Aspen Center for Physics

Physical Applications of Millisecond Pulsars

Candidate optical companions to Globular Cluster Pulsars

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Cosmic-Lab

www.cosmic-lab.eu

erc

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

MSPs in Globular Clusters

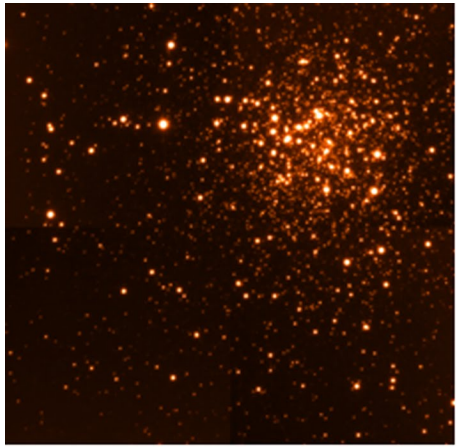
More than 50% of known MSPs is found in GCs

Galactic Field

Globular Clusters

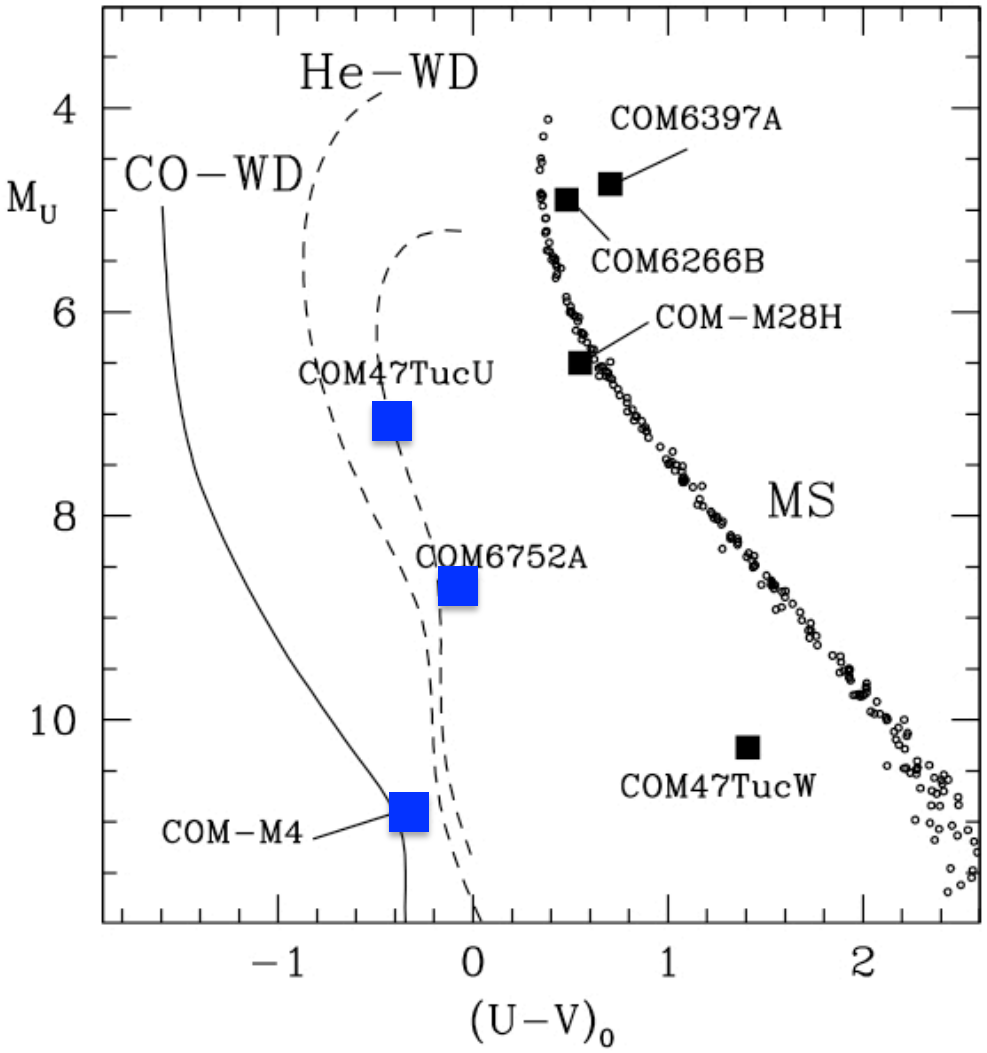
Evolution of primordial binaries

Dynamical interactions can promote the formation of binaries suitable for recycling NSs into MSPs



The study of the optical companions is crucial to understand how dynamical interactions could modify the standard outcome of the recycling scenario

The state of the art

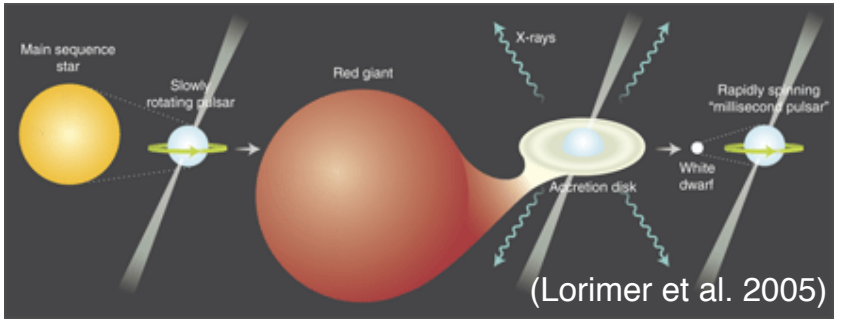


3 He WD

(Edmonds et al. 2001; Ferraro et al. 2003; Sigurdsson et al 2003)

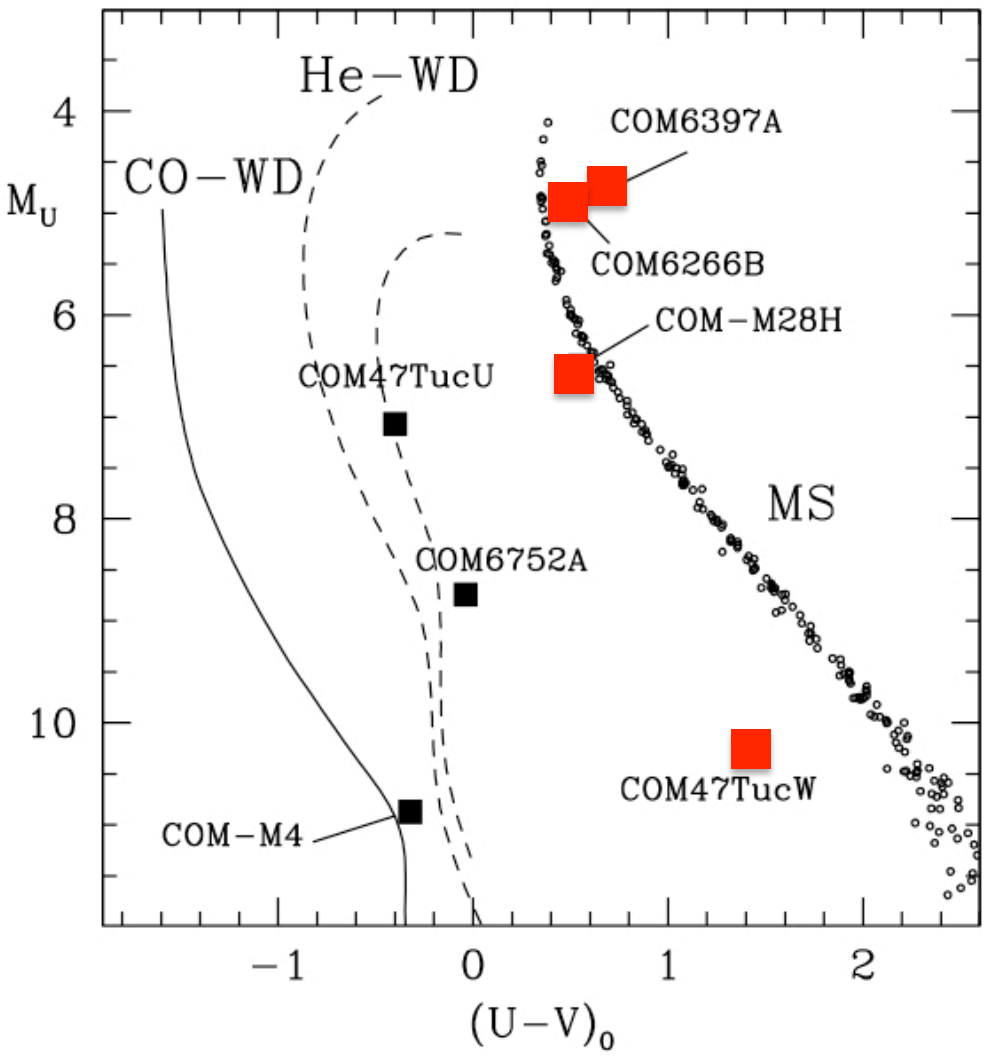
CONFIRMATION OF THE RECYCLING SCENARIO:

low mass He-WD is the "final stage" of the pulsar recycling process

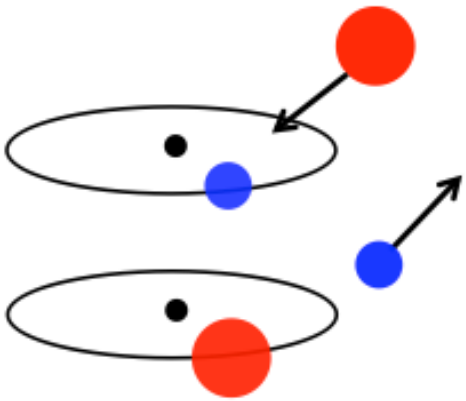


(Lorimer et al. 2005)

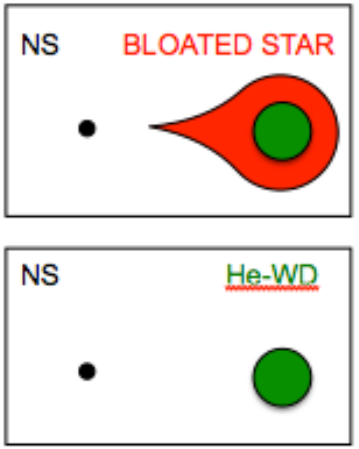
The state of the art



4 NON Degenerate Objects
(Ferraro et al. 2001; Edmonds et al 2002; Cocozza et al 2008; Pallanca et al. 2010).



EXCHANGE INTERACTION



The optical approach

Radio

Very Accurate position

Orbital parameters

Orbital period
Time ascending node

PSR Mass function

Total mass

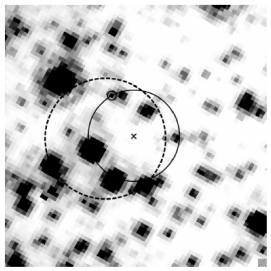
The optical approach

Radio

Optical

Photometry

Astrometry



Very Accurate position → High resolution

CMD position
(Out of sequence) → Deep

Nature and physical parameters

Orbital parameters

Orbital period
Time ascending node ↔ Light curve (Variability in agreement with the orbital motion) → Multiple epochs

PSR Mass function ↔ i, M_{COM}, M_{PSR}

Total mass ↔ $M_{PSR}=M_{TOT}-M_{COM}$

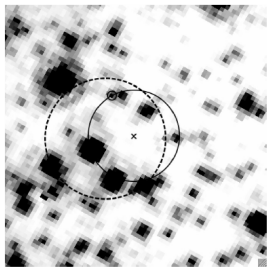
The optical approach

Radio

Optical

Photometry

Astrometry



Very Accurate position → High resolution

!!! Positional coincidence !!!

CMD position
(Out of sequence) → Deep

Nature and physical parameters

Orbital parameters

Orbital period
Time ascending node

PSR Mass function

↔ Light curve
(Variability in agreement with the orbital motion)
i, M_{COM}, M_{PSR}

Multiple epochs

!!! Orbital variability !!!

Total mass ↔ $M_{PSR}=M_{TOT}-M_{COM}$

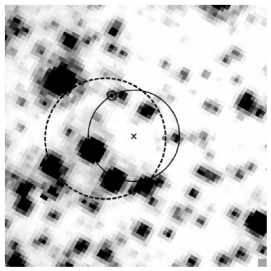
The optical approach

Radio

Optical

Photometry

Astrometry



Very Accurate position →

CMD position
(Out of sequence)

Nature and physical parameters

Orbital parameters

Orbital period
Time ascending node ↔

Light curve
(Variability in agreement with the orbital motion)

PSR Mass function ↔

i, M_{COM}, M_{PSR}

Total mass ↔

$M_{PSR}=M_{TOT}-M_{COM}$

IF
BRIGHT
ENOUGH

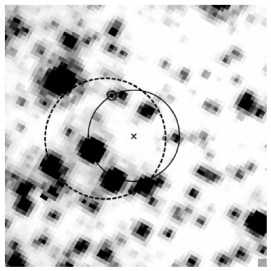
The optical approach

Radio

Optical

Photometry **Spectroscopy**

Astrometry



Very Accurate position

CMD position
(Out of sequence)

Nature and physical parameters

Orbital parameters

Orbital period
Time ascending node

PSR Mass function

Light curve
(Variability in agreement with the orbital motion)

i, M_{COM}, M_{PSR}

Total mass

$M_{PSR}=M_{TOT}-M_{COM}$

Radial Velocity

COM mass function

+

PSR mass function

Mass ratio

System solved

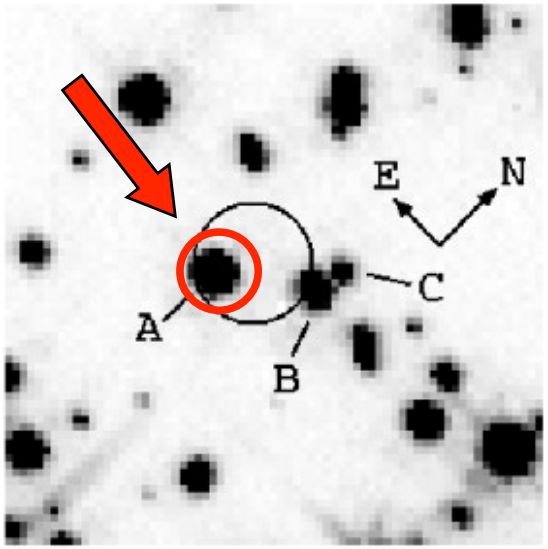
Chemical abundances

Positional coincidence

In order to look for a companion it is mandatory to obtain an accurate astrometric solution.

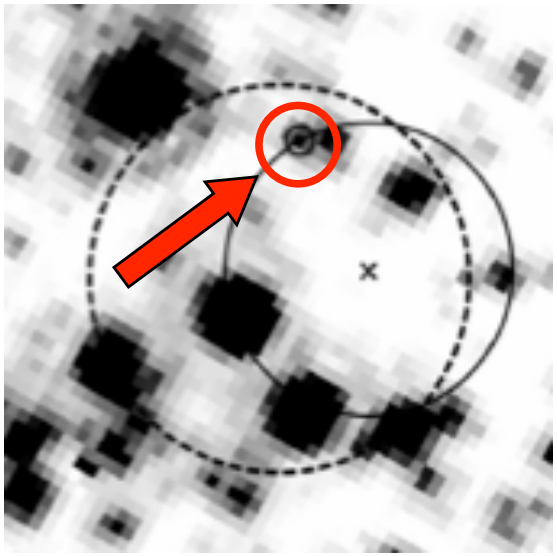
In previous identifications we found an agreement between radio and optical positions with an accuracy < 0.3”

COM 6397A



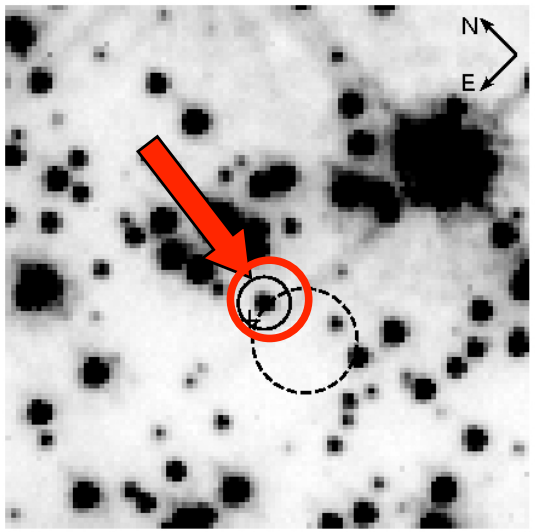
(Ferraro et al. 2001)

COM 6266B



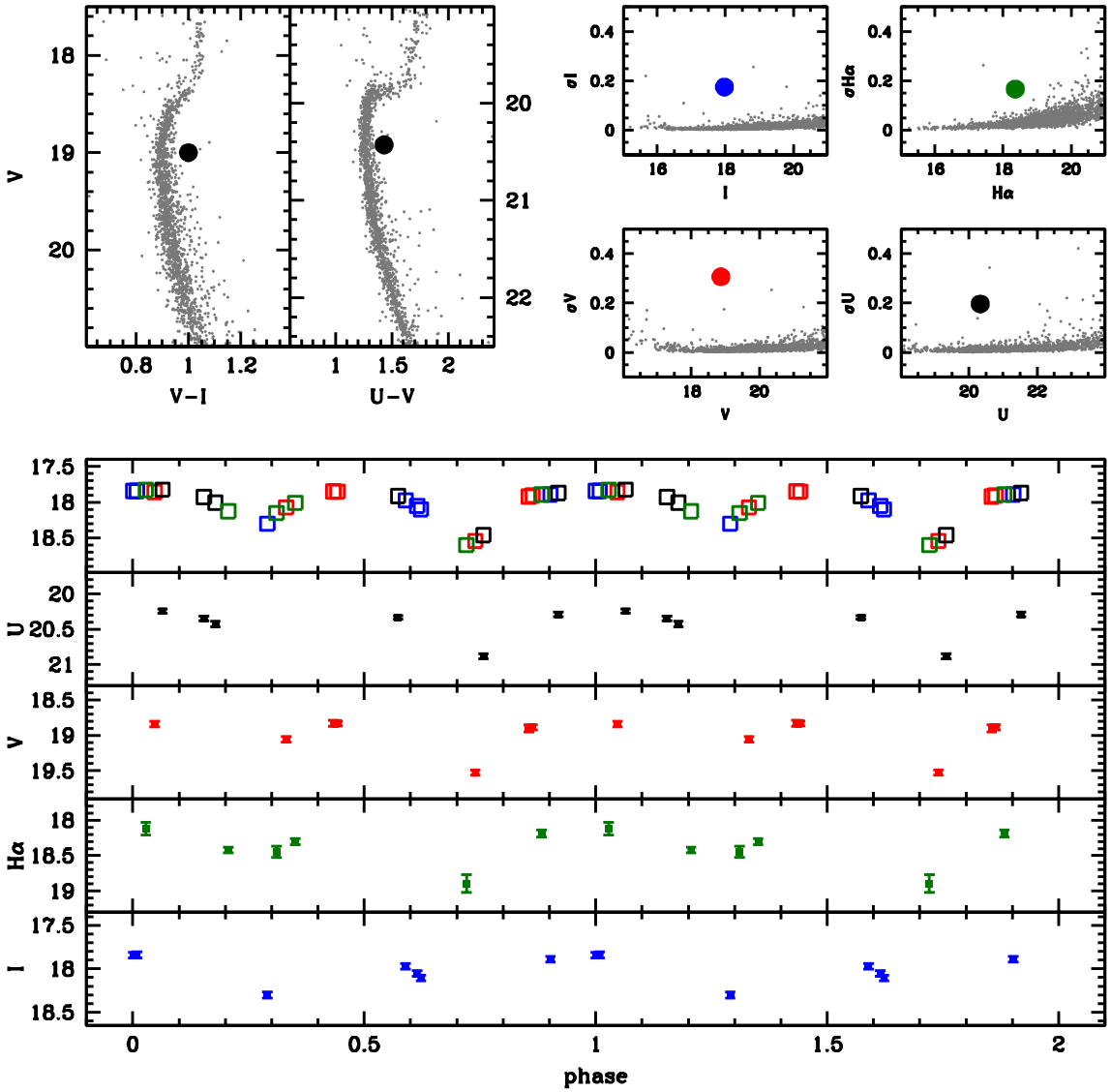
(Cocozza et al. 2008)

COM-M28H



(Pallanca et al. 2010)

COM M28I: a candidate companion

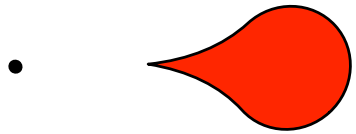


Eclipsing system
P_b~0.459 d

Preliminary
radio position!

I looked for objects with variability compatible with the orbital motion

NS BLOATED STAR ?

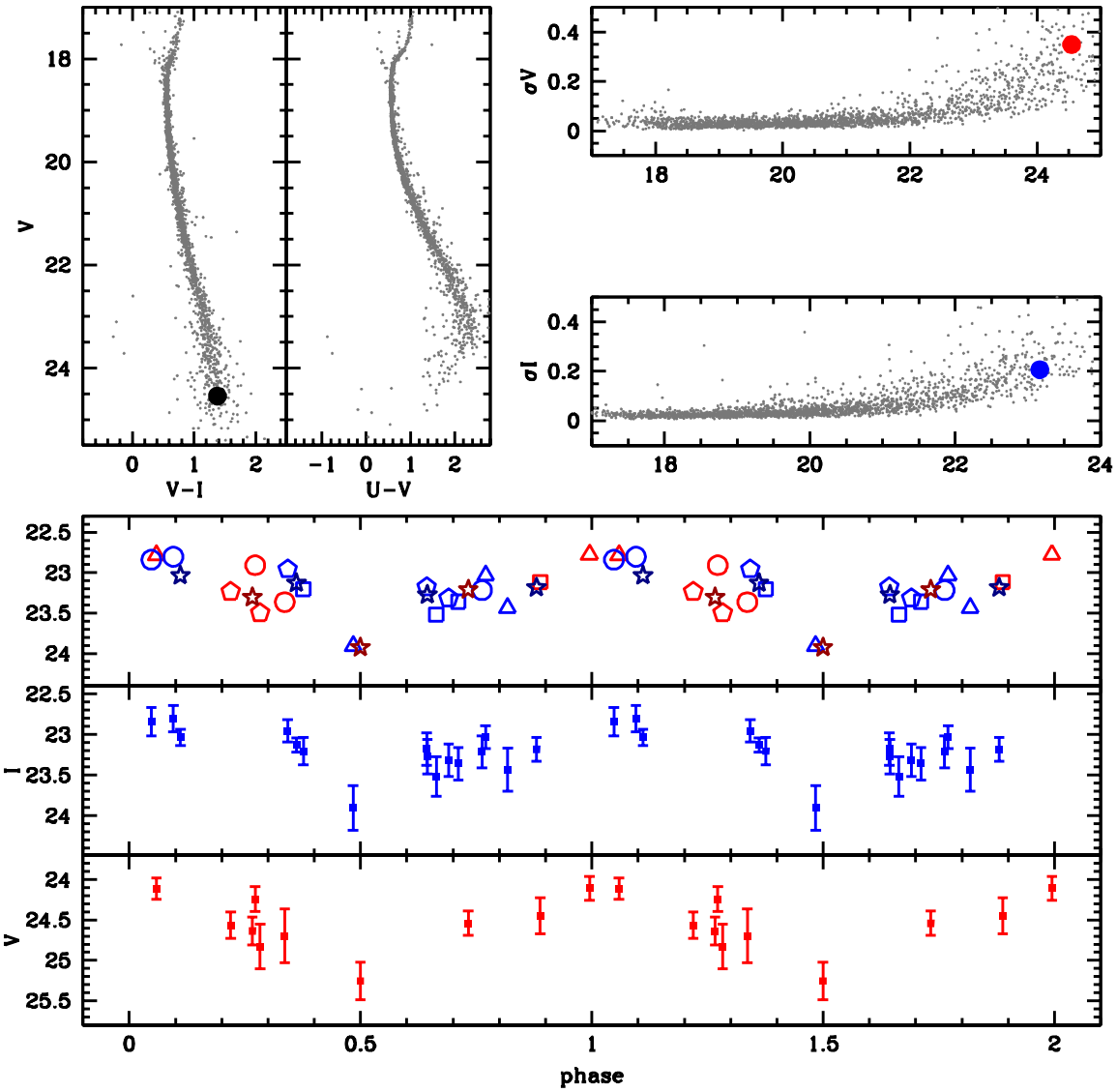


The CMD position is similar to that of COM6397A and COM6266B

The optical location seems to be in agreement with radio timing

Spectroscopical analysis ?
X ray counterpart?

COM-M5C: a low mass star?



Eclipsing
Low mass

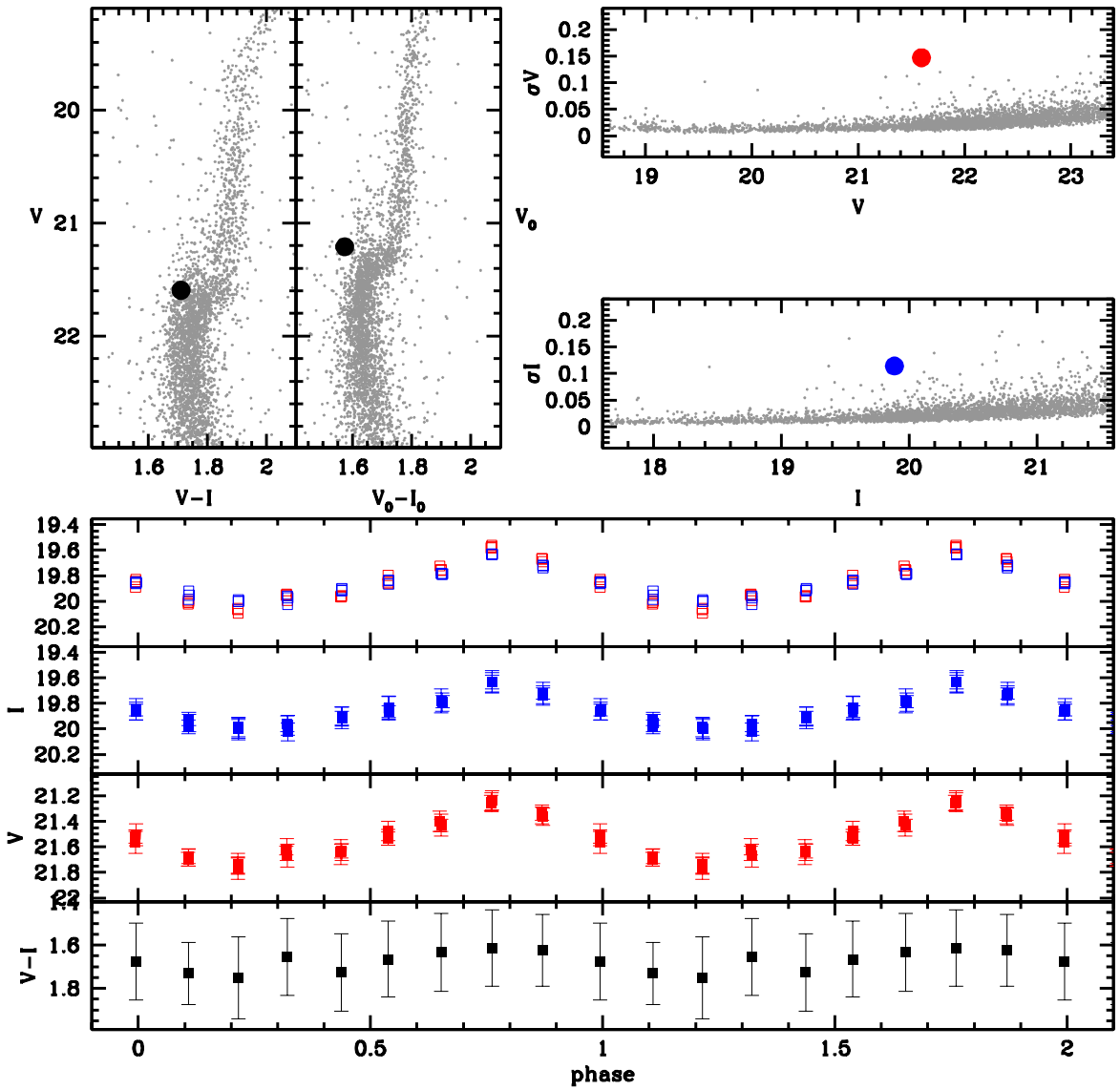
P_B = 0.087 d

Heating?
ΔI, ΔV>1 mag

d~2.9” from a very preliminary position

Try to fit radio data by fixing the position of this star

COM 6440B?



Supermassive
M_{TOT}=2.9 Msun?

P_B = 20.55 d

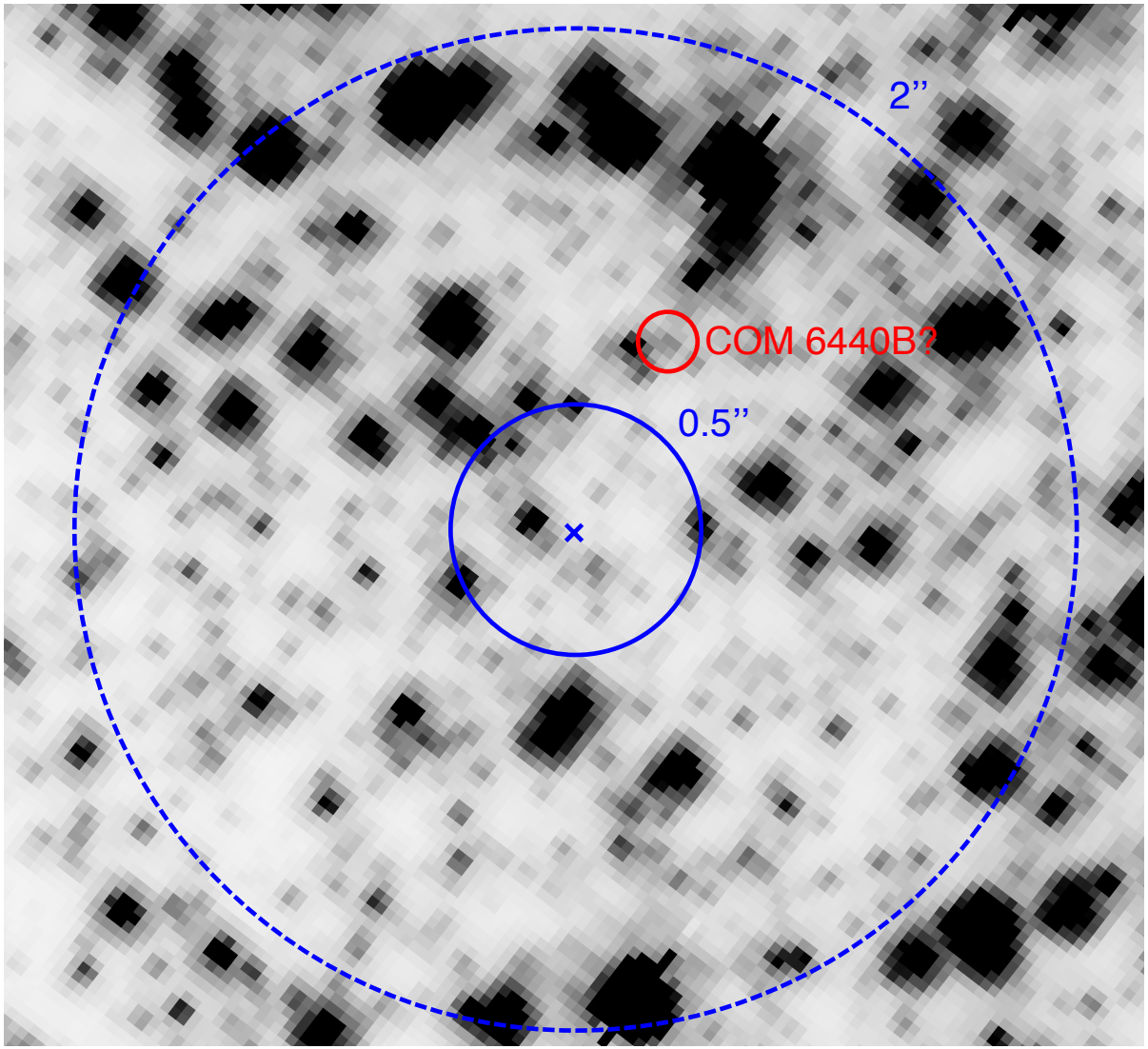
Heating?

Peculiar object
-Swallen object?
-BSS?

M_{COM} ~ 0.9-1 $M_\odot$

Evolutionary model?

COM 6440B?



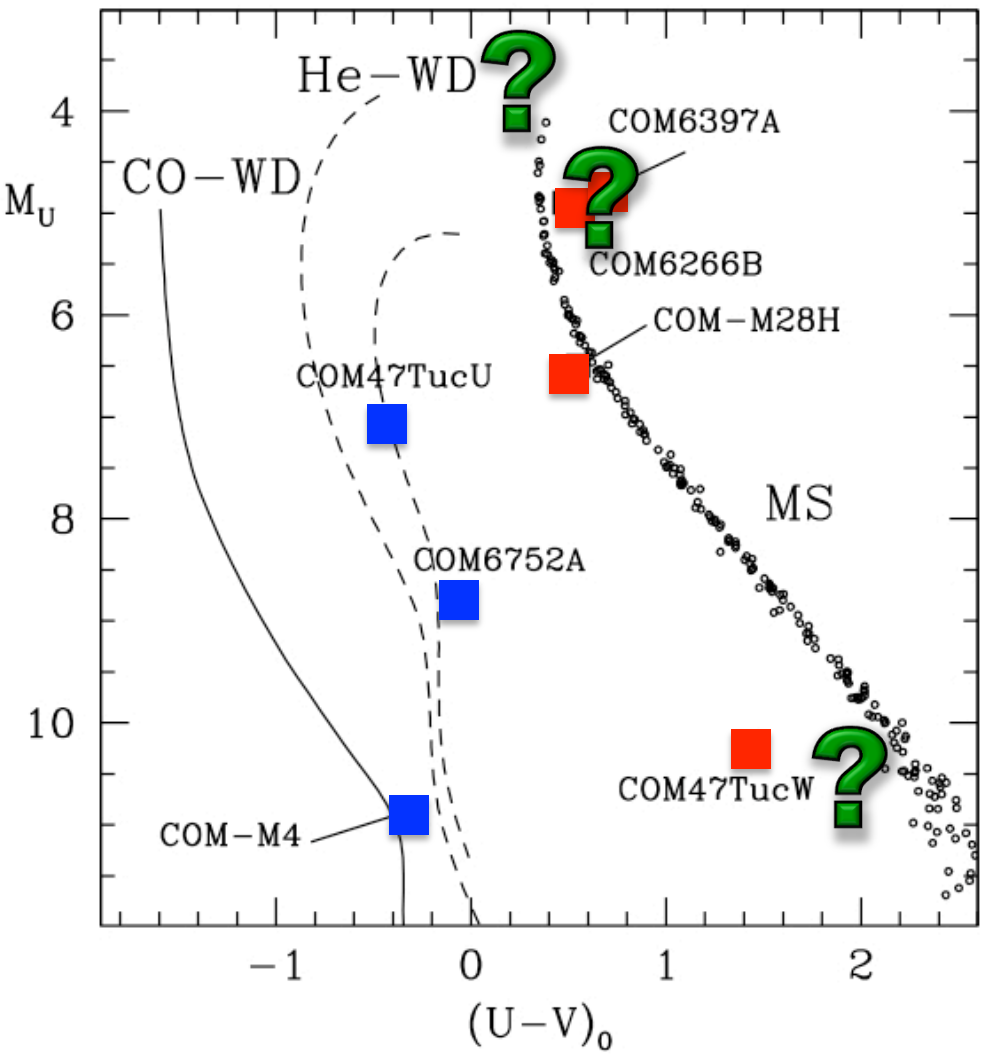
Combined image of 54 WFC3@HST frames

Could be the companion despite the distance (d ~ 0.8”)?

- Spectroscopical analysis → Too faint and too crowded.
- A X-ray counterpart?

- Any idea?

Conclusions



COM-M28I?
COM6440B?
COM-M5C?

3 new non degenerate companions

✓COM-M28I: A tidally distorted star?
(like COM 6397A and 6266B)
✓COM 6440B: a BSS?
✓COM-M5C: A low MS star?

Indirect tool to understand how dynamical interactions can affect the evolution of binary MSPs in GCs
(How exchange interactions are efficient)

The optical identification to PSR companions could help to constrain their locations

Future

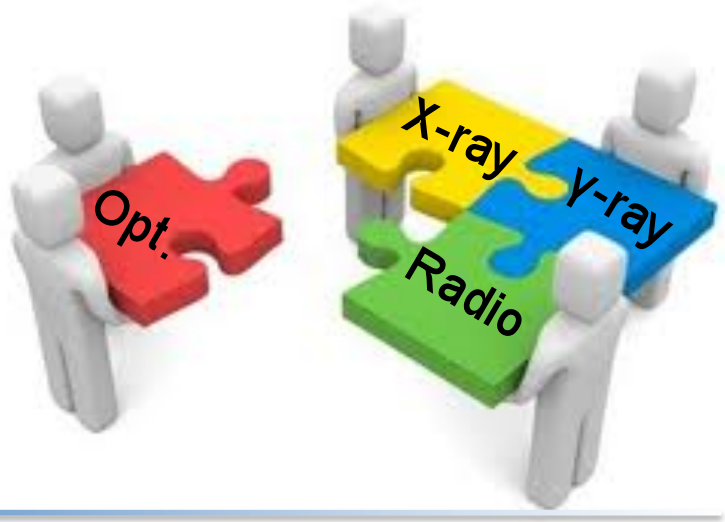
HST cycle 20 - GO 12932 - PI: Ferraro

- NGC 6838 — 4 orbits @ WFC/ACS
- NGC 6544 — 6 orbits @ UVIS/WFC3
- M28H — 8 orbits @ G750L/STIS

SCHEDULED FOR THE END OF 2013

HST call for proposal for cycle 21 – Deadline: March 1, 2013

The deadline is approaching,
so, if you have any interesting target,
please contact me…



Thanks

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www.cosmic-lab.eu

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