

1. Early in a star cluster's formation ( $T=0$ ), some of the lower mass stars are still in the  $\tau$  Tauri phase while some of the high-mass stars have reached the Main Sequence.
2. **Ten million years** later, the highest mass O stars have used up all of their hydrogen and begin to evolve off the Main Sequence.
3. After **100 million years** all of the O stars have gone supernova. The B stars begin to evolve off of the Main Sequence.
4. After **1 billion years** all of the B stars that are massive enough have gone supernova and the rest have evolved into red giants. The A stars begin to evolve off of the Main Sequence.
5. After **5 billion years** the G stars begin to evolve off of the Main Sequence. The red giant branch is populated with some of the originally more massive stars. Some of the first red giant stars that formed have already become white dwarfs.
6. After **10 billion years** the OBAFG stars are all missing from the Main Sequence, the red giant branch is very well populated, and there are also many white dwarfs. Only K & M stars remain on the Main Sequence.

**Universe** 13.700 Myr  
**Solar System** 4.571 Myr

OC	NGC	Con	Age (Myr)	Dist (Kpc)	Diam	App Mag	Name
			<b>5: Age (Myr) &gt;5.000 Myr</b>			<b>Sanatorium</b>	<b>G&gt; off MS</b>
Be 54	--	Cyg	7.000	2.3	5'		
--	N188	Cep	7.200	1.7	15'		Polarissima
			<b>6: Age (Myr) &gt;10.000 Myr</b>			<b>Hospice</b>	<b>KM on MS</b>
--	N6791	Lyr	10.200	4	16'	9.5	
Be17	--	Aur	12.600	3.1	15'		

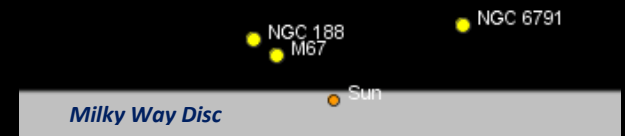
The brightest stars in the ancient OCs are orange/red giants on the RGB (types G8-K4 III), and several of these have evolved further through the post-AGB stage to end up as white dwarfs.

The ancient OCs also contain many blue and yellow straggler stars created by red giant interaction with a binary companion.

The main sequence turn-off point for these ancient OCs is  $\sim 1 - 0.9$  solar mass, corresponding to stars of type late-G to K and M. The heavier stars have all left the MS and are now up the RGB or down in the WD corner of the CMD. Heavier mass transfers and mergers of binary stars can be found as blue lurkers and stragglers (BSS), predominantly segregated towards the core of the OCs.

The oldest open clusters are typically those located away from the galactic plane, where they are not strongly affected by tidal forces and direct interactions with *Milky Way* nebulae and stars. These old OCs may have formed in the *Milky Way* inner disk, close to the bulge, but have then moved outward because of perturbations induced by the bar and spiral arms.

A location outside the MW disk is characteristic for the ancient open clusters I have included in this Messier-sweep, namely: Be 54, NGC 188, NGC 6791 and Be17. In age they span from 7-12.6 Gyr, and in distance from our solar system they range from 2-4 Kpc.

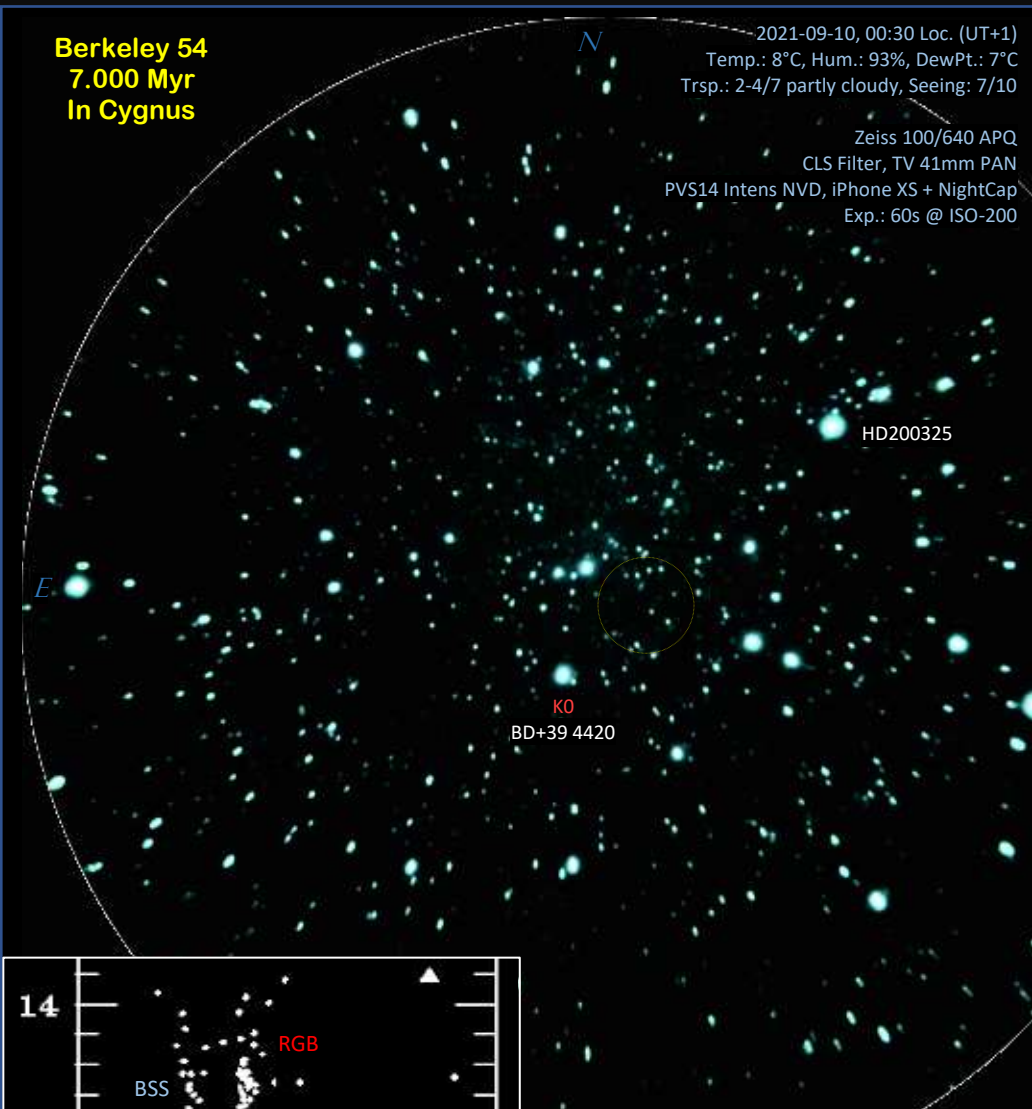


*Milky Way Disc*

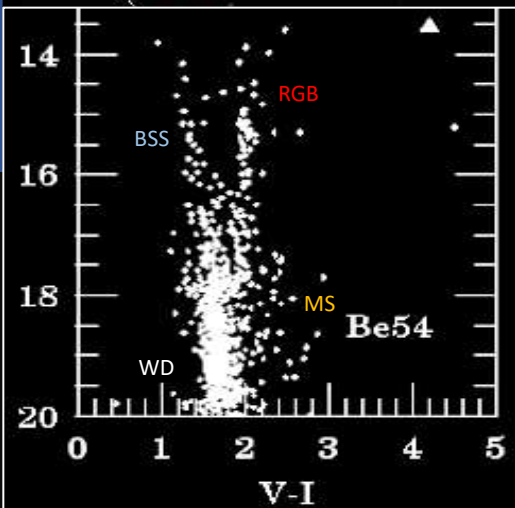
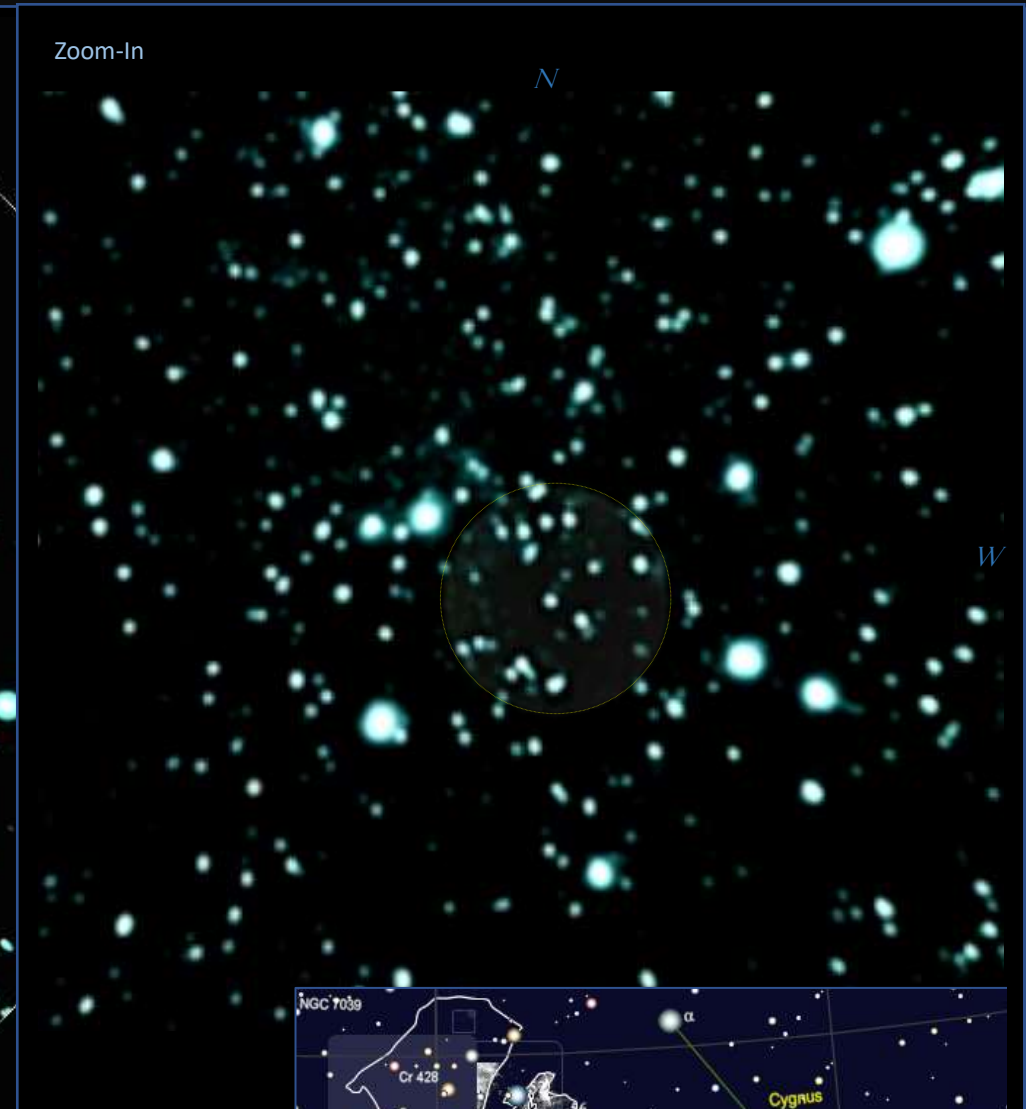
**Berkeley 54**  
**7,000 Myr**  
**In Cygnus**

2021-09-10, 00:30 Loc. (UT+1)  
 Temp.: 8°C, Hum.: 93%, DewPt.: 7°C  
 Trsp.: 2-4/7 partly cloudy, Seeing: 7/10

Zeiss 100/640 APQ  
 CLS Filter, TV 41mm PAN  
 PVS14 Intens NVD, iPhone XS + NightCap  
 Exp.: 60s @ ISO-200



**Zoom-In**



Be 54 is located at an intermediary distance of 2.3 Kpc up our local spiral arm towards Cygnus. It is a very old cluster (~7 Gyr) showing a "bifurcated" high-luminosity branch with blue straggler stars (BSS) plus many bloated orange/red giants on the red giant branch (RGB), and with only lower mass and slow-burning low luminosity type K-M stars remaining on the Main Sequence (MS).

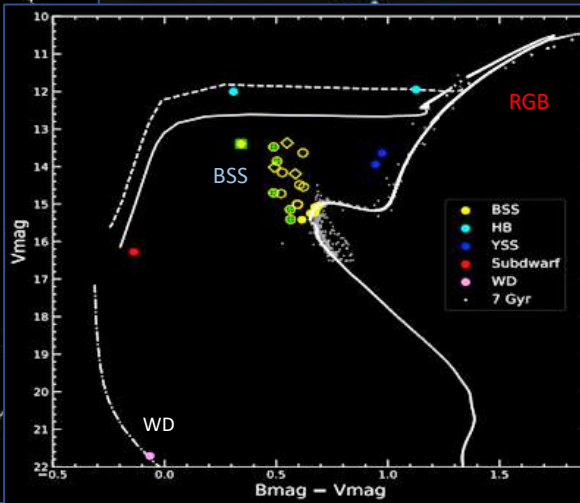
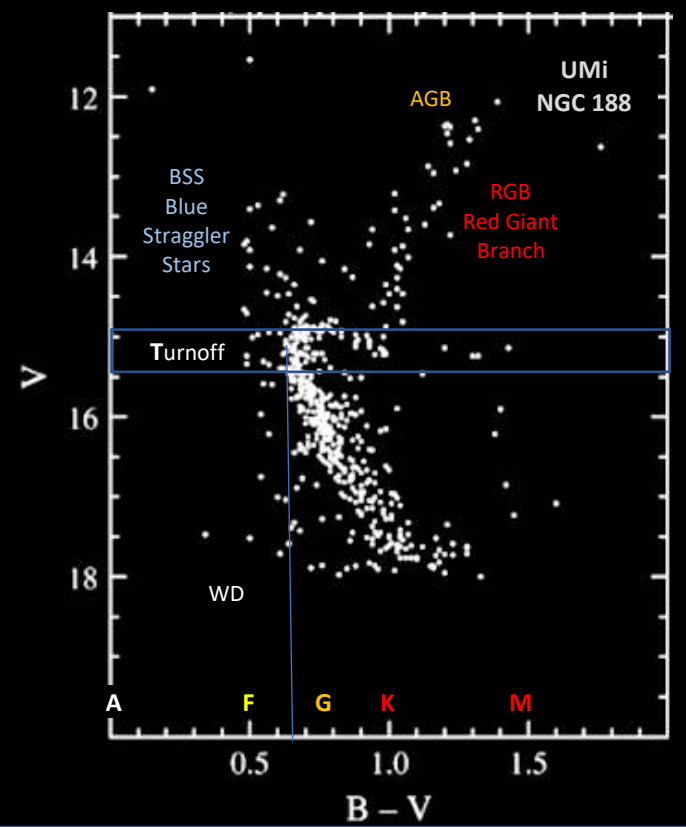
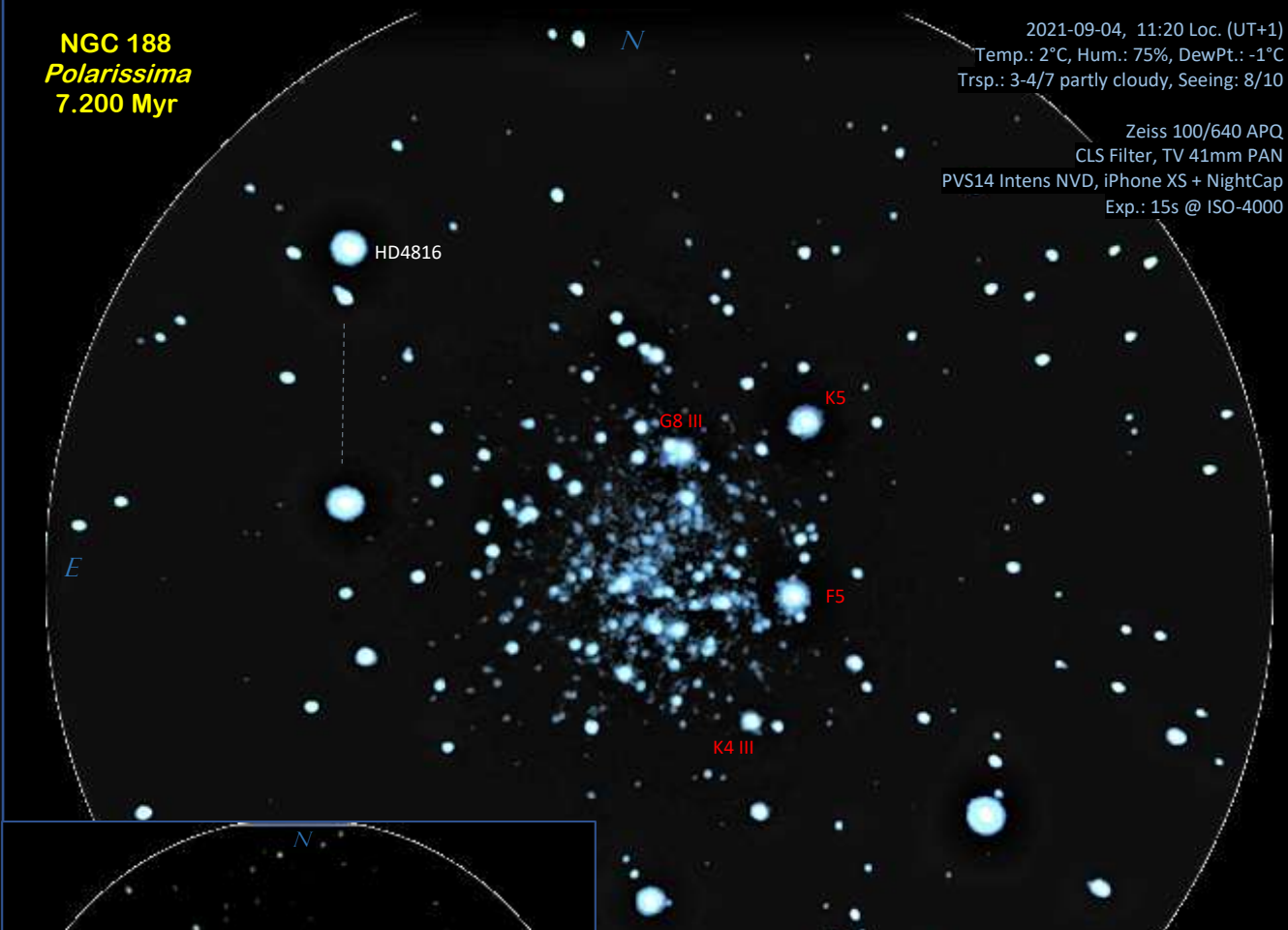
Also, some of the higher mass stars have by now ended their terminal core hydrogen fusing phase on the RGB, then gone through a core helium flash moving down left to the "red clump", and from there started shell helium fusing on the AGB, whereafter their life has ended in a supernova or planetary nebula event, with the stellar remnant sinking down as a white dwarf to the lower left "corner" of the CMD/HRD.



**NGC 188**  
*Polarissima*  
 7.200 Myr

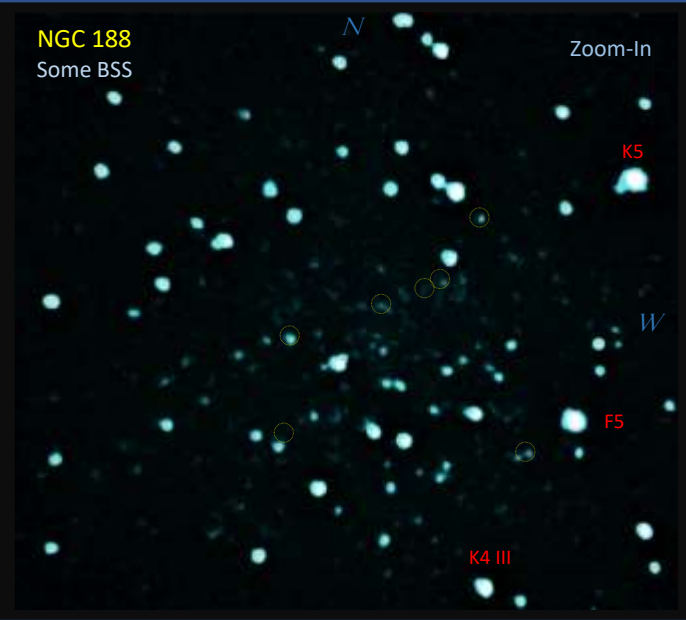
2021-09-04, 11:20 Loc. (UT+1)  
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 Trsp.: 3-4/7 partly cloudy, Seeing: 8/10

Zeiss 100/640 APQ  
 CLS Filter, TV 41mm PAN  
 PVS14 Intens NVD, iPhone XS + NightCap  
 Exp.: 15s @ ISO-4000



N188 is a very old, rich OC located at 1.7 Kpc distance out in the inter-arm gap towards the Perseus Arm in Cassiopeia.

This ancient OC contains ~120 stars, the hottest MS-star being of type F2. The 10 brightest stars are orange/red giants of types G8-K4 and ~24 bright Blue Straggler Stars (BSS; -- I've marked some of these with a circle on my photo to the right).

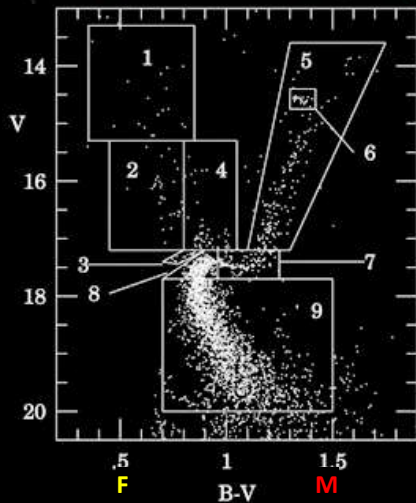
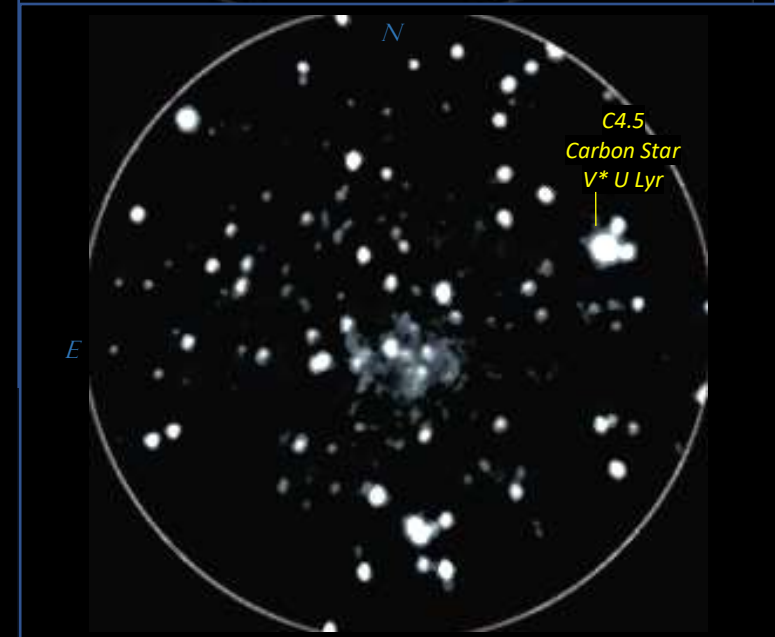
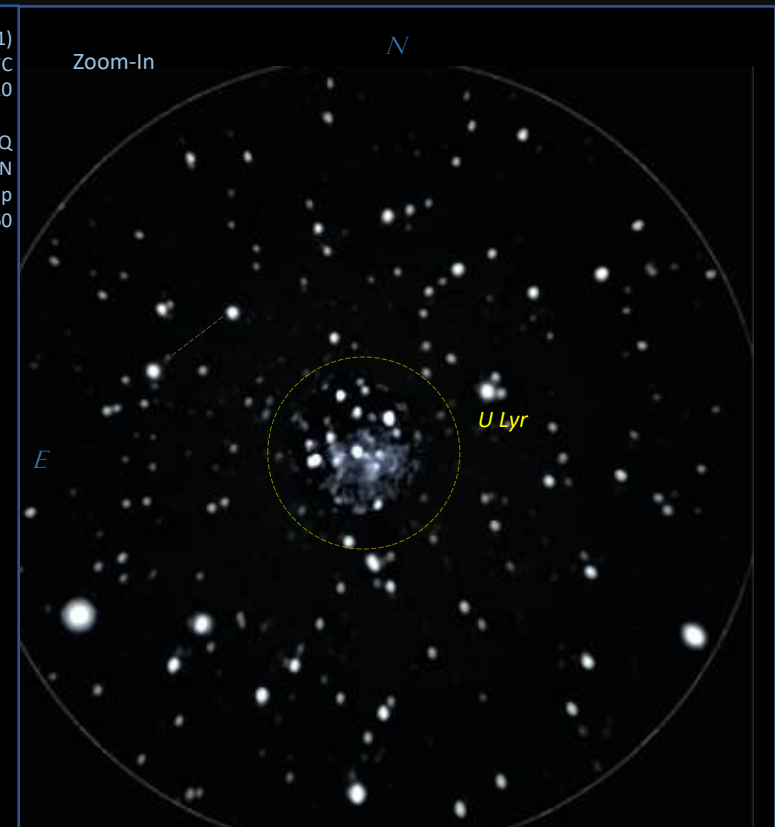
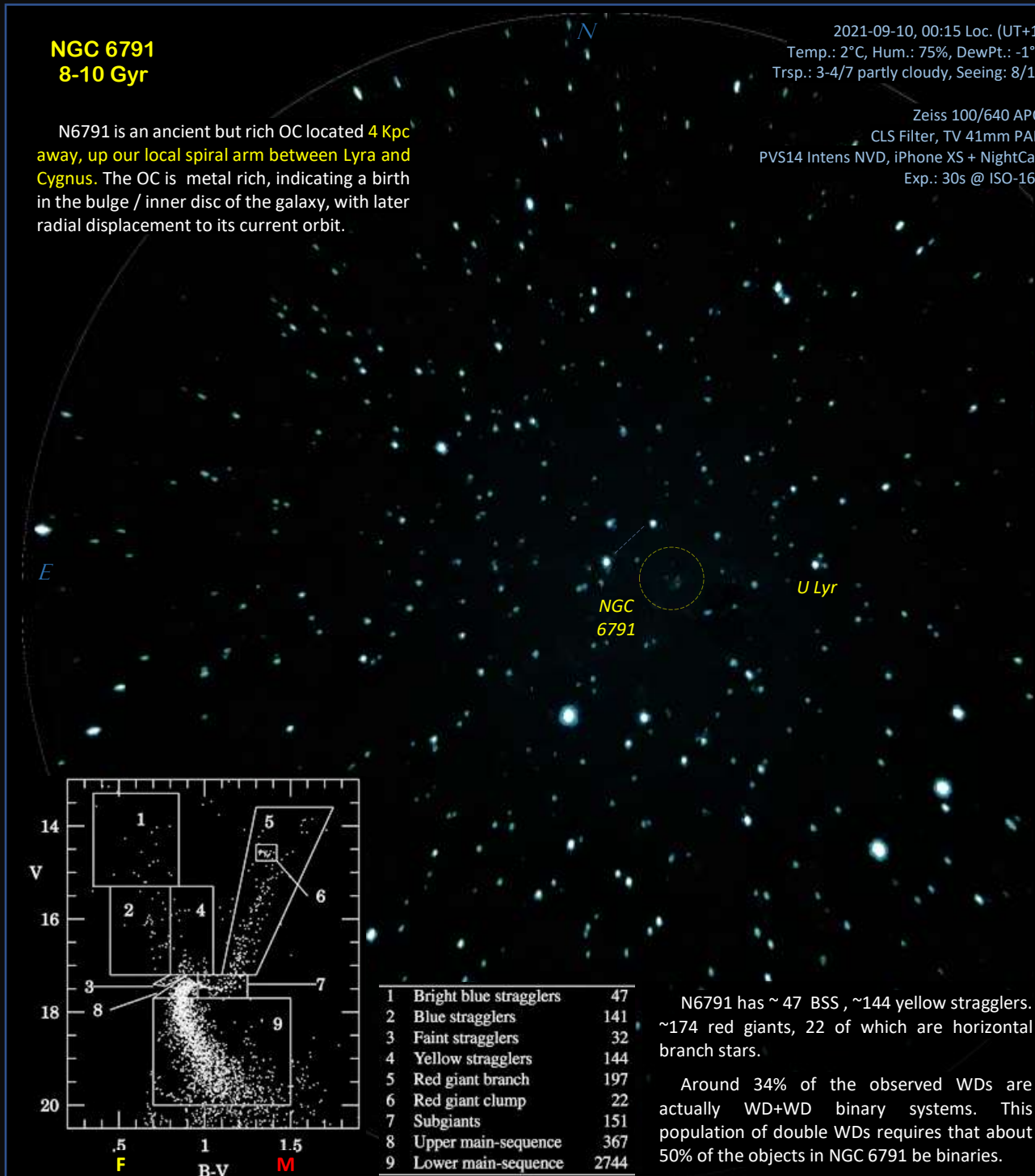


**NGC 6791**  
8-10 Gyr

N6791 is an ancient but rich OC located 4 Kpc away, up our local spiral arm between Lyra and Cygnus. The OC is metal rich, indicating a birth in the bulge / inner disc of the galaxy, with later radial displacement to its current orbit.

2021-09-10, 00:15 Loc. (UT+1)  
Temp.: 2°C, Hum.: 75%, DewPt.: -1°C  
Trsp.: 3-4/7 partly cloudy, Seeing: 8/10

Zeiss 100/640 APQ  
CLS Filter, TV 41mm PAN  
PVS14 Intens NVD, iPhone XS + NightCap  
Exp.: 30s @ ISO-160



1	Bright blue stragglers	47
2	Blue stragglers	141
3	Faint stragglers	32
4	Yellow stragglers	144
5	Red giant branch	197
6	Red giant clump	22
7	Subgiants	151
8	Upper main-sequence	367
9	Lower main-sequence	2744

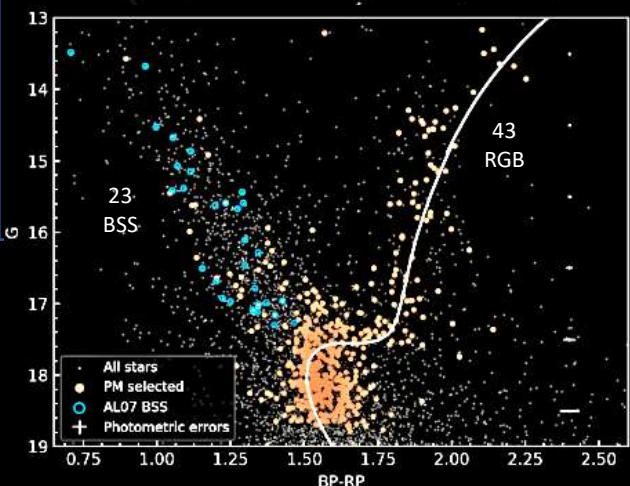
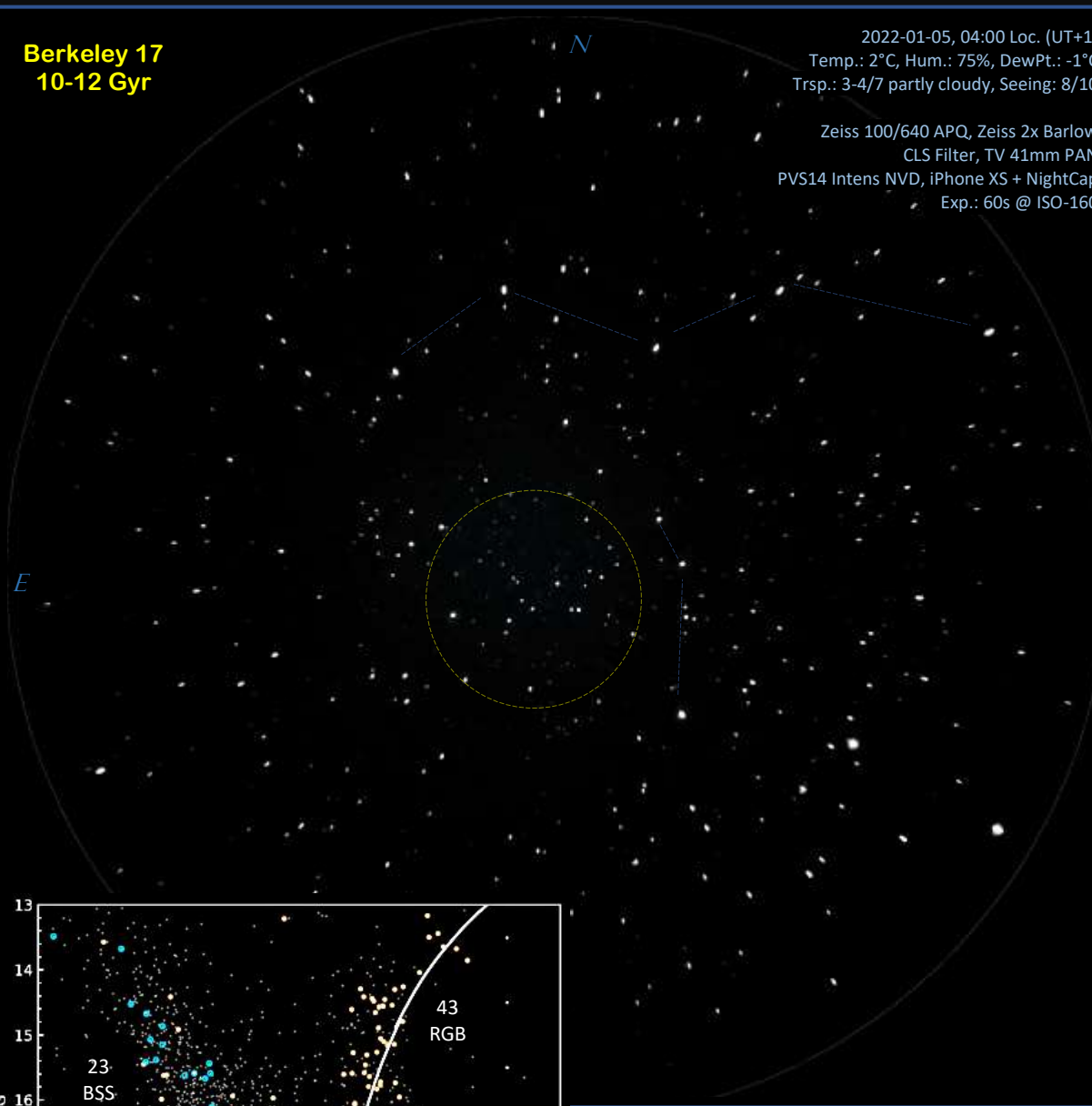
N6791 has ~ 47 BSS, ~144 yellow stragglers. ~174 red giants, 22 of which are horizontal branch stars.

Around 34% of the observed WDs are actually WD+WD binary systems. This population of double WDs requires that about 50% of the objects in NGC 6791 be binaries.

**Berkeley 17**  
10-12 Gyr

2022-01-05, 04:00 Loc. (UT+1)  
Temp.: 2°C, Hum.: 75%, DewPt.: -1°C  
Trsp.: 3-4/7 partly cloudy, Seeing: 8/10

Zeiss 100/640 APQ, Zeiss 2x Barlow  
CLS Filter, TV 41mm PAN  
PVS14 Intens NVD, iPhone XS + NightCap  
Exp.: 60s @ ISO-160



Be 17 is located at a distance of 3.1 Kpc below the galactic plane towards the galactic anticenter in Auriga.

Be 17 is currently (as of 2022) the oldest known OC in the Milky Way galaxy, with an age of 10-12 Gyr, showing mass segregation and a distinct tidal tail caused by interaction with the Perseus spiral arm.