



Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for

Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast

Rotators in

Cygnus OB2

References

Very first approach to the lack of fast rotators in Cygnus OB2

D. Galán-Diéguez ^{1,2} 

S.R. Berlanas ^{1,2}

A. Herrero ^{1,2}

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²*Universidad de La Laguna, Dpto. Astrofísica*

July 19, 2024





Hot Massive Stars Systems

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

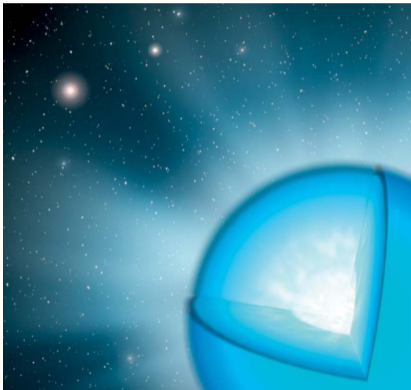
Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



Massive blue star credit: Instituto de Astrofísica de Canarias

Principal Characteristics

- $M_* \geq 8 M_{\odot}$
- Most powerful & luminous phenomena
- Rapid evolution

Crucial role in cosmos

Mechanical & radiative feedback

Langer (2012); Geen et al. (2015)



Hot Massive Stars Systems

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

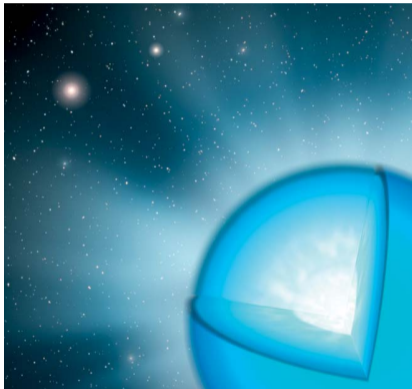
Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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Hot Massive Stars Systems

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

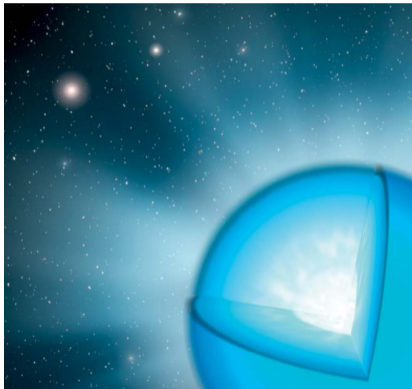
Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

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Lack of Fast Rotators in Cygnus OB2

References



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Rotation in Massive Stars

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References

Importance of rotation

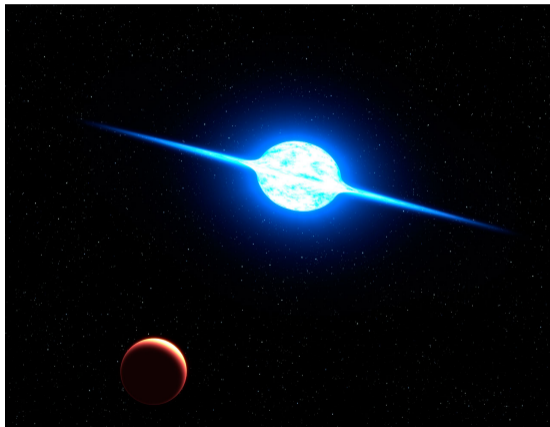
- Rotation key element

- Evolution
- Fate

- Similar

- Stellar mass
- Metallicity

Maeder & Meynet (2000)



Massive rotating blue star credit: NASA, ESA, and G. Bacon (STScI)



Rotation in Massive Stars

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References

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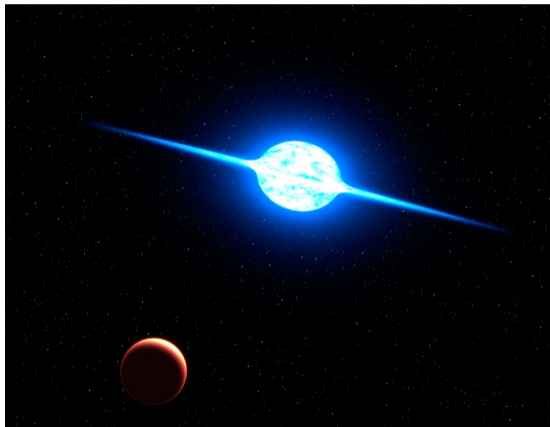
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Rotation in Massive Stars

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

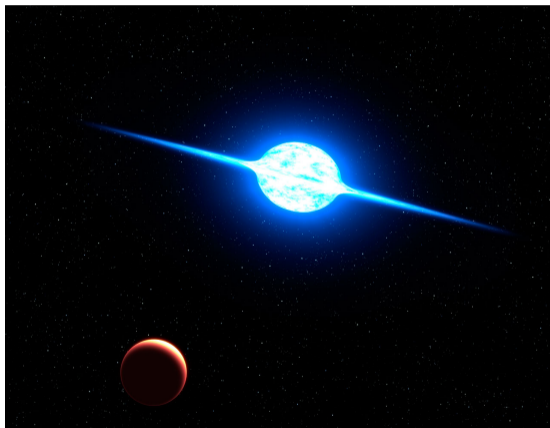
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Rotation in Massive Stars

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

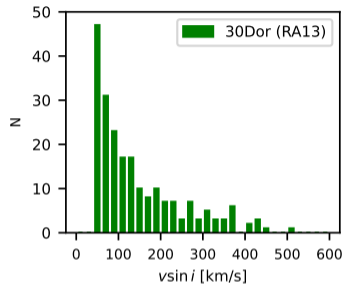
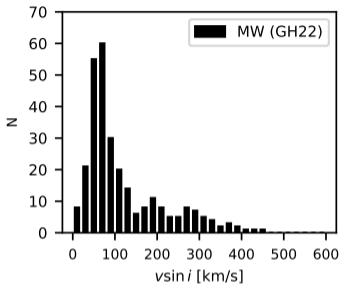
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Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



Distributions of rotational velocities

- O-type stars

- Milky Way Holgado et al. (2022)

- 30 Doradus Ramirez-Agudelo et al. (2013)

- Bimodal distribution

- Peak slow rotators ($v \sin i \sim 80 \text{ km s}^{-1}$)

- Tail fast rotators ($v \sin i > 200 \text{ km s}^{-1}$)



Rotation in Massive Stars

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for

Cygnus OB2

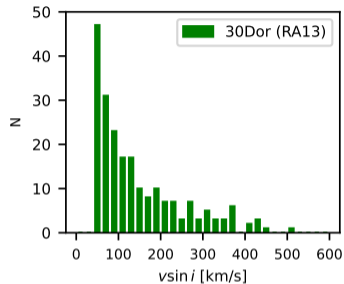
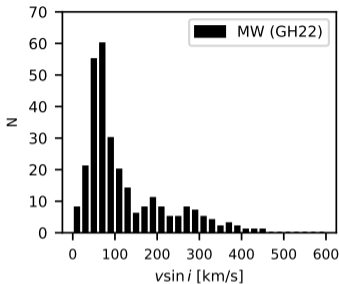
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Lack of Fast

Rotators in

Cygnus OB2

References



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Rotation in Massive Stars

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

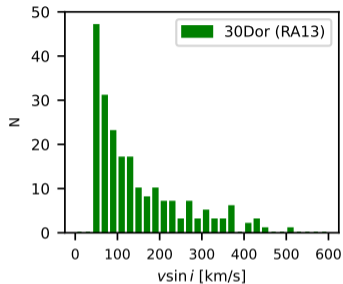
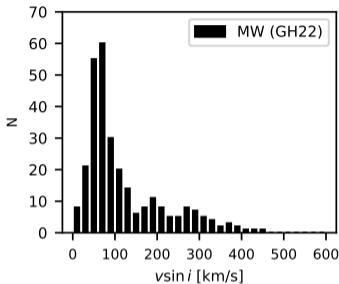
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Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

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Rotation in Massive Stars

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

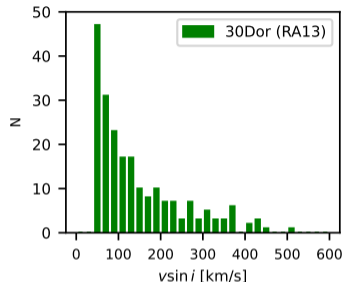
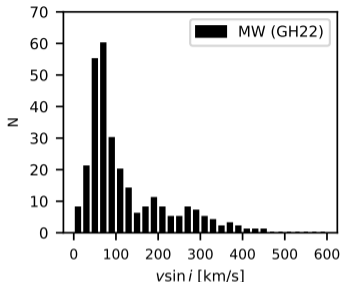
Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast

Rotators in Cygnus OB2

References



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Rotation in Massive Stars

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

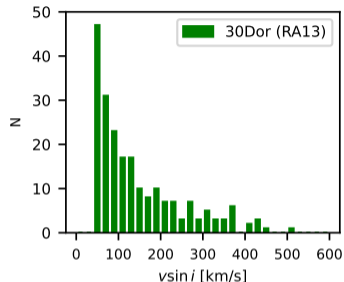
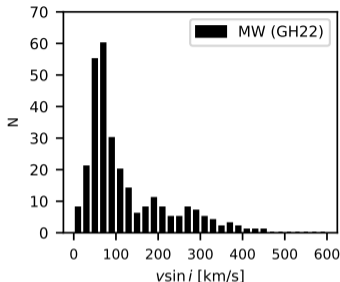
Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast

Rotators in Cygnus OB2

References



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Fast Rotators: post binary products

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

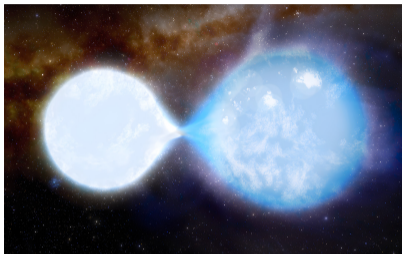
New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



Blue massive binary system: University College of London (UCL) / J. daSilva.

Massive stars systems

- Most found in multiple systems
- Interaction between members systems
 - Evolution & Fate

Sana et al. (2014)

Interactions in massive stars systems

- Different interactions
 - Tides, mass-exchange, ...
- Rotation rate change

de Mink et al. (2013)



Fast Rotators: post binary products

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

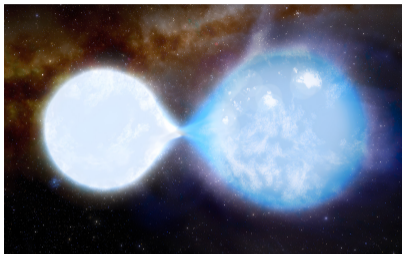
New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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Fast Rotators: post binary products

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

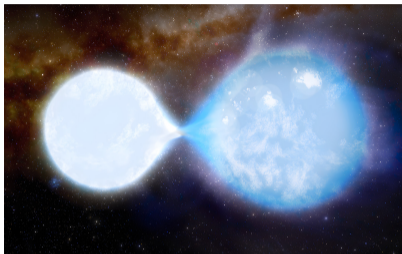
New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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Fast Rotators: post binary products

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

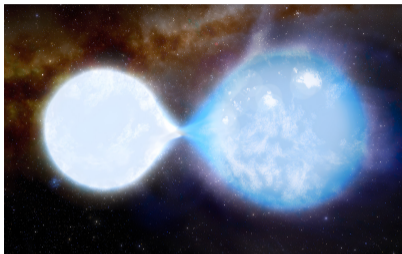
New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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Fast Rotators: post binary products

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

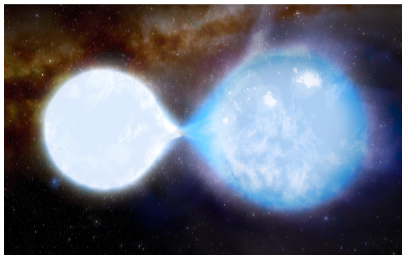
New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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Fast Rotators: post binary products

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

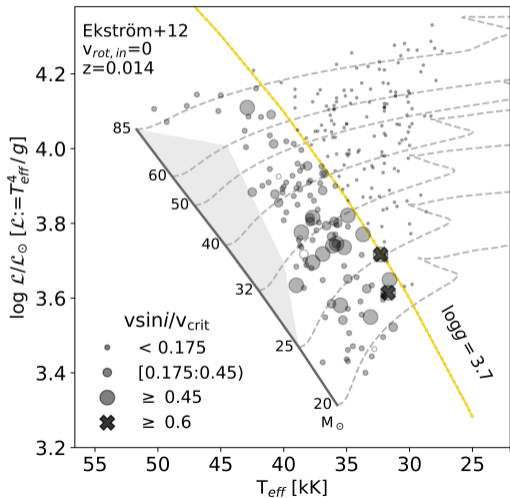
Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



Fast-rotators

- **Late O-type stars**

- $M_* < 32 M_{\odot}$

- Binary interactions \rightarrow fast rotators

Holgado et al. (2022)



Fast Rotators: post binary products

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

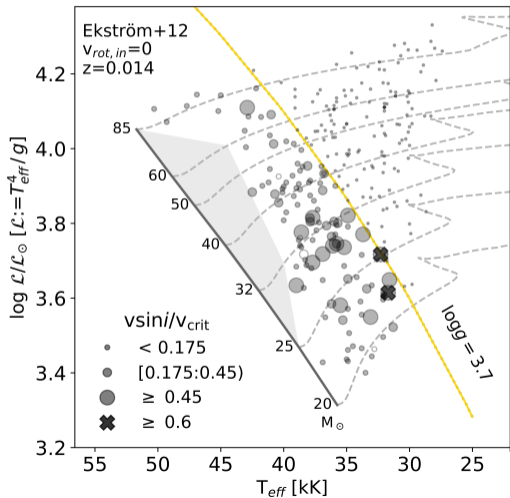
Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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Cygnus OB2 association

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References

Key Region

- One of the richest areas of star formation in MW
- Nearest from Earth
~ 1.7 kpc
- Understanding of massive stars

formation and evolution
of massive stars
dynamics of star
clusters
feedback processes



Cygnus OB2 image credit: X-ray: NASA/CXC/SAO/J. Drake et al; H-alpha: Univ. of Hertfordshire/INT/IPHAS; Infrared: NASA/JPL-Caltech/Spitzer



Cygnus OB2 association

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References

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Cygnus OB2 association

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References

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$v \sin i$ distribution in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

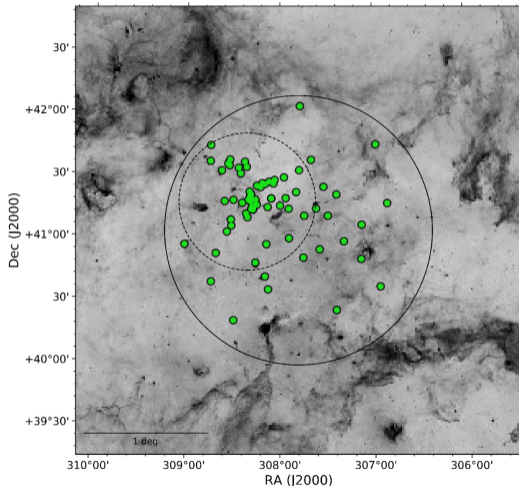
Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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- Literature & new spectra
- $v \sin i$ distribution



$v \sin i$ distribution in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

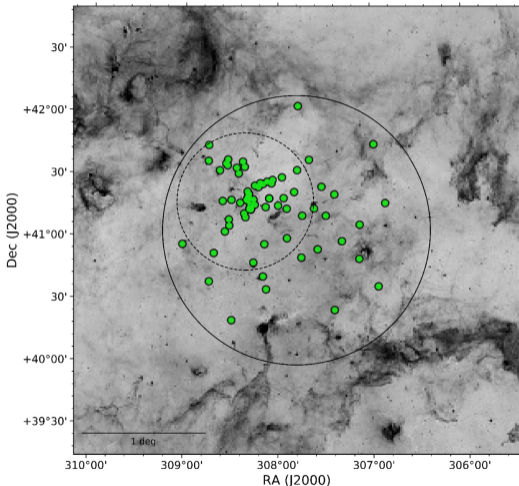
Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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$v \sin i$ distribution in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

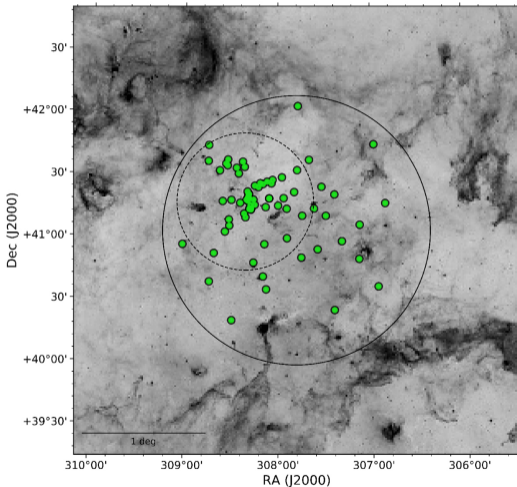
Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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$v \sin i$ distribution in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

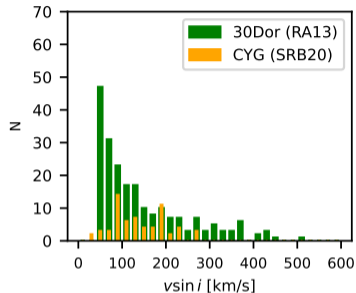
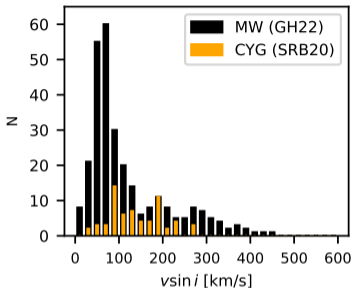
New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



Cygnus OB2 $v \sin i$ distribution

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– 30 Doradus [Ramírez-Agudelo et al. \(2013\)](#)

- Lack of fast rotators

– $v \sin i \geq 200 - 250 \text{ km s}^{-1}$



$v \sin i$ distribution in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

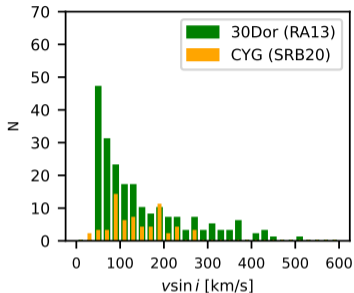
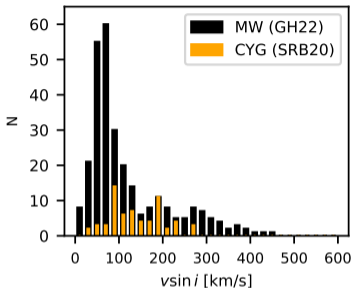
New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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- Lack of fast rotators

- $v \sin i \geq 200 - 250 \text{ km s}^{-1}$



$v \sin i$ distribution in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

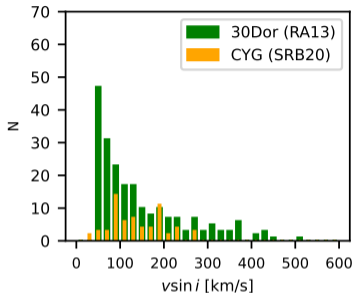
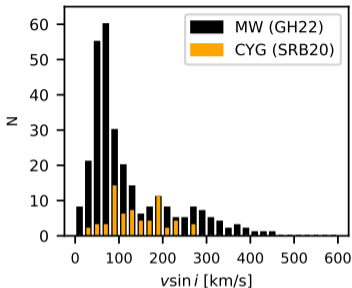
New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



Cygnus OB2 $v \sin i$ distribution

- Comparison

- Milky Way [Holgado et al. \(2022\)](#)

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- 30 Doradus [Ramírez-Agudelo et al. \(2013\)](#)

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$v \sin i$ distribution in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

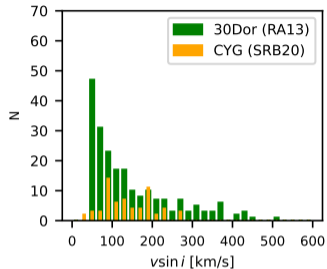
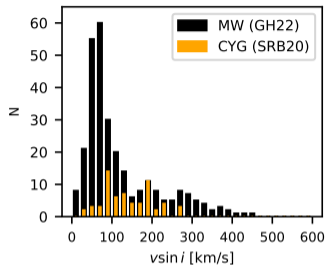
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Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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- WHAT'S GOING ON IN CYGNUS OB2?
 - Fast-rotators expected: 15-20



$v \sin i$ distribution in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

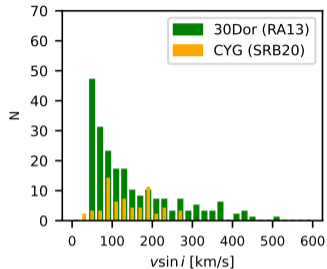
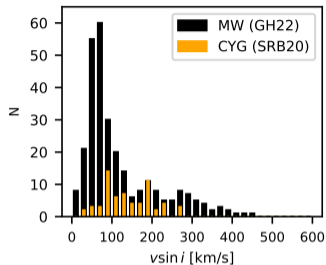
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Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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$v \sin i$ distribution in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

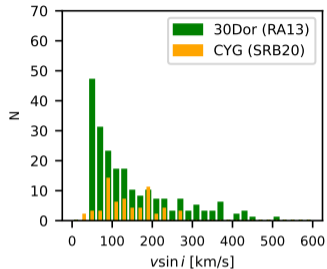
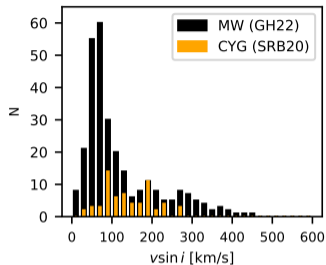
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Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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WHAT'S GOING ON IN CYGNUS OB2?

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$v \sin i$ distribution in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

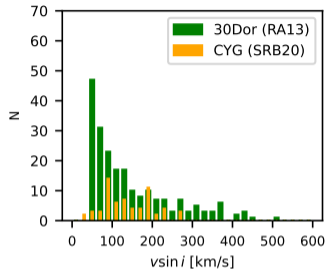
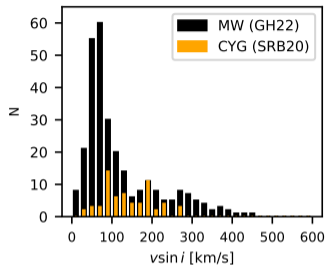
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Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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Lack of fast rotators in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for Cygnus OB2

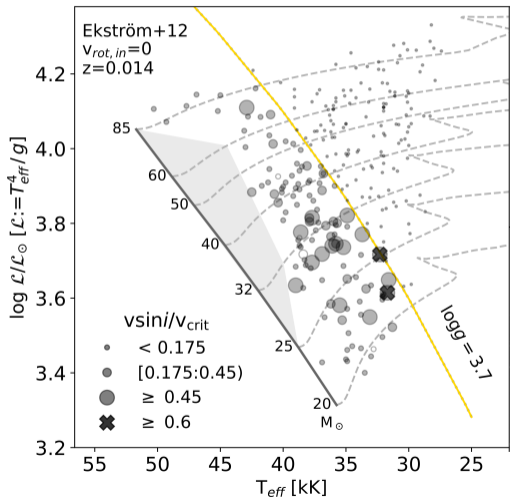
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Lack of Fast Rotators in Cygnus OB2

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D. Galán-Diéguez et al. (in prep)

- **Rotation affects spectral classification**
- Fast rotators $\iff M_* < 32 M_\odot$
Late-O types





Lack of fast rotators in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for Cygnus OB2

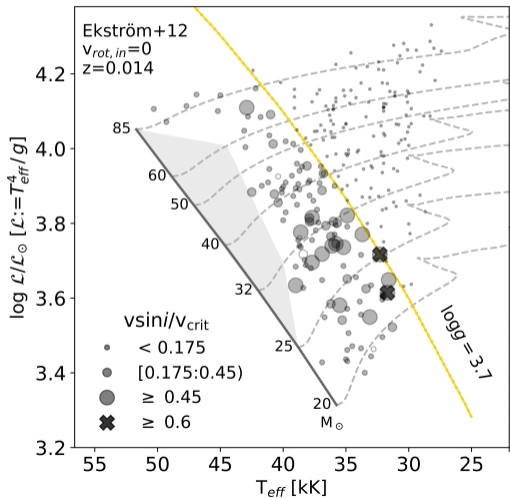
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Lack of fast rotators in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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Lack of fast rotators in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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Lack of fast rotators in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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- 1 Are the early-B type stars well classified?
 - **late-O types?**
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Lack of fast rotators in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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How Rotation Affects Spectral Classification?

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

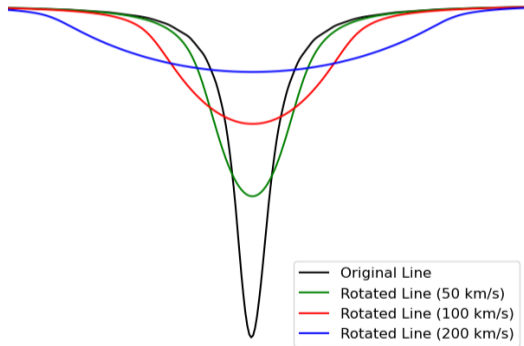
Lack of Fast Rotators in Cygnus OB2

References

Synthetic Spectra

- FASTWIND
 - $T \in [30000 - 35000]$ K
 - Main-sequence star
- Degradation
 - Rotational broadening
 - Signal-to-noise ratios (SNRs)

Santolaya-Rey et al. (1997), Puls et al. (2005),
Rivero González et al. (2011)





How Rotation Affects Spectral Classification?

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References

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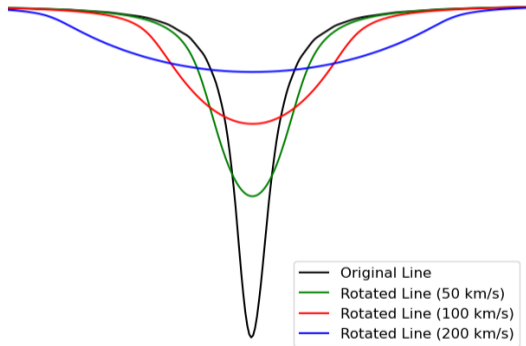
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How Rotation Affects Spectral Classification?

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

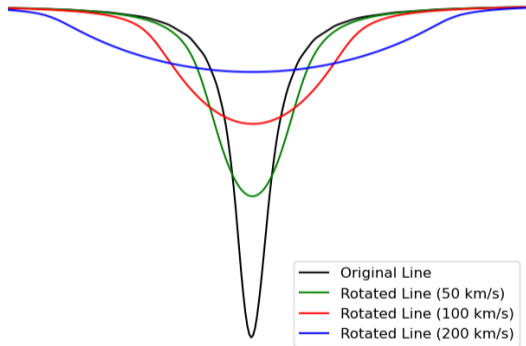
Lack of Fast Rotators in Cygnus OB2

References

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How does Rotation Affect Spectral Classification?

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

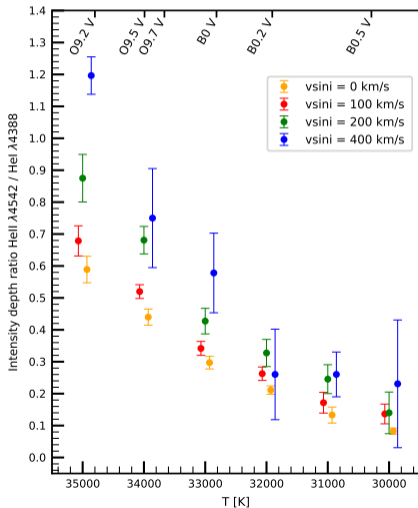
New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



Figure

- X-axis: model effective temperature (spectral type)
- Y-axis: intensity depth ratio
 - Line fitting



How does Rotation Affect Spectral Classification?

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

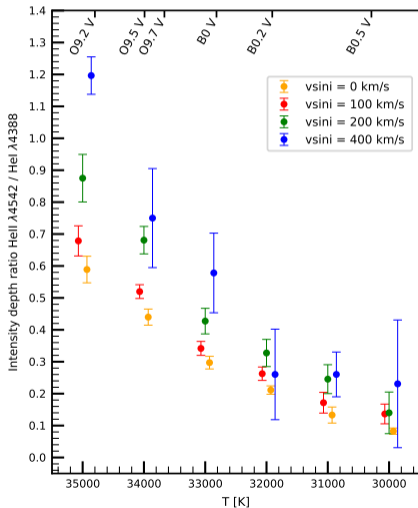
New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



Results

- \uparrow ratio - \uparrow rotation
- \uparrow temperature
- \uparrow error - \uparrow rotation
- Trend reversal
- $T < 33000$ K



How does Rotation Affect Spectral Classification?

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

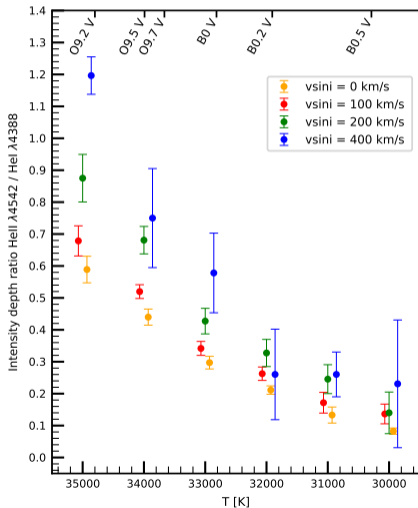
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Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



Results

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- $T < 33000$ K



How does Rotation Affect Spectral Classification?

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

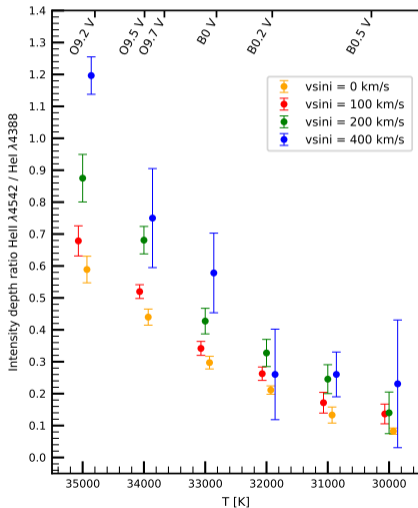
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Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



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- \uparrow **error** - \uparrow **rotation**
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- $T < 33000$ K



How does Rotation Affect Spectral Classification?

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

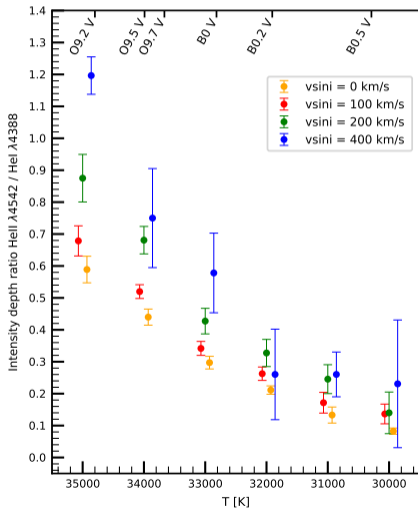
New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



Results

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How Rotation Affects Spectral Classification?

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

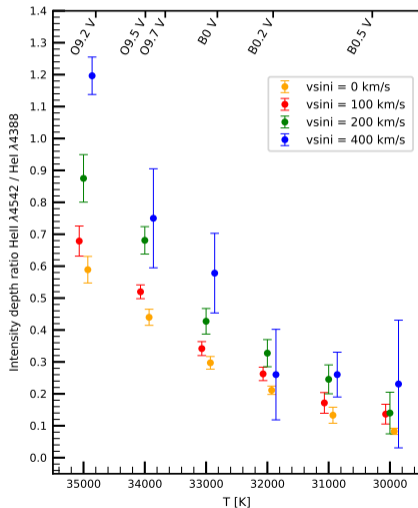
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Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



Conclusions

- 1 High-rotators confused with earlier types rotating at lower velocities.
- 2 High-rotators early-B types confused with later types.



How Rotation Affects Spectral Classification?

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

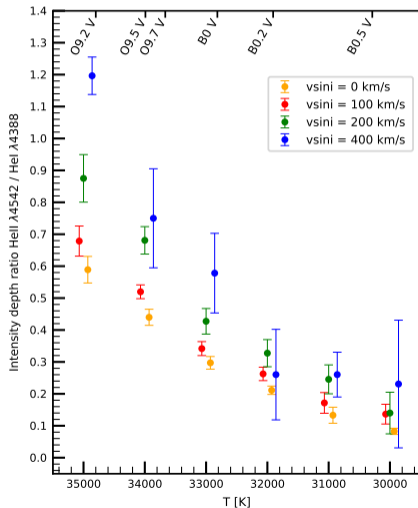
Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



Conclusions

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How Rotation Affects Spectral Classification?

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

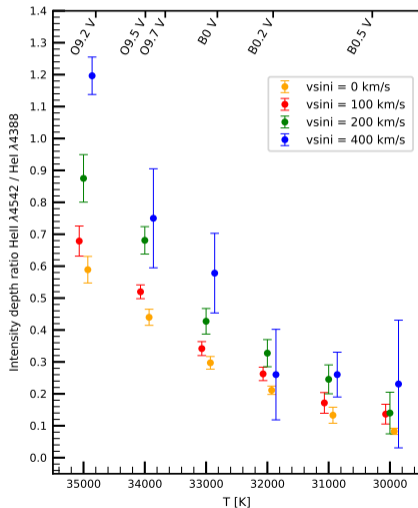
New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



Conclusions

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How Rotation Affects Spectral Classification?

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

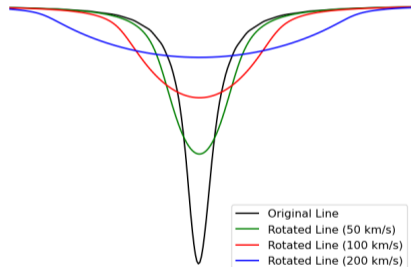
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Lack of Fast Rotators in Cygnus OB2

References

ROTATION AFFECTS SPECTRAL CLASSIFICATION

Reclassify the B0 stars to confirm that they are not early O-type stars rotating fast





Reclassification BO-type stars

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References

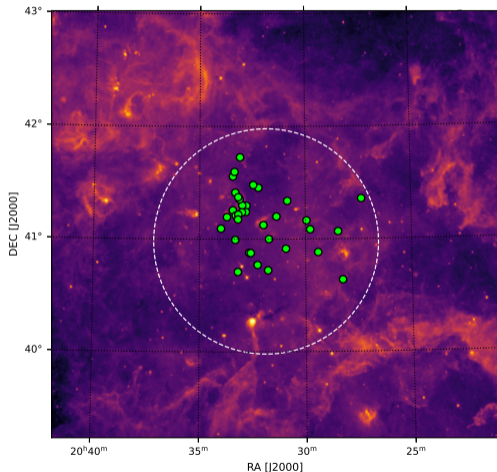
Reclassification

- **Stars selection**
 - Early-B stars
 - 1° center Cygnus OB2
- MGB (Marxist Ghostbusters Code)
 - Specific line ratios
 - Rotation included

Maíz Apellániz et al. (2015)

Results

- 30% B0 stars \rightarrow O-type





Reclassification BO-type stars

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References

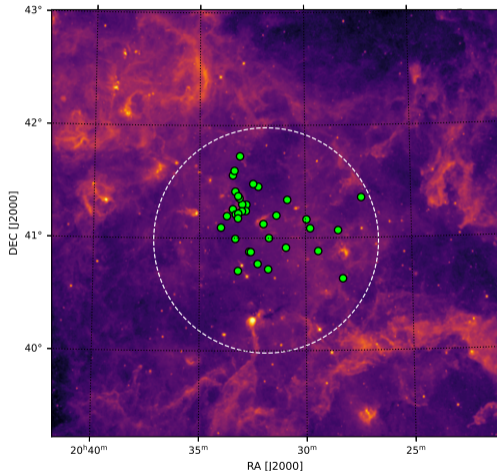
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Reclassification BO-type stars

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References

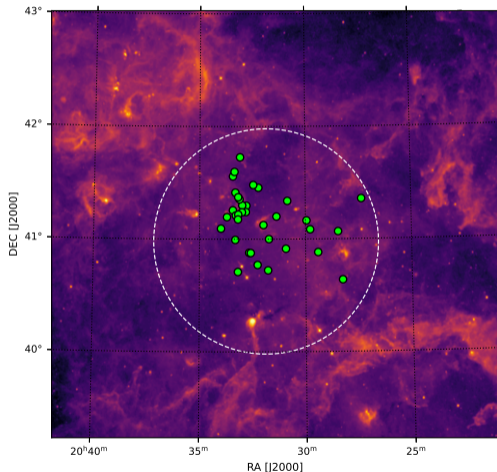
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Reclassification BO-type stars

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References

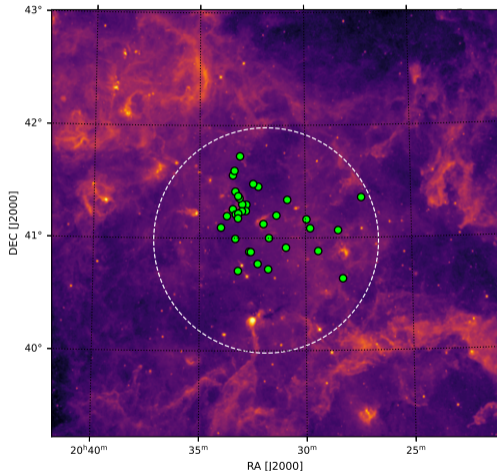
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Cygnus OB2 Rotational Velocities Distribution

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

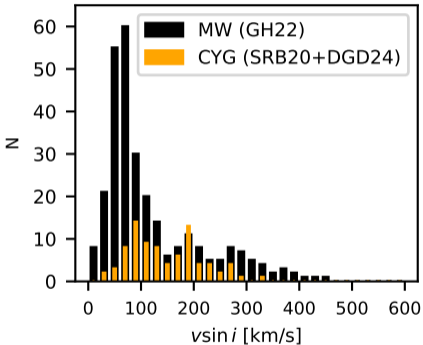
New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

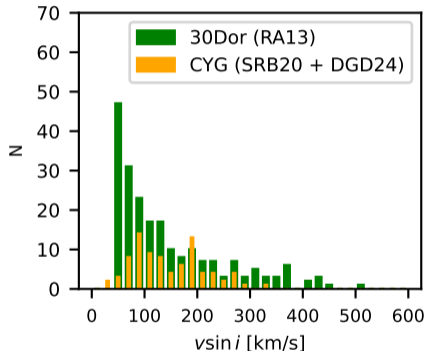
Lack of Fast Rotators in Cygnus OB2

References



Cygnus OB2 vs Milky Way

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Cygnus OB2 vs 30 Doradus

Ramírez-Agudelo et al. (2013)



Cygnus OB2 Rotational Velocities Distribution

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

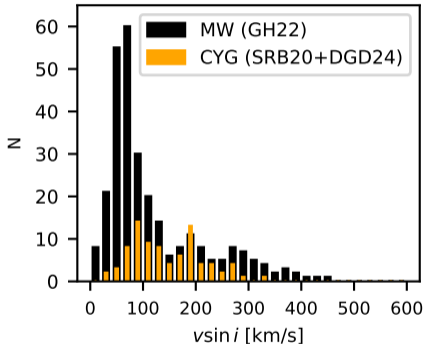
New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

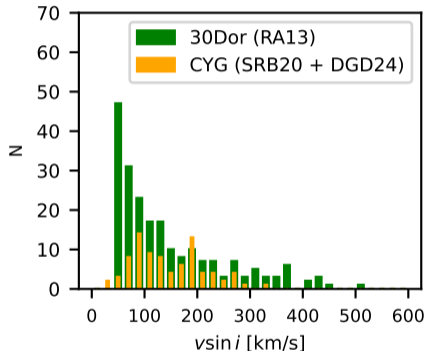
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Ramírez-Agudelo et al. (2013)



The Lack of Fast Rotators in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



WORK IN PROGRESS!

- Runaways
 - Fast-rotators ejected by SN explosion
- Spin rotation direction
 - Fast-rotators from the front
- Molecular cloud density
 - No formation enough binary systems
- Cygnus OB2 age
 - No enough time for binary interactions



The Lack of Fast Rotators in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



WORK IN PROGRESS!

- **Runaways**
 - Fast-rotators ejected by SN explosion
- Spin rotation direction
 - Fast-rotators from the front
- Molecular cloud density
 - No formation enough binary systems
- Cygnus OB2 age
 - No enough time for binary interactions



The Lack of Fast Rotators in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



WORK IN PROGRESS!

- Runaways
 - Fast-rotators ejected by SN explosion
- **Spin rotation direction**
 - Fast-rotators from the front
- Molecular cloud density
 - No formation enough binary systems
- Cygnus OB2 age
 - No enough time for binary interactions



The Lack of Fast Rotators in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



WORK IN PROGRESS!

- Runaways
 - Fast-rotators ejected by SN explosion
- Spin rotation direction
 - Fast-rotators from the front
- **Molecular cloud density**
 - No formation enough binary systems
- Cygnus OB2 age
 - No enough time for binary interactions



The Lack of Fast Rotators in Cygnus OB2

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References



WORK IN PROGRESS!

- Runaways
 - Fast-rotators ejected by SN explosion
- Spin rotation direction
 - Fast-rotators from the front
- Molecular cloud density
 - No formation enough binary systems
- **Cygnus OB2 age**
 - No enough time for binary interactions



References

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References

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Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References

Very first approach to the lack of fast rotators in Cygnus OB2

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Fast Rotators: post binary products

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

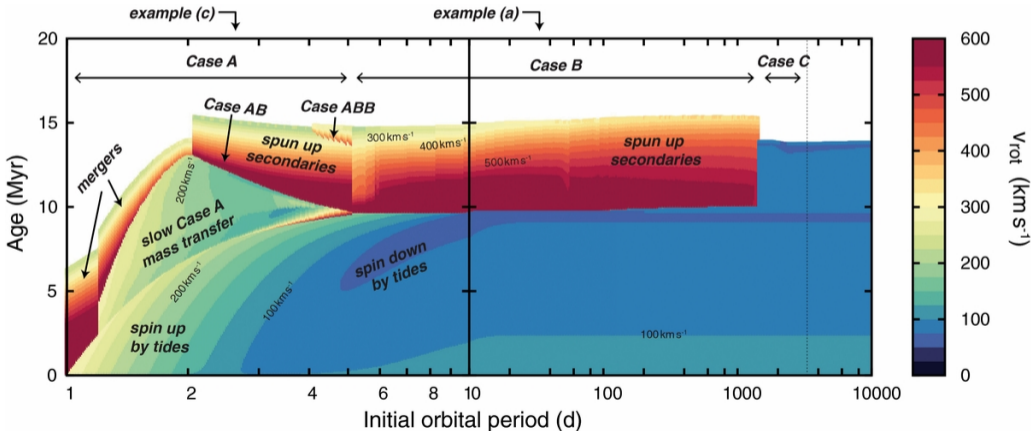
Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References

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How Rotation Affects Spectral Classification?

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spectral Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

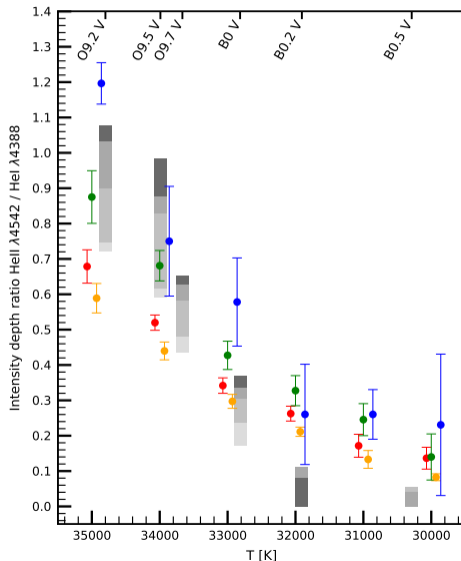
New $v \sin i$

Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References





Cygnus OB2 Rotational Velocities Distribution

Hot Massive Stars

Introduction

Rotation

Fast Rotators: post binary products

Cygnus OB2

Introduction

$v \sin i$ distribution

Rotation & Spec Classification

How Rotation Affects Spectral Classification?

Reclassification B0 Stars

New $v \sin i$ Distribution for Cygnus OB2

Cygnus OB2 Rotational Velocities Distribution

Lack of Fast Rotators in Cygnus OB2

References

