Hunting for Black Widow Optical Companions in Globular Clusters

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Tenerife, June 24-25 2015

Cosmic-Lab

- 5-year project (web site at **www.cosmic-lab.eu**)
- *Advanced Research Grant* funded by the European Research Council (ERC)
- PI: Francesco R. Ferraro (Dip. of Physics & Astronomy – Bologna University)
- AIM: **to understand the complex interplay between dynamics & stellar evolution**
- HOW: using **globular clusters** as cosmic laboratories and

Blue Straggler Stars
Millisecond Pulsars
Intermediate-mass Black Holes

} as probe-particles

Eclipsing Millisecond Pulsars

- Periodical Eclipses of the Radio Signal
- Orbital Periods Shorter Than 1 Day
- No Orbital Eccentricity → Tidal Circularization
- X-ray and γ-ray Counterparts

Redbacks

$0.1\ M_{SUN} < M_{COM} < 0.5\ M_{SUN}$

Black Widows

$M_{COM} < 0.1\ M_{SUN}$

Why searching for the optical counterparts?

The optical band is the only spectral window where the emission is almost entirely dominated by the companion star.

If the companion star is variabile, its variability can be used to study the processes which take place on the star and in the intrabinary space.

All this allow to study the evolution and the destiny of the different classes of MSPs.

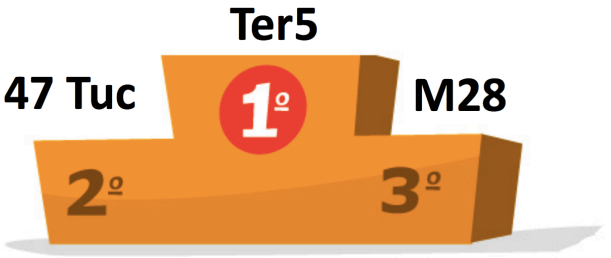
Why Globular Clusters?

- The Galactic Globular Cluster System is **0.01 less massive** than the Galactic Disk
- However, **about 40% of the entire MSP population** is found in Globular Clusters

Galactic Disk → **Evolution of primordial binaries**

Globular Clusters → **Dynamical interactions which promote the formation of binaries suitable for reciclying NSs into MSPs**

The study of GC MSPs is crucial to understand the role of dynamical interactions in MSP evolution.



The Optical Companion to the Black Widow System PSR J1953+1846A in the Globular Cluster M71

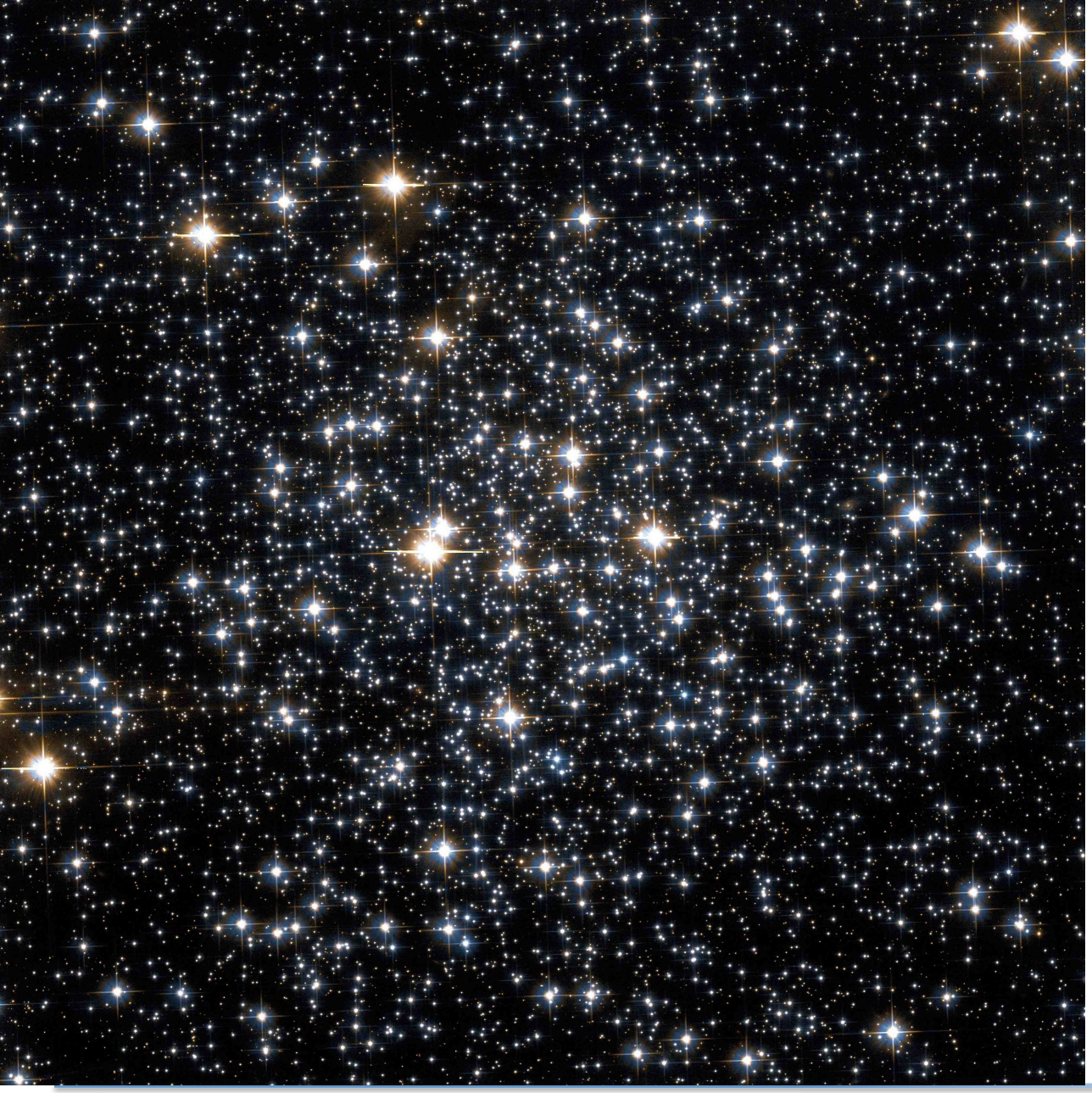
Cadelano et al., 2015a, ApJ, in press (arXiv:150503531C)

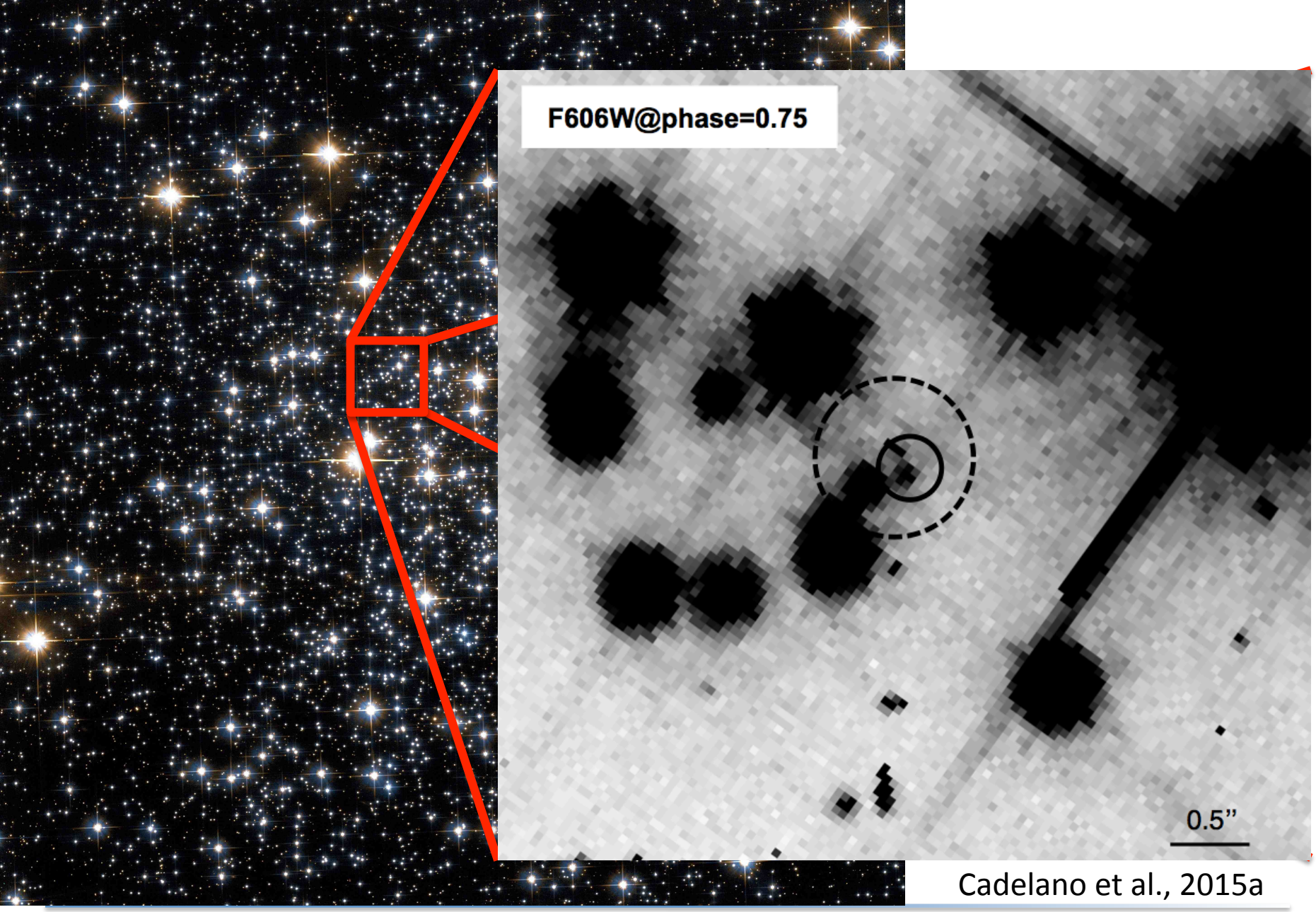
PSR J1953+1846A (M71A)

- Short Orbital Period of ~4 hours. No orbital eccentricity.
- Eclipses for about 20% of the orbital period during the PSR superior conjunction.
- Companion mass of ~0.03 Msun.
- X-ray counterpart. Non thermal emission likely due to an intrabinary shock.

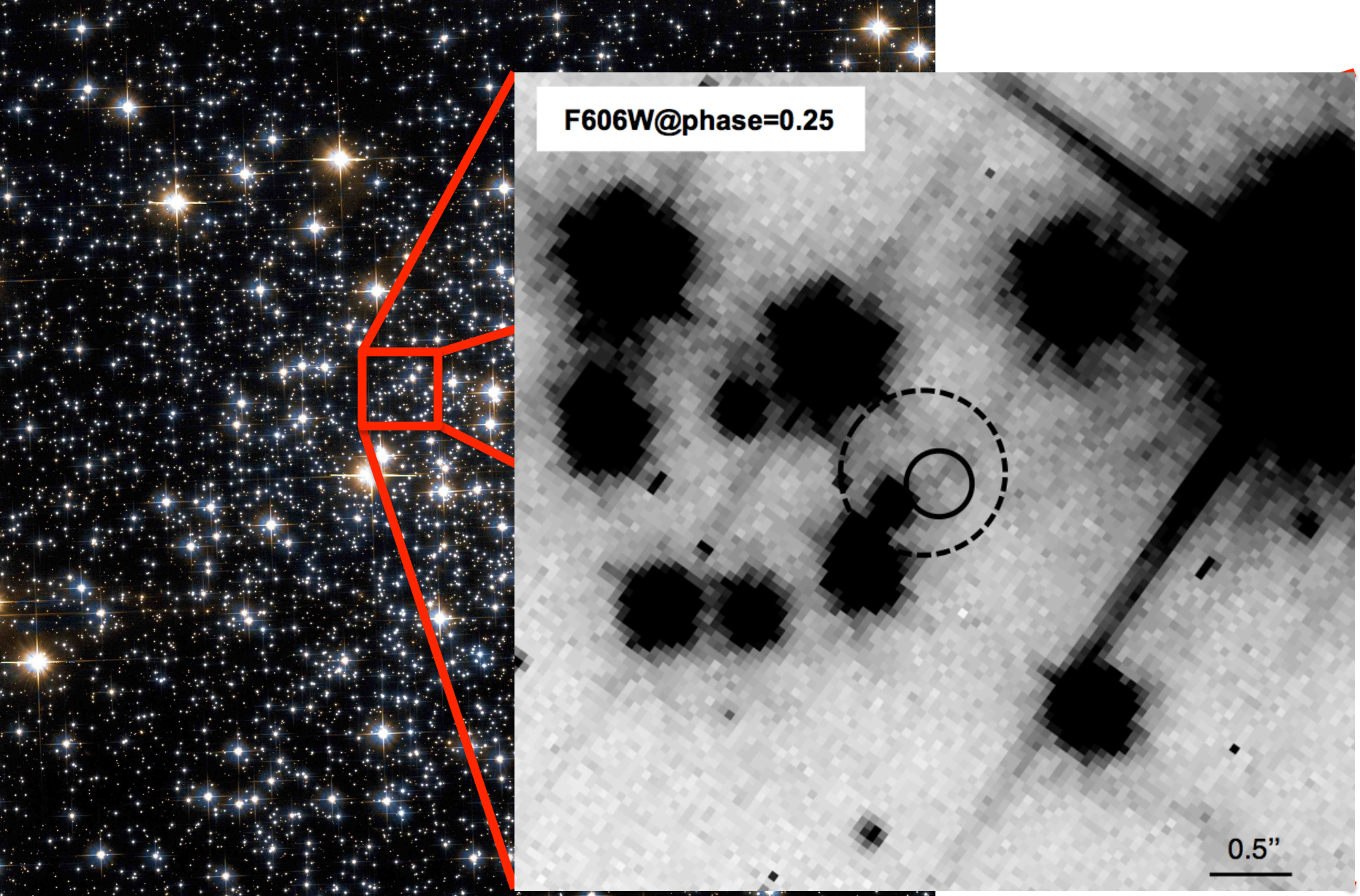
Hessels et al., 07
Elsner et al., 08

We identified the optical counterpart by using deep observation obtained with the ACS@HST





Cadelano et al., 2015a



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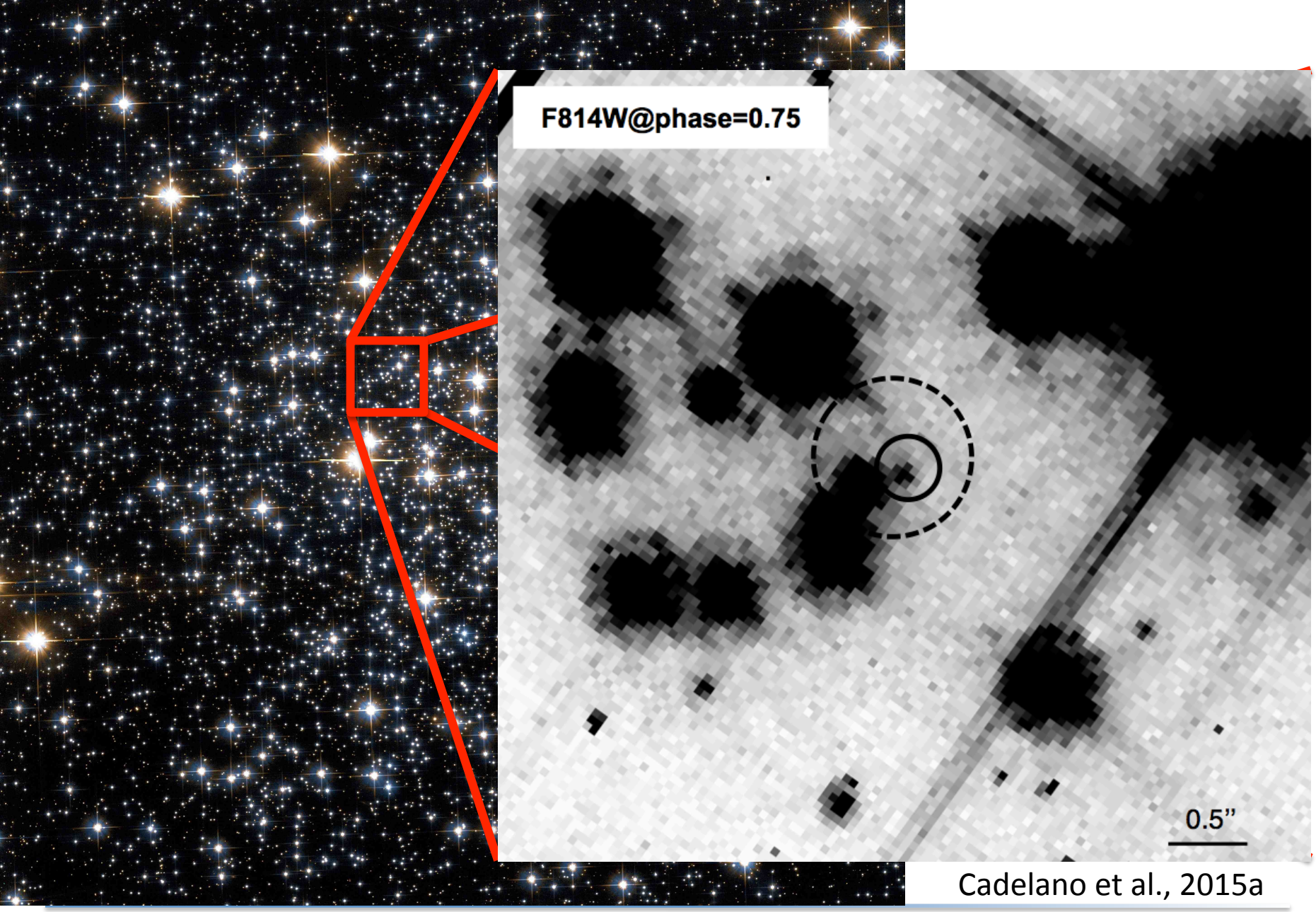
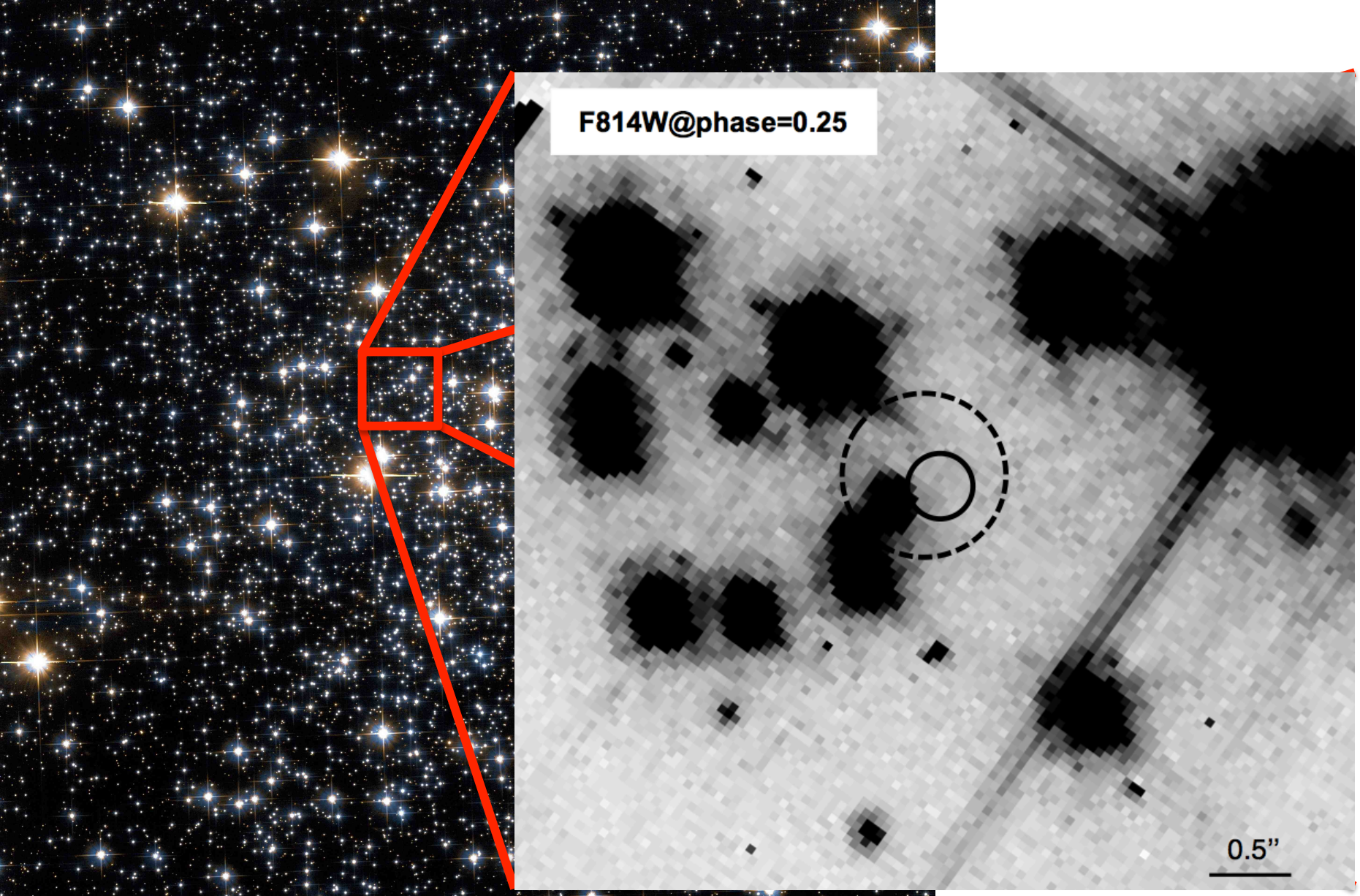
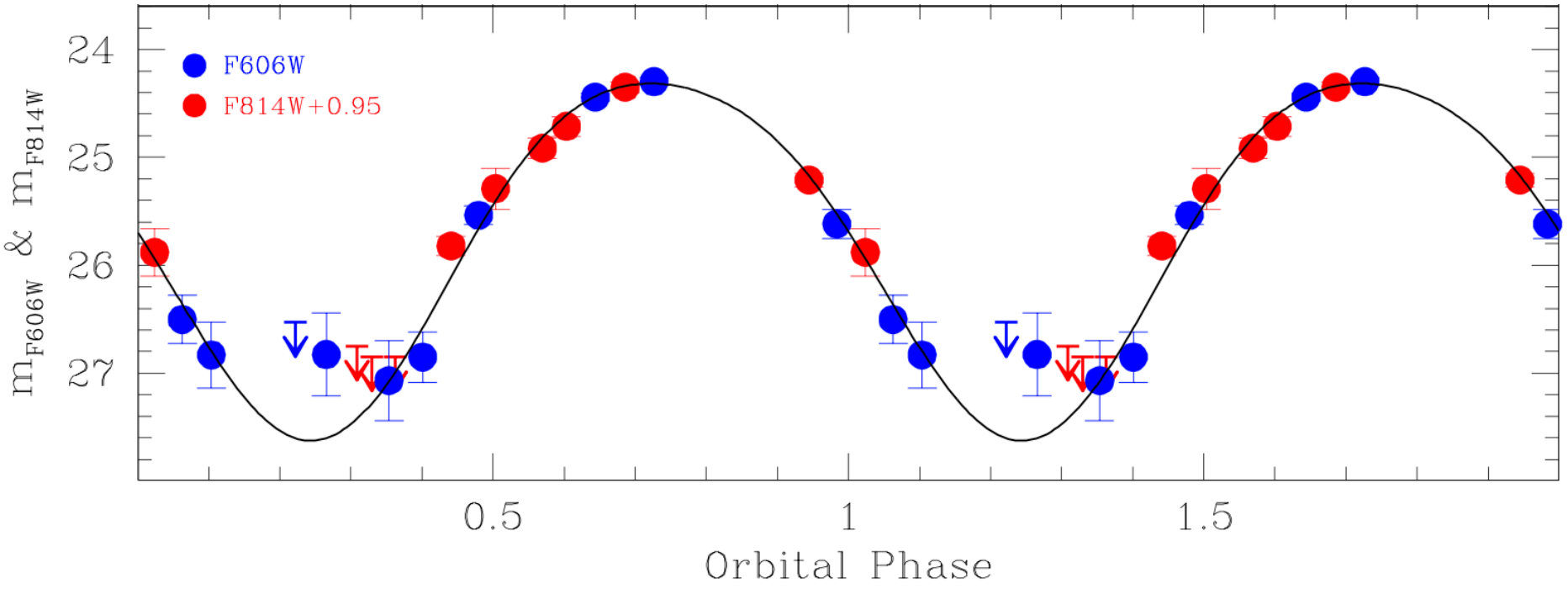


Cadelano et al., 2015a



Cadelano et al., 2015a

COM-M71A light curve



Cadelano et al., 2015a, ApJ, in press

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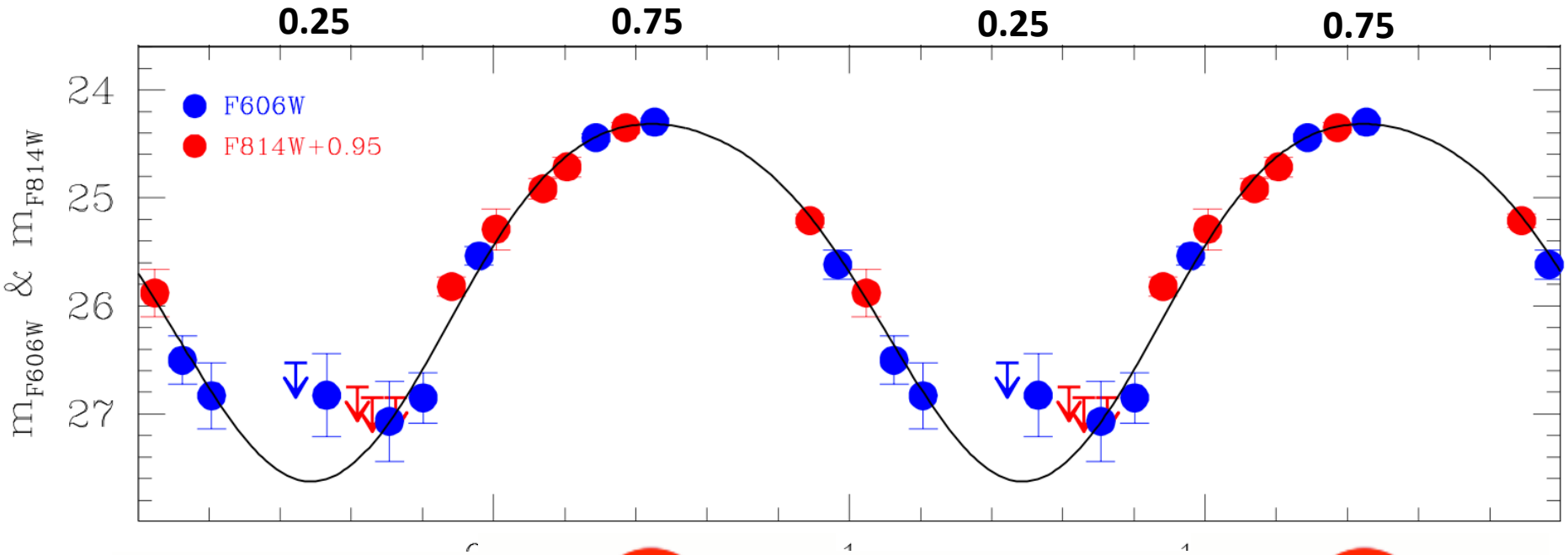
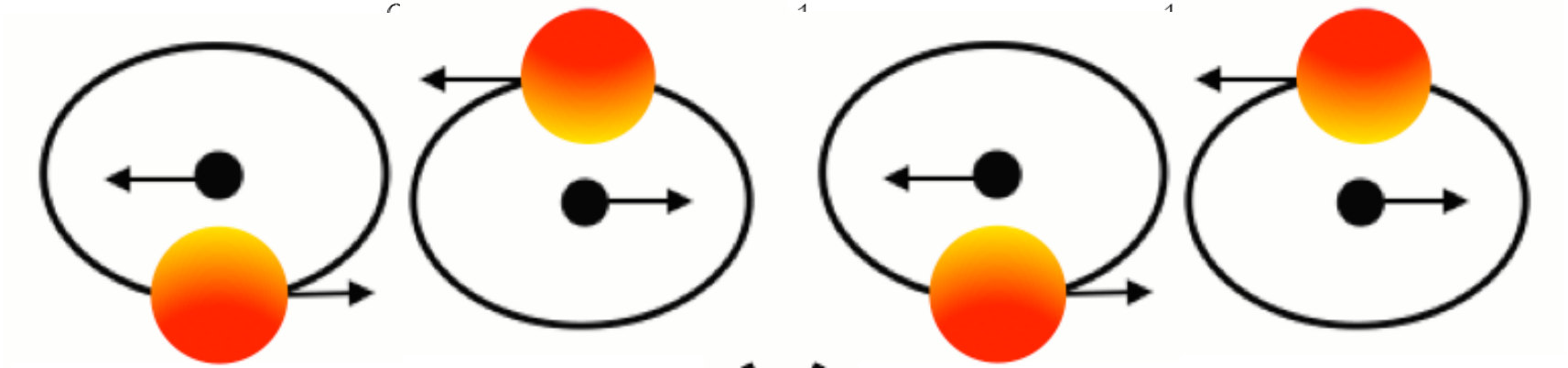
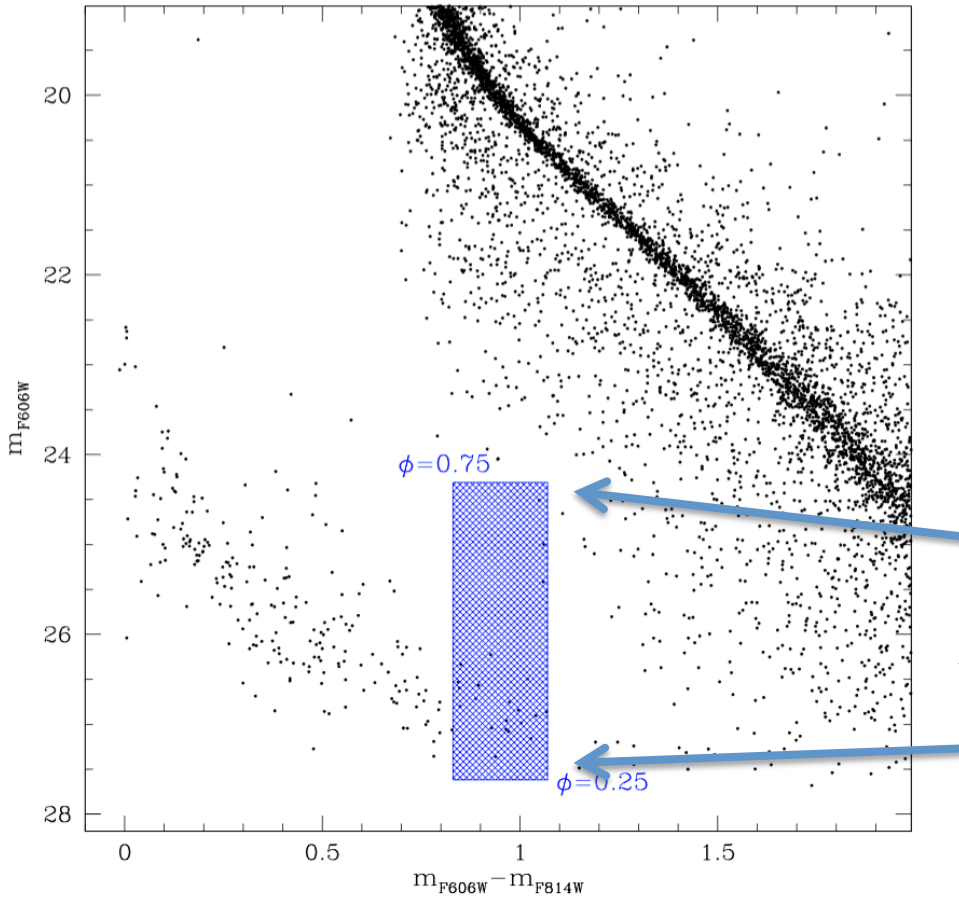
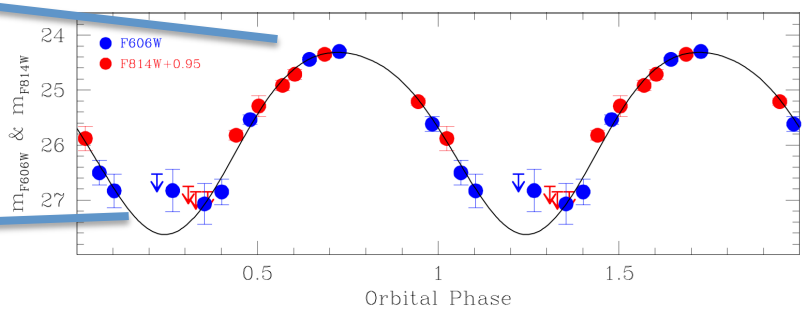




CMD Position





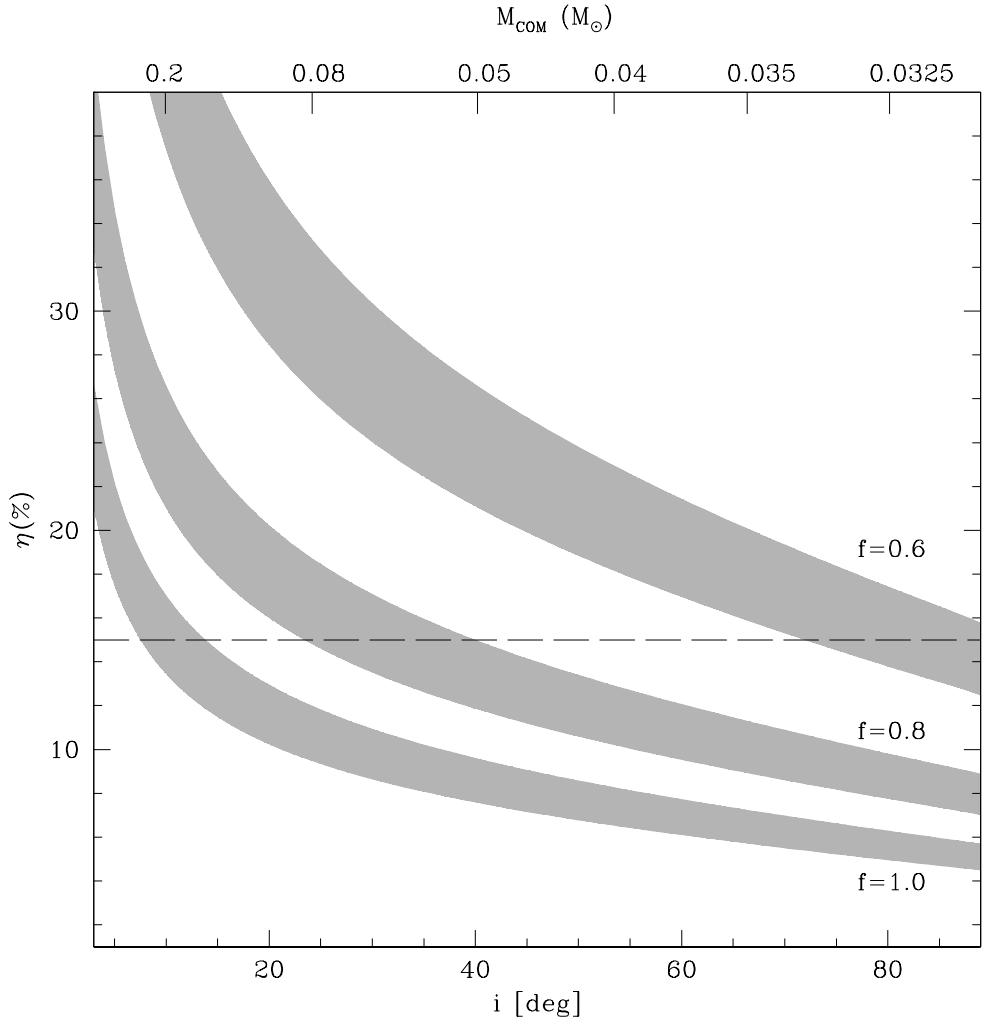
This is a region where no unperturbed stars are expected!

COM-M71A is likely a non-degenerate and highly perturbed star.

$$T \approx 5100K$$

Cadelano et al., 2015a, ApJ, in press

Reprocessing efficiency and RL filling factor



Magnitude modulation due to the **reprocessing of the PSR injected flux**

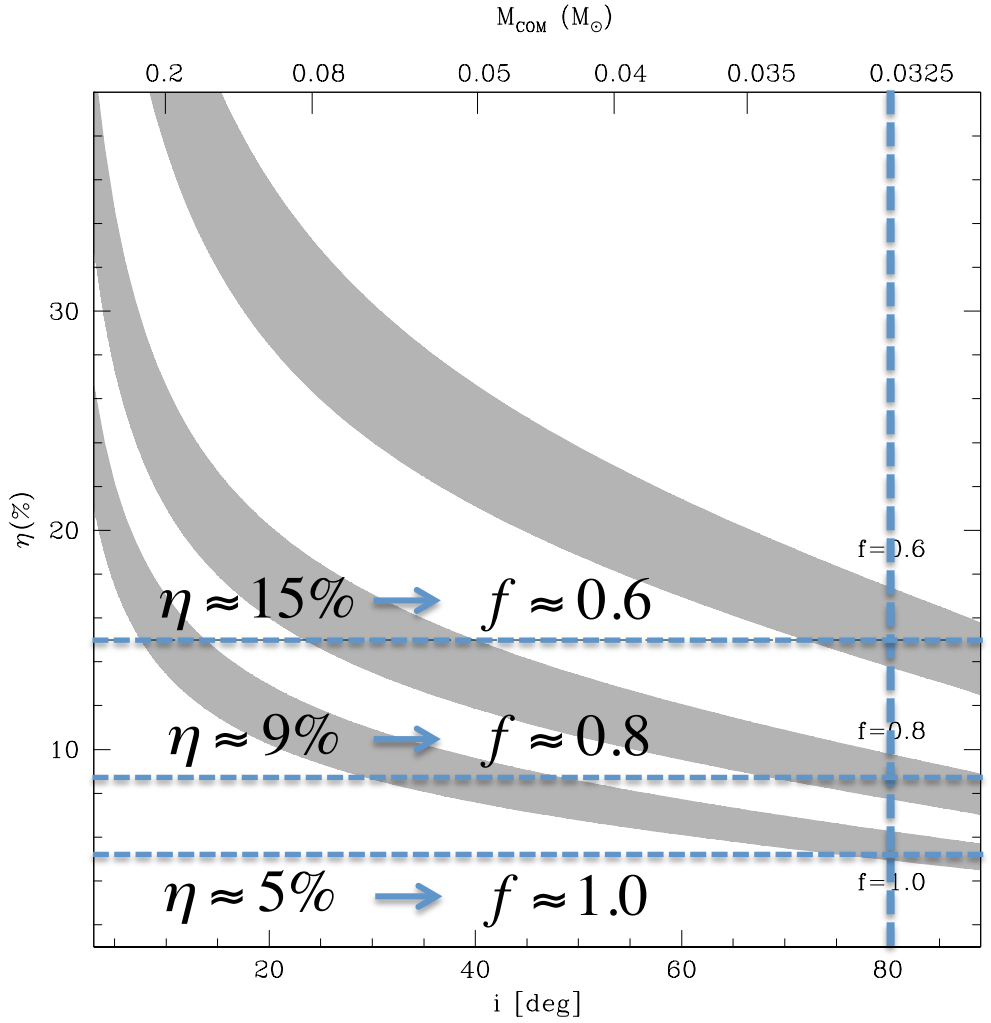
$$\dot{E}_{rot} \cong 4.6 - 5.8 \times 10^{33} ergs/s$$

$$\Delta F_{\exp}(i) = \eta \frac{\dot{E}_{rot}}{a^2} (fR_{RL})^2 \frac{\varepsilon(i)}{4\pi d_{PSR}^2}$$

Flux difference between the minimum and the maximum.

Cadelano et al., 2015a, ApJ, in press

Reprocessing efficiency and RL filling factor



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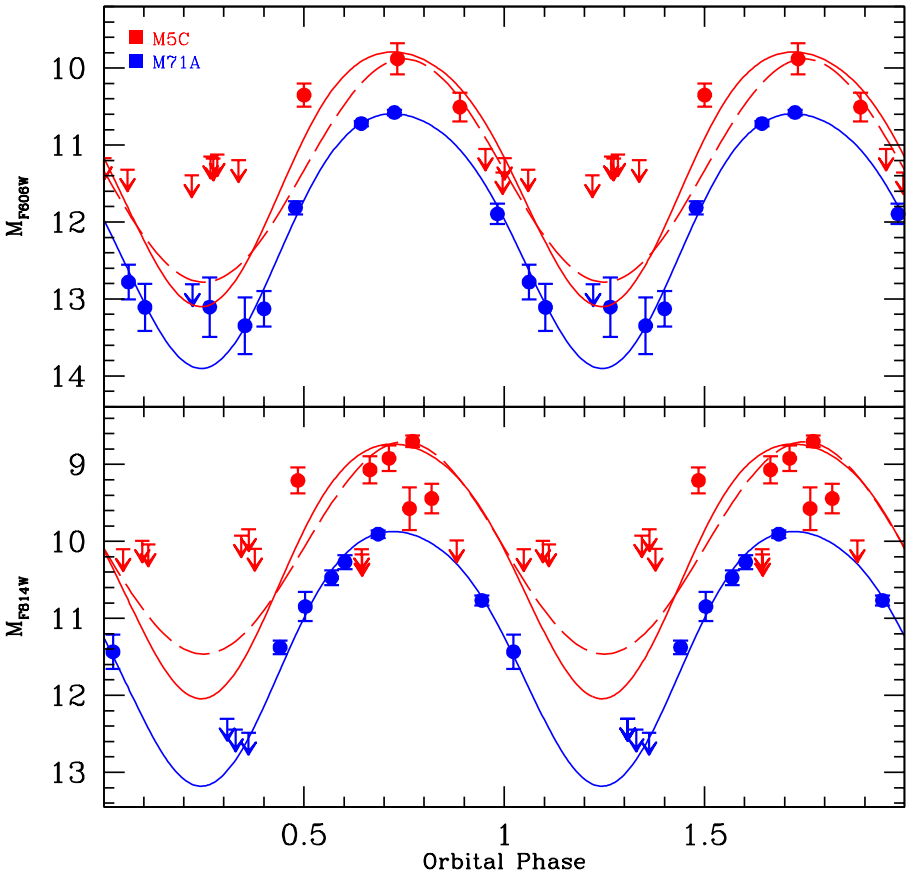
Cadelano et al., 2015a, ApJ, in press

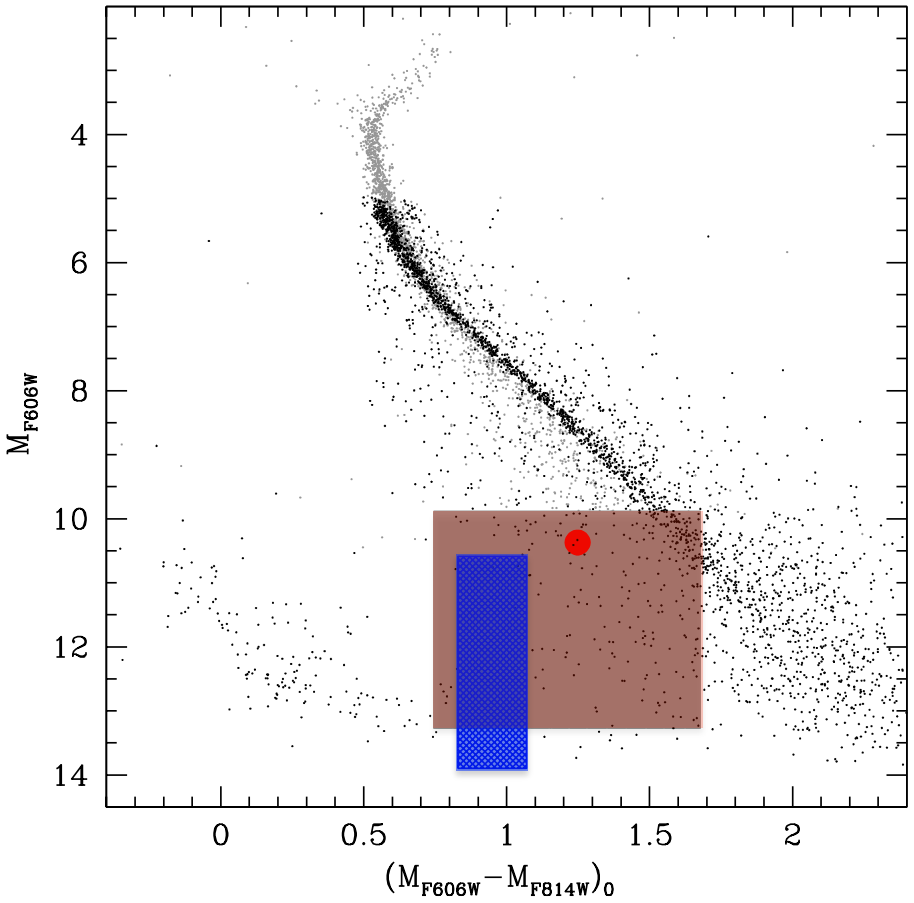
A Comparison Between the Optical Companion to the Black Widow Systems M71A and PSR J1518+0204C (M5C)

Pallanca et al., 2014, ApJ 795:29

Cadelano et al., 2015a, ApJ, in press

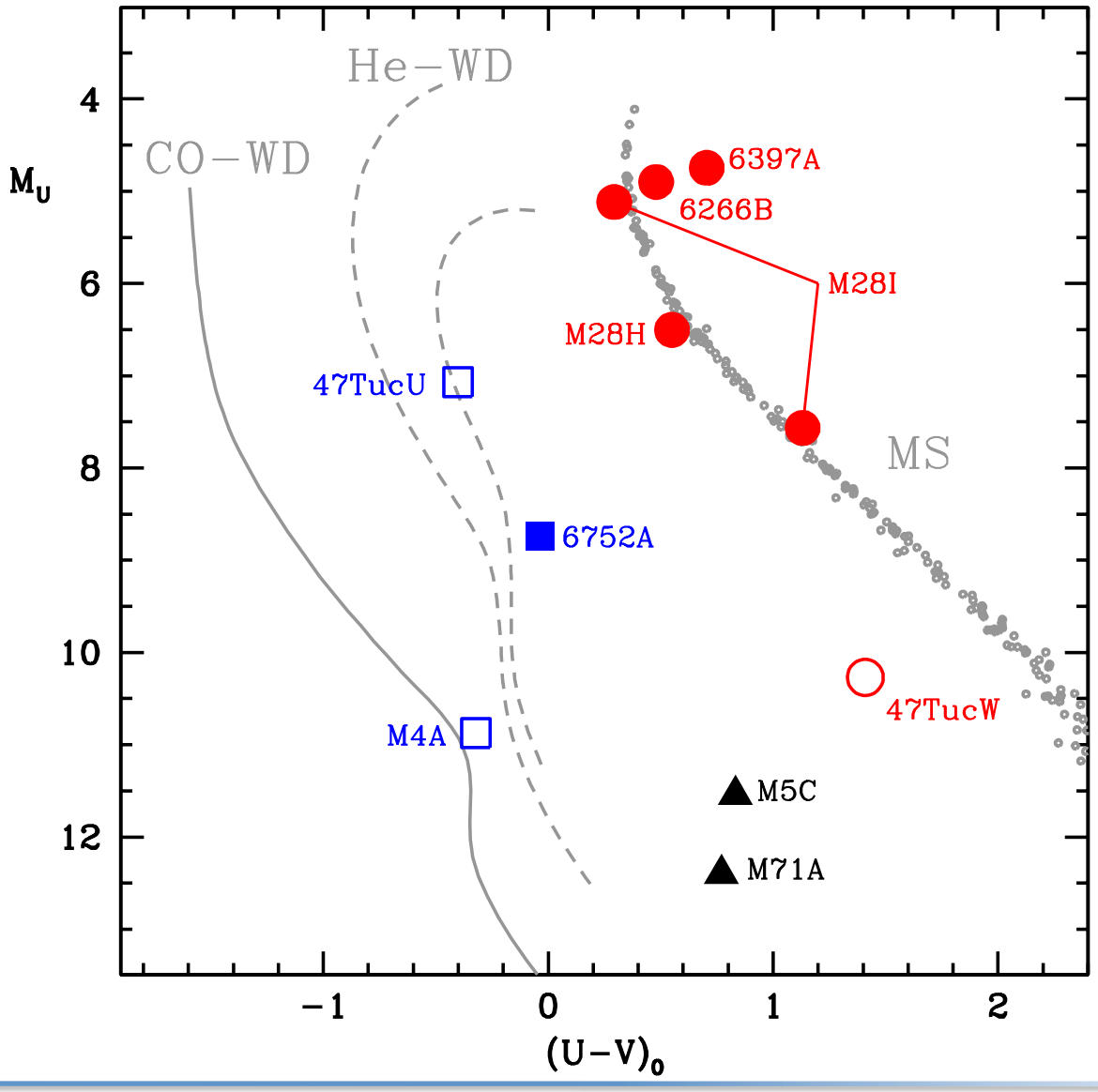
A Comparison Between M71A and M5C





Cadelano et al., 2015a, ApJ, in press

The state of the art



Edmonds et. al, 01
Ferraro et al., 01
Edmonds et al., 02
Ferraro et al., 03
Bassa et al., 03
Sigurdsson et al., 03
Cocozza et al., 08
Pallanca et al., 10,13,14
Cadelano et al., 15

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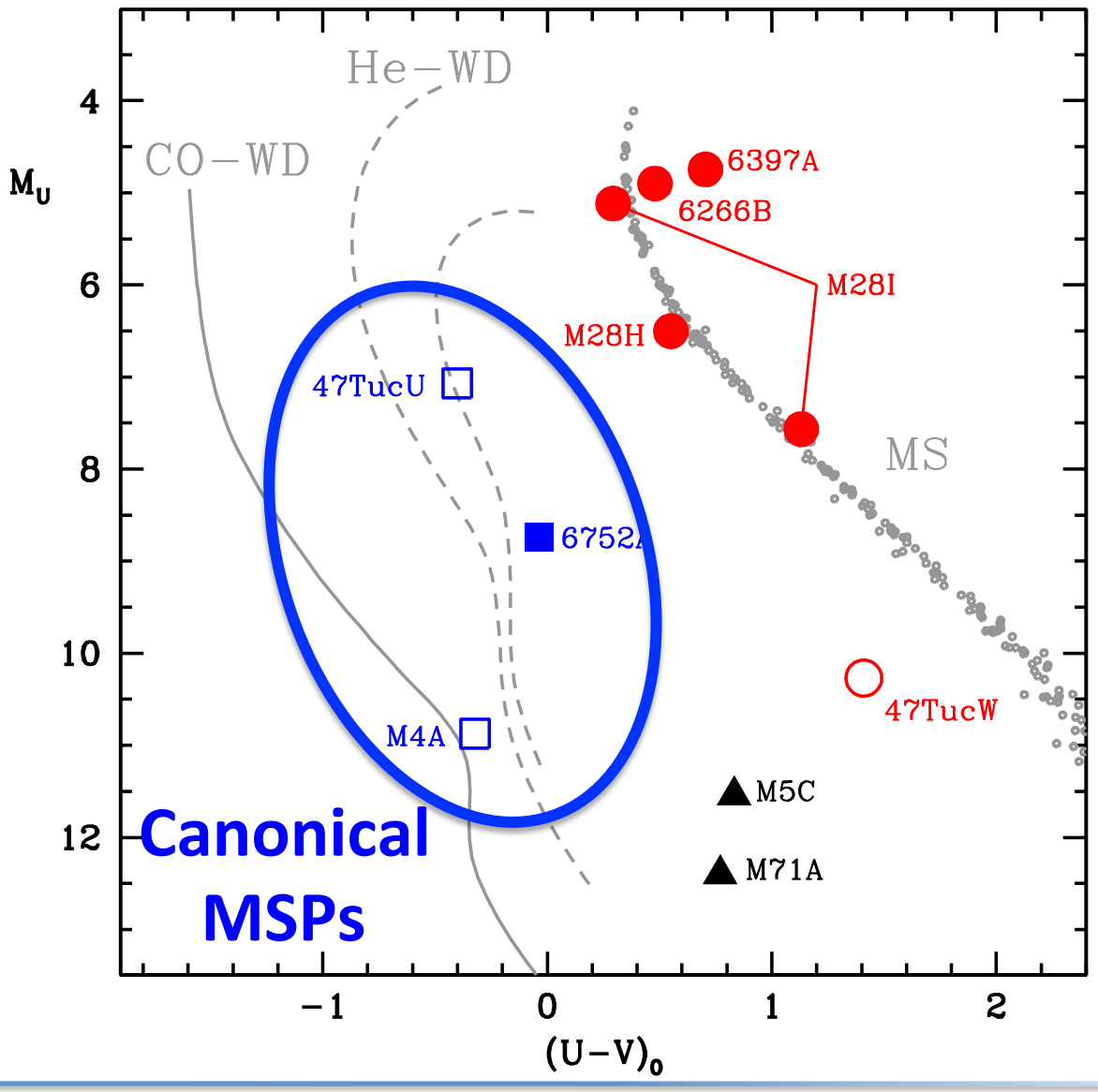

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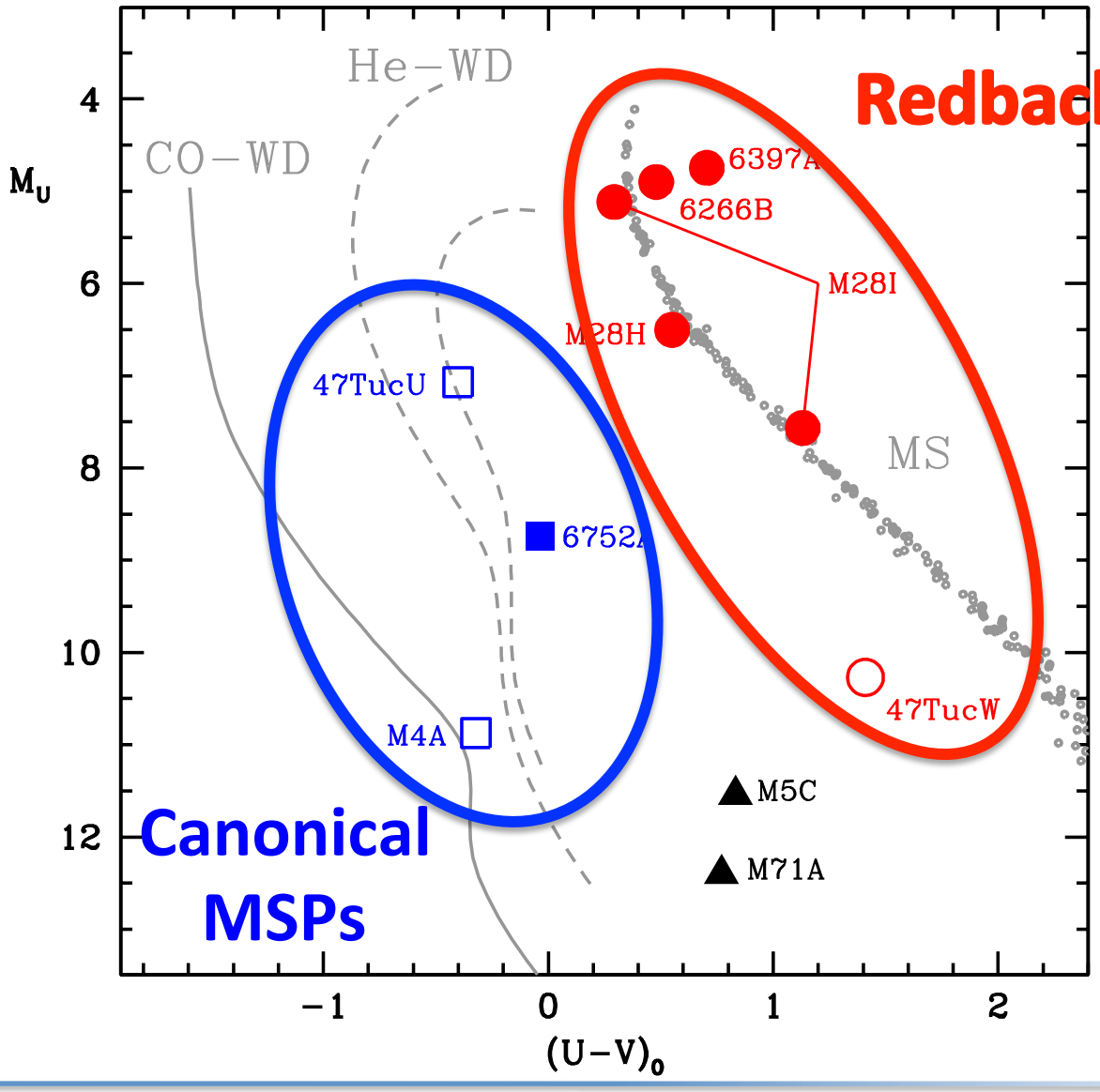

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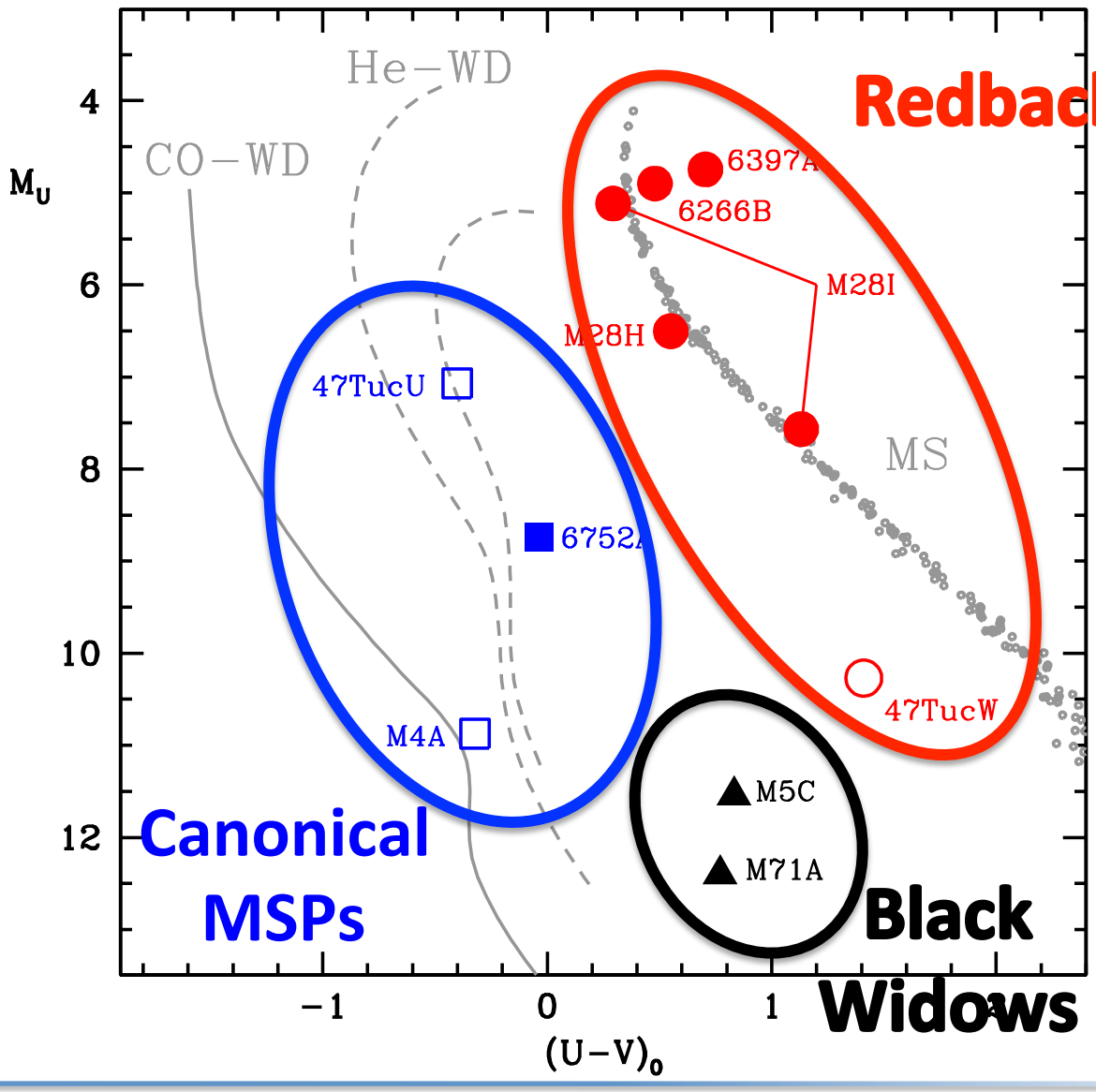

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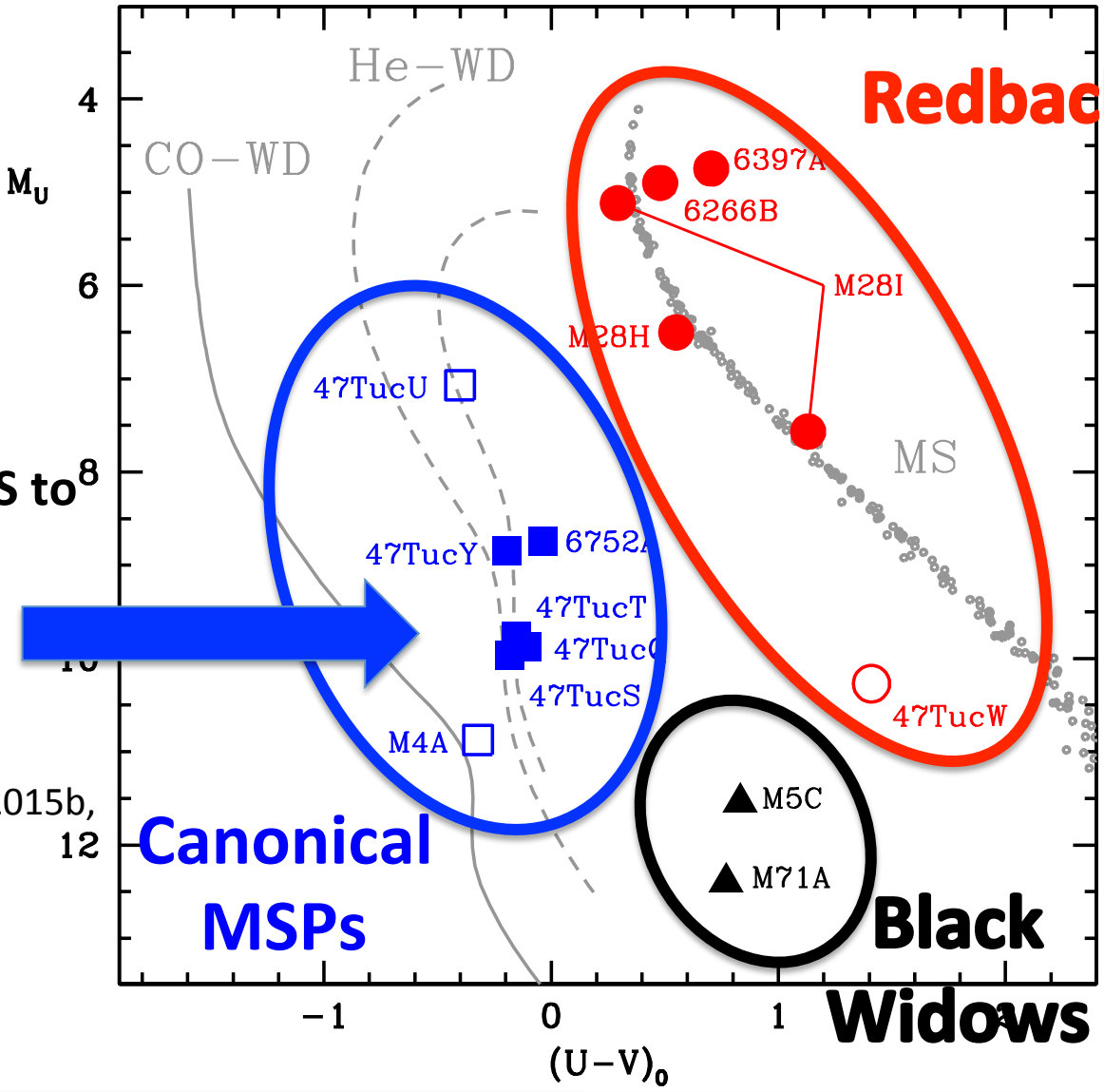
4 New Companions in 47 Tucanae



COMPANIONS to
47TucQ
47TucS
47TucT
47TucY

Cadelano et al., 2015b, to be submitted

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Thanks for your attention!