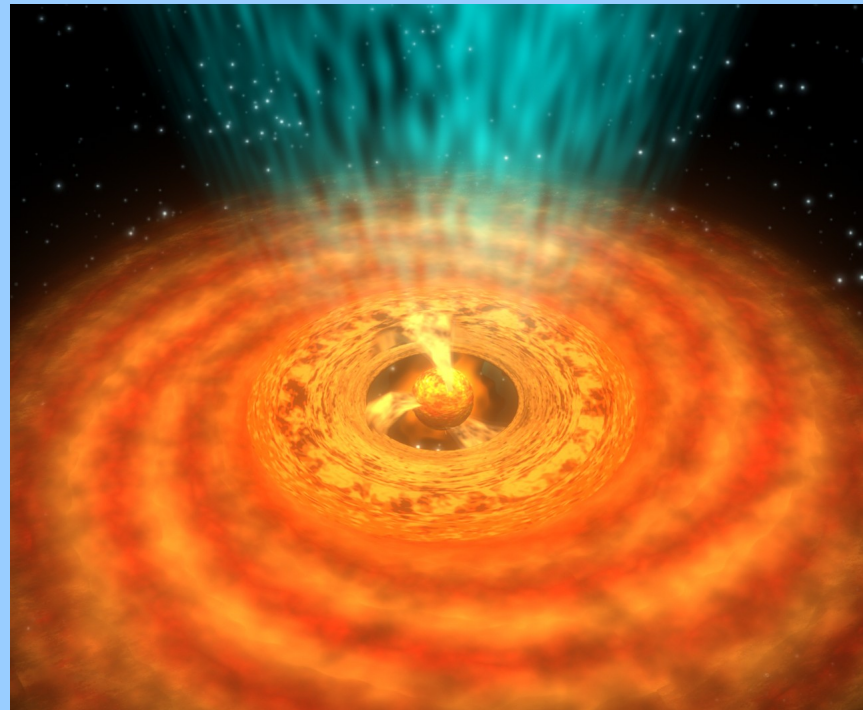
# When does accretion cease?

T Tauri stars in general and IM Lup in particular

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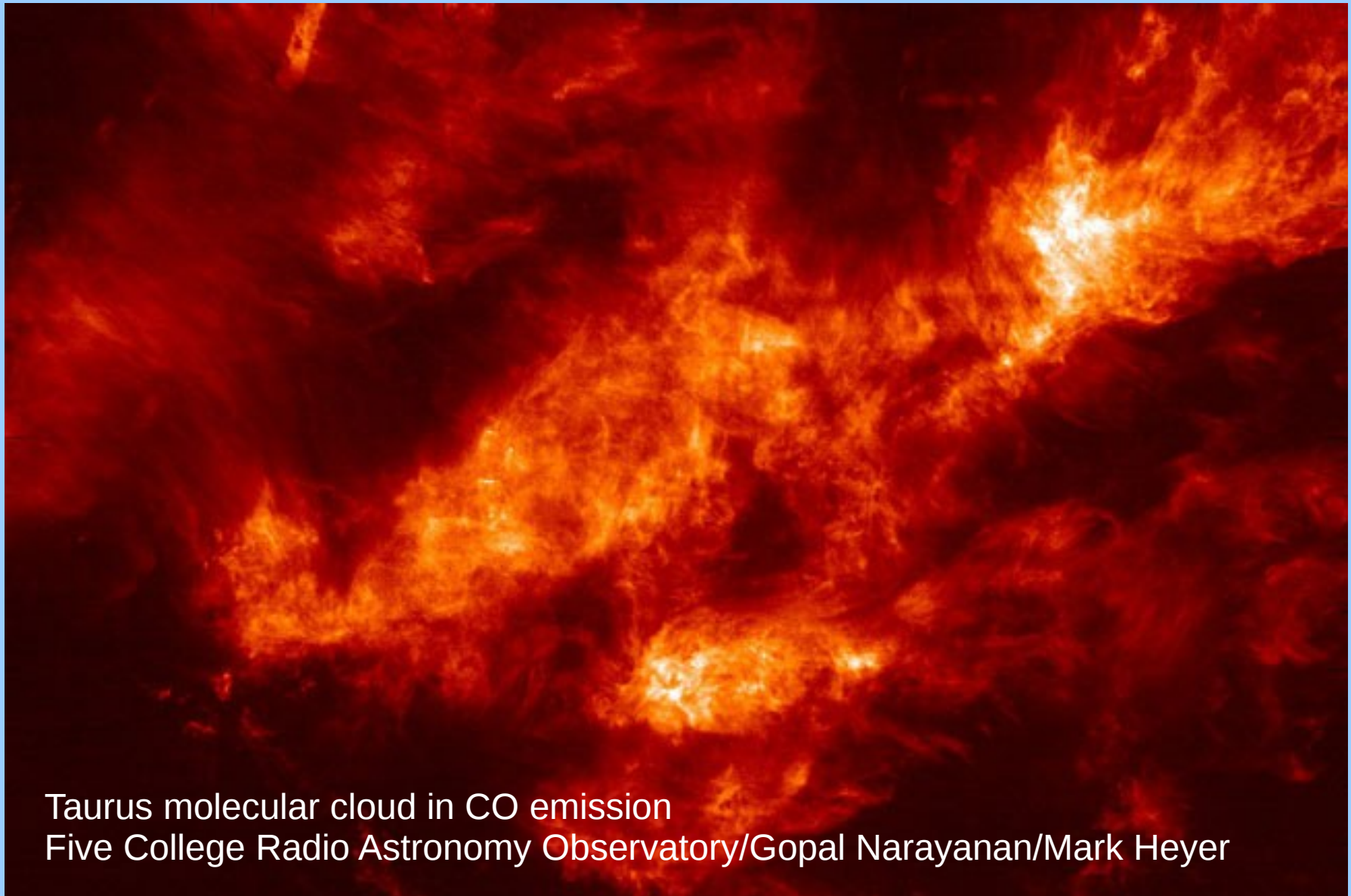
# Outline

- Introduction to star formation
- Accretion onto young stars
  - H $\alpha$
  - Soft excess
  - He-like triplets
  - Model
- IM Lup as a transitional object
- Summary

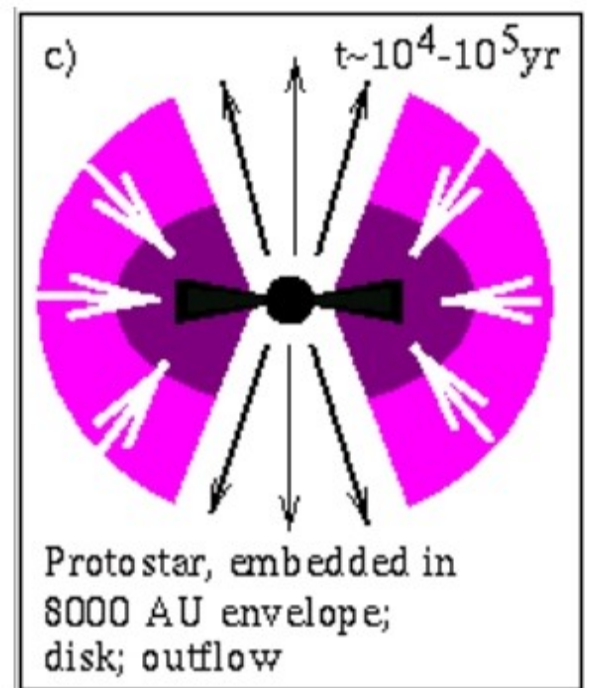
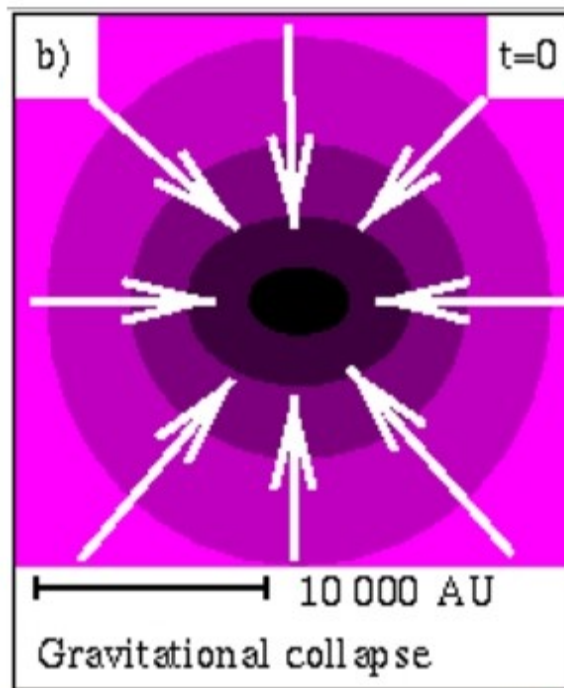
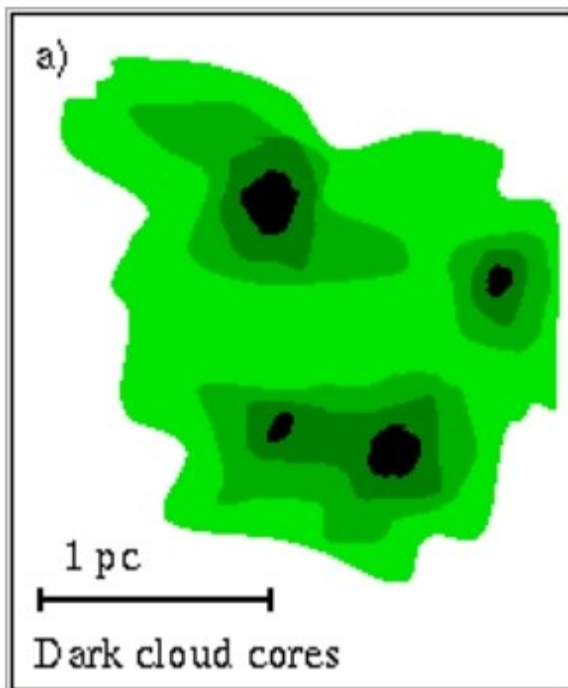


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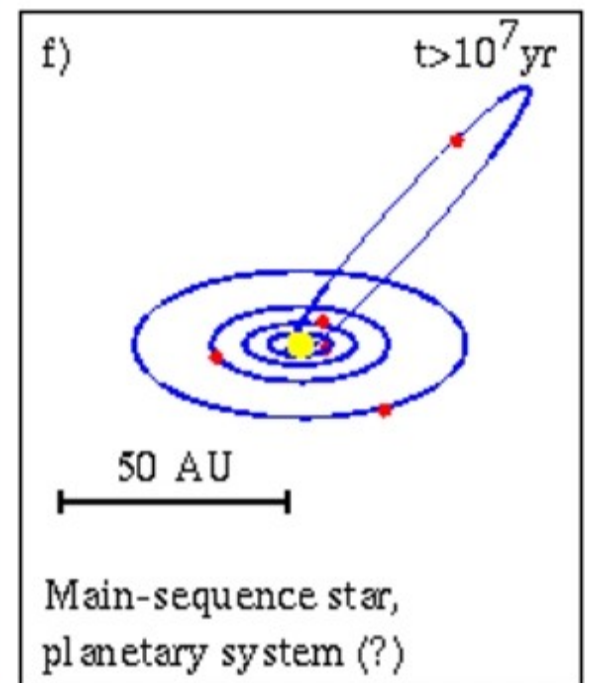
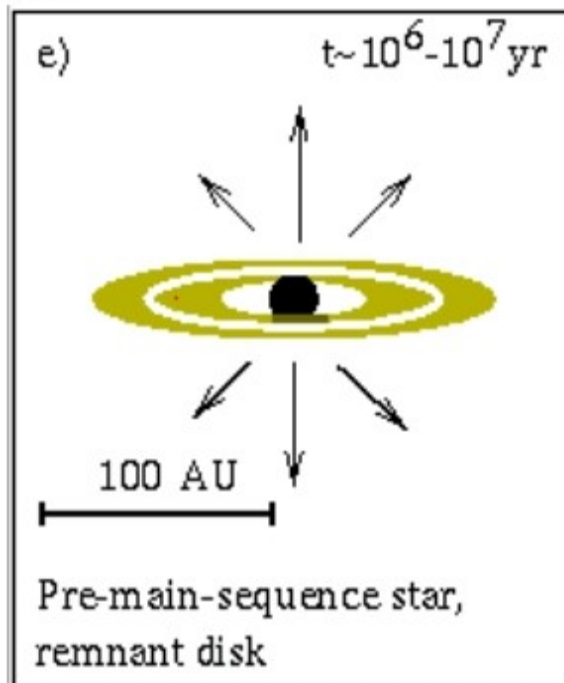
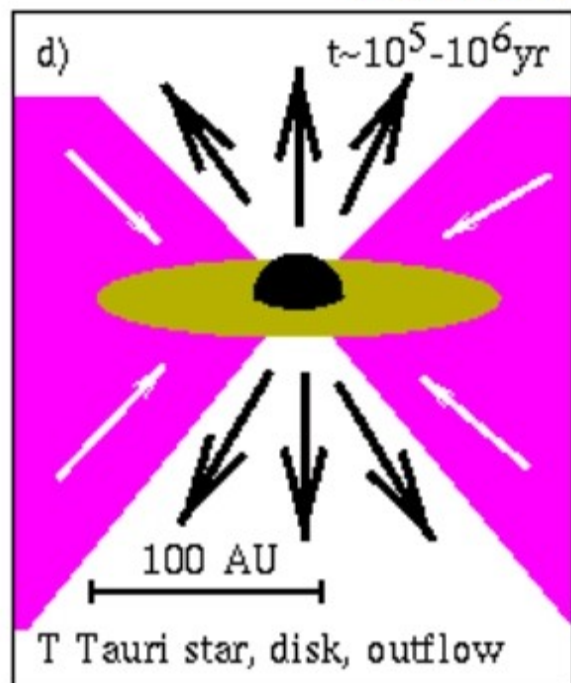
# Introduction



Taurus molecular cloud in CO emission  
Five College Radio Astronomy Observatory/Gopal Narayanan/Mark Heyer



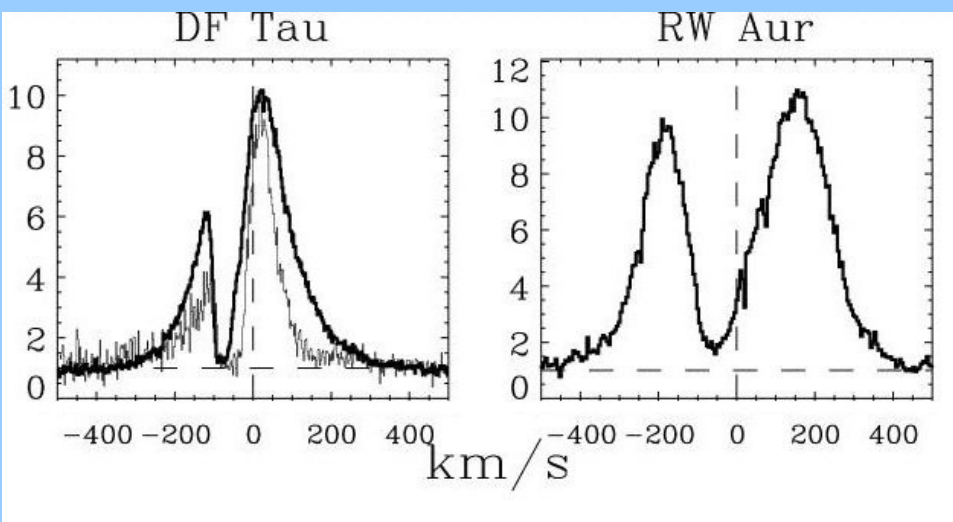
## Planet formation



# T Tauri Stars (TTS)

## Classical TTS (CTTS)

- $H\alpha$  EW  $> 10 \text{ \AA}$
- Opt. thick disks
- accretion

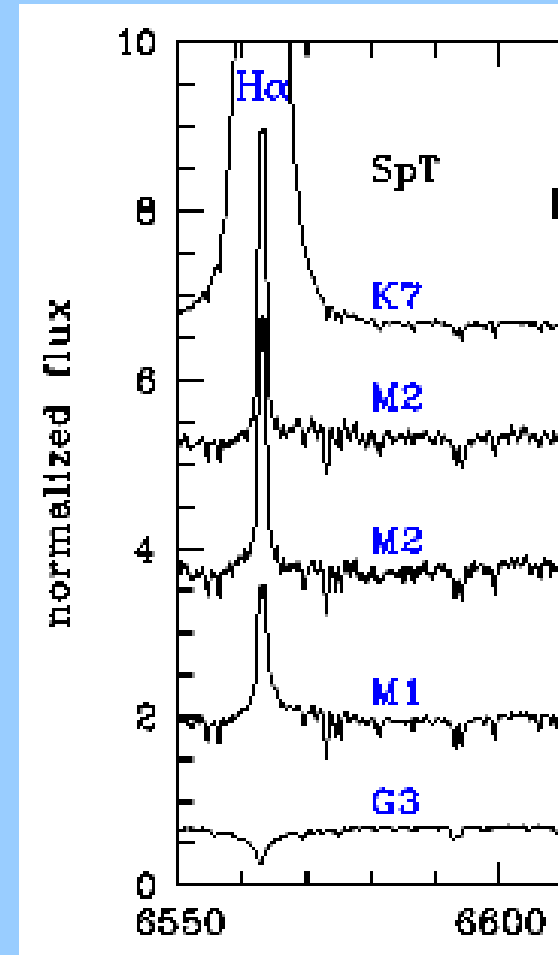


$H\alpha$ : Ardila et al., ApJ (2002)

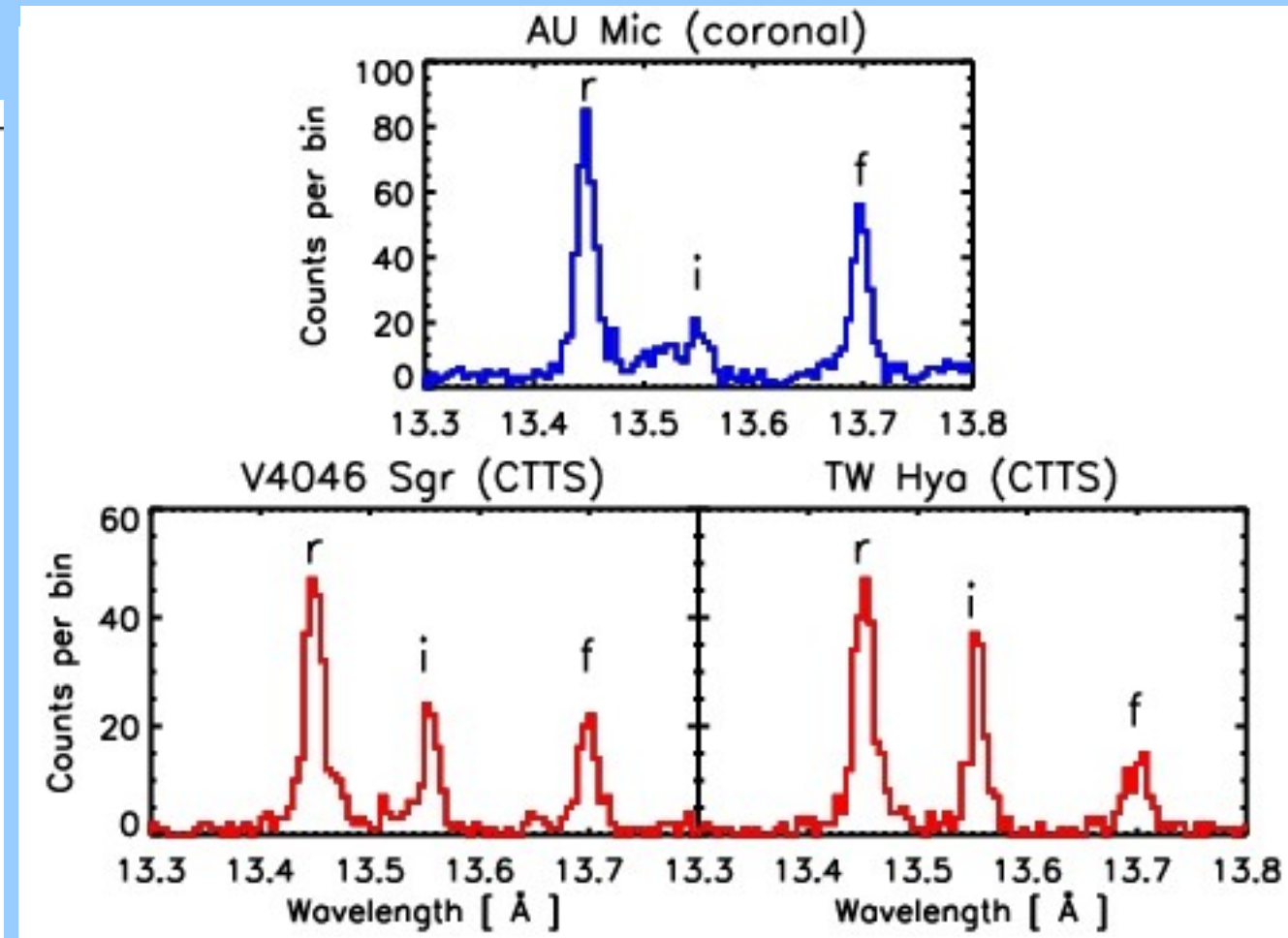
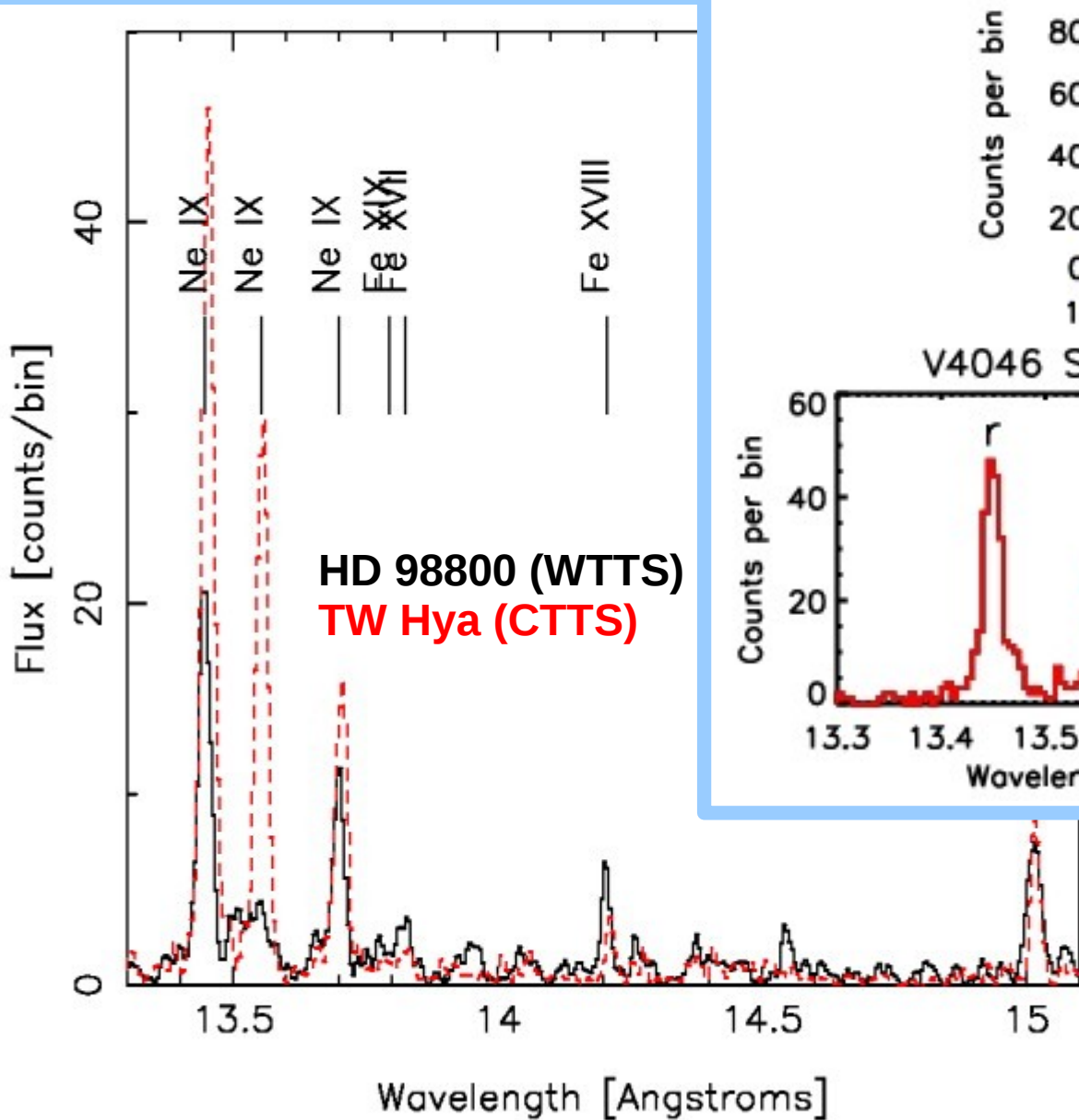
## Weak-line TTS (WTTS)

- $H\alpha$  EW  $< 10 \text{ \AA}$
- Little or no disk
- No accretion

Sterzik et al.,  
A&A (1999)

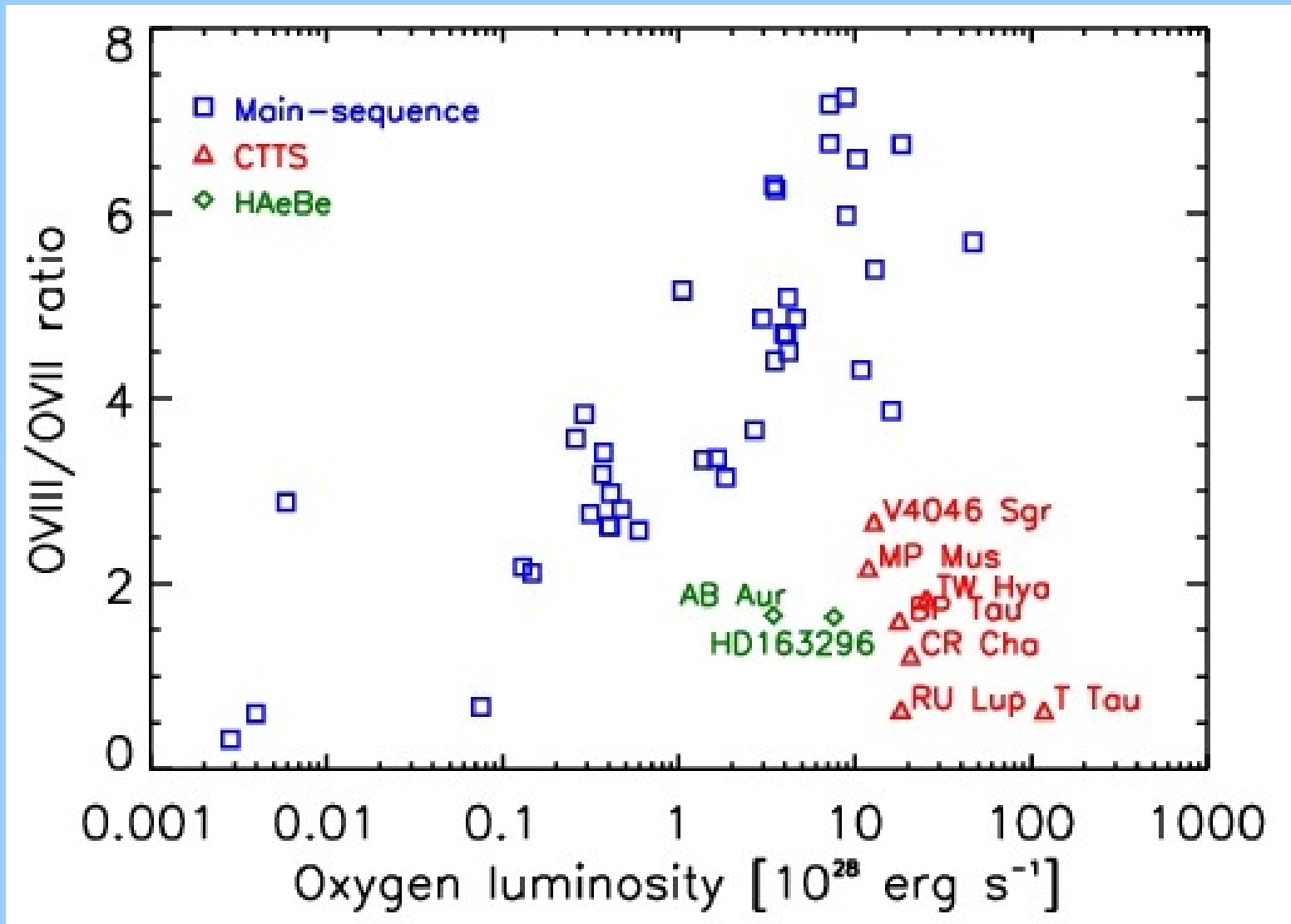


# Collection of He-like triplets



Archival data

# Soft excess



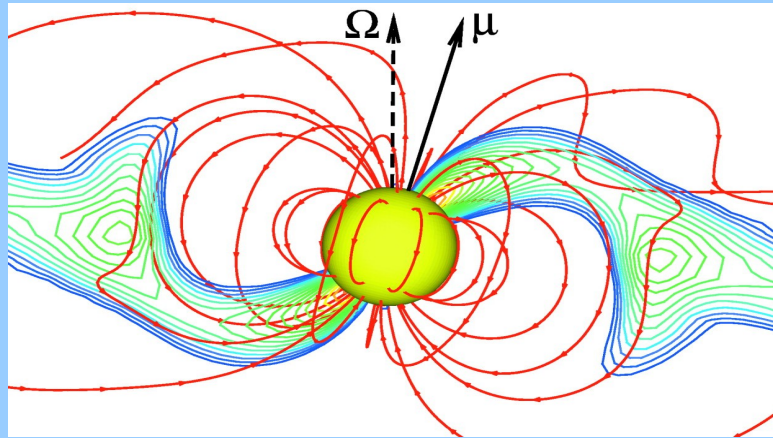


# Classical T Tauri stars are special.

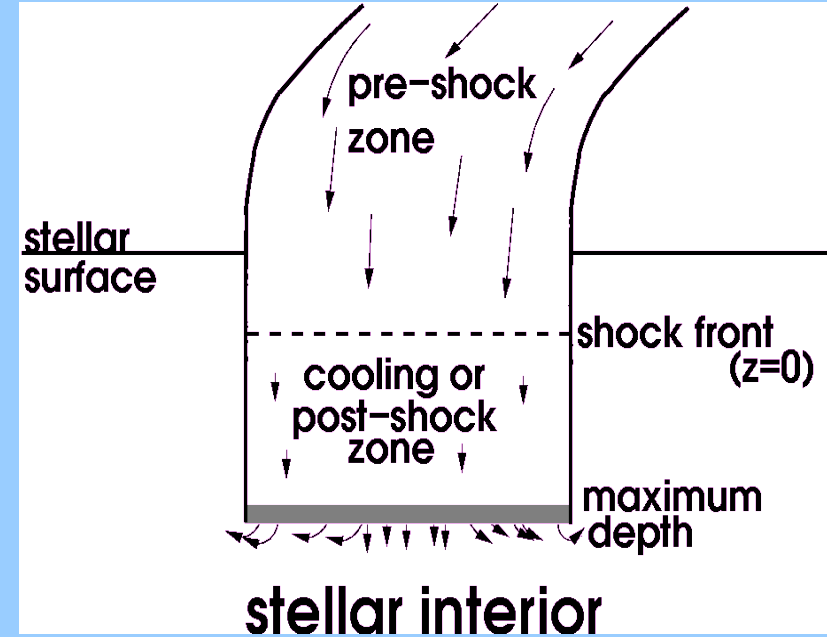
- Broad H $\alpha$  lines
- Low f/i ratio in He-like triplets
- Soft excess



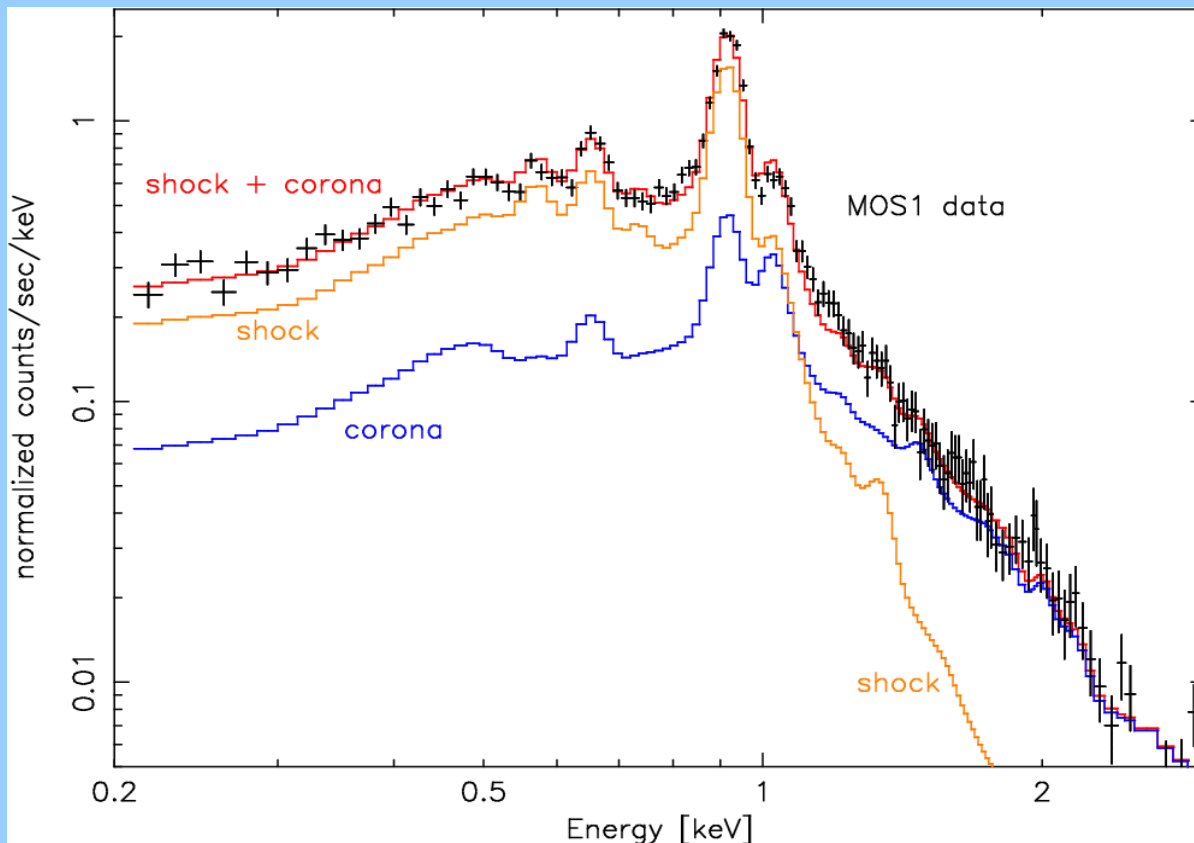
# The accretion shock model



Romanova et al.,  
ApJ (2004)



Günther et al., A&A (2008)

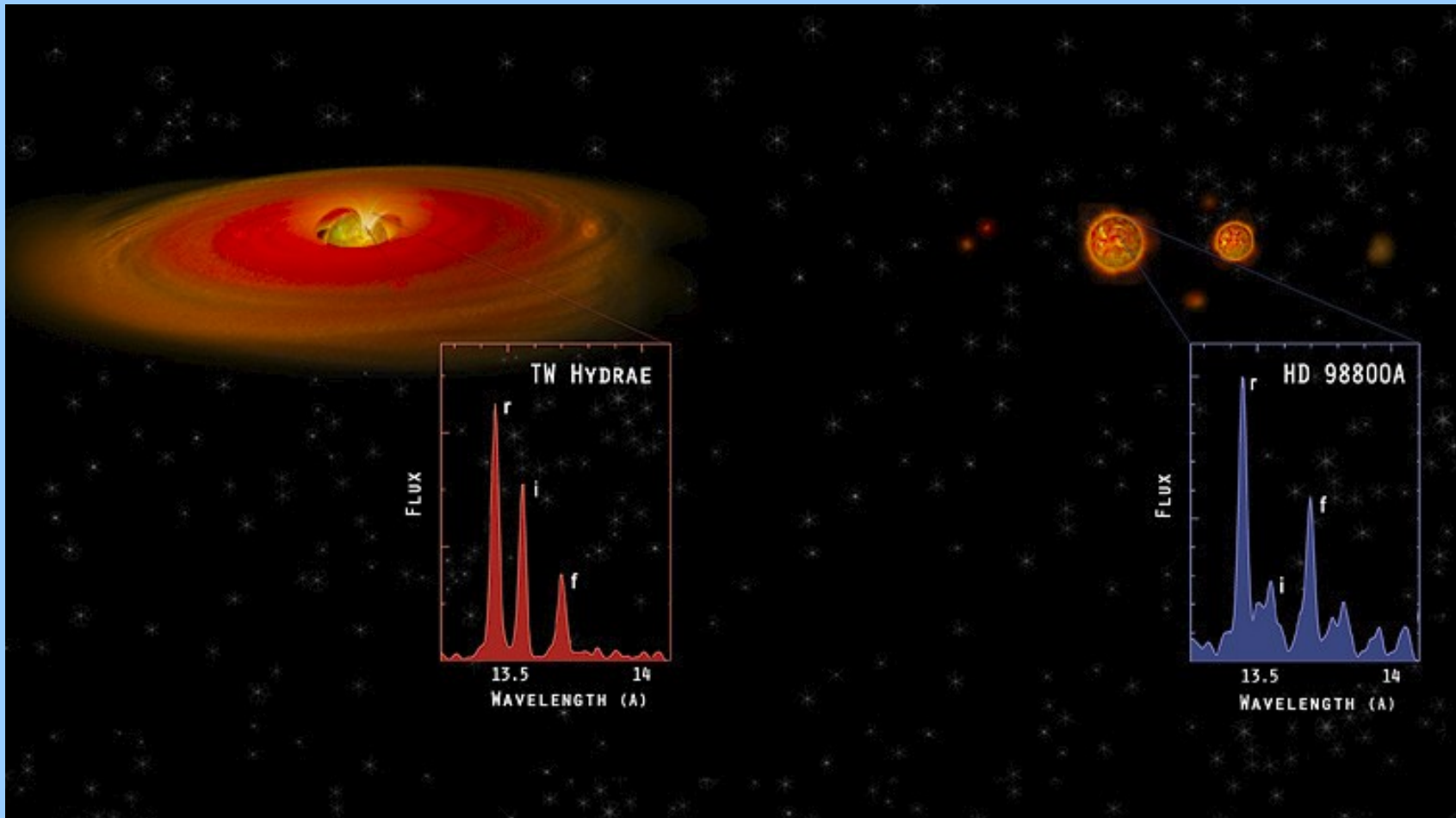


**A combination of dense accretion shock and thin corona can explain the X-ray emission from CTTS.**

# T Tauri stars

Classical T Tauri stars

Weak-lined T Tauri stars



Spectra: NASA/CXC/RIT/J.Kastner et al.; Illustration: NASA/CXC/M.Weiss

**CTTS have accretion, WTTS do not.**



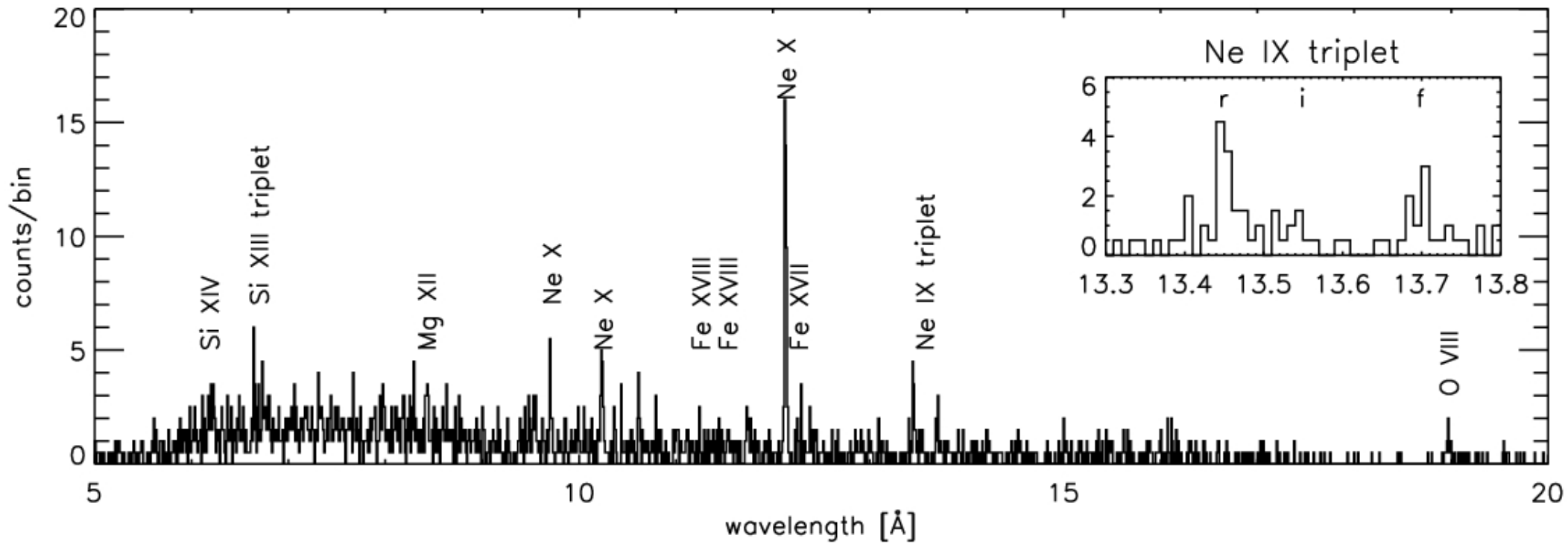
# When does accretion cease?

150 ks Chandra HETGS spectrum of IM Lup

- Has a disk
- $H\alpha$  EW  $< 10 \text{ \AA}$

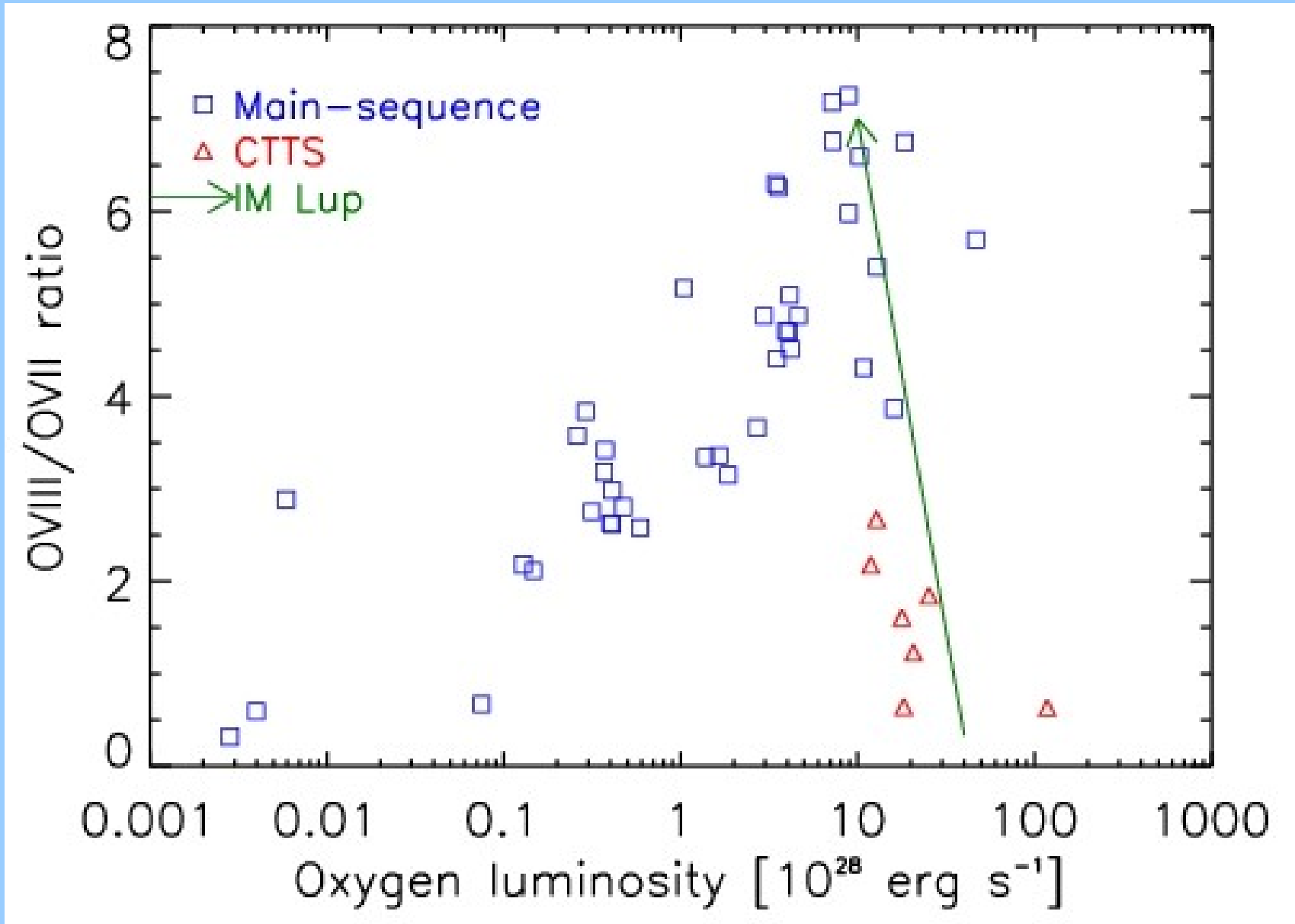
→ CTTS or WTTS?

# IM Lup: X-ray spectrum

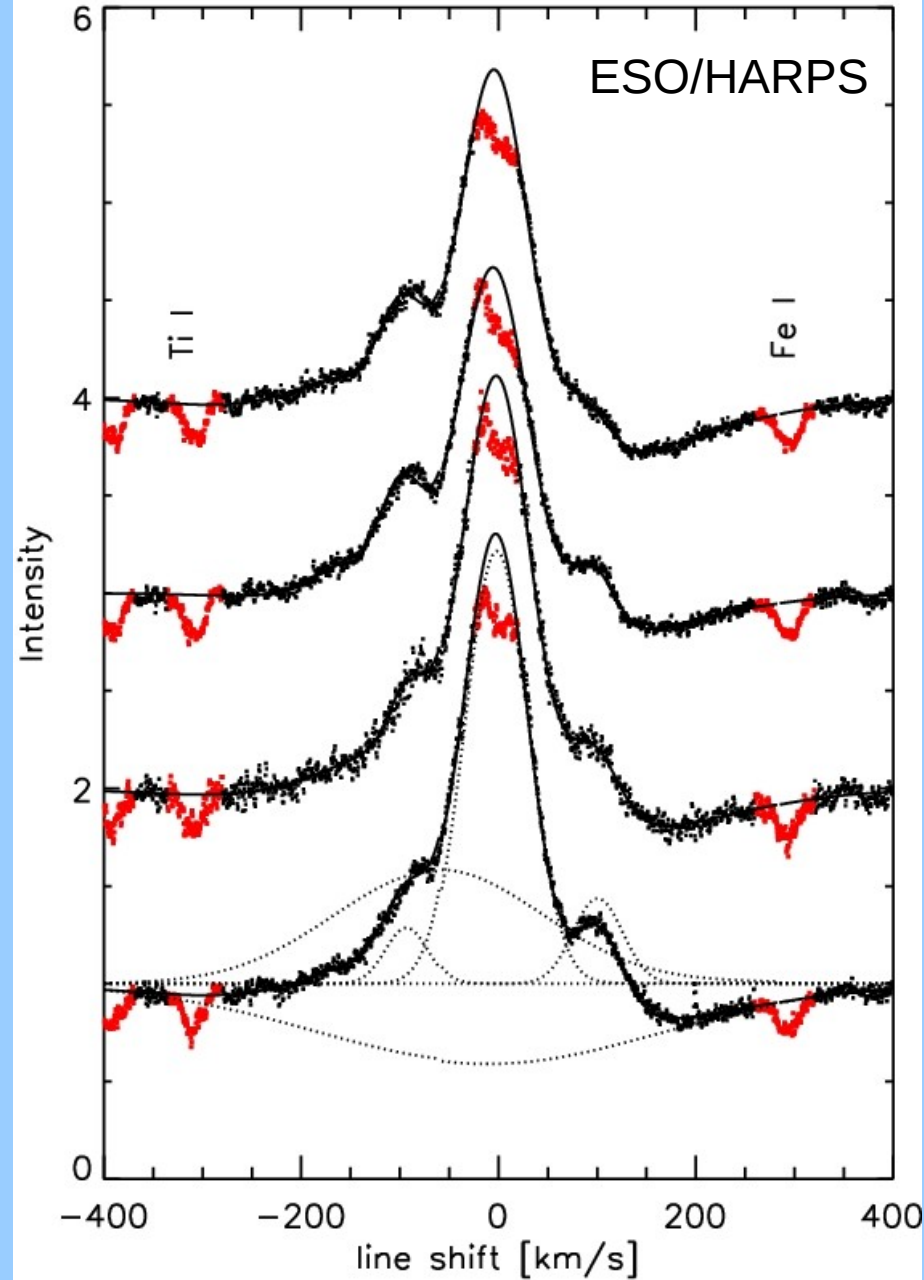
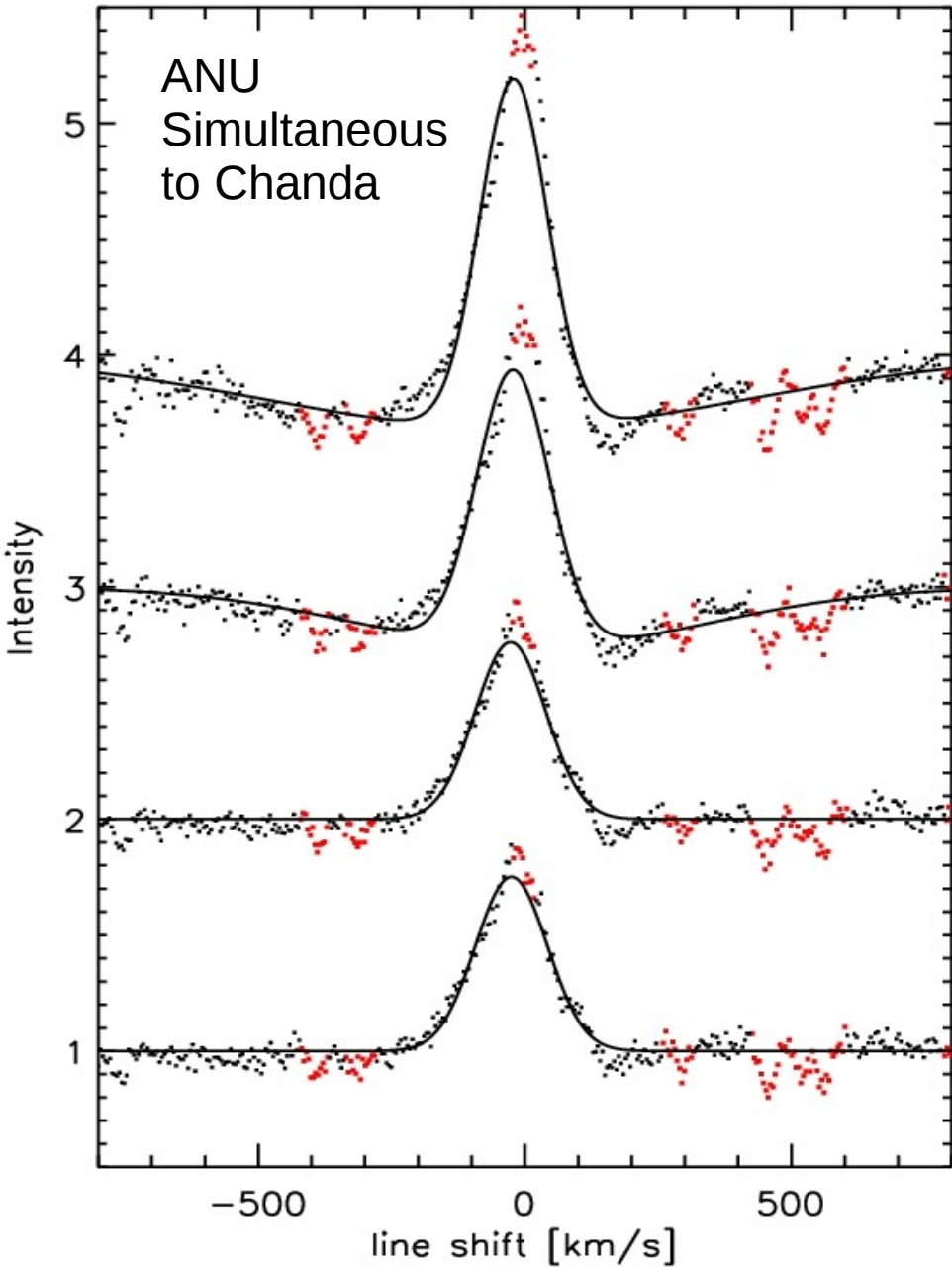


150 ks Chandra MEG spectrum

# IM Lup: soft excess



# IM Lup: H $\alpha$ line



# Summary

	<b>CTTS</b>	<b>IM Lup</b>	<b>WTTS</b>
<b>disk</b>	yes	yes	some
<b>H<math>\alpha</math> EW</b>	> 10 Å	3-5 Å	< 10 Å
<b>H<math>\alpha</math> line profile</b>	complex	complex	simple
<b>He-like triplets</b>	low f/i	large f/i (?)	large f/i
<b>X-ray soft excess</b>	yes	?	no
<b>accretion</b>	yes	little	no

IM Lup is truly a transitional object with characteristics of both CTTS and WTTS.