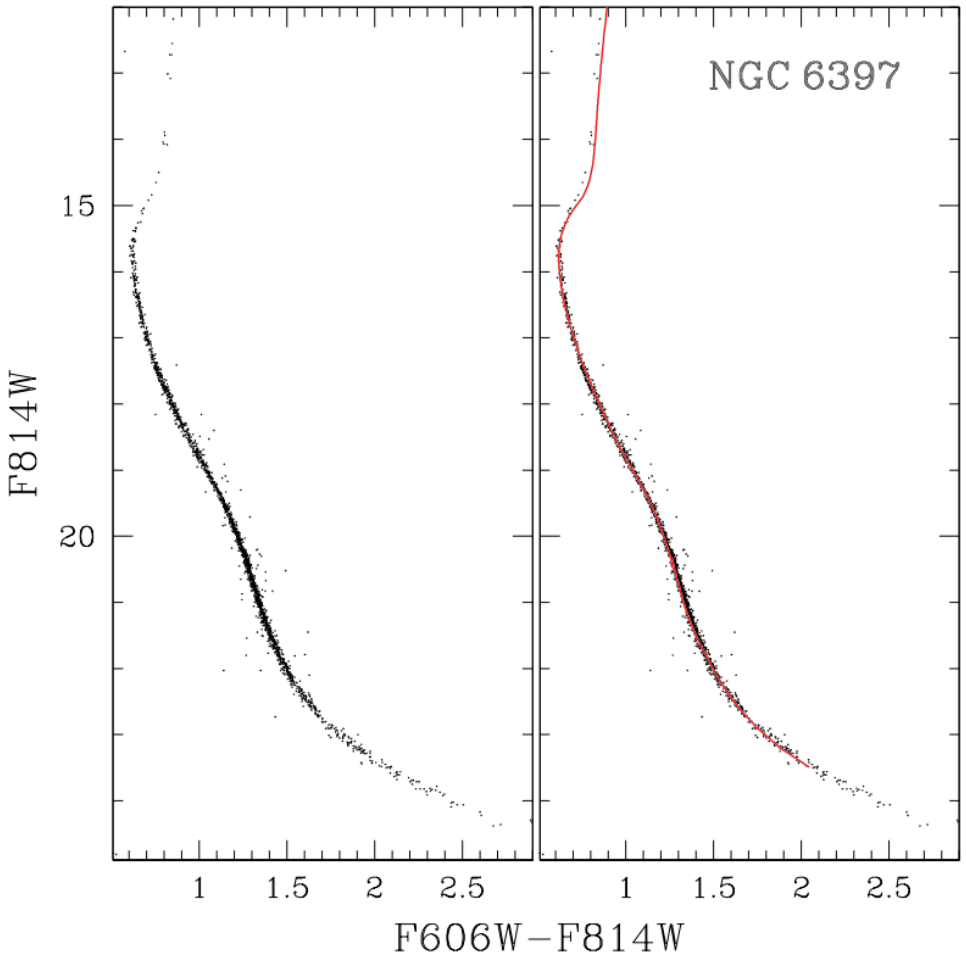
Exploring the phenomenon of split main sequence in young star clusters via binary stars

MODEST 24

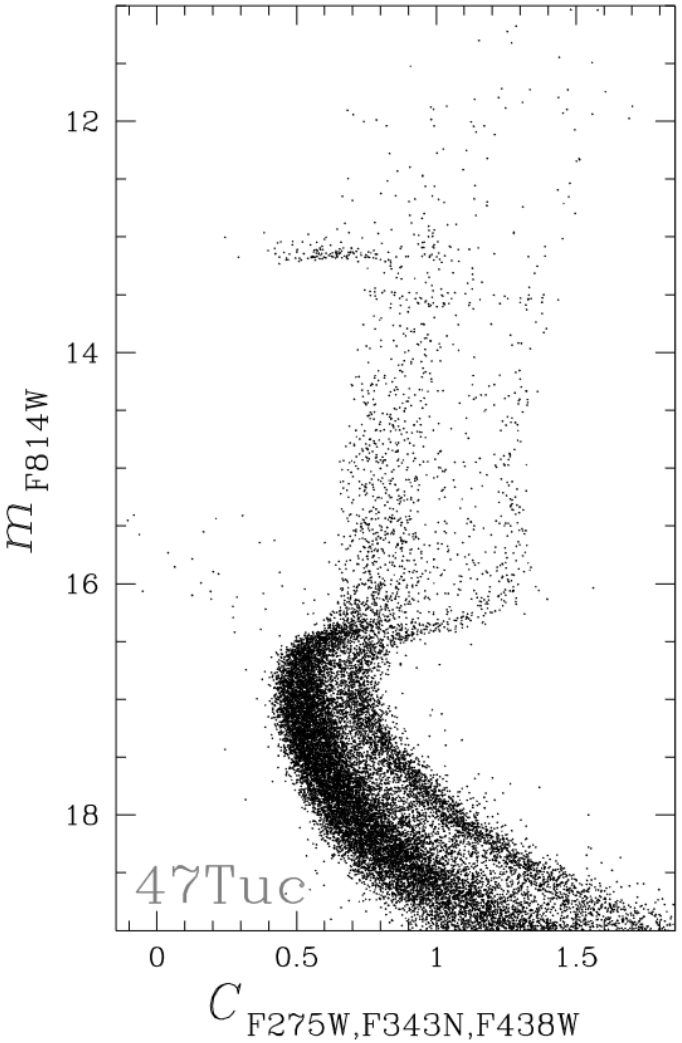
Fabrizio Muratore, PhD student
University of Padua

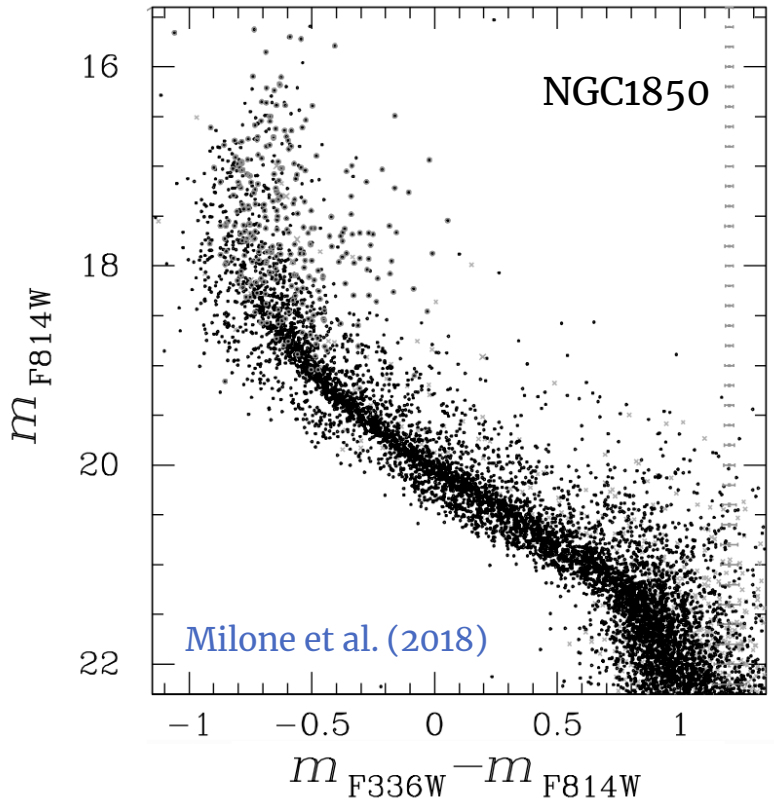
Stellar clusters

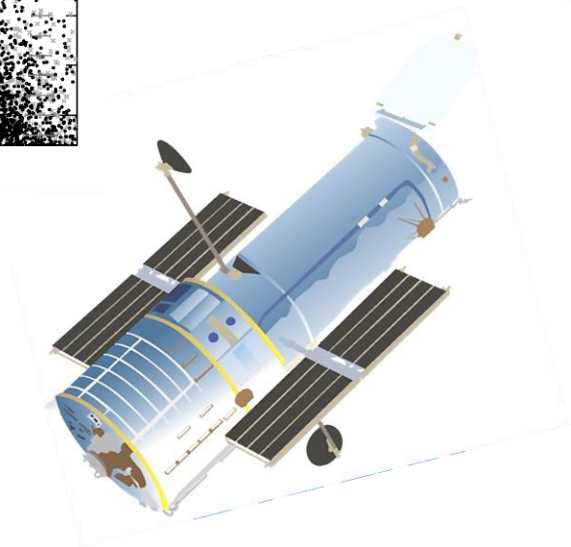


Richer et al. (2008)

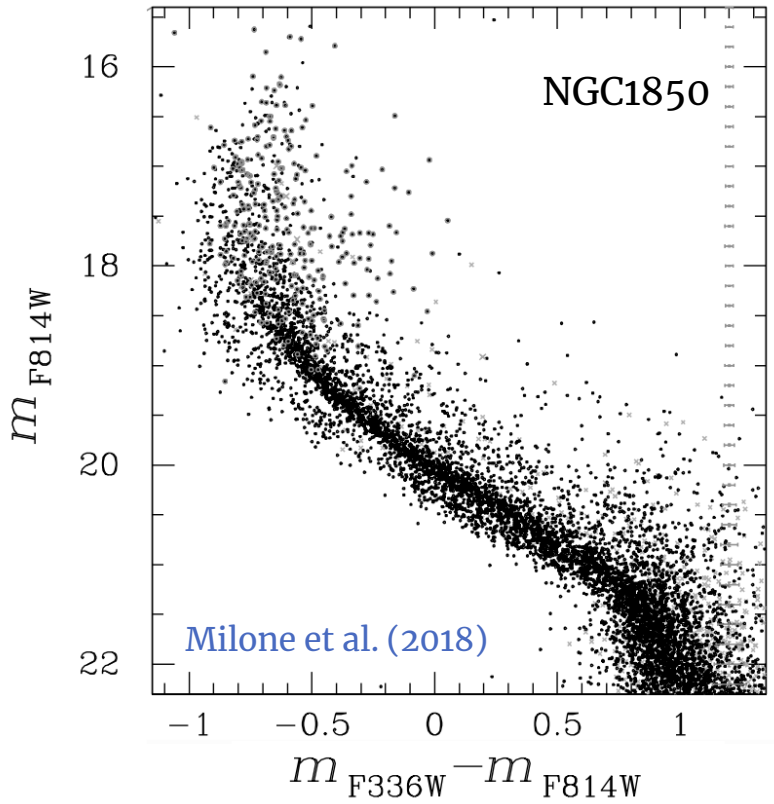
Stellar clusters

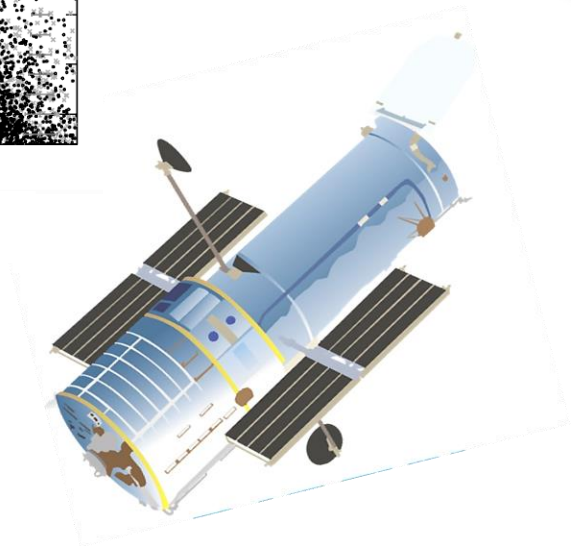






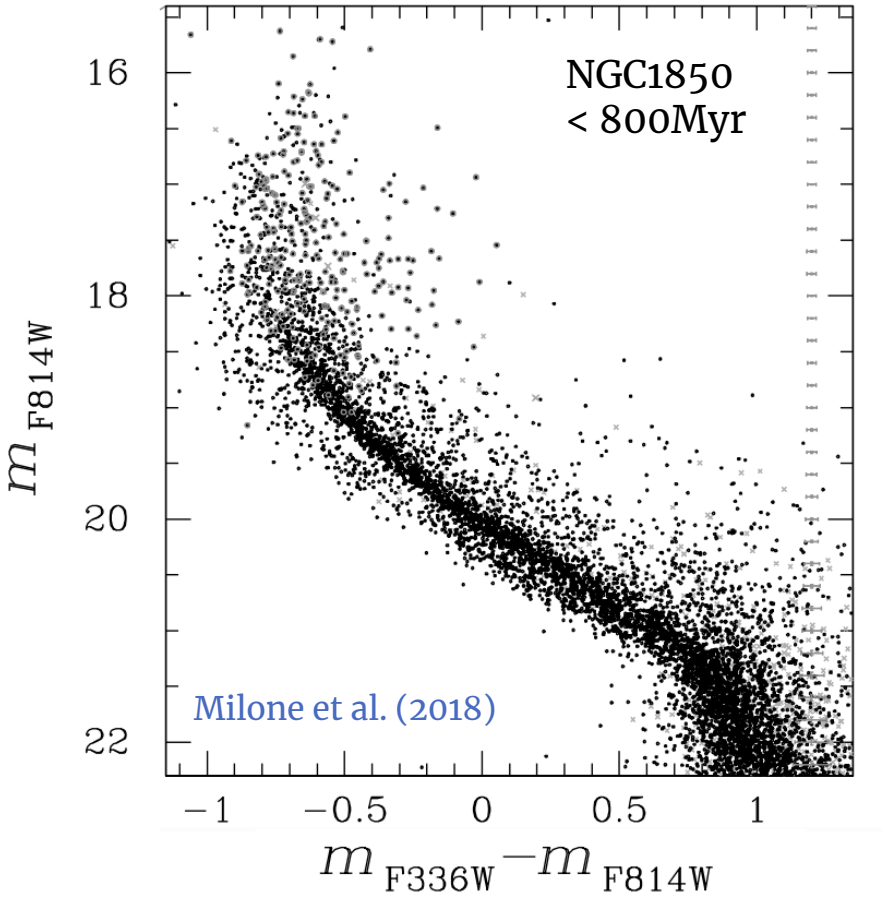
Stellar clusters

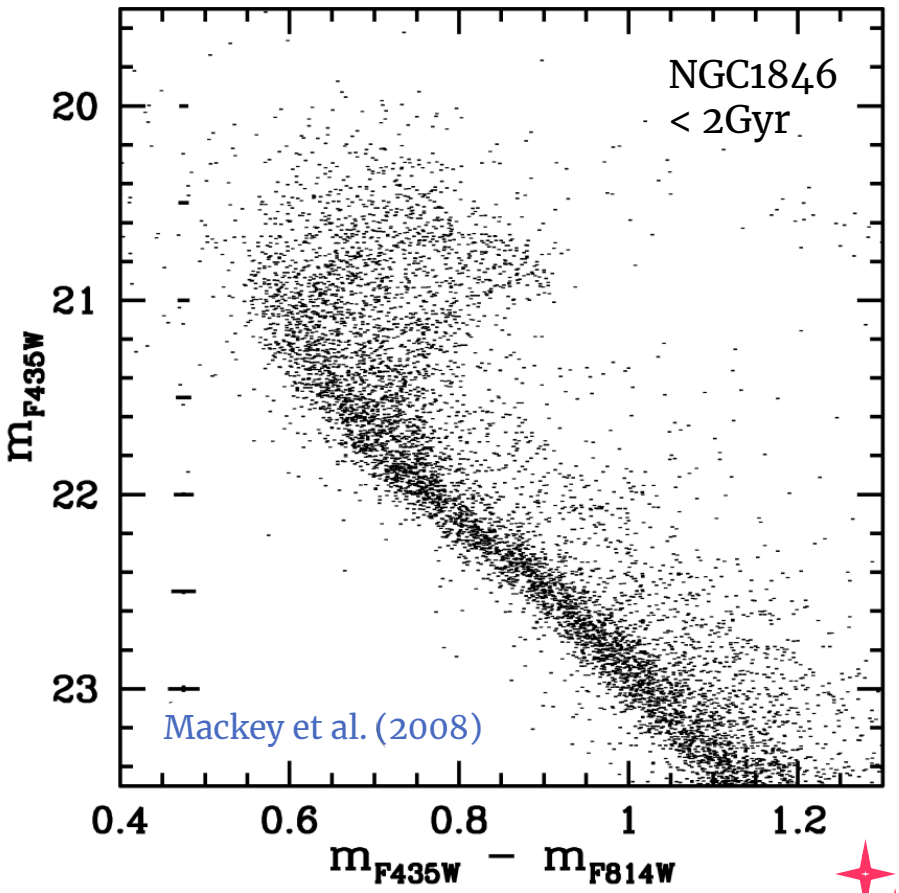




Young & intermediate-age star clusters

Young and intermediate-age star clusters in Magellanic Clouds exhibit complex CMDs





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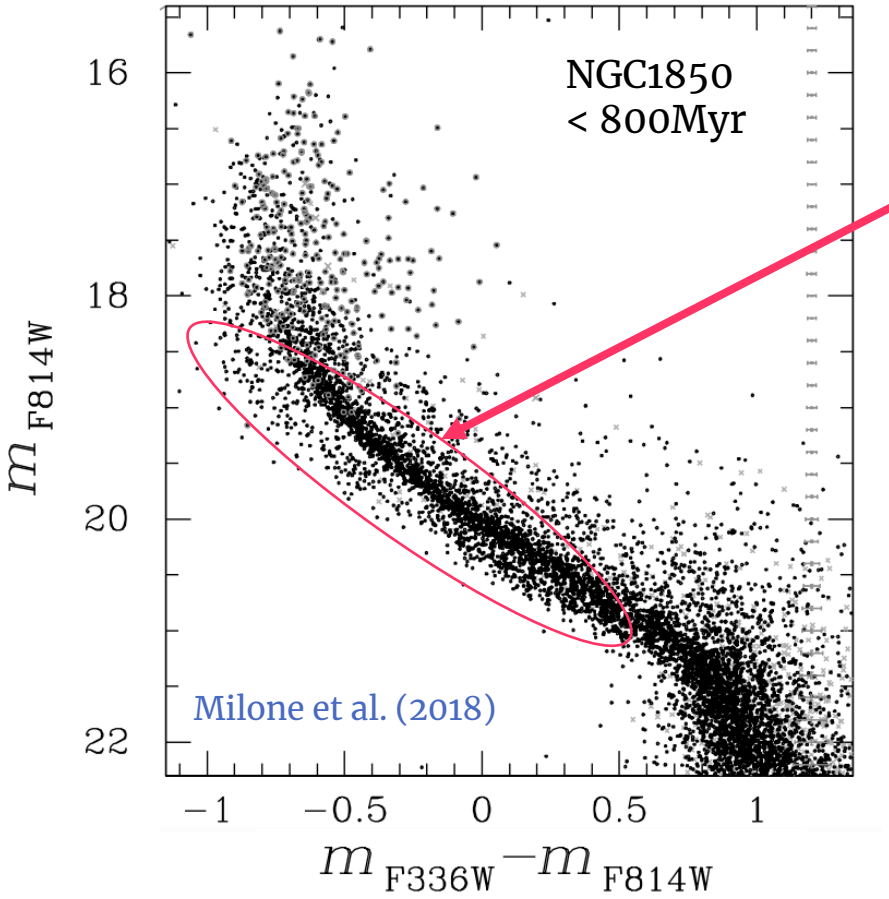
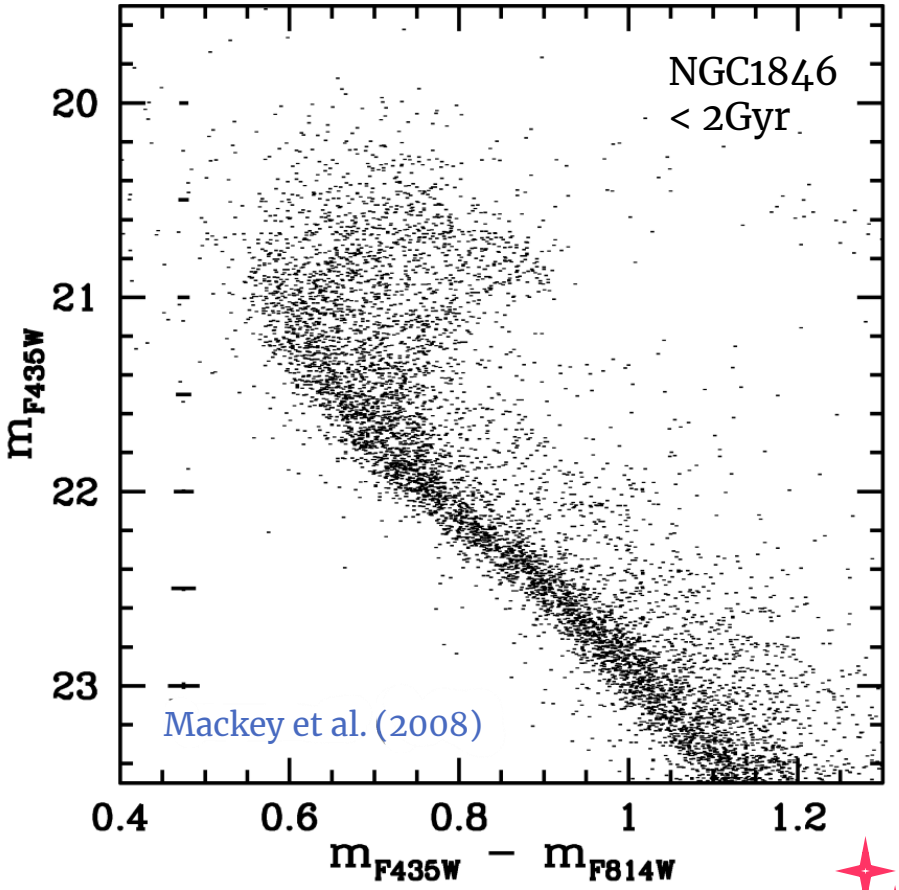
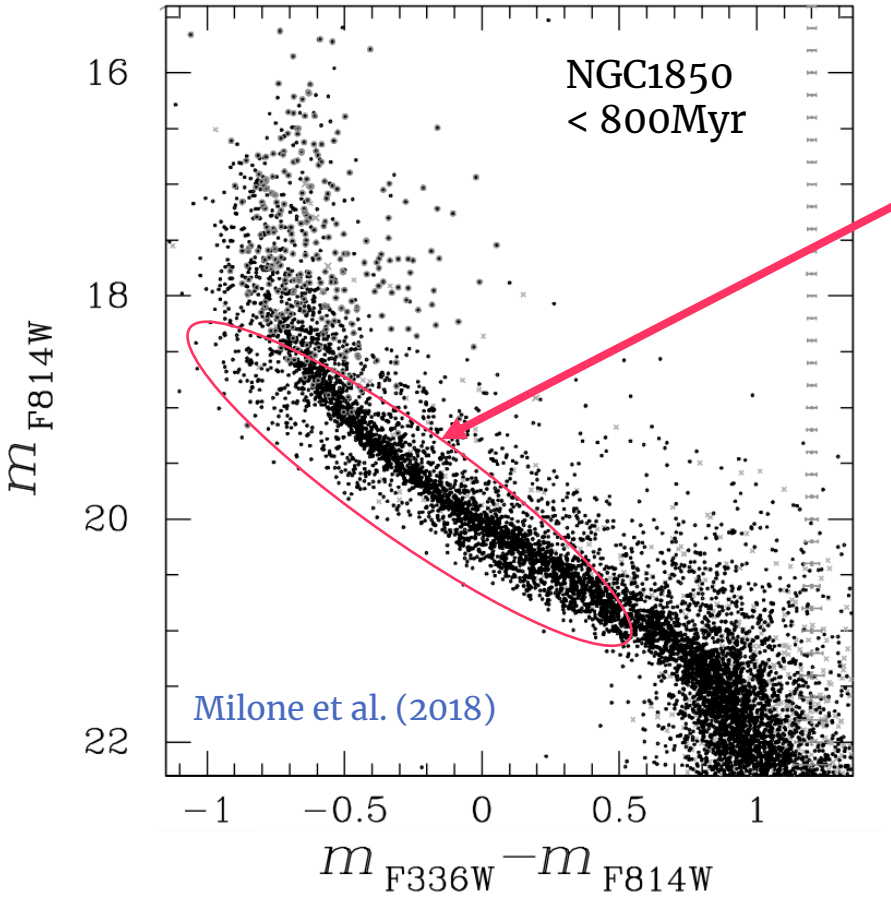


The split main sequence



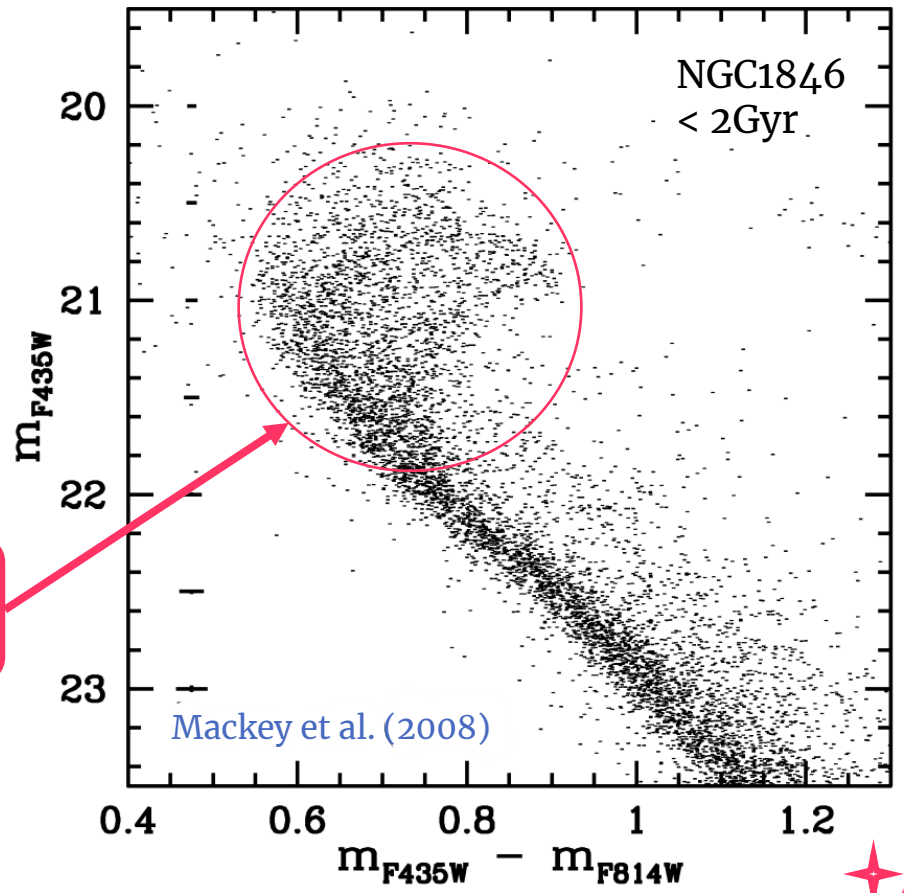
Young & intermediate-age star clusters

Young and intermediate-age star clusters in Magellanic Clouds exhibit complex CMDs

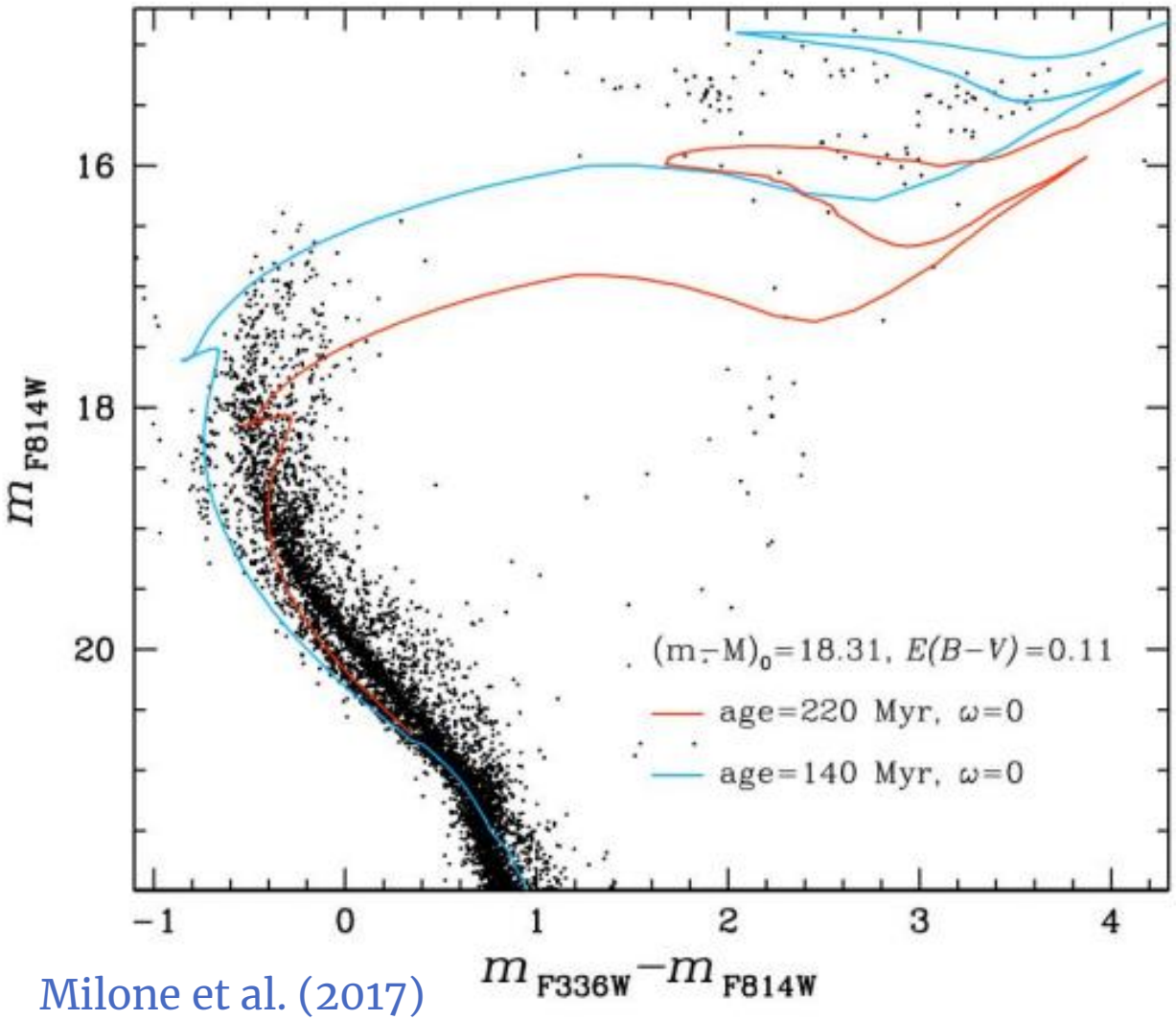


The split main sequence

The extended main sequence turn off



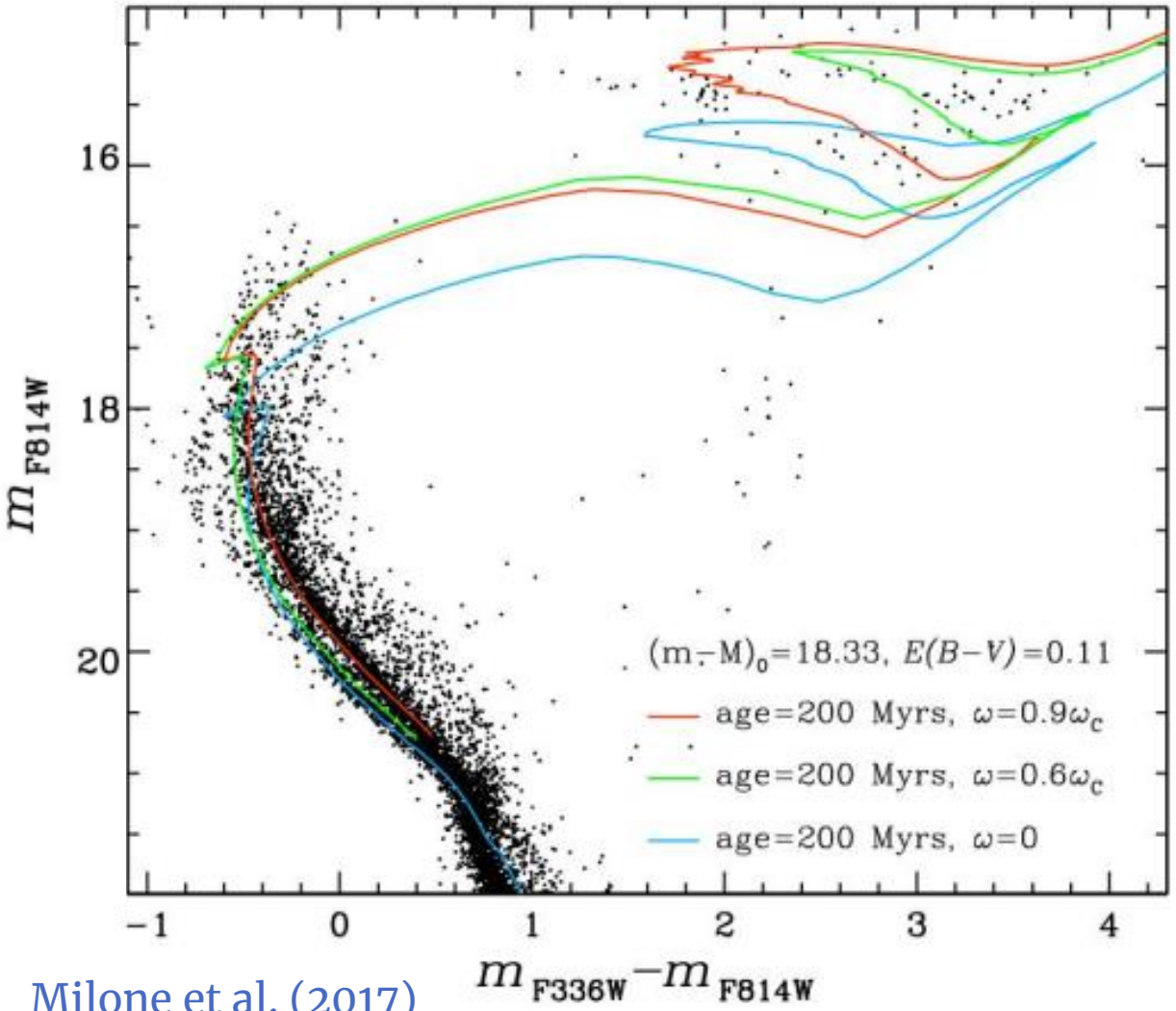
Young & intermediate-age star clusters



Milone et al. (2017)

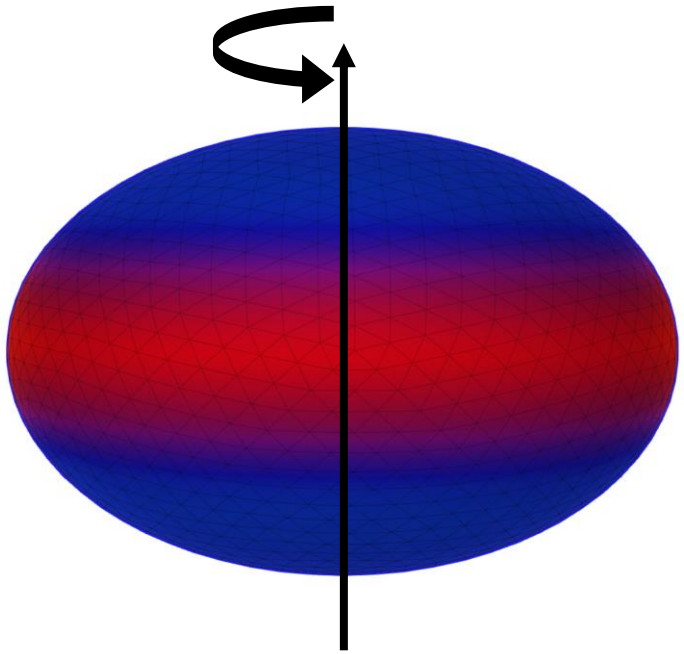
Age-spread scenario

Young & intermediate-age star clusters



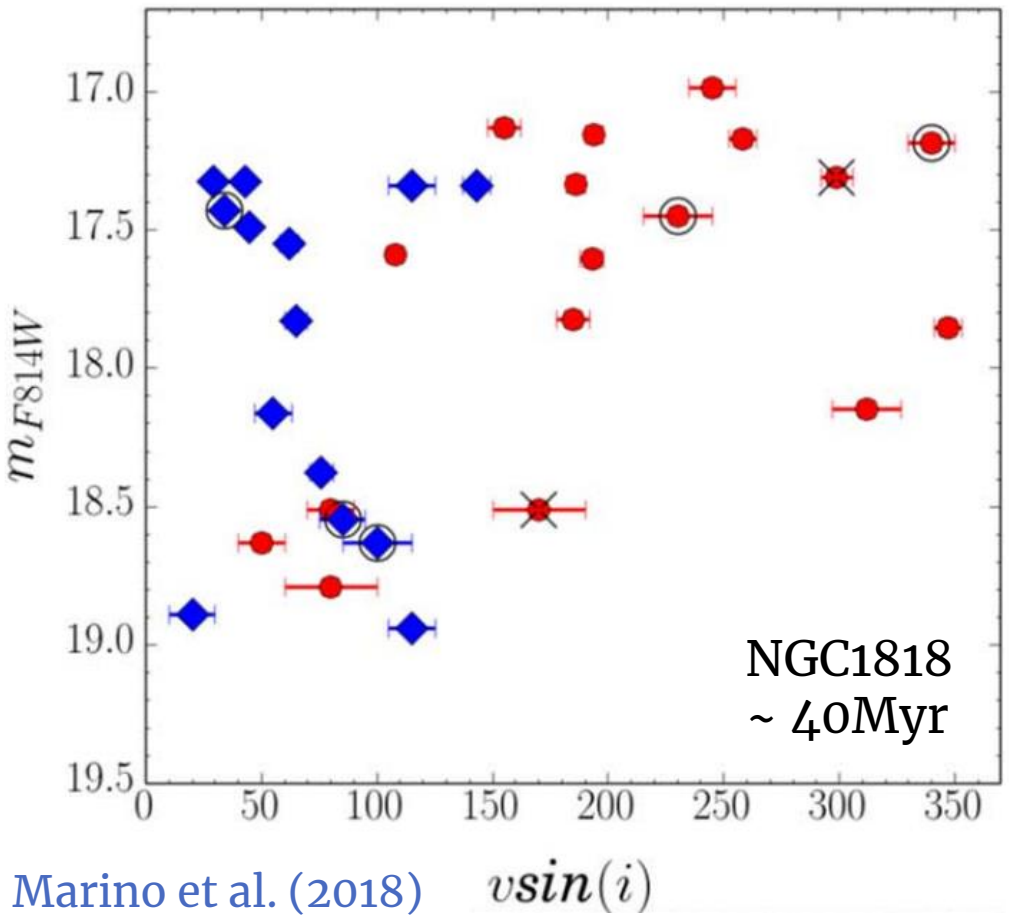
Milone et al. (2017)

Rotational-spread scenario

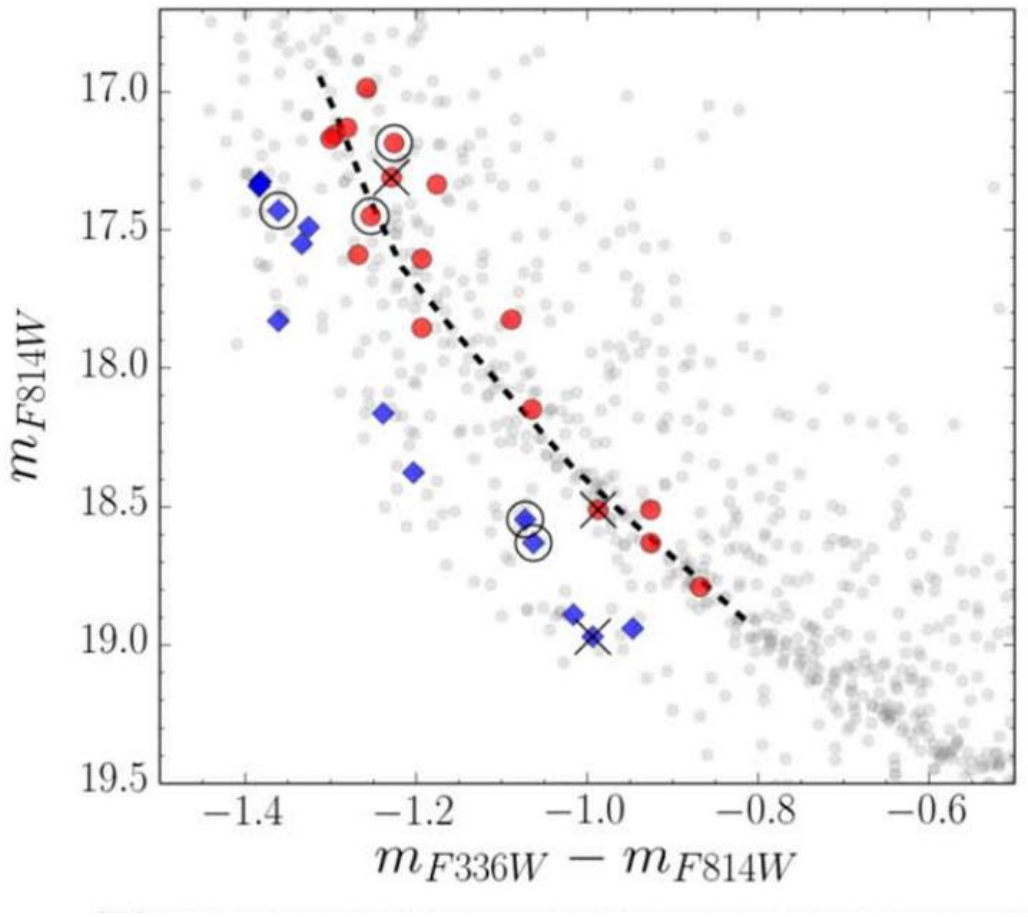


Young & intermediate-age star clusters

Direct spectroscopic evidence



Marino et al. (2018)

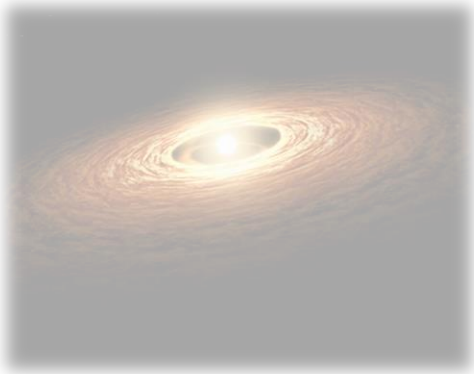


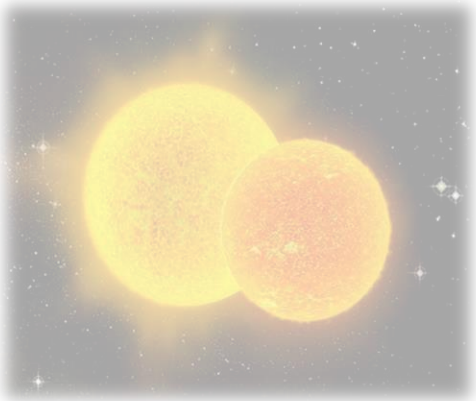
Rotational-spread scenario

Rotational-spread scenario

Braking mechanism!

Braking mechanism





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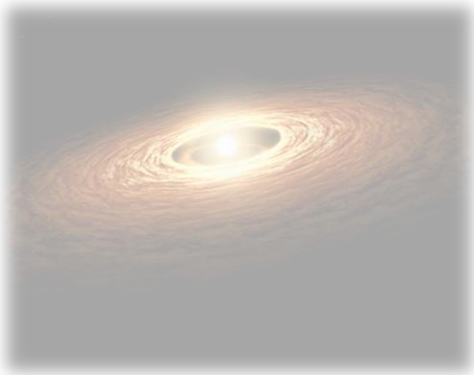
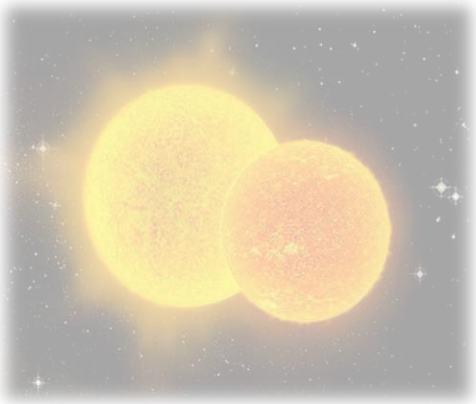
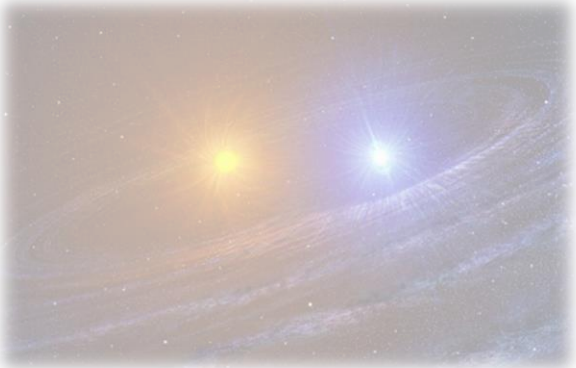


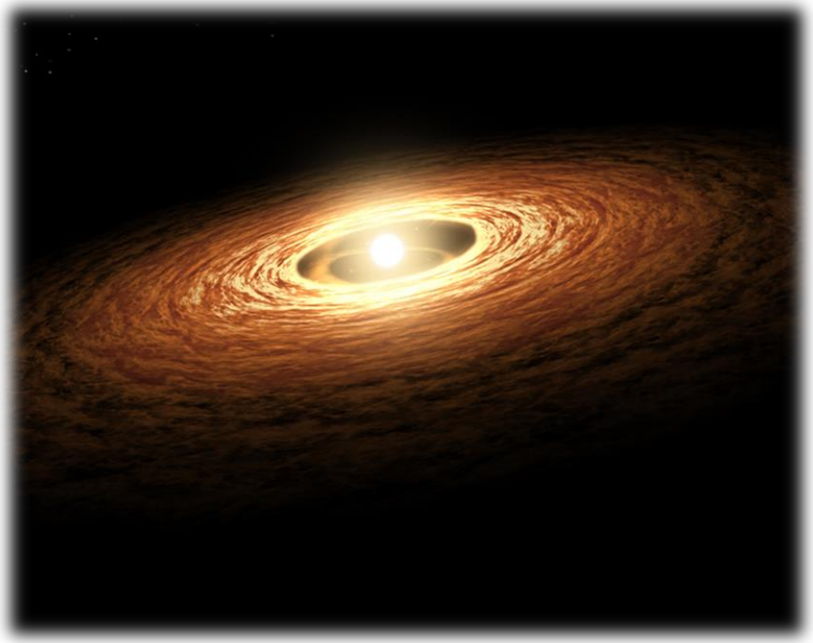


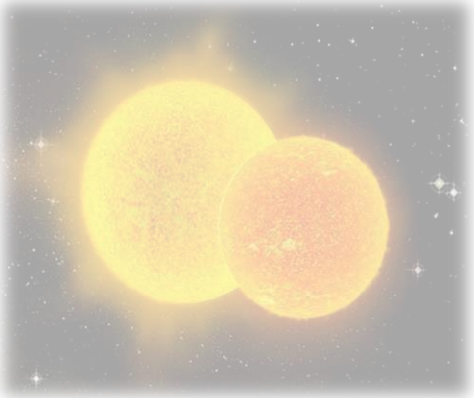
Tidal interactions → Predominance of binaries among the blue MS.

D'Antona et al. (2015, 2017)

Braking mechanism



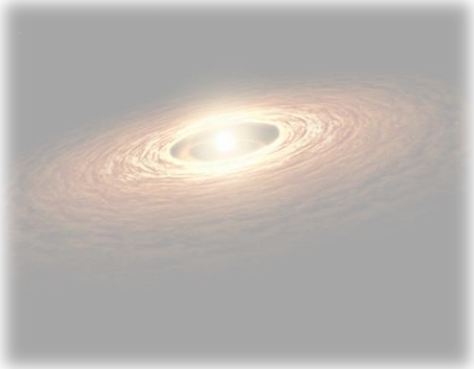


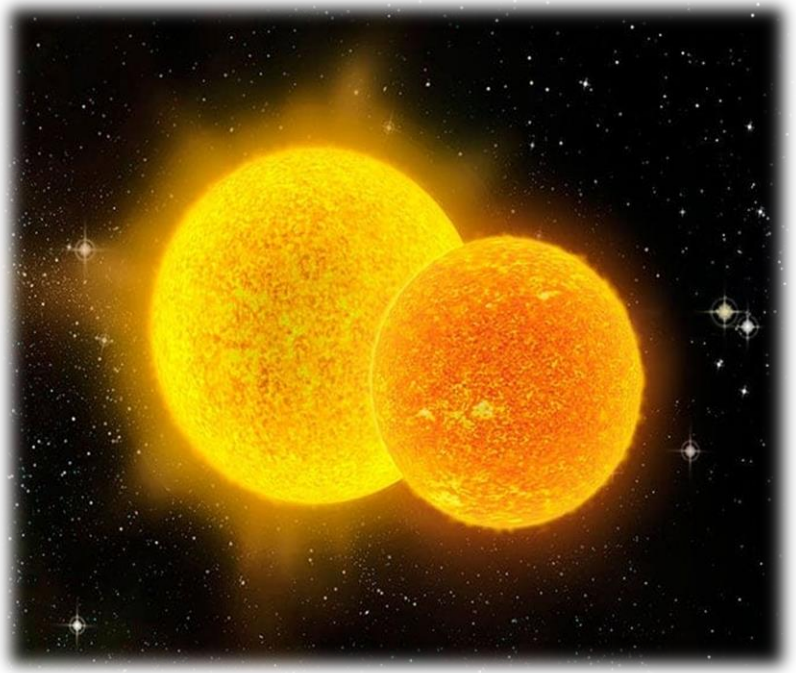


Disk interaction → No predominance of binaries among the blue MS

Bastian et al. (2020)

Braking mechanism



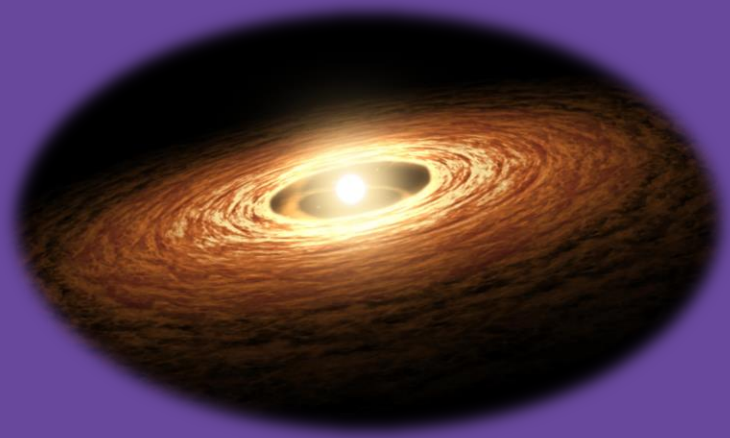


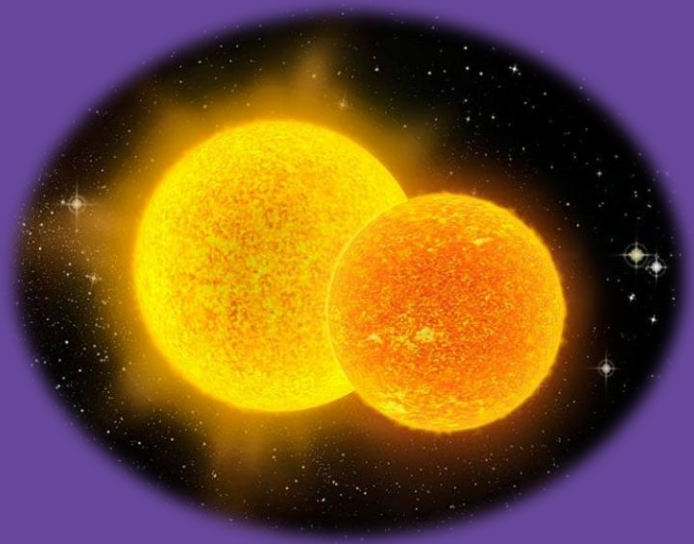
Merging events → A lack of binaries among the blue MS

Wang et al. (2022)

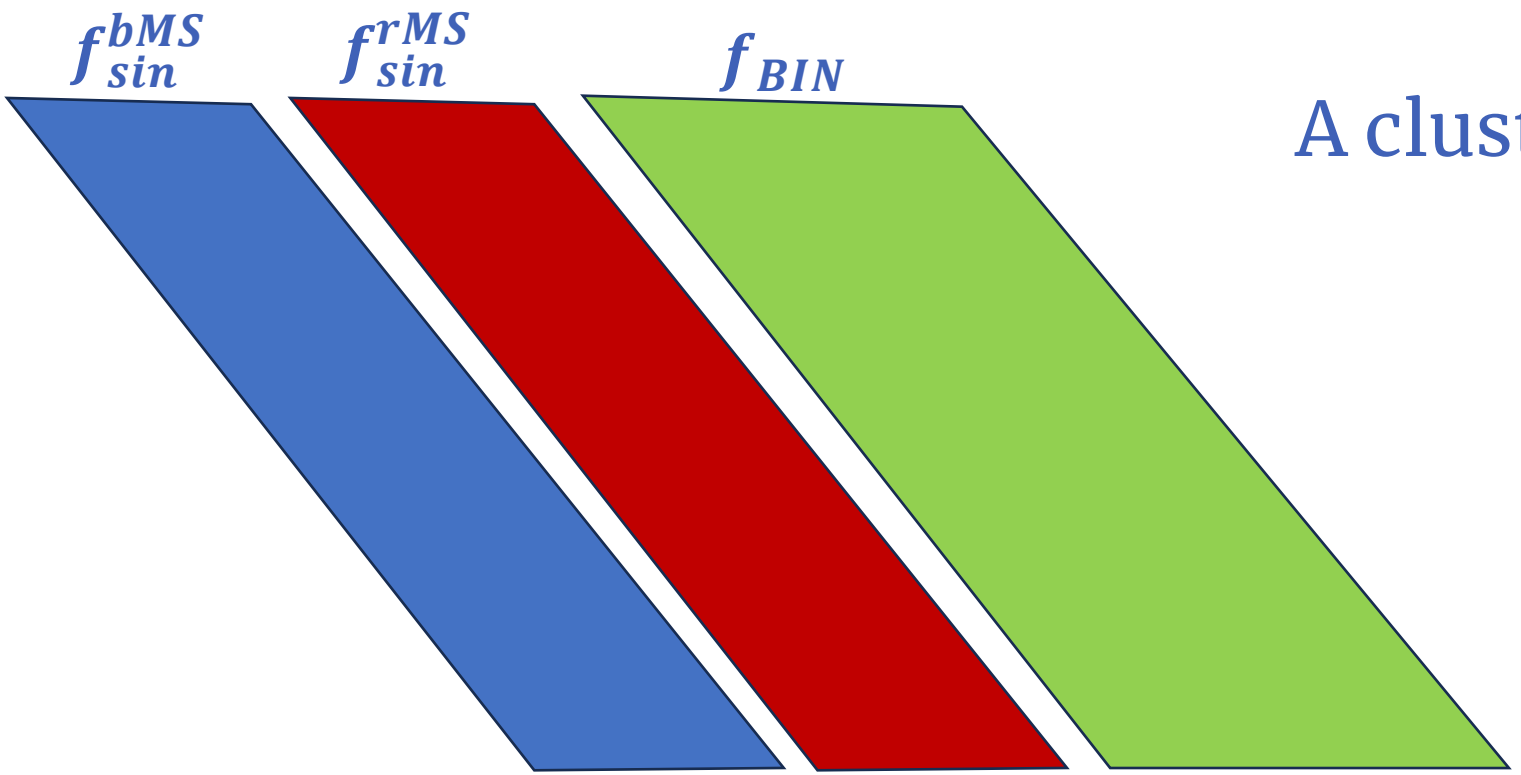
The Key

Constrain the scenario by deriving **the fraction of binaries** among the blue and red MS





The receipt



Let's think
about an ideal case...
A cluster composed of **N stars**

$$Cluster = N \cdot f_{sin}^{bMS} + N \cdot f_{sin}^{bMS} + N \cdot f_{BIN}$$

The receipt

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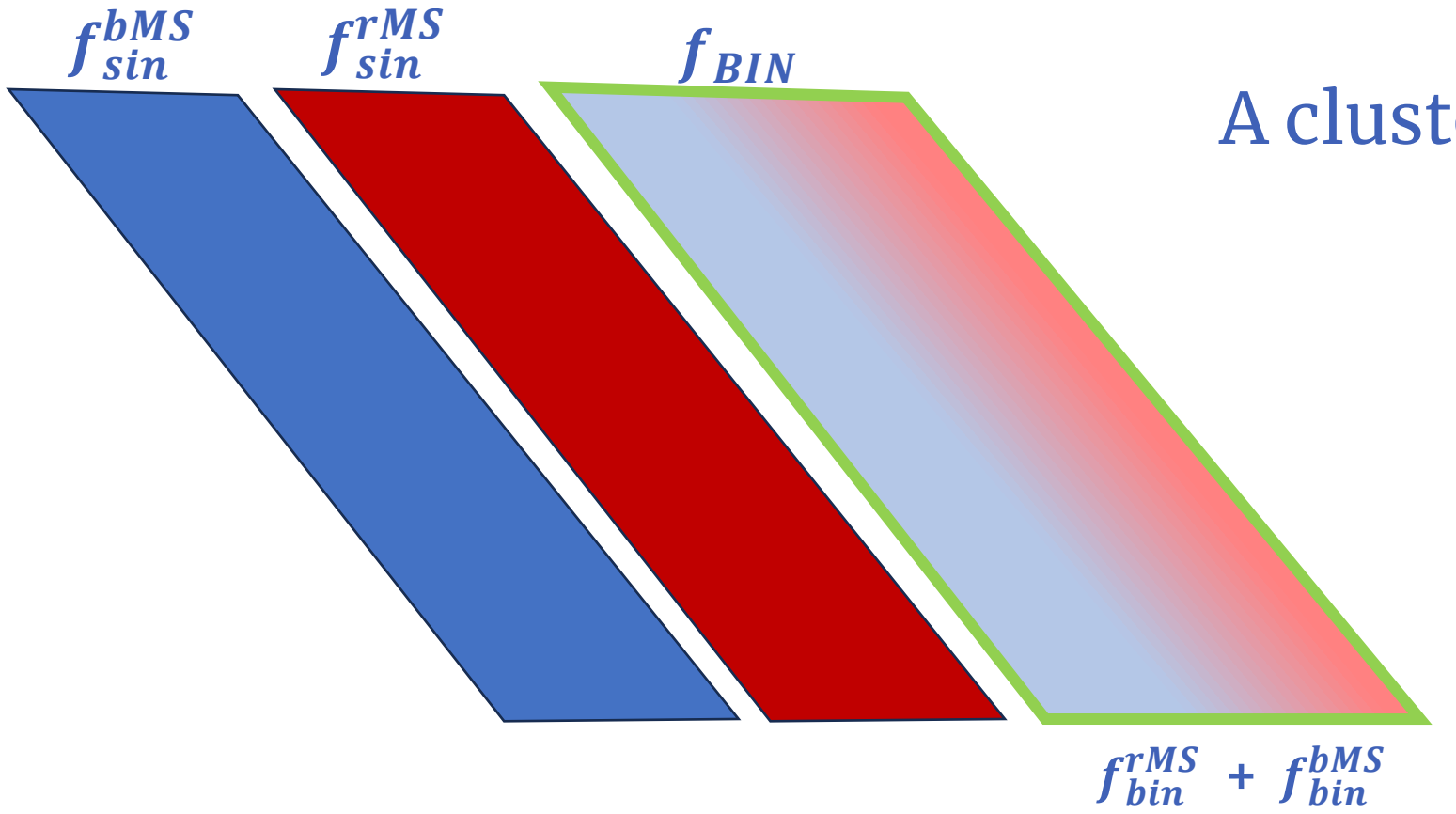

$$Cluster = N \cdot f_{sin}^{bMS} + N \cdot f_{sin}^{bMS} + N \cdot f_{BIN} \cdot \left(f_{bin}^{rMS} + f_{bin}^{bMS}\right)$$

The receipt

1

Studying the equal-luminosity binaries
Cumulative distribution

↓

f_{bin}^{rMS} and f_{bin}^{bMS}

2

Studying the MS stars

↓

f_{sin}^{rMS}, f_{sin}^{bMS} and f_{BIN}

The receipt

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Studying the equal-luminosity binaries
Cumulative distribution

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f_{bin}^{rMS} and f_{bin}^{bMS}

2

Studying the MS stars

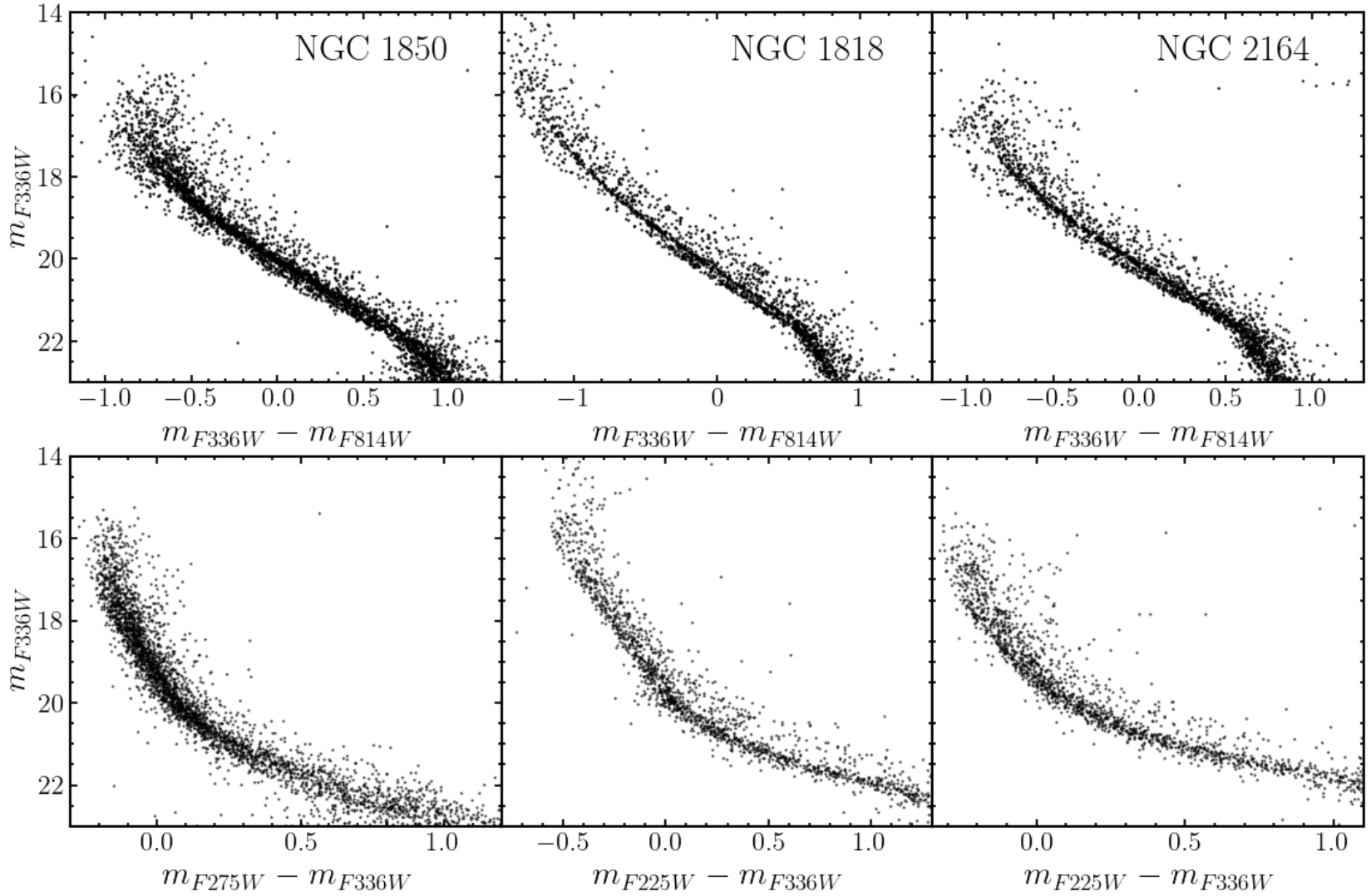
↓

f_{sin}^{rMS}, f_{sin}^{bMS} and f_{BIN}

3 → Fraction of binaries among split MSs

$$F_{bMS}^{bin} = \frac{N \cdot f_{BIN} \cdot f_{bin}^{bMS}}{N \cdot f_{sin}^{bMS} + N \cdot f_{BIN} \cdot f_{bin}^{bMS}}$$

The targets

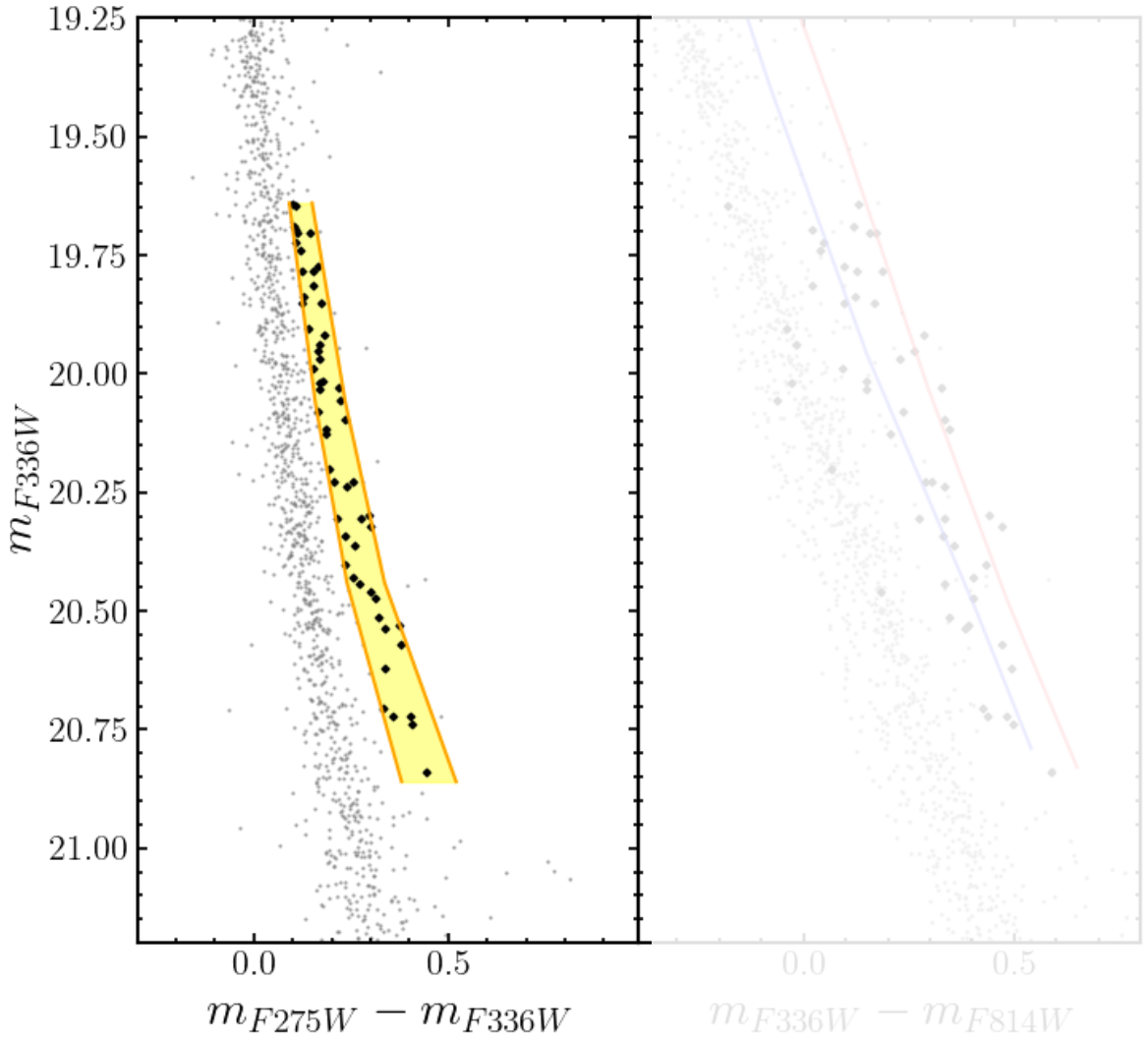


Muratore et al. (submitted)

1

Fraction

Muratore et al. (submitted)



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Fraction

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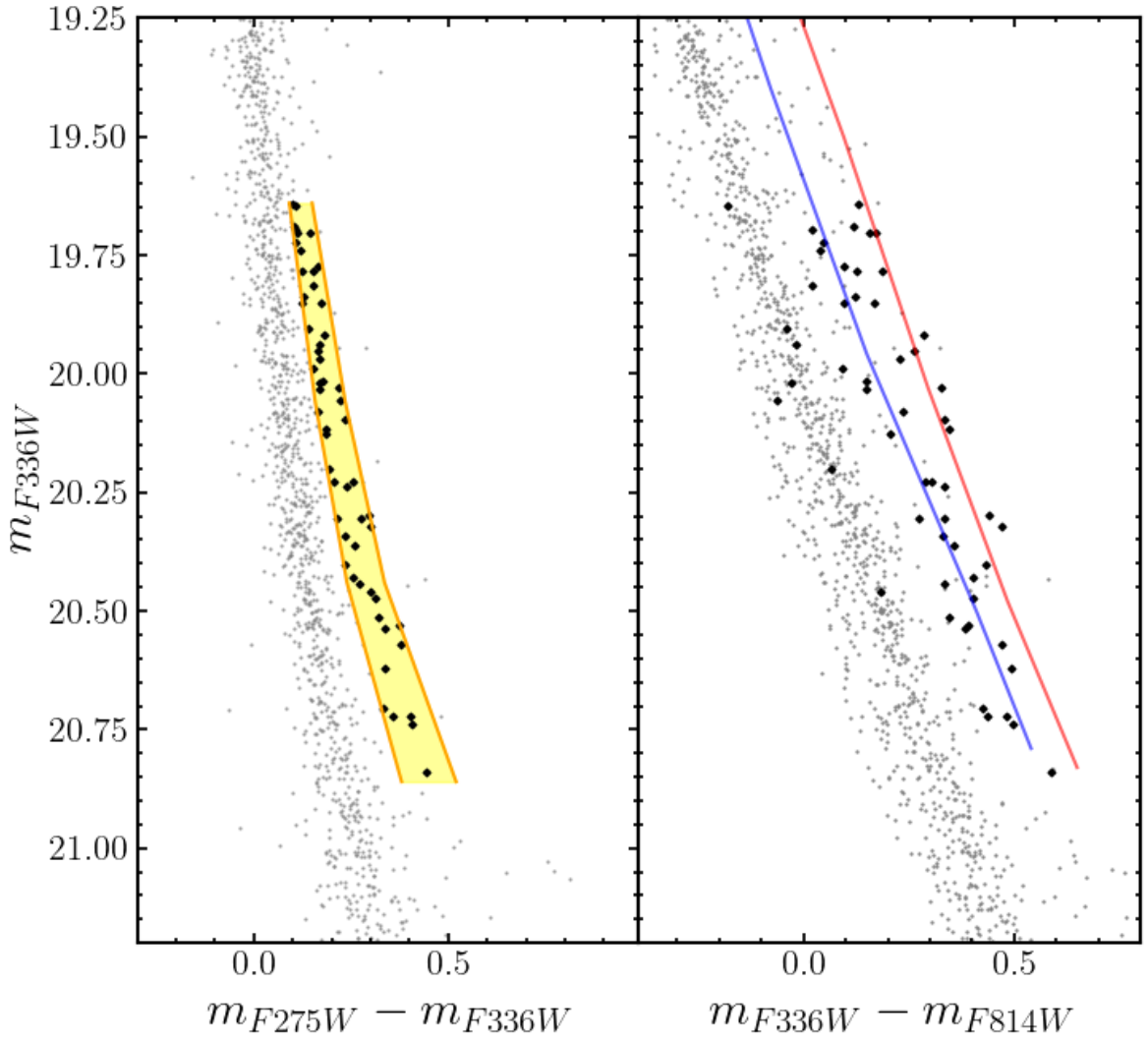

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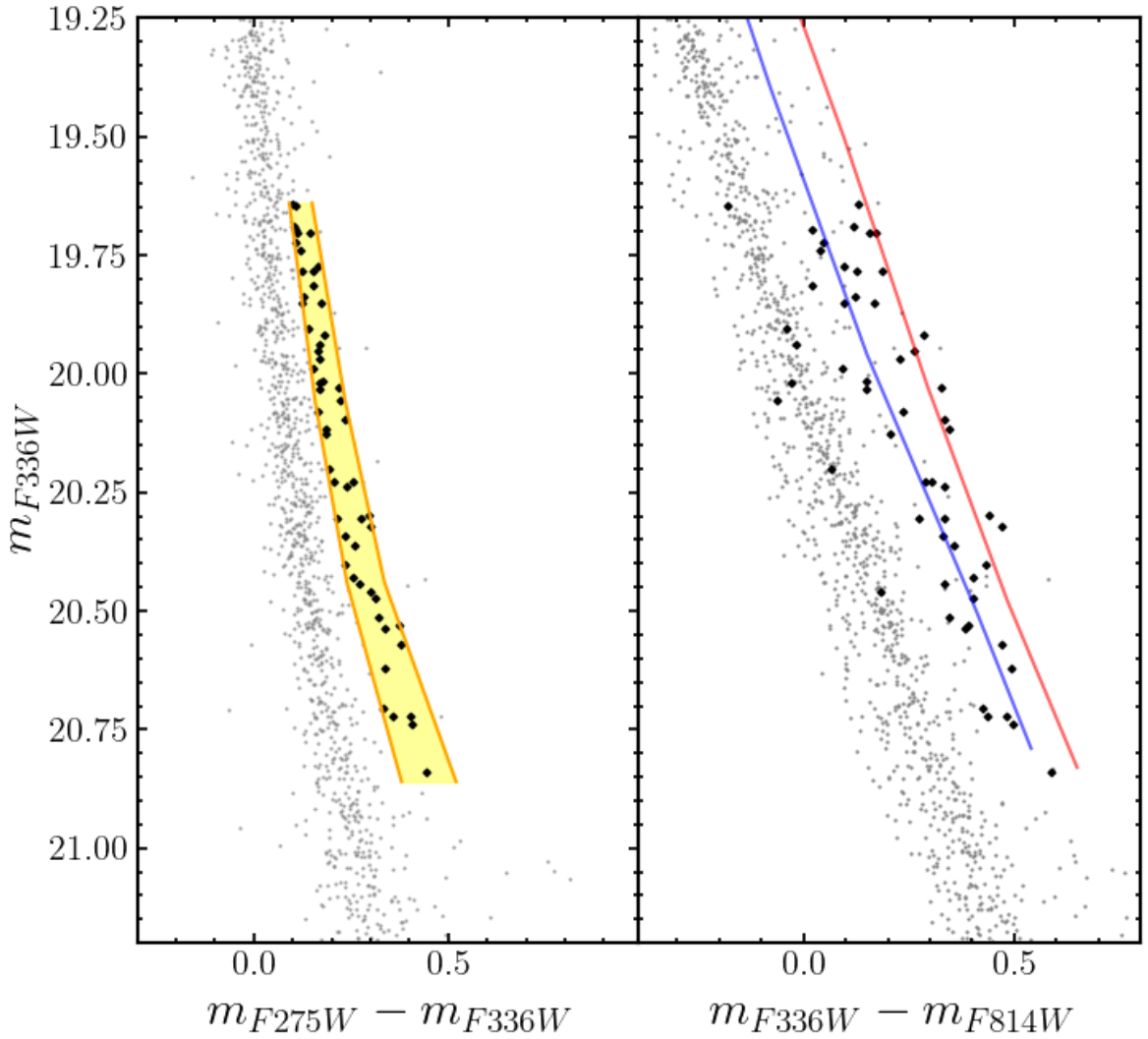
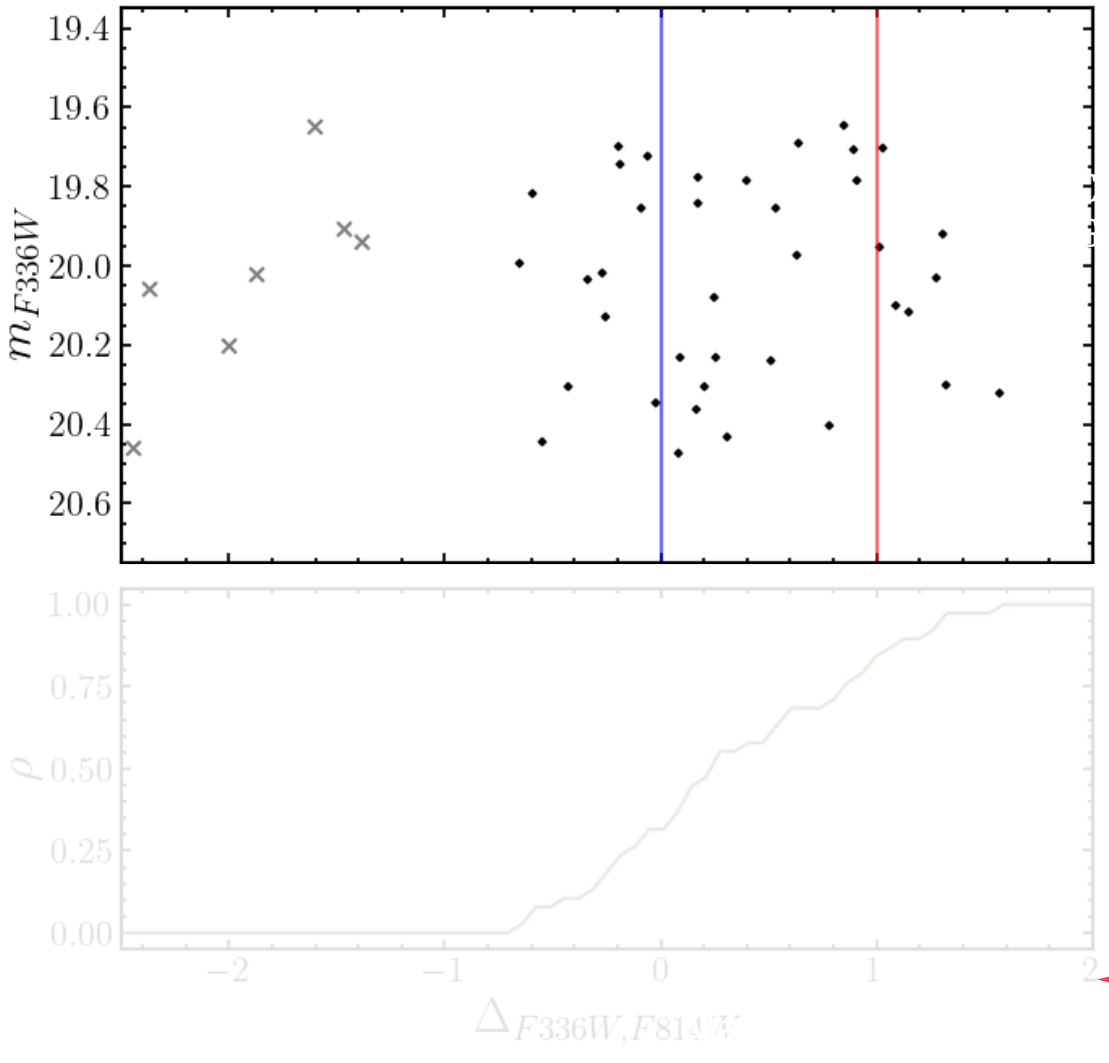
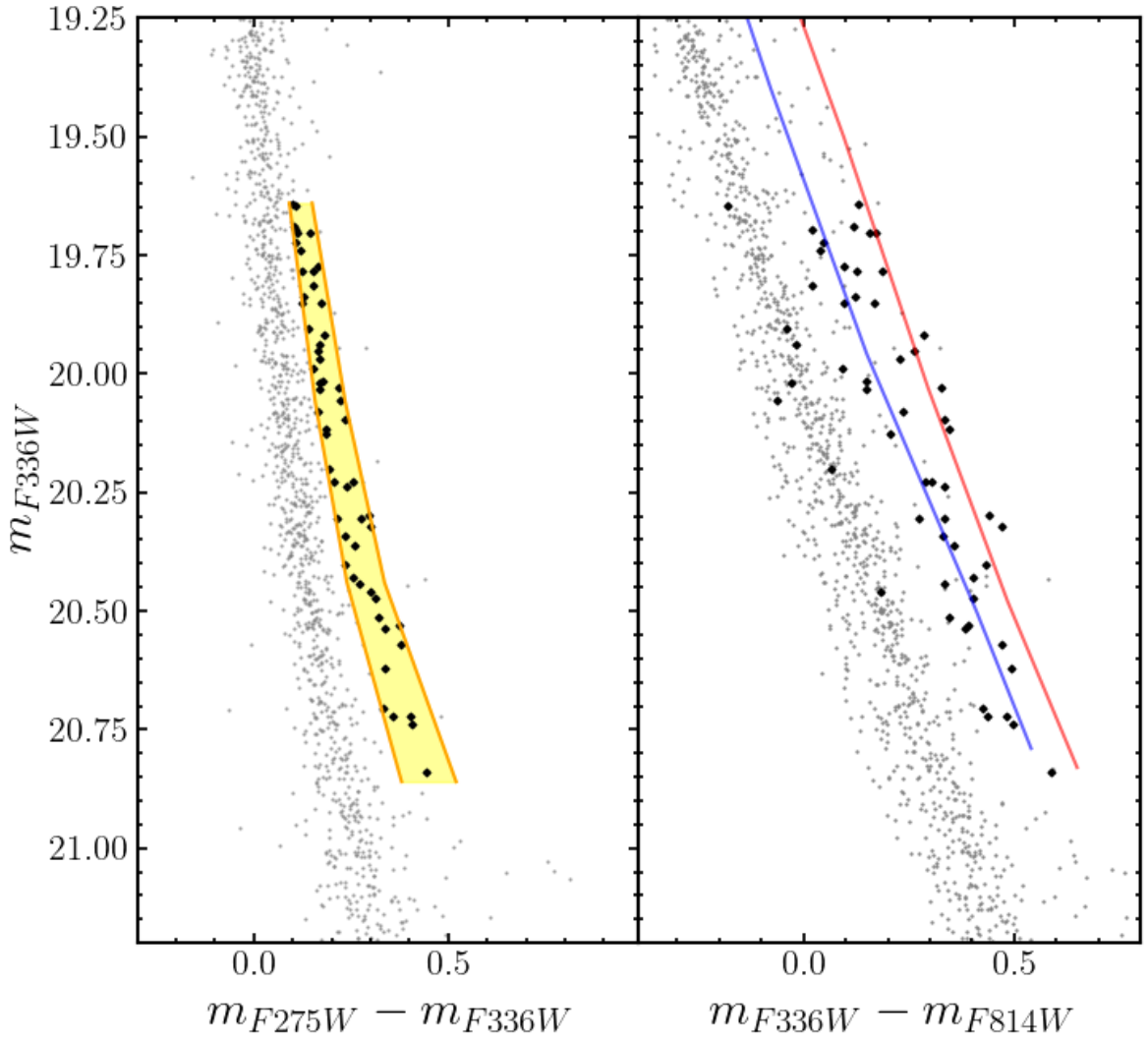
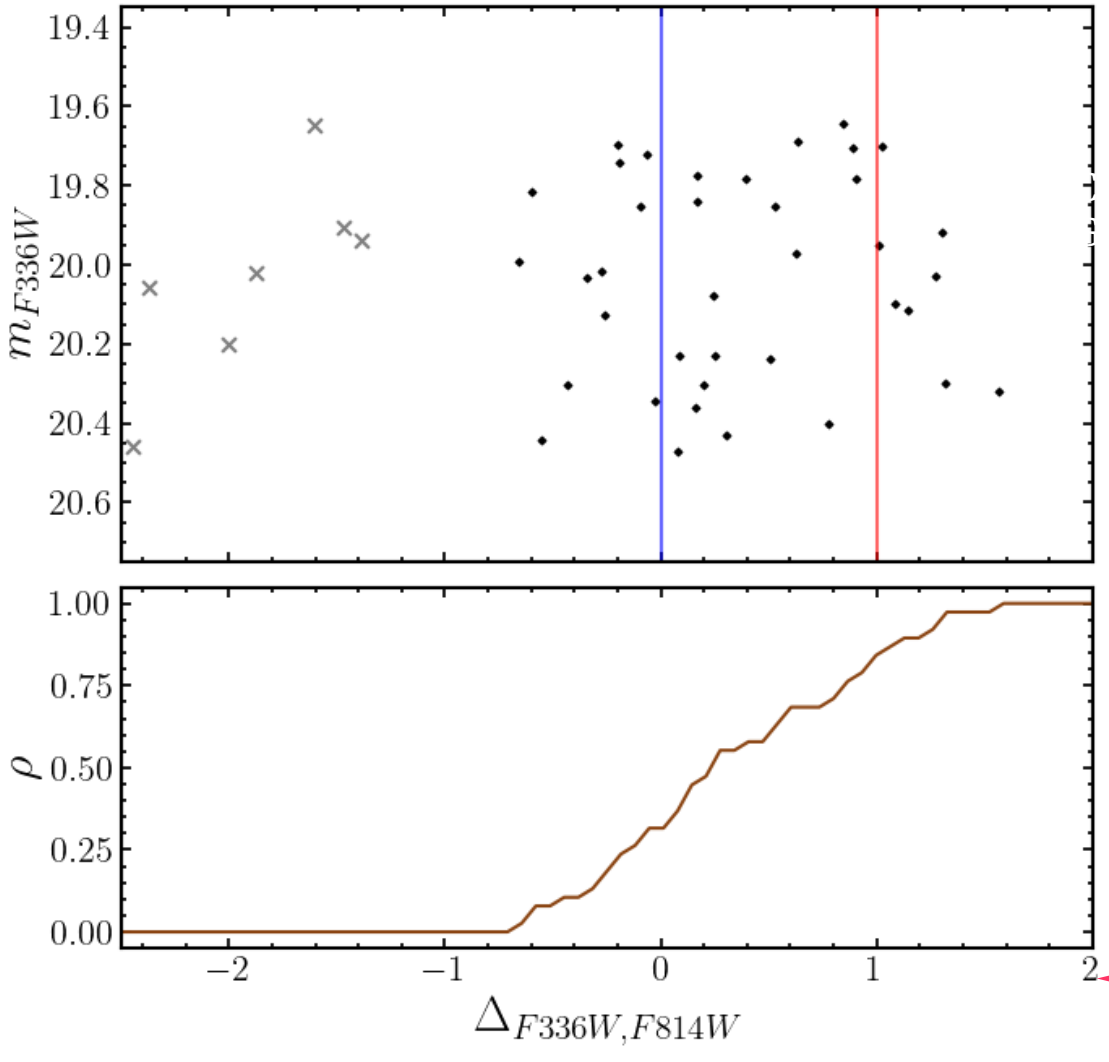




1 Fraction

Muratore et al. (submitted)





Reproducing distributions

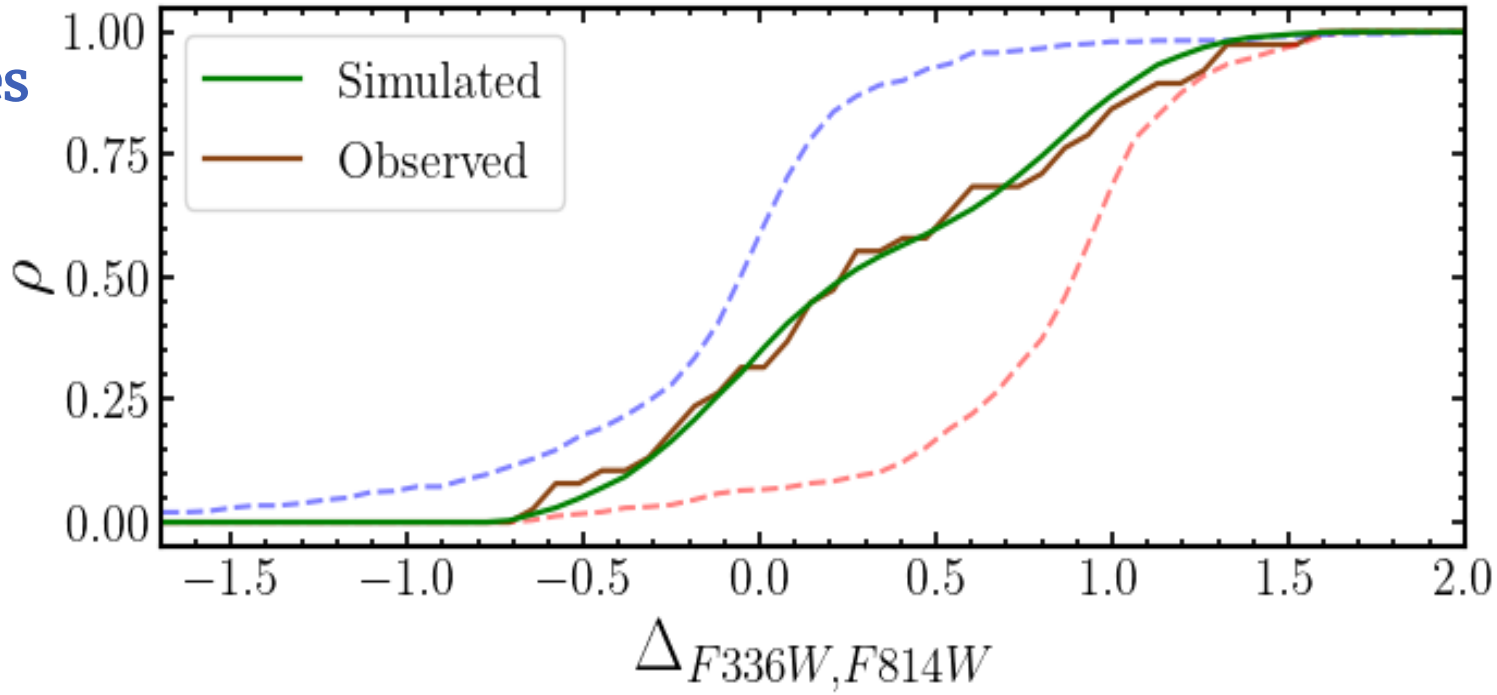
1

Studying the equal-luminosity binaries

↓

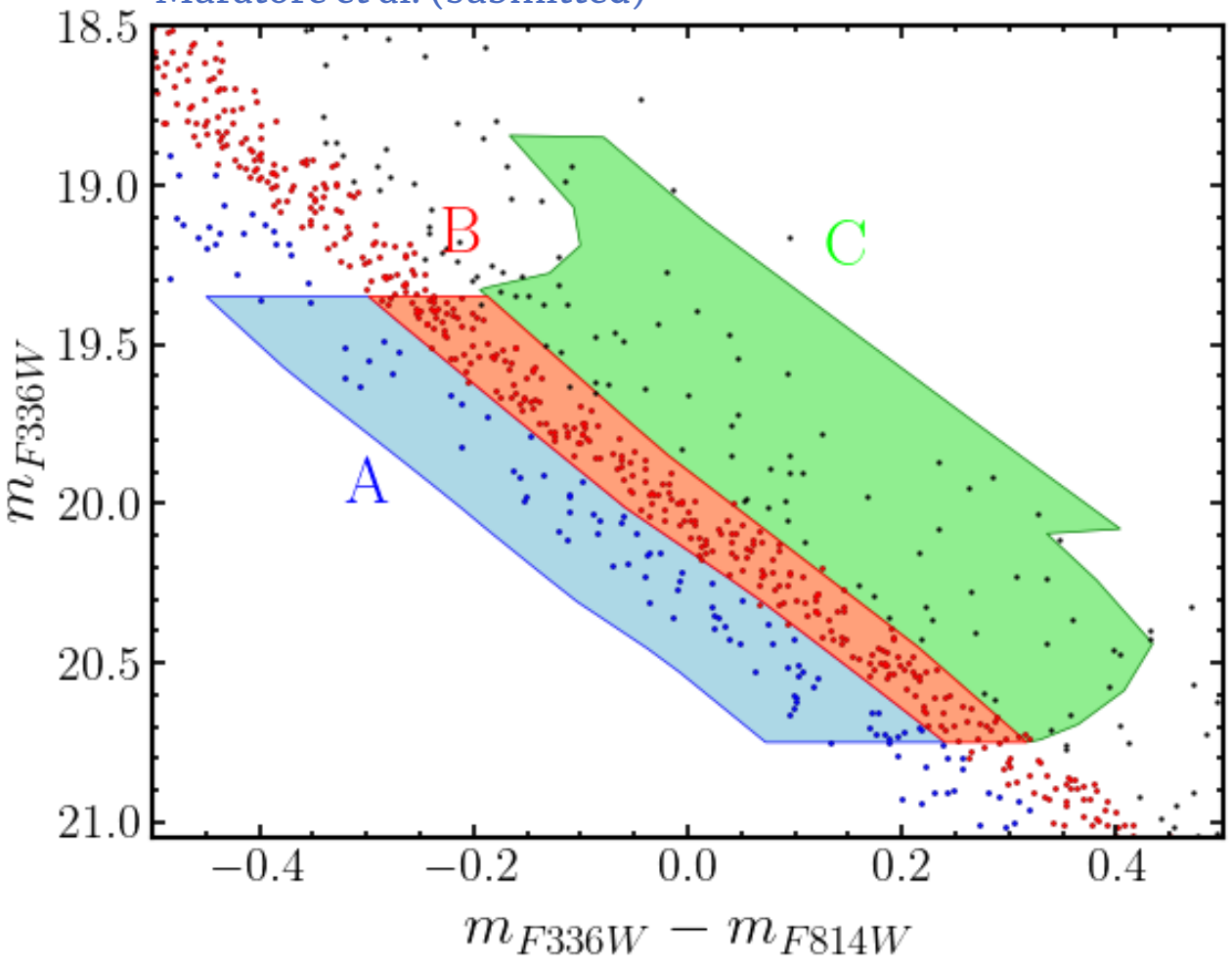
$$f_{bin}^{rMS} = 0.40$$
$$f_{bin}^{bMS} = 0.60$$

Muratore et al. (submitted)



Fraction among MS

Muratore et al. (submitted)



2

Studying the MS stars

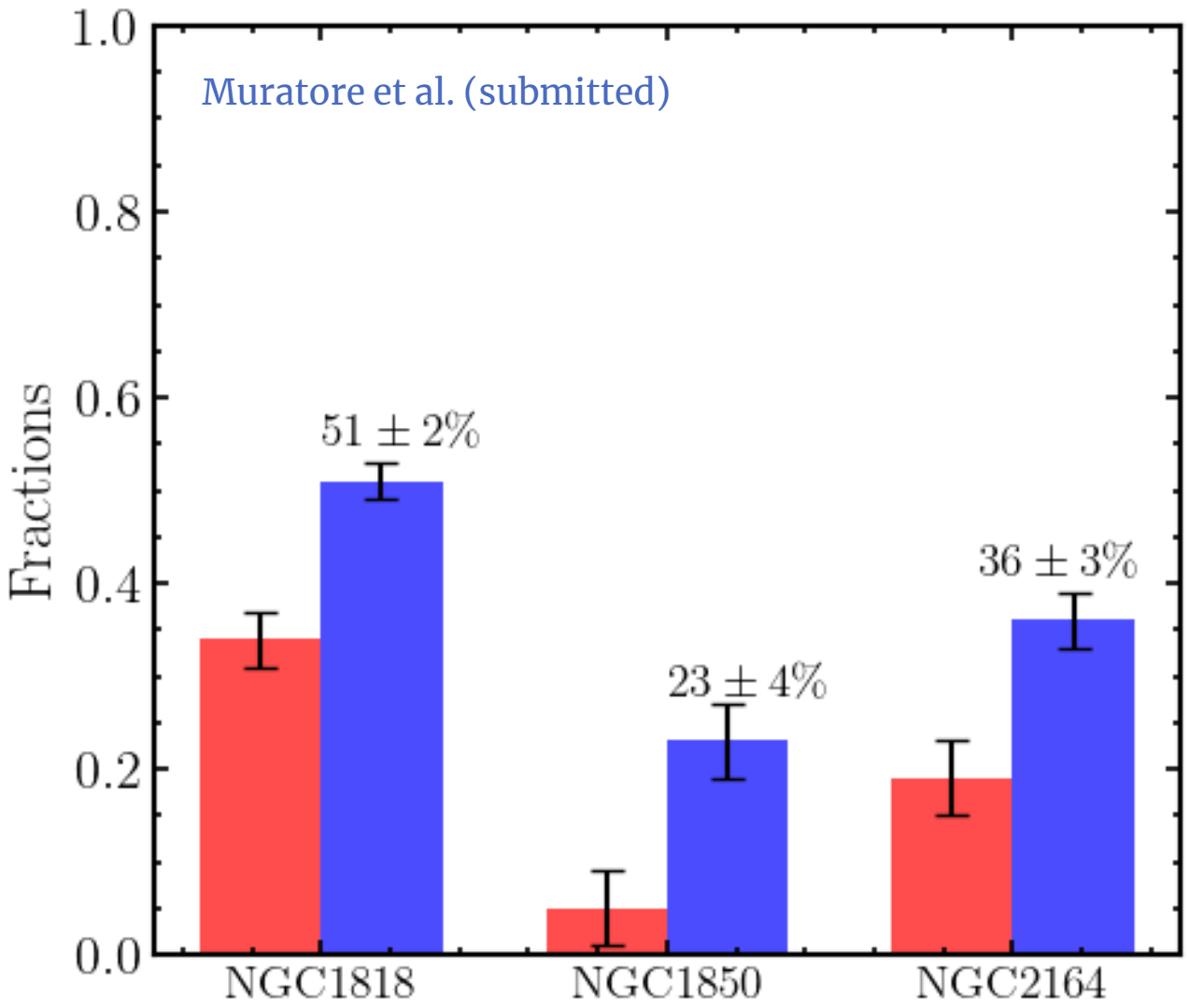
↓

$$f_{sin}^{rMS} = 0.70 \pm 0.03$$

$$f_{sin}^{bMS} = 0.20 \pm 0.01$$

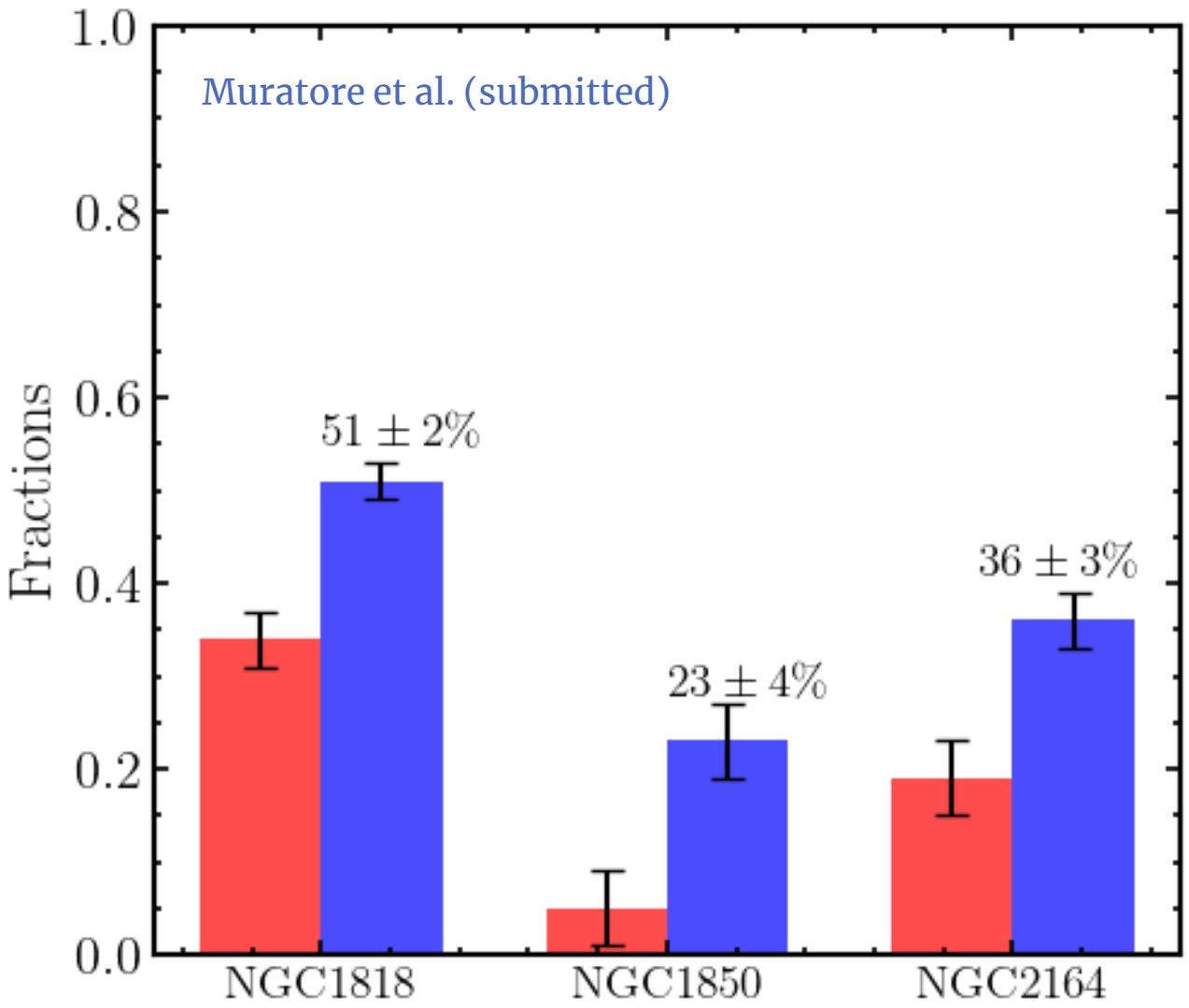
$$f_{BIN} = 0.10 \pm 0.04$$

Results


Muratore et al. (submitted)
Fractions
1.0
0.8
0.6
0.4
0.2
0.0
51 ± 2%
23 ± 4%
36 ± 3%
NGC1818
NGC1850
NGC2164

3

Results



3

Incidence:

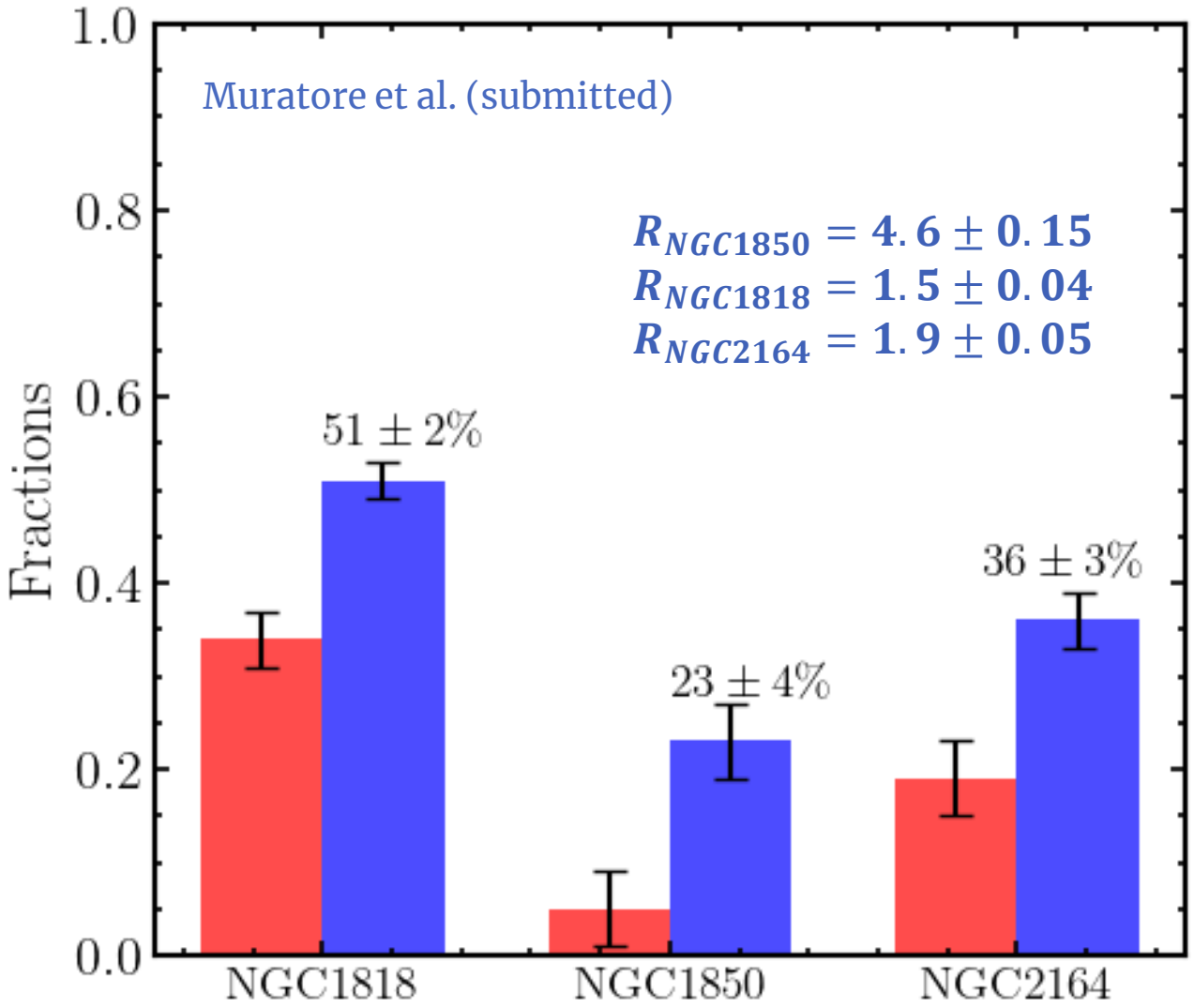
$$R_{NGC1850} = 4.6 \pm 0.15$$

$$R_{NGC1818} = 1.5 \pm 0.04$$

$$R_{NGC2164} = 1.9 \pm 0.05$$

Thanks for your attention

SCAN ME

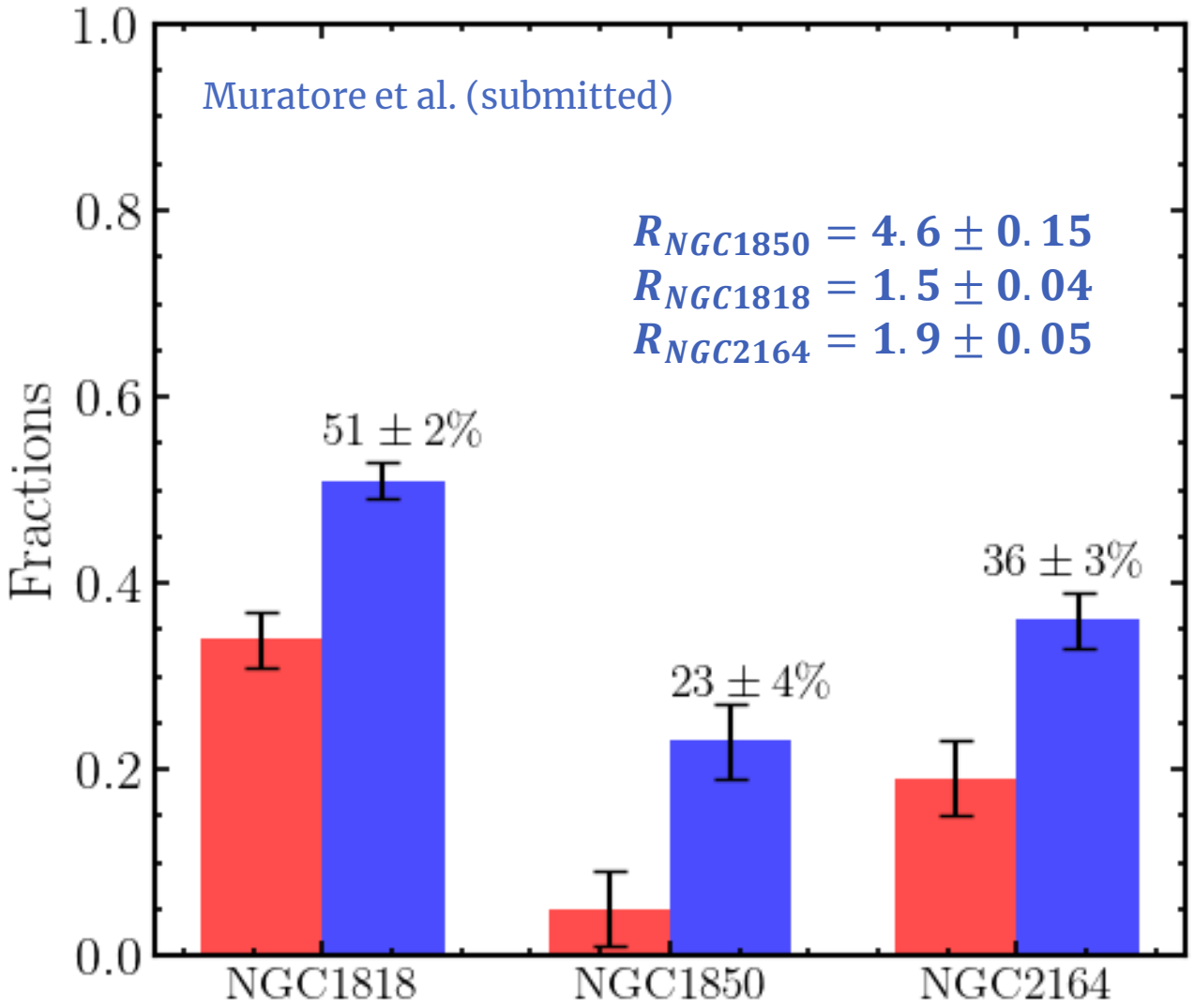


1) Predominance of binaries among the bMS stars in all the studied clusters.

(D'Antona et al (2015,2017))

Thanks for your attention

SCAN ME



1) Predominance of binaries among the bMS stars in all the studied clusters.

(D'Antona et al (2015,2017))

2) Similar to what is observed in the Galactic field, where the binaries rotate much slower than the single stars

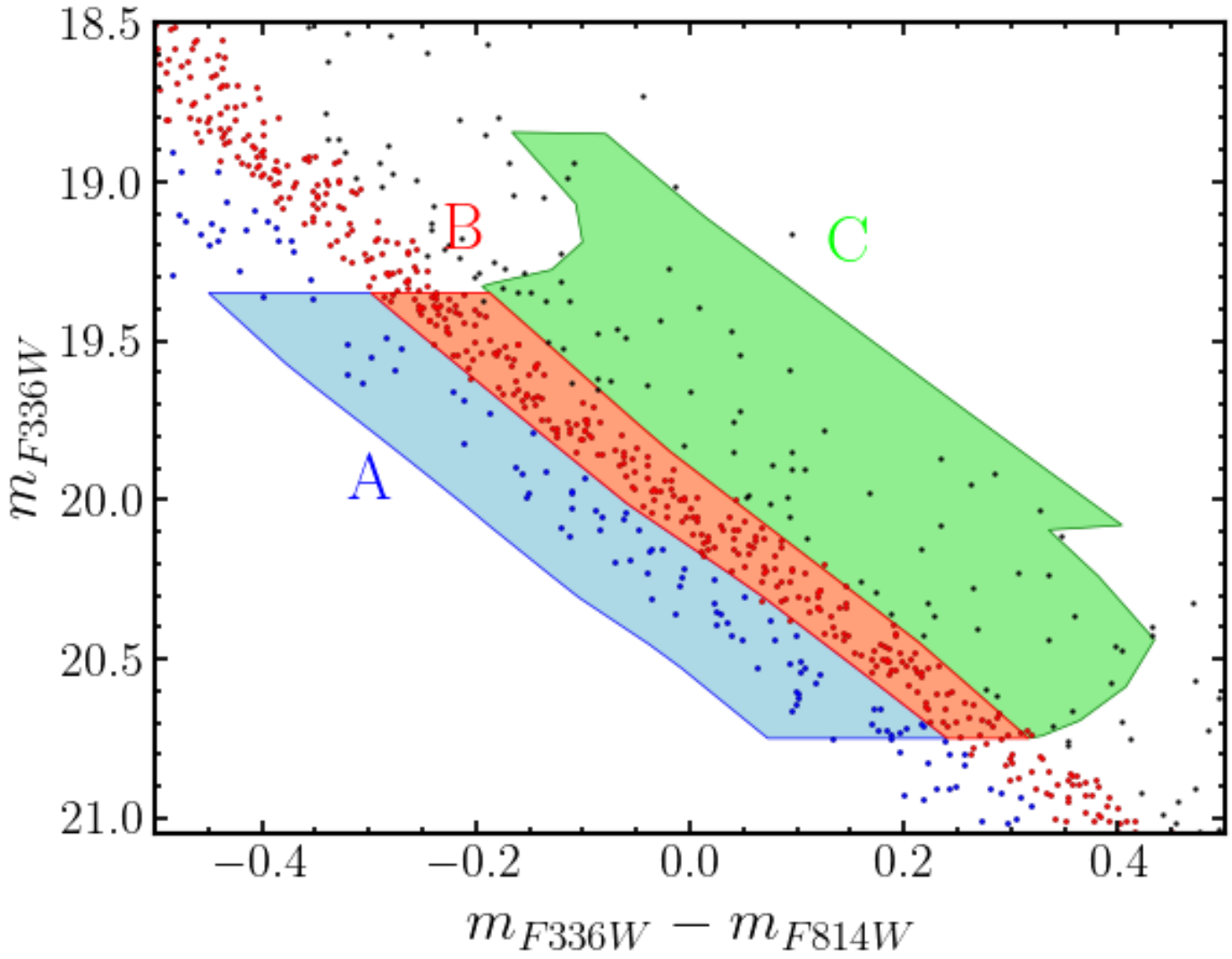
(Abt & Boonyarak (2004))

Backup slide

Steps:

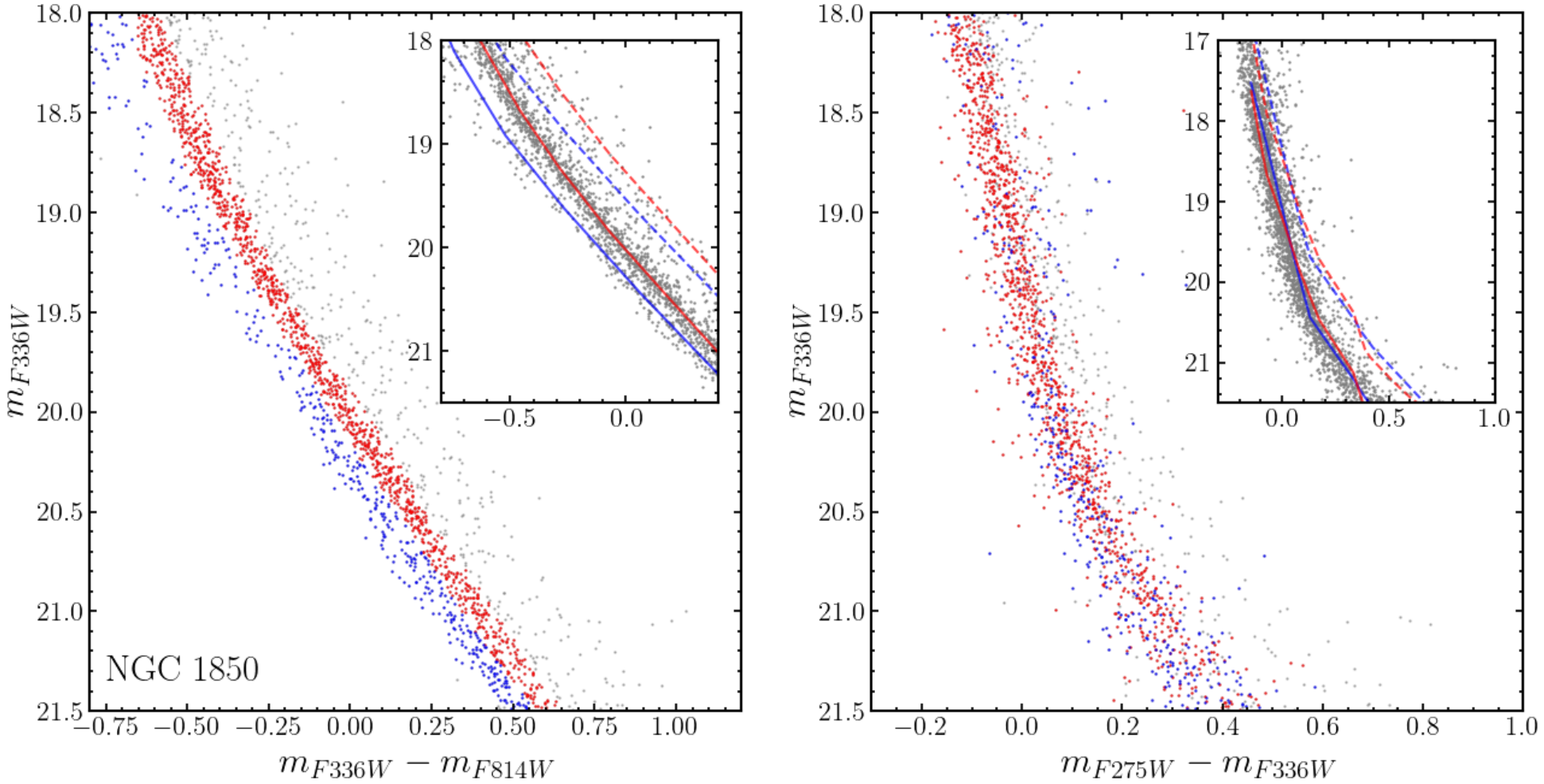
- Counting real stars inside each regions (A,B,C)
- Producing a synthetic CMD and counting
- Solving a system of equation to determine N_{bMS} , N_{rMS} , and N_{BIN}
- Iterating steps 1-3 using previous results to improve the results.

$$f_{sin}^{rMS} = 0.70 \pm 0.03$$
$$f_{sin}^{bMS} = 0.20 \pm 0.01$$
$$f_{BIN} = 0.10 \pm 0.04$$



Muratore et al. (submitted)

Backup slide



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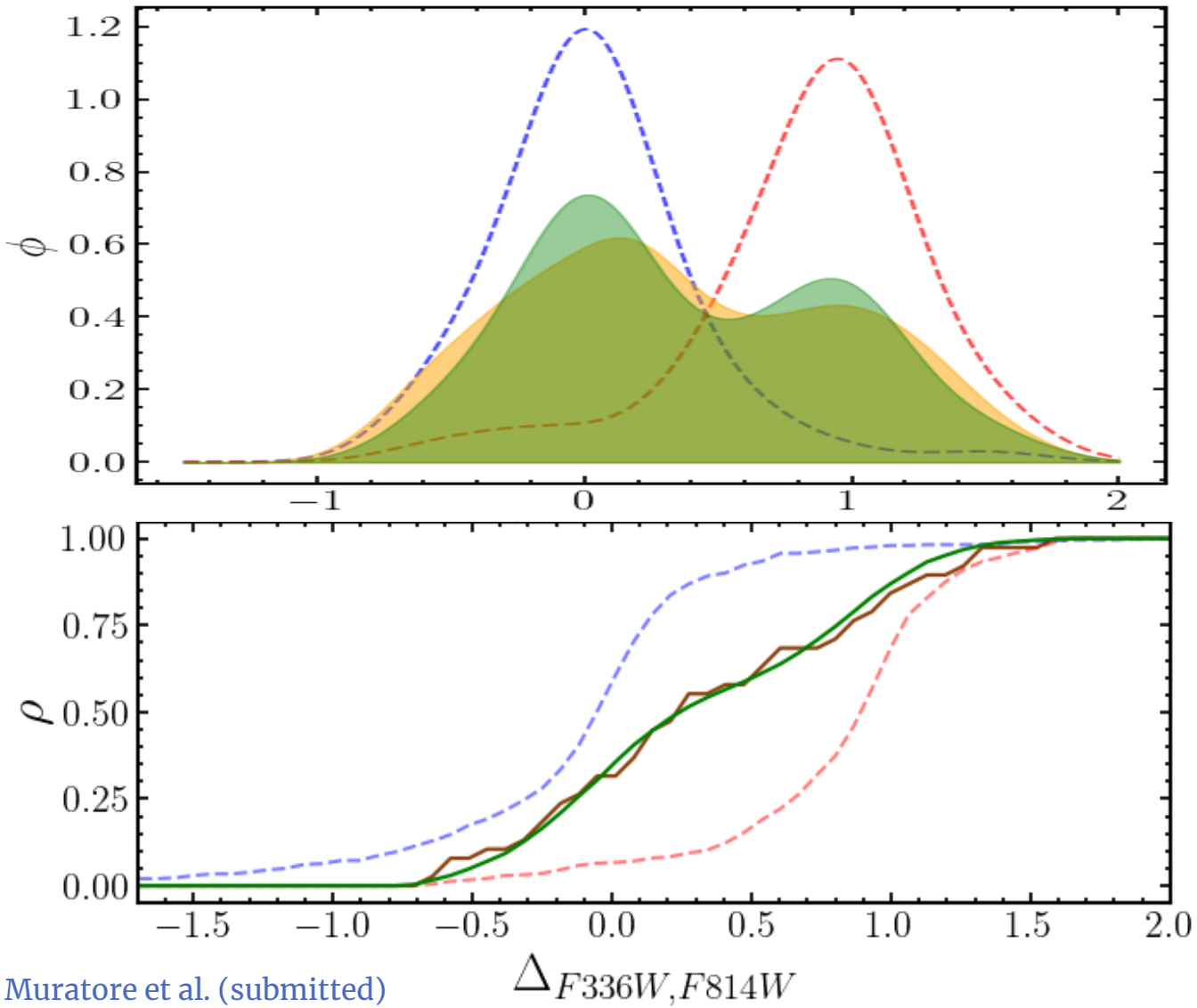
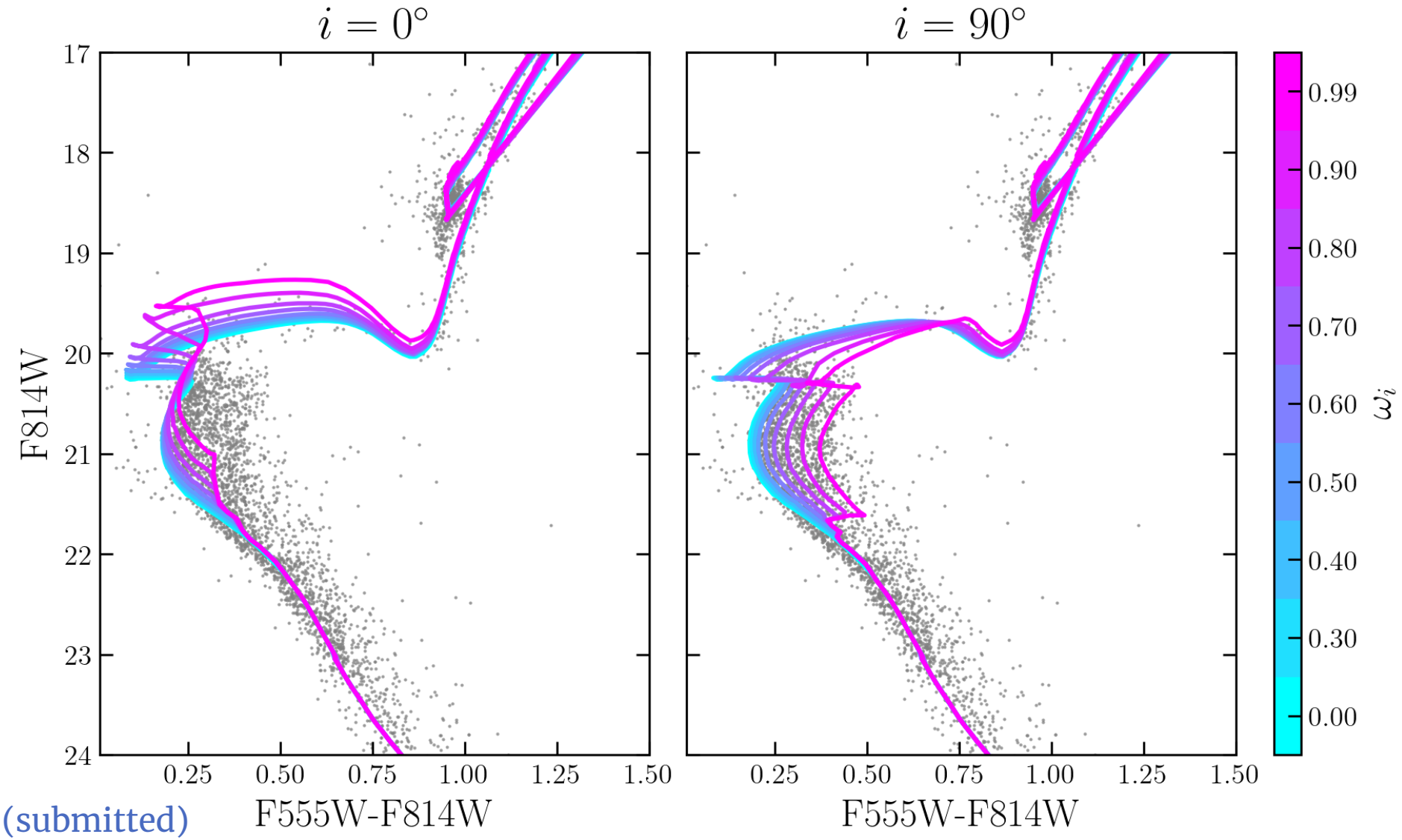


Muratore et al. (submitted)

Results:

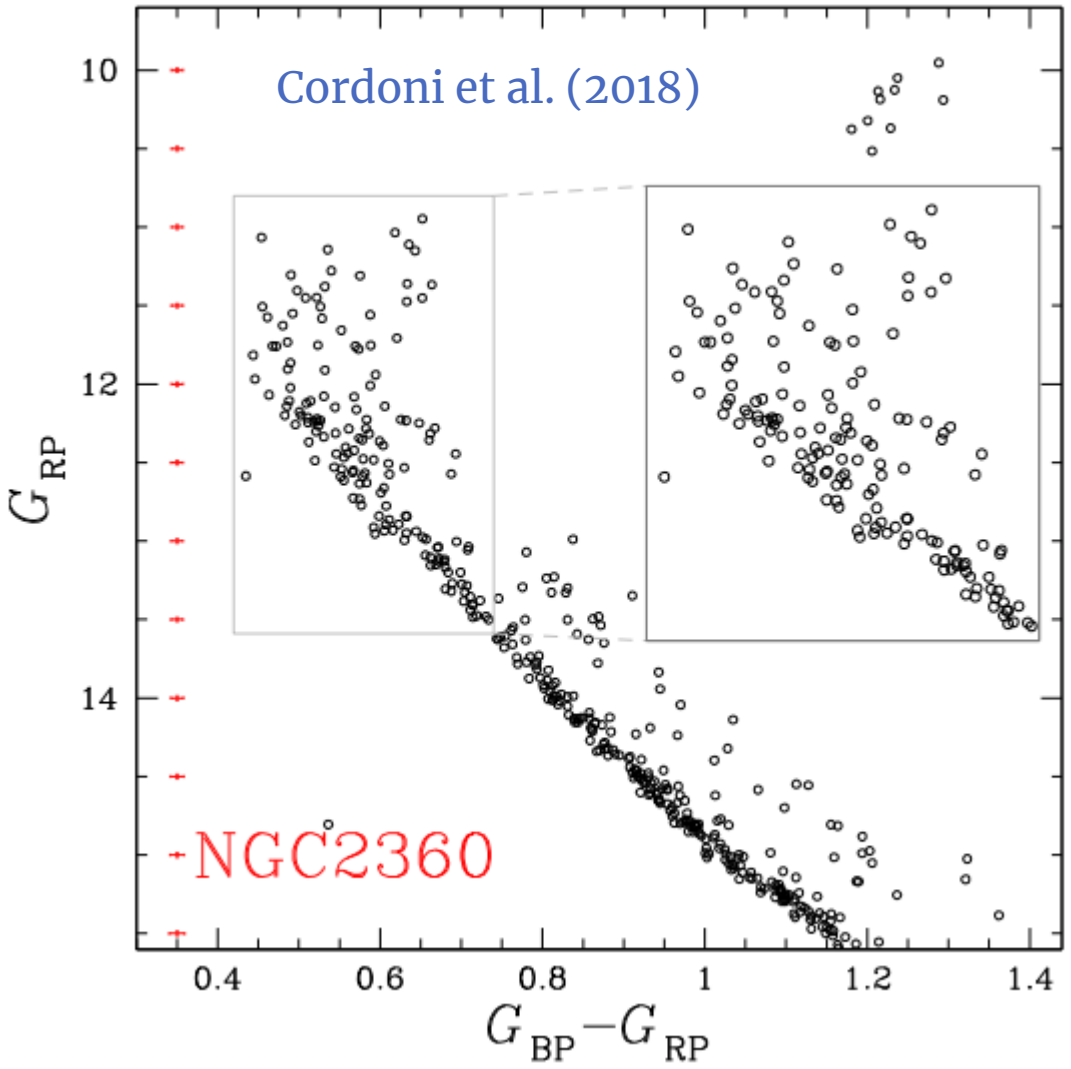
- $f_{bin}^{rMS} = 0.40$
- $f_{bin}^{bMS} = 0.60$

Backup slide



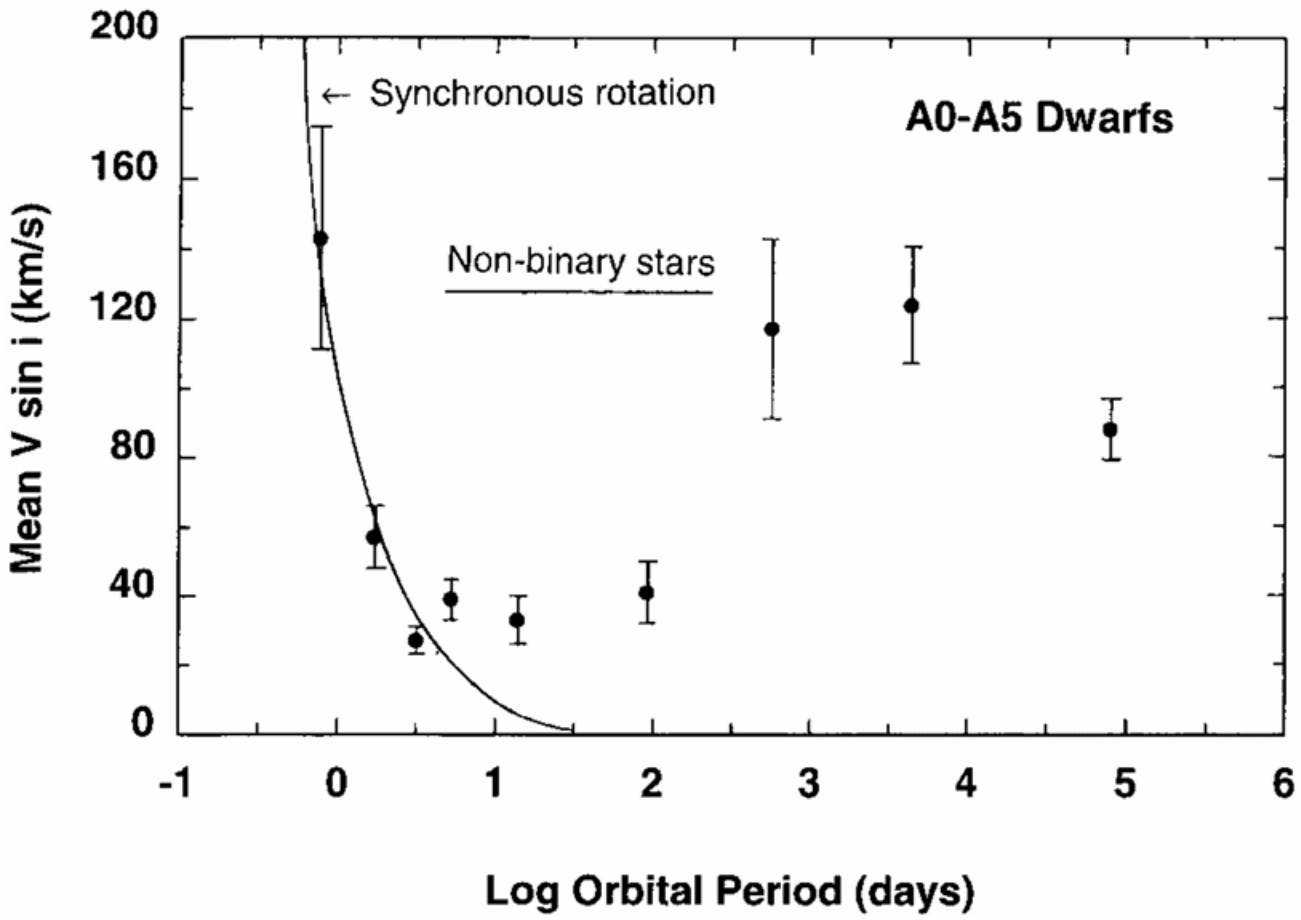
Ettorre et al. (submitted)

Backup slide



The eMSTO in a Galactic young star cluster

Backup slide

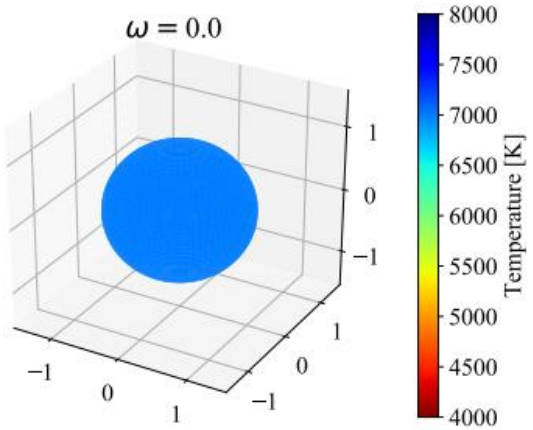


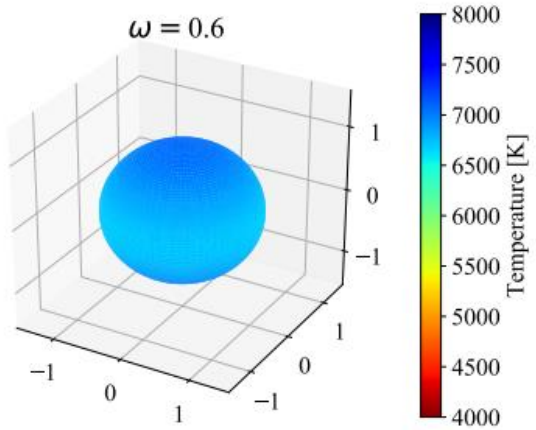
Abt & Boonyarak (2004)

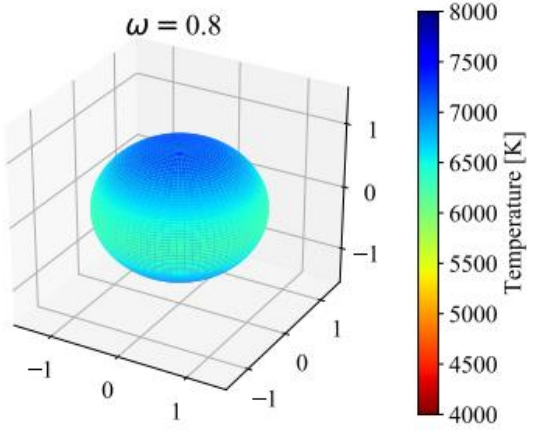
Have analyzed the tidal effects in binaries.

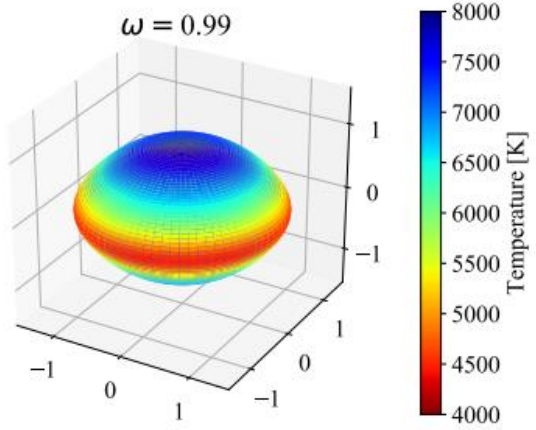
Rotational velocity is significantly smaller for binaries with periods between 4 and 500 days than for single stars.

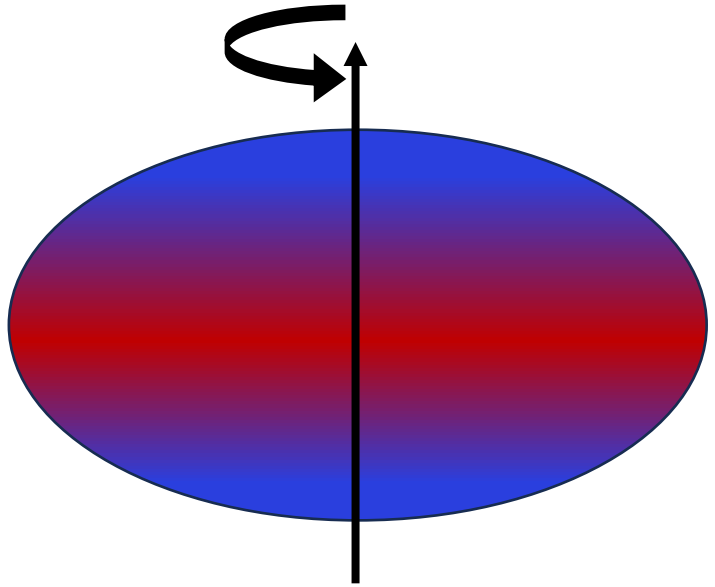
Backup slide







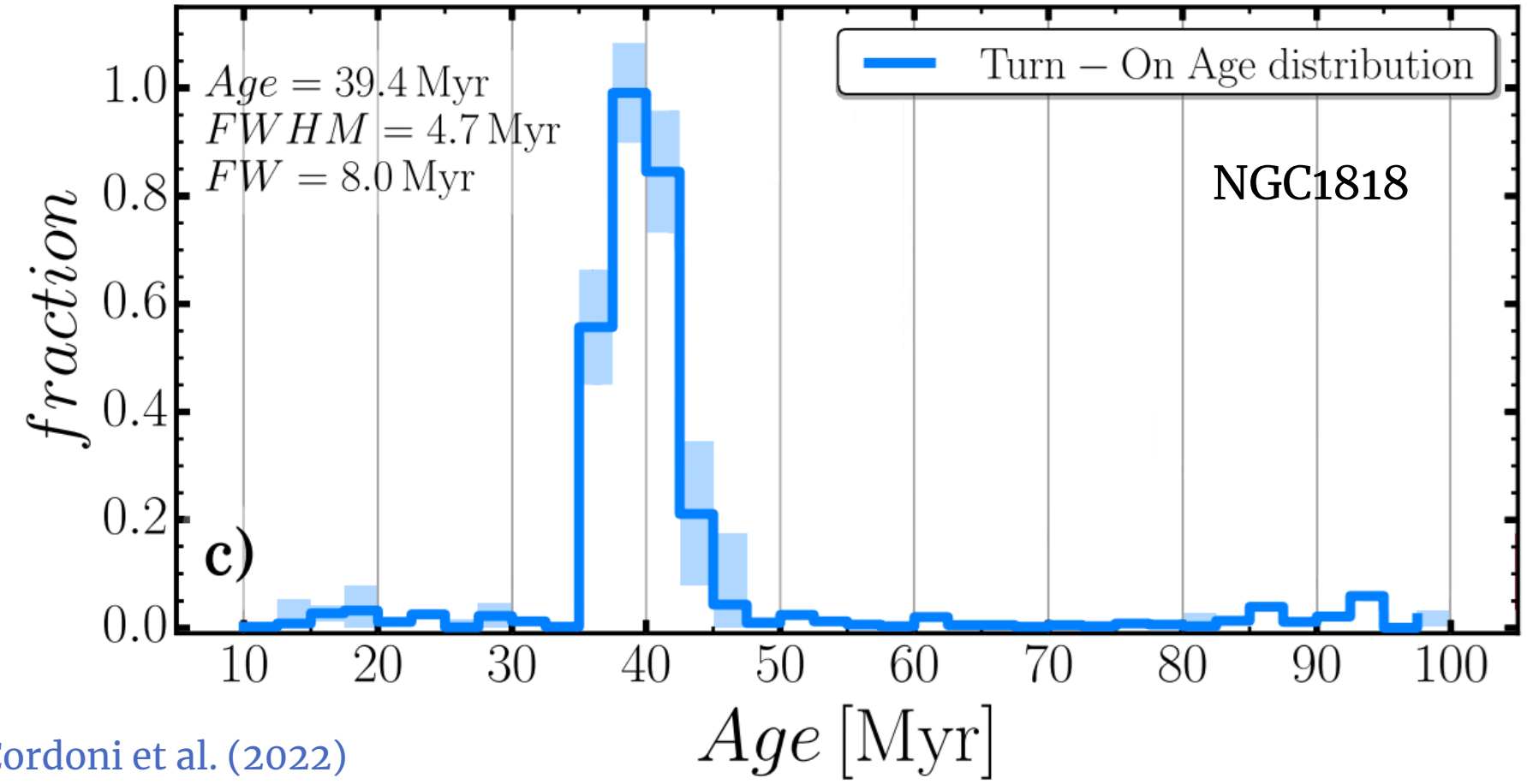




Costa (2019)

Backup slide

The first direct evidence of single star formation episode



Cordoni et al. (2022)