

# **A Science case for MAD MAX:**

## **Hunting for optical companions to binary MSPs in GCs**

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# Optical companions to MSPs in GGCs

**THE MSP RE-CYCLING SCENARIO** - MSPs are thought to form in binary systems containing a NS which is eventually spun up through mass accretion from an evolving companion

The result is a new-born MSP + an exhausted star (which has lost most of its envelope) = the core of a peeled star (He-WD).

50% of the Galaxy MSP have been found in GGCs suggesting the effect of dynamical interactions

Optical identification of MSP companions = optical and spectroscopic follow-up.

**Light curve = orbital inclination**  
**+ mass ratio from the velocity curve = empirical estimate of the pulsar mass .. Constraining the state of the degenerate matter in a neutron star**

# Optical companions to MSPs in GGCs

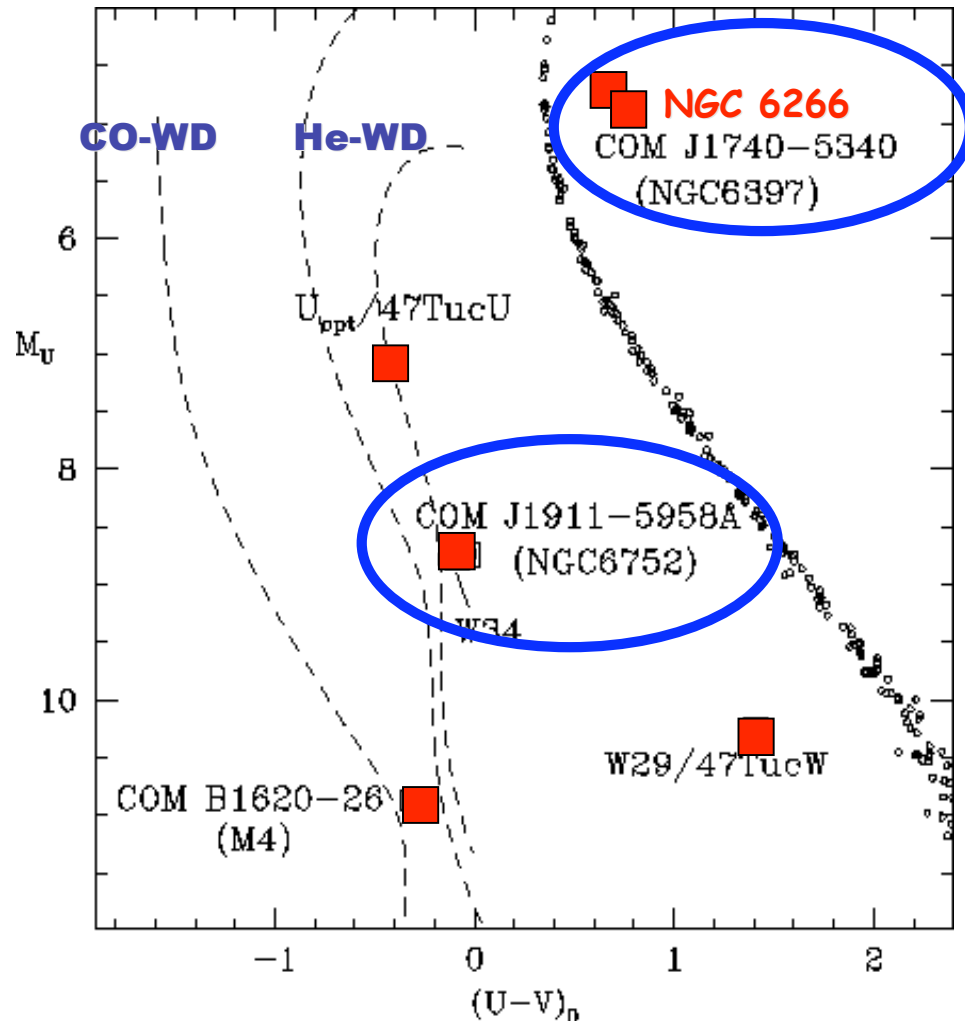
**6 optical companions in 5 GCs have been detected so far:**

**1 is a “strange” MS**

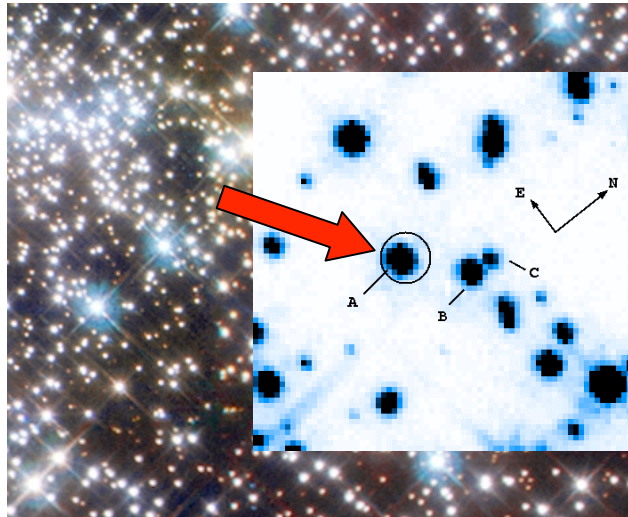
**3 are He-WD**

**2 are pre He-WD**

**Three of them have been discovered by our group !!!**

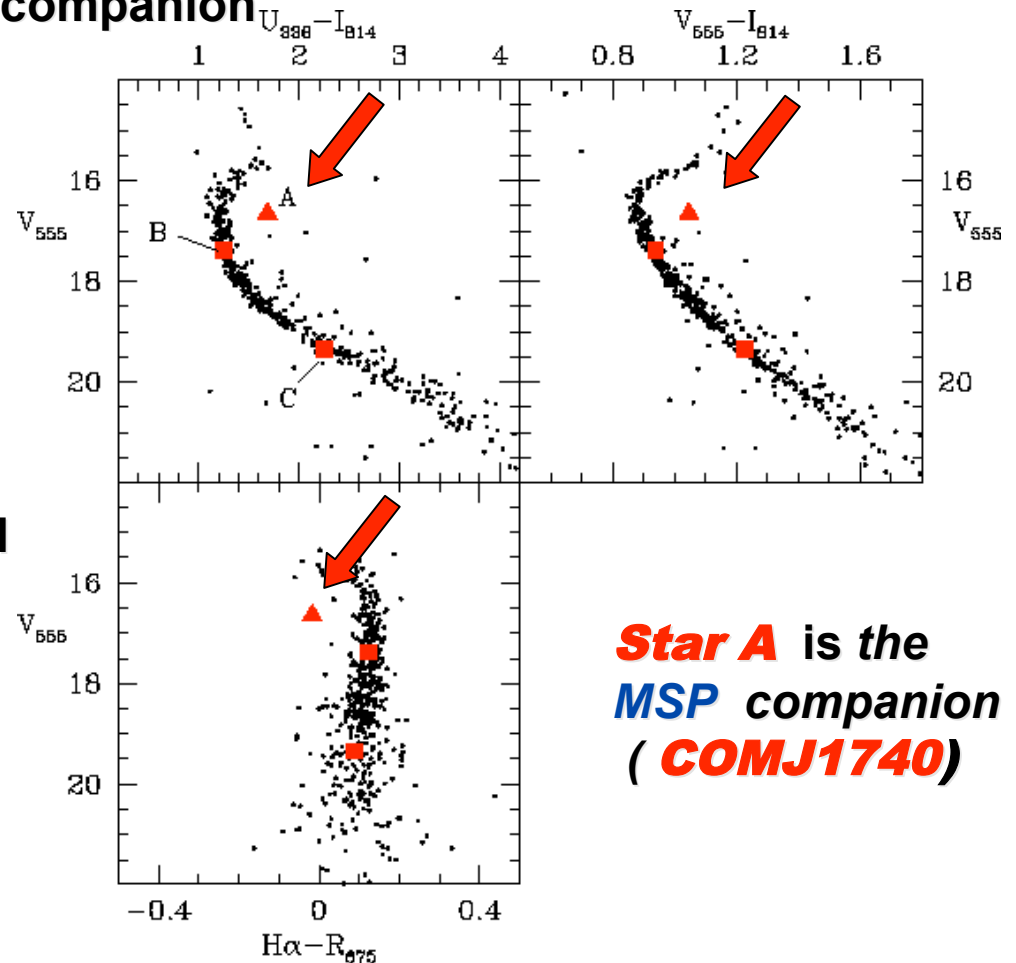


# The bright companion to the MSP in NGC6397



**MSP J1740-5340** in **NGC6397** shows eclipse of the radio signal for about 40% of the orbit (*D'Amico et al 2001*) suggesting that the NS is orbiting within a large envelope of matter released by the companion

**COMJ1740** is **NOT** a **WD** as expected in the framework of the **MSP** recycling scenario



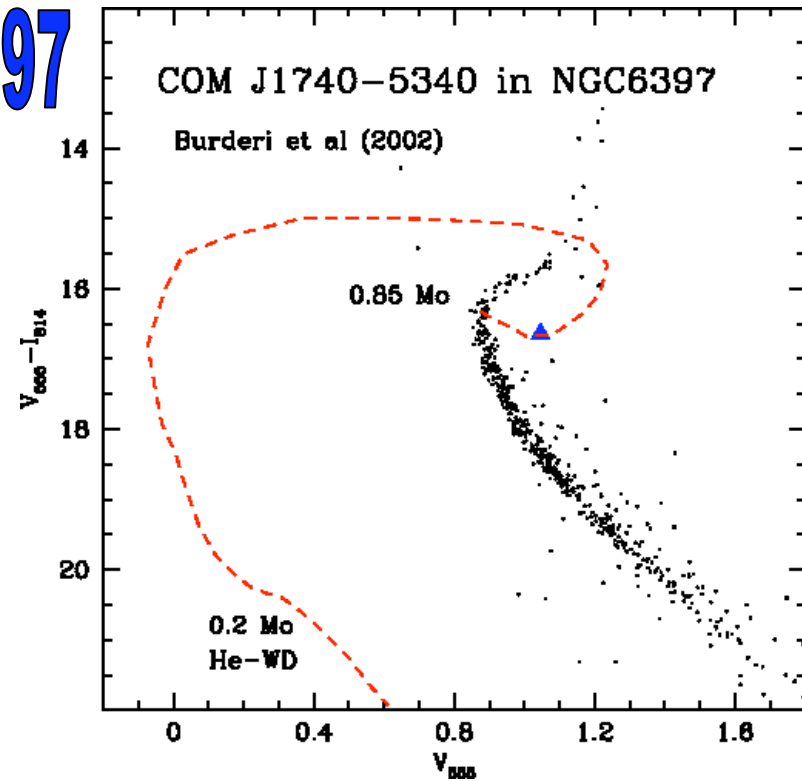
**Star A** is the **MSP** companion (**COMJ1740**)

*Ferraro et al (2001,ApJ,561,L93)*

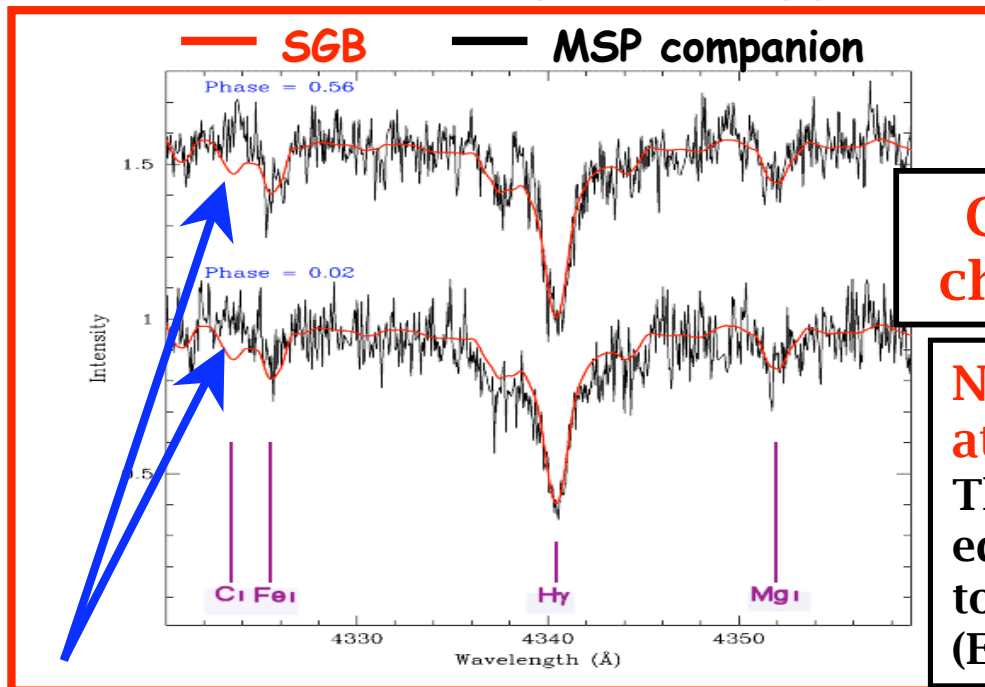
# The bright MSP companion in NGC6397

**COM J1740** is tidally distorted star and it is losing mass from its Roche lobe

Burderi et al (2002) suggested that the position of COMJ1740 in the CMD is consistent with the evolution of a slightly evolved TO star orbiting the NS and losing mass. The evolution would generate a He-WD



## UVES@VLT spectroscopy



COMJ1740 has the same overall chemical composition of the SGBs

No C in the COM J1740-5340 atmosphere.

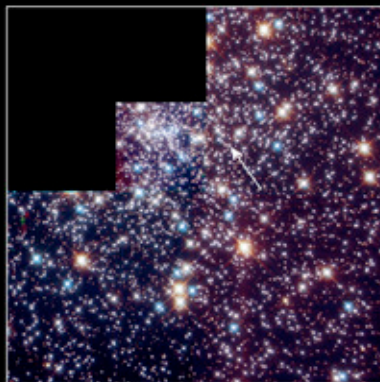
This would suggest a CN cycle at equilibrium, (when all C has been burned to N), hence it is a deeply peeled star (Ergma & Sarna 2003)

Ferraro et al (2002, ApJ, 584, L13) & Sabbi et al (2003, ApJ, 589, L41)

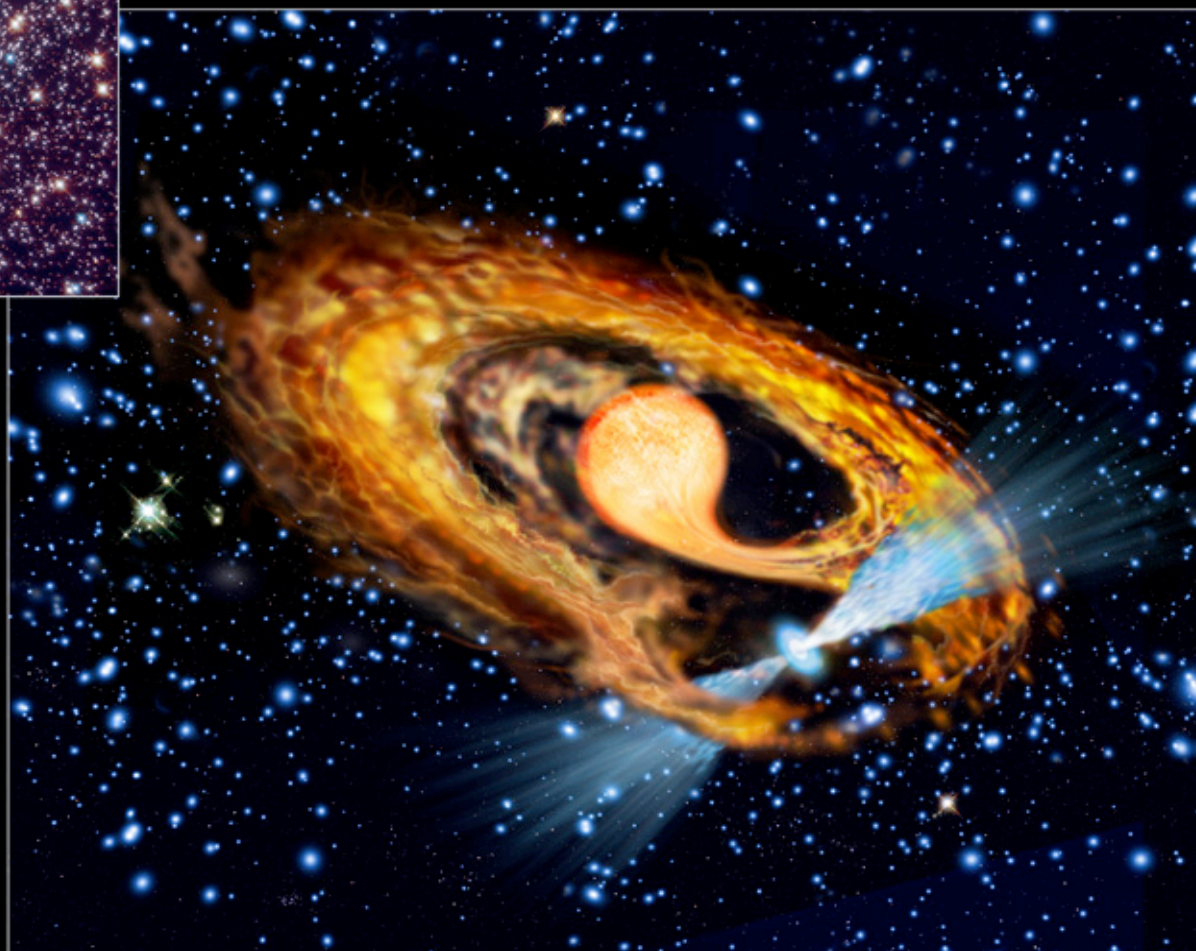
# The bright companion to the MSP in NGC6397

**NEWS RELEASE**

**First Wailing of a New-born Millisecond Pulsar?**



**WFPC2**



HEIC 0201



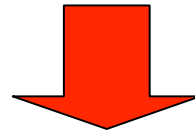
**HUBBLE SPACE TELESCOPE**

The European Space Agency, NASA & F. Ferraro (Bologna Astronomical Observatory, Italy)



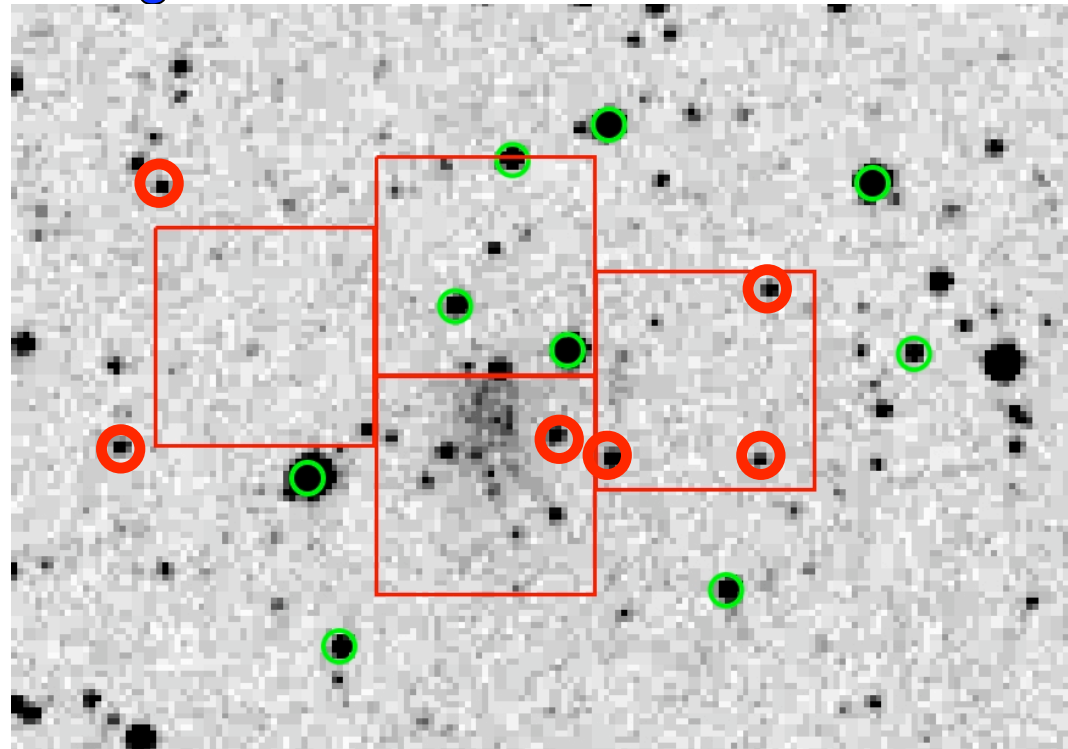
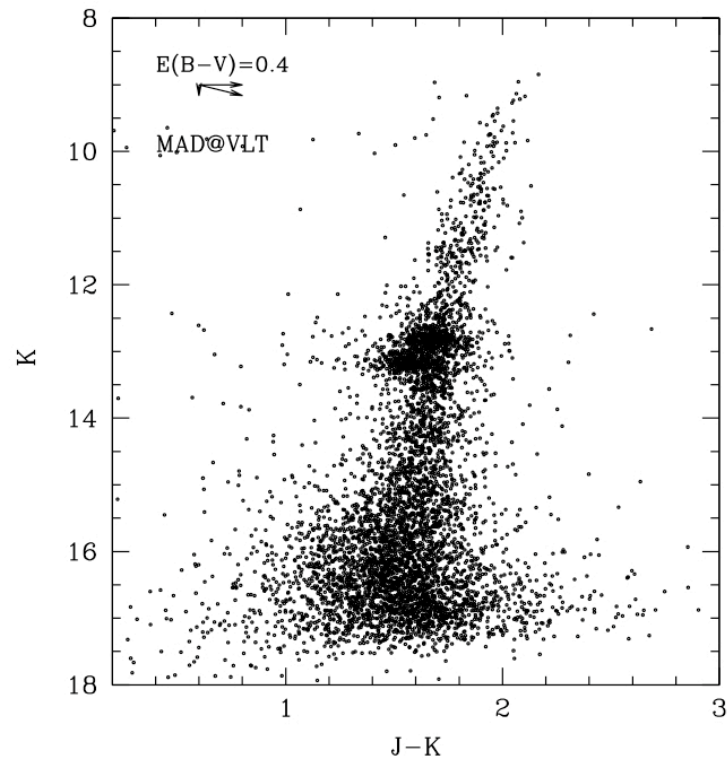
# Targets:

|                 |    |    |      |     |    |       |
|-----------------|----|----|------|-----|----|-------|
| <b>Terzan 5</b> | 17 | 11 | 13.2 | -27 | 11 | 38.00 |
| <b>NGC6440</b>  | 17 | 48 | 52.7 | -20 | 21 | 35.00 |
| <b>M28</b>      | 18 | 24 | 32.9 | -24 | 52 | 11.00 |



**Eclipsing MSPs and supermassive NS**

# Exploring the MSP zoo & the origin of the double HB in Terzan5



## Two-folder proposal:

1. Identify optical companion for most of the 17 MSP in binary systems
2. Search for the origin of the double HB detected with MAD

4 fields at  $K=22$   $J=23.5$   $S/N=20-30$

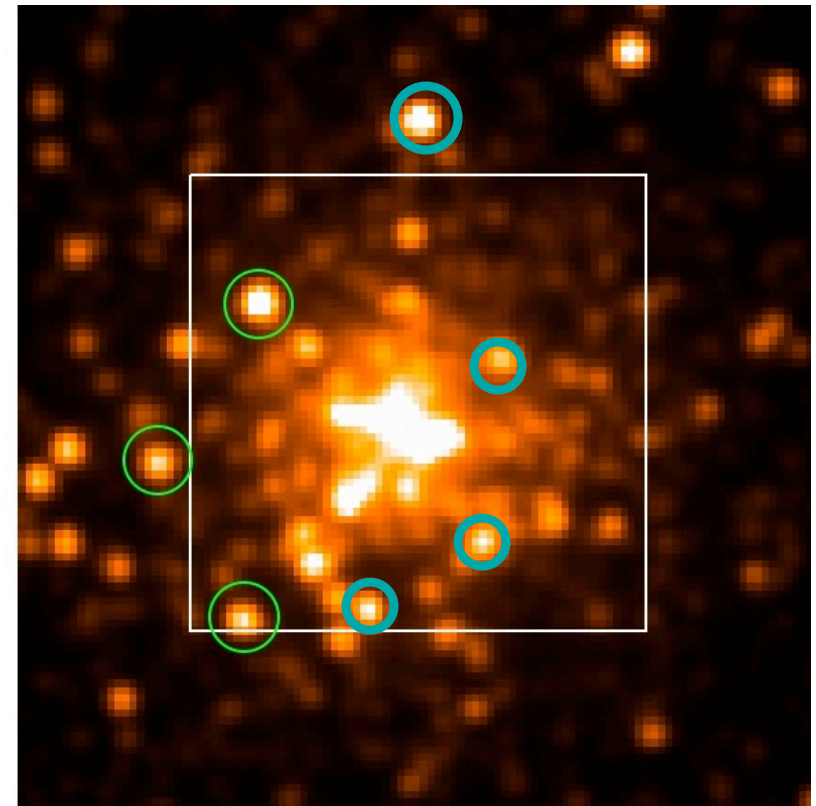
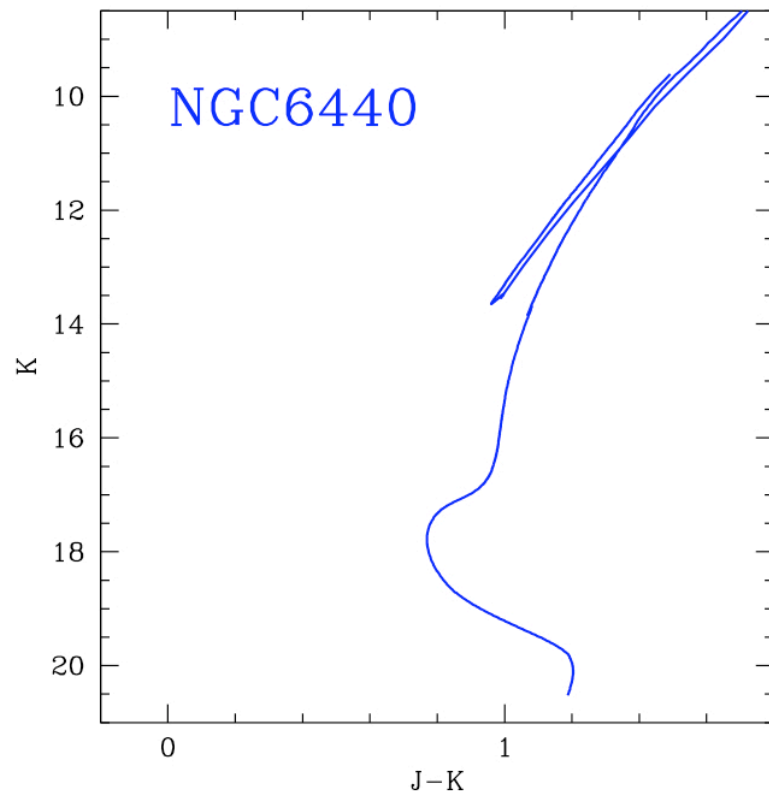


# A supermassive NS in NGC6440

6 known MSP (3 in binary systems).

N6440B is a system with total mass 2.9Mo, with a suspected large pulsar Mass (larger than 2.5 Mo)....

The direct measure of the companion mass will yield the estimate of the NS mass



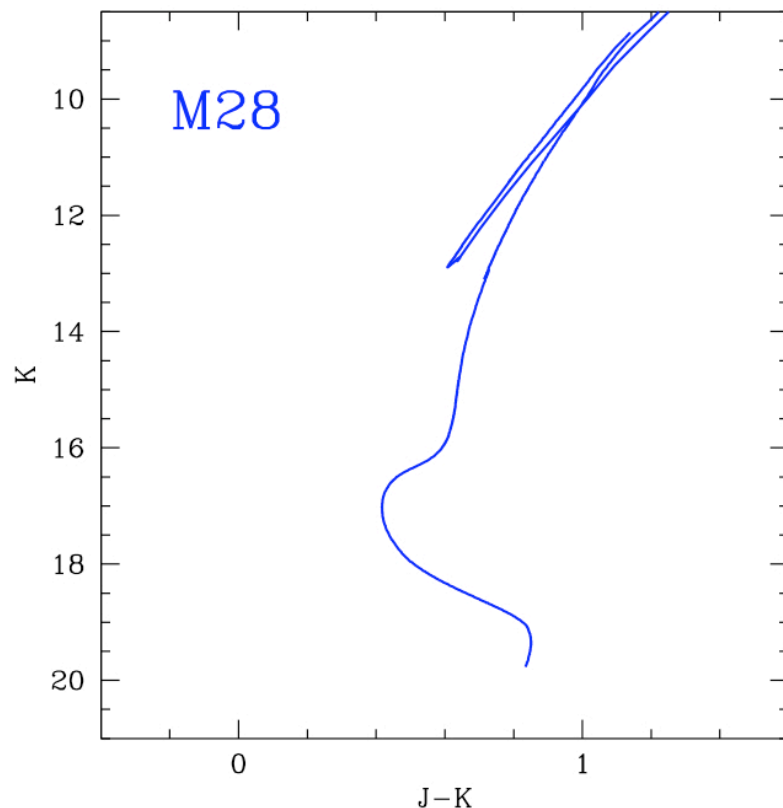
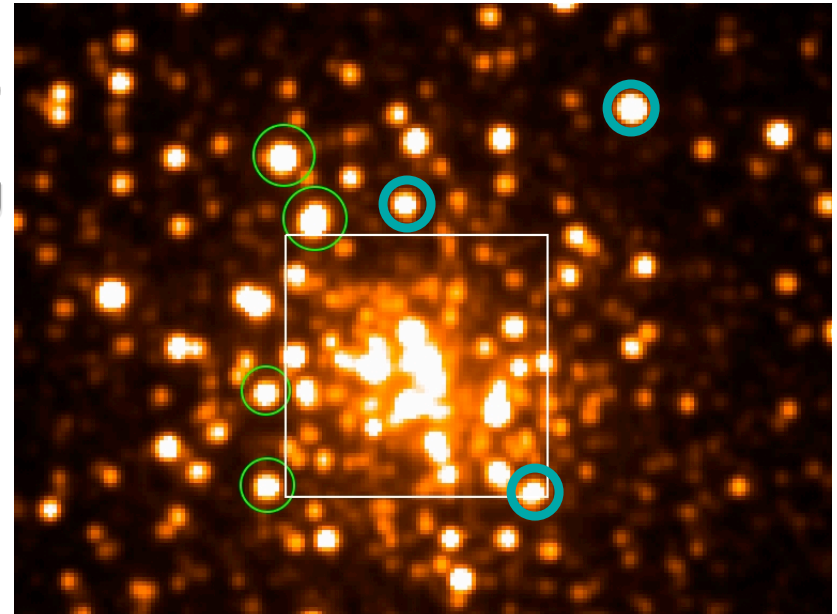
This will possibly lead to the discovery of the **most massive NS ever measured** with a huge impact on the Equation of state of the dense matter

**K=22 J=23 S/N=20** to exclude companion mass larger than 0.4Mo

# An eclipsing MSP in M28

**MSP showing eclipse of the radio signal along the orbit suggesting that the NS is orbiting within a large envelope of matter released by the companion**

**Object similar to the companion found in NGC6266 And NGC6397**



**The identification of these companions can clarify the rate of exchange interactions in GCs and the process that lead to the formation of the He-WD**

**K=21 J=22 at S/N=20 to identify the (bloated) companion star**



The End