

# Large Spectroscopic Investigation of Over 90 Herbig Ae/Be Objects with X-Shooter

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Science & Technology  
Facilities Council

# Introduction



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A quick overview:

# Introduction



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A quick overview:

- What we are after
- Why X-Shooter and Spectroscopy

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- What we are after
  - Why X-Shooter and Spectroscopy
- Spectral Typing
  - Stellar Parameters

# Introduction



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A quick overview:

- What we are after
  - Why X-Shooter and Spectroscopy
  
- Spectral Typing
  - Stellar Parameters
  
- Accretion Rates
  - Balmer Excess
  - Lines Tracing Accretion

# Introduction



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A quick overview:

- What we are after
  - Why X-Shooter and Spectroscopy
- Spectral Typing
  - Stellar Parameters
- Accretion Rates
  - Balmer Excess
  - Lines Tracing Accretion
- Upcoming work

# What and Why?



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**What  
And Why?**

# What and Why?



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Why X-shooter:



# What and Why?



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Why X-shooter:

- Huge Spectral Range 300nm-2.3 $\mu$ m
- All simultaneous



# What and Why?



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Why the large sample

# What and Why?



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Why the large sample

- Need large statistical study
- Known sources: Thé et al. (1994), Vieira et al. (2003)
- Also so that we can quantitatively compare with the T Tauri



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What this sample covers

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What this sample covers

- Very large range in temperatures and properties
  - Temperatures from 6000-33000K
- Covers potential switch in accretion regimes; thought to be Around early B-type Vink et al. (2005); Mottram et al. (2007)





# Stellar Parameters

# Stellar Parameters



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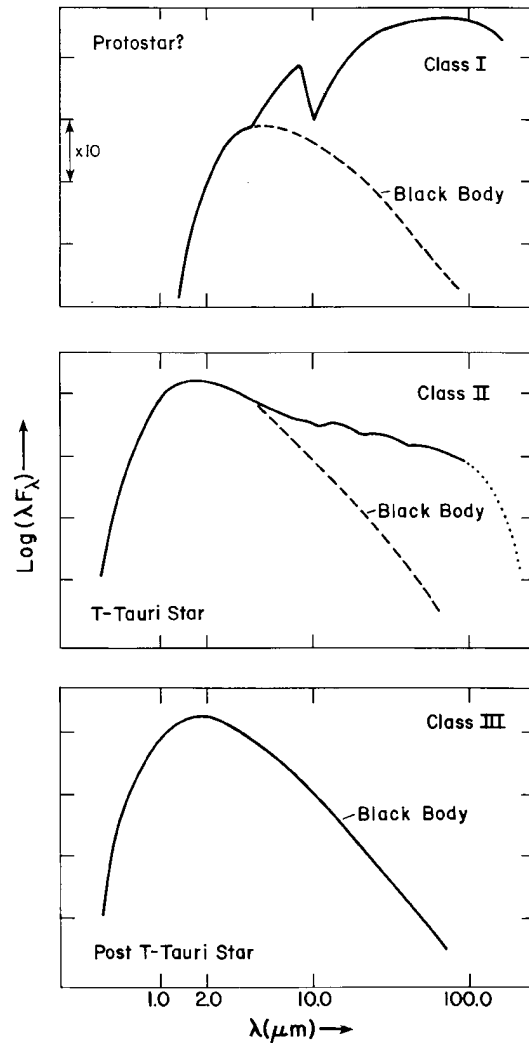
Temperature and Gravity

# Stellar Parameters



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Determine Temperature and surface gravity

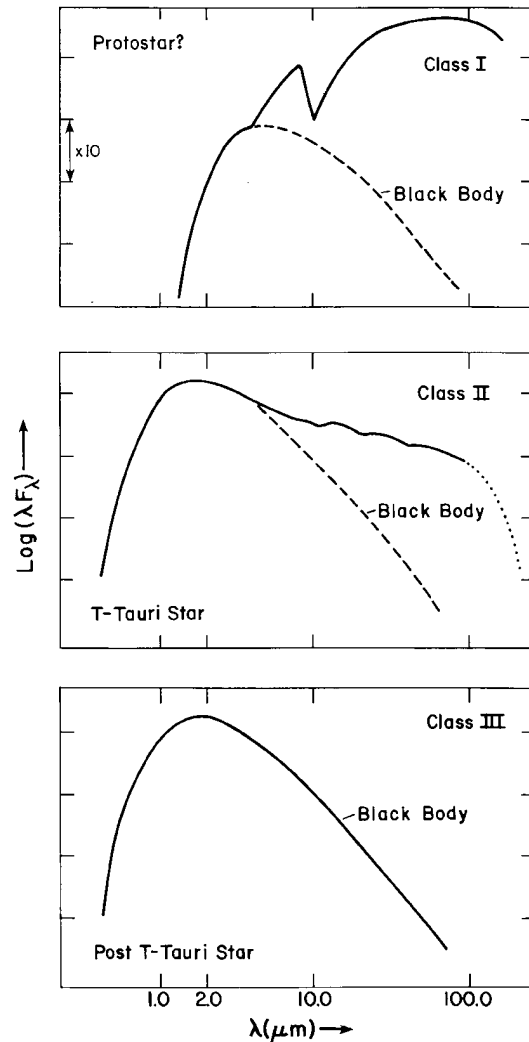


# Stellar Parameters



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Lada (1987)

Determine Temperature and surface gravity

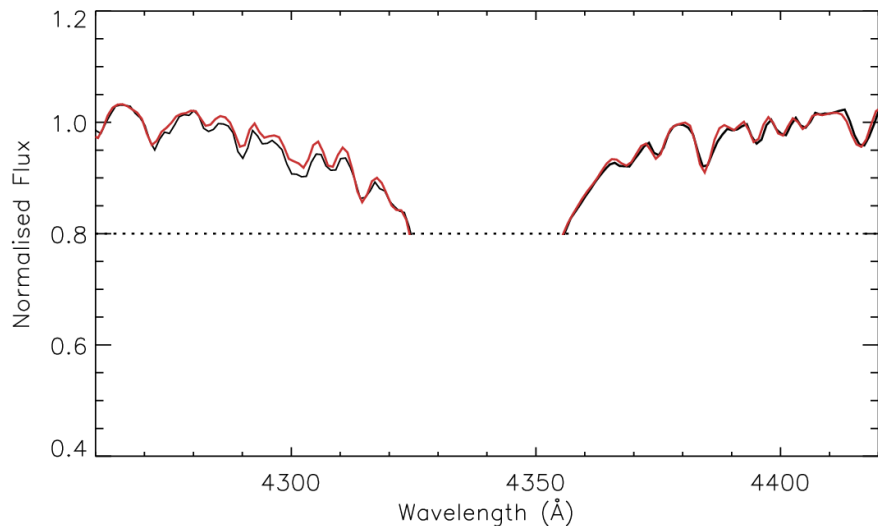
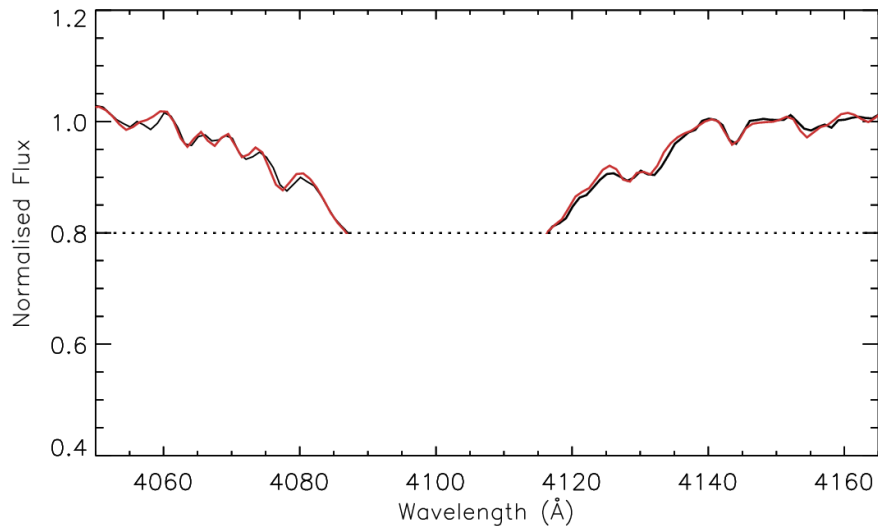
-- Use Balmer recombination lines

# Stellar Parameters



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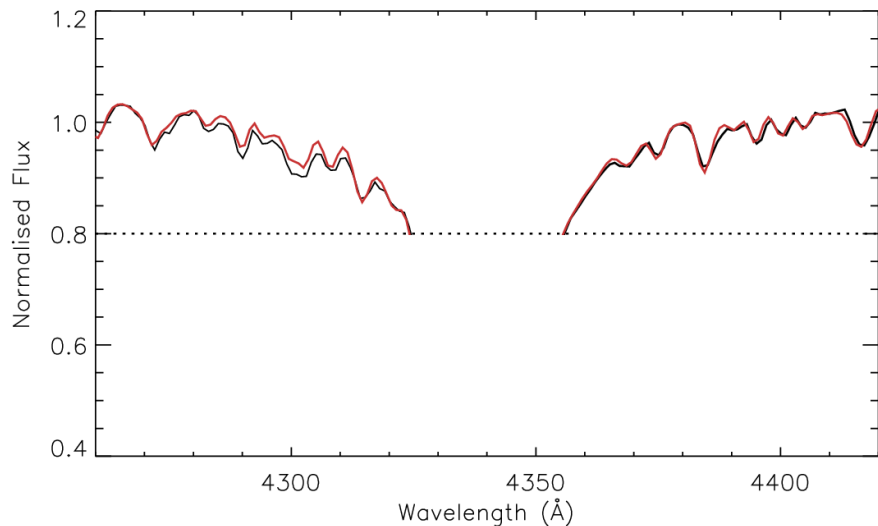
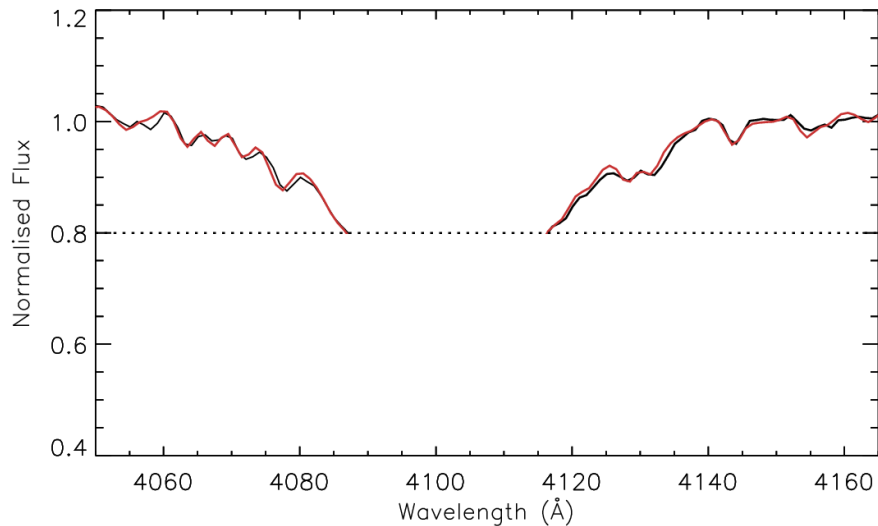
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(Guimarães 2006, Montesinos 2009)

# Stellar Parameters



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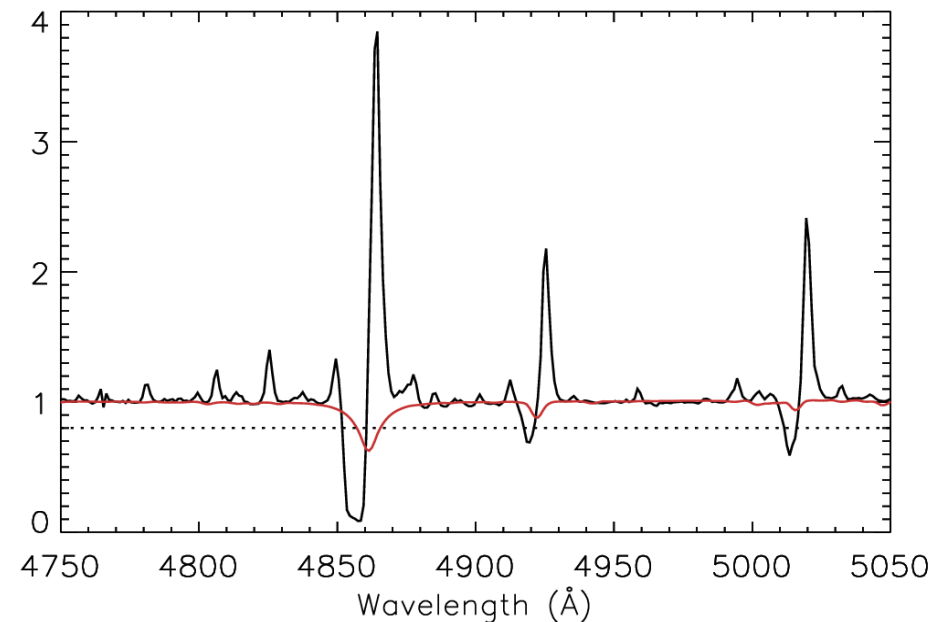


Determine Temperature and surface gravity

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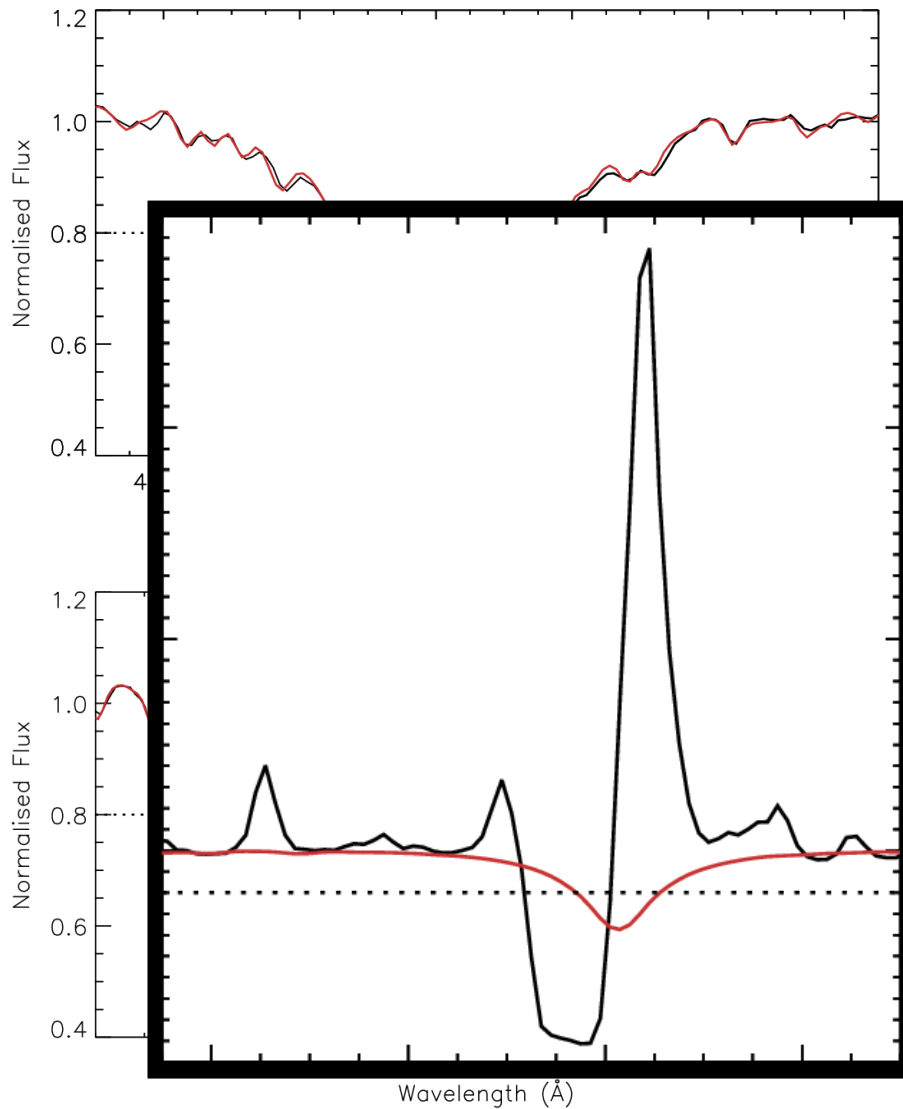


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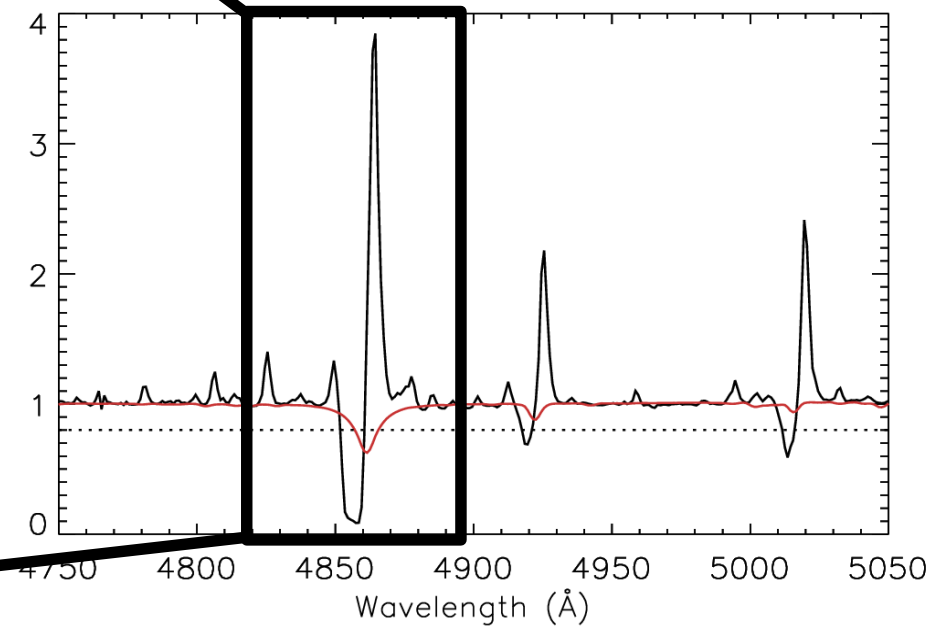


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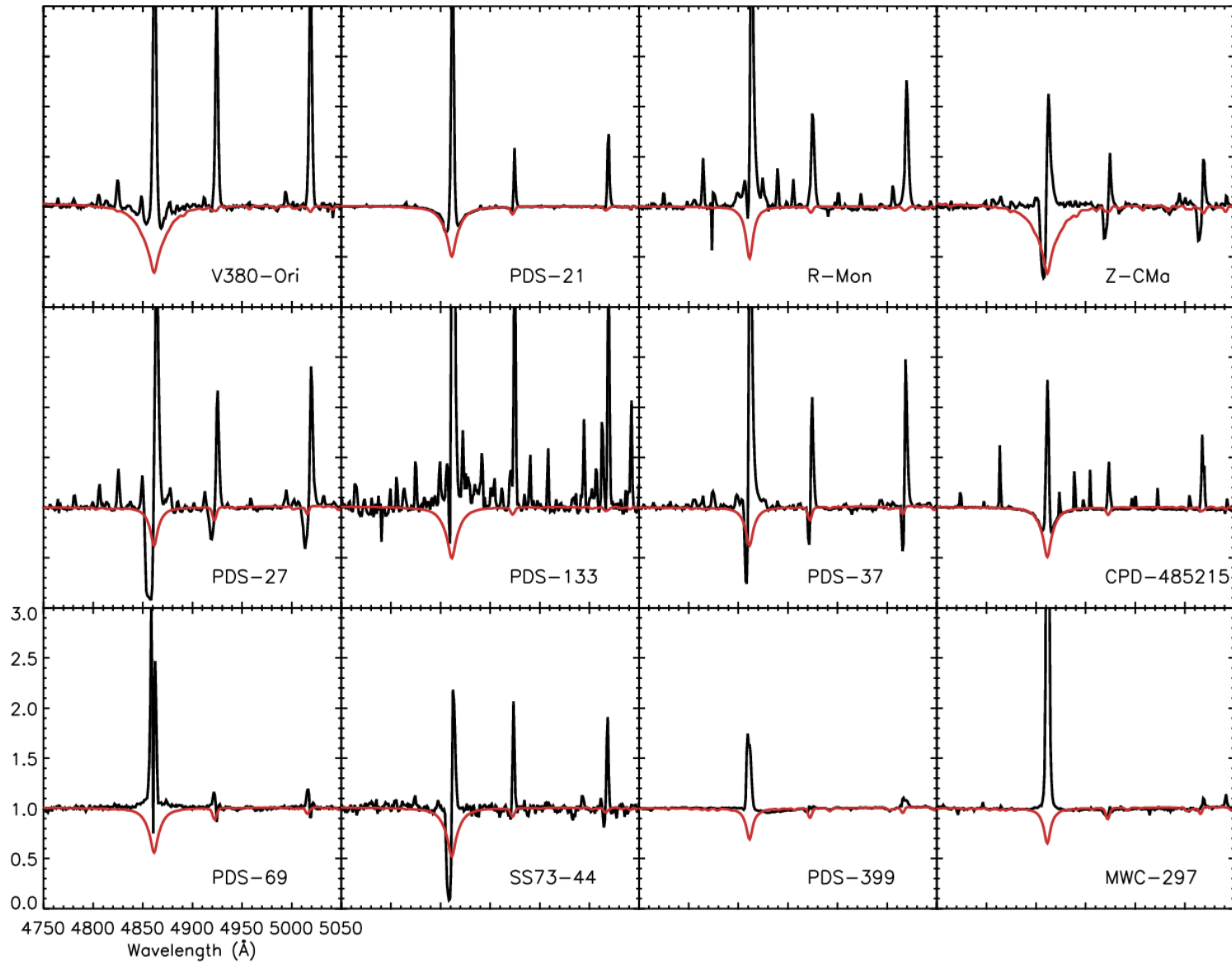


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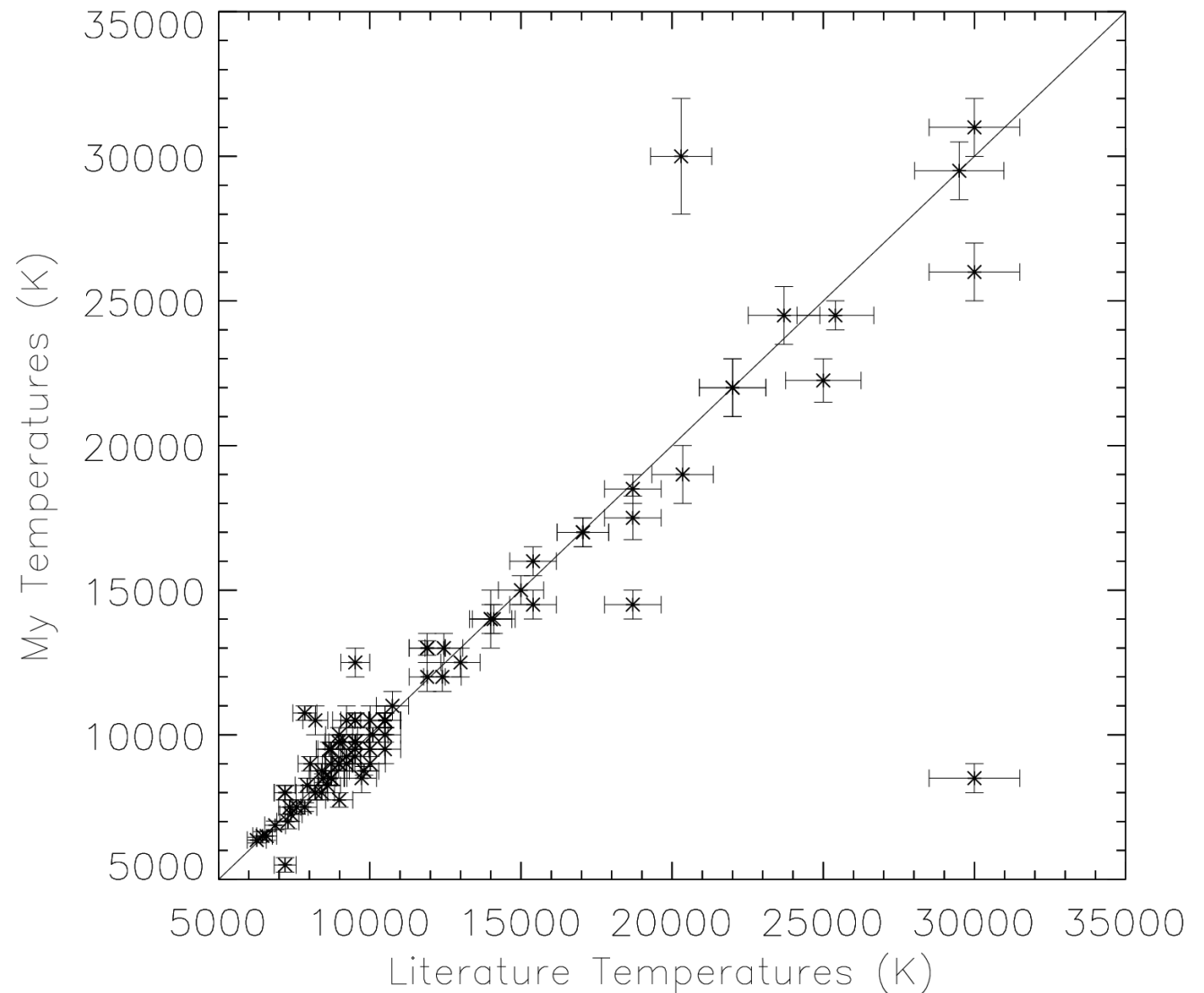


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Good Agreement!

- Only a few outliers



# Stellar Parameters



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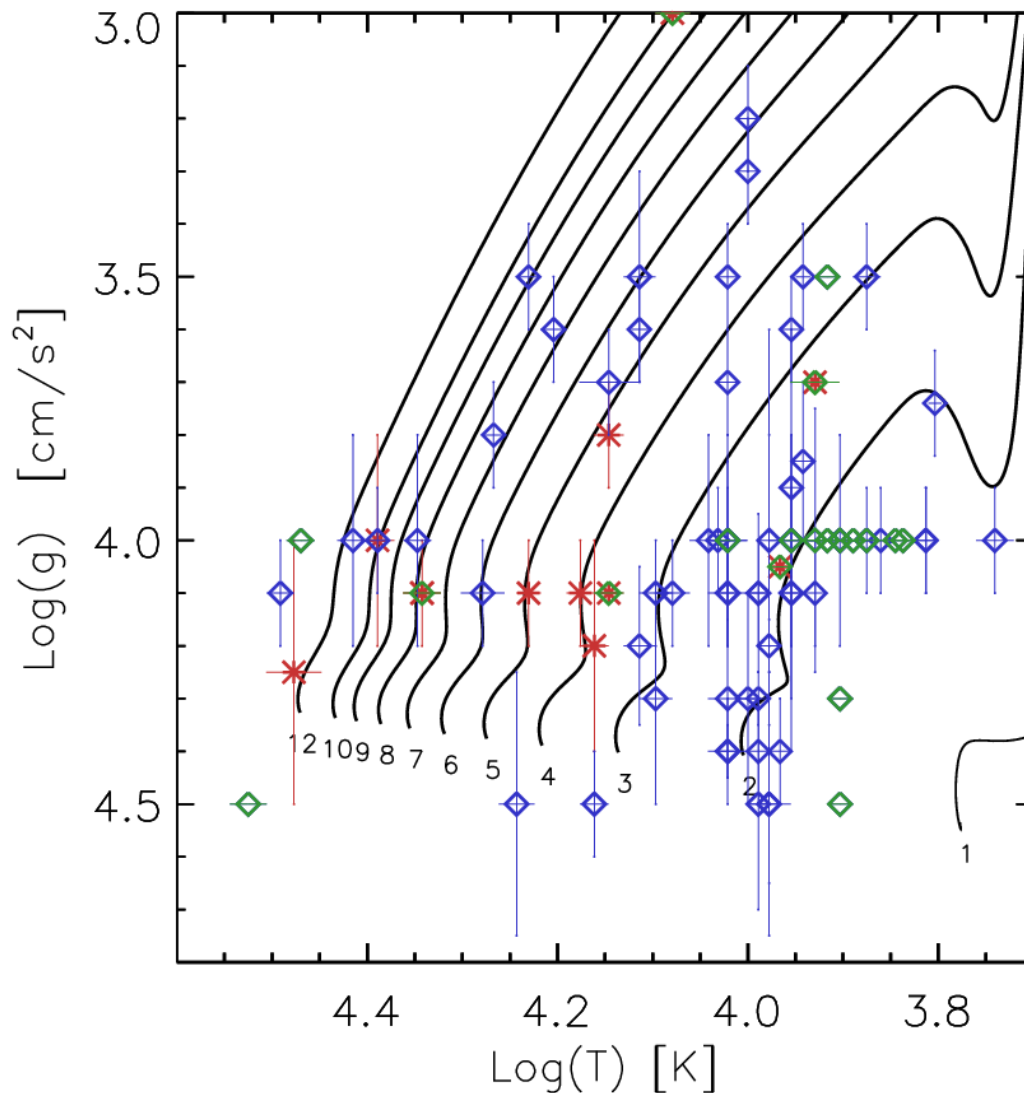
Mass and Radius

# Stellar Parameters



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Plot Temperature and  $\log(g)$ :

- Use PMS tracks of Bressan et al. (2012)
- Siess et al. (2000) and Yi et al. (2000) are also appropriate
- Dominated by T and Log(g) errors

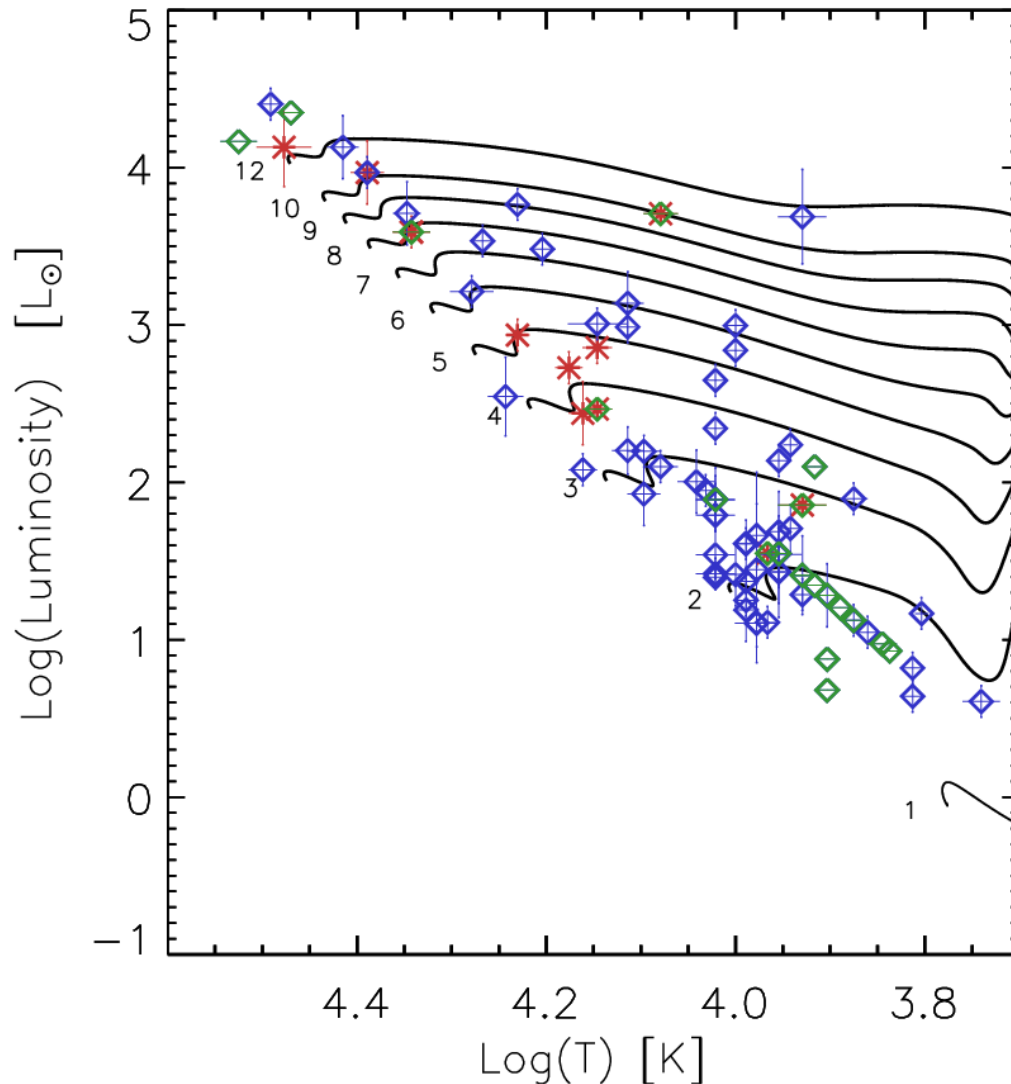


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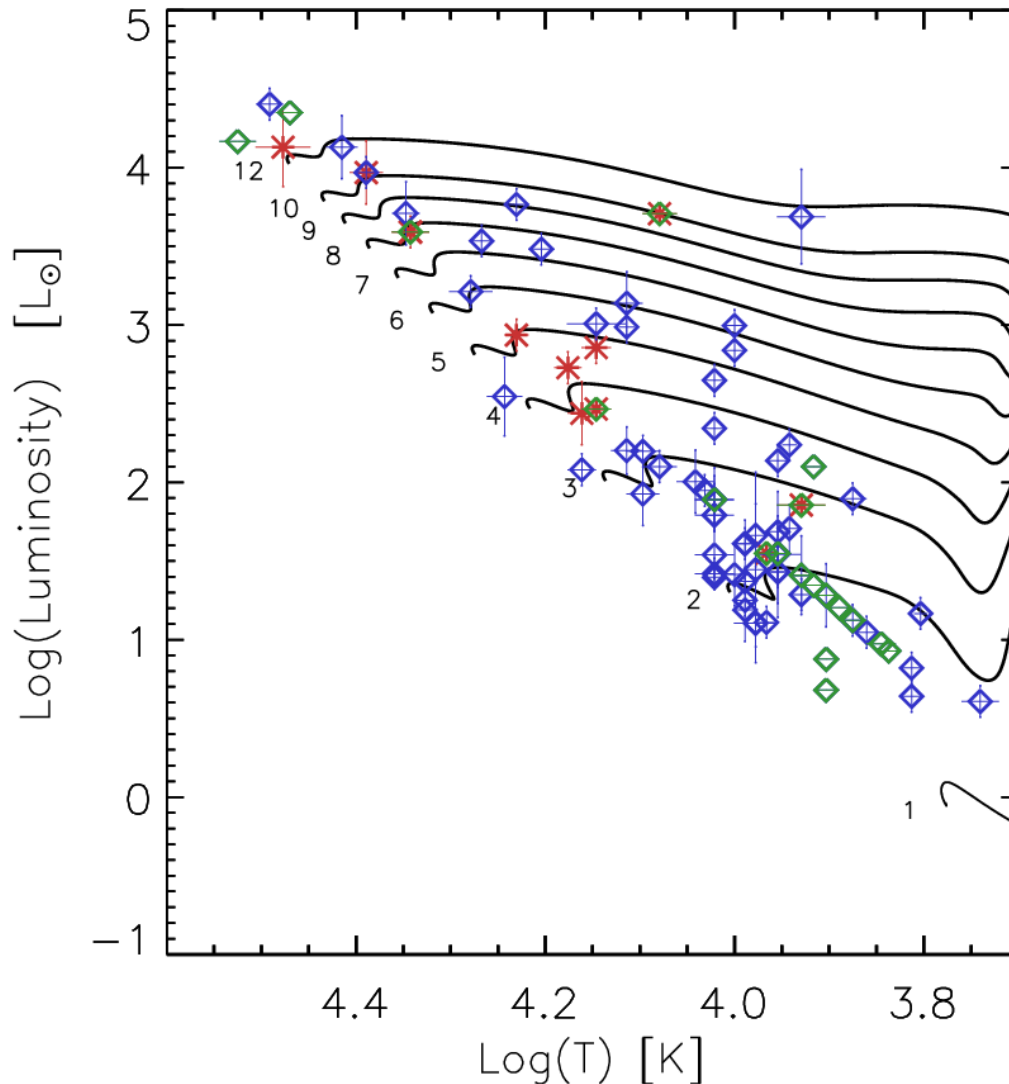
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- Can also be translated into a Luminosity vs. Temperature plot
- Helps with  $A_v$  and Distance estimates

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- Can also be translated into a Luminosity vs. Temperature plot
- Helps with  $A_v$  and Distance estimates
- Use known photometry to constrain luminosity/radius in cases where  $\log(g)$  is uncertain.

# Accretion Rates



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**Accretion  
Rates**

# Accretion Rates



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Why are they important?

# Accretion Rates



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Why are they important?



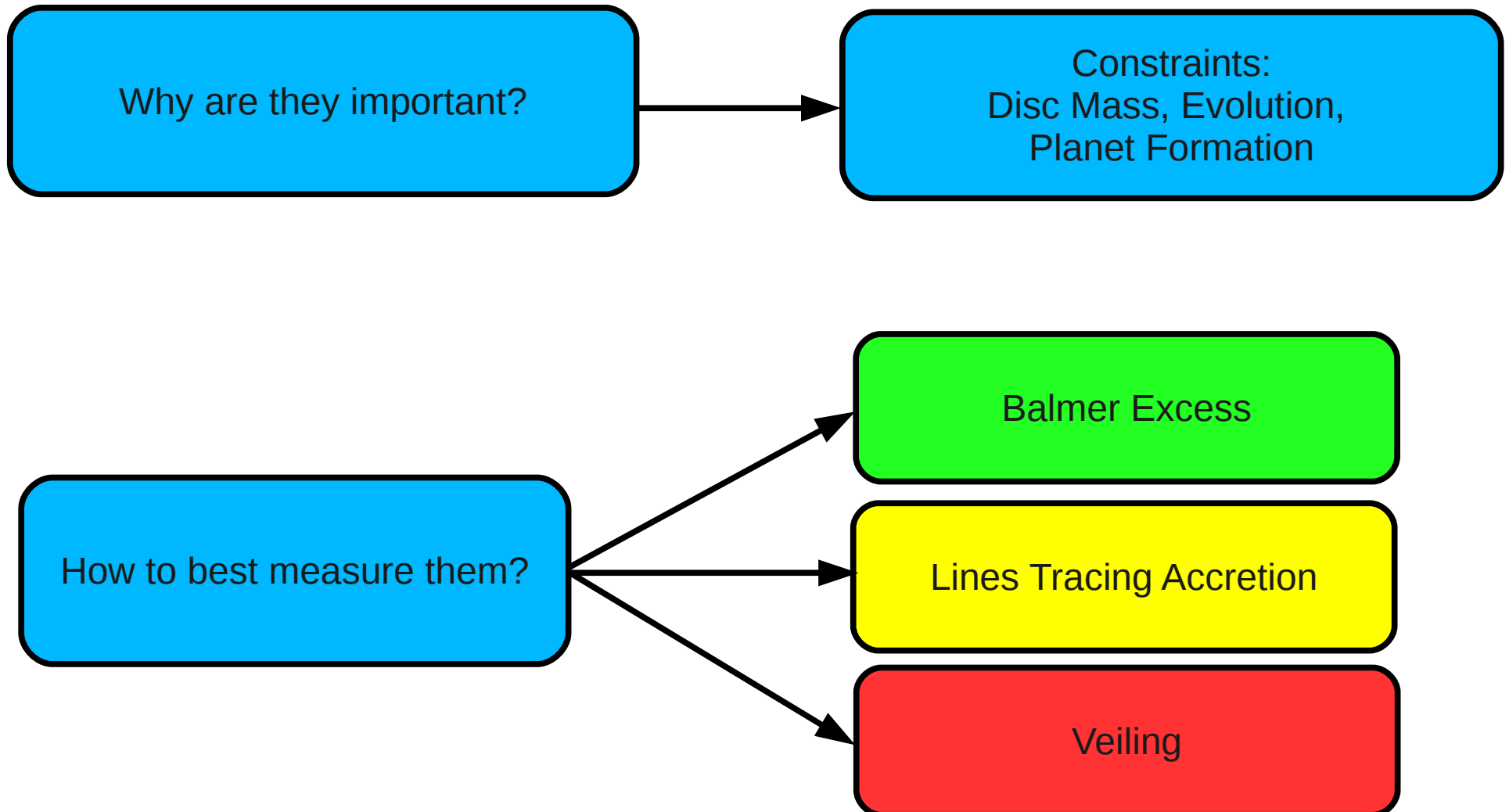
Constraints:  
Disc Mass, Evolution,  
Planet Formation

# Accretion Rates



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## Accretion Rates Balmer Excess

# Balmer Excess

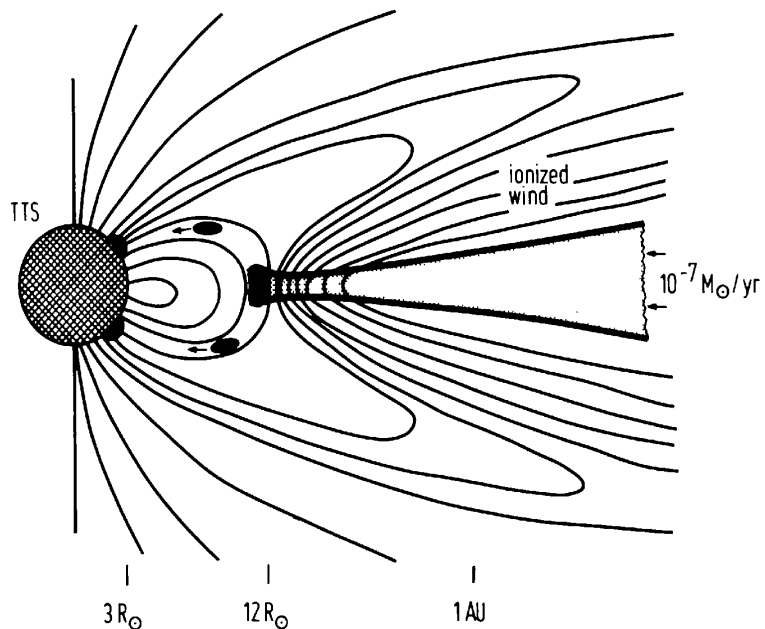


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Assume Magnetospheric Accretion:

First, we need to go through the theory...  
-- Use modeling of Calvet & Gullbring (1998)



Camenzind (1990)



# Balmer Excess

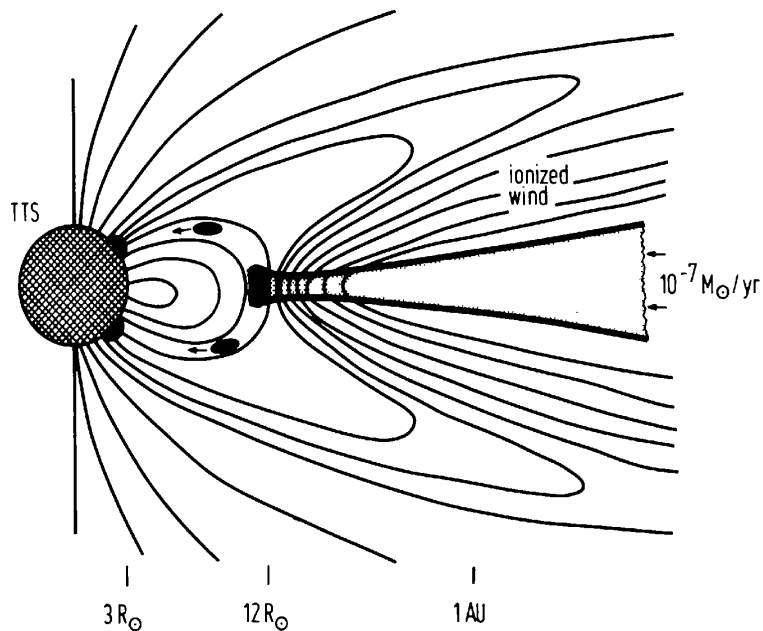


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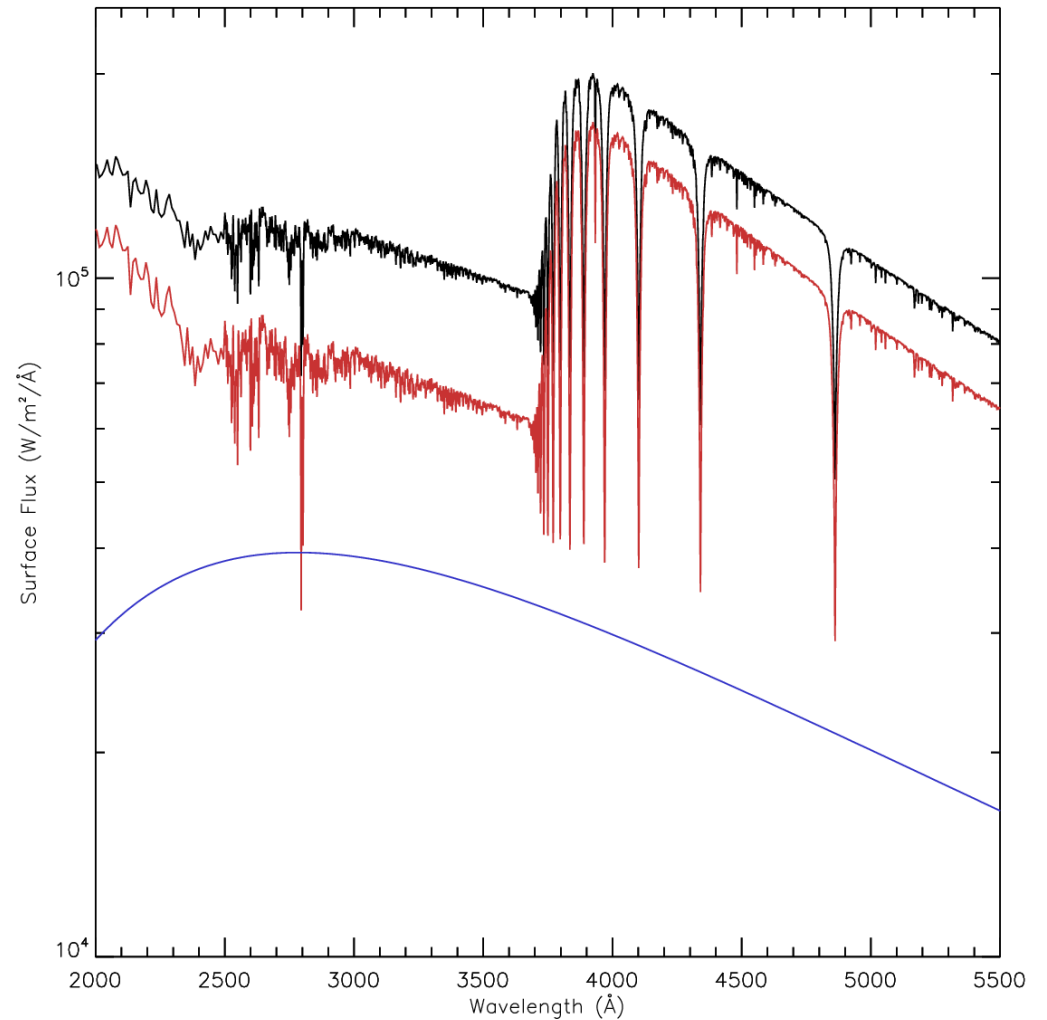
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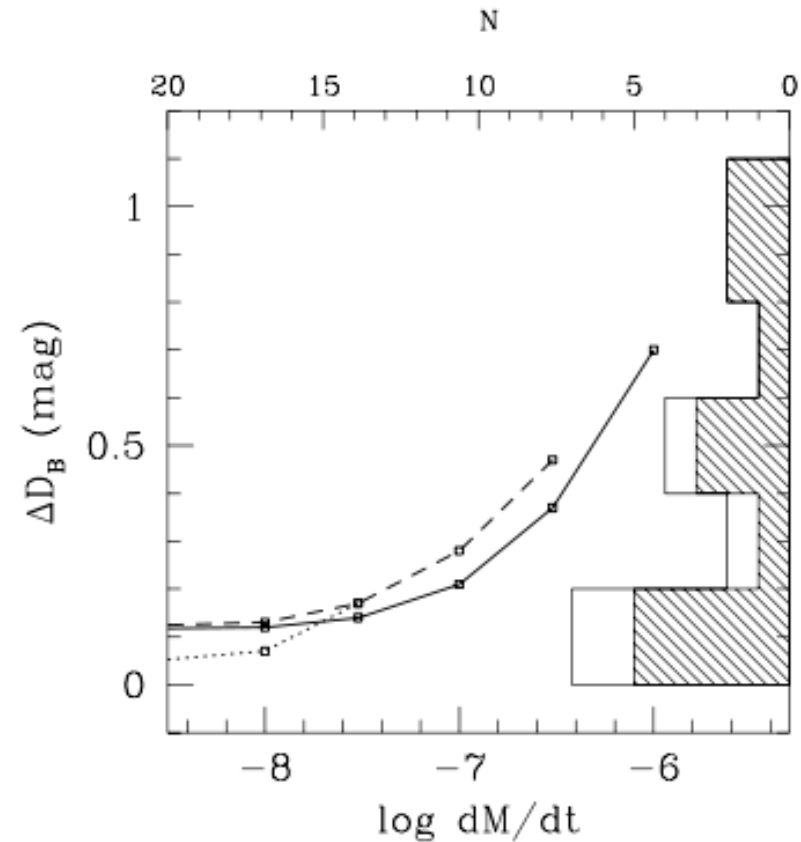
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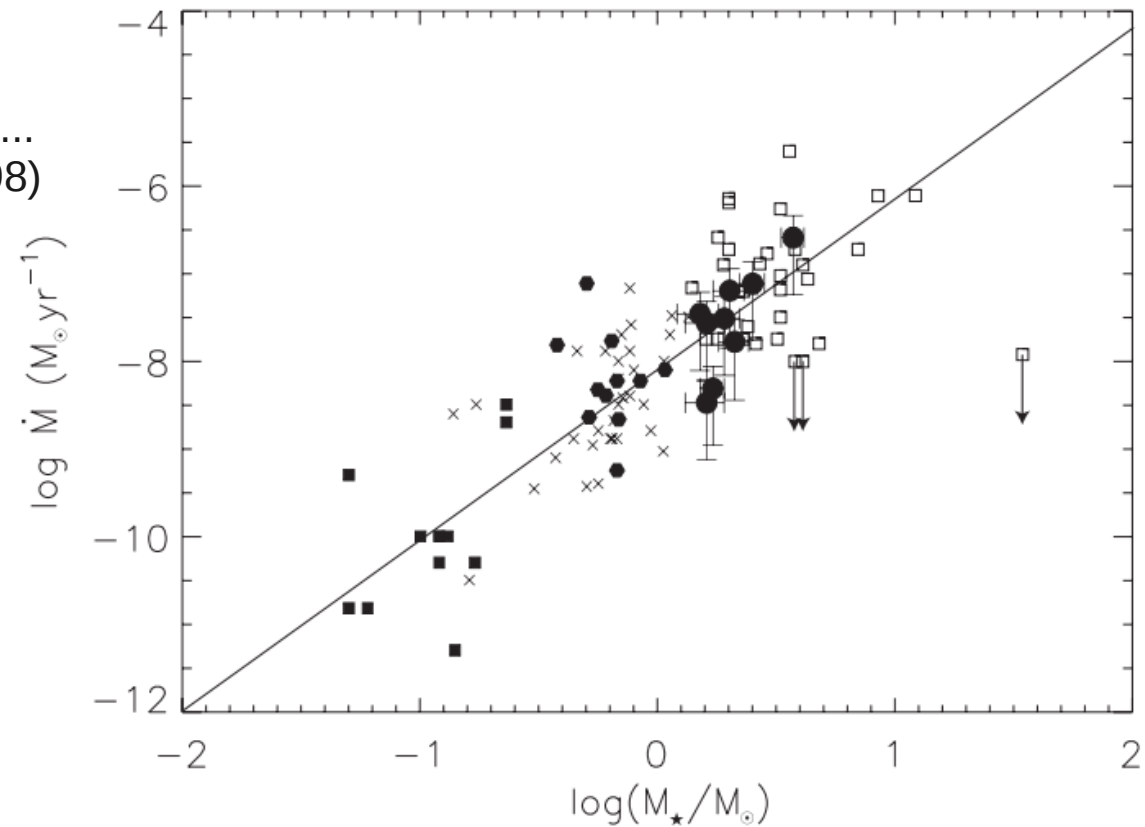
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-- Measurements under this assumption:  
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Donehew & Brittain et al. (2011)

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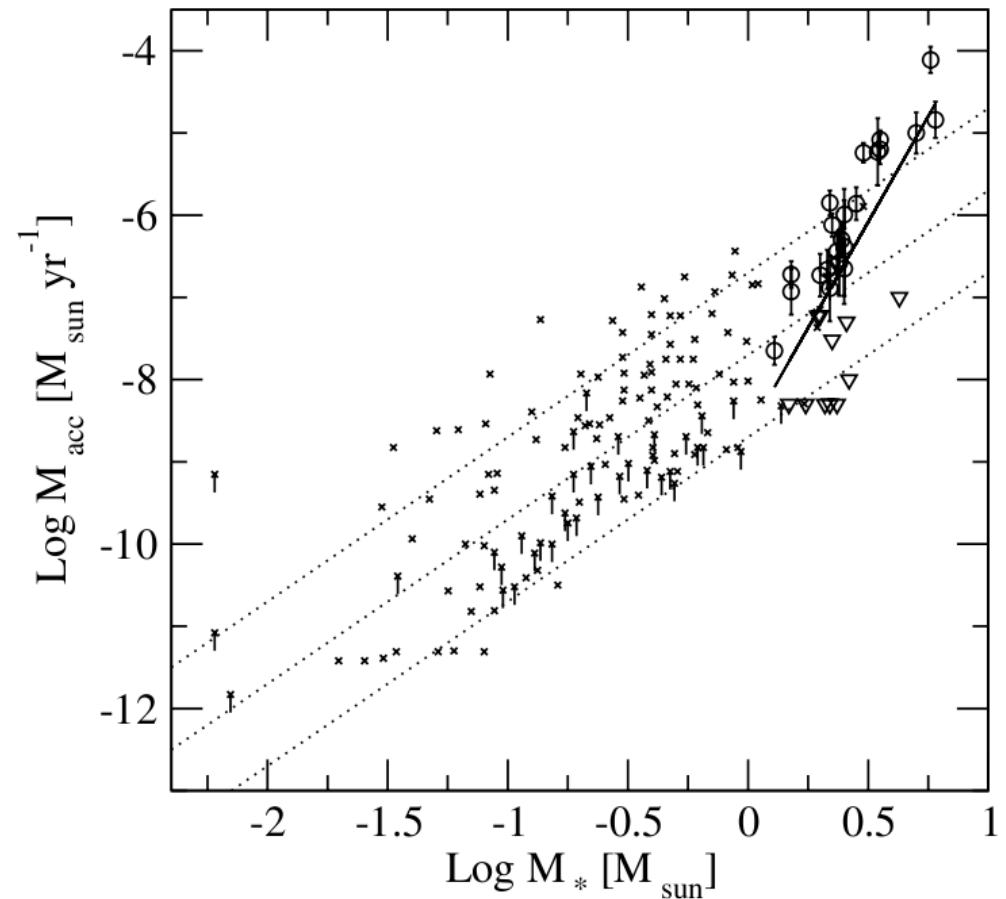
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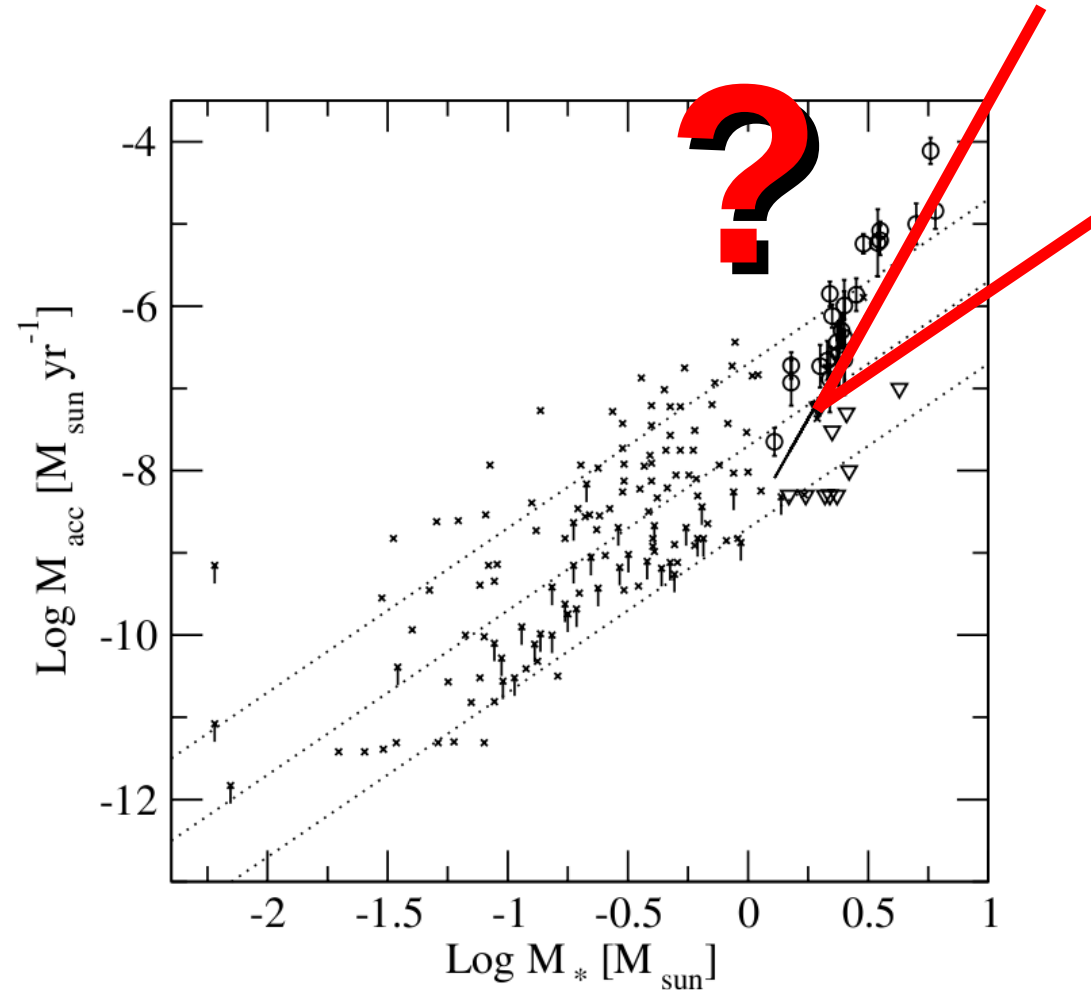
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Can this be applied to HBes?

- Particularly the early-type ones



Mendigutía et al. (2011)

# Balmer Excess



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Measurements

# Balmer Excess



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Process:

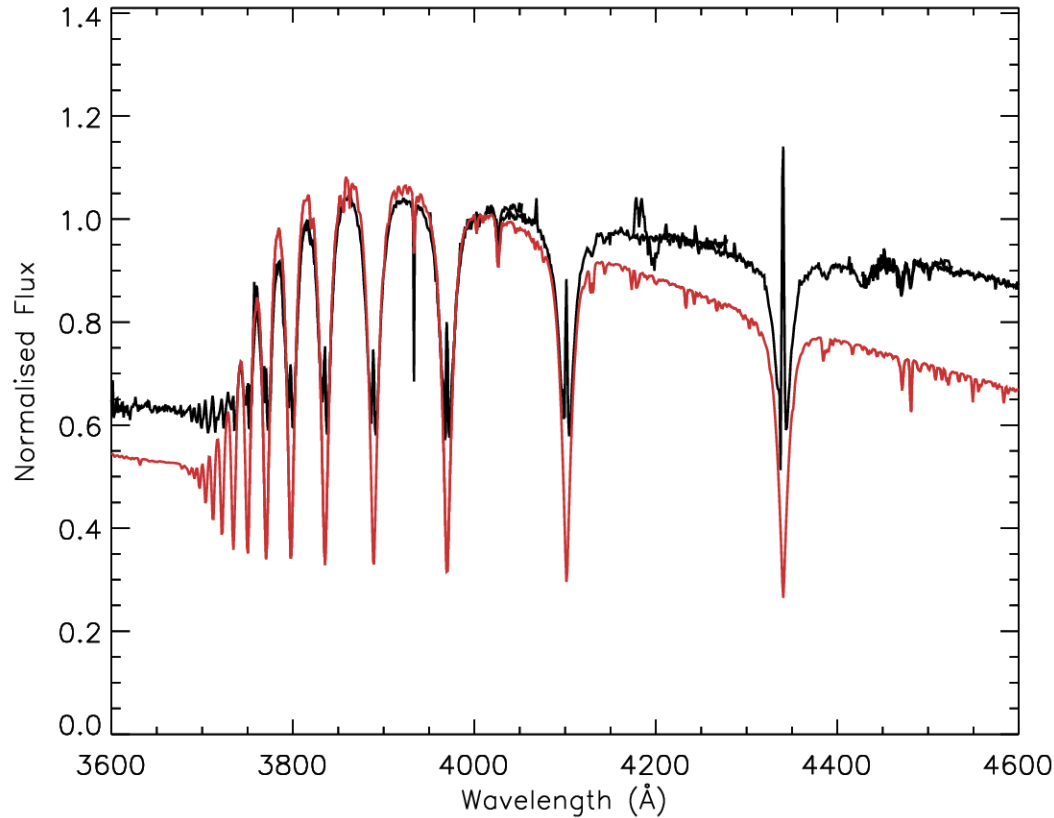
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# Balmer Excess



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Process:

- Mostly follow Donehew & Brittain (2011)
- Normalise spectra and model to 4000Å

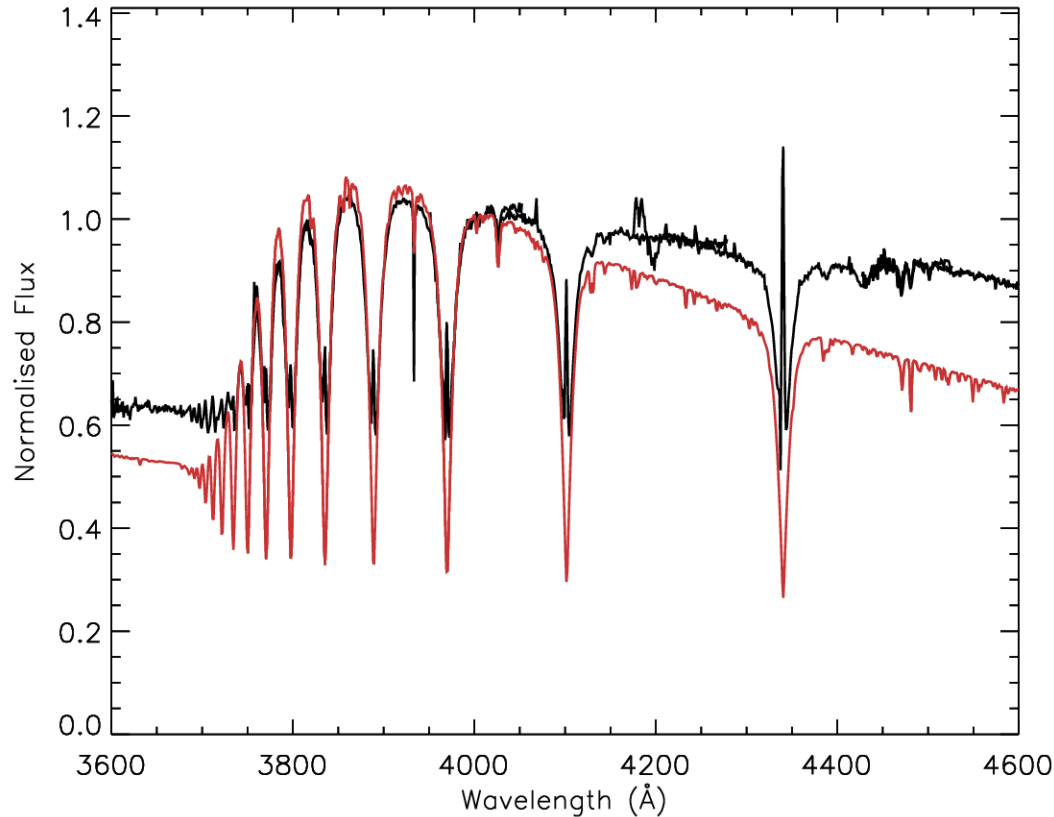


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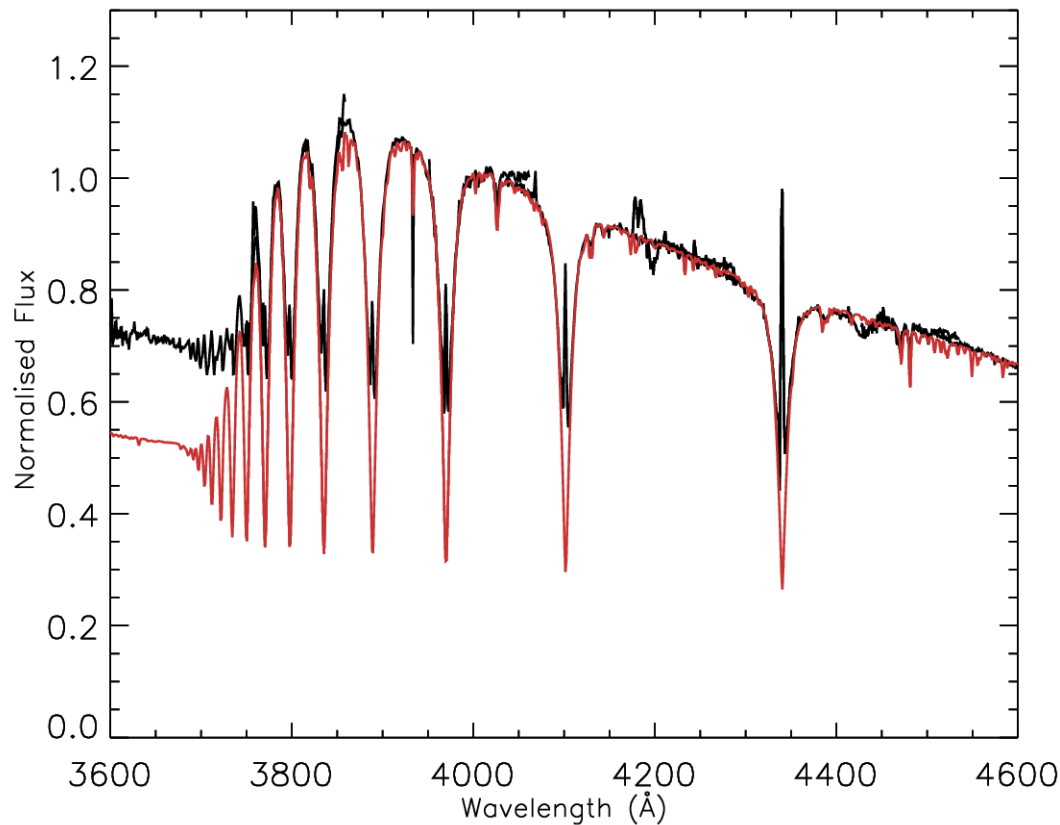
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- Adjust spectra using reddening law from Cardelli, Clayton & Mathis (1989)
  - Allows it to be reddening independent

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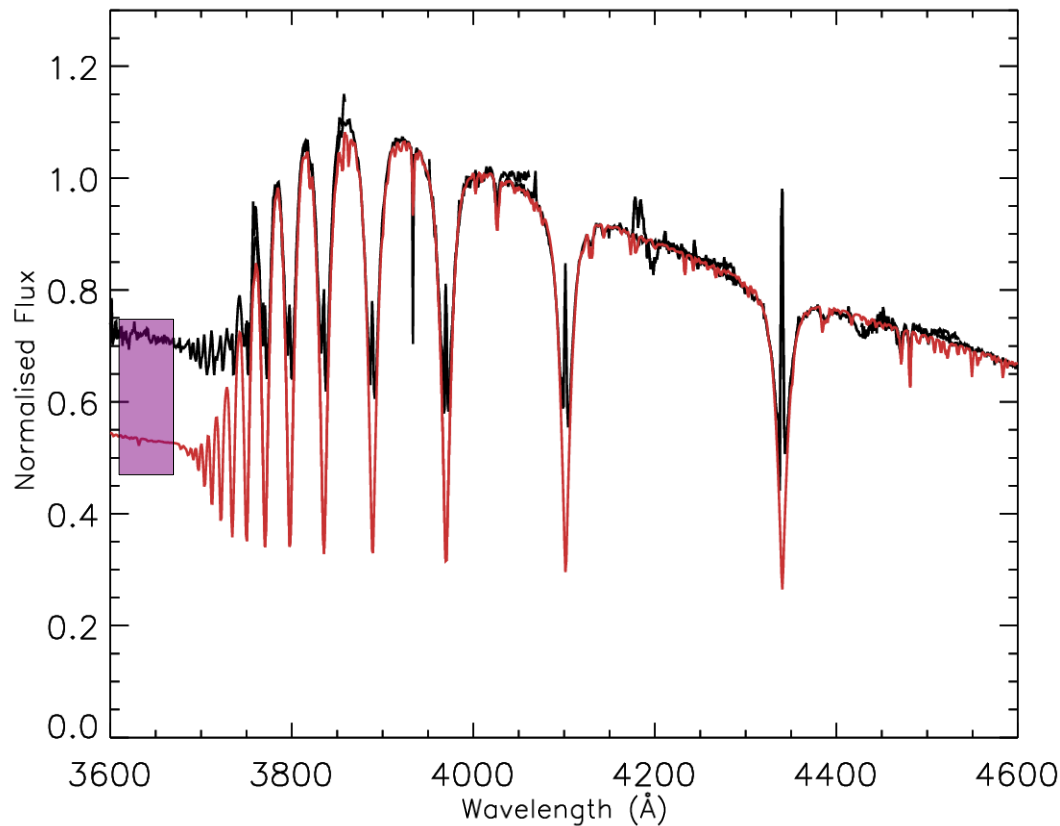
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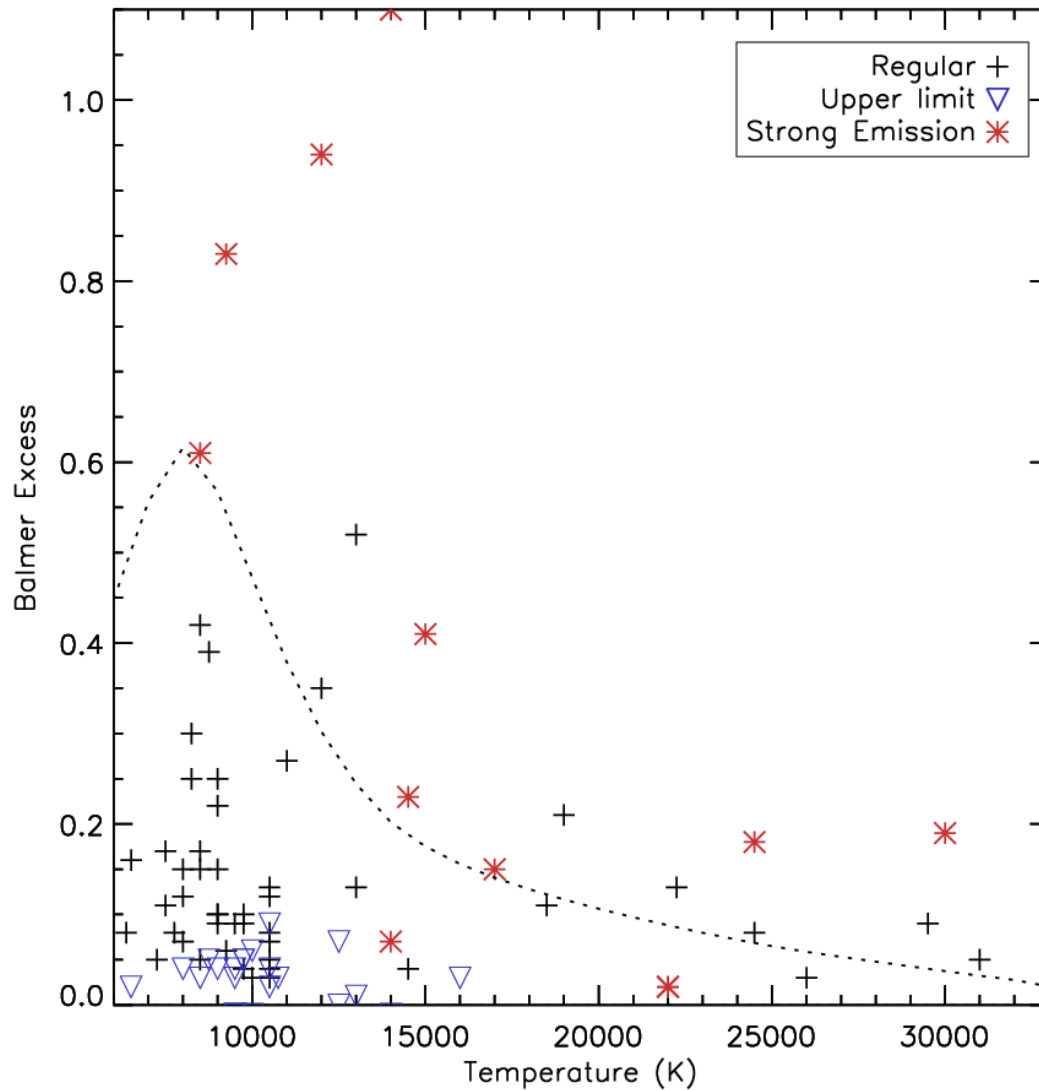
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- SED matches from 4000-4600Å
- Simply measure at around 3640Å
- Result!

# Balmer Excess



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Results so far:

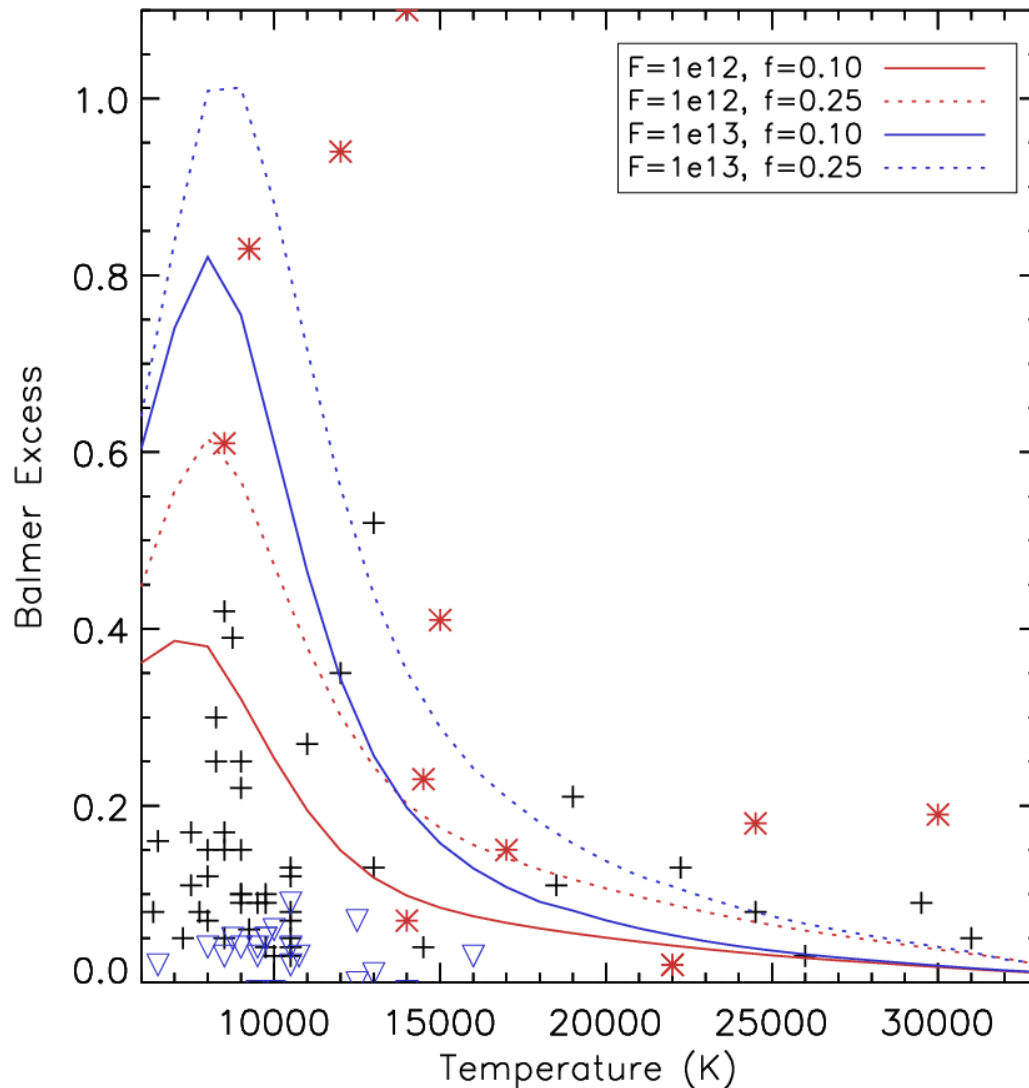
- See a large range in values
- Most HAe objects within MA regime
- Extreme emission objects mostly above the MA limit

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$$L = (\mathcal{F} + F_*)A = \zeta G \frac{\dot{M}M}{R} + F_* A = \zeta L_{\text{acc}} + F_* A$$

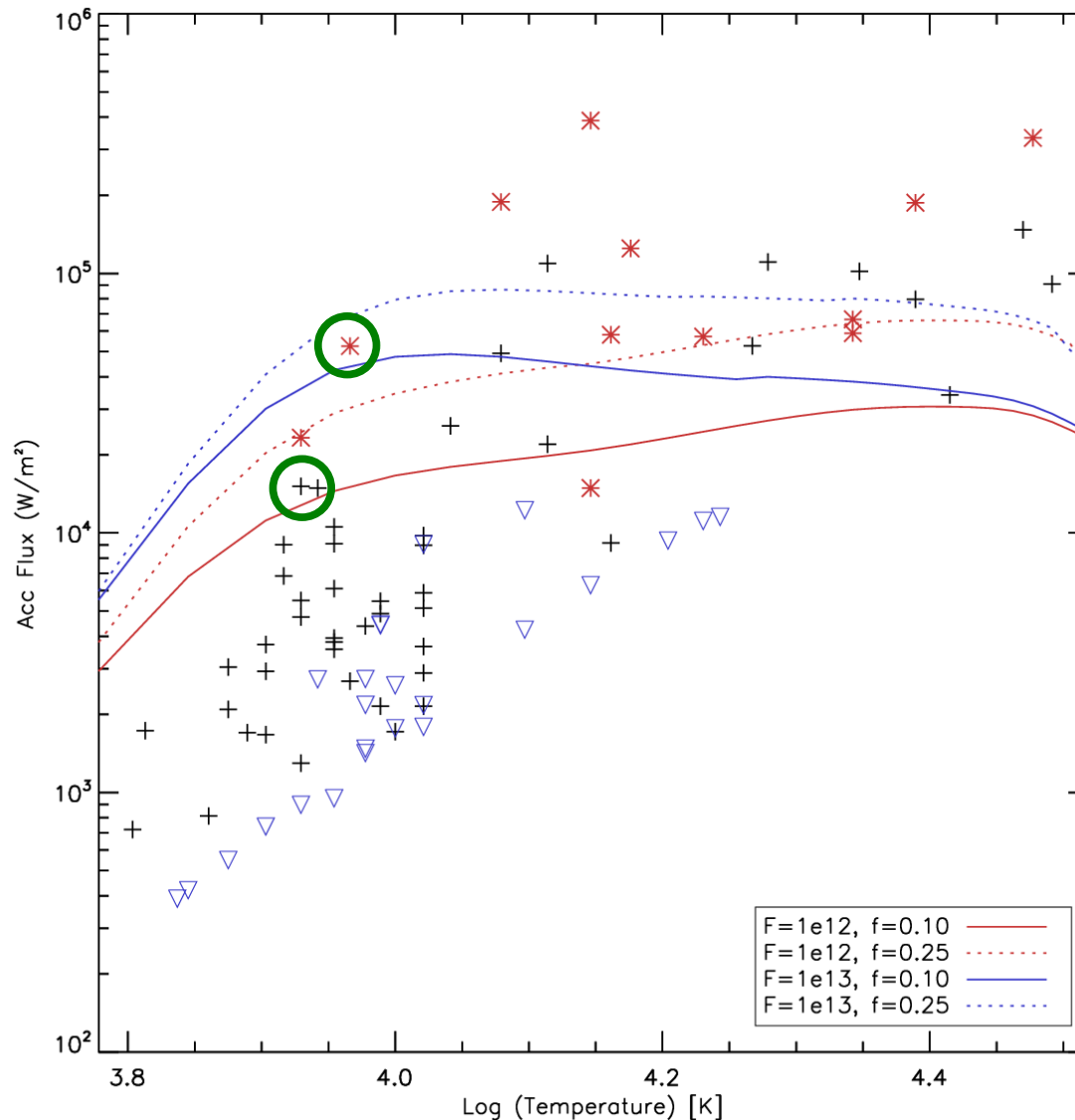
- Even with adjustments
  - Many lie above the limit; can we justify the change?

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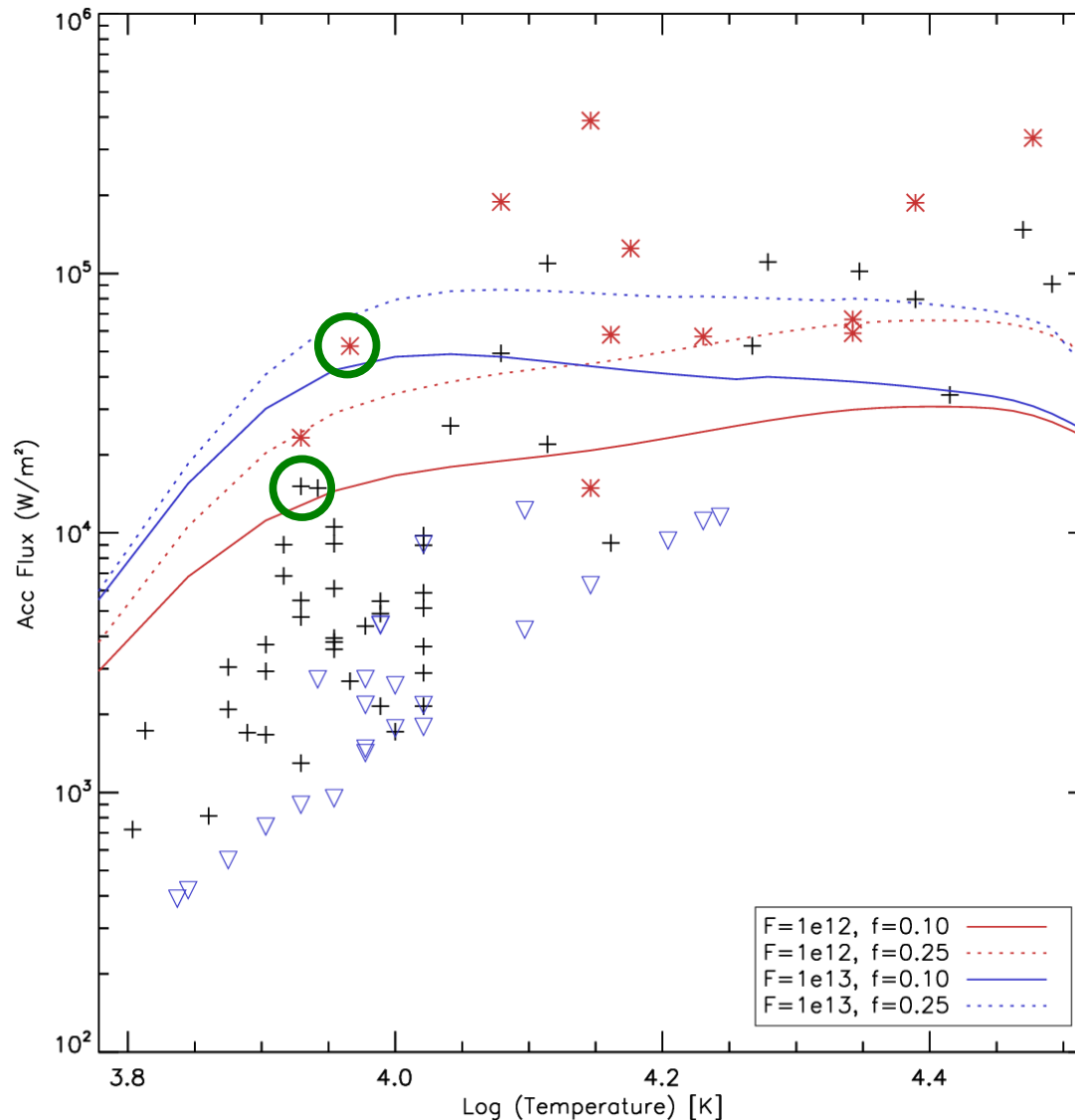
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- Even with adjustments:
  - Many lie above the limit; can we justify the change?
  - Alecian et al. (2013); 93% of H AeBes show no direct mag-field.
  - Multiple columns, Ingleby (2013)

# Balmer Excess



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Mass accretion as a function  
of stellar mass

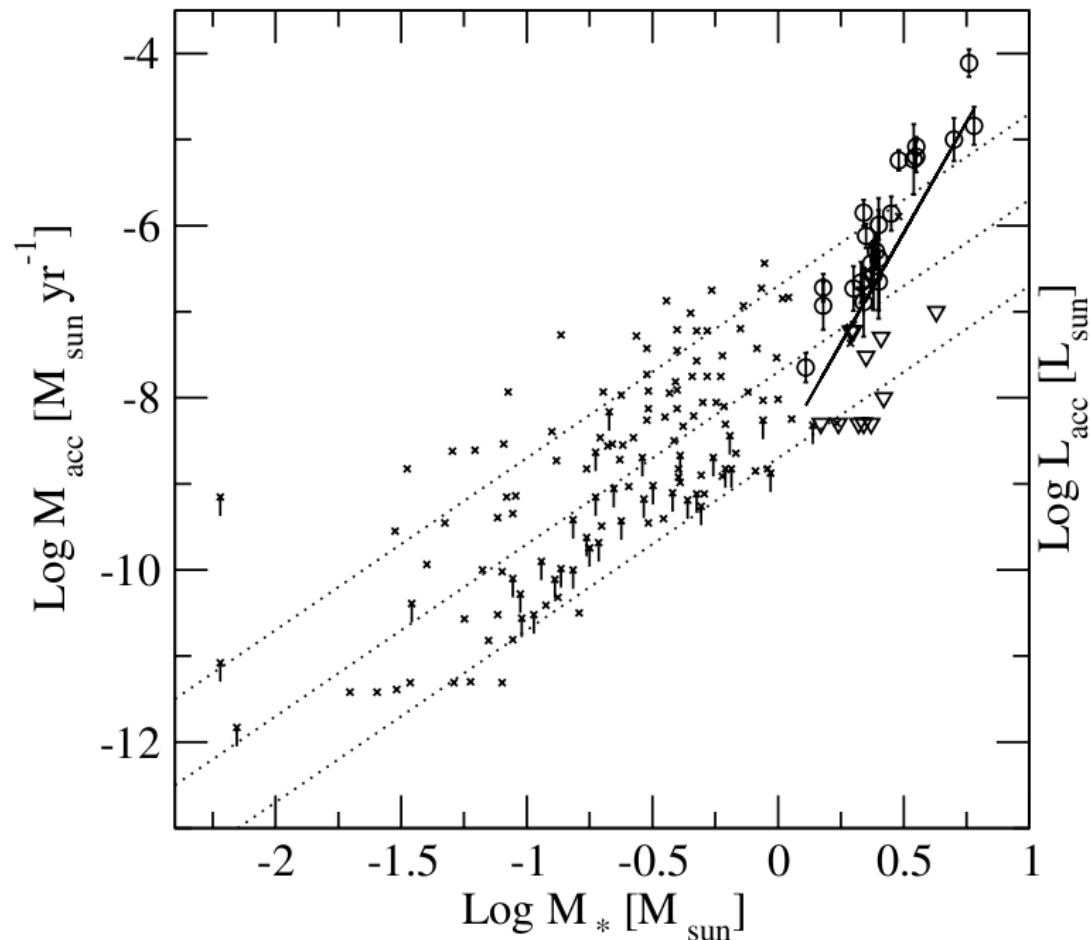


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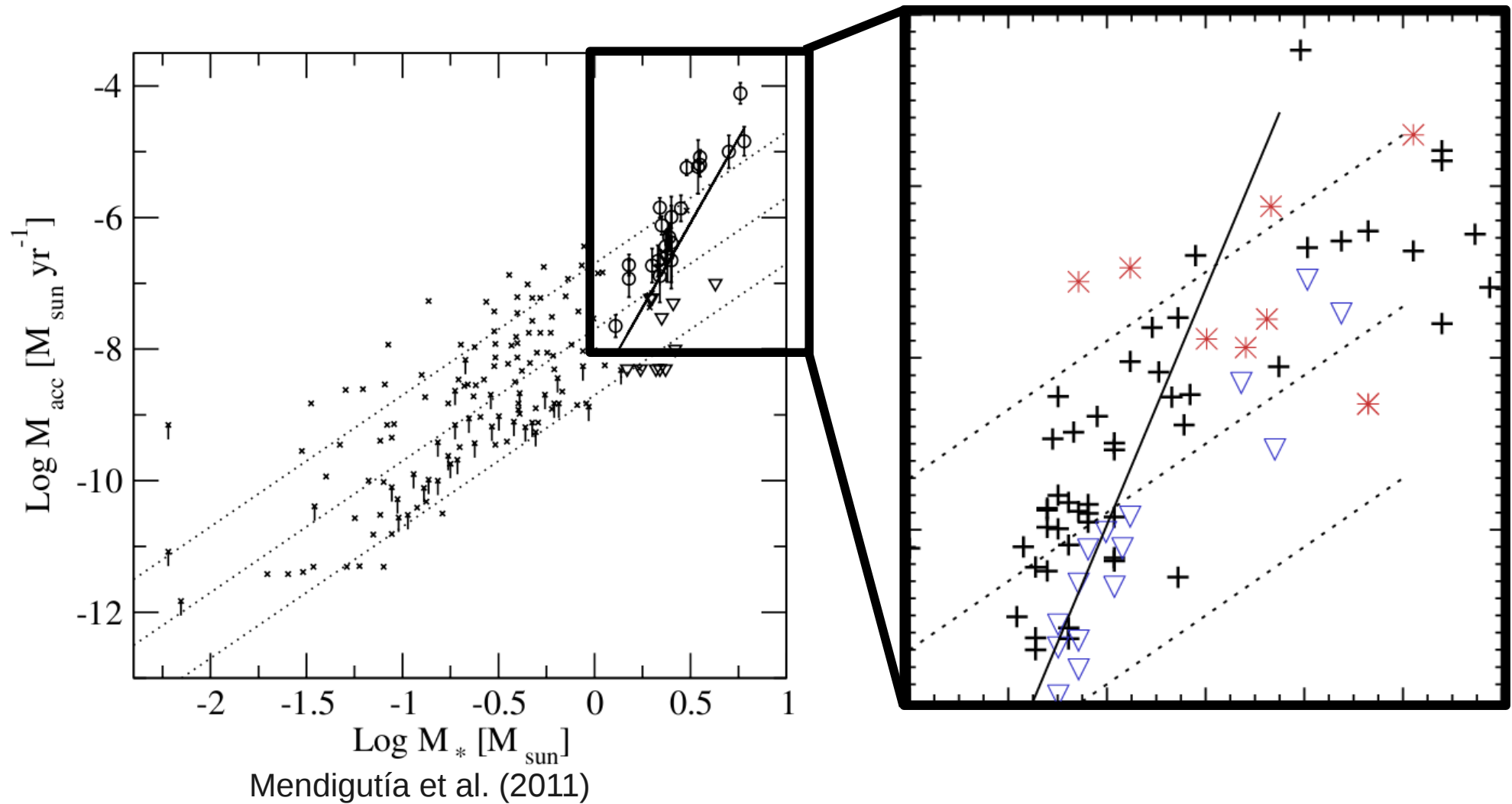
Mendigutía et al. (2011)

# Balmer Excess



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**Accretion Rates  
Lines Tracing  
Accretion**

# Lines Tracing Accretion

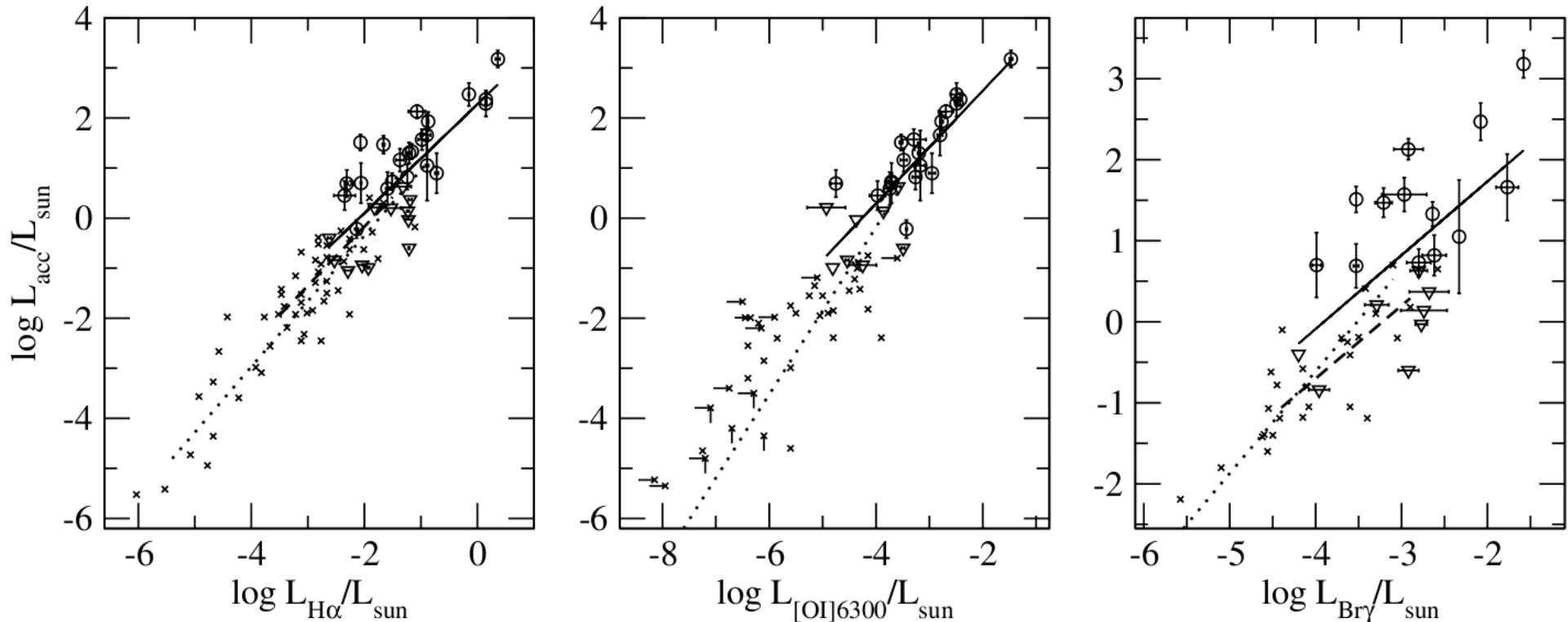


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Relationship between line luminosity and accretion luminosity well established for TTS

-- Relationships extended to the HAes



Mendigutía et al. (2011) – With data from Fang et al. (2009), Herczeg & Hillenbrand (2009) and Calvet et al. (2004)

# Lines Tracing Accretion



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H alpha

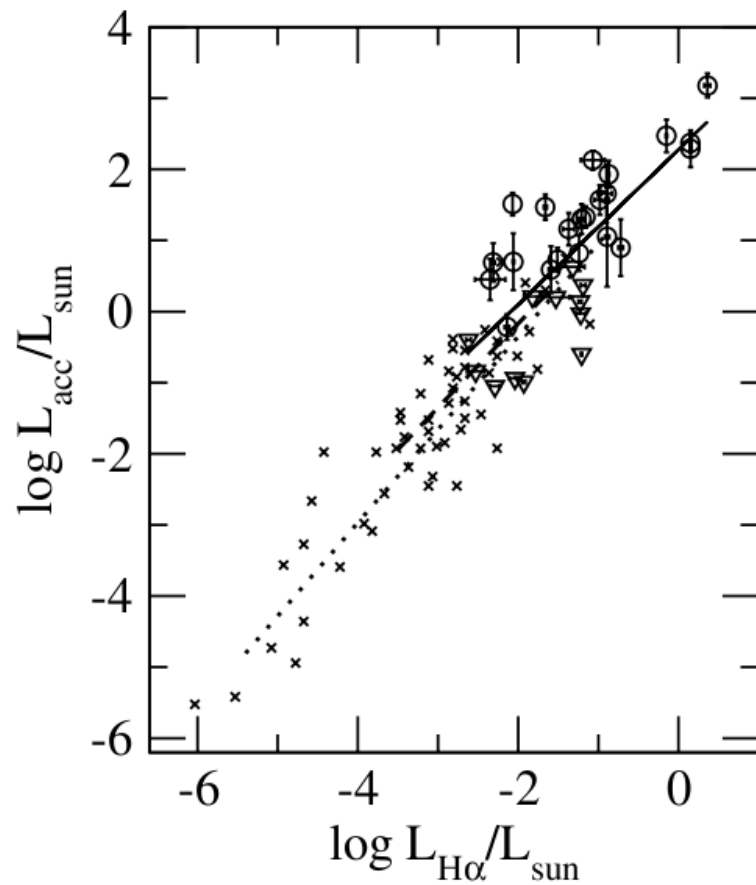
# Lines Tracing Accretion



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H alpha (Balmer Series):



Mendigutía et al. (2011)

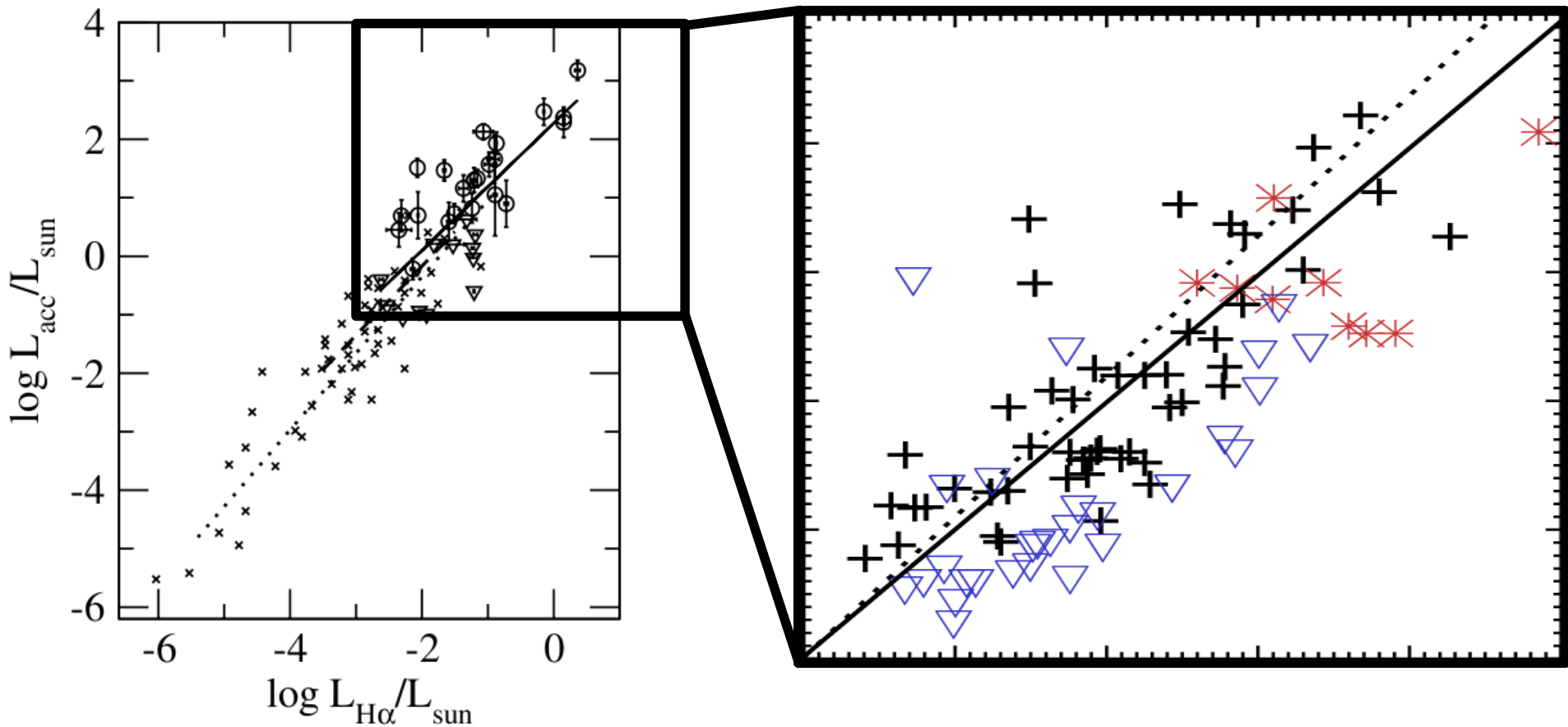
# Lines Tracing Accretion



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H alpha (Balmer Series):



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# Lines Tracing Accretion



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Brackett Gamma



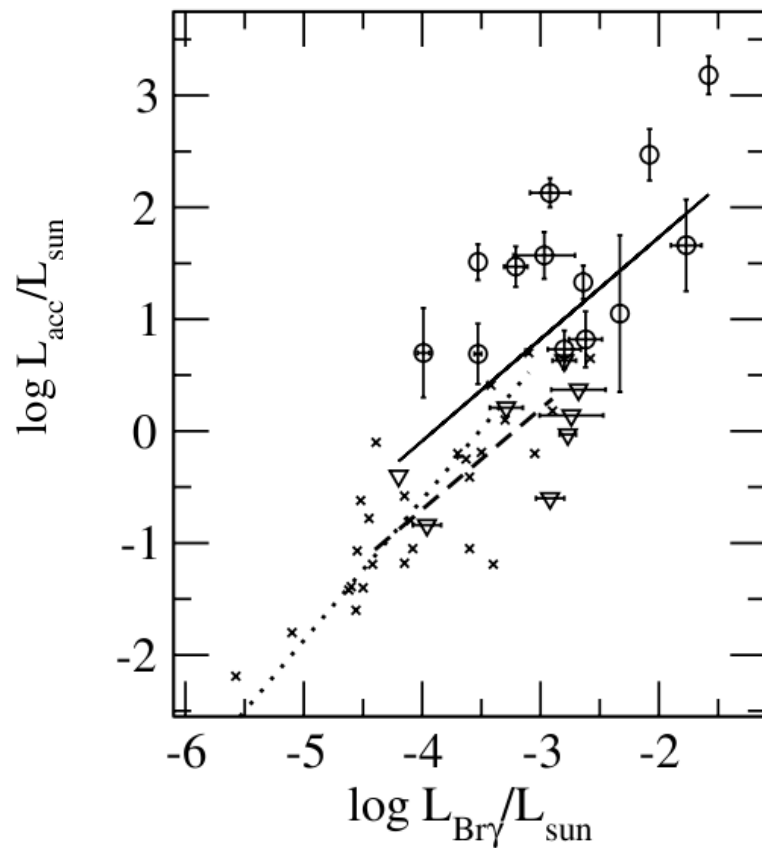
# Lines Tracing Accretion



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Brackett Gamma Line:



Mendigutía et al. (2011)

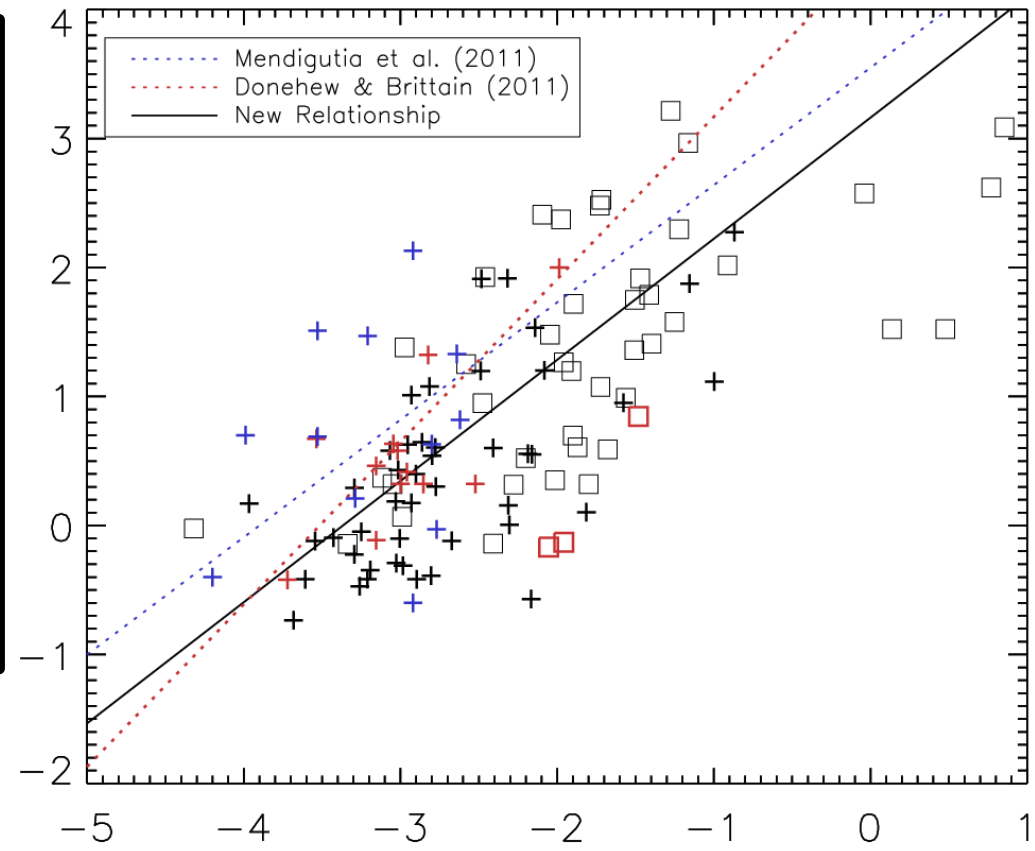
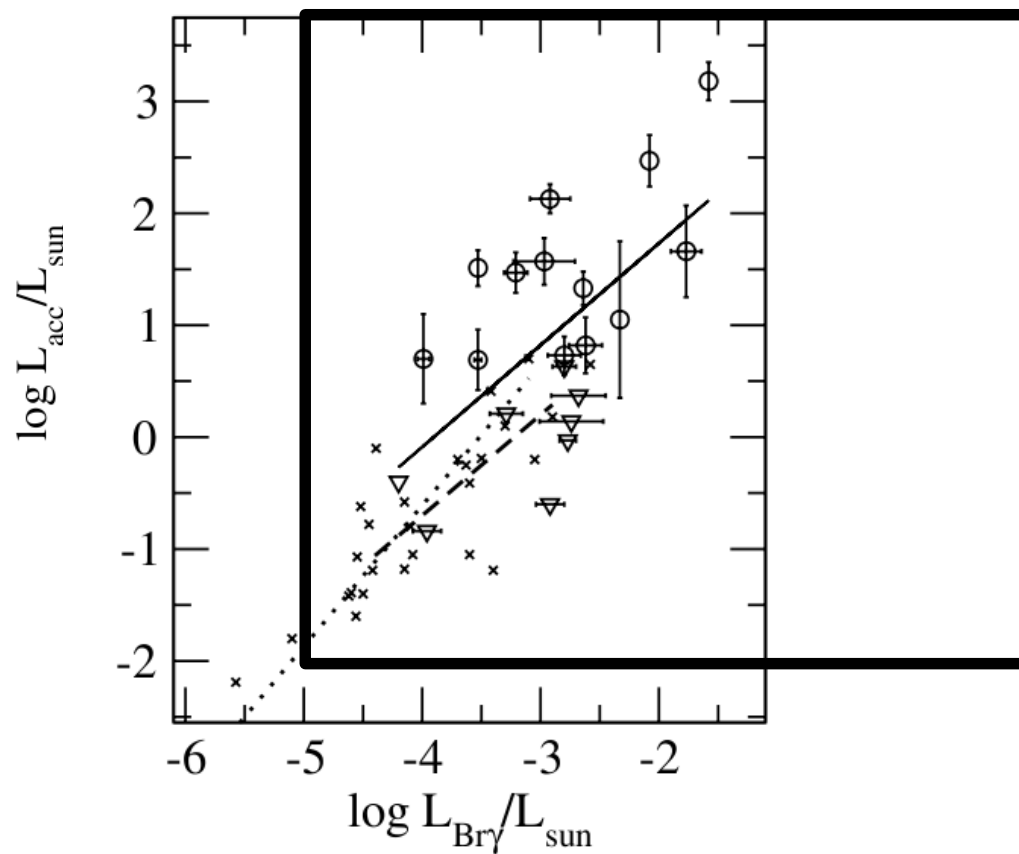
# Lines Tracing Accretion



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Brackett Gamma Line:



Mendigutía et al. (2011)

**Next?**



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**Next?**

# What is Next?



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Other Known Tracers

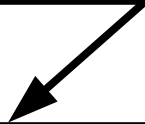
# What is Next?



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Other Known Tracers



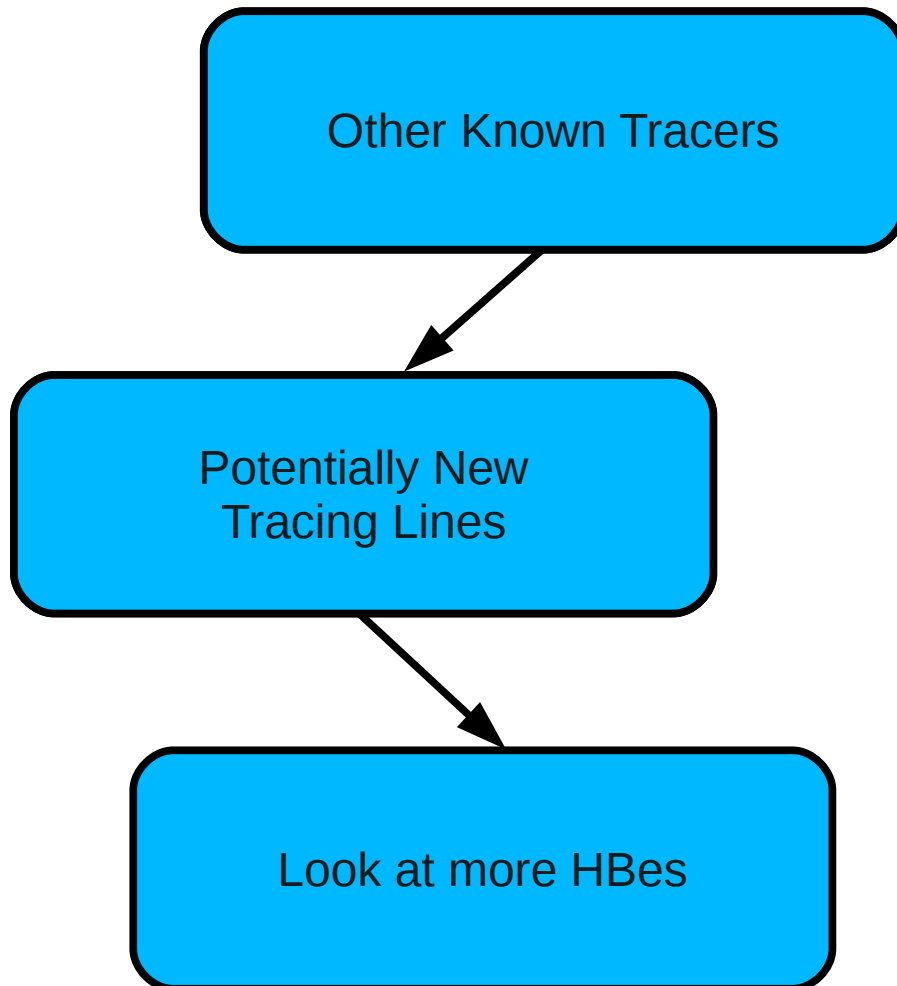
Potentially New  
Tracing Lines

# What is Next?



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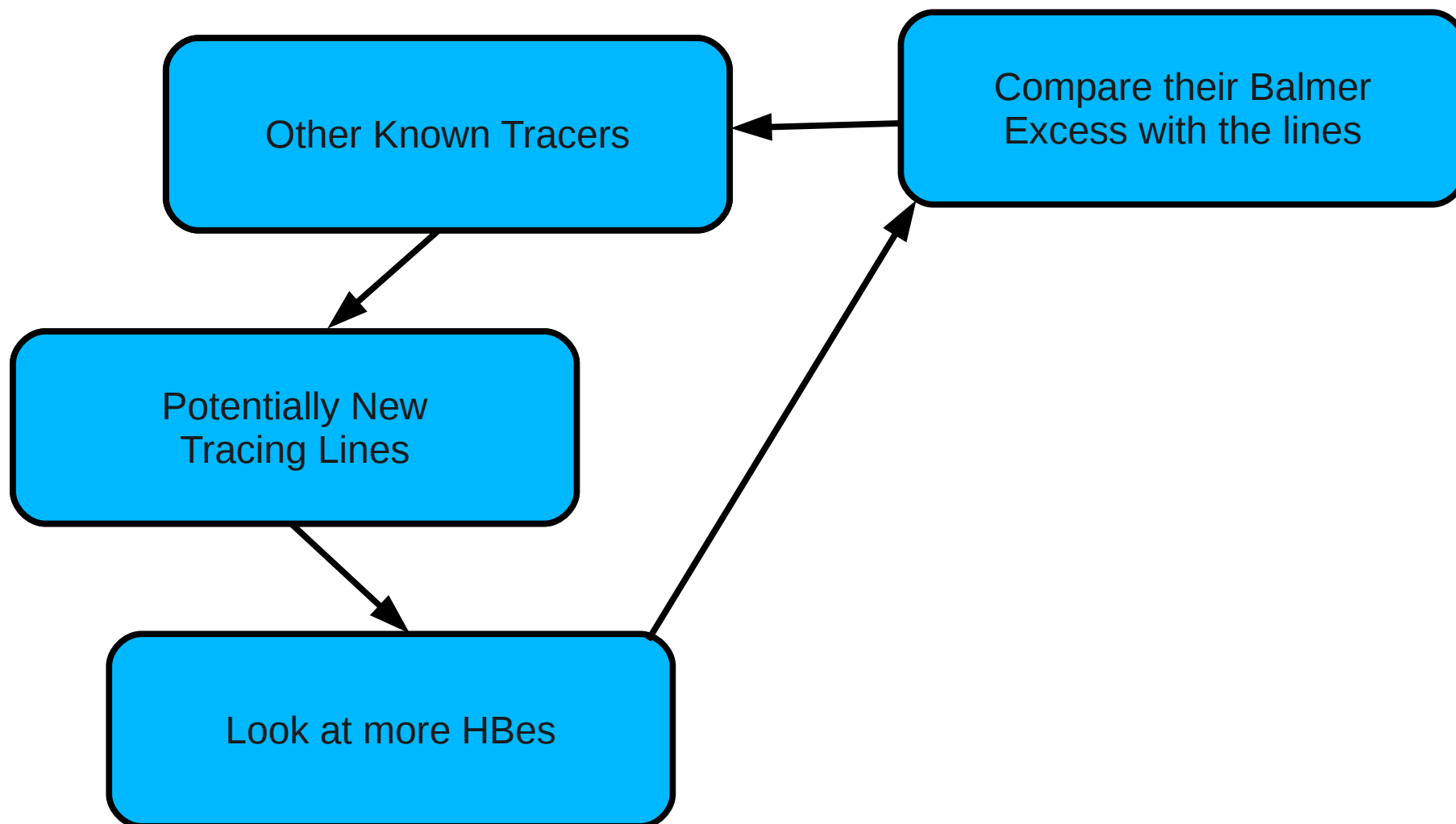


# What is Next?



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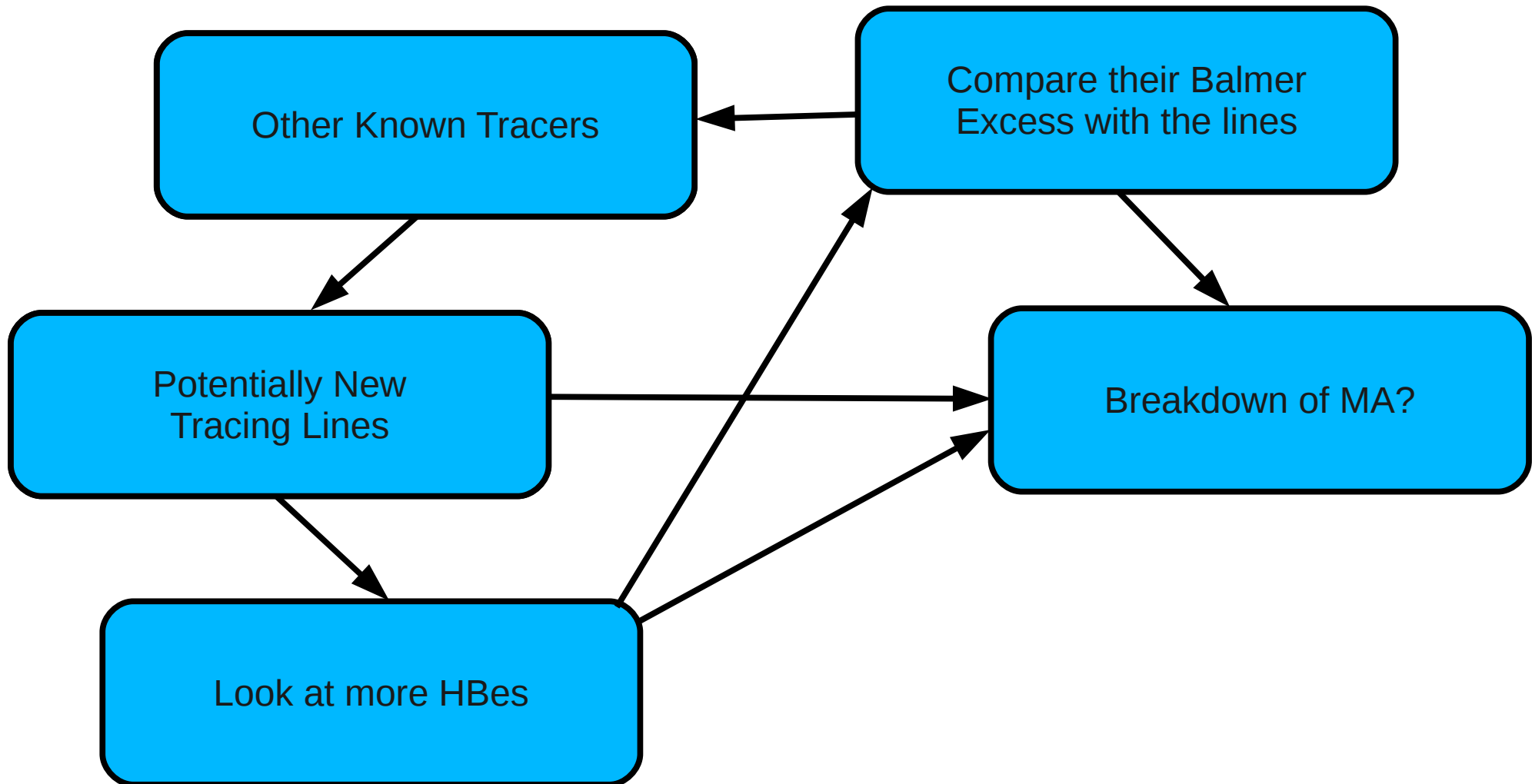


# What is Next?



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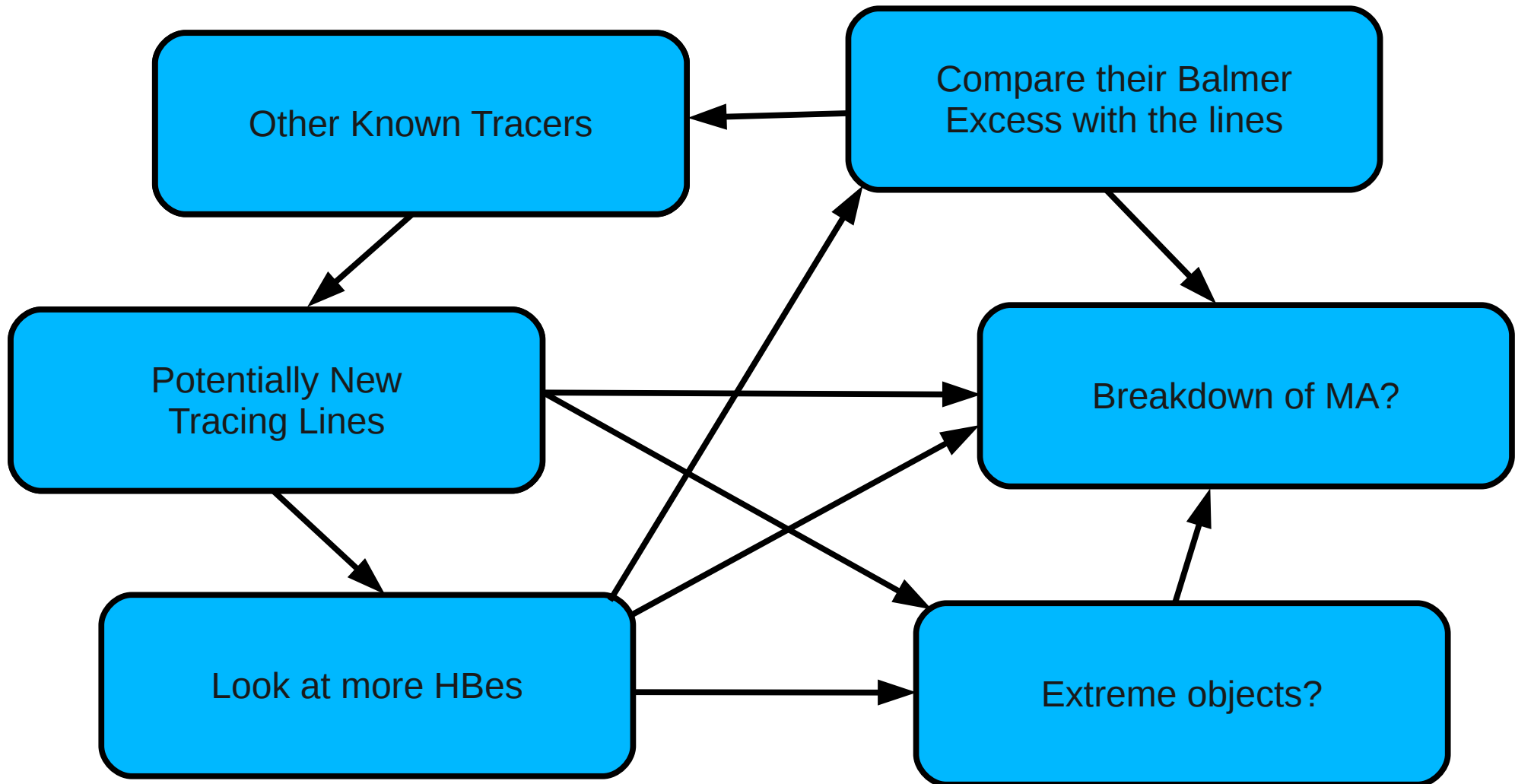


# What is Next?



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# Thanks



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**Thanks**