

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 O-B-A-F-G 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.

#### 4: Age (Myr) 1000-5000

Retirees

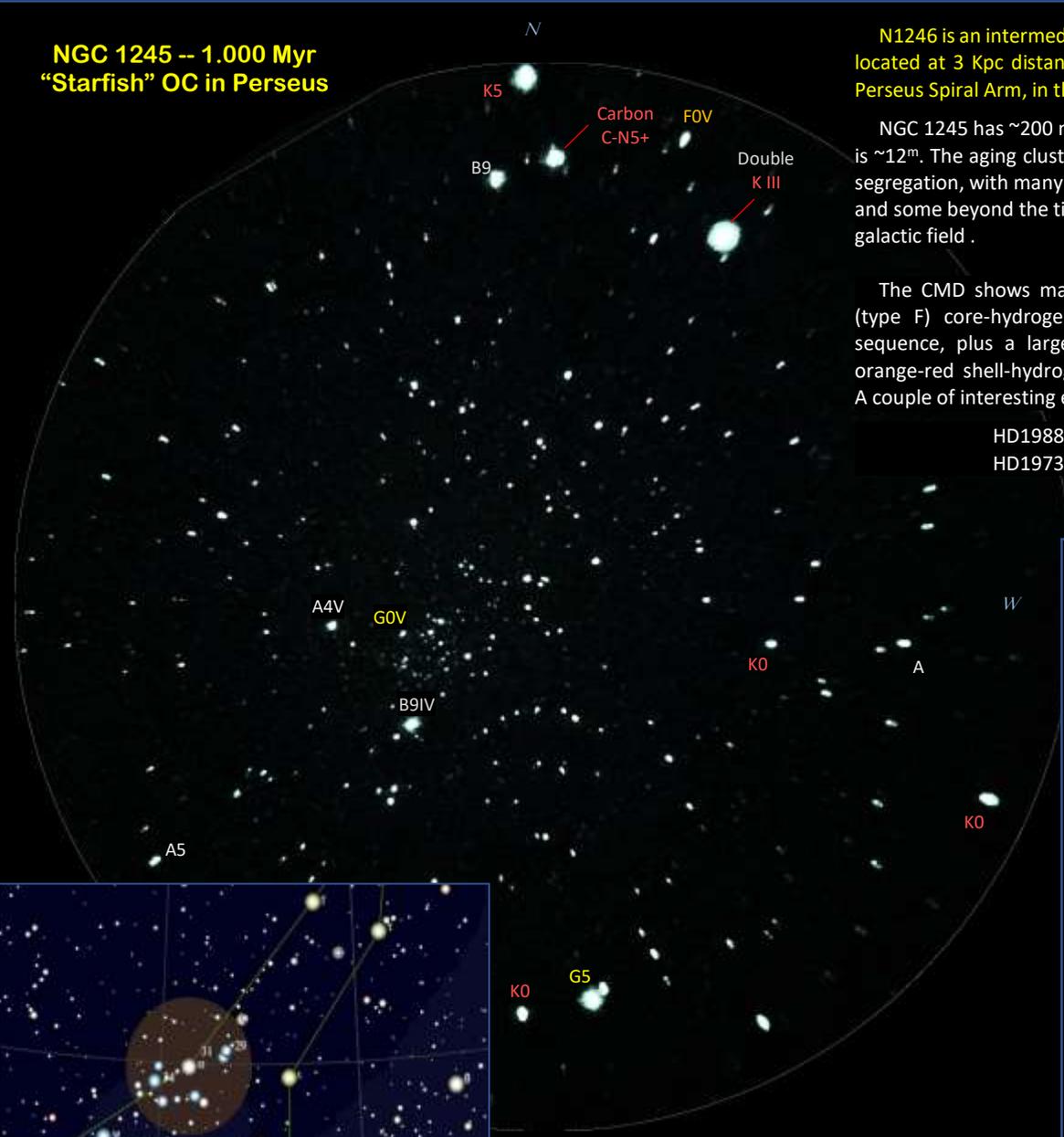
AF> off MS

OC	NGC	Con	Age (Myr)	Dist (Kpc)	Diam	App Mag	Name
H045	N1245	Per	1.000	3.0	10'	8.4	Starfish OC
--	N752	And	1.400	0.4	75'	5.7	C28, Cr23
--	N7789	Cas	1.800	2.3	16'	6.7	Caroline's Haystack
--	N6819	Cyg	2.500	2.3	7'	7.3	Fox Head
M67	N2682	Cnc	4,000	0.9	25'	6.9	Crawfish
King 2	--	Cas	5,000	5.7	5'	17	--

In the age frame [1 – 5 Gyr: the "Retirees"], we find only **one Messier open cluster, the ~4.3 Gyr old M67**, so for this group and the following age frame [OC >5 Gyr: the "Hospice"], I have included a few NGC objects to complete the picture of stellar evolution, as seen through observation of galactic open clusters.

As can be seen from the following observations, the older the OCs get, the more the main sequence turnoff point moves towards lower-mass and cooler stars: from A-F towards K-M stars, with evolved orange/red giants on the red giant branch (RGB), and an increasing number of blue straggler stars (BSS, from stellar mergers) plus white dwarf core remnants (WD).

**NGC 1245 -- 1.000 Myr  
"Starfish" OC in Perseus**

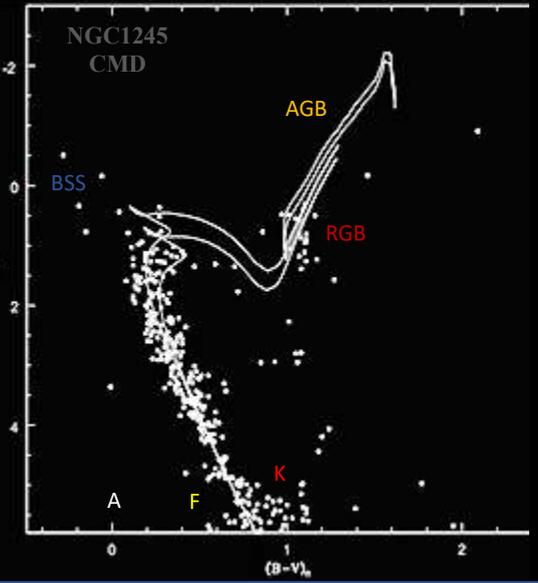


NGC 1245 is an intermediate age OC (around 1 billion yr), located at 3 Kpc distance out on the inner side of the Perseus Spiral Arm, in the direction of, -- well, Perseus!

NGC 1245 has ~200 members, the brightest of which is ~12<sup>m</sup>. The aging cluster shows a high degree of mass segregation, with many lower mass stars out in the halo and some beyond the tidal radius of the OC, lost to the galactic field .

The CMD shows many white (type A) and Orange (type F) core-hydrogen burning stars on the main sequence, plus a large population of more evolved orange-red shell-hydrogen burning stars on the RGB; A couple of interesting evolved stars are:

- HD19881: C.N5+ Carbon Star
- HD19735: Double, A-component K2 III



2021-09-29, 00:45 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.: 15s @ ISO-250

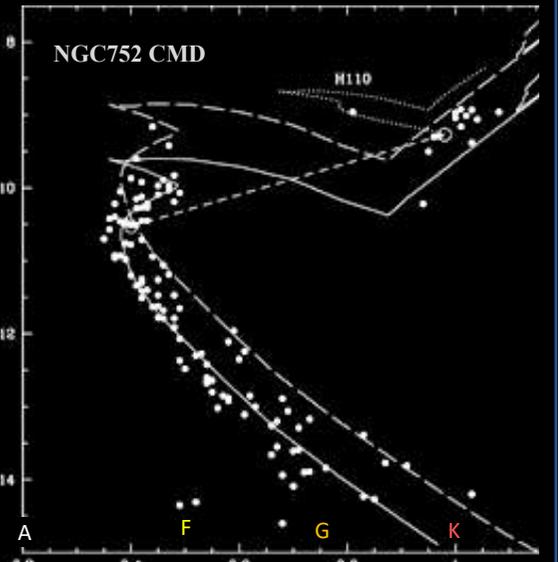


## NGC 752 -- 1.400 Myr OC in Andromeda

N752 is located close by at only 0.4 Kpc in the outer part of our Local Ori-Cyg spiral arm, looking out towards Andromeda. Being close by, the OC is rather large on our night sky (~1.25°) and well resolved in even binos and small telescopes.

N752 is an intermediate age, dissolving cluster with the heaviest stars in the core (through mass segregation), and a tidal disintegration with 90% mass loss of the least massive members to tidal tails.

Looking at the N752 CMD, it is striking that there's an almost complete absence of stars earlier than F2, as is the presence of numerous F-type subgiants (III)

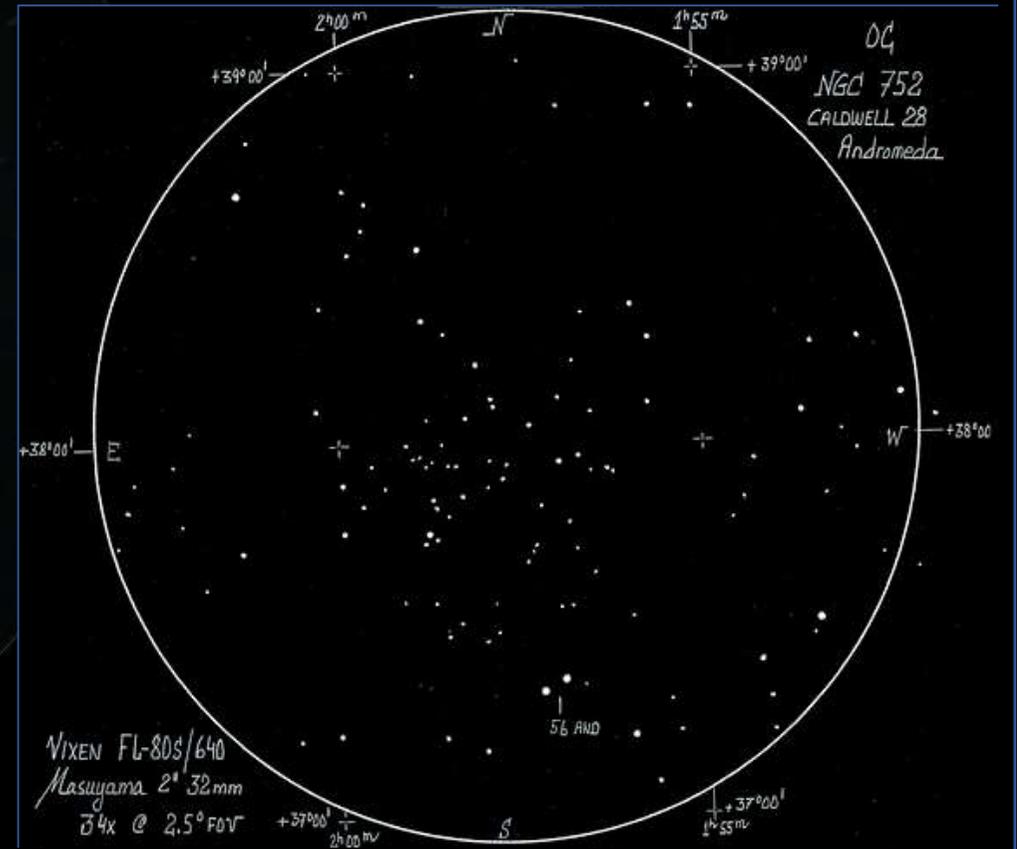


Time: 2016-08-27, 22:30-23:30 UT,  
 Loc.: 56N 12E Denmark, Allerød,  
 Setup: 1.7xGPC + K40/O25/O16mm; R2 live video  
 Transp.: 4/7 (no moon), Seeing: 6/10, Bortle:  
 Orange, bright suburban (SQM 18.6, NELM 5.4m)



2021-09-29, 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.: 30s @ ISO-160



VIXEN FL-80S/640  
 Masuyama 2" 32mm  
 34x @ 2.5° FOV

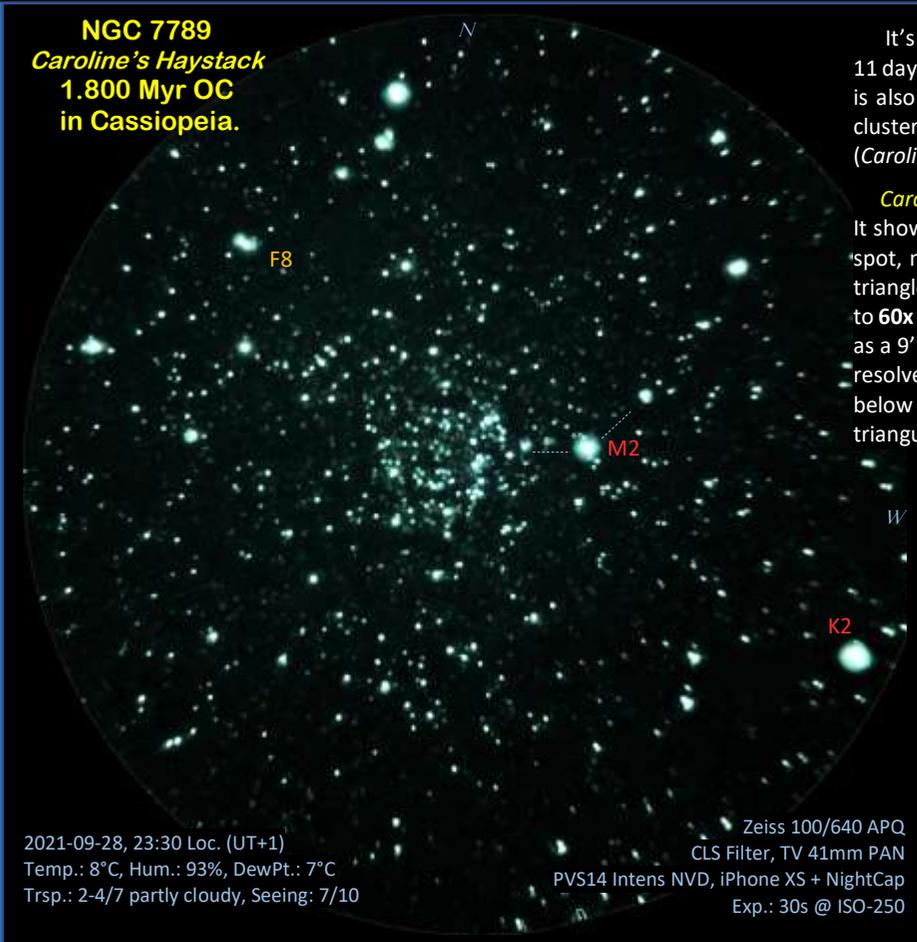
**NGC 7789**  
**Caroline's Haystack**  
**1.800 Myr OC**  
**in Cassiopeia.**

It's a mild mid-September late summer evening, with a 11 day (89%) moon up at 18° Alt in Capricornus. The NELM is also up around 4.8<sup>m</sup> (SQM 17.4), so I choose an open cluster close to zenith as my first target tonight : NGC 7789 (*Caroline's White Rose / Haystack*) in Cassiopeia.

When switching to the **R2 ccd/lcd for 110x @ 0.3° FOV**, the cluster core resolves into a swarm of 13<sup>m</sup>-14<sup>m</sup> stellar points, with small groups of brighter 12<sup>m</sup> stars arranged in a N-S pattern, as a "Needle" in the Haystack. An almost 3D view, very nice!

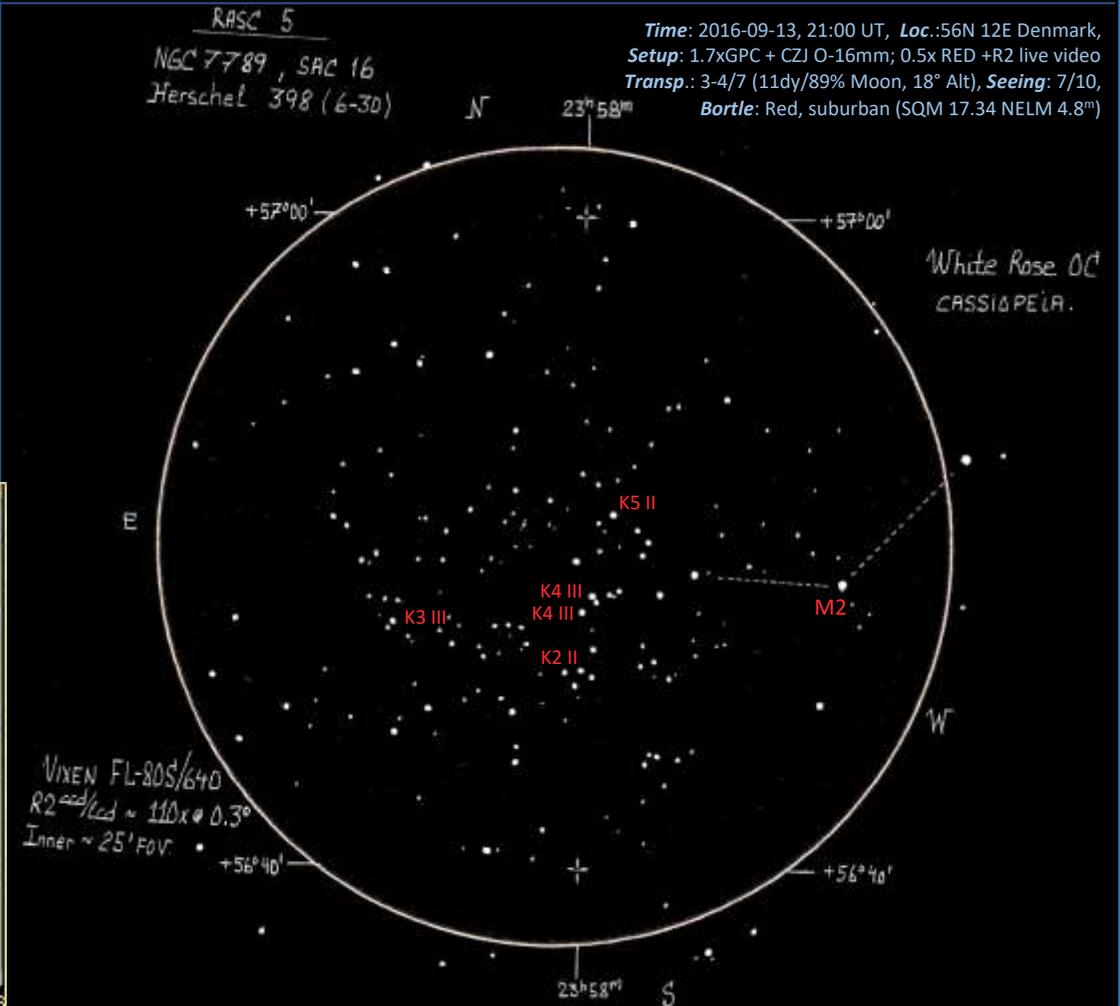
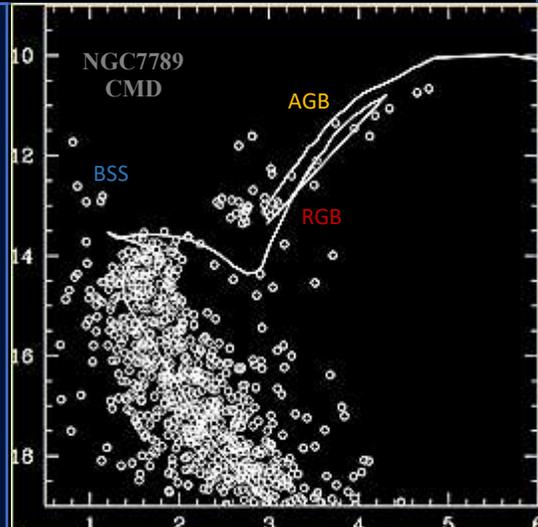
*Caroline's Haystack* is easily located 3° SW of Beta CAS; It shows up in my **10 x 56mm Bino** as a faint, round hazy spot, midway between a pair of 6<sup>m</sup> stars to the N and a triangle of 6<sup>m</sup> stars to the S. Clicking up the magnification to **60x (CZJ O-16mm)**, the OC is seen in my 80mm refractor as a 9' large, round nebulosity with a handful of 11<sup>m</sup> stars resolved in the center plus countless more glimmering just below resolution, with a slight concentration in a triangular core.

**N7789** is a rather distant OC located at 2.3 Kpc out in the gap from our Local spiral arm towards the Perseus Arm. Over 50 light-years across, *Caroline's Rose* spans about half a degree in the sky (the angular size of the moon). Its loops of stars and dark lanes look like the swirling pattern of rose petals as seen from above. The many orange/red giant stars give the cluster a yellowish cast, like a haystack; -- I've marked a few of these evolved giants in the "red clump" on the RGB in my photo and drawing.



2021-09-28, 23:30 Loc. (UT+1)  
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 Trsp.: 2-4/7 partly cloudy, Seeing: 7/10

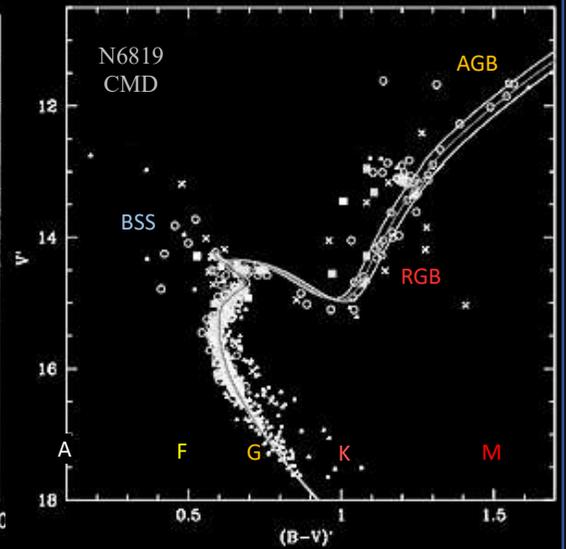
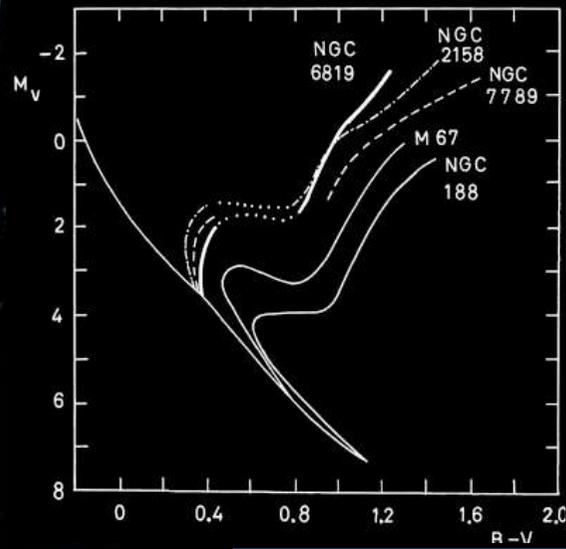
Zeiss 100/640 APQ  
 CLS Filter, TV 41mm PAN  
 PVS14 Intens NVD, iPhone XS + NightCap  
 Exp.: 30s @ ISO-250



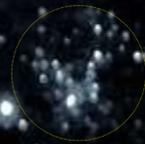
**NGC 6819**  
**"Fox Head"**  
**a 2500 Myr OC**  
**in Cygnus**

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

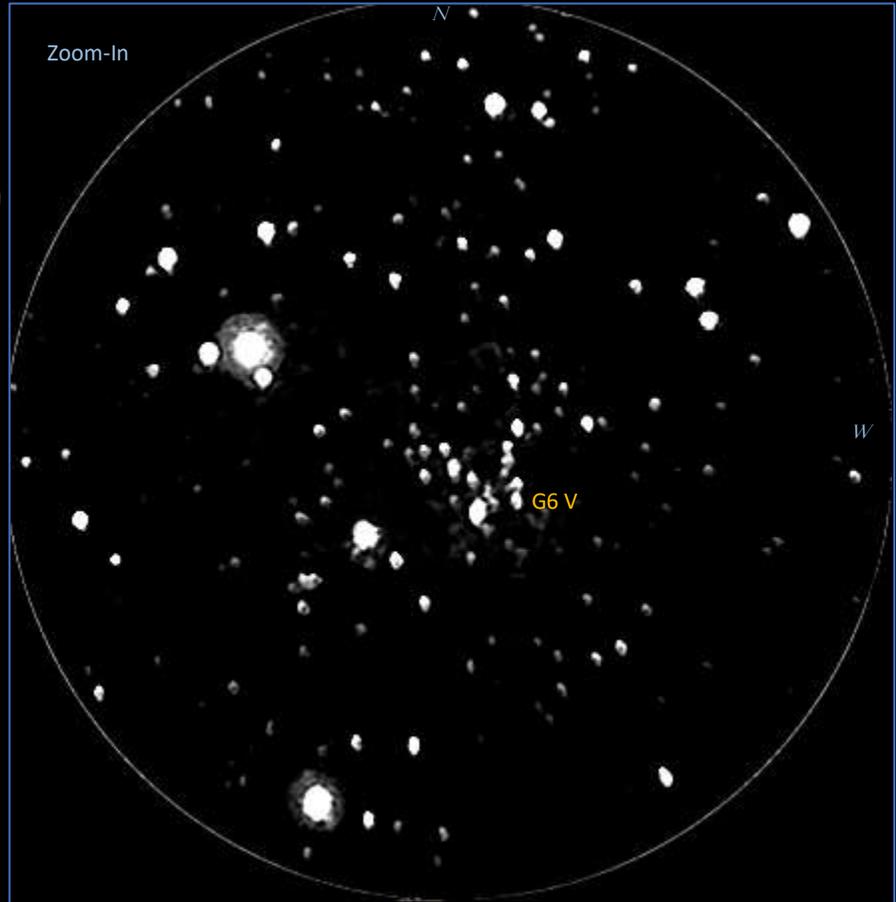
Zeiss 100/640 APQ  
 CLS Filter, TV 41mm PAN  
 PVS14 Intens NVD, iPhone XS + NightCap  
 Exp.: 20s @ ISO-160



E



Zoom-In

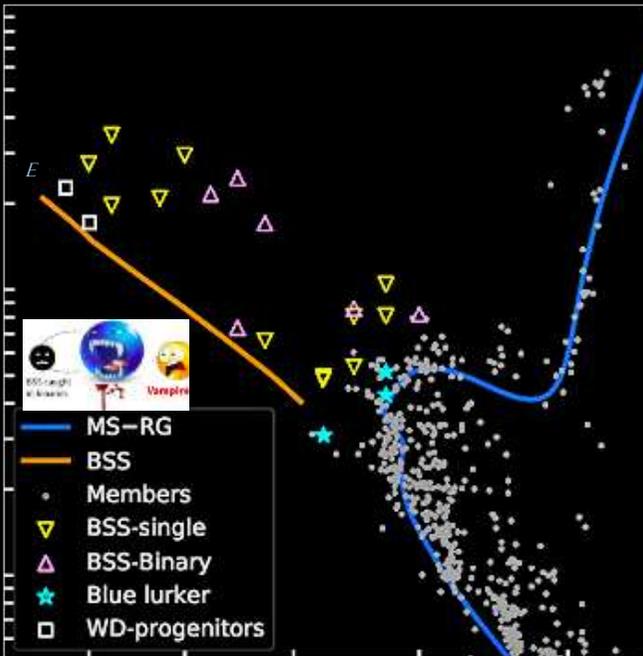


NGC 6819 is a 2.5 Gyr aging OC located at 2.3 Kpc distance, up our Local spiral arm, towards Cygnus. It is a rich but tight (~5' diameter) open cluster.

There is a large population of evolved orange/red giants on the RGB, and also many blue straggler stars (BSS). The old OC shows mass segregation, with the lower mass MS-stars out in the periphery (or dissipated as field stars).



# M67, 4.300 Myr old OC in Cancer



## CM diagram of M67

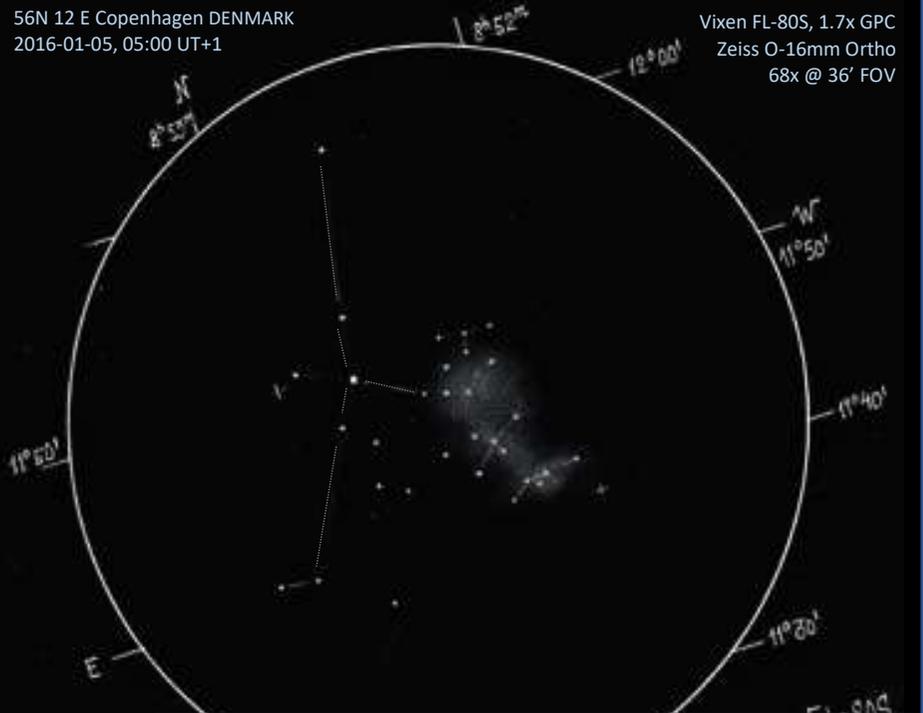
M67 is a rich (>500 stars) and old (~4 Gyr) OC, located very close to our solar system, only 0.9 Kpc down our Local spiral arm towards the Cancer constellation.

All of the high mass O, B, and A stars have used up their core hydrogen, so we don't see any of these on the HR main sequence. Almost all the bright stars in M67 are RGB stars, with some BSS stars in between, predominantly located near the cluster center (mass segregation). The MS starts at type-F, and has many (>20) type G stars of the same age and composition as our Sun. M67 has a large population (~150) of burnt out WD stars.

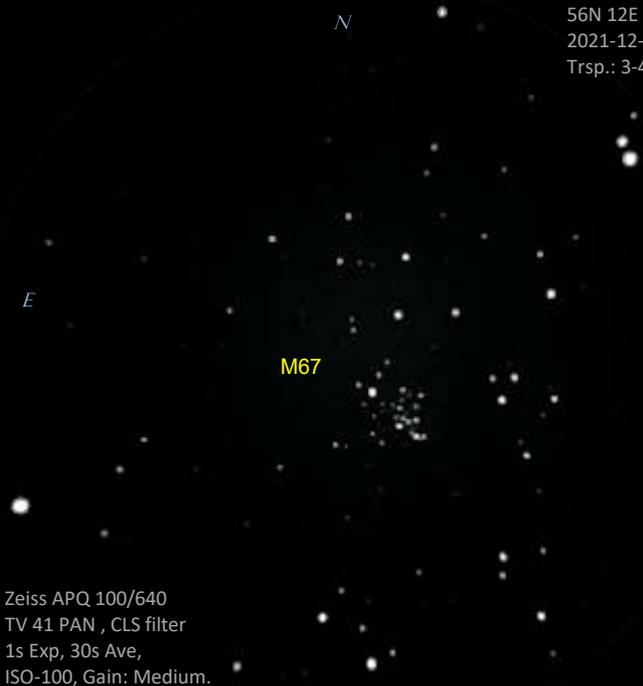
<- Signatures (ESO GAIA DR2):  
 Triangles: BSS single and BSS+WD binaries  
 Stars: blue lurker binaries of BL+WD  
 Squares: progenitors of the heaviest WDs

56N 12 E Copenhagen DENMARK  
 2016-01-05, 05:00 UT+1

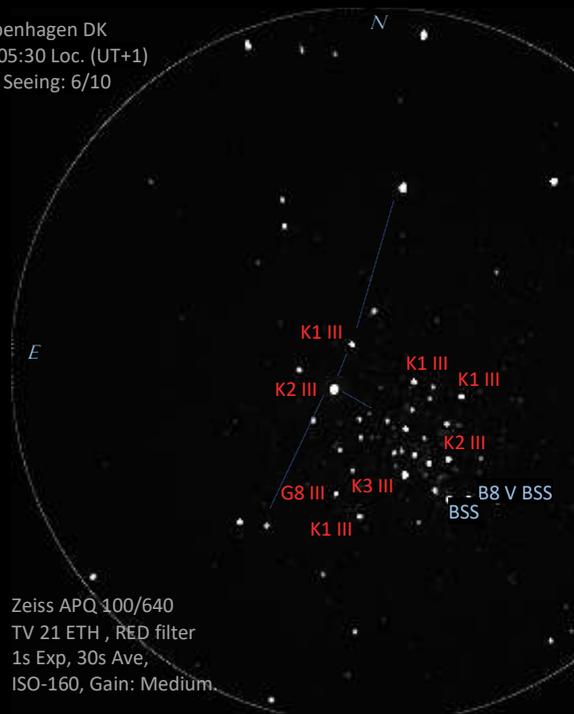
Vixen FL-80S, 1.7x GPC  
 Zeiss O-16mm Ortho  
 68x @ 36' FOV



56N 12E Copenhagen DK  
 2021-12-27 05:30 Loc. (UT+1)  
 Trsp.: 3-4/7, Seeing: 6/10



Zeiss APQ 100/640  
 TV 41 PAN, CLS filter  
 1s Exp, 30s Ave,  
 ISO-100, Gain: Medium.



Zeiss APQ 100/640  
 TV 21 ETH, RED filter  
 1s Exp, 30s Ave,  
 ISO-160, Gain: Medium.

In my K-40mm finder eyepiece (27x @ 1.5° FOV), I can hold α Cnc (*Acubans*) at the E edge and M67 at the W edge of the field; I center now on M67 and click up the magnification to the O-16mm eyepiece for 68x @ 36' FOV; This nicely frames the 25' wide cluster, with the bright 7.8<sup>m</sup> orange (class K2 III) star to the E and a stellar clump around a small triangle of 10<sup>m</sup> stars to the W. Others have imagined the cluster as a King Cobra (with the triangle clump forming the head) – but in my 80mm refractor I rather see a Crawfish (Spiny Lobster) with the triangle as the bent abdomen, an oval to the NE forming the carapax, and the bright central K2 III star as a spiny head, with two long antennae extending N and S.

The many unresolved stars forming the compact nebulous crustacean body make this cluster interesting to explore visually, and the old age and diverse composition of the stellar population only increases the interest.

M67 is a rather close (2.6 KLY), compact (25' ~ 21 LY) and old (4 GYR) star cluster– in fact the oldest OC in the M-catalogue.

- The *Pleiades*, (80 MYR) has no O-stars, but plenty of B-stars.
- *Praesepe* (600 MYR) has no O-or-B-stars, but plenty of A-stars.
- But *M67* is so old, that it does not even have any stars of type-A left. M67 contains >500 stars, of which ca 1/5 are sun-like type G, and the “bluest” type is of class F. The ~30 blue stars in M67 are not original, main-sequence stars, but rather blue straggler stars (BSS), i.e., stars that have formed from the merger of lower-mass stars at the core of the cluster. M67 contains many red giants and ~150 white dwarfs.

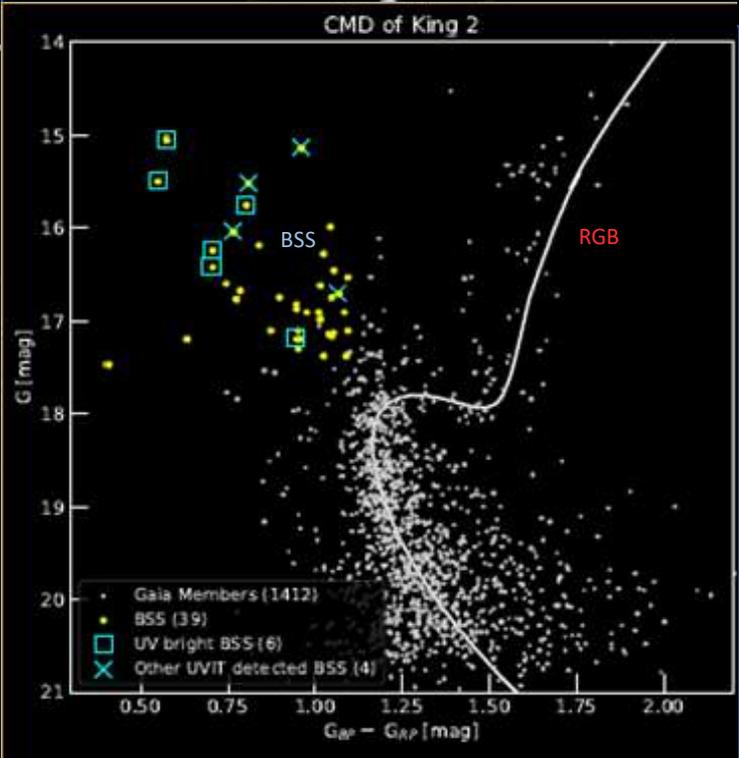
**King 2**  
5.000 Myr

56N 12E Copenhagen DK  
2021-10-09 01:15 Loc. (UT+1)  
Trsp.: 3-4/7, Seeing: 6/10

The old open cluster *King-2* is located at a considerable distance of  $\sim 5.7$  Kpc in the inner Perseus Arm towards the galactic anticenter in Cassiopeia.

At the age of  $\sim 5-6$  Gyr, K2 has a MS turn-off mass of  $\sim 2$  solar, which results in a mild core He-ignition with an extended RGB. There is also a large population of  $\sim 39$  Blue Straggler Stars (BSS) in this old OC, which have formed by white dwarfs stripping mass from an expanding post-MS companion in a close binary system (the early phase of such a mass-stripping binary has been identified as "blue lurkers").

K2 is observed here at low magnification (around 30x), and as the OC is distant and of small diameter, the resolution in these images is rather poor.



Eta Cas

Zeiss APQ 100/640  
TV 21 ETH, CLS filter  
1s Exp, 30s Ave,  
ISO-160, Gain: Medium.