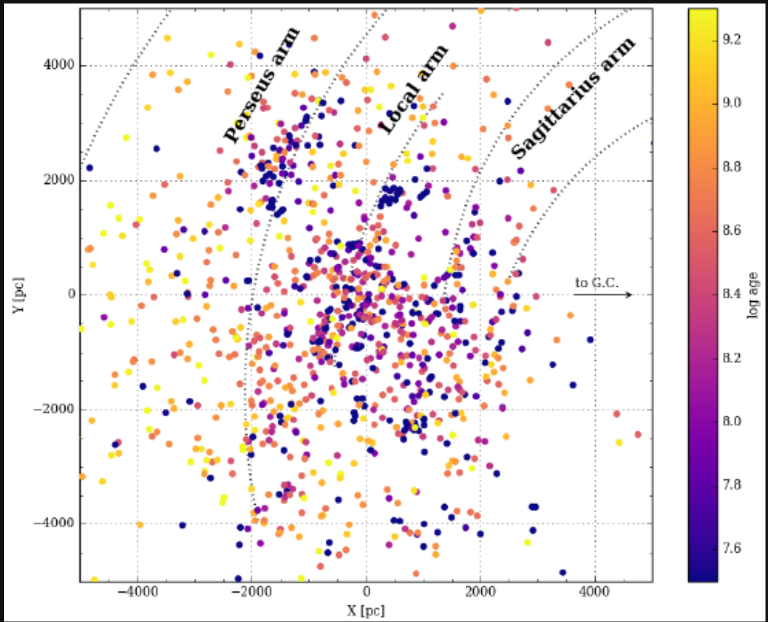
Messier Open Clusters

The process of galaxy formation is still an active research area; By studying the timescale for the formation of different Milky Way stellar populations (halo, bulge, thick and thin disc) astronomers are beginning to understand the astrophysics of this process. As seen in my previous description of Messier emission nebulae, star formation takes place by mass and magnetic dynamic resonance, turbulence and gravitational collapse deep inside long filaments of primordial clouds of galactic hydrogen-gas and dust.

Homogeneous groups of stars with the same initial composition, distance and kinematics are born and co-evolve, partly as open star clusters in the thin disc, and partly as globular clusters in the halo, thick disc and bulge. The majority of these bound stellar systems are being disrupted in their first few million years of existence through gas-stripping and gravitational disturbance caused by stars as well as giant molecular clouds (GMC). Disturbed clusters end up as unbound stellar streams dispersing into the field stars in the galactic arms, but a fraction of the open clusters survives the embedded phase in star-forming nebulae and remain bound over longer timescales.



Here's a recent plot (Gaia DR2, ESO 2018) of the location of 1229 OCs out to 4 Kpc from the solar system, projected on the Galactic plane: The OCs are colour-coded by age, and superimposed on the plot is the spiral arms of our Milky Way.

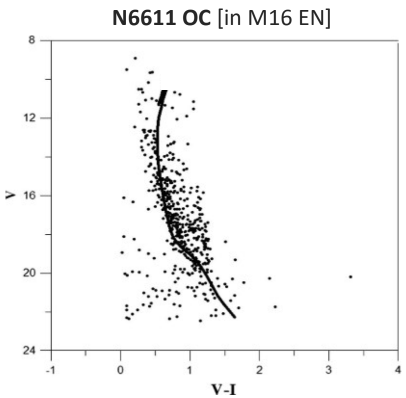
It is seen that the many young OCs are still located mostly in filaments tracing the galactic spiral arms, while the fewer older OCs (those that have not long ago become unbound and dispersed as field stars) are now found more uniformly scattered across the galactic plane, with a skew towards larger galactocentric distances.

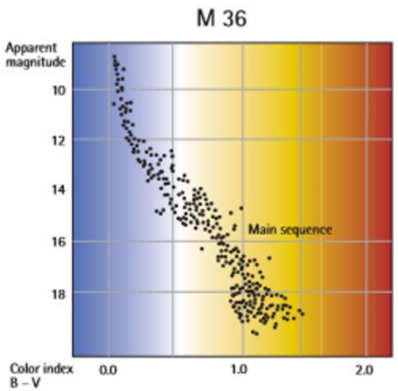
The Messier OCs range from new-born proto-OB associations such as the one found embedded in M20 (0.4 Myr), past young clusters like M36 (25 Myr) to mature clusters like M23 (300 Myr), to aging clusters like M93 (390 Myr) and to the ancient Messier cluster M67 (4000 Myr). In my following observation reports I'll share an evolutionary view of the Messier open clusters, and also include a few interesting very young and very old OCs.

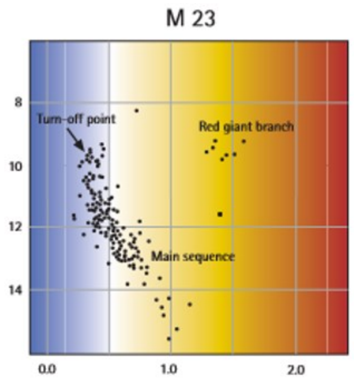
The age and evolution of OCs is best illustrated by Hertzsprung-Russel diagrams (HRD) showing the relationship between the cluster stars' spectral types (aka temperature aka colour index) and their luminosity (aka mass). I'll include HRDs for the OCs that are most representative of the evolutionary stages in the Milky Way population of the open clusters.

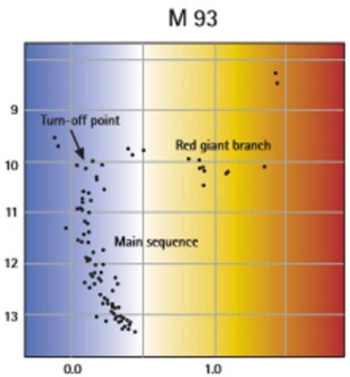
A Gaia DR2 view of the Open Cluster population in the Milky Way.
T. Cantat-Gaudin et al, A&A manus, July 13, ESO 2018

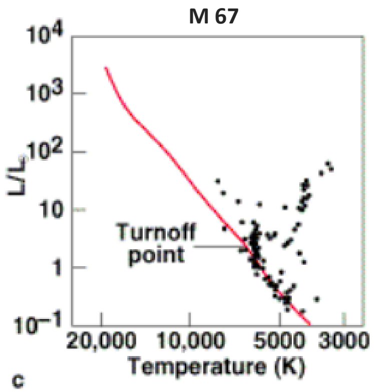
The age of the oldest Open Clusters.
M.Salaris et. Al., A&A 414 163-174, ESO 2004









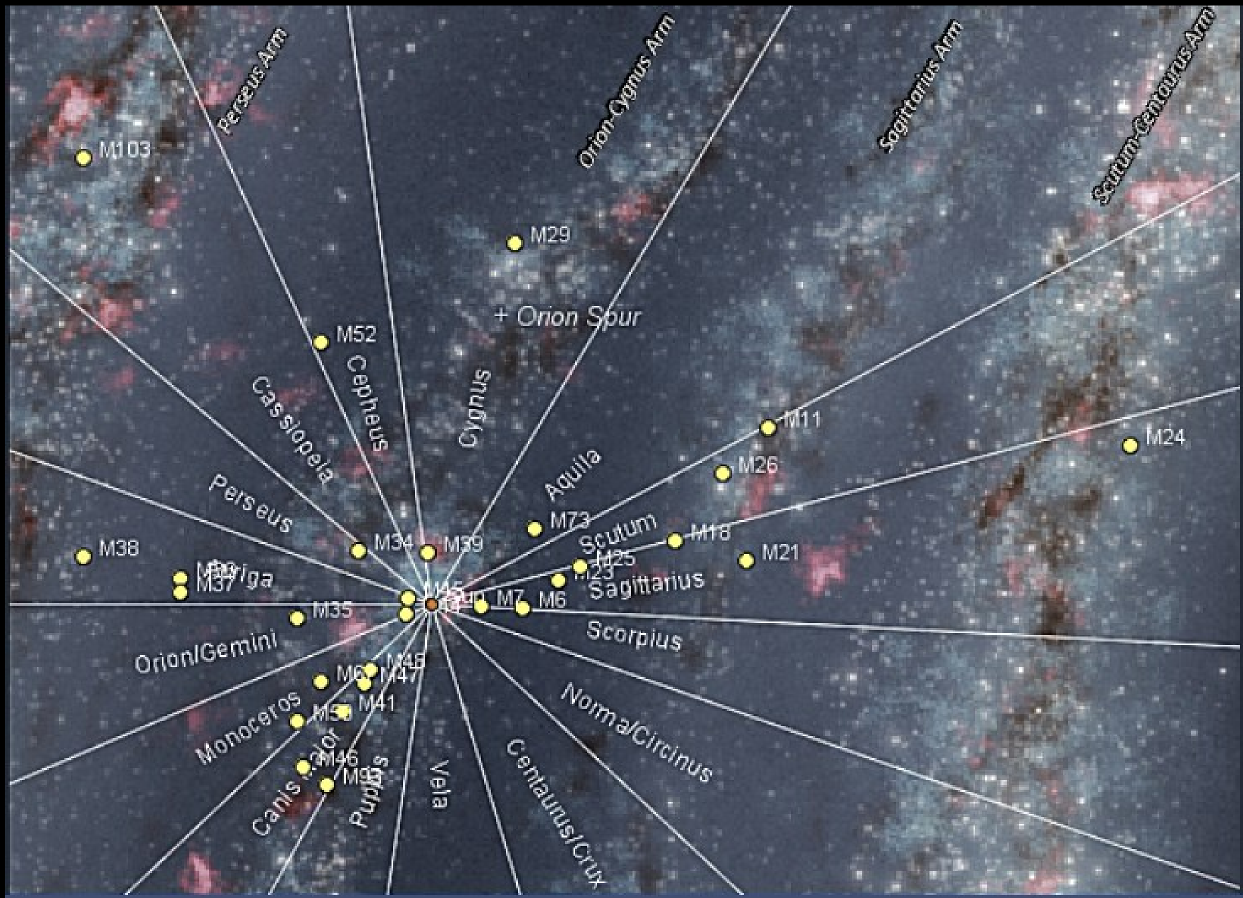


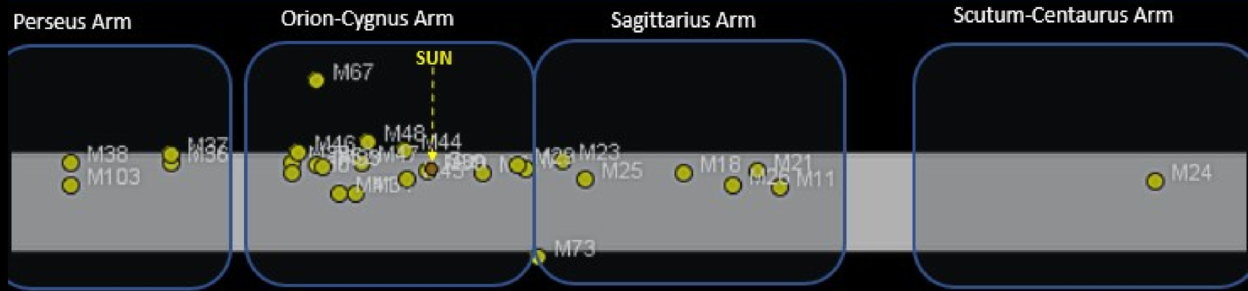
2: Open Clusters [26+2] + 4EN

OC	NGC	Con	Myr	pc	Name	Galaxy Arm
M24	I4715	Sgr	220	3070	SgrCloud	Scu-Cen
M17	N6618	Sgr	1	2200	Swan-OC	Sgr Arm
M11	N6705	Scu	250	1900	WildDuck	
M16	N6611	Ser	1.3	1800	Eagle-OC	
M08	N6530	Sgr	2	1600	Lagoon-OC	
M20	N6514	Sgr	0.4	1600	Trifid-OC	
M26	N6694	Scu	85	1600	Pufball	
M18	N6613	Sgr	17	1296	BlackSwan	
M21	N6532	Sgr	12	1205	Firefly	
M25	I4725	Sgr	92	613	Beetle	Interarm
M23	N6494	Sgr	300	628	Bat	
M06	N6405	Sco	94	487	Butterfly	
M07	N6475	Sco	224	280	Ptolemy	
M29	N6913	Cyg	10	1800	Llama	Ori-Cyg
M44	N2632	Cnc	830	187	Beehive	
M45	Cr42	Tau	125	136	Pleiades	
M40	WNC4	UMa		140	Double-Star	
---------------SUN---------------------						
M39	N7092	Cyg	280	311	Triangle	Ori-Cyg
M47	N2422	Pup	73	490	The-Q	
M34	N1039	Per	180	499	French-Lilly	
M41	N2287	CMa	240	710	Tiny-Beehive	
M48	N2548	Hya	400	770	The-Lambda	
M67	N2682	Cnc	4000	908	Crawfish	
M35	N2168	Gem	180	912	Ram's-Head	
M50	N2323	Mon	130	1000	The-S	
M93	N2447	Pup	390	1037	Arrow-Head	
M46	N2437	Pup	250	1510	The-Sieve	
M36	N1960	Aur	25	1330	WaterFlea	Interarm
M37	N2099	Aur	347	1400	The-Tick	
M52	N7684	Cas	160	1400	Spider	
M38	N1912	Aur	316	1400	JumpingFrog	Per
M103	N581	Cas	16	3000	The-Fan	

1: Emission & Reflection Neb. [4+3]

M	NGC	Name	Sagittarius Arm
M08	N6523	Lagoon-Neb.	Sgr
M16	I4703	Eagle-Neb.	Sgr
M17	N6618	WhiteSwan-Neb	Sgr
M20	N6514	Trifid-Neb	Sgr
M	**NGC**	**Name**	**Orion-Cygnus Arm**
M42	N1976	Great Orion	Ori
M43	N1982	De Marian	Ori
M78	N2068	Frosty Window	Ori

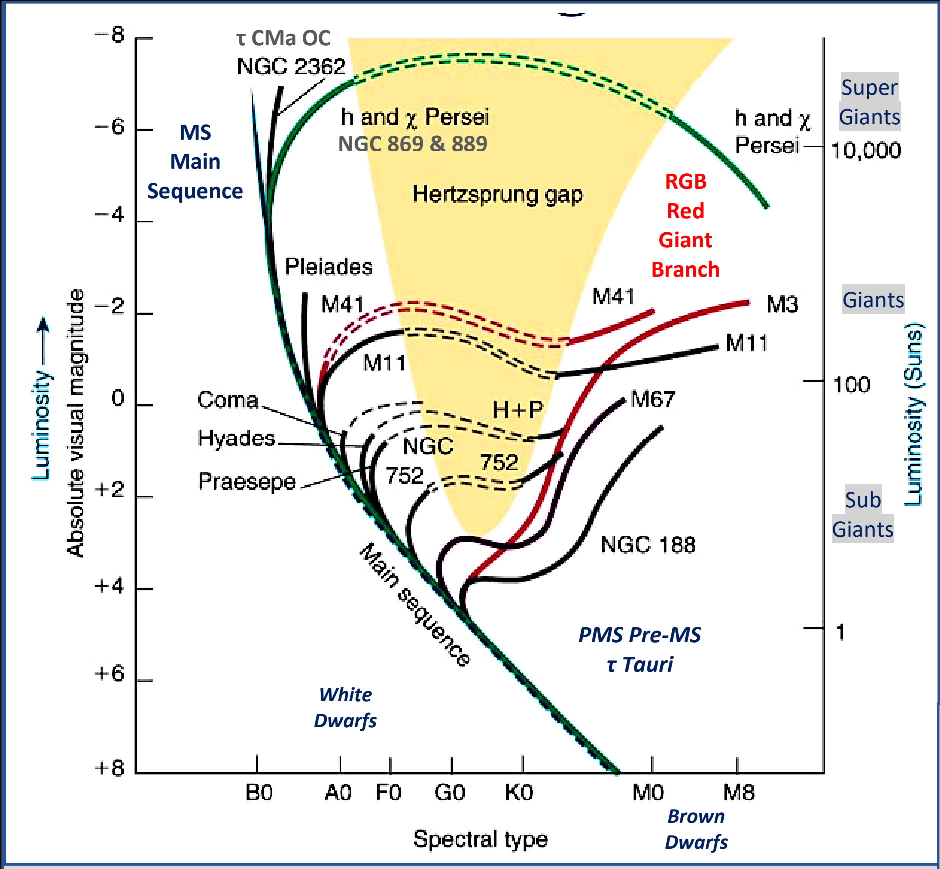




Per Arm	Inter Arm Gap	Ori-Cyg Arm		Inter Arm Gap	Sgr Arm	Inter Arm Gap	Scu-Cen Arm
CAS M103 AUR M38	CAS M52 AUR M36 M37	CYG M29 M39 PER M34 TAU M45 GEM M35 MON M50	CMa M41 CNC M44 M67 PUP M46 M47 M93 HYA M48	AQL M73 SGR M23 M25 SCO M06 M07	SCU M11, M26 SGR M21, M18 M17, M16 M08, M20		[SGR M24]

OC	NGC	Con	Age (Myr)	Dist (Kpc)	Diam	App Mag	Name
M24	I4715	Sgr	220	3,070	90'	4.6	Sgr_Star_Cloud
M40	WNC4						Double_Star
			1: Age (Myr) T~0			Kindergarten	OB-Assoc.
M20	N6514	Sgr	0.4	1.6			Trifid
M17	N6618	Sgr	1	2.2	46'	6	White_Swan
M16	N6611	Ser	1.3	1.8	6'	6	Eagle
M08	N6530	Sgr	2	1.6	10'	7	Lagoon
---	N2362	CMa	5	1.5	6'	4	τ CMa OC
			2: Age (Myr) 10 -100			Teenagers	O>Supernova
M21	N6532	Sgr	12	1.2	14'	5.9	Firefly
---	N869-884		13	2.3			h – ξ Per double OC
M103	N581	Cas	16	3.0	5'	7.4	The_Fan
M18	N6613	Sgr	17	1.3	5'	6.9	Black_Swan
M36	N1960	Aur	25	1,3	10'	6	Water_Flea
M47	N2422	Pup	73	0.5	25'	4.4	The Q
M26	N6694	Scu	85	1.6	7'	8	Pufball
M29	N6913	Cyg	90	1.8	8'	8	Llama
M25	I4725	Sgr	92	0.6	30'	4.6	Beetle
M06	N6405	Sco	94	0.5	20'	4.2	Butterfly
			3: Age (Myr) 100 – 1000			Boomers	B>Supernova
M45	Cr42	Tau	125	0.14	120'	1.2	Pleiades
M50	N2323	Mon	130	1.0	14'	5.9	The_S
M52	N7684	Cas	160	1.4	15'	6.9	Spider
M34	N1039	Per	180	0.5	36'	5.2	French_Lilly
M35	N2168	Gem	180	0.9	25'	5	Ram's_Head
M07	N6475	Sco	224	0.3	80'	3.3	Ptolemy
M41	N2287	CMa	240	0.7	40'	4.5	Tiny_Beehive
M46	N2437	Pup	250	1.5	20'	6.1	The Sieve
M11	N6705	Scu	250	1.9	13'	5.8	Wild_Duck
M39	N7092	Cyg	280	0.3	30'	4.6	Triangle
M23	N6494	Sgr	300	0.6	30'	5.5	Bat
M38	N1912	Aur	316	1.4	20'	6.4	Jumping_Frog
M37	N2099	Aur	347	1.4	14'	5.6	The_Tick
M93	N2447	Pup	390	1.0	10'	6.2	Arrow_Head
M48	N2548	Hya	400	0.8	30'	5.8	The_λ
M44	N2632	Cnc	830	0.2	70'	3.1	Beehive
			4: Age (Myr) 1000-5000			Retirees	AF> off MS
M67	N2682	Cnc	4,000	0.9	25'	6.9	Crawfish
			5: Age (Myr) >5000			Hospice	G> off MS
--	N6791	Cyg	13.000				

Proto OB Associations within Emission Nebulae



1. Early the star cluster's formation (T=0), some of the lower mass stars are still in the τ Tauri phase while some of the high-mass stars have reached the Main Sequence. (N2368,
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.

MASS (solar masses)	SPECTRAL TYPE ON THE MAIN SEQUENCE	PERIOD OF CONTRACTION TO MAIN SEQUENCE (10^6 yrs)	ESTIMATED LIFETIME ON THE MAIN SEQUENCE (10^6 yrs)	PERIOD FOR MAIN SEQUENCE TO RED GIANT (10^6 yrs)	RED GIANT DURATION (10^6 yrs)
30	O5	0.02	4.9	0.55	0.3
15	B0	0.06	10	1.7	2
9	B2	0.2	22	0.2	5
5	B5	0.6	68	2	20
3	A0	3	240	9	80
1.5	F2	20	2,000	280	
1.0	G2	50	10,000	680	
0.5	M0	200	30,000		
0.1	M7	500	10^7