The origin of magnetic fields in low-mass young stars

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Michael Connelley[1,2], Bo Reipurth[1]

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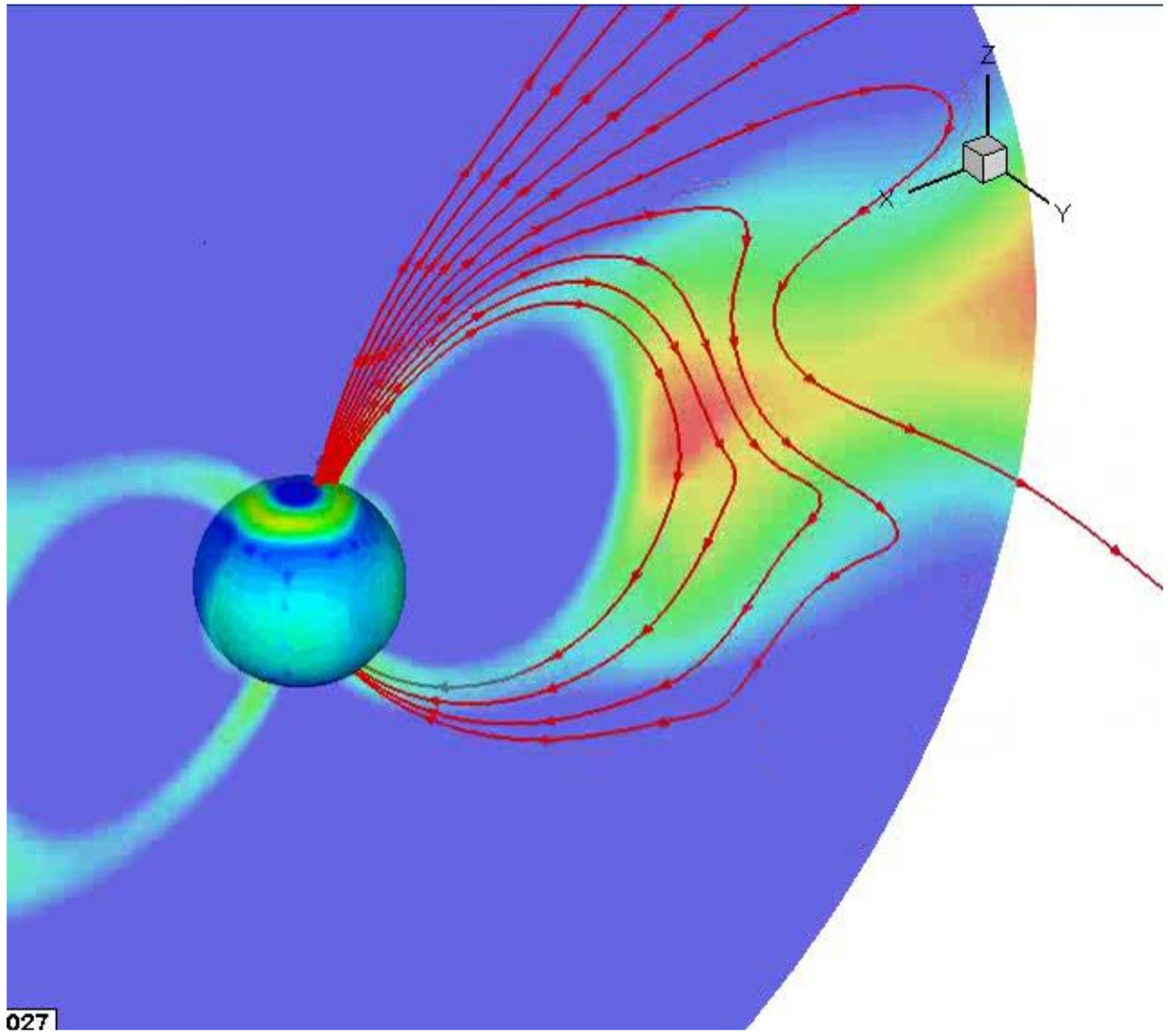
[2]NASA Infrared Telescope Facility

The Importance of Magnetic Fields

- **Magnetospheric accretion and Disk locking**

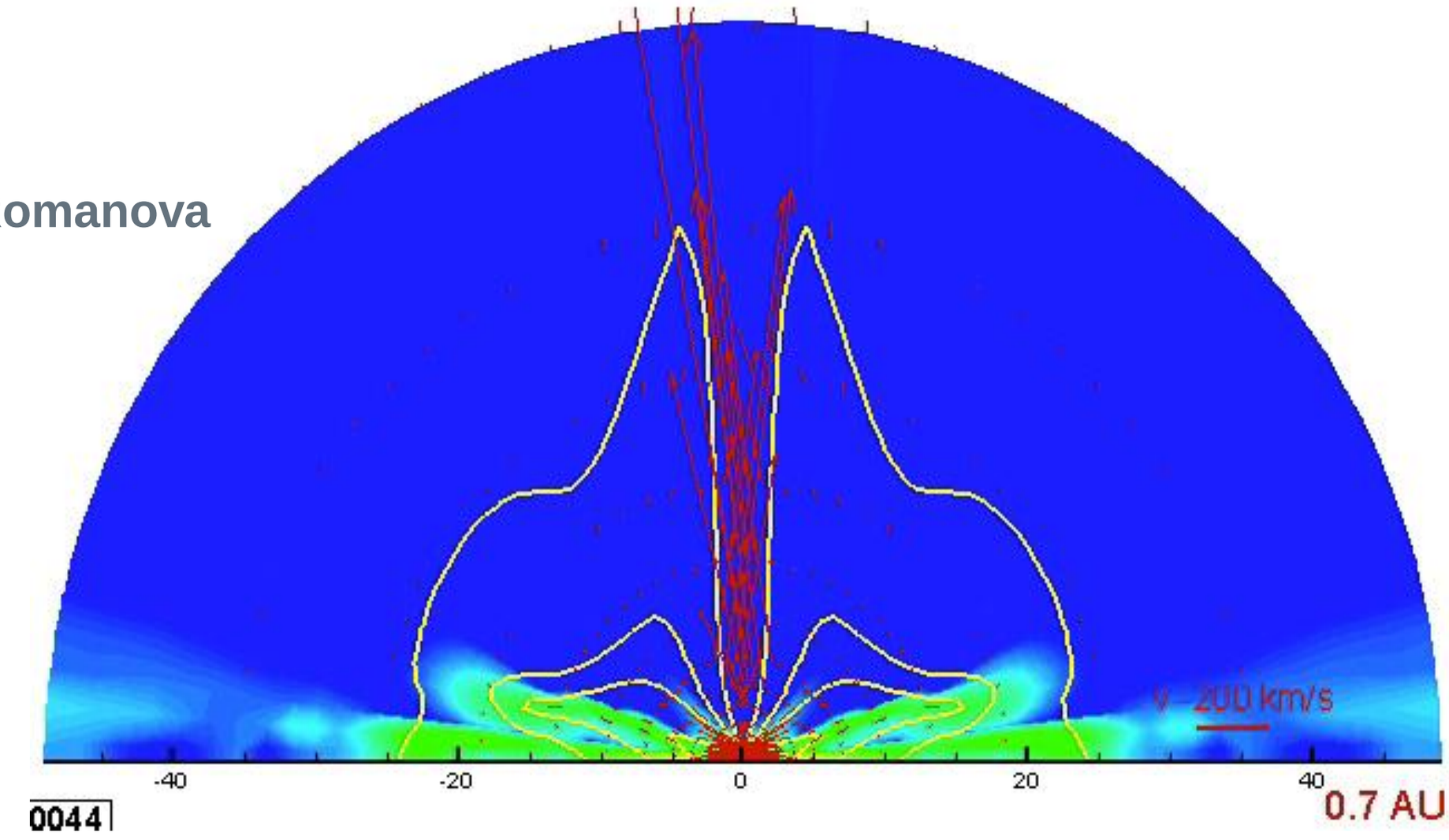
Marina Romanova



The Importance of Magnetic Fields

- **Outflows and winds**

Marina Romanova



The Importance of Magnetic Fields

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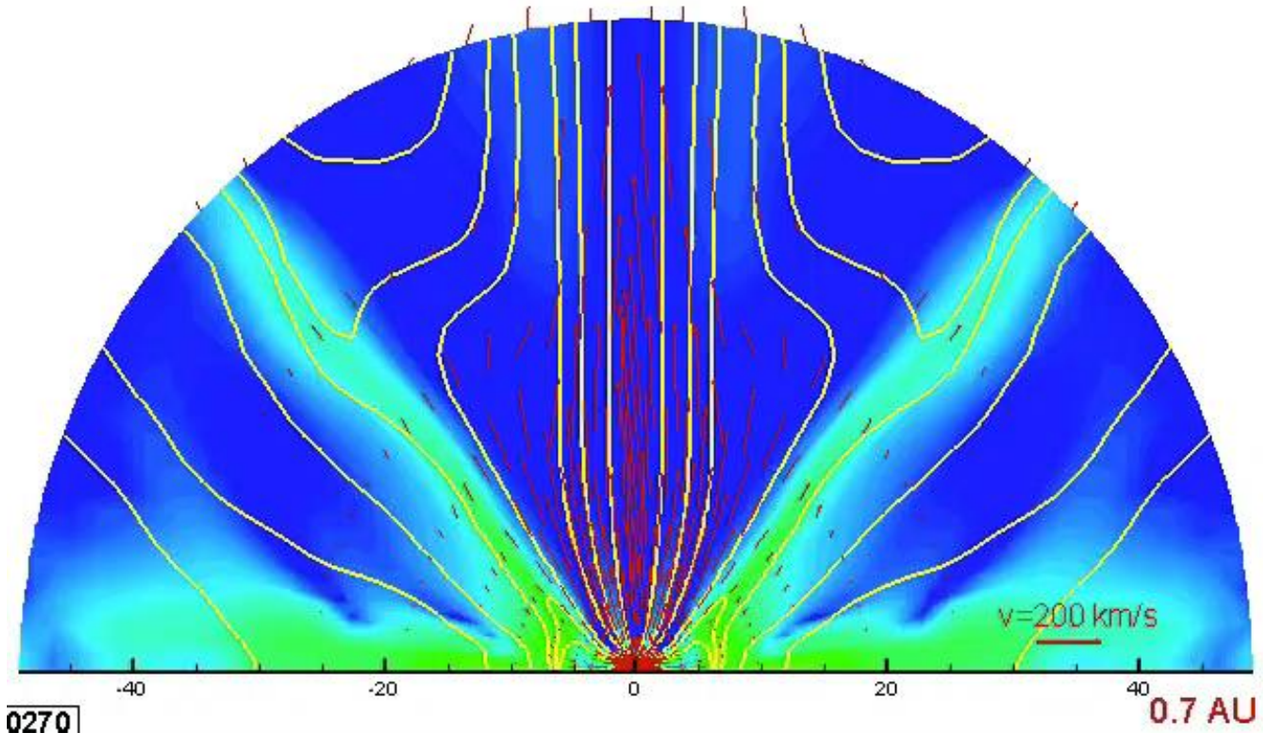
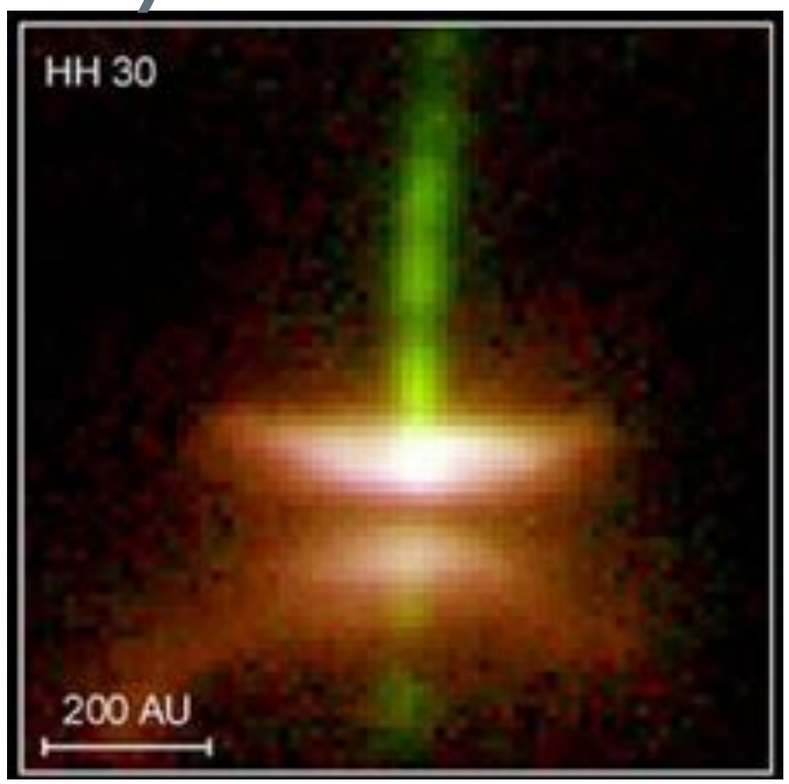


Marina Romanova

Credit: Chris Burrows (STSCcI)



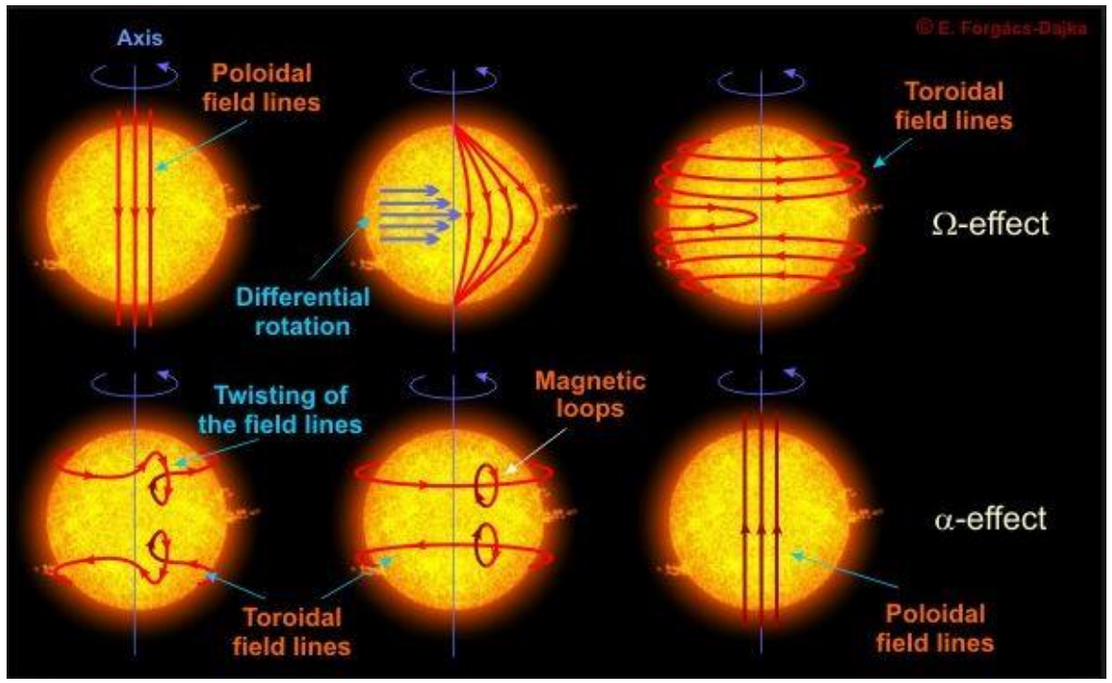
What is the origin of magnetic fields in low mass young stars?

The Origin of Magnetic Fields

Dynamo

The Origin of Magnetic Fields

Dynamo



The Origin of Magnetic Fields

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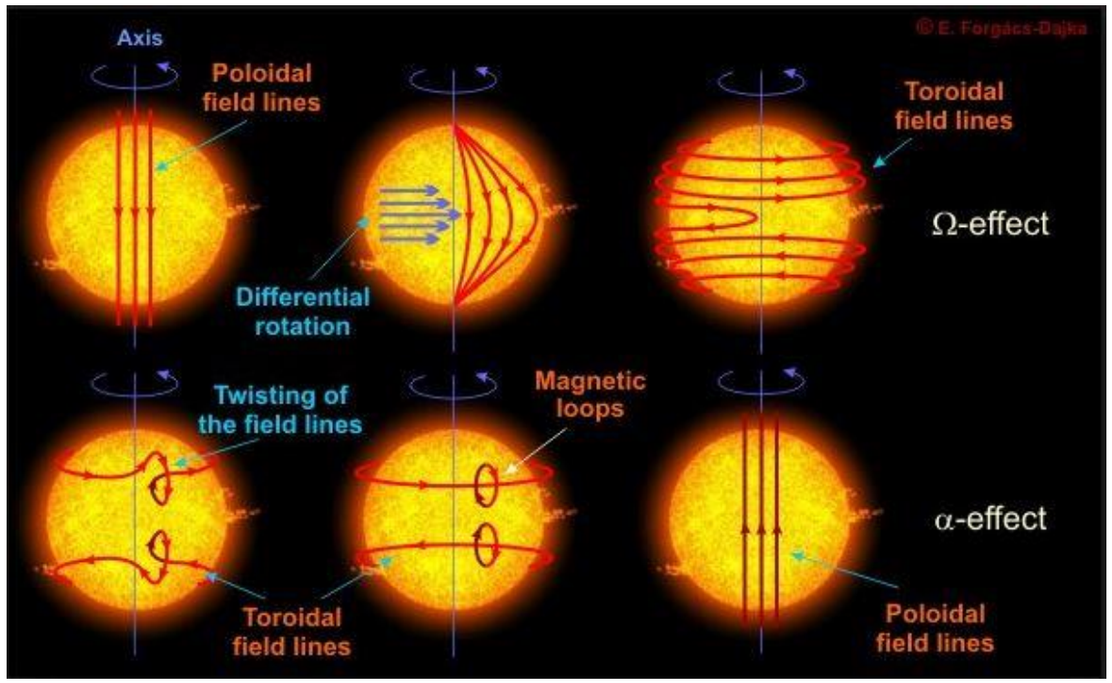

- Rotation
- Convection depth
- Activity cycles

The Origin of Magnetic Fields

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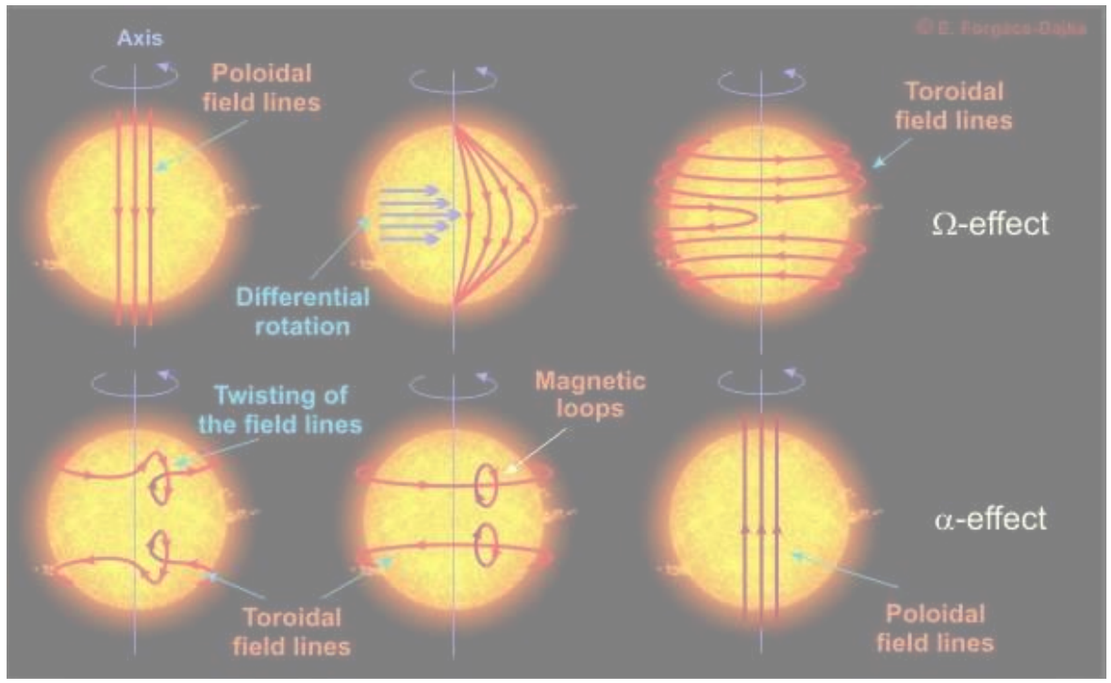
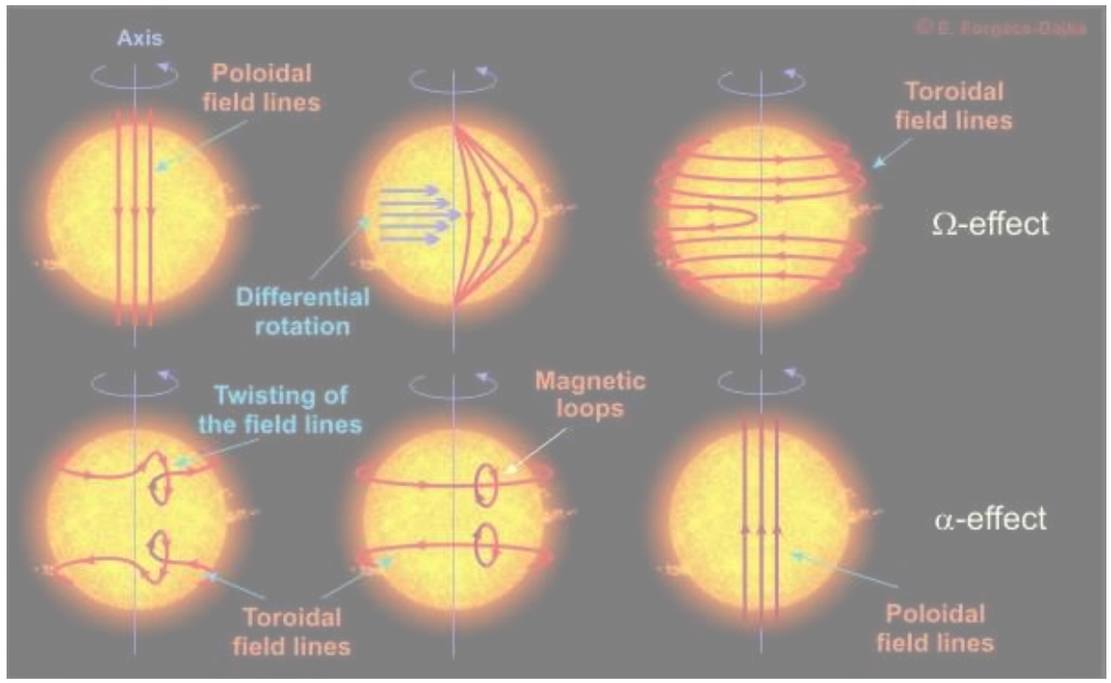


- Rotation
- Convection depth
- Activity cycles

Fossil

The Origin of Magnetic Fields

Dynamo



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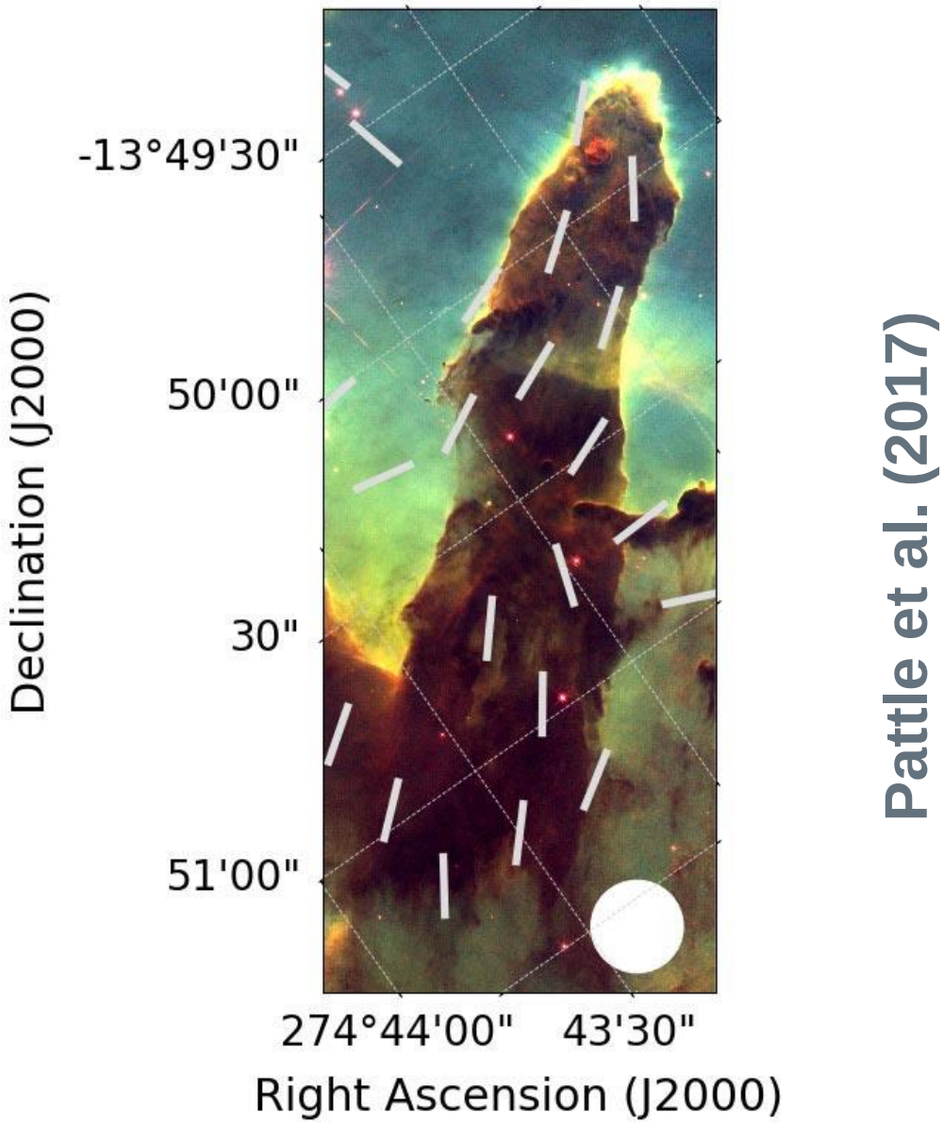

Pattle et al. (2017)

The Origin of Magnetic Fields

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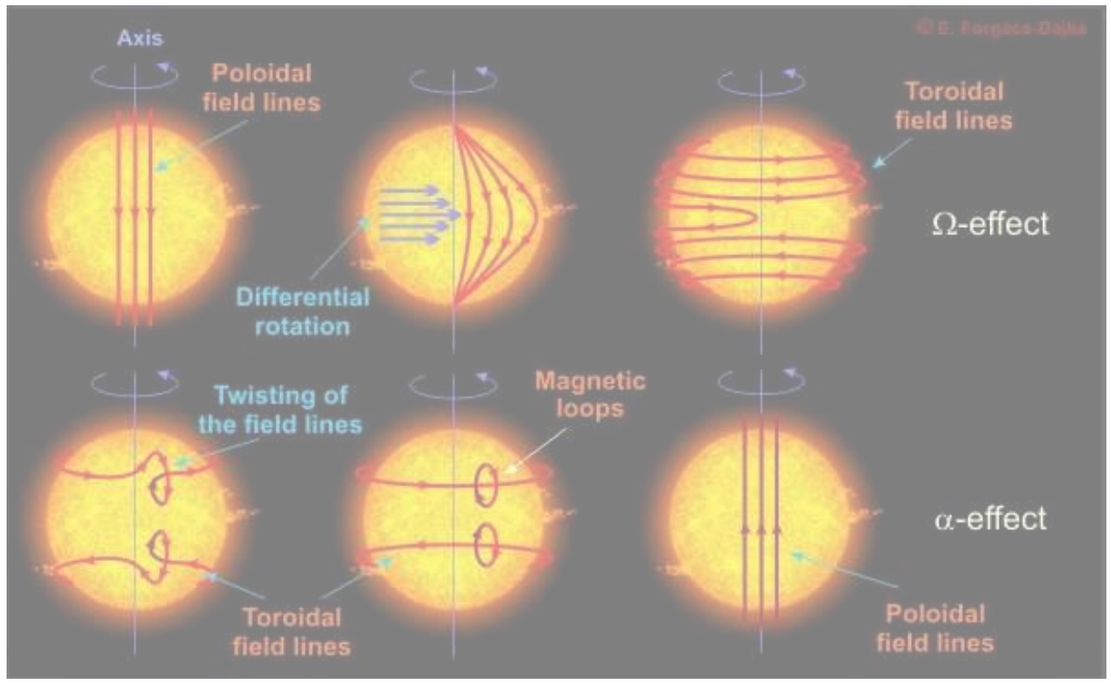

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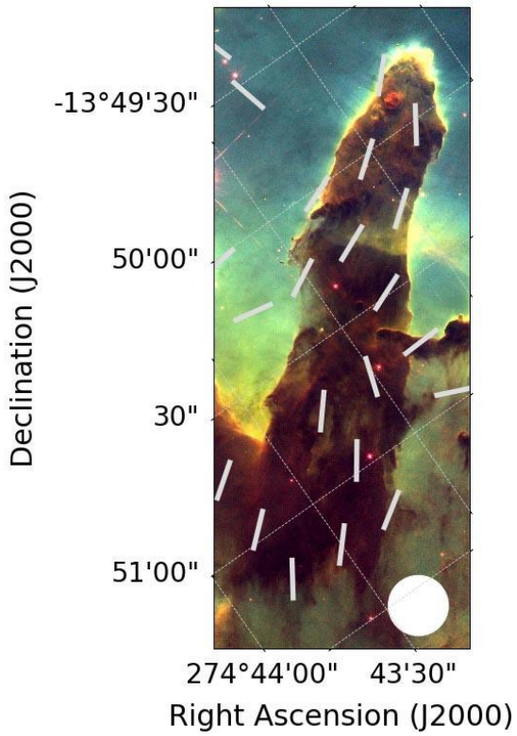

Pattle et al. (2017)

- No rotation
- No convection
- Stellar age

The Origin of Magnetic Fields

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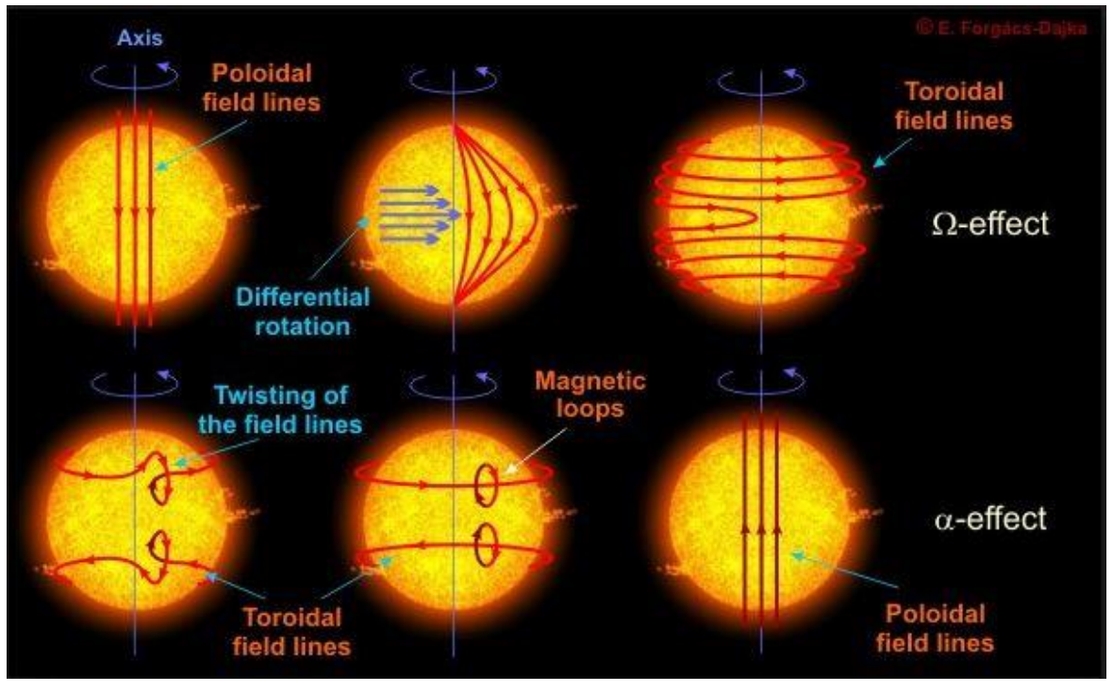

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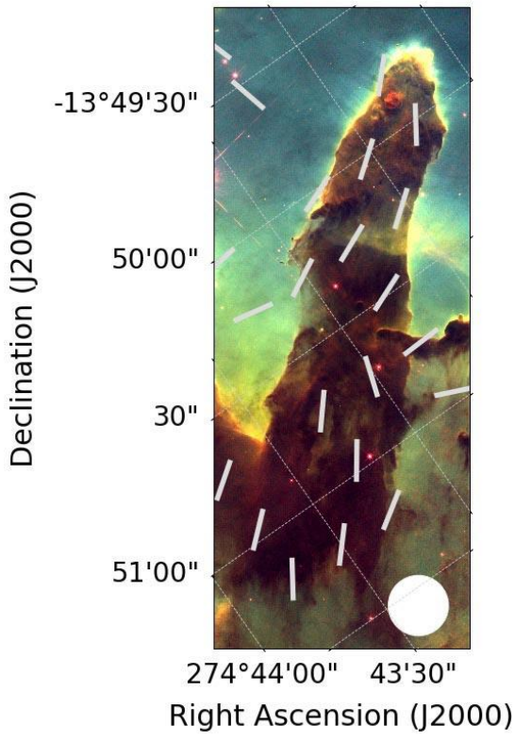

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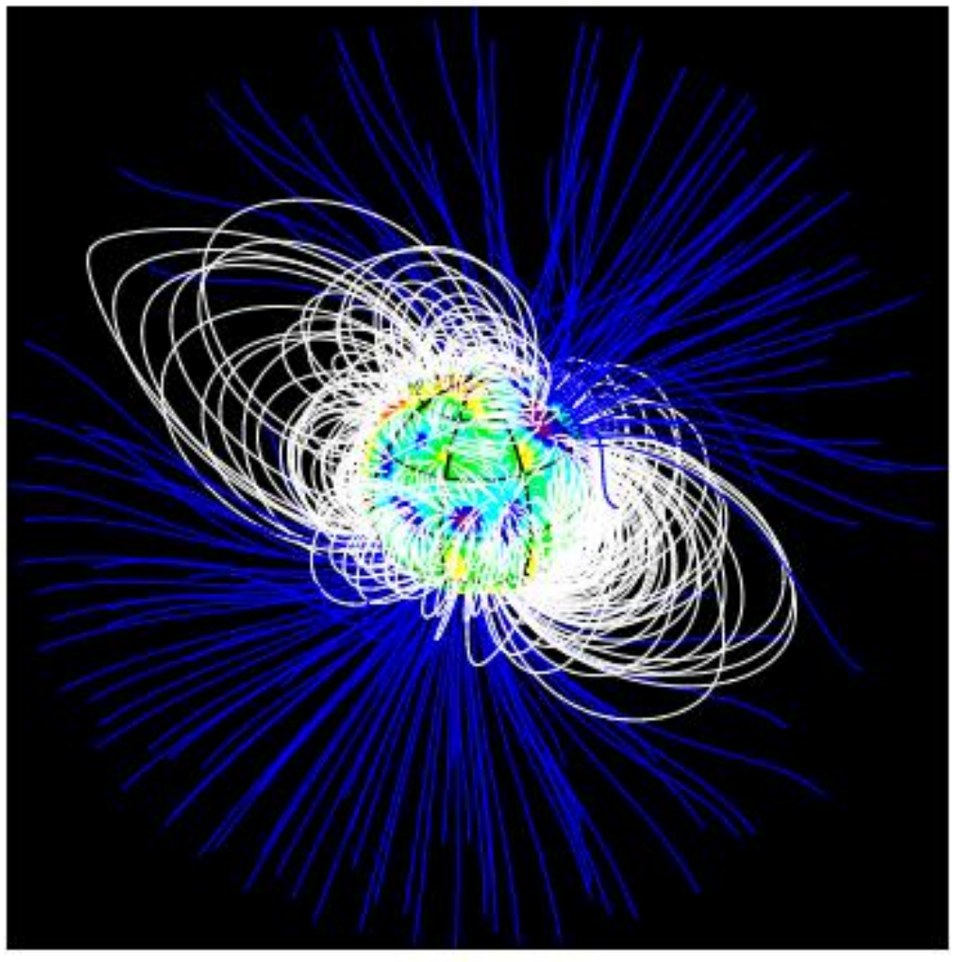
Dynamo or Fossil?

Polarized light

Dynamo or Fossil?

Polarized light: ZDI



Donati et al. (2011, 2012, 2013)

Hill et al. (2017) Par 224

Dynamo or Fossil?

Polarized light: ZDI

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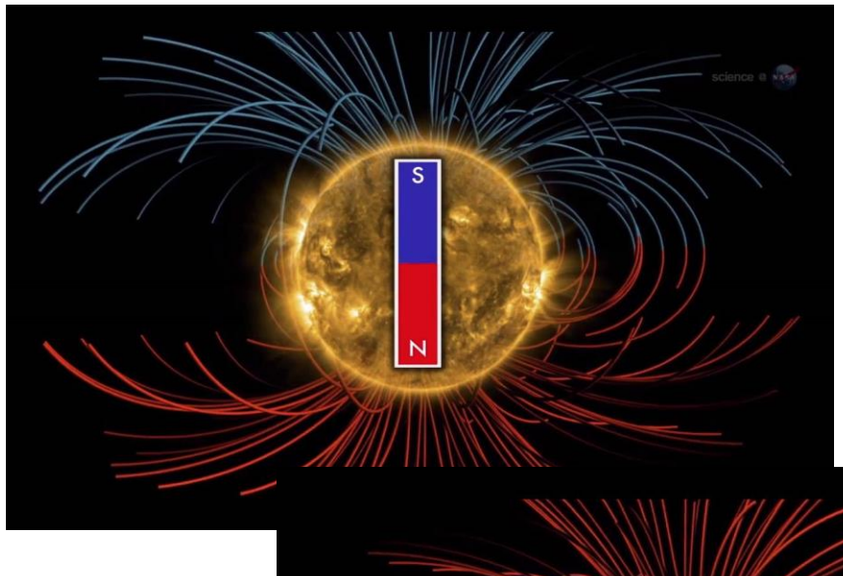

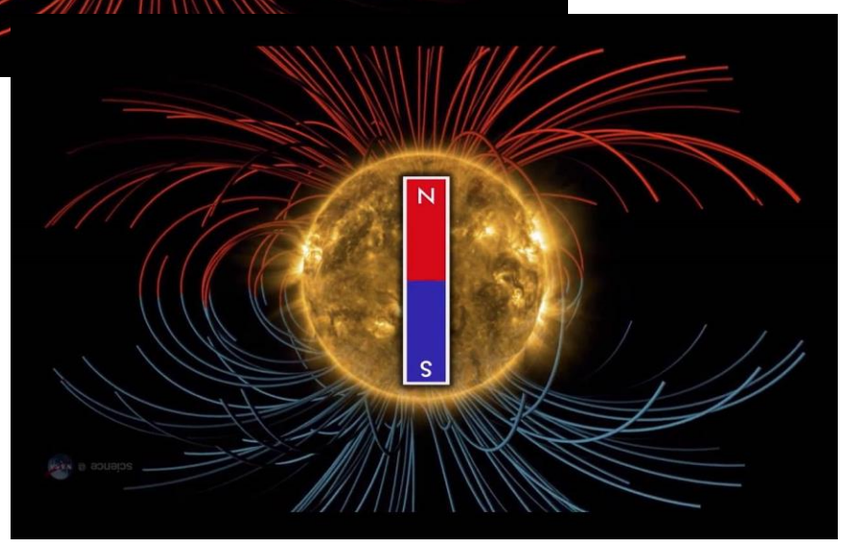

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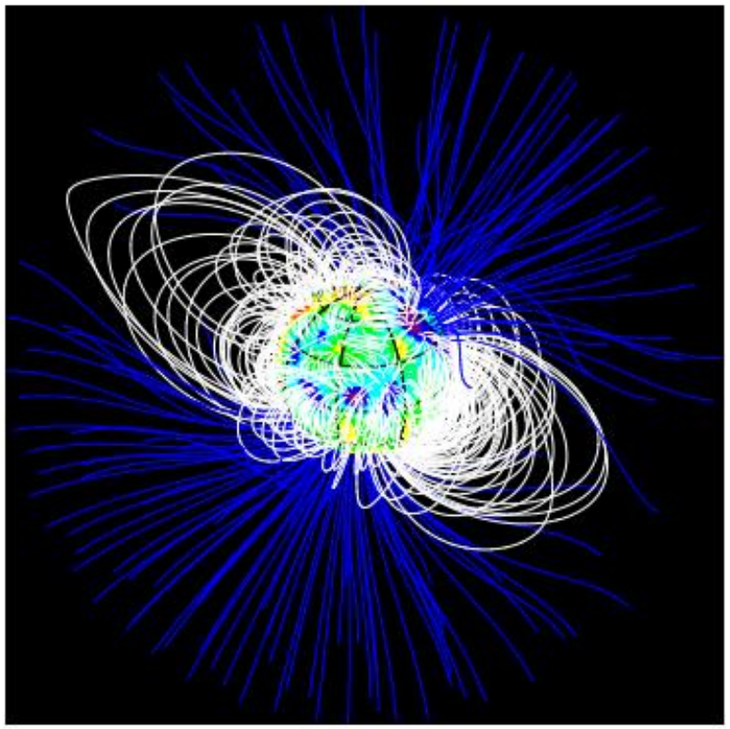

Donati et al. (2011, 2012, 2013)

Dynamo

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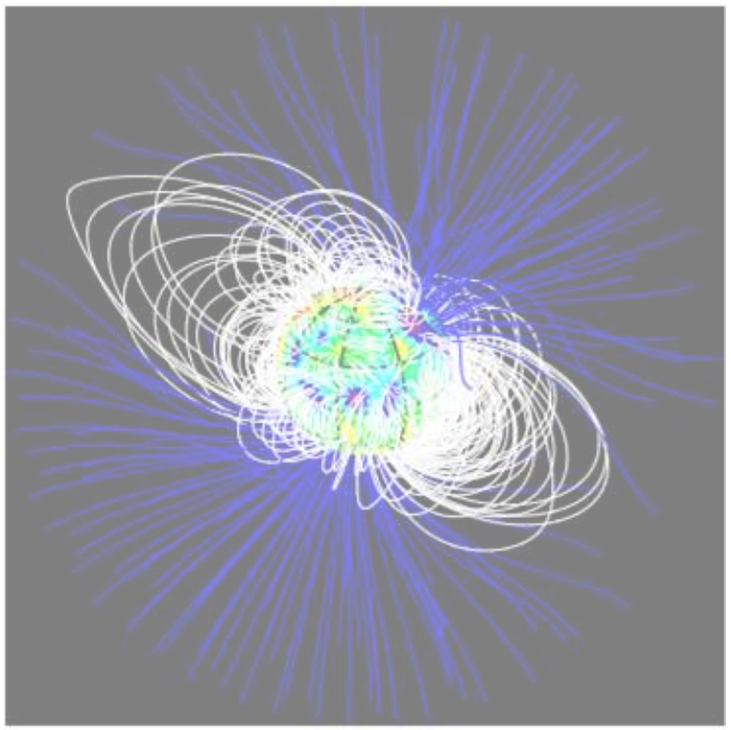

Donati et al. (2011, 2012, 2013)

Dynamo

Unpolarized light

Dynamo or Fossil?

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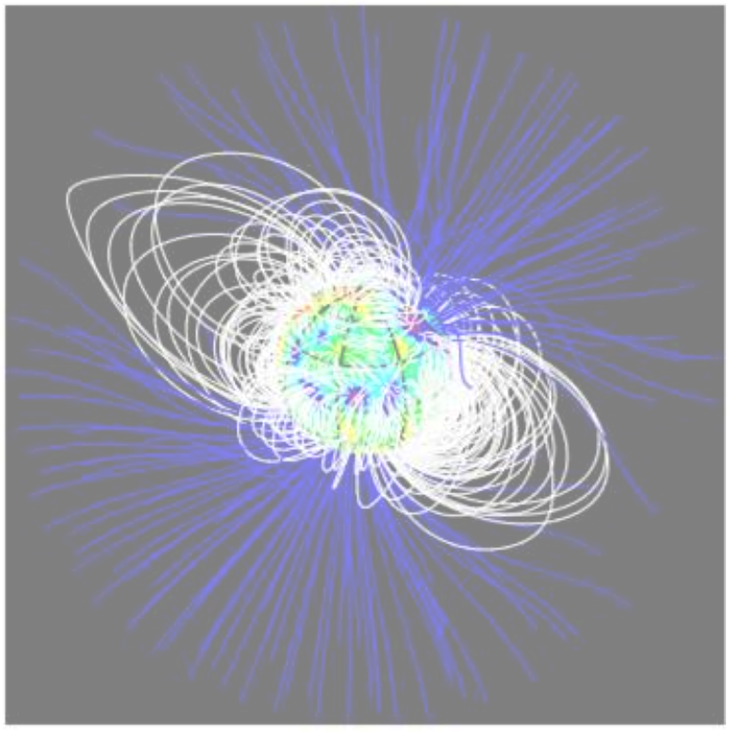
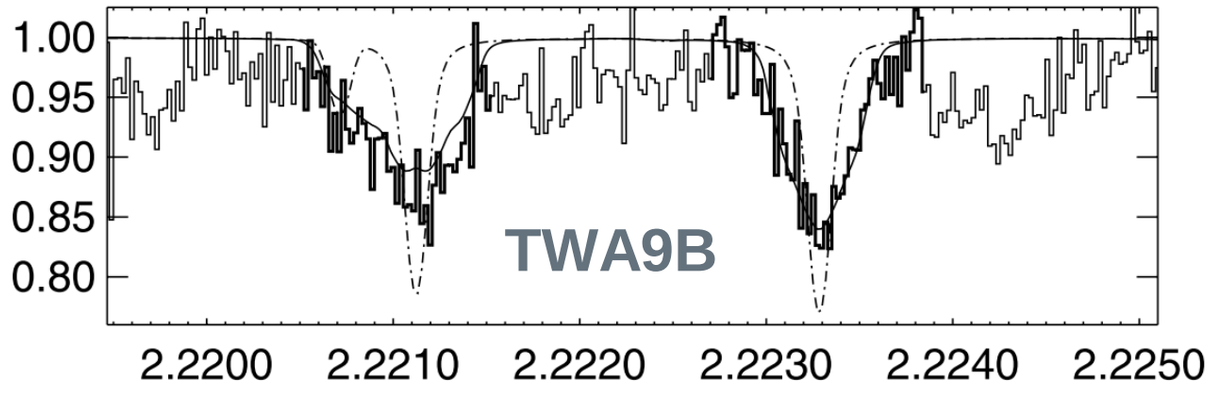


Donati et al. (2011, 2012, 2013)

Dynamo

Unpolarized light: Zeeman Broadening



Yang, Johns-Krull, & Valenti. (2008)

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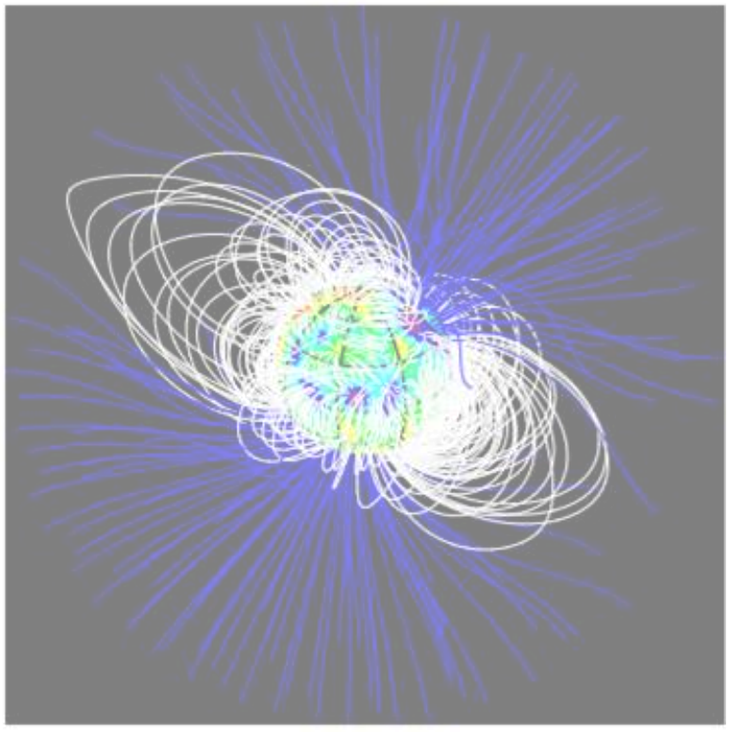

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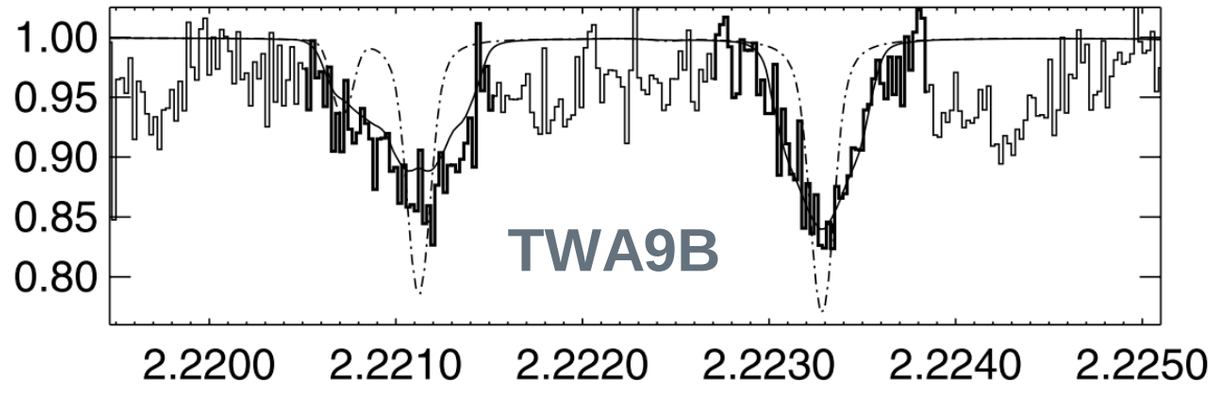

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33 CTTS: Taurus, TWA and ONC

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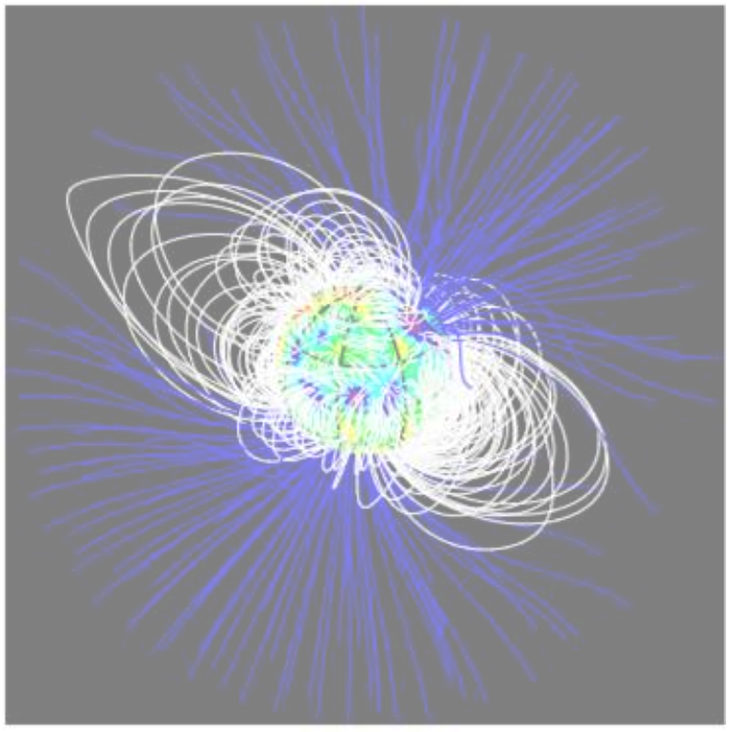

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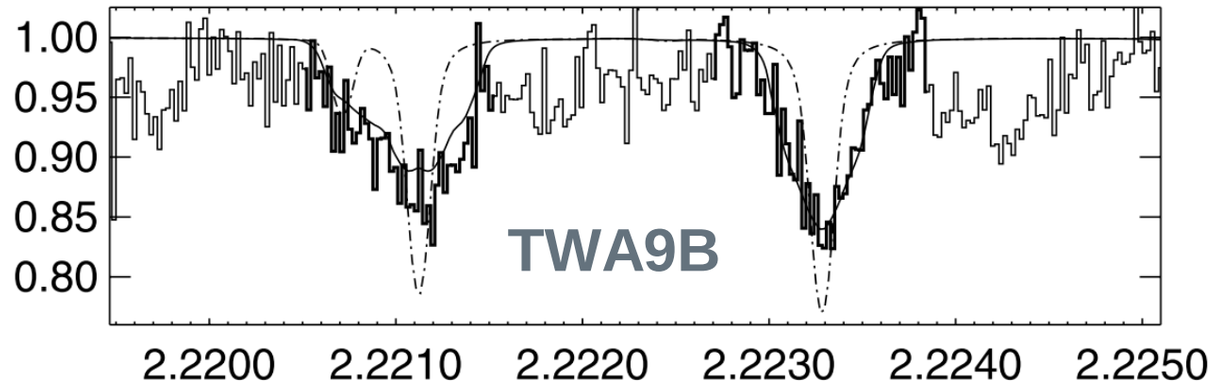
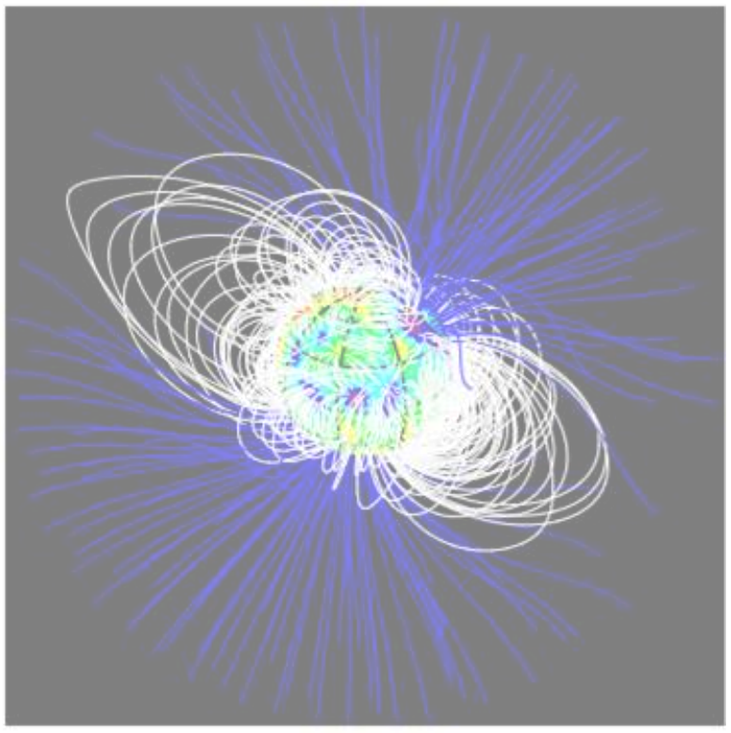


- B ≠ Convection depth
- B ≠ Rotation

Dynamo or Fossil?

Polarized light: ZDI



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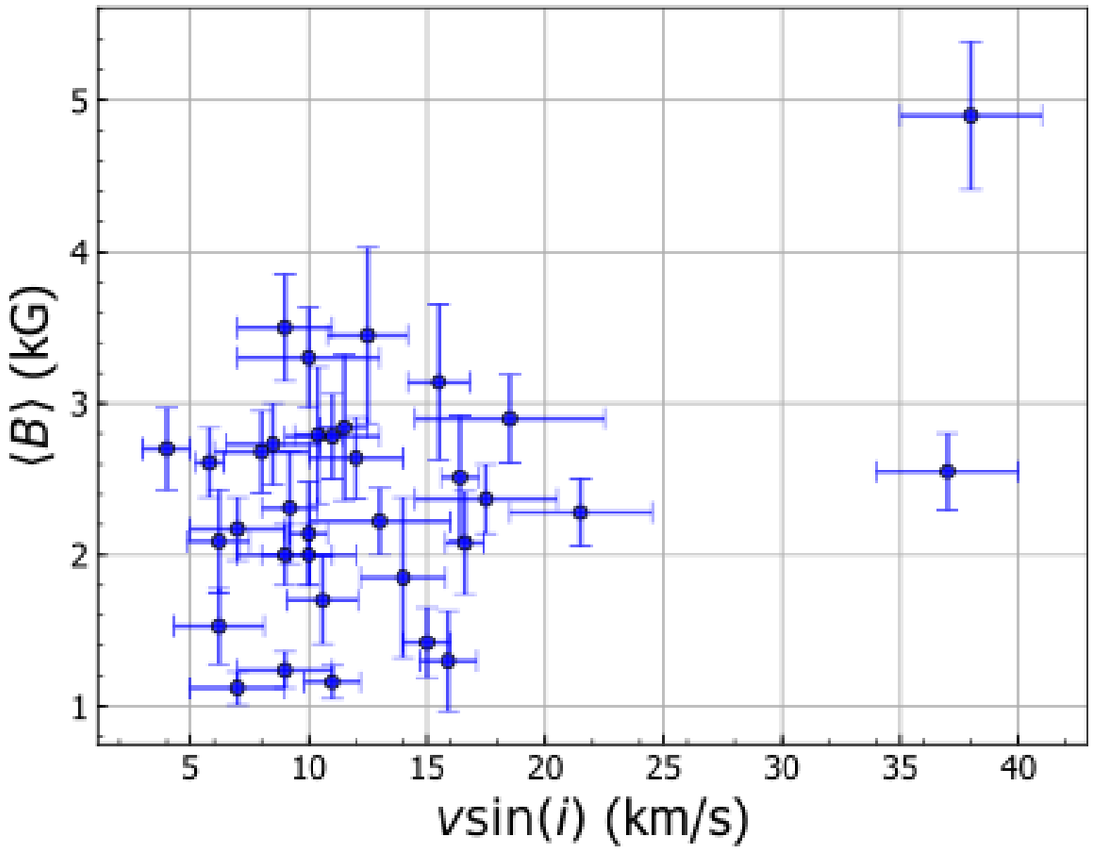

Reproduced from: Yang & Johns-Krull (2011)

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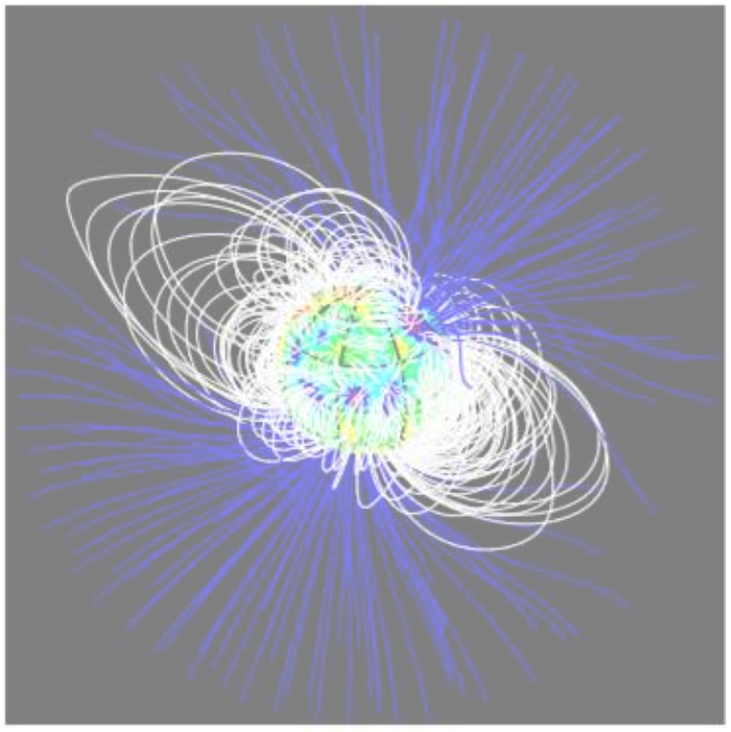

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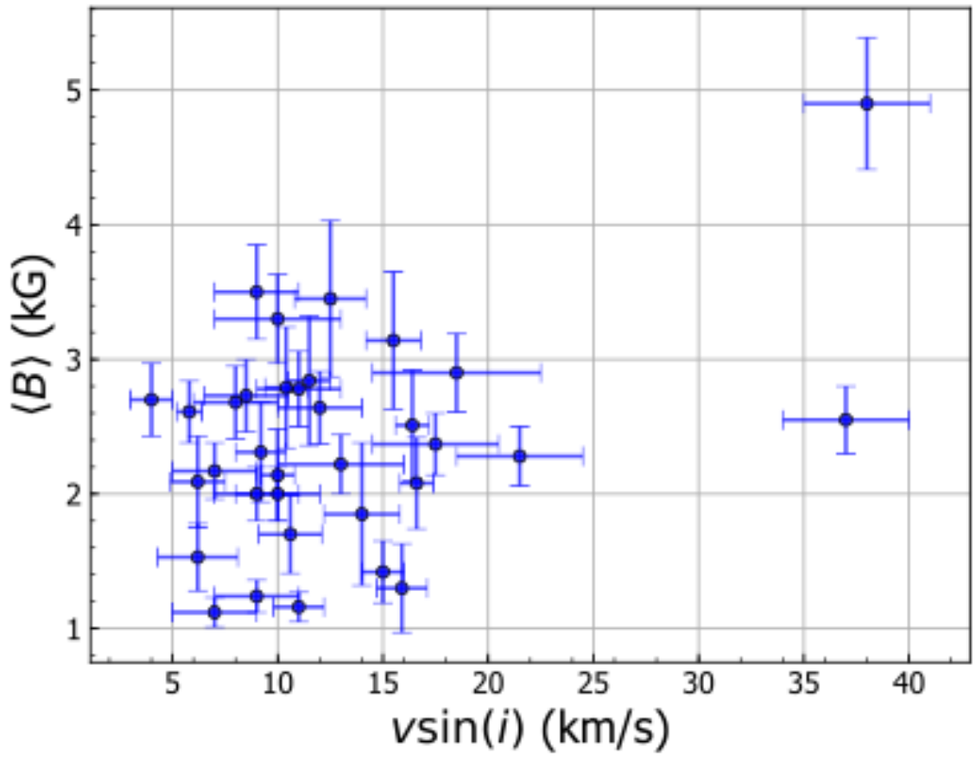

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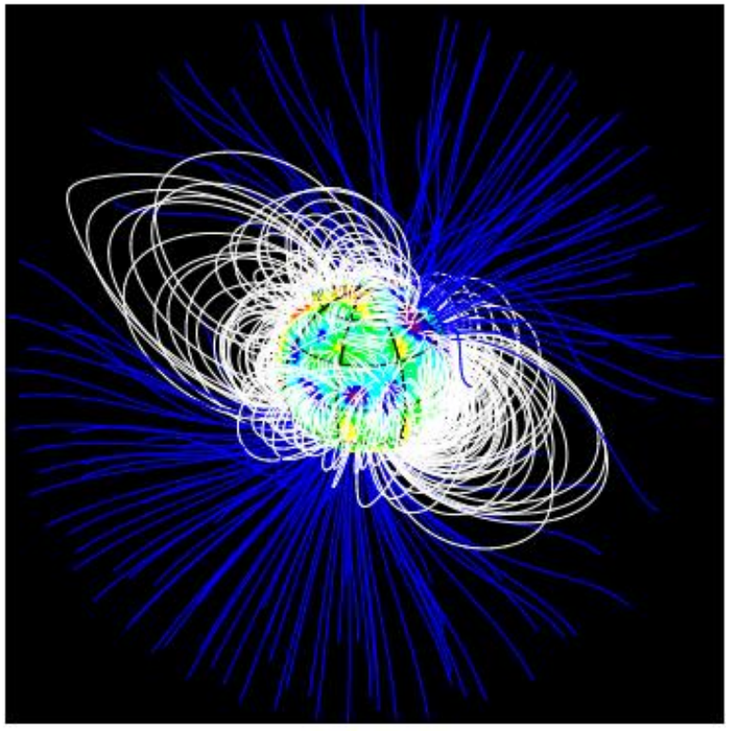

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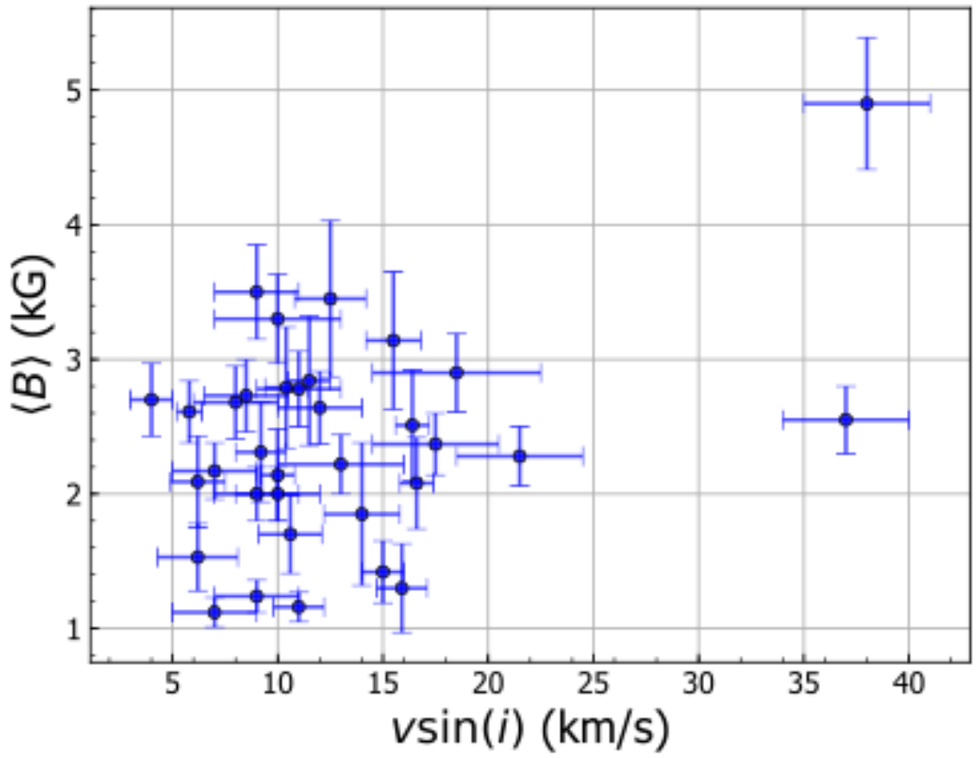


Reproduced from: Yang & Johns-Krull (2011)

Dynamo

Fossil

Dynamo

or

Fossil

Observations

iSHELL : High resolution NIR spectrograph

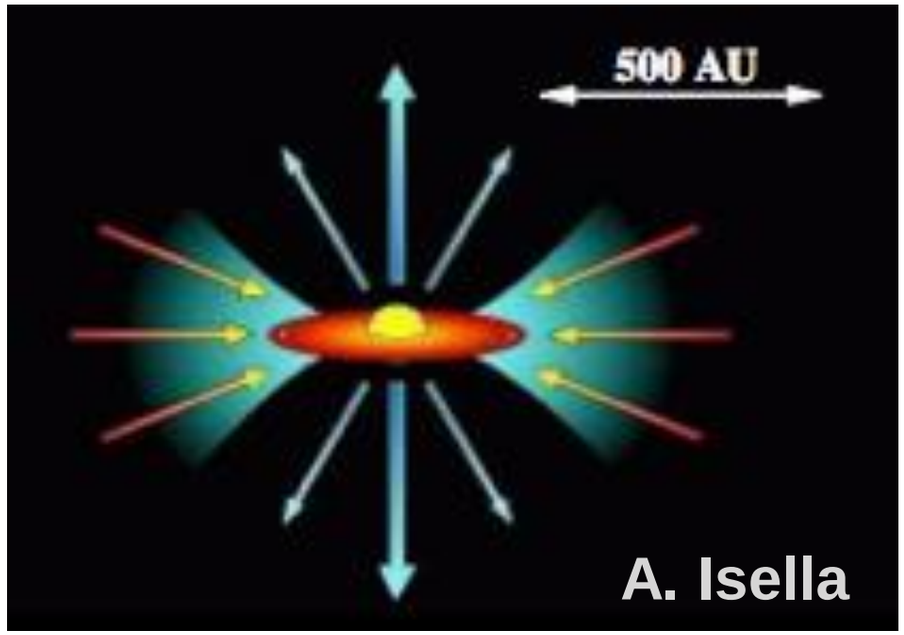
- 3-m telescope
- Unpolarized Light
- K-band
- R~50,000

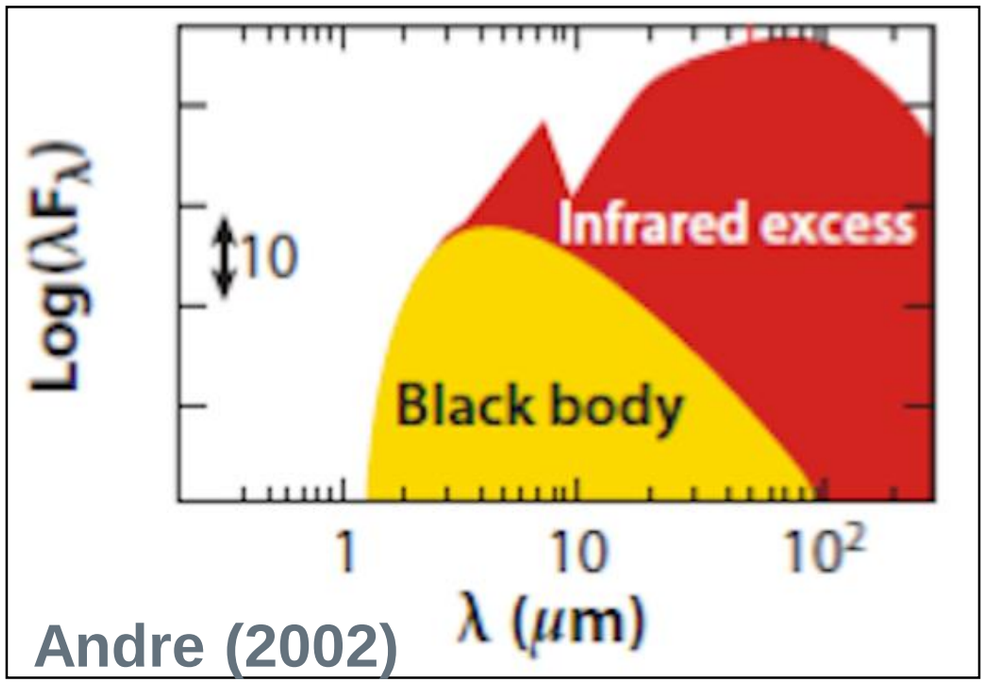
IRTF

Sample

- 15 Class I + Flat spectrum sources
- Taurus-Aurigae, Ophiuchus, Orion and Perseus

Class I source



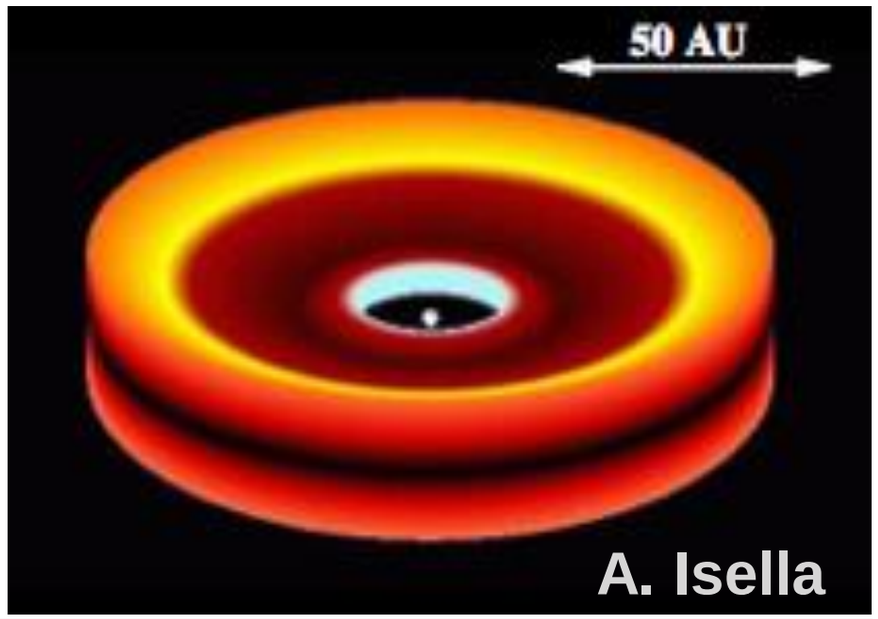


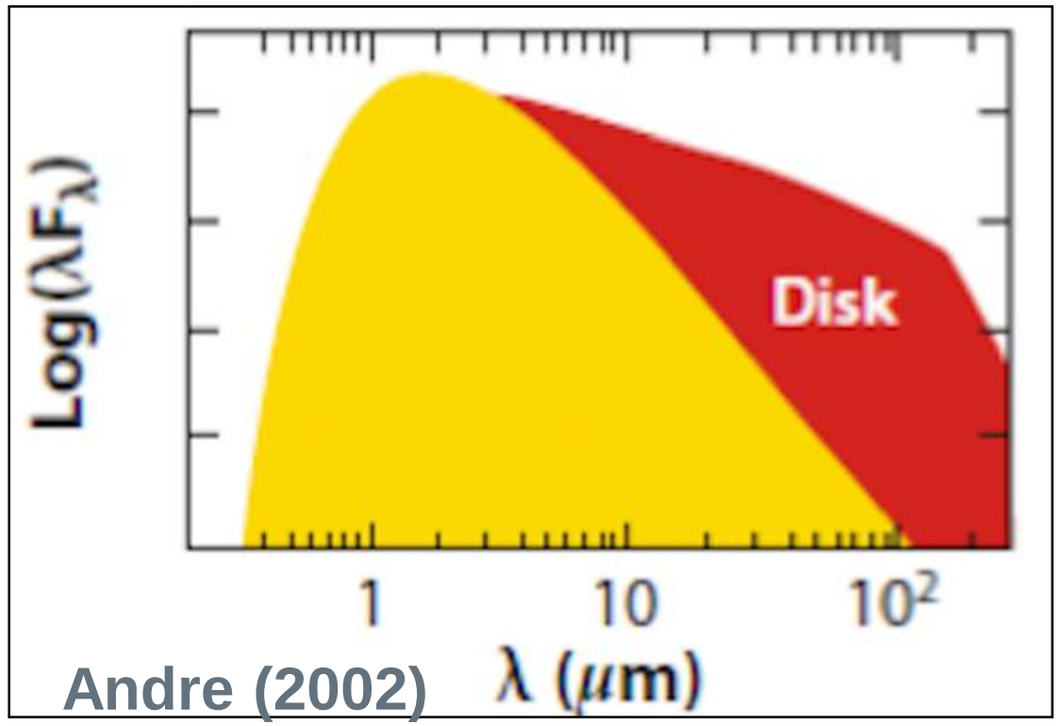
Andre (2002)

Sample

- 26 Class II sources
- Taurus and Ophiuchus

Class II source



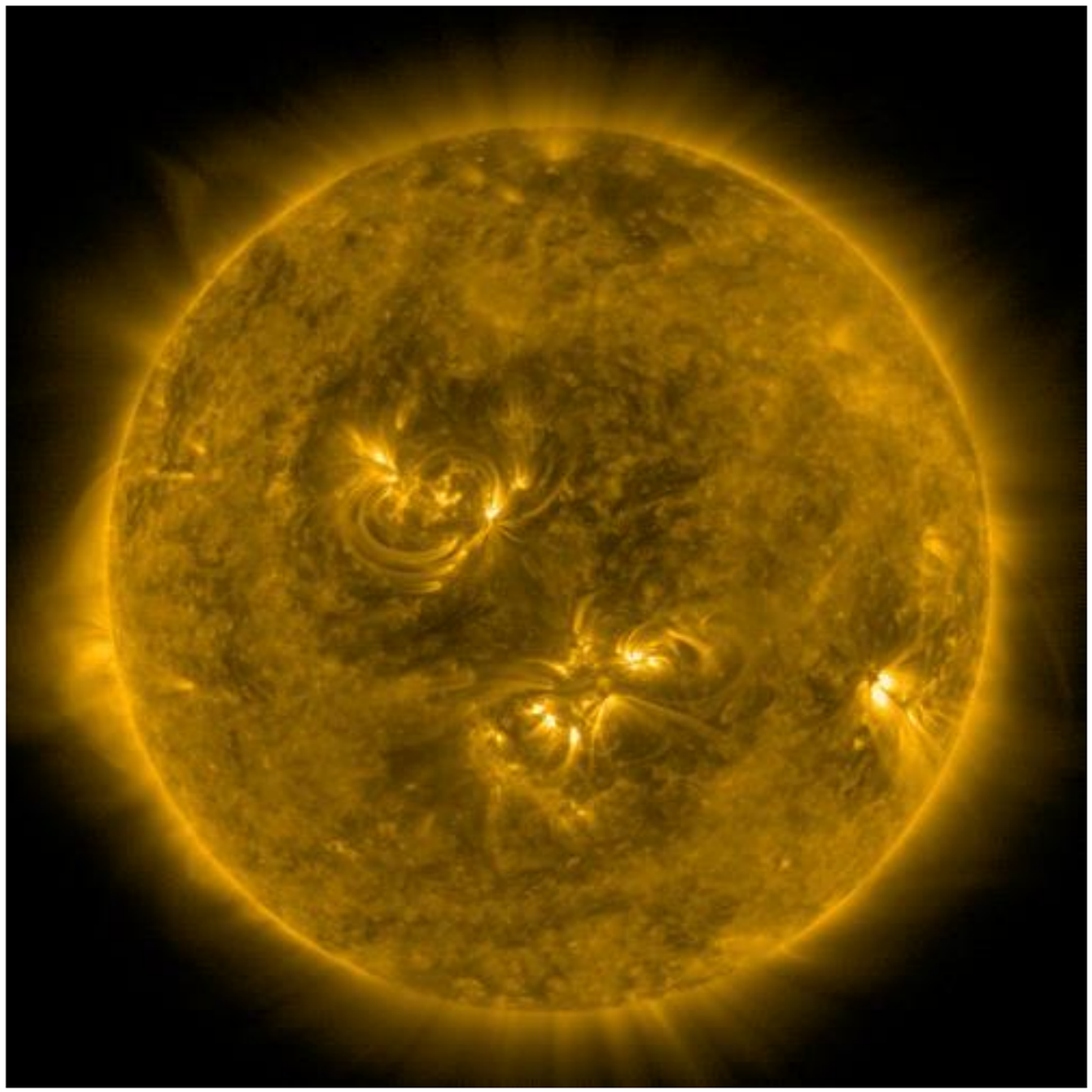


YSO Modeling

Deen (2013)

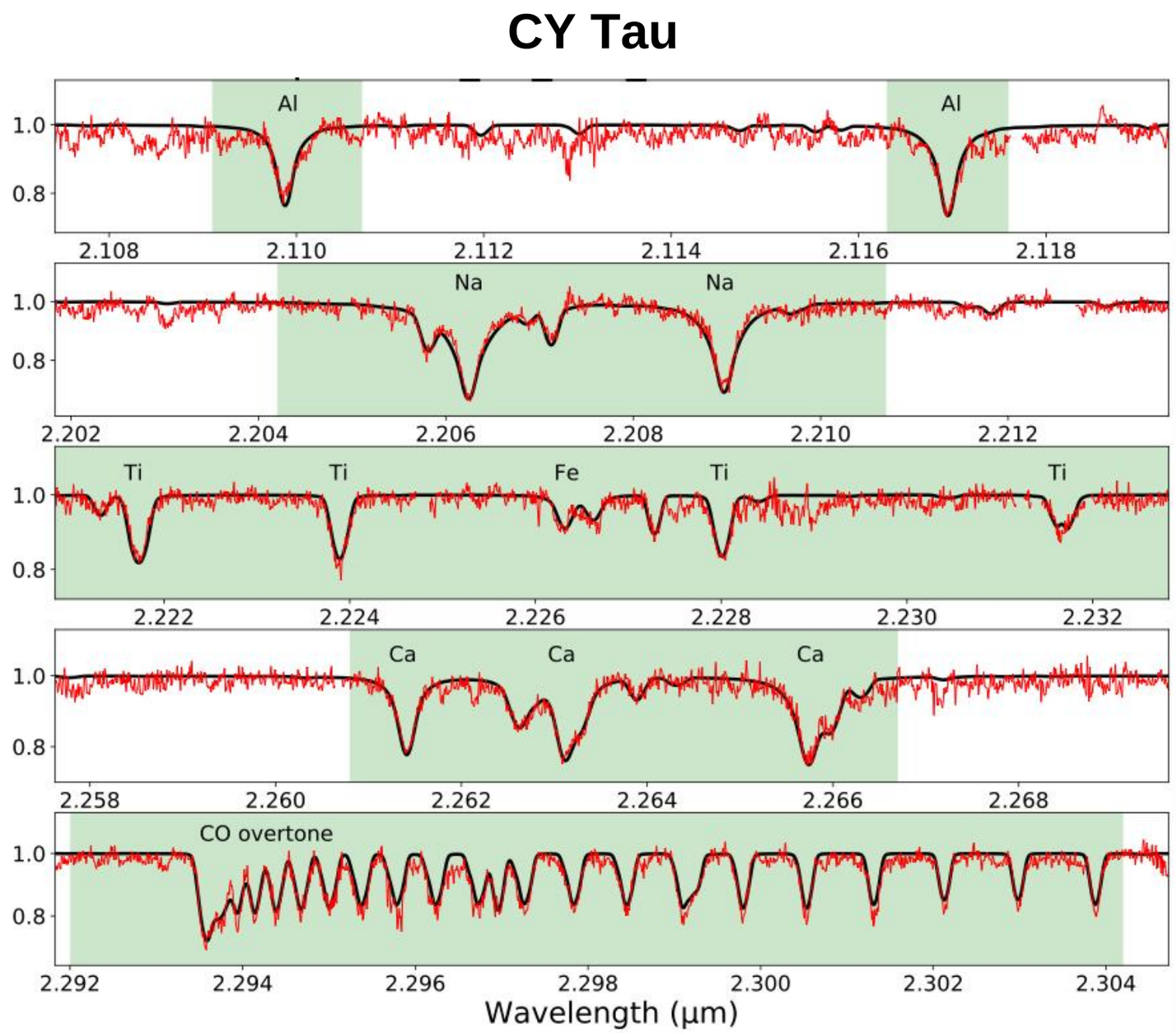
MoogStokes

- Single Temperature
- Single Magnetic Field
- Rotating Star
- Infrared Re-radiation from the Disk



Flores et al. (2019, in press)

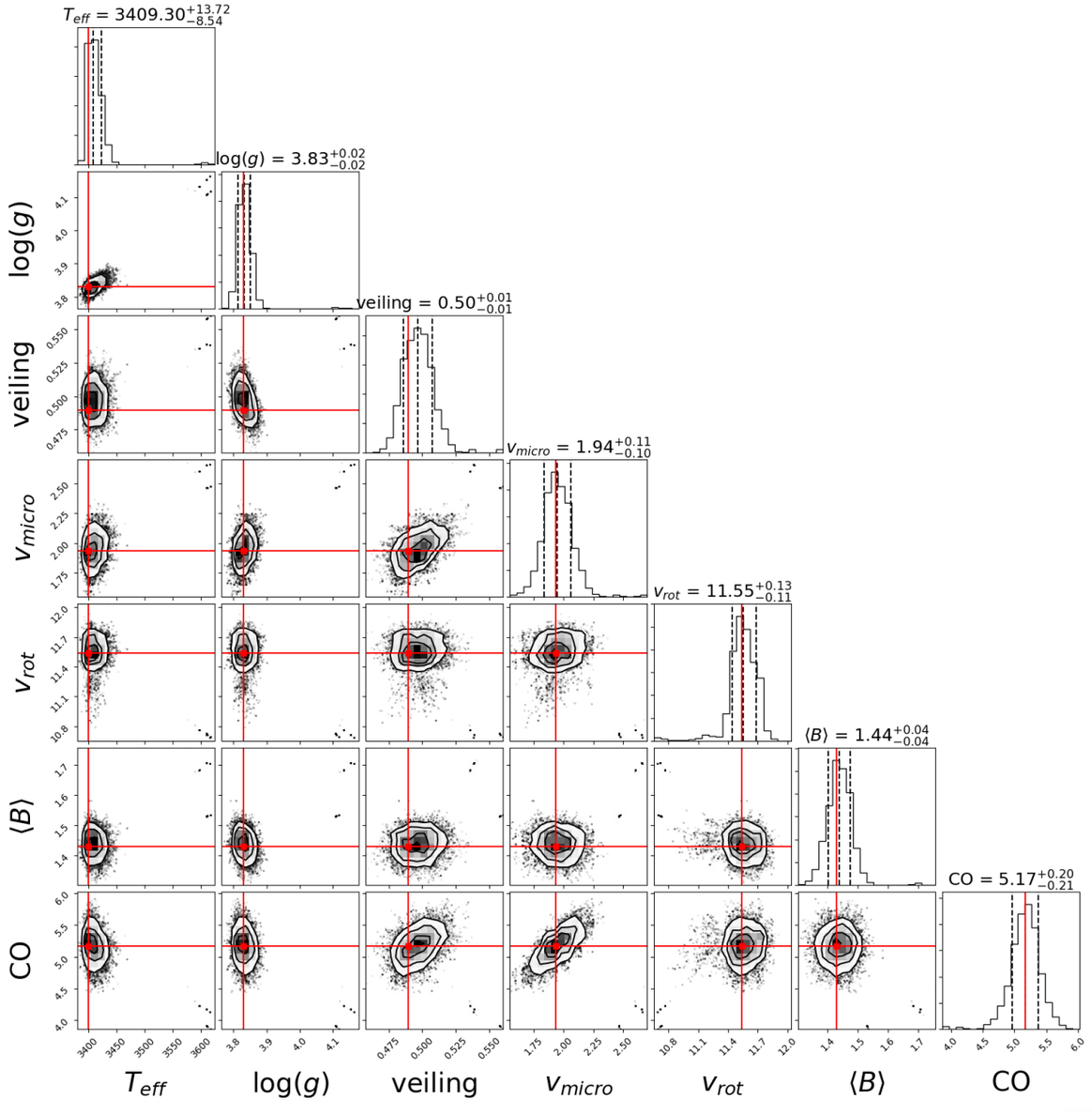
Magnetic Field Measurements

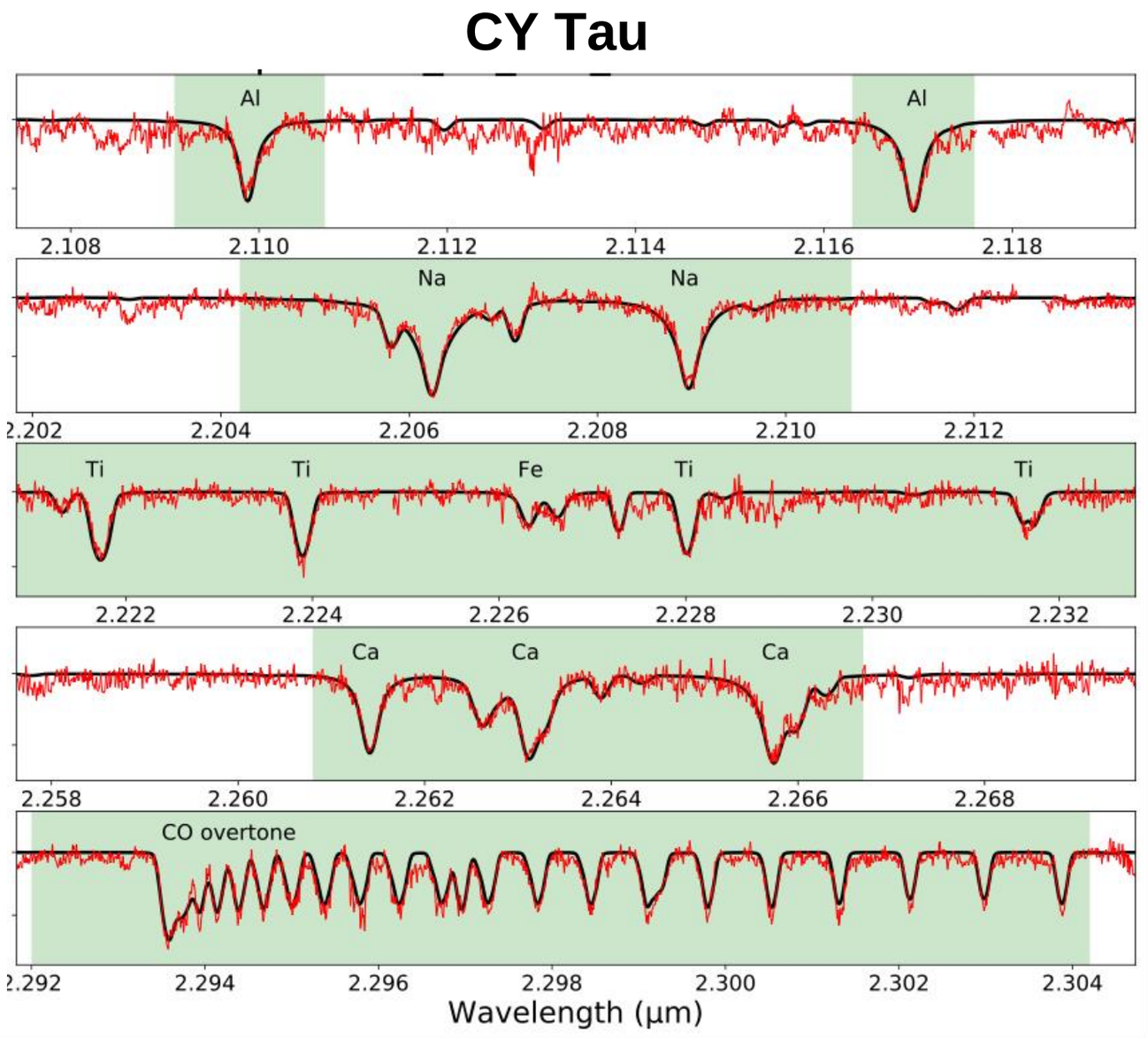


Model

Observations

Magnetic Field Measurements





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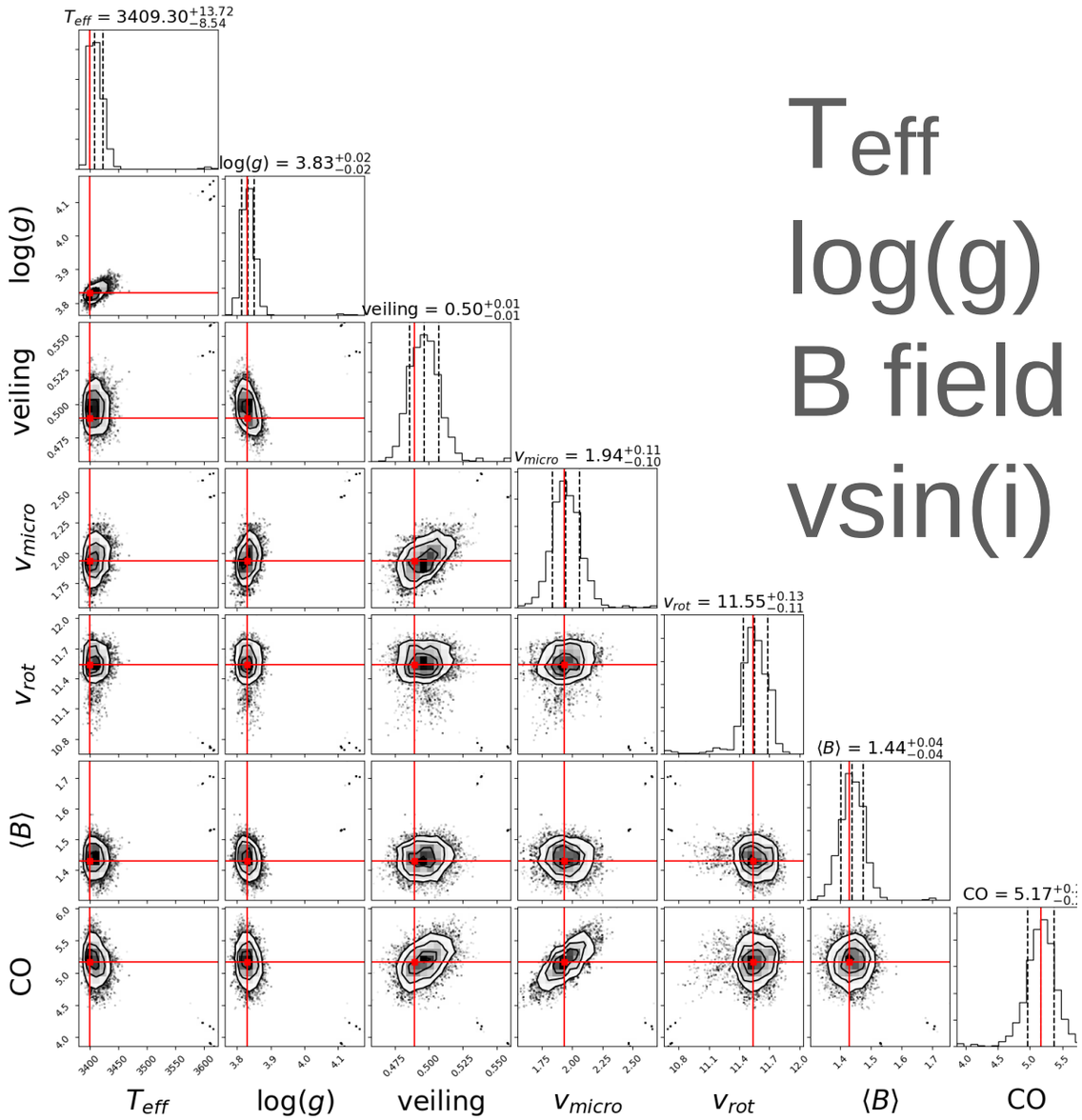
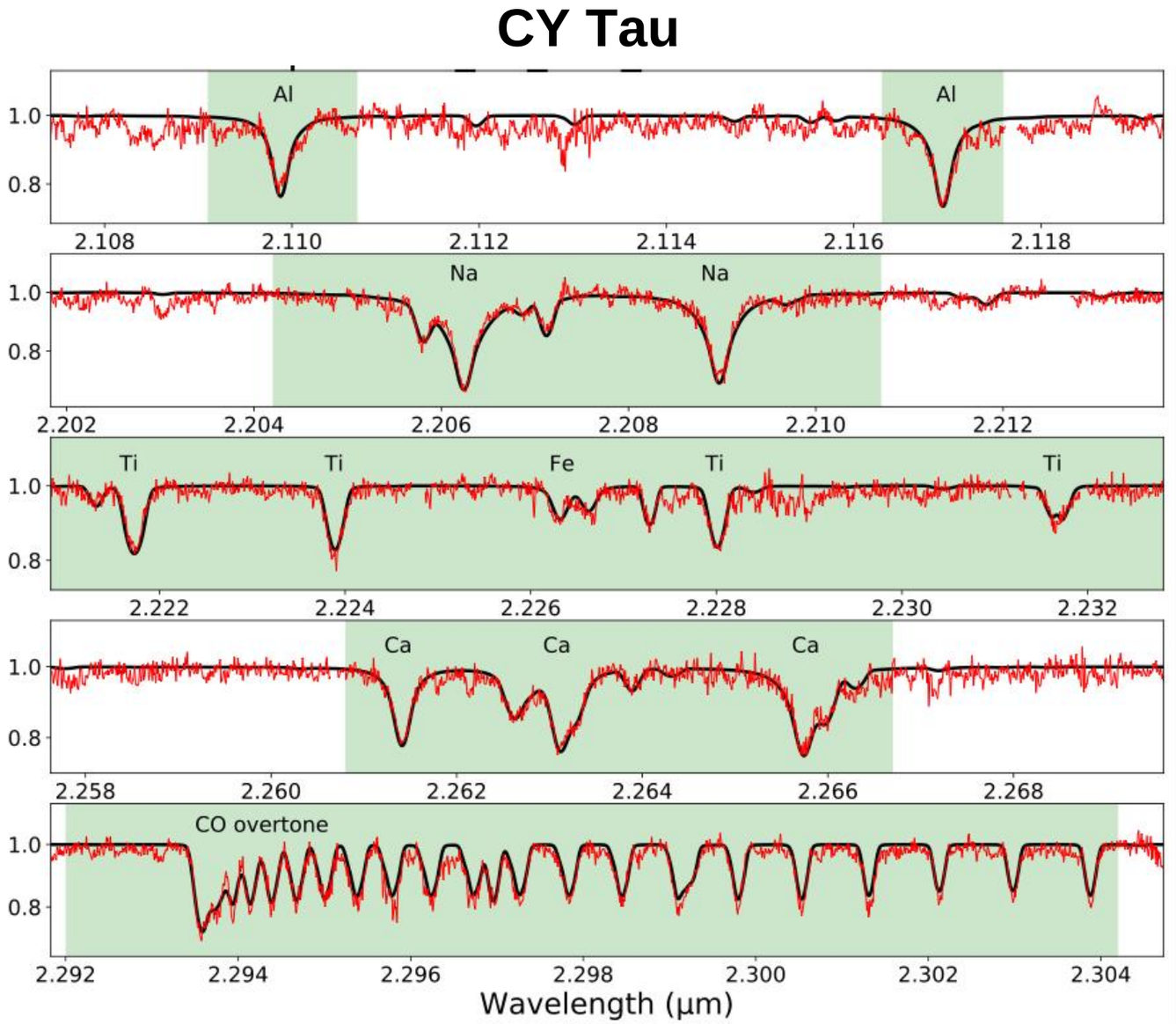


T_{eff}

log(g)

B field

vsin(i)



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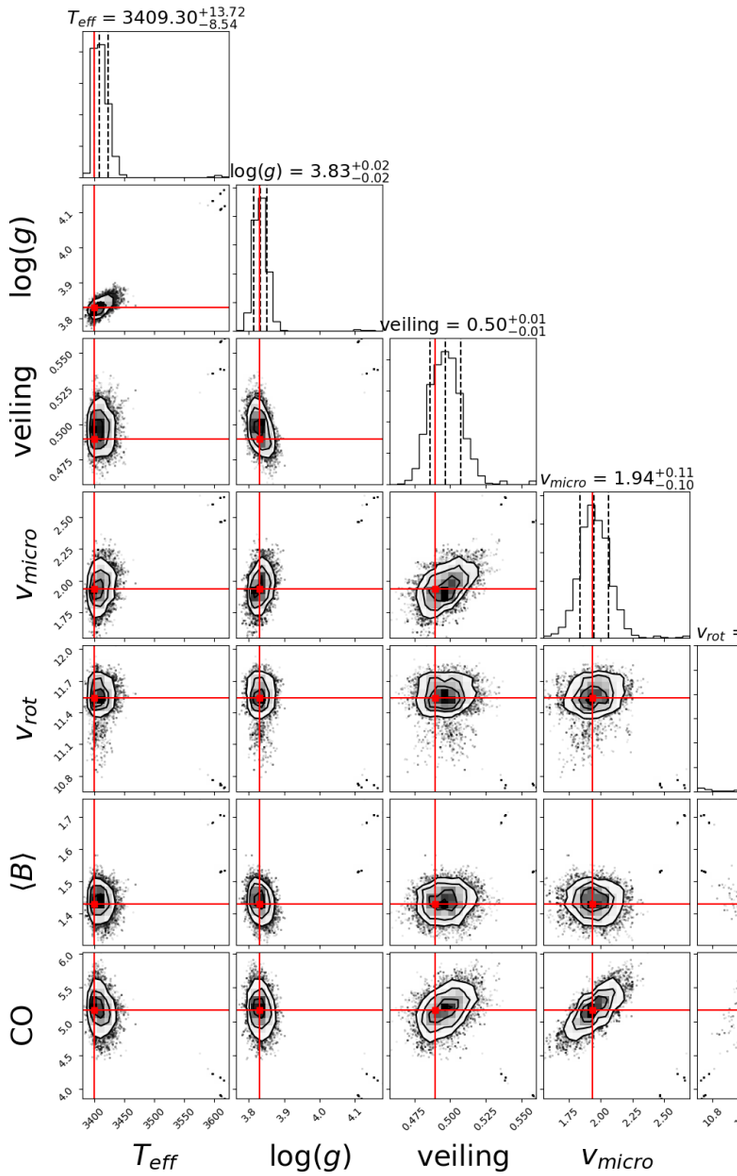

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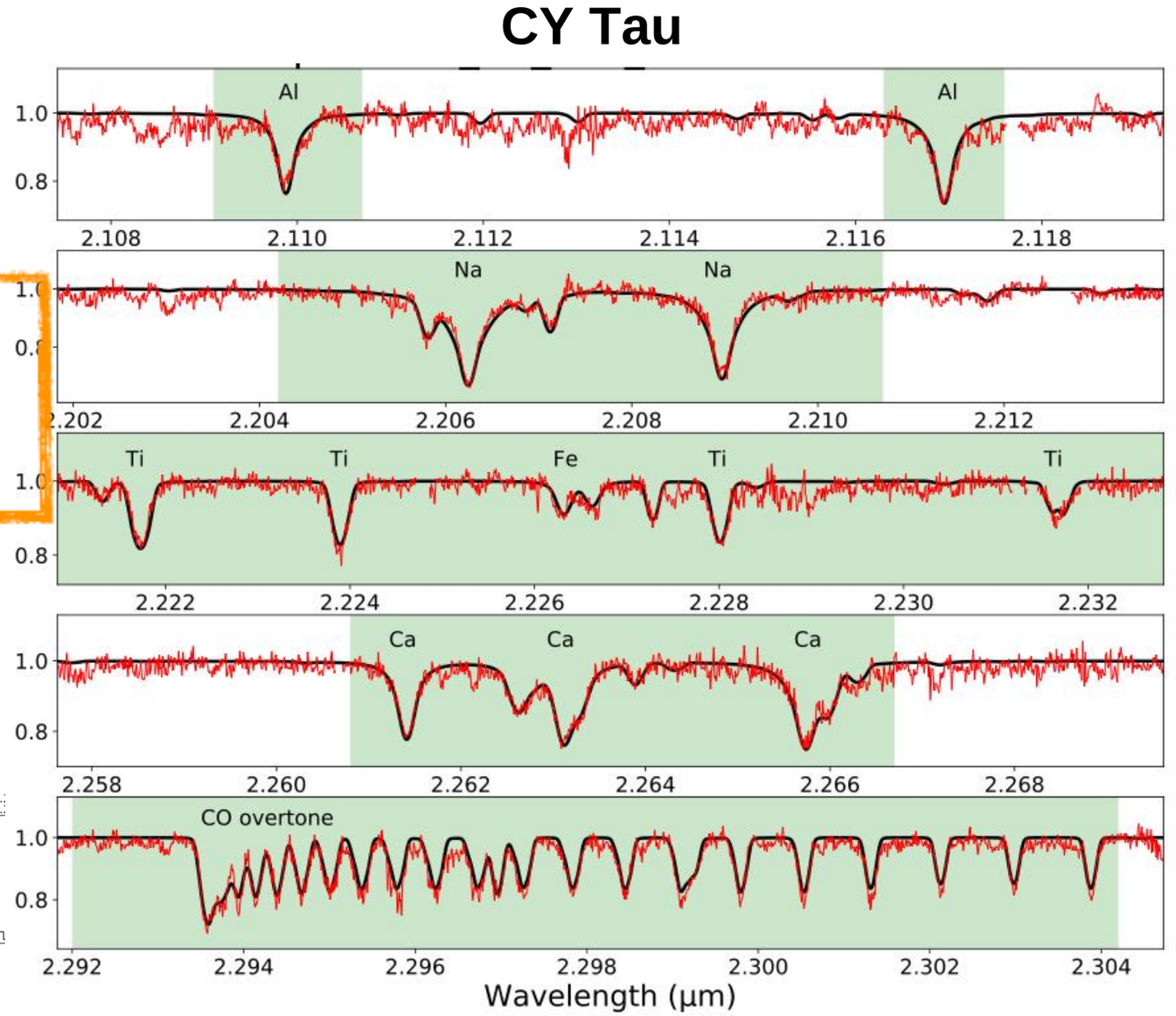
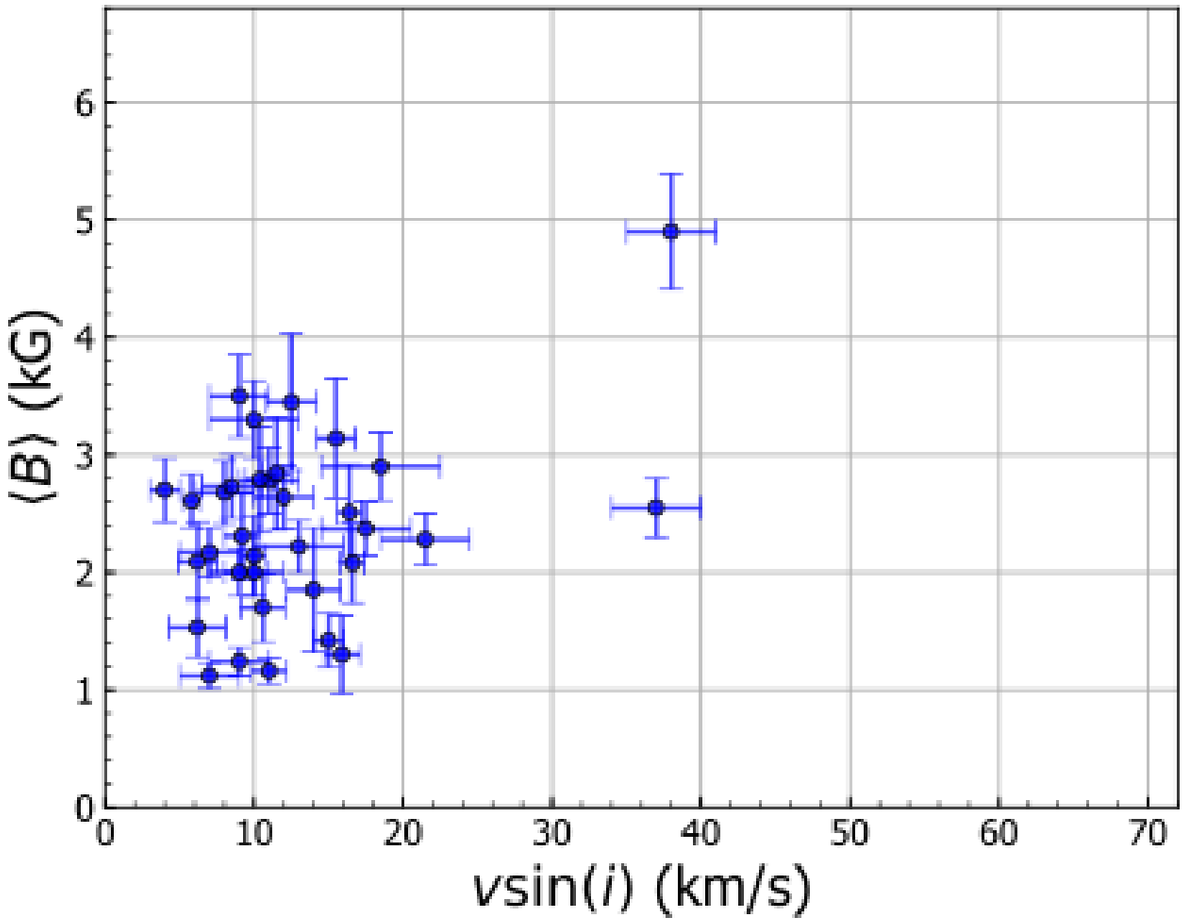


Magnetic Fields and Rotation

Reproduced from: Yang & Johns-Krull (2011)



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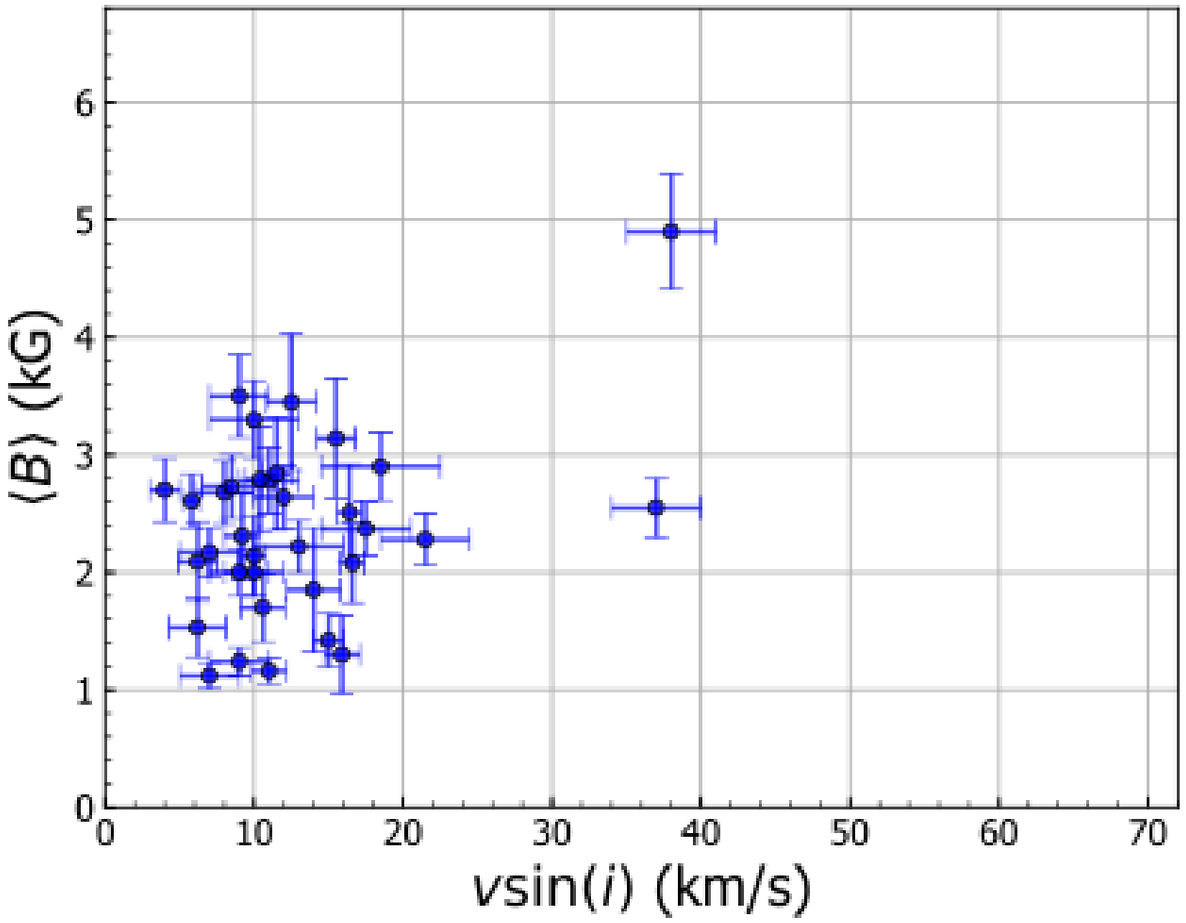
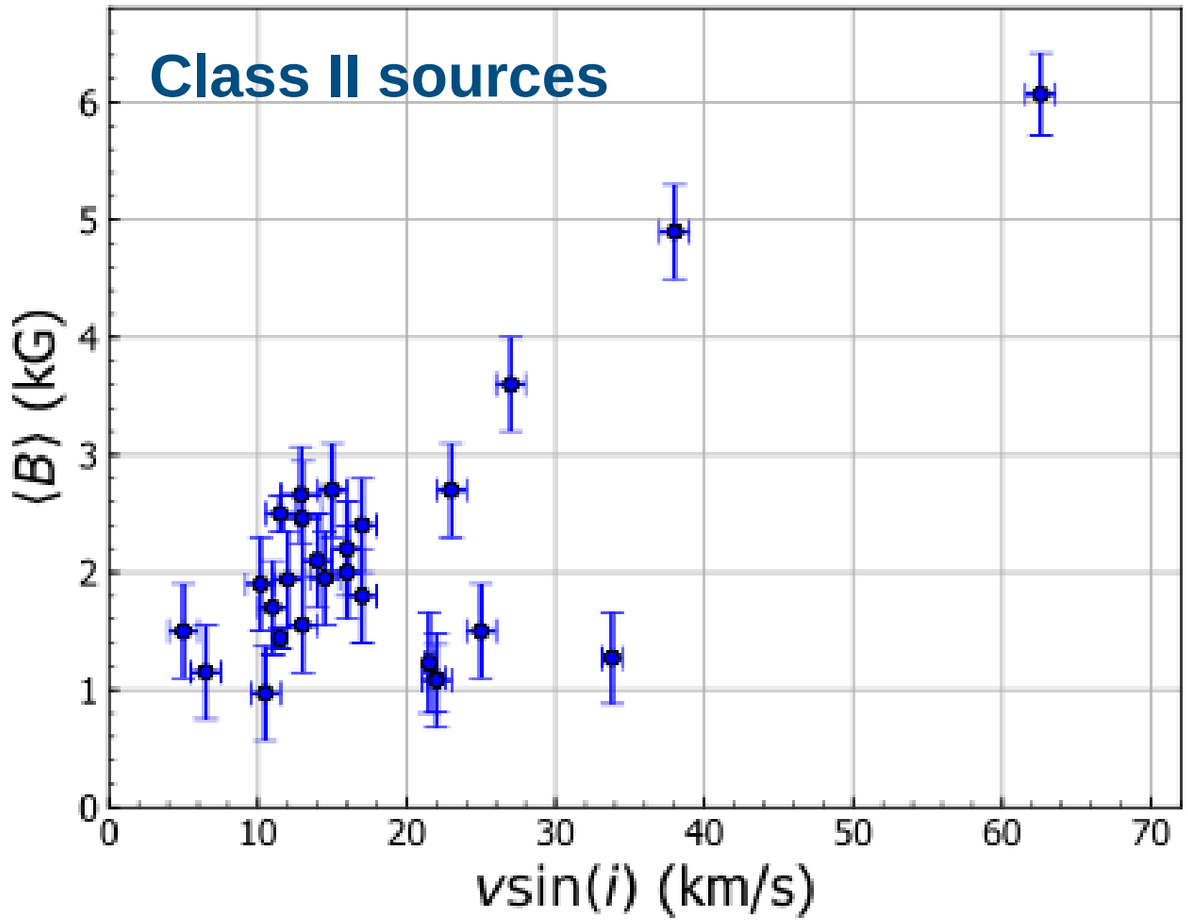


Our work



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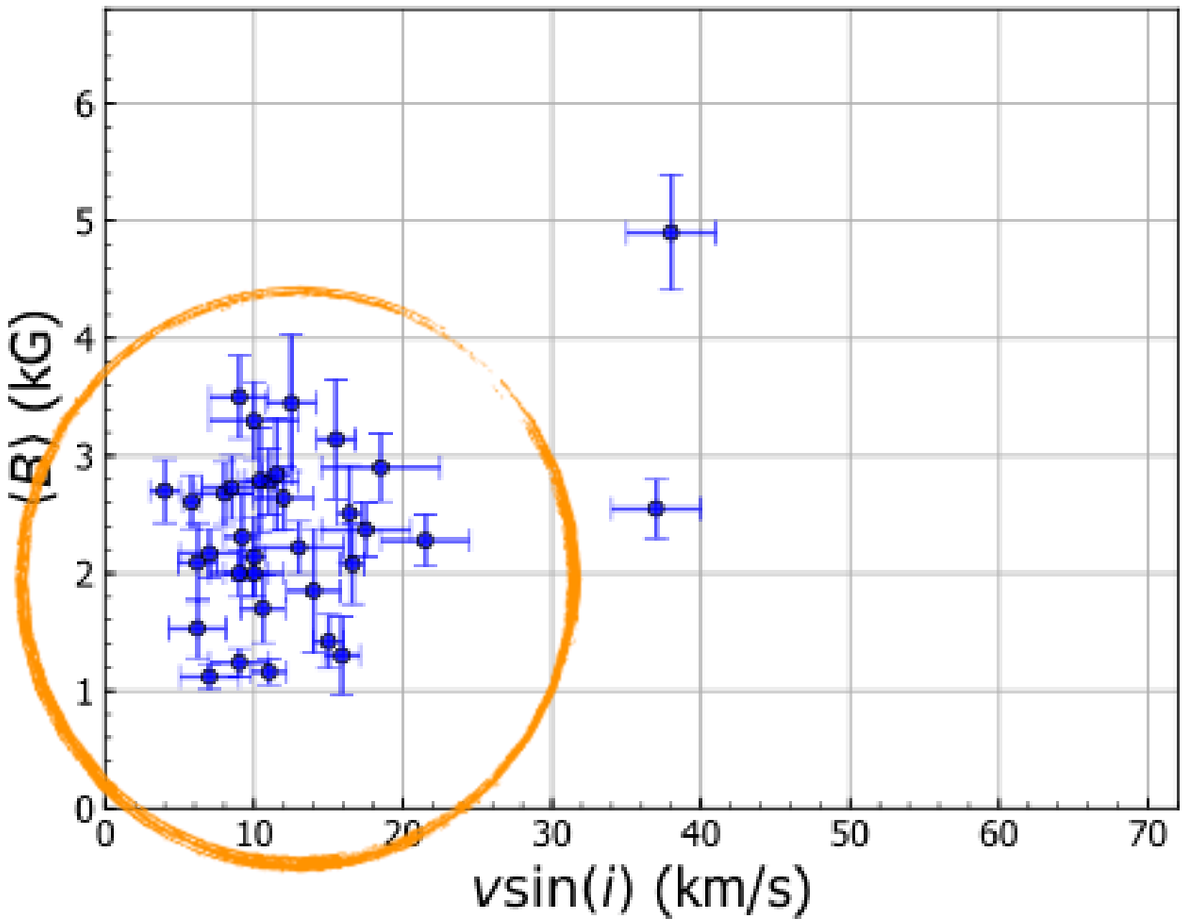

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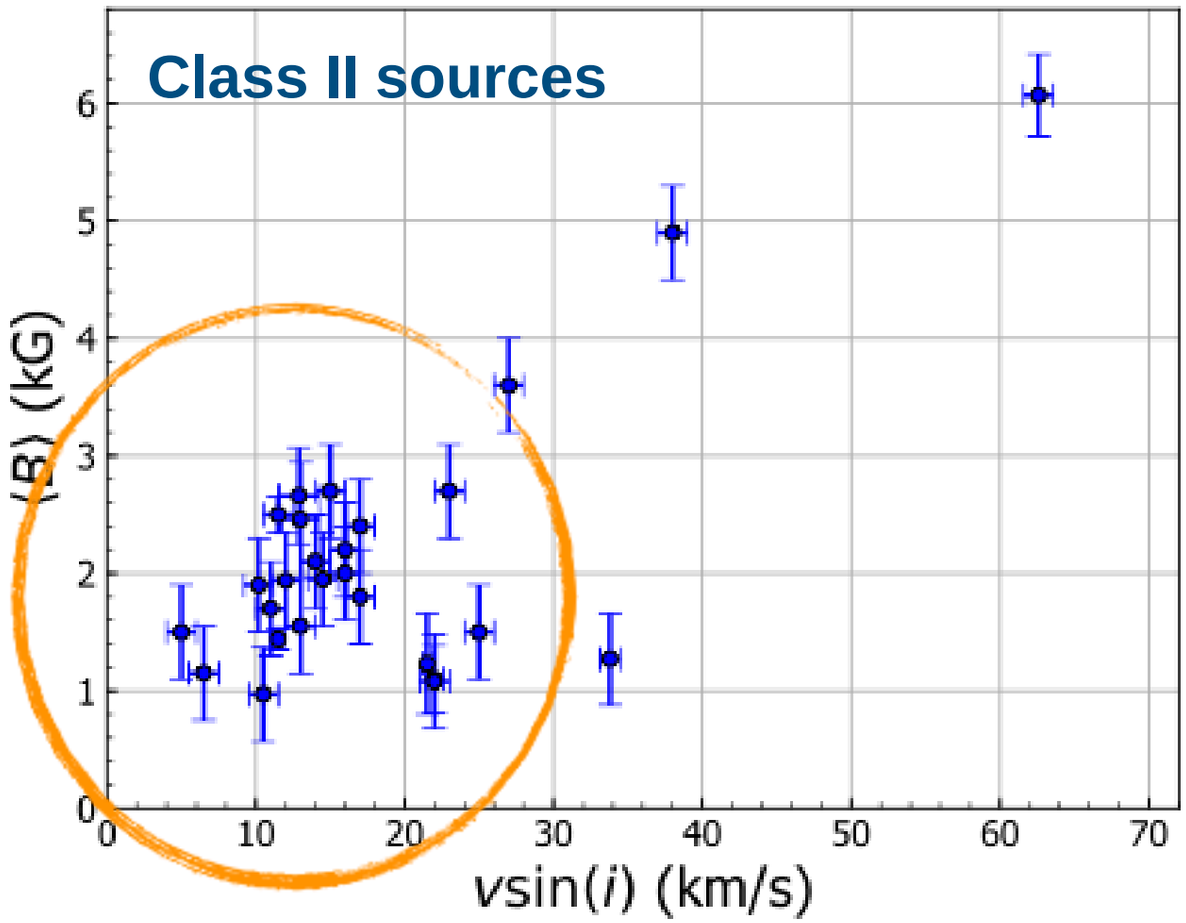

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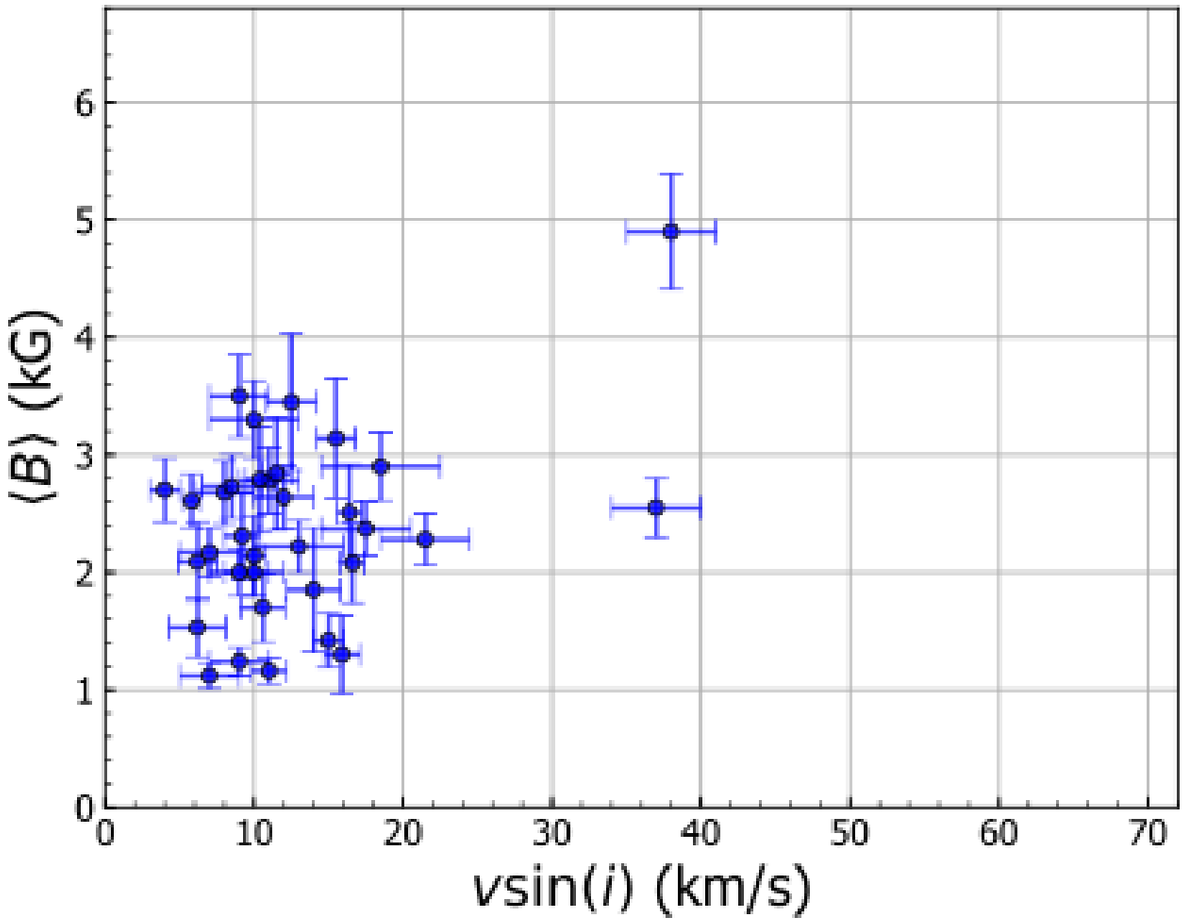

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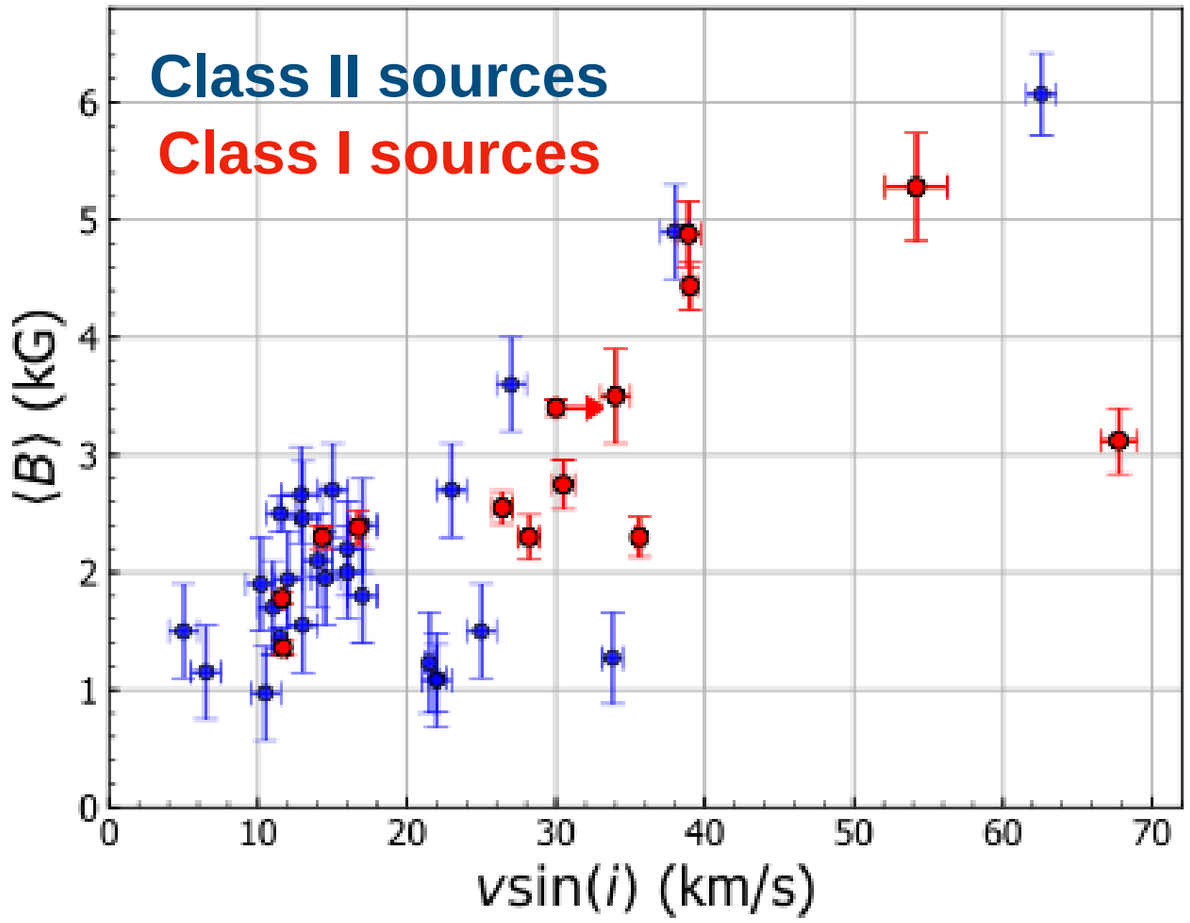
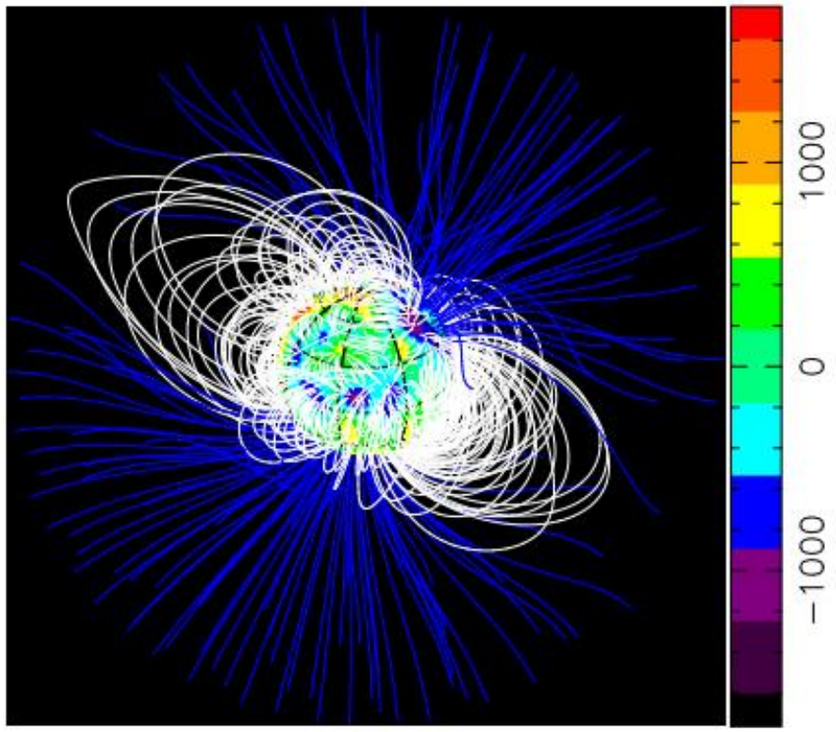


Dynamo Origin of Magnetic fields

Polarized light: ZDI



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Dynamo

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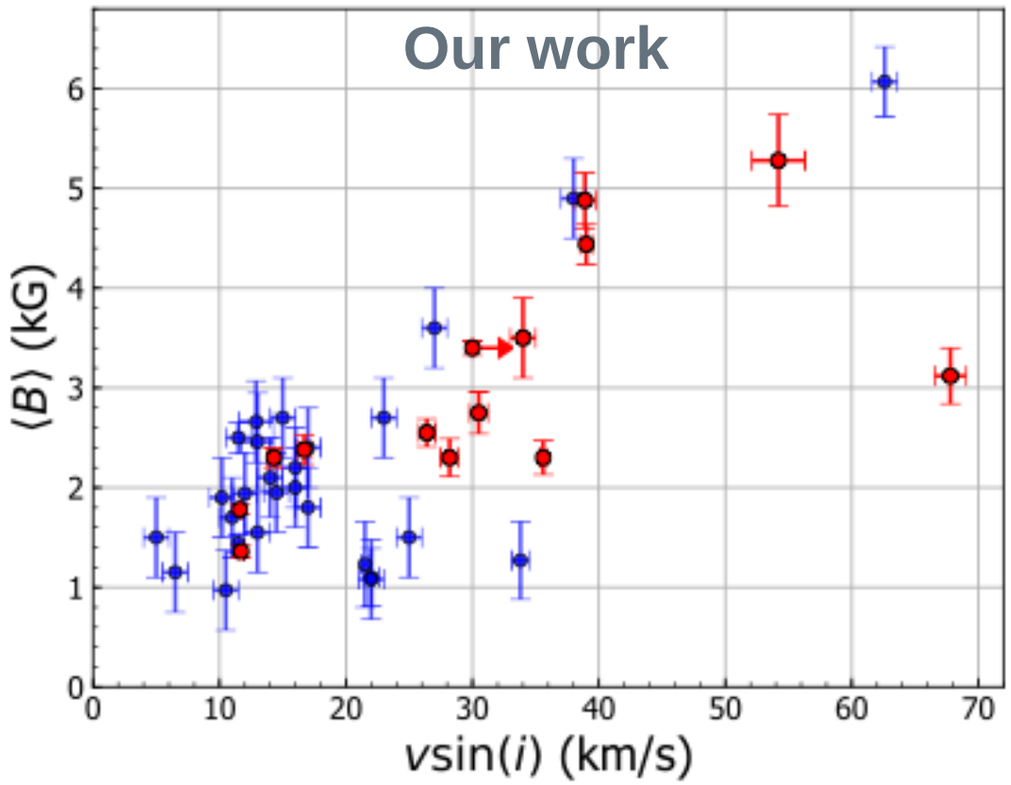
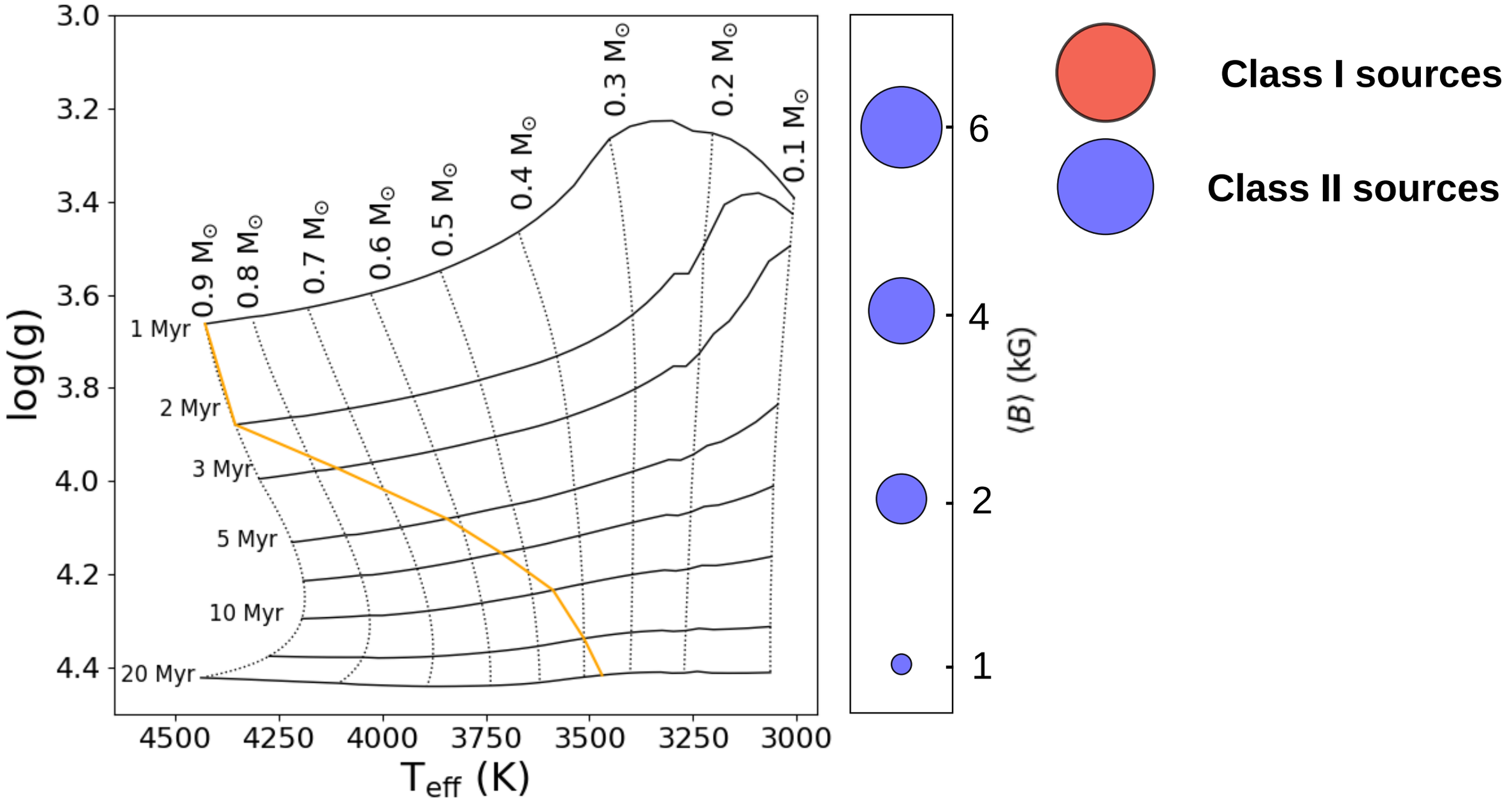


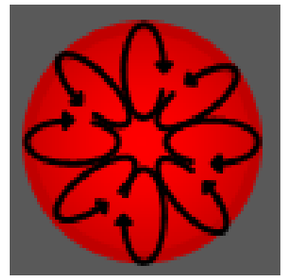
Flores et al. (2019b, in prep)

Dynamo

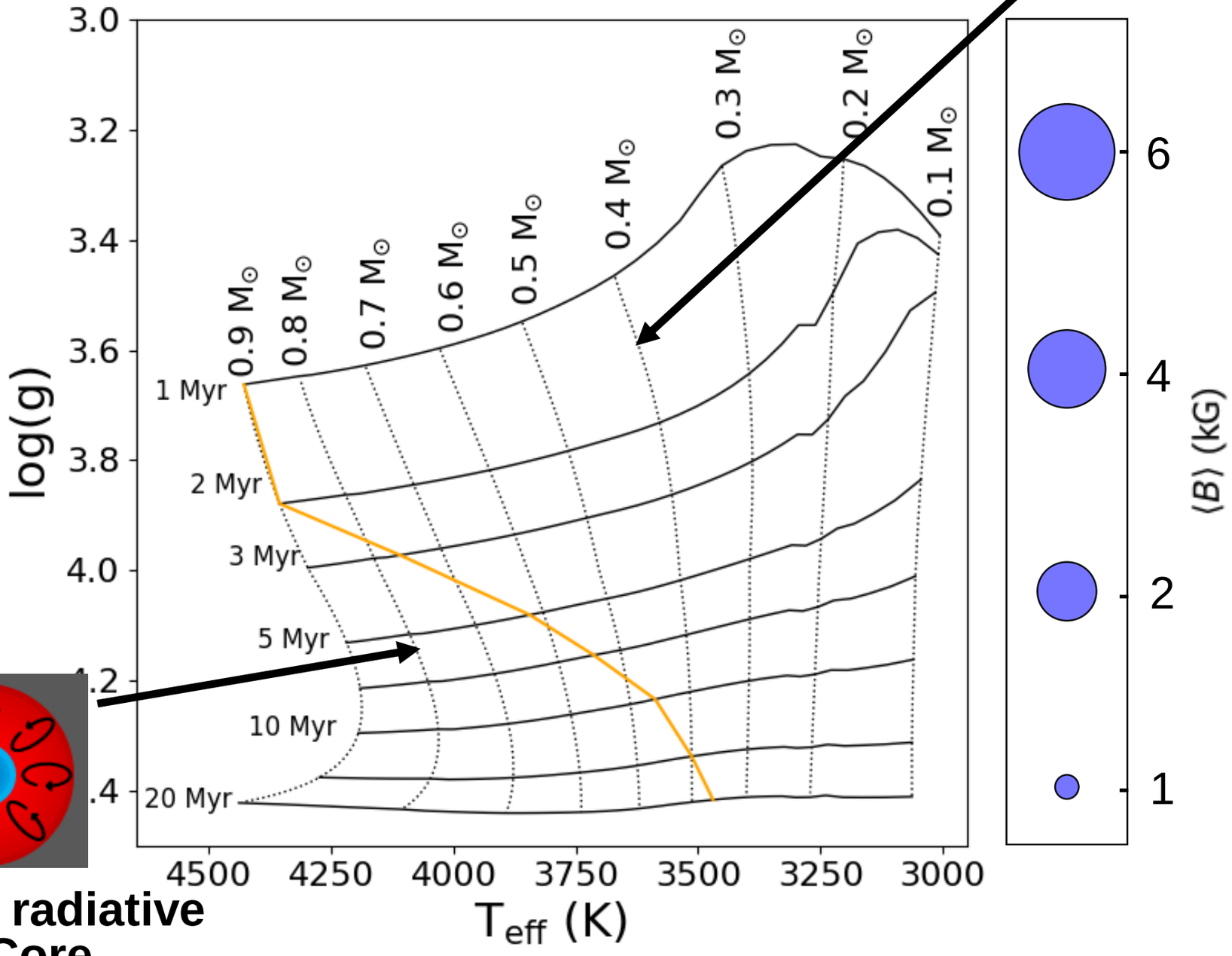
In the HR Diagram

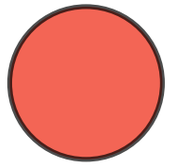


In the HR Diagram

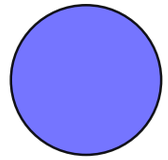


Fully convective stars

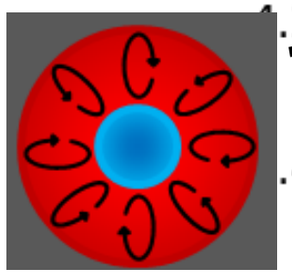




Class I sources

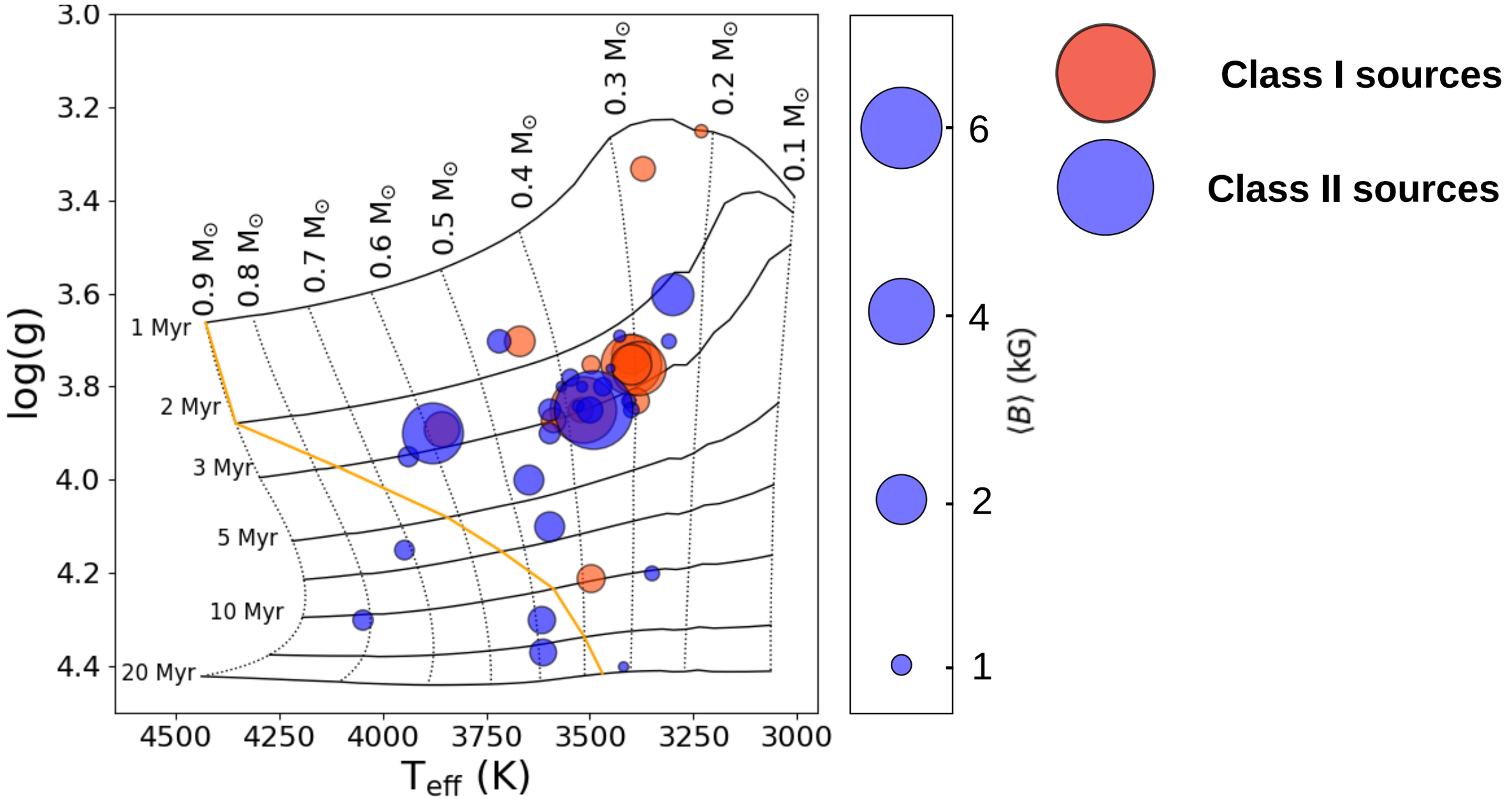


Class II sources



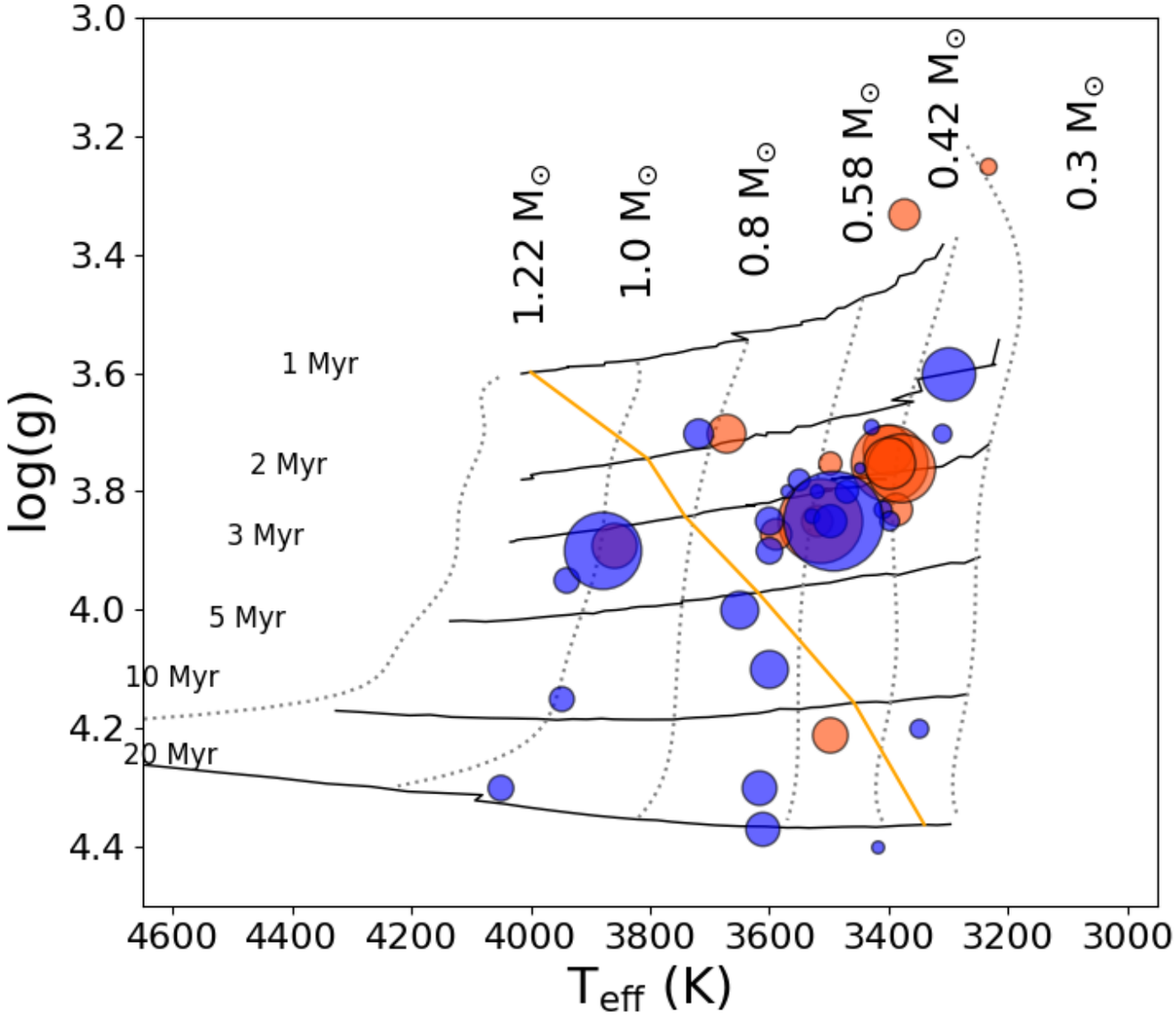
Small radiative Core

In the HR Diagram

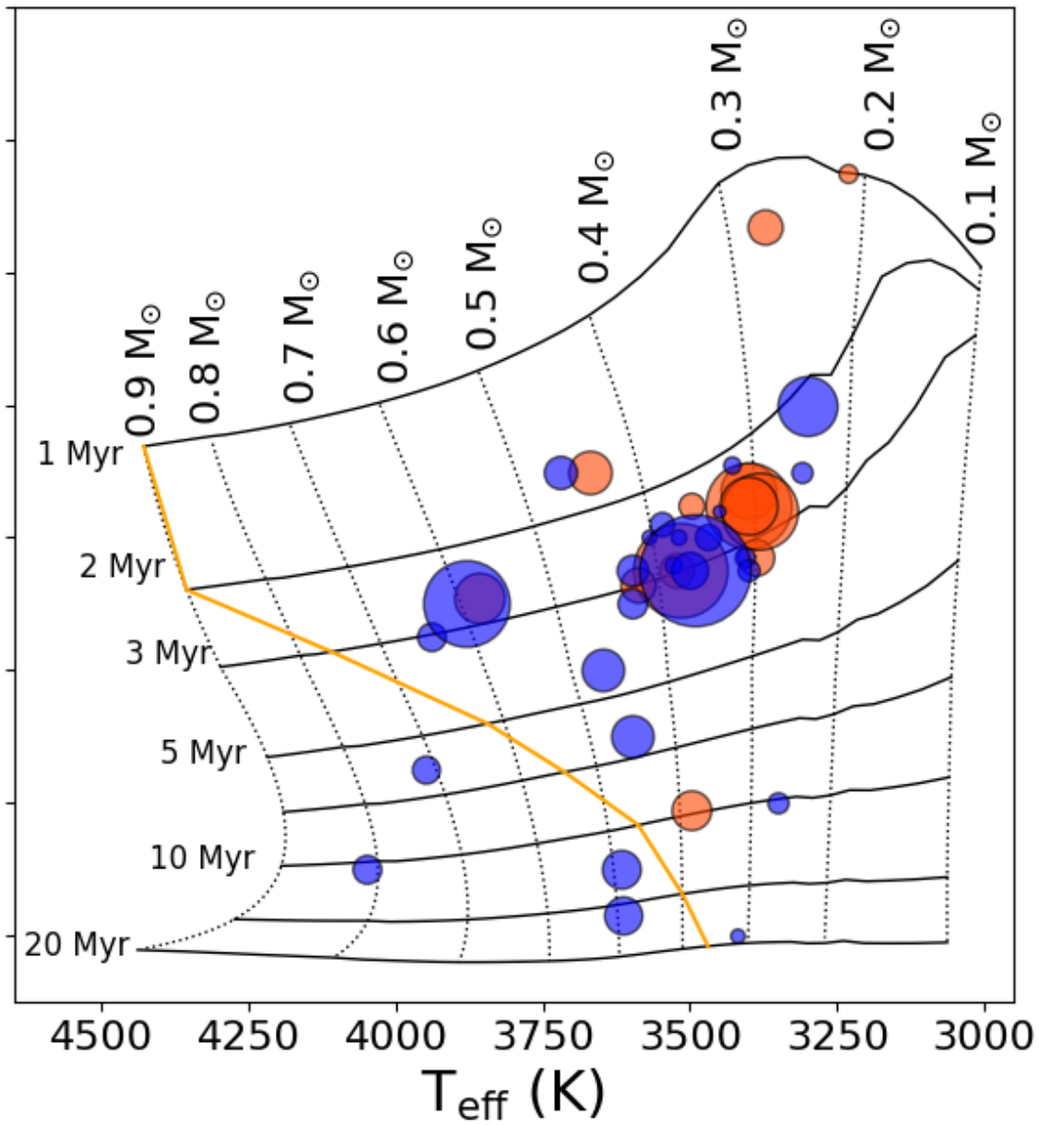


Evolutionary models comparison

Magnetic Evolutionary Models



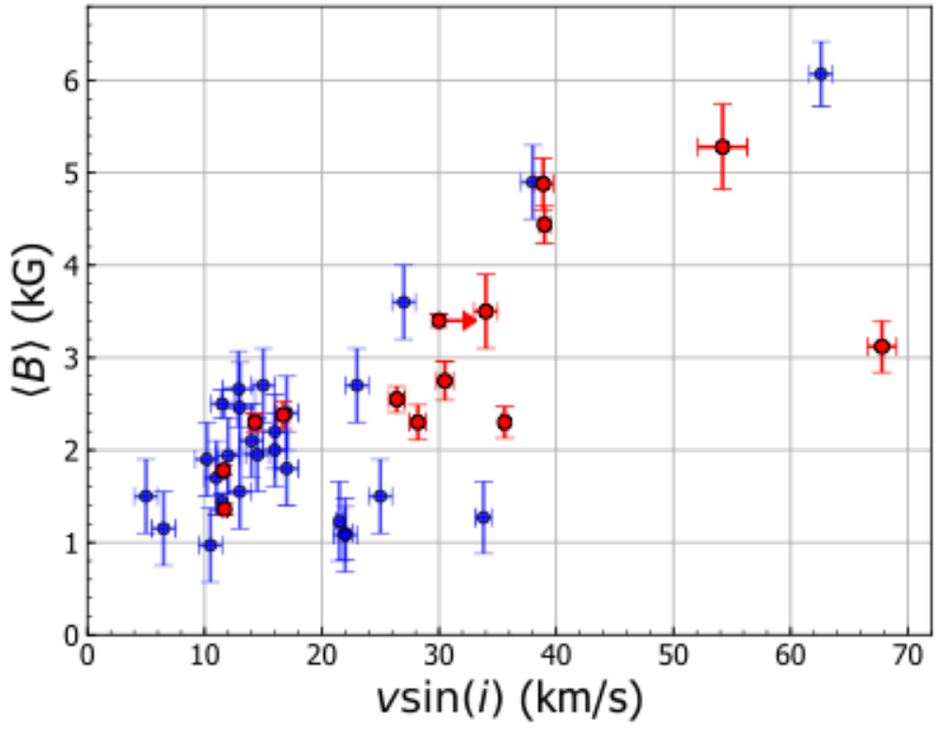
Non-magnetic Evolutionary Models



Evolutionary models: Feiden (2016)

Summary

1. Correlation between magnetic field strength and rotation
   - ➔ Dynamo origin of the magnetic fields in low-mass young stars

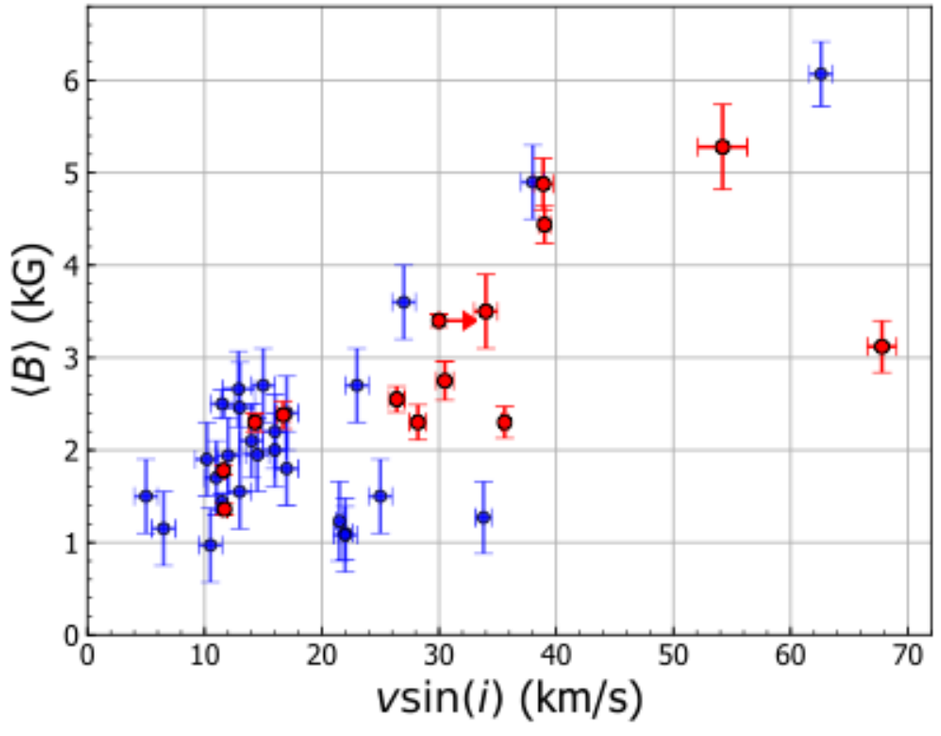


Summary

1. Correlation between magnetic field strength and rotation
   - ➡ Dynamo origin of the magnetic fields in low-mass young stars
2. Tentative evidence that fully convective stars have stronger magnetic fields
   - ➡ Need more data
   - ➡ Models are uncertain

Summary

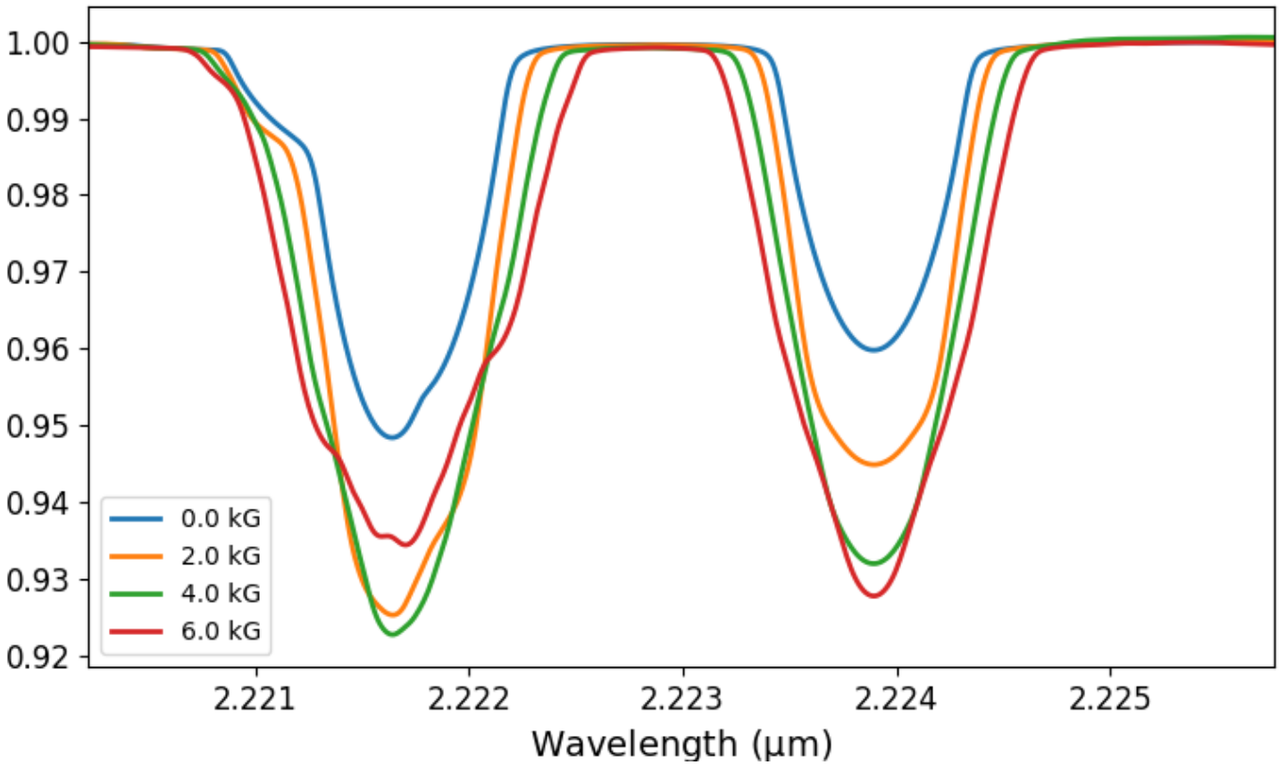
1. Correlation between magnetic field strength and rotation
   - Dynamo origin of the magnetic fields in low-mass young stars

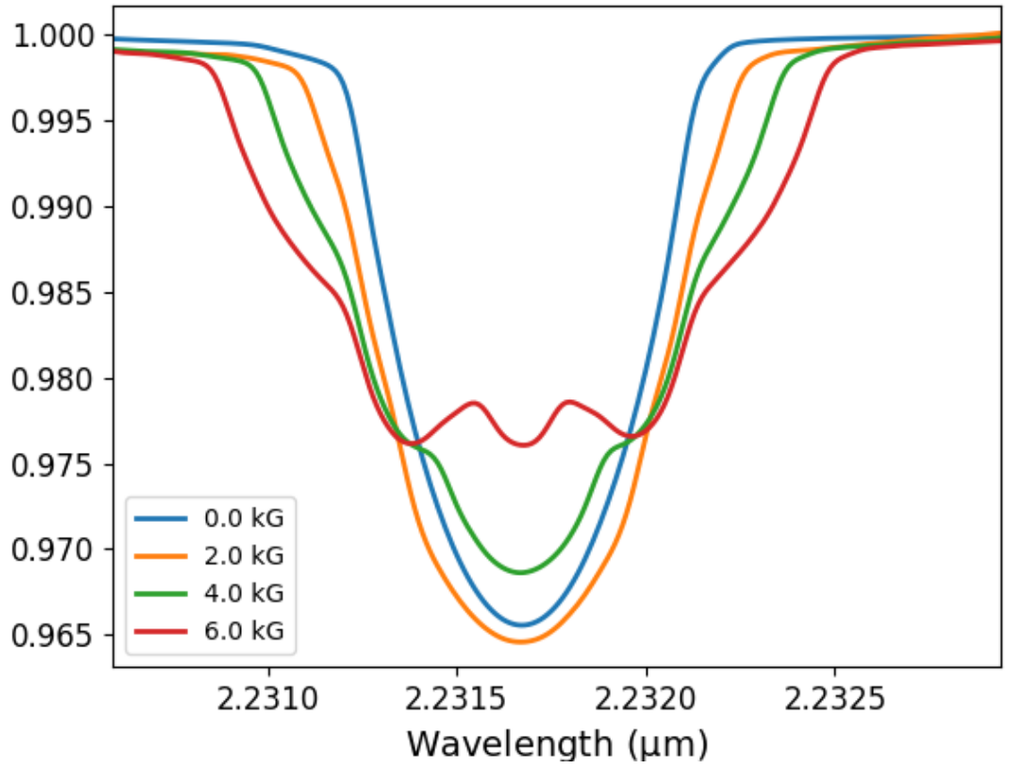


Thank you!

Back up Slides

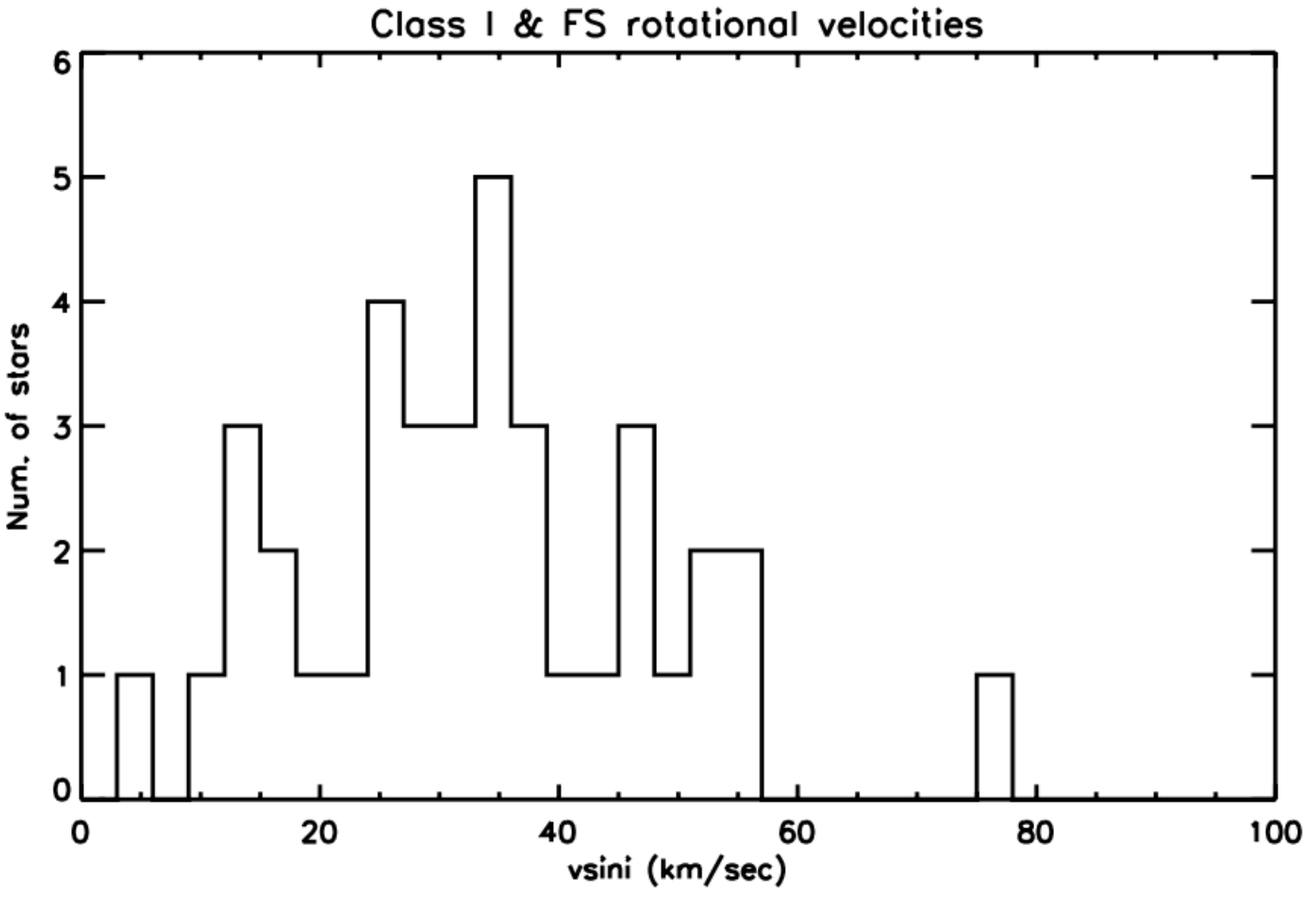
Magnetic fields in fast rotating stars

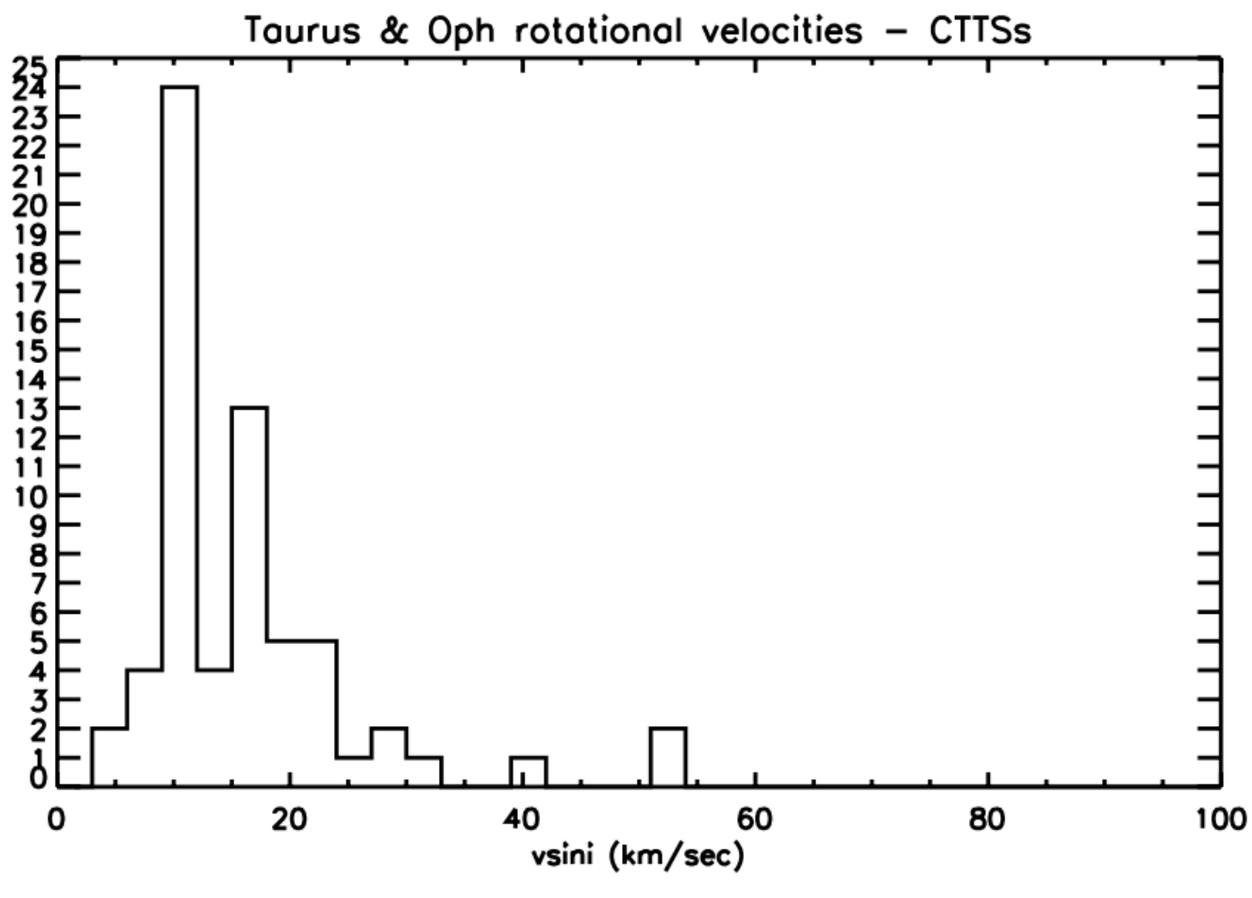




- 3 highly magnetically sensitive Ti lines
- Teff=3600 K, log(g)=3.8, vsin(i)=60km/s

Rotational velocity distributions

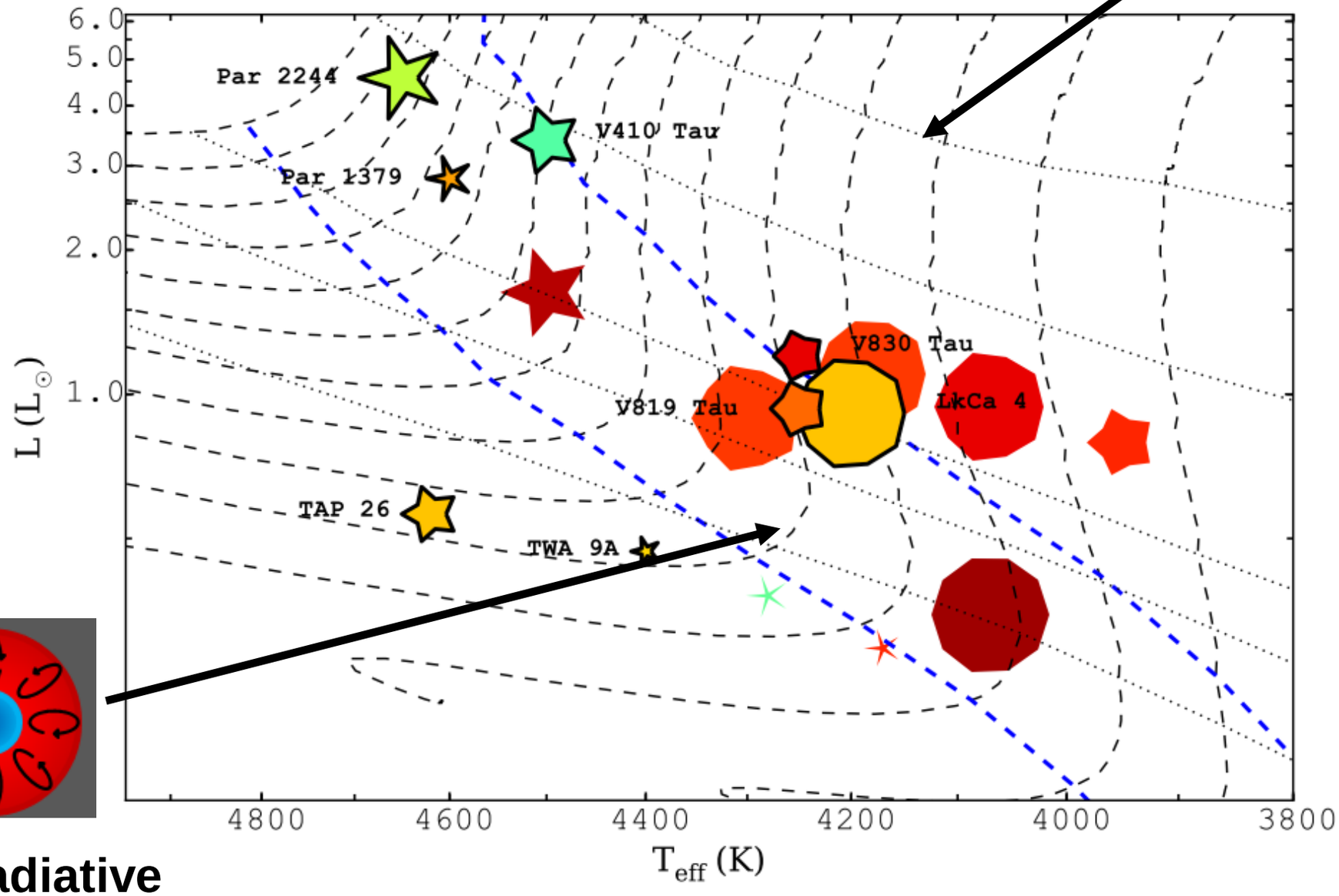


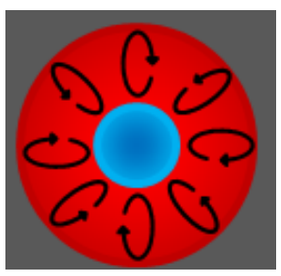


Covey et al. (2005)

In the HR diagram

Fully convective stars

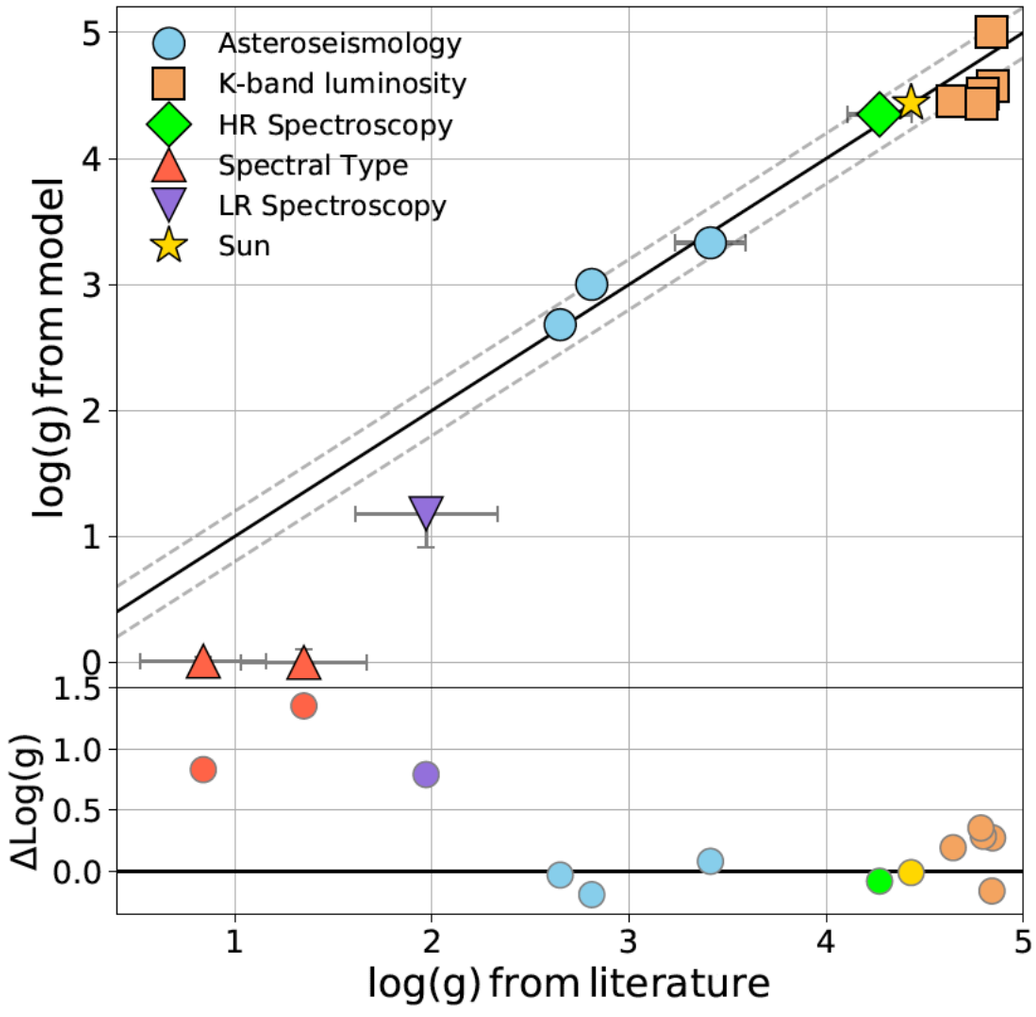


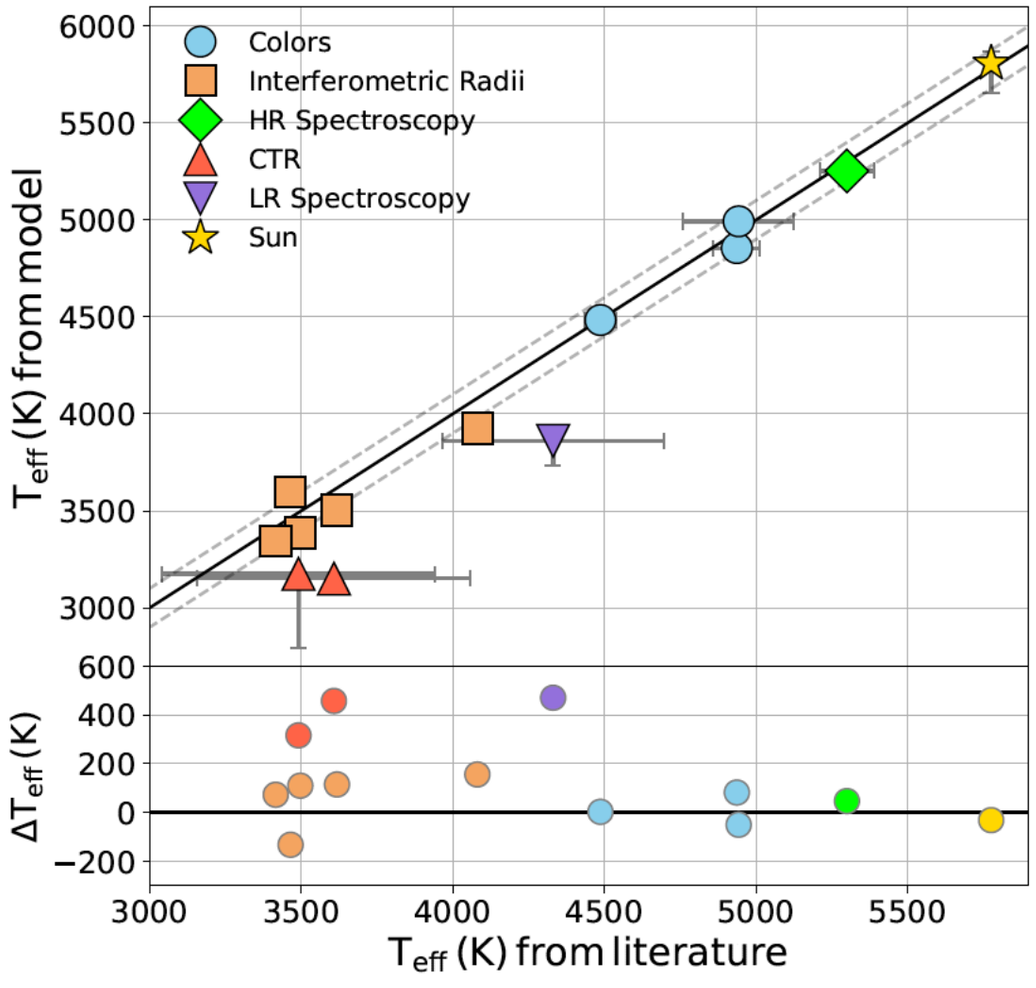


Small radiative Core

Hill et al. (2017)

Stellar parameters





Flores et al. (2019, in press)