# Chasing the Double Sunsets

Christine Mazzola Daher

No-Jargon Talk

July 29, 2021

# Question 1:

*What is a binary star system?*

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“A **binary star** is a star system consisting of two stars orbiting around their common barycenter.”

[Wikipedia, “Binary star”]

https://en.wikipedia.org/wiki/Binary_star

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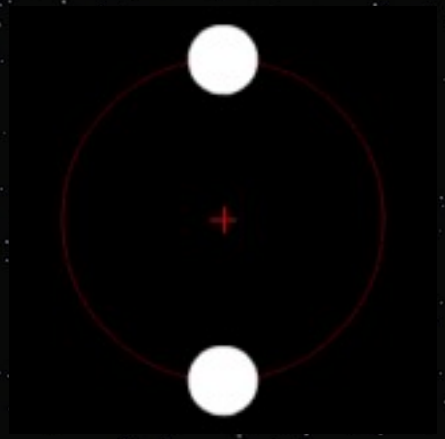
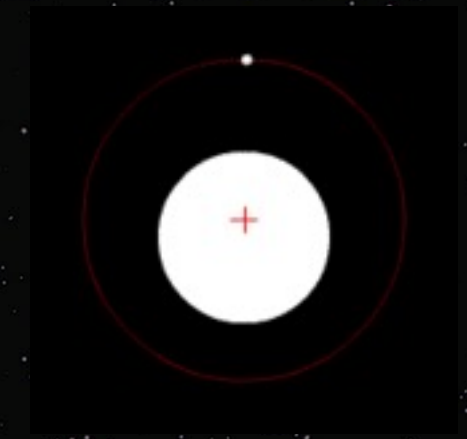
“A **binary star** is a star system consisting of two stars orbiting around their common barycenter.”

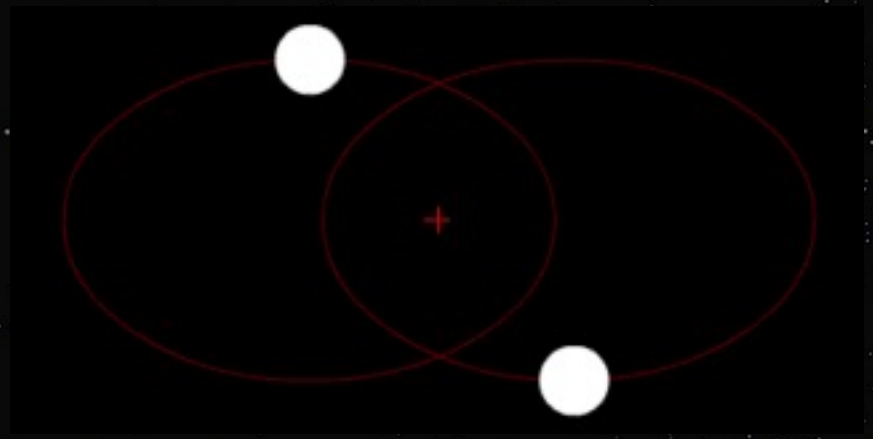
[Wikipedia, “Binary star”]



Similar masses



Earth/Sun masses



Similar masses, elliptical orbit

https://en.wikipedia.org/wiki/Binary_star

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# Some binaries in media:

*Star Wars Rebels*, Season 3 Ep 4

https://starwars.fandom.com/wiki/File:MontrossSystem_BinaryStars.png

*Star Trek: Deep Space Nine*, Season 5 Ep 9

https://memory-alpha.fandom.com/wiki/File:Risan_sunset.jpg

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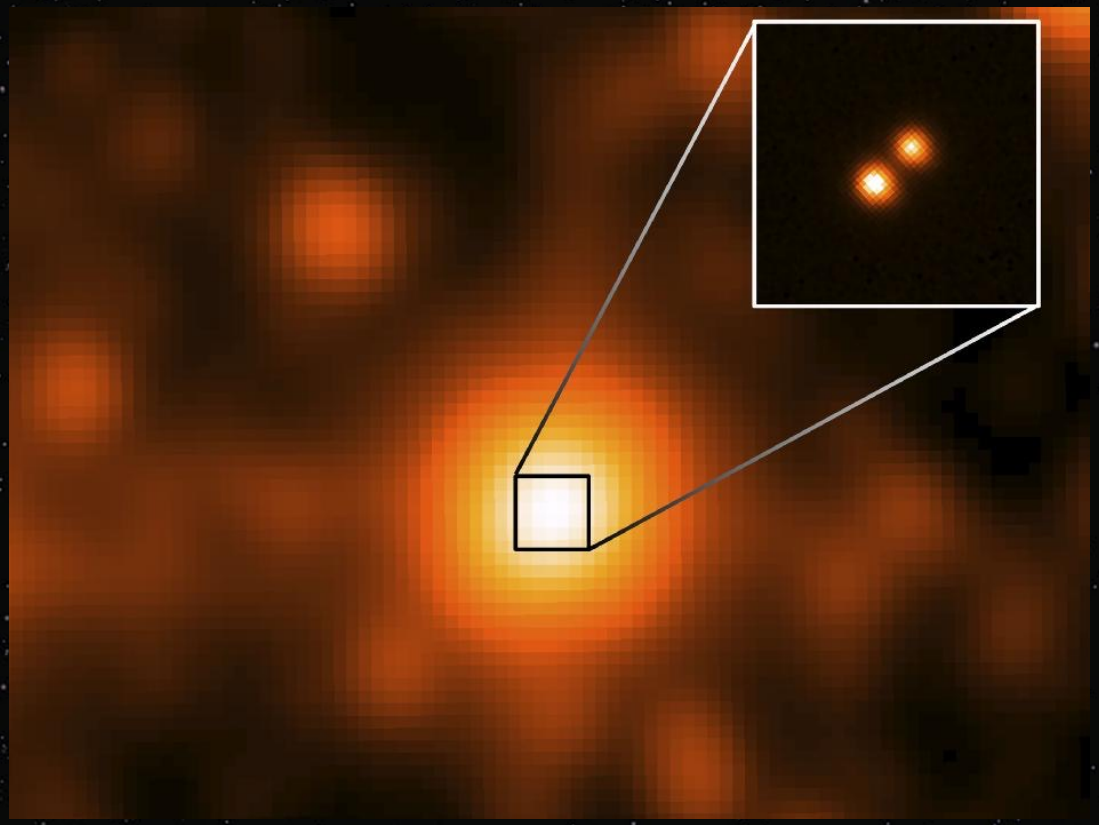
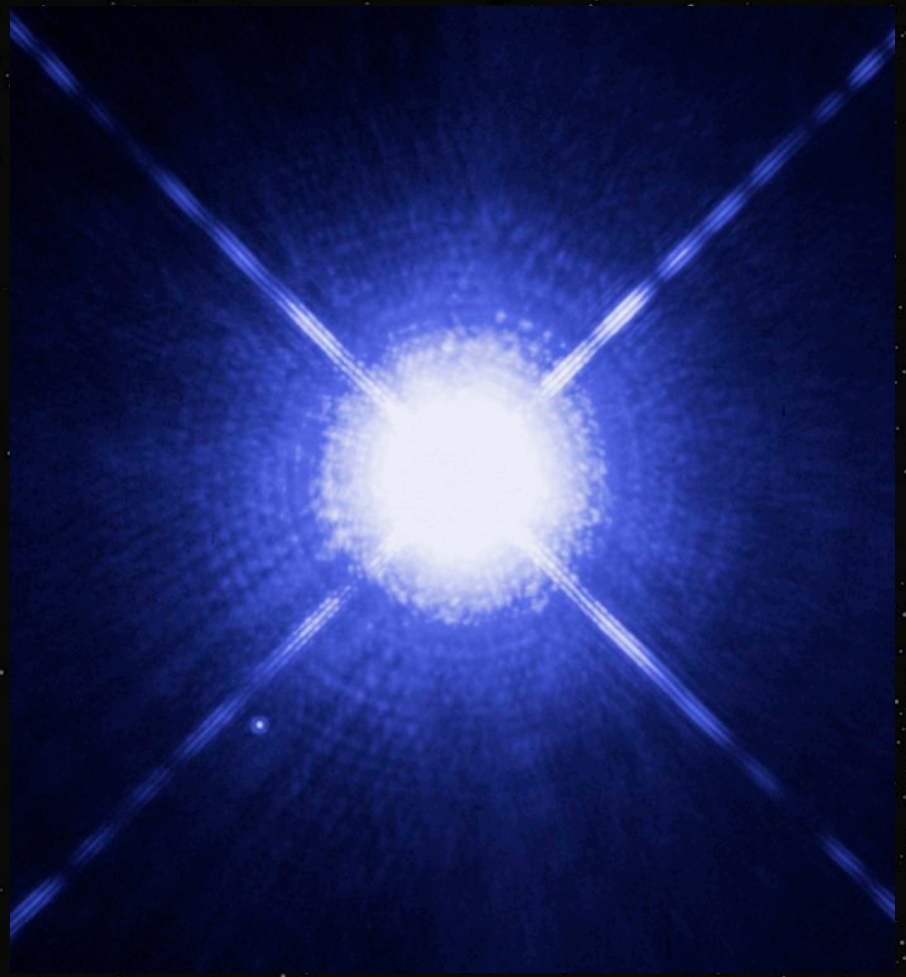
# Some real binaries:



**Brown dwarfs observed by WISE and Gemini**
*https://www.nasa.gov/mission_pages/WISE/multimedia/pia16872.html*



**Bright Sirius A and dim companion Sirius B**
*https://esahubble.org/images/heic0516a/*

# Question 1:

*What is a binary star system?*

## Answer:

Cool desktop background pics

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# Question 2:

*Should astronomers care about binary stars?*

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# Question 2:

## *Should astronomers care about binary stars?*

Astro2020 Science White Paper

# Stellar multiplicity: an interdisciplinary nexus

*Thematic Areas:*

- ☑ Planetary Systems
- ☑ Star and Planet Formation
- ☑ Formation and Evolution of Compact Objects
- ☑ Cosmology and Fundamental Physics
- ☑ Stars and Stellar Evolution
- ☑ Resolved Stellar Populations and their Environments
- ☑ Galaxy Evolution
- ☑ Multi-Messenger Astronomy and Astrophysics

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# Binaries + Stars

*1) What can binaries tell us about star formation?*

Answer:

Trends with chemistry hint at formation mechanisms

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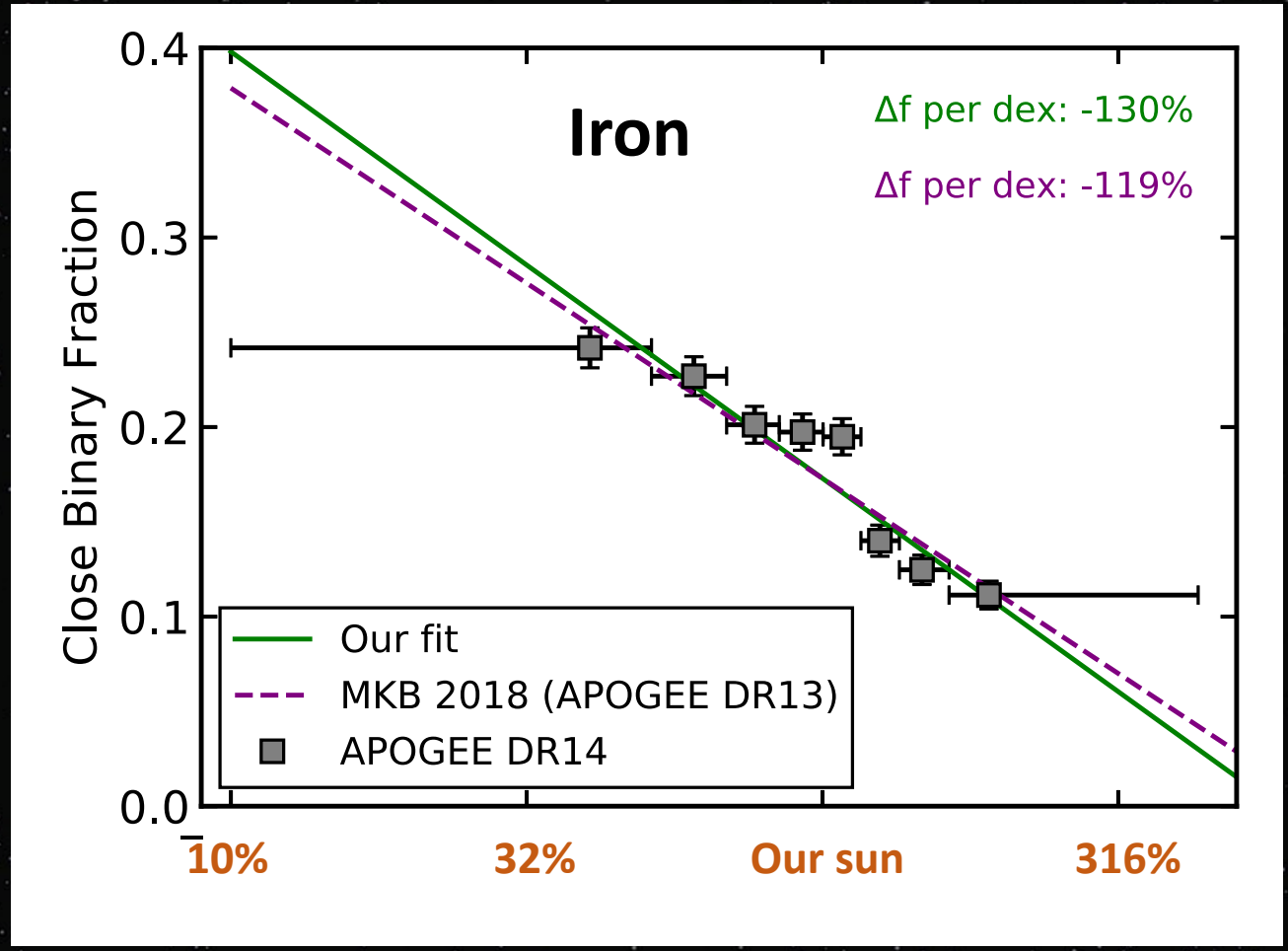
# Binaries + Star Formation: Chemistry

Stellar chemistry is negatively correlated to the close binary fraction.

More metals

=

*less* likely to be in a binary!




Mazzola et al. 2020

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# Binaries + Star Formation

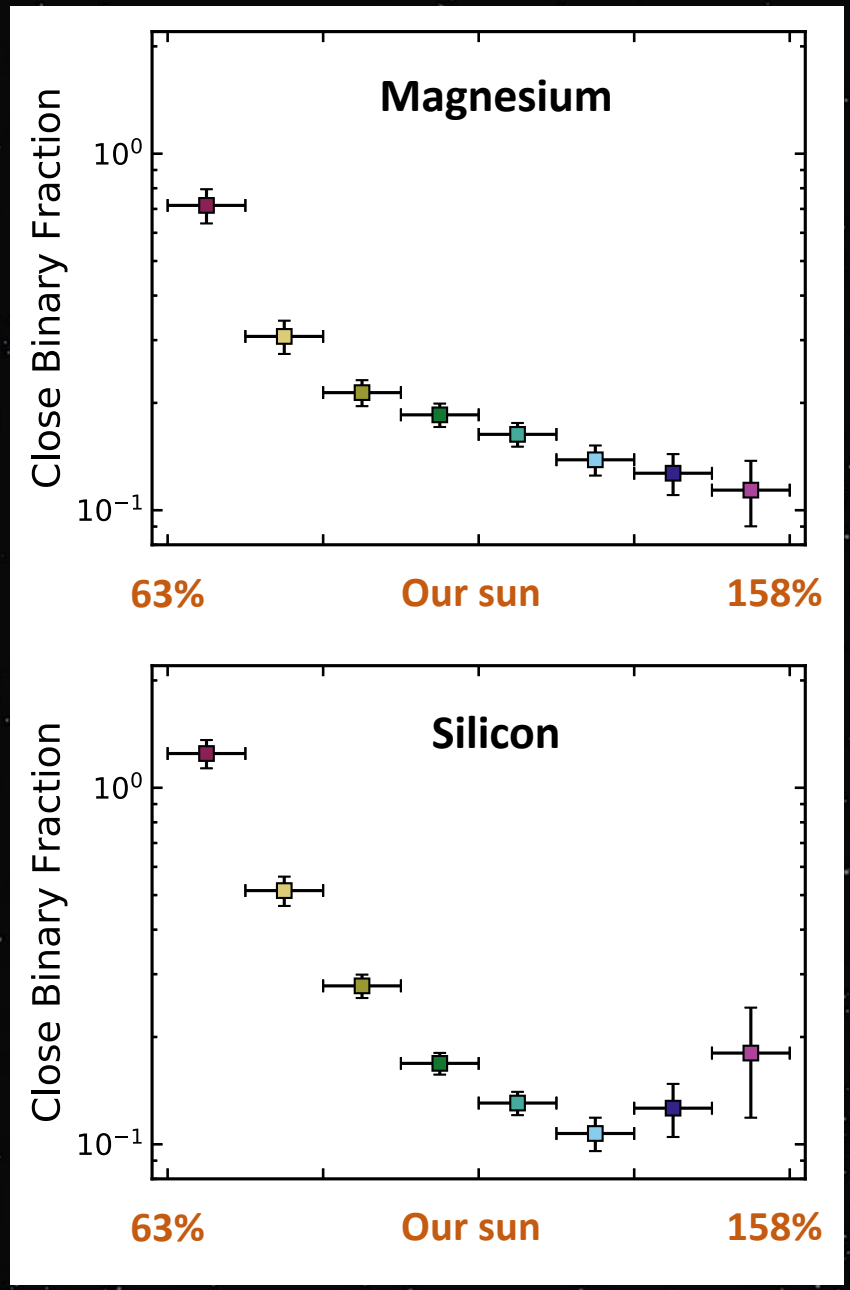
Stellar chemistry is negatively correlated to the close binary fraction.

More metals

=

*less* likely to be in a binary!

But different elements can have different relations…




Mazzola et al. 2020

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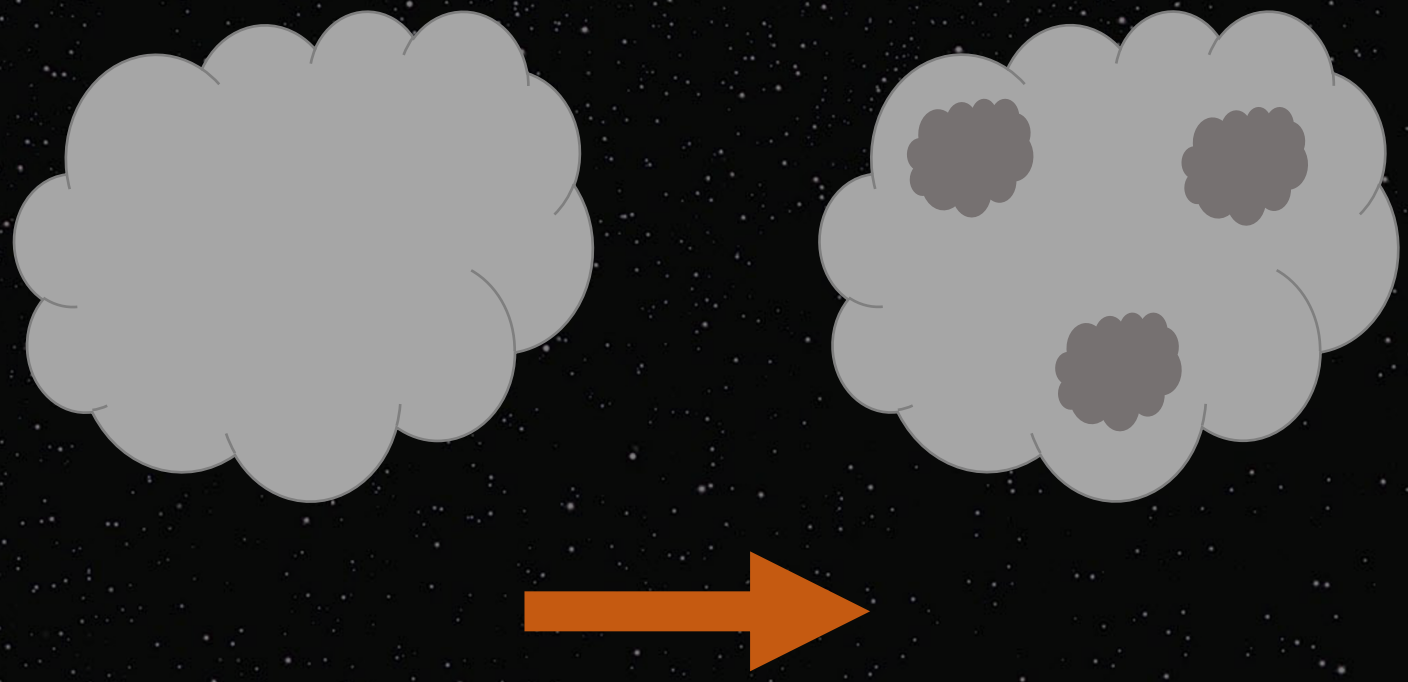
# Binaries + Star Formation

Giant cold hydrogen gas cloud

© 2020 Lucasfilm Ltd

# Binaries + Star Formation



Shock causes fragments to form

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# Binaries + Star Formation

We think planets may form in these disks!

Fragments cool and collapse into cores and disks

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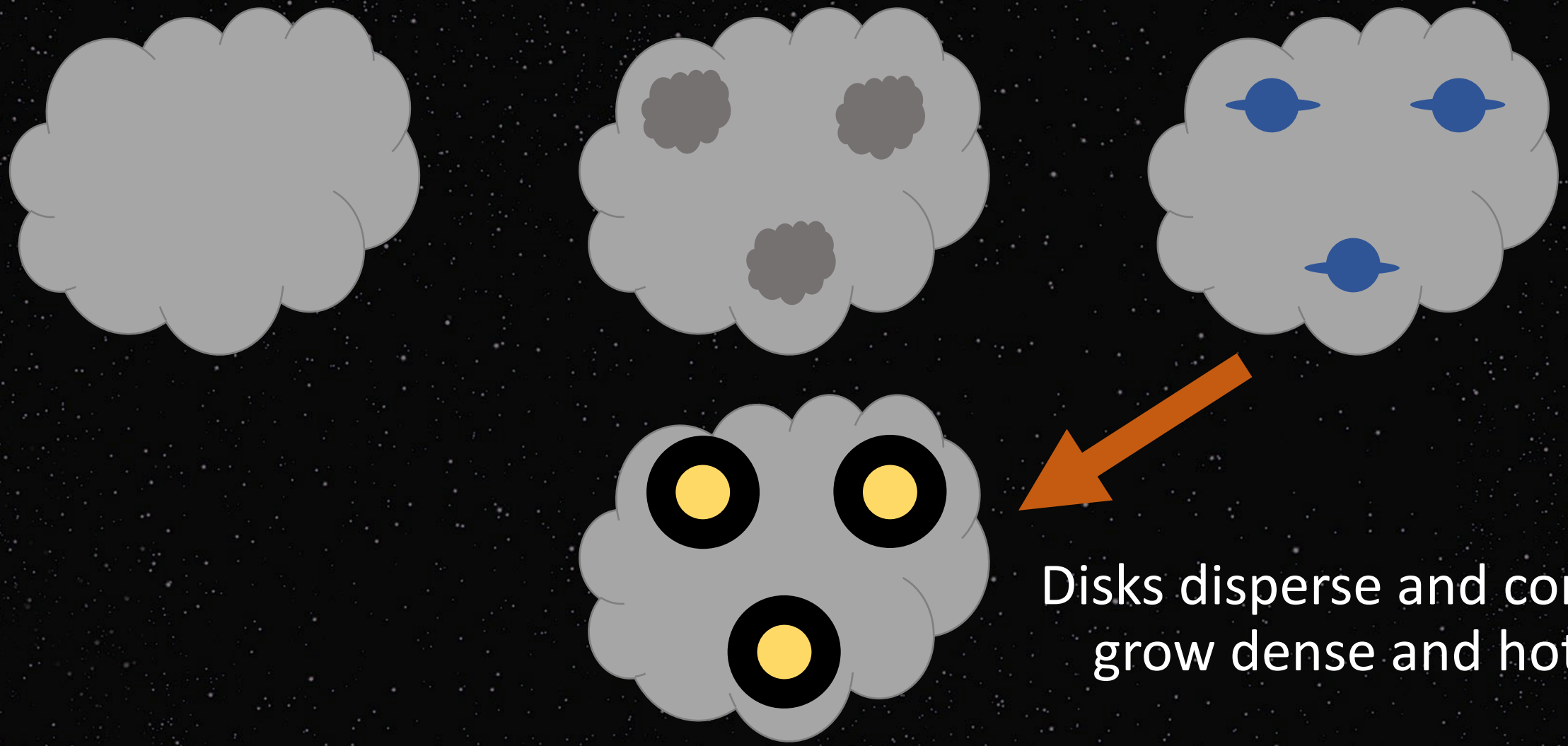
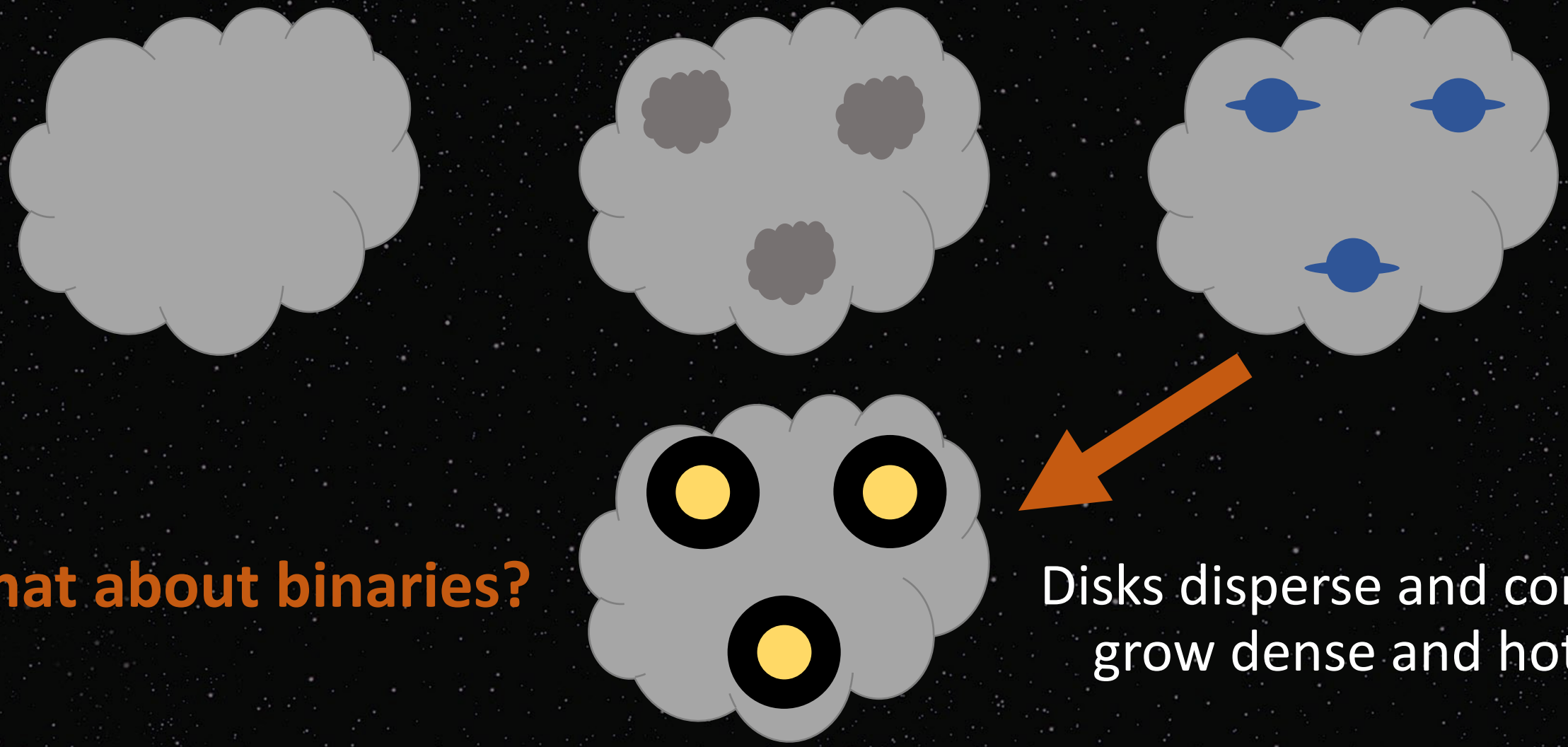
# Binaries + Star Formation



Disks disperse and cores grow dense and hot

© 2020 Lucasfilm Ltd

# Binaries + Star Formation



**What about binaries?**

Disks disperse and cores grow dense and hot

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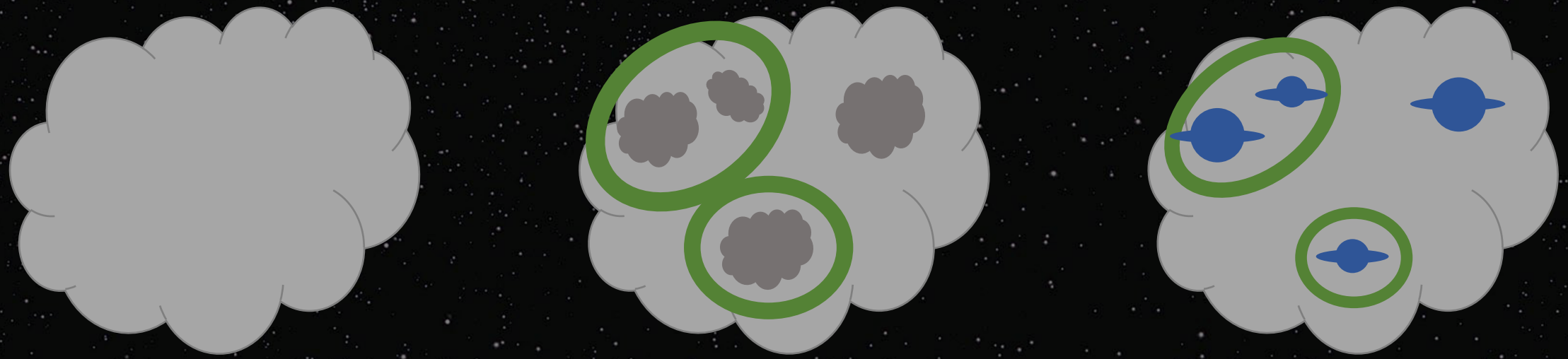
# Binaries + Star Formation



Nearby fragments can form wide binaries

Disks can fragment and form close binaries

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# Binaries + Star Formation: Chemistry

## Interpretation

- Fewer chemicals → more likely to fragment → more binaries

  True for Fe, Mg, Si…

- Lots of *certain* chemicals → cool more effectively → also more likely to fragment → more binaries

  True for Si…

**Mon R2 cloud complex**
*Credit: Adam Block, Mt. Lemmon SkyCenter, U. Arizona*

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# Binaries + Stars

*2) What can binaries tell us about stellar evolution?*

Answer:

Spin fast and die young: stellar rotation and engulfment

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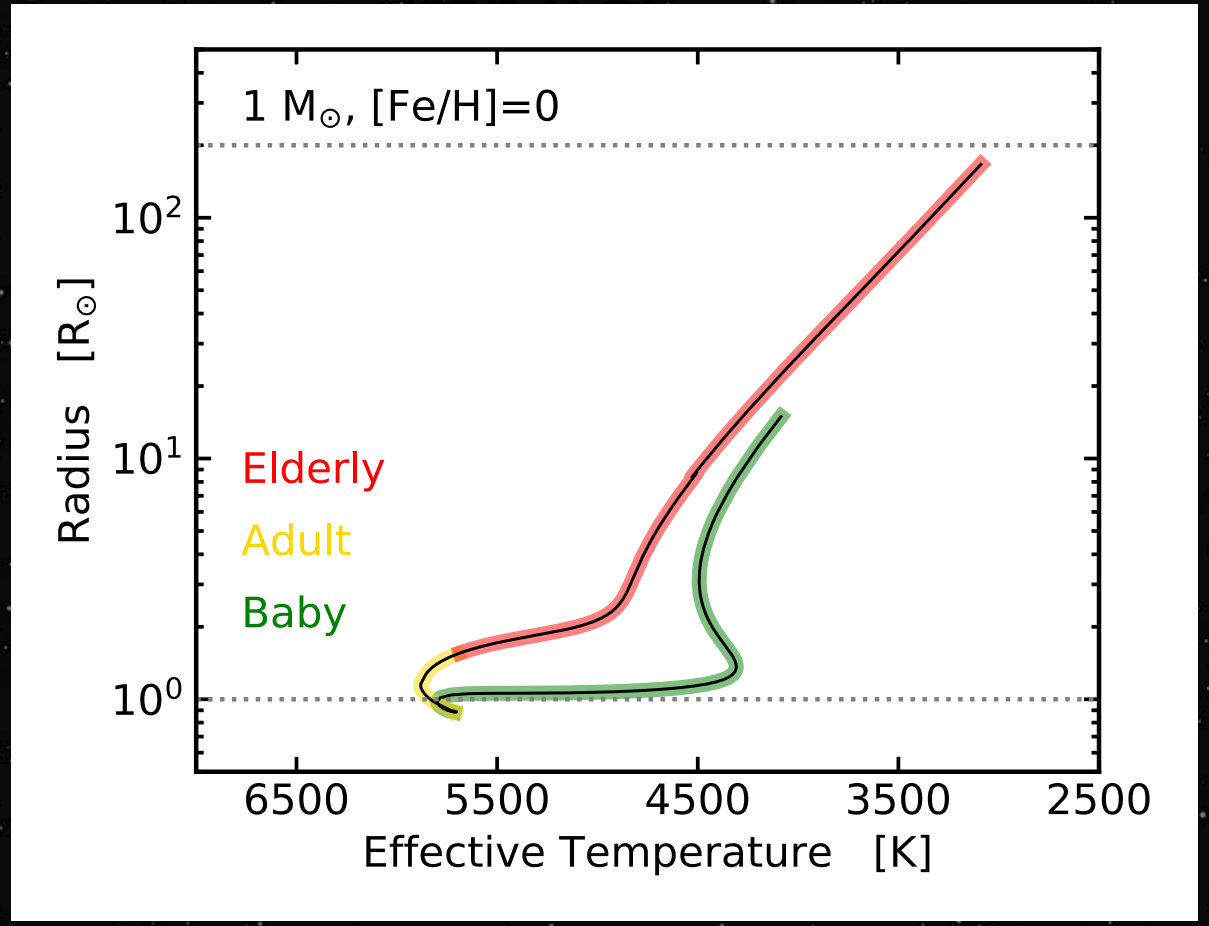
# Binaries + Stellar Evolution: Radius

As a star ages, its radius changes.

- Youth: grow denser and smaller until fusion starts

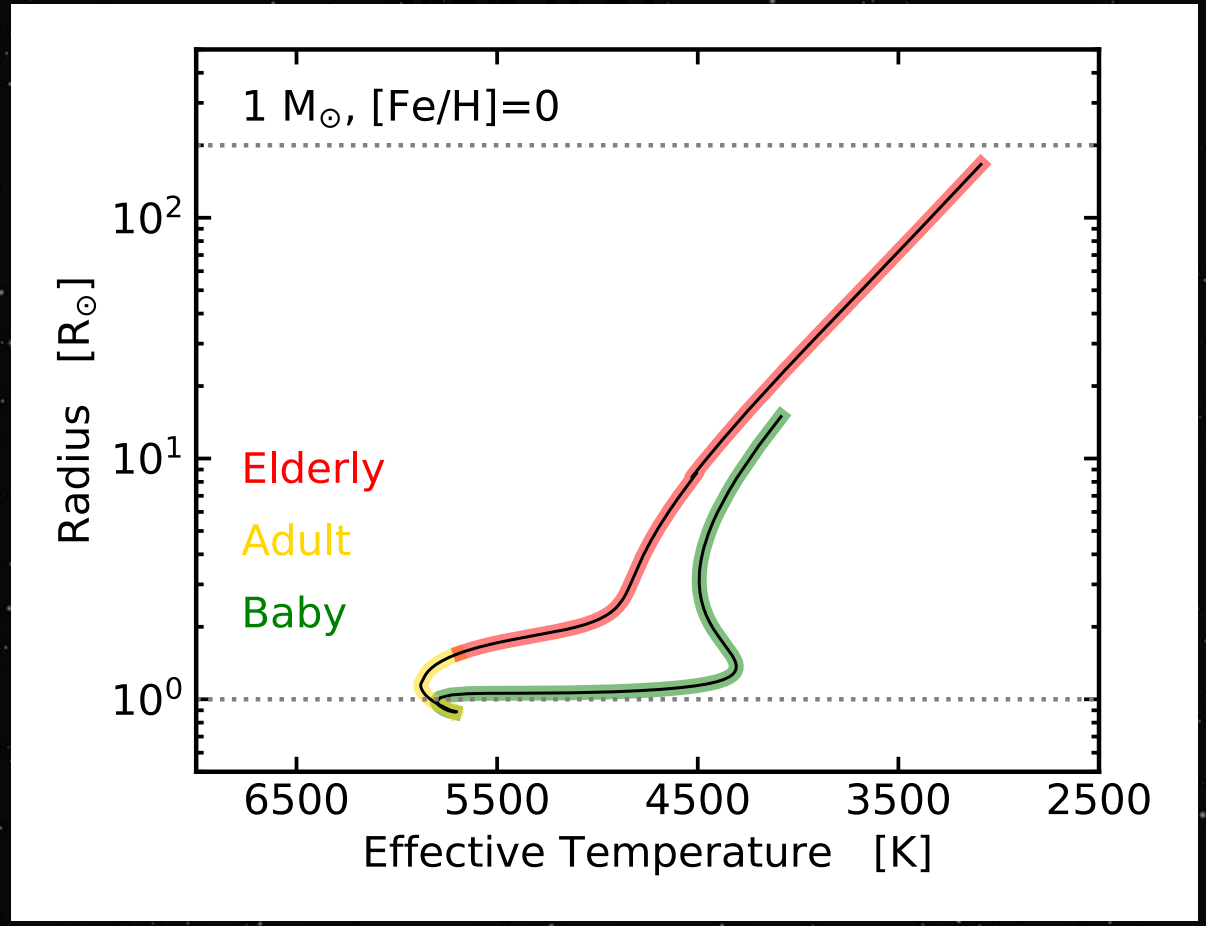



© 2020 Lucasfilm Ltd

# Binaries + Stellar Evolution: Radius

As a star ages, its radius changes.

- Youth: grow denser and smaller until fusion starts
- Adult (like our sun): pretty stable!
  [...for now...]

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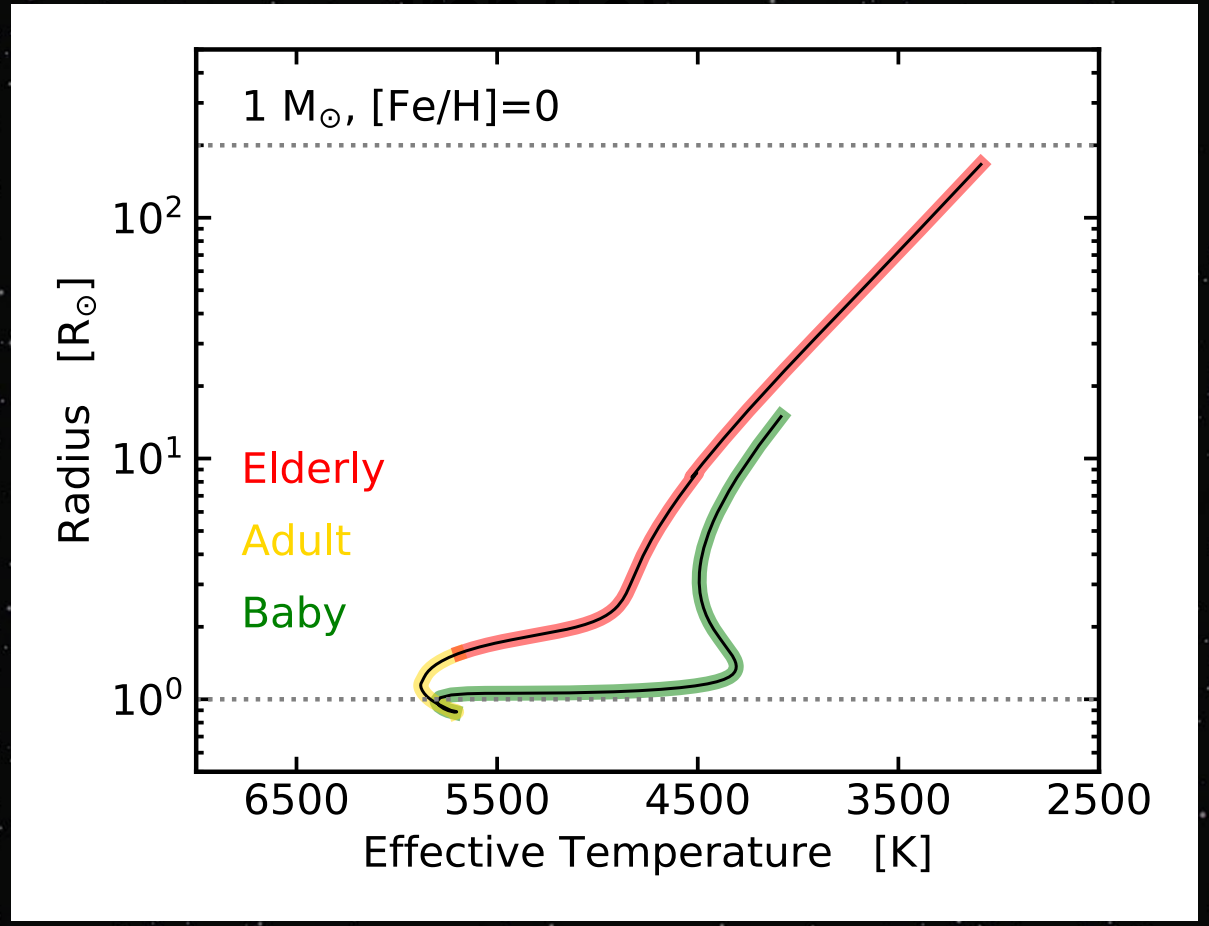
# Binaries + Stellar Evolution: Radius

As a star ages, its radius changes.

- Youth: grow denser and smaller until fusion starts
- Adult (like our sun): pretty stable!
  [...for now...]
- Elderly: low on fuel, becomes less dense and puffs up, increasing its size up to several 100x

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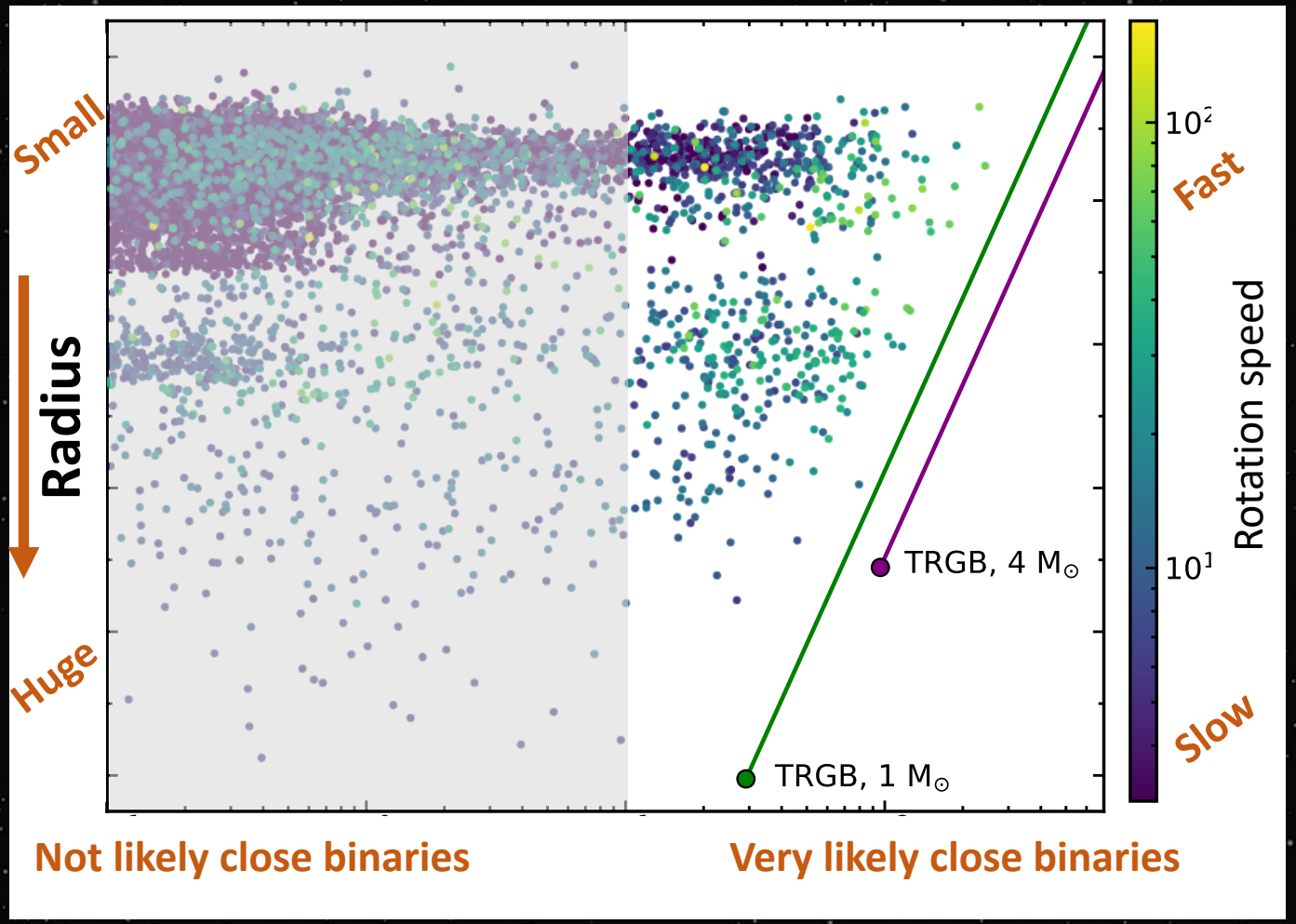
# Binaries + Stellar Evolution: Radius

For very close binaries, the **size** of the stars matters *a lot*.

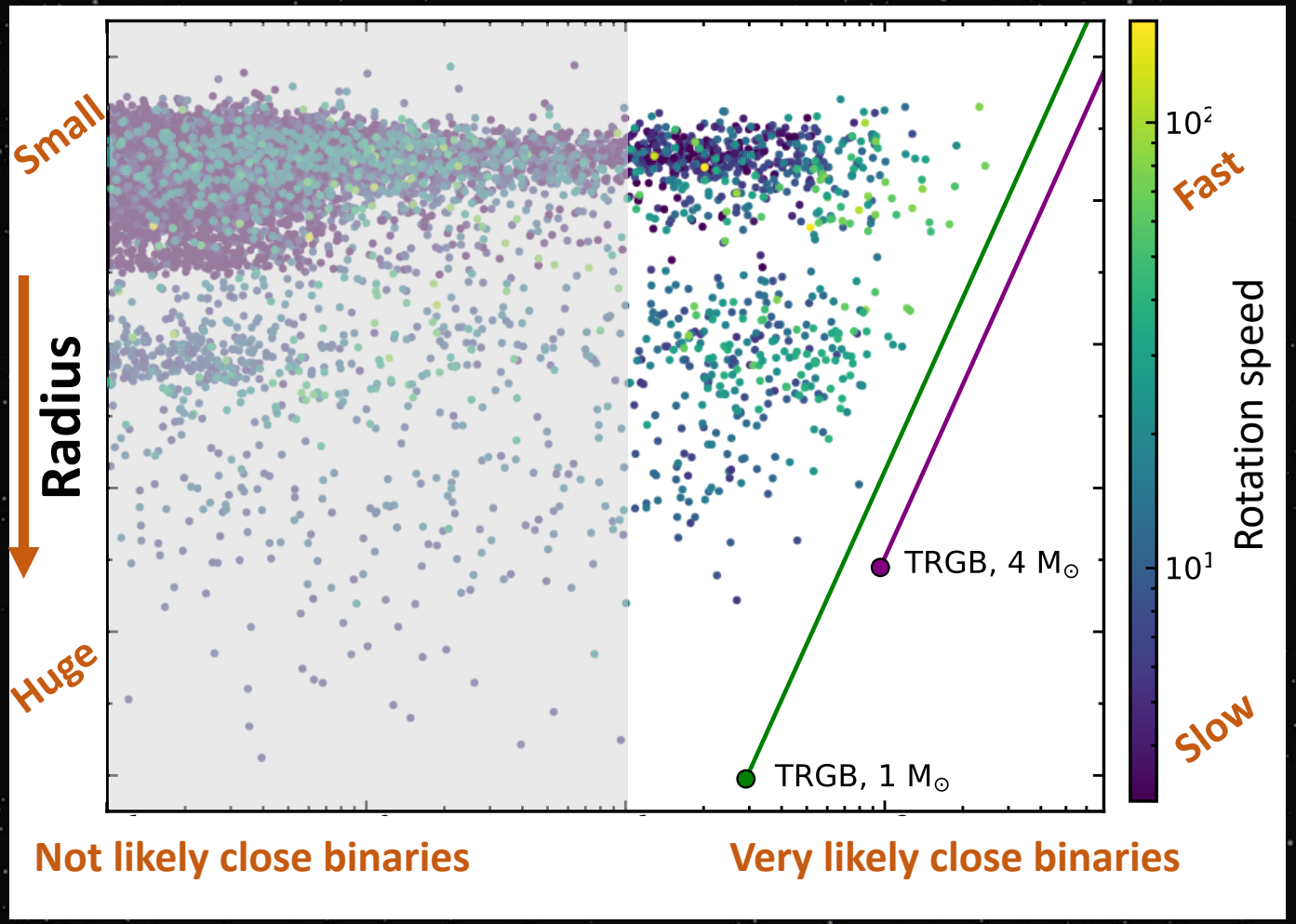



Daher et al. (in prep)

# Binaries + Stellar Evolution: Radius

For very close binaries, the **size** of the stars matters *a lot*.

- Small radius: much friendlier to nearby companions




Daher et al. (in prep)

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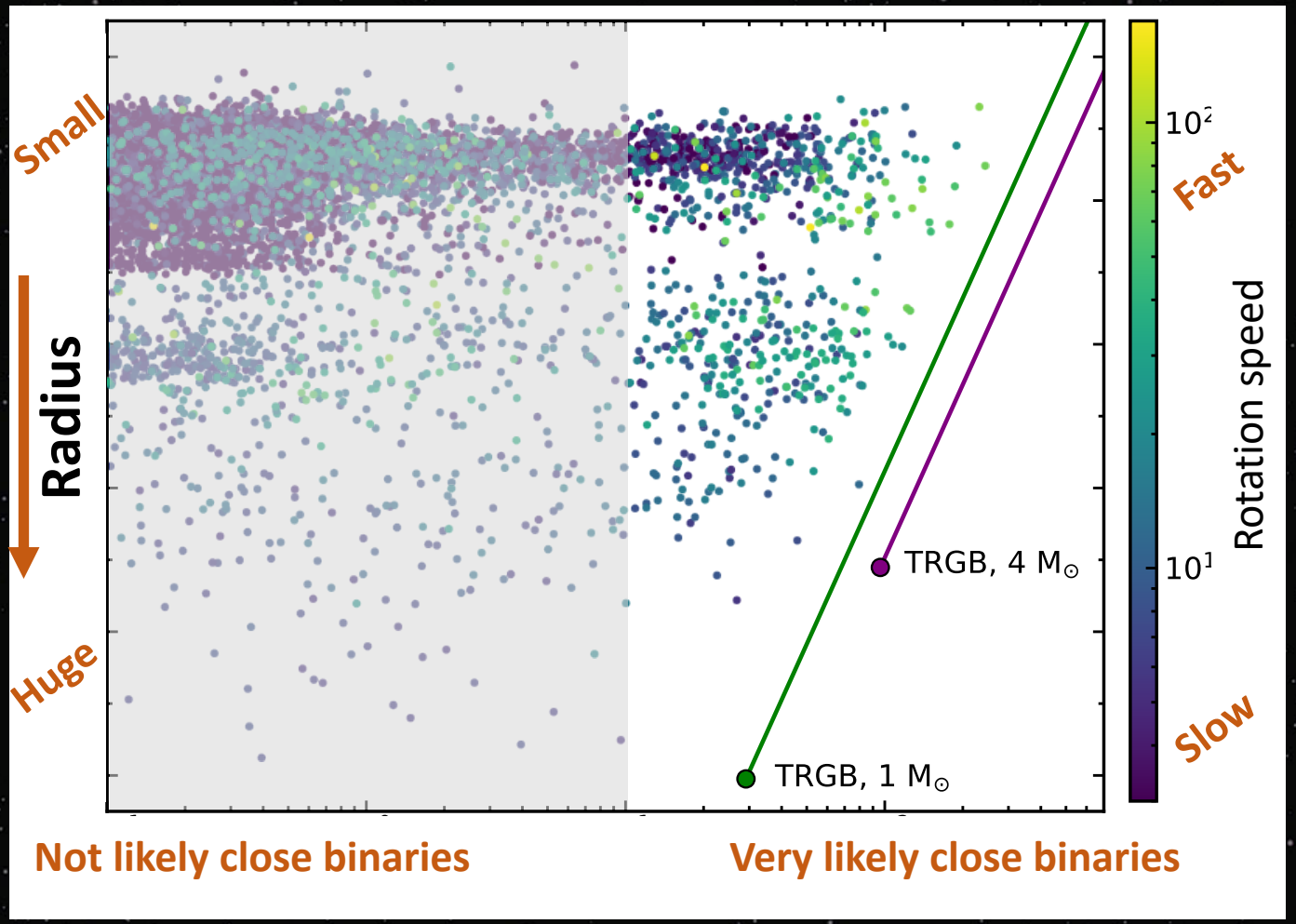
# Binaries + Stellar Evolution: Radius

For very close binaries, the **size** of the stars matters *a lot*.

- Small radius: much friendlier to nearby companions
- Large radius: probably already evicted its neighbor :(

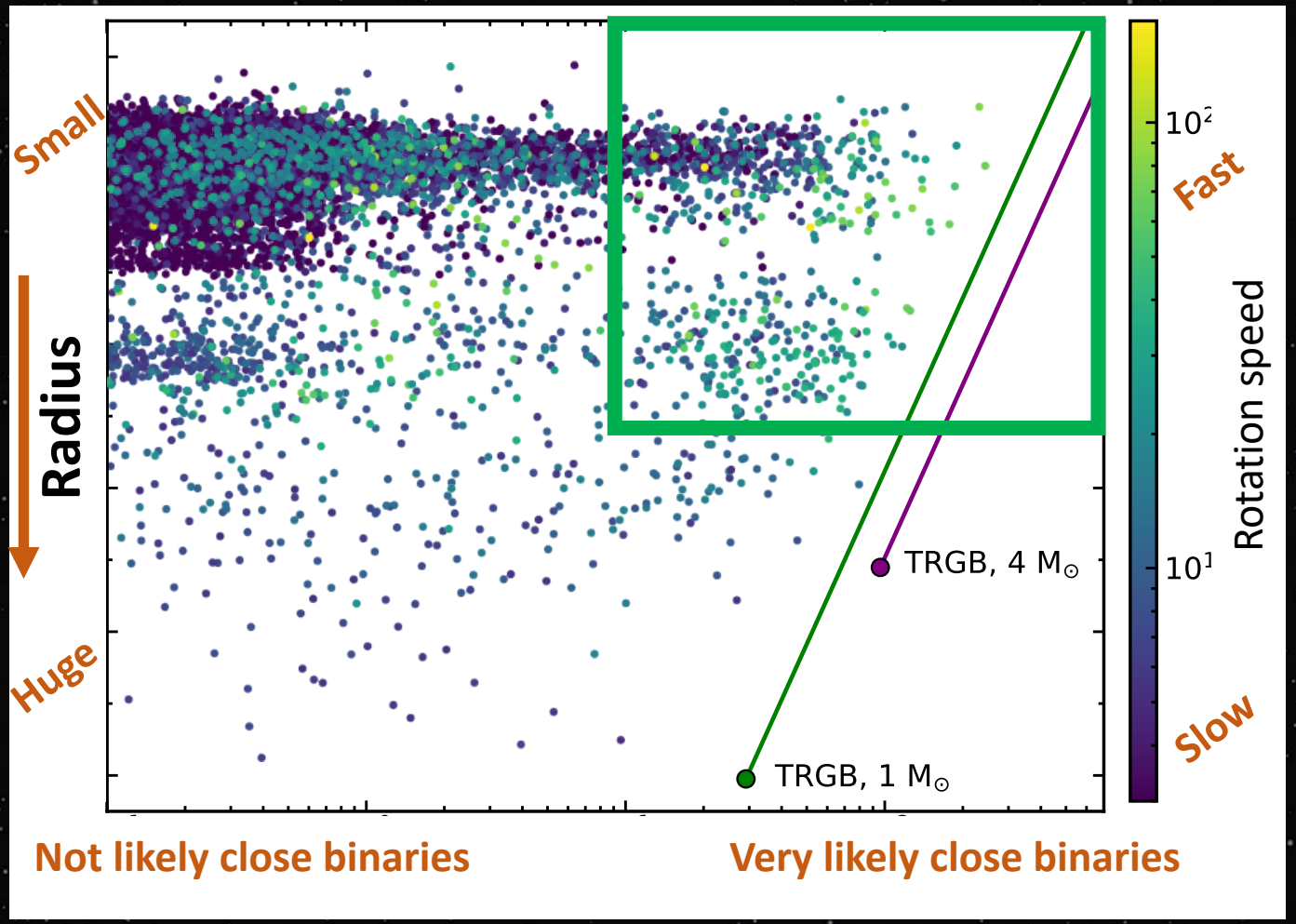



Daher et al. (in prep)

# Binaries + Stellar Evolution: Rotation

Close binaries have tides that "tug" on each other, causing them to rotate fast!

Small radius + close binary tend to have fast rotation speeds!




Daher et al. (in prep)

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# Racing off into the Sunsets...

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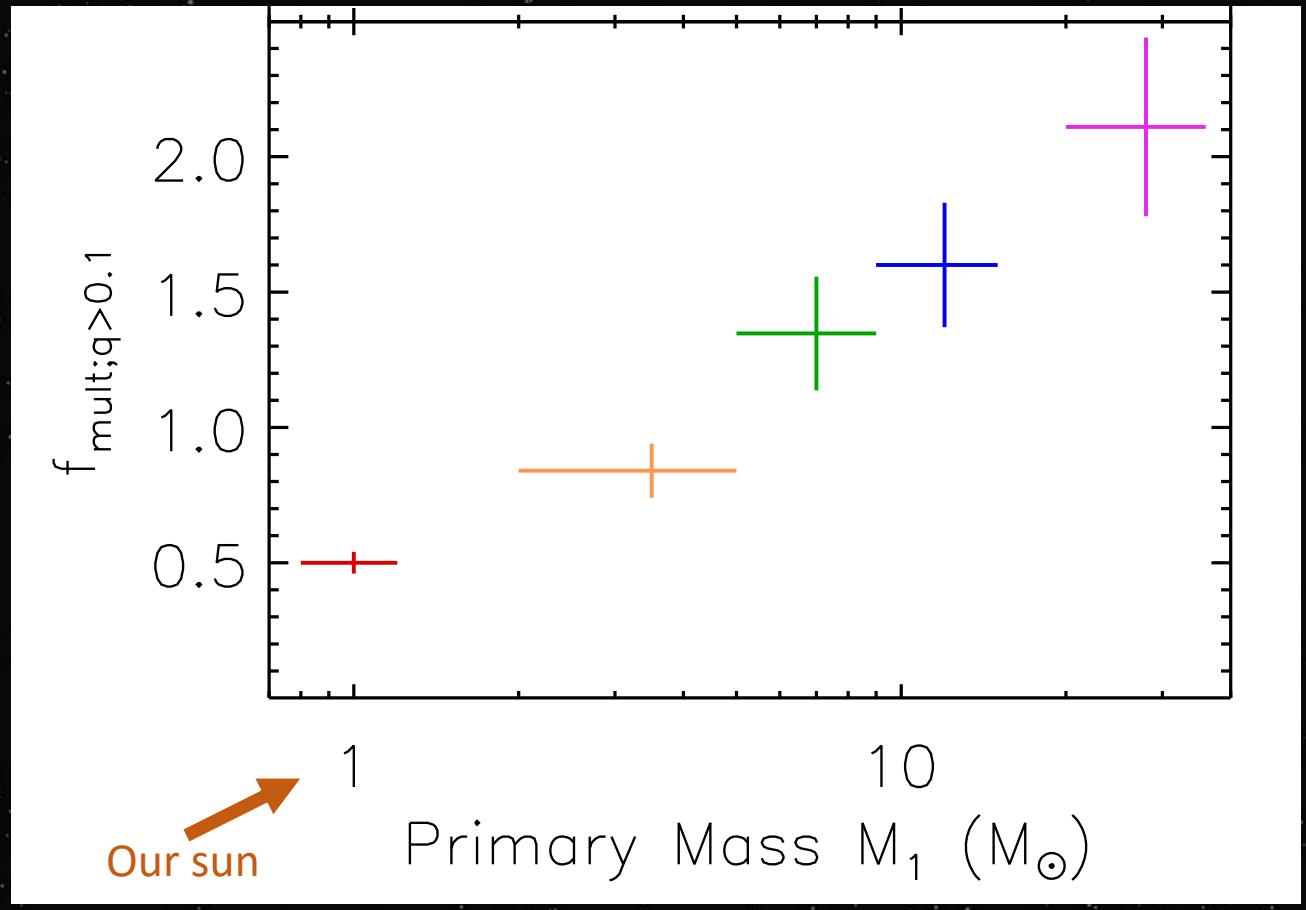
# Binaries + Star Formation: Mass

The mass of a star is positively correlated to the close binary fraction.

More mass

=

*more* likely to have binaries!




Moe & Di Stefano 2017

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# Binaries + Star Formation: Mass

## Interpretation

- Larger clumps → larger stars and more fragments to form more companions

- Smooth function of mass → similar formation mechanism across all sizes of stars

**Mon R2 cloud complex**
*Credit: Adam Block, Mt. Lemmon SkyCenter, U. Arizona*

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# Binaries + Stars and Planets

*3) What can binaries tell us about planets?*

*Answer:*

1) Impact formation and detection

2) Impact habitability

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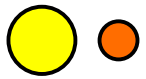
# Binaries + Planets: Formation and Detection

Close binaries suppress close planet formation.

Bright companions in wide binaries make planet transits more difficult to see.

| | Close Binaries Suppress Planets  | Wide Bright Companions Dilute Transits  | Total |
|---|---|---|---|
| M-dwarfs | 28% ± 5% | ≈4% | 32% ± 6% |
| G-dwarfs | 43% ± 7% | 9% ± 3% | 52% ± 8% |
| F-dwarfs | 46% ± 7% | ≈13% | 59% ± 8% |

Moe and Kratter 2020

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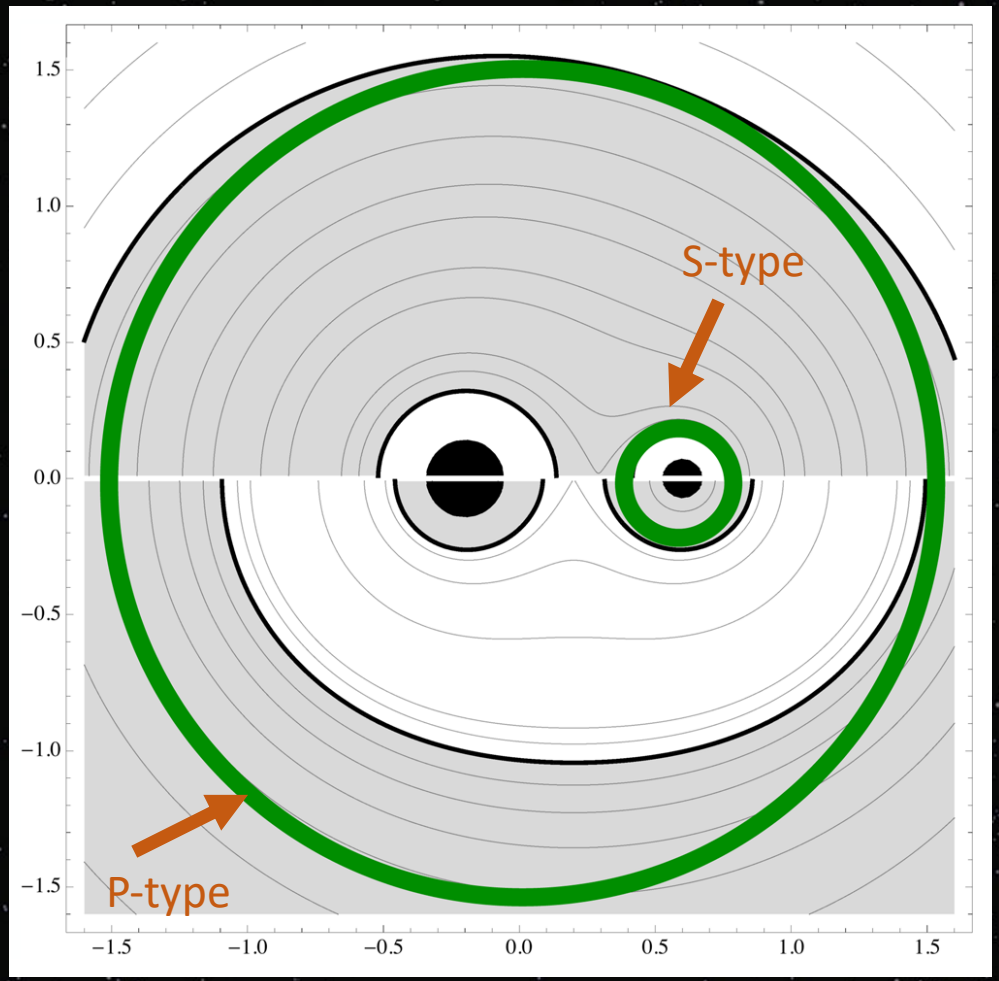
# Binaries + Planets: Habitability

Habitability is a balance of a radiative safe zone (top, gray) and a stable orbit (bottom, gray).

Green shows where both conditions are met, though not every system has a solution!




Jaime, Aguilar, and Pichardo 2014

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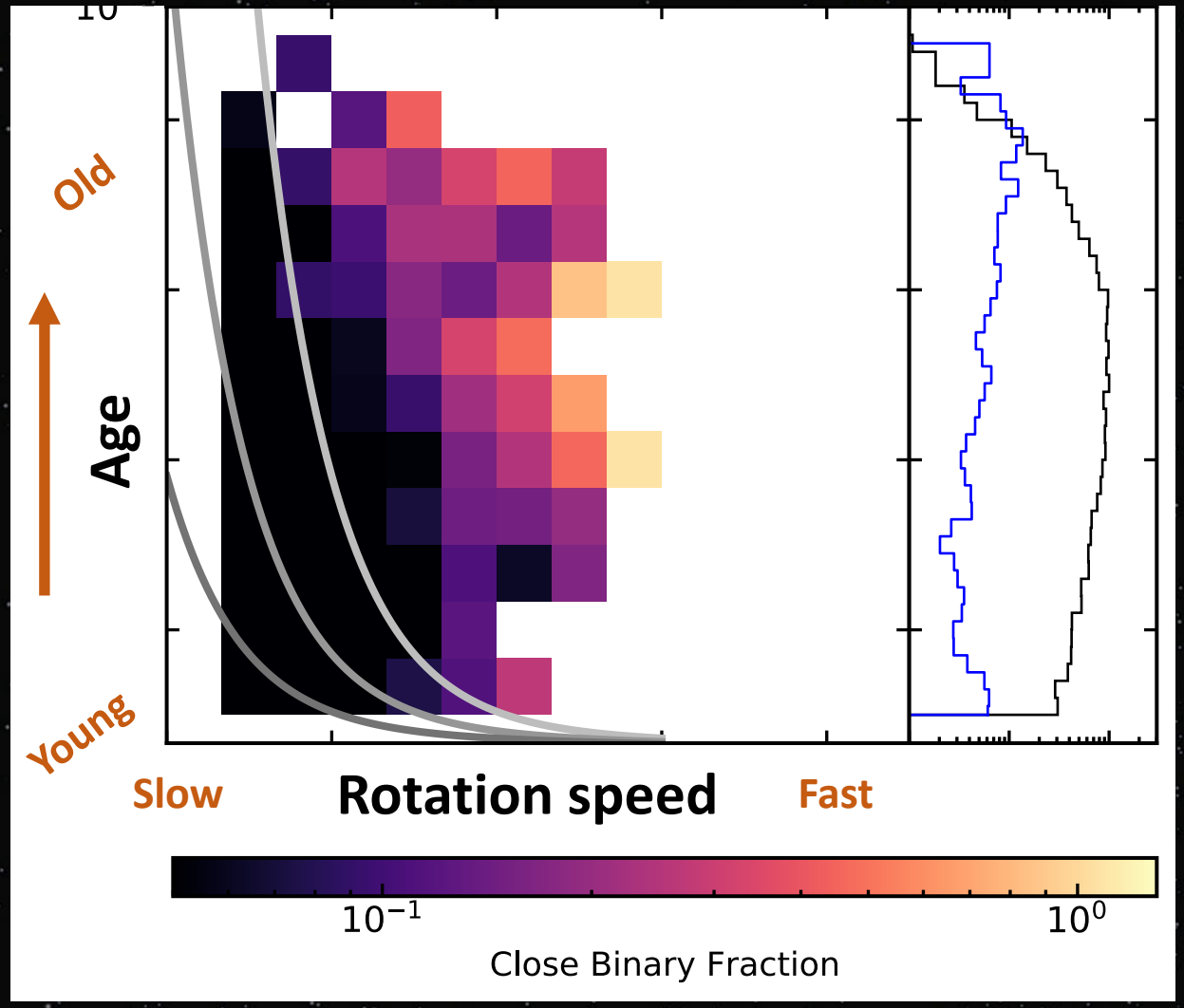
# Binaries + Stellar Evolution: Rotation + Age

We can guess an adult star's age based on its rotation speed…




Daher et al. (in prep)

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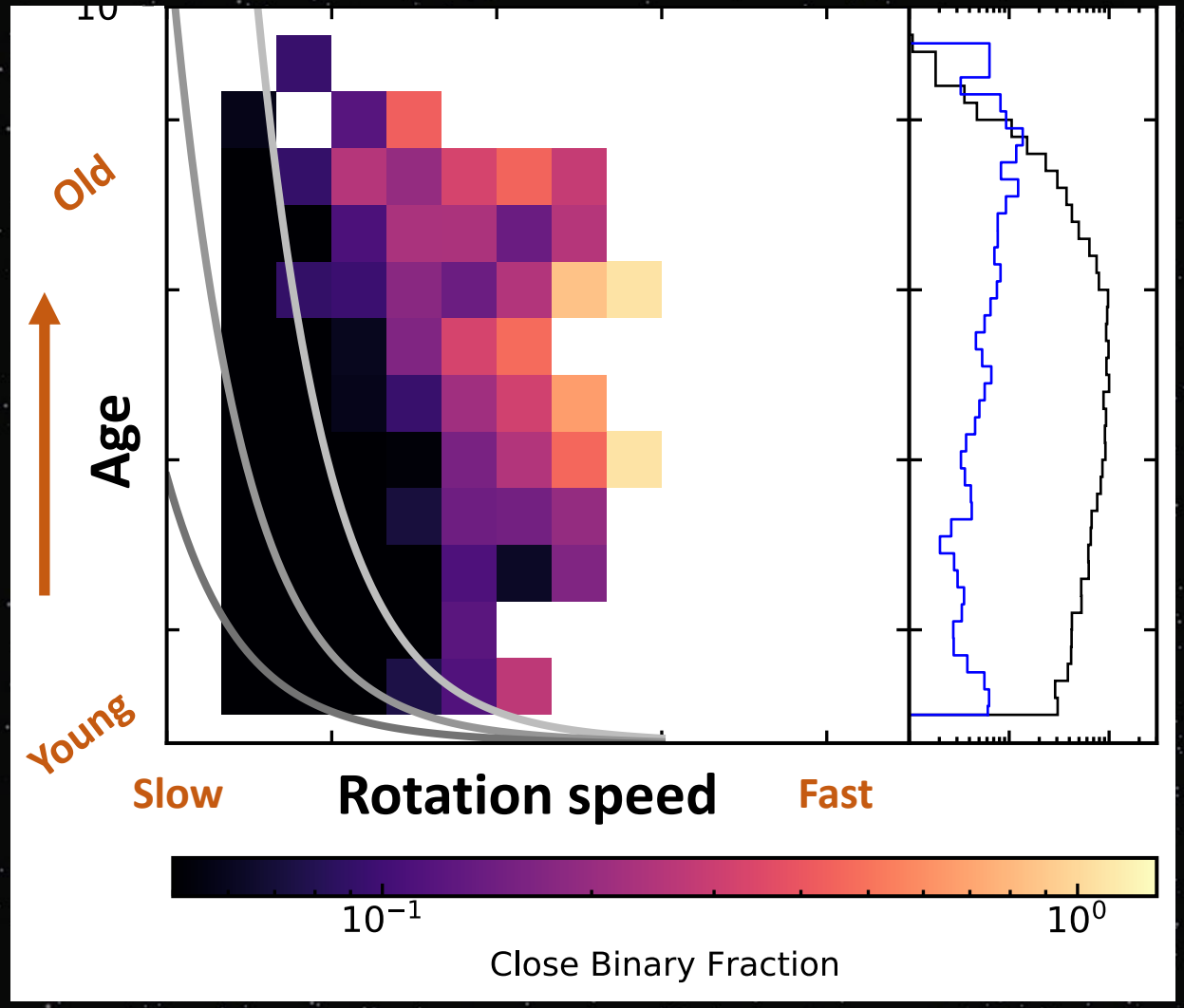
# Binaries + Stellar Evolution: Rotation + Age

We can guess an adult star's age based on its rotation speed…

…but a binary's "tug" affects those age estimates.




Daher et al. (in prep)

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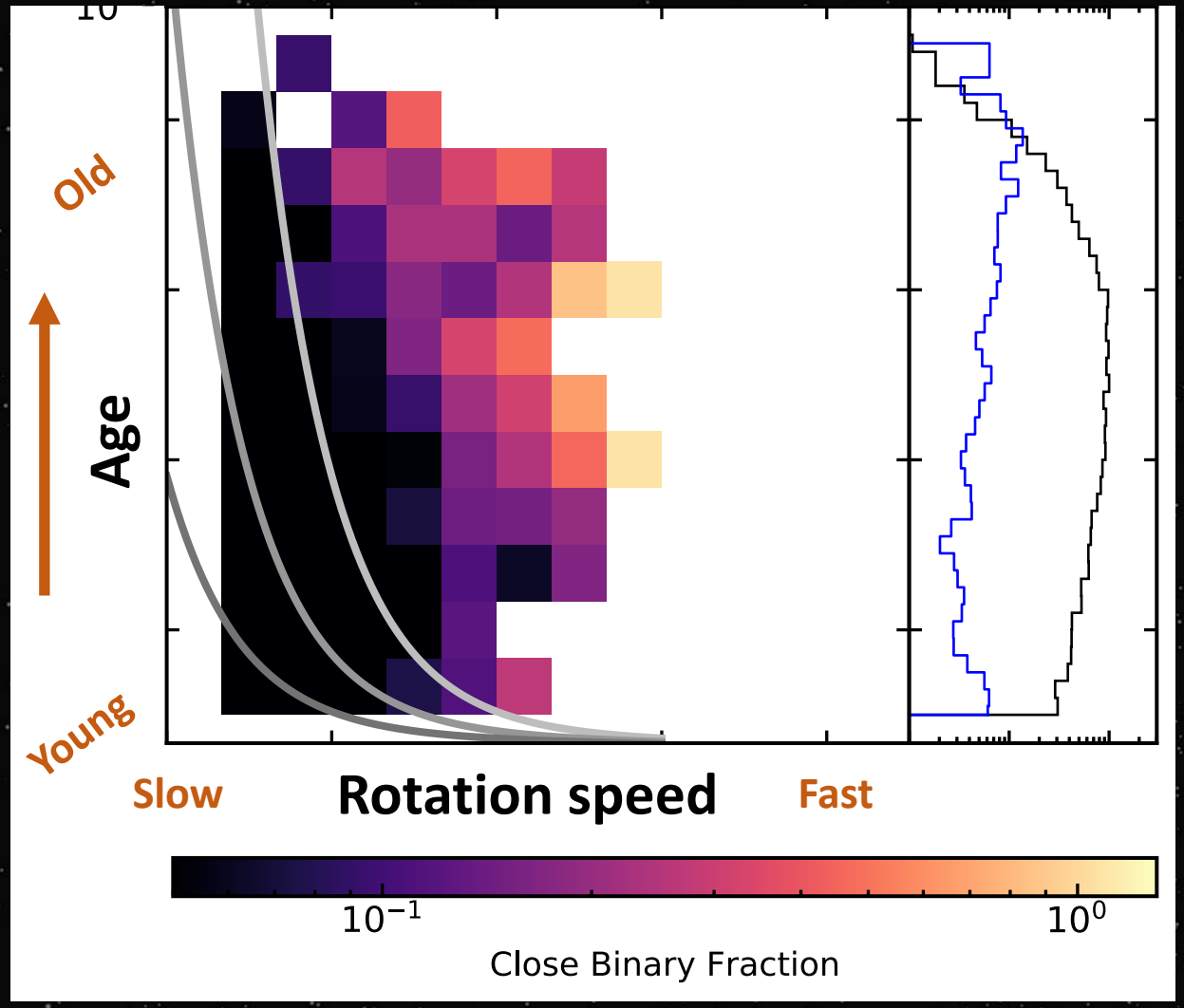
# Binaries + Stellar Evolution: Rotation + Age

We can guess an adult star's age based on its rotation speed…

…but a binary's "tug" affects those age estimates.

- Old + no binary:
  slow down over time
- Old + close binary:
  keeps spinning faster than expected, giving wrong age

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