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A Cosmic Tarantula, Caught by NASA's James Webb Space Telescope

In this new mosaic image stretching 340 light-years across, the James Webb's Near-Infrared Camera (NIRCam) displays the Tarantula Nebula star-forming region in a new light, including tens of thousands of never-before-seen young stars that were previously shrouded in cosmic dust. The most active region appears to sparkle with massive young stars, appearing pale blue.
Credits: NASA, ESA, CSA, STScI, Webb ERO Production Team

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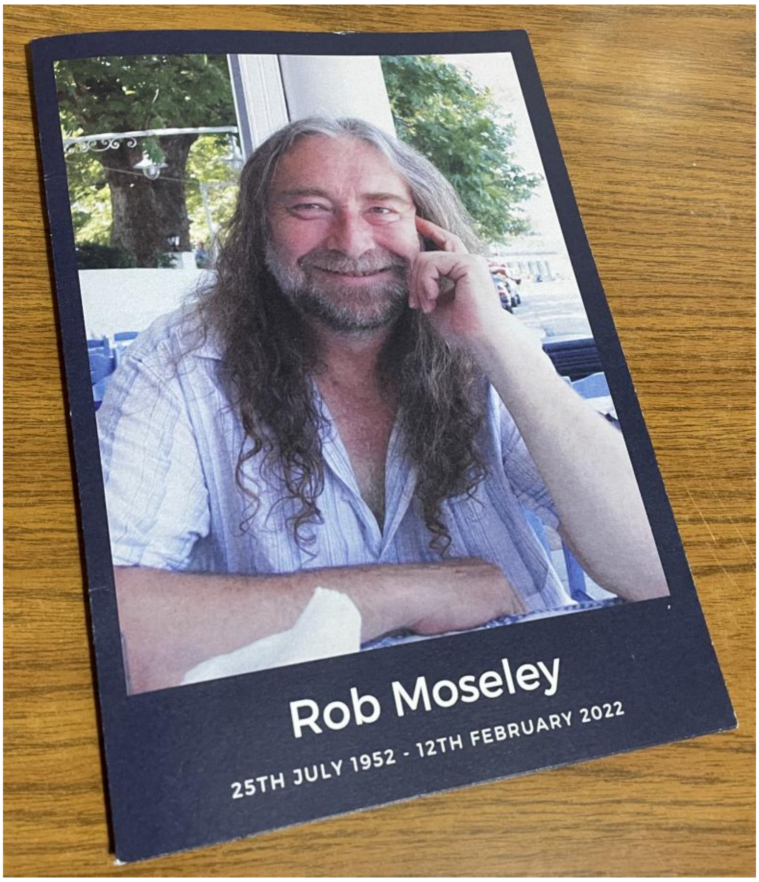
Memories of Rob Moseley

Many of our older members will remember Rob Moseley who died last February after a long illness aged 69. He was married to Lesley and had two children. He was quite a character with long hair and a beard and had many hobbies and interests even though his main interest was astronomy. He attended the C&WAS for many years and was a keen observer with his own observatory in his garden with a run-off roof. He also used the Technical College Observatory at the Butts which had a 6½" Cooke refractor in a dome located on the roof of the main building. Rob was the first editor of MIRA in December 1982 and continued for two years before handing over to Richard Barrett who did 3 issues before Vaughan Cooper took over in February 1986. Rob continued to send observational reports into MIRA and also drawings and notes for many years until 1989, particularly double star measures and observations. He also belonged to the BAA Lunar Section and was the editor of the sections publication, *The New Moon* from May 1986 to 1991. He also joined the Webb Society and one of his last reports was a paper in the *Webb Deep-Sky Society Double Star Section Circular No 27*, with Martin Grahn on double star measures made during 2016-18 from his observatory in Coventry.



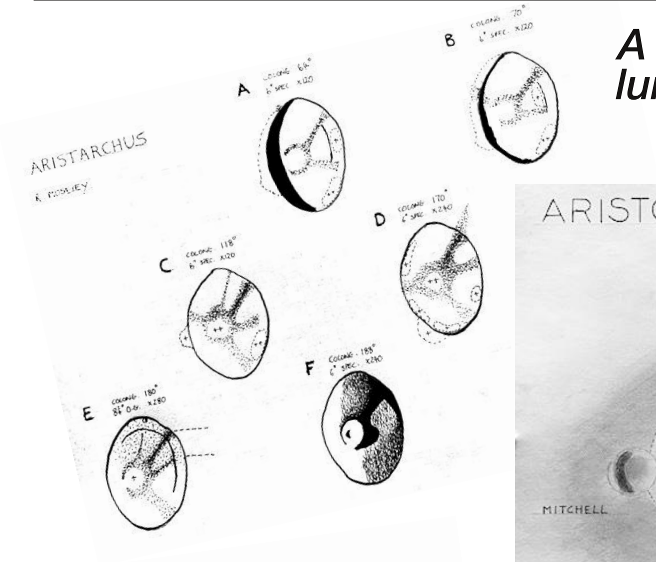
Rob also contributed to the *Sky & Telescope* magazine section *Deep-Sky Wonders* by Walter Scott Houston with a mention in a book of the same name:

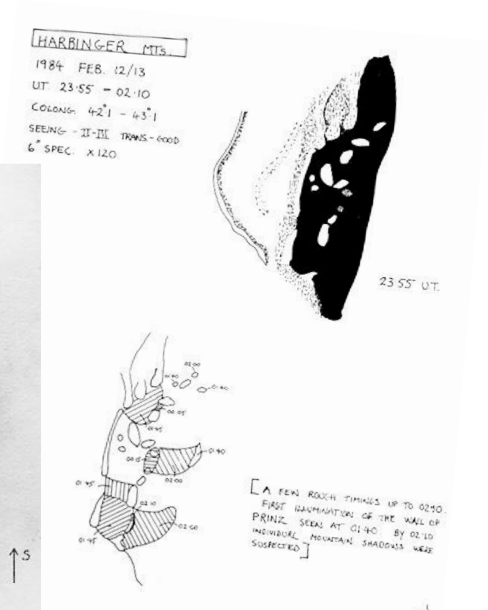
One of the great pleasures of deep-sky observing is the individuality that certain objects acquire in the eyepiece. I'm always delighted to learn that someone sees an object in a new perspective. One such example comes from Robert Moseley of Coventry, England, who tracked down NGC 6804 while testing a new 10-inch f/6 reflector. His best view was at 120x. He writes, "It gives the impression of a highly condensed but partially resolved cluster. It is a faintish oval nebulosity with a 12th-magnitude star toward its northeast edge. With averted vision at least one other star could be seen superimposed on it." Moseley questioned the 13th magnitude I had given for NGC 6804 in an earlier column. Published magnitudes for planetary nebulae cause many disagreements, and I believe it is best "to slightly mistrust all of them and to record your own magnitude estimates with your notes."

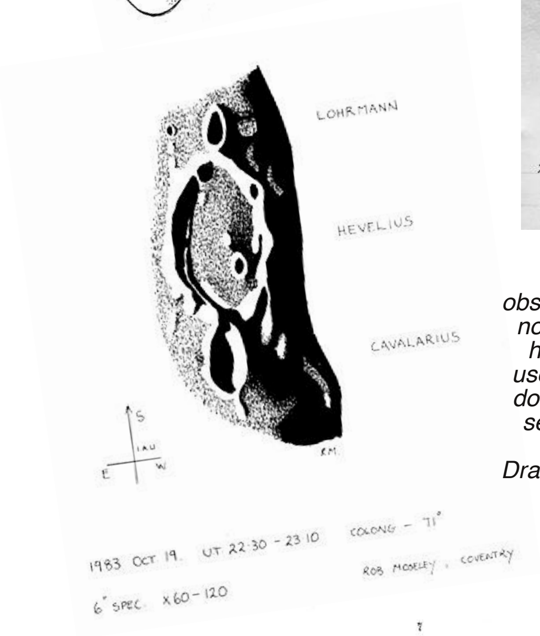
Geoffrey Johnstone remembered several things about Rob.

"He was a very good chairman, and very knowledgeable on astronomical matters. When Halley's comet came round I was one of the earliest to photograph it and Rob organised an event inviting the local Mayor, who was clearly out of her depth, and didn't have a clue what a comet was. Also the keynote speaker to coincide with the apparition was Allan Chapman. I remember giving the vote of thanks and he was then given a tour of the observatory on the roof of the college. Finally I was out observing one evening and there was an amazing aurora. I phoned Rob and asked him if he was going out observing that evening. He said in a rather depressed tone that he wasn't up to it for some reason. I told him he should be out as he was missing something. He brightened up and said which direction should he look. I told him to look north. At the next meeting he was full of it, but we were the only two members who saw it, but it made the local paper, big time.

A few of Rob's lunar drawings

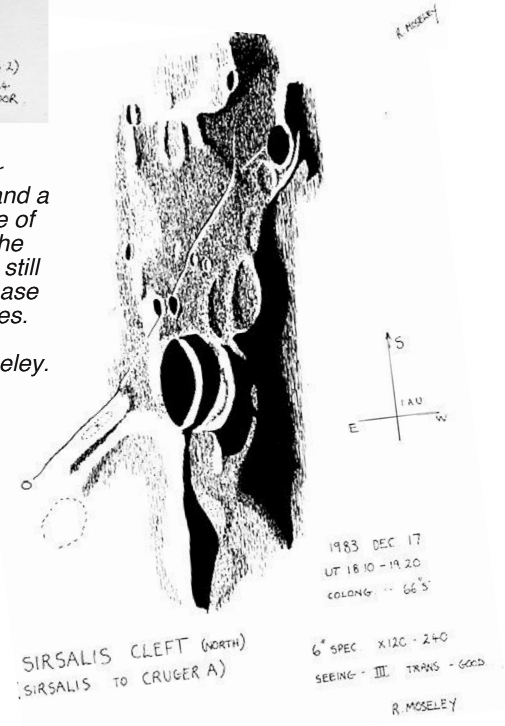


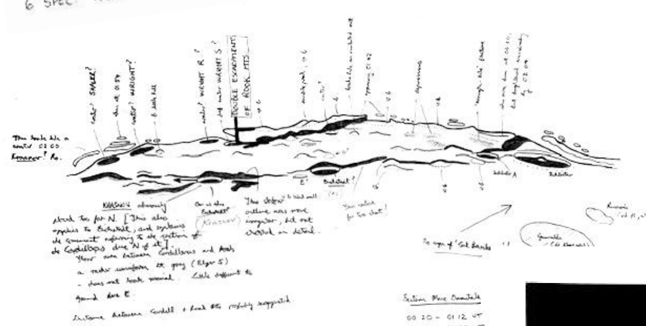


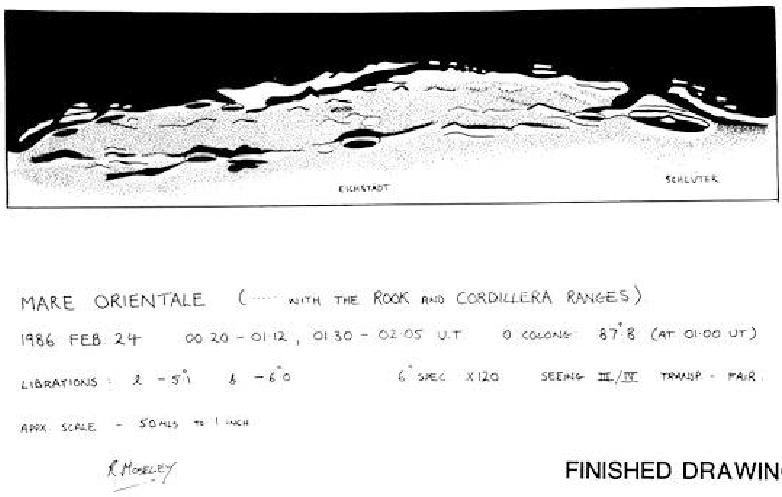


Rob was one of the old school lunar observers, with an eye at the eyepiece and a notebook and pencil. He finished some of his observations in ink and for others he used pencil drawing. Do any members still do drawings at the telescope? If so please send them in with any observation notes.

Drawings kindly provided by Lesley Moseley.







FINISHED DRAWING

Star Clusters

By Paritosh Maulik

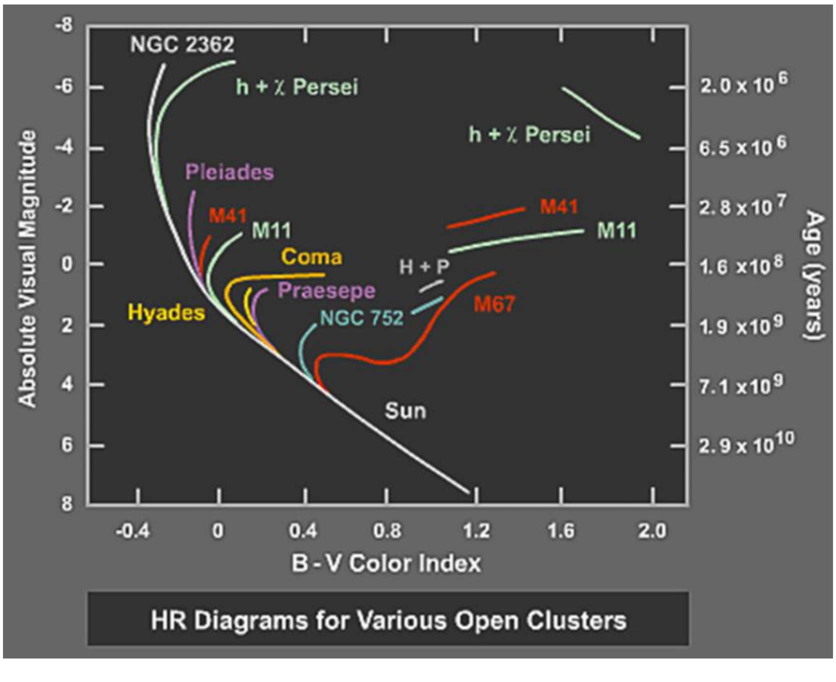
When we look up at the night sky unaided, we see stars and planets. We join the stars, dot to dot in the sky, we imagine patterns and name them. To us these patterns move across the sky; for example Orion, Hercules, Leo and Cassiopeia to name a few. Then there are clusters of stars like the Pleiades. It does not form a pattern, but even with a binocular the we see reasonably spaced blue white stars in a gaseous nebula. This is an open star-cluster; the stars are gravitationally bound. Also there are some fuzzy objects seen under low magnification. With a reasonably powered telescope we can resolve these as a massive collection of stars. These are the globular clusters. Stars in both of these clusters form from a molecular cloud and formed at the same time. Although most the stars in the clusters formed at the same time, they have different masses and hence different life spans. Studying the star-clusters gives us the opportunity to see the evolution of stars.

Asterism

We tend to group stars in the sky as a pattern. These stars appear to move across the sky as a group. But in reality these stars are not in a group or collection. Only due to their relative locations from the Earth these stars appear as a group. These are not gravitationally bound, the technical name is an asterism. Examples, the Plough, the Coathanger (Brocchi's Cluster; also known as Collinder 399, Cr 399 or Al Sufi's Cluster), Cassiopeia and most the constellations.

Star System

Often two (or more) stars rotate around each other; there is no tidal effect or no other forces and no mass exchange between the stars. These are called double star systems. Such systems are common with binary or two star systems. However there are some examples of star systems with more than two stars as appear from the Earth. The stars may be gravitationally bound, these are multiple star systems and the stars may appear physically close. Stars systems with three stars are somewhat common, but with the increase in the number of stars, there is a decrease in the stability of the system.



HR Diagrams for Various Open Clusters

Open Clusters

Stars form from the collapse of large gas clouds. Both observations and computer simulations show that stars do not form individually but in groups or clusters. Newly born stars radiate UV radiation. This heats the remnant gas. We see the remnant gas as emission nebulae and the stars appear white or blue in colour. Radiation from the newly formed stars can cause the gas to be blown away, preventing the formation of more stars. Although the stars in an open cluster are grouped together by gravity, these are not strongly bound by gravity. Open clusters are mobile compared to the strongly bound globular clusters. These stars exchange energy between themselves; as a result some of the stars acquire escape velocity, leave the group and become runway stars. The rest remains as a gravitationally bound group, orbiting each other for the rest of their lives. The Sun is unique amongst the other stars as it does not appear to be in a group. It is thought that originally the Sun was a part of a group and then due to the interaction of other stars it left the group and became a lone star.

Young bright stars, millions of years of age, often stay as a loose collection; individual stars can be resolved by telescope. These open clusters can contain 10s to 1,000s of stars; with a size of about 60 lightyears. The Pleiades is a good example of an open cluster. We can see the evidence of nebulosity, indicating Population I young stars of high metallicity. Some other examples of open clusters are NGC3766, M35 and M11. Molecular clouds from which these stars formed are enriched with elements heavier than helium from previous supernova explosions and therefore the stars show higher metallicity.

Globular Clusters

Stars in a globular cluster are gravitationally bound and may contain 1000s to millions of stars. Size of the globular cluster can vary from 50–450ly; these are spherical in shape. These clusters in the Galaxy occur far away from the Sun and tend to occur in the halo region of the galactic plane. This is the outer edges of the galactic plane. There are about 150 globular clusters around our Galaxy, most of the stars in them tend to be older than F or G class stars and are off the main sequence. The Sun is a G class star. Large stars end their life in supernova explosions. This blows away the star forming gas cloud. Since the globular clusters are relatively free of gas and dust, no new star formation has taken place in the globular clusters. Most of the stars are 10 billion years old and contain the oldest stars in the Galaxy. These closed clusters might have formed before the Galaxy flattened into a disc. The very early galaxies were probably spherical and rotation of the galaxy created the flattened disc shape of the galaxy we see today. Studying the globular clusters is useful to understand stellar evolution.

Although the majority of the stars in the globular clusters are old, sometimes there are bright blue young stars. These are called Blue Strugglers. A possible reason may be collisions between the stars give rise to a new set of stars. The distance between the stars in the cluster is often less than a fraction of light year and collisions can occur. An example is NGC6397. Due to this high packing density low mass x-ray binary and millisecond pulsars can occur in the globular cluster.

M45, Pleiades star cluster; Anglo-Australian Observatory, Royal Observatory, Edinburgh. 75 to 175 million years old

Age of Clusters

From star clusters we can find out general information about the stars. We assume that all the stars formed simultaneously from the same interstellar gas cloud of uniform composition; hence all the stars are very similar in their properties. The only significant difference between the stars in a cluster is their masses. So if we determine the age, composition and distance of one star we can assume that all the stars in the cluster are similar.

In reality there will be age differences between the stars in the cluster, but compared the lifetime of stars we can assume all the stars are of the same age. The distance of all stars in the cluster from the Earth can also be assumed to be the same. For example, globular cluster M31: its distance from the Earth is over 23,000lys, this distance is very large compared to the distance from the centre to the edge of the cluster of about 150lys.

Stars evolve with time; they age. By monitoring a star we can estimate their age. Stars can have a range of masses, say from 100 solar mass to 0.08 solar mass. Stars which have formed recently tend to be smaller. Near to the Sun, about 90% of stars are of mass comparable to that of the Sun; of the rest, 10% of the population of stars consists of 2*Mass of the Sun and about 0.05% of 8*solar masses. The distribution of the mass of the stars does not appear to depend upon size, location, the nature of the star forming cloud and when the stars formed. So if we know the age of one of the clusters, the other clusters would be of similar age. In a star cluster it is assumed that all stars formed at the same time. But the stars have different masses. The life of a star depends on its mass. High mass stars have more hydrogen, the fusion reaction inside the star is more vigorous, these stars do not live long, whereas low mass stars live longer.

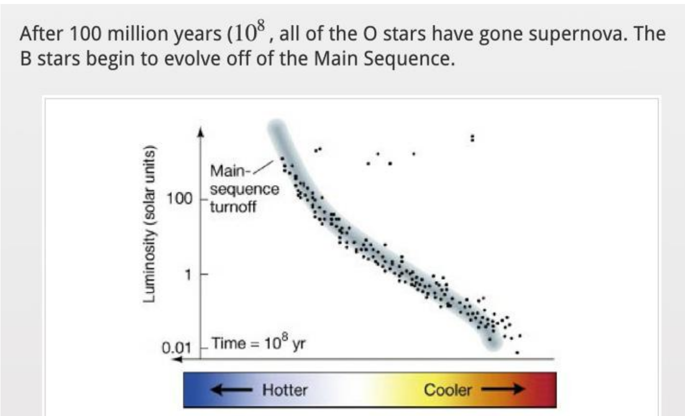
To determine the age of a star cluster, astronomers monitor a large number of stars in a cluster to get a representative population and plot a Hertzsprung–Russel (H–R) diagram of the cluster. Since all the stars in the cluster have the same age, it is called an Isochrone. The H–R diagram is a plot of luminosity (vertical axis) versus spectral type (horizontal axis). The spectral type depends on the temperature of the star; therefore the horizontal axis is an indication of temperature as well. High mass stars have high luminosity and are of blue, white end of the colour spectrum. These are the O, B stars. Low mass stars are of spectral type K and M are at redder end of the colour spectrum. The Sun is a G class star somewhere in between.

Let us take a couple of examples. Fig 1 is a schematic plot of two H–R diagrams, isochrones of two clusters.

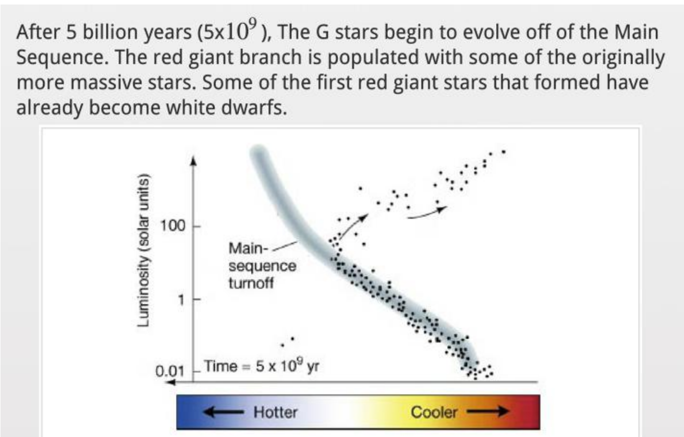
A) After 100 million years, all of the O stars have gone supernova. The B stars begin to evolve off of the Main Sequence to the red giant branch.

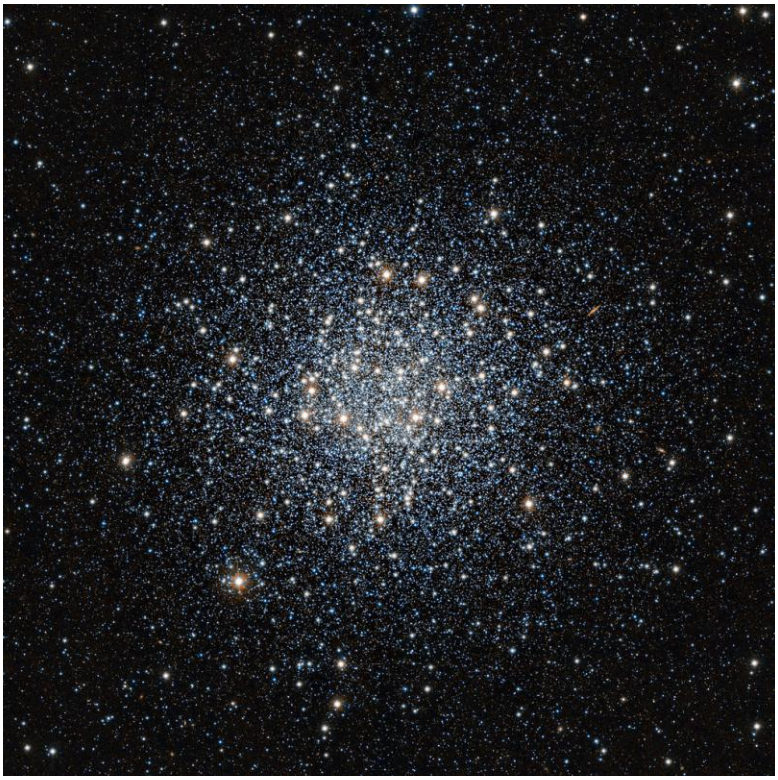
B) After 5 billion years, the G stars begin to evolve off of the Main Sequence. The red giant branch is populated with some of the originally more massive stars. Some of the very first red giant stars formed have already become white dwarfs.

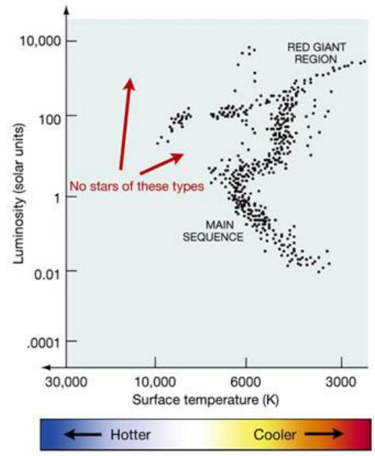
From plots like these astronomers determine which type of stars are leaving the main sequence line, the diagonal top (left) to bottom (right) to become (top right) horizontal branch. Once we have determined which type of stars are leaving the main sequence, we can find out the age of the cluster. Since all the stars in the cluster formed at the same time, this is the age of all of the stars in the cluster. There are theoretical models which correlates the life span of stars with their mass. Fig 2 is a such a plot (page 3). Let us consider a few examples. The diagonal line is the main sequence and the curved lines are the point when stars are leaving the main sequence to the red giant phase. The colour tells us us that

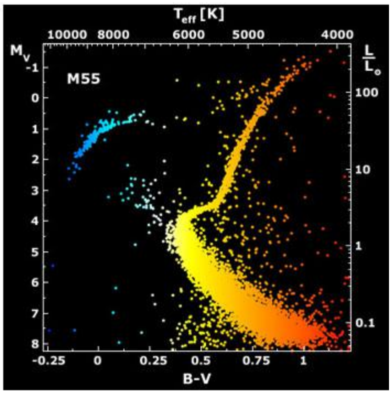


Top Fig. 1a, Bottom Fig 1b, H-R diagrams for two star clusters









Globular star cluster Messier 55 in Sagittarius (The Archer) was obtained in infrared light at ESO's Paranal Observatory in Chile. This vast ball of ancient stars is located at a distance of about 17 000 light-years from Earth. Image: ESO/J. Emerson/VISTA. With a HR diagram showing the stars distribution.

there are more blue, white stars in NGC 2362. Its luminosity is high. These stars have high masses and they have shorter life span. So this is the youngest cluster in the plot. Then comes h & x Persei. On the colour index scale its colours are moving away from blue white to the redder end of the spectrum. The stars are less massive than the stars in NGC2362. These live longer. On the average these stars are older than those in NGC2362. Stars in the M67 have moved to the more redder end of colour. These are smaller stars and lived longer than NGC2362 and h & x Persei. This plot tells us that NGC2362 is the youngest group of stars, h & x Persei, is the second eldest and eldest of the group is M67.

Star clusters are groups of stars gravitationally bound. In open clusters the gravitational force is not so strong. These tend to contain young stars; whereas in the globular cluster the stars are strongly gravitationally bound. These contain older stars. Stars in a cluster formed from a given molecular cloud, all the stars formed at the same time so their composition is similar. These stars have different masses. But since the evolution of stars depends on their mass, some stars would be older. These are the heavy stars, whereas the low mass stars live longer. By observing the luminosity and the spectral type astronomers determine which stars are leaving the main sequence and joining the red giant state. From theoretical calculations astronomers determine the spectral type and the age of the stars and the age of the cluster. From star clusters astronomers study the evolution of stars.

Further reading

`https://www.e-education.psu.edu/astro801/content/l7_p6.html`

`https://astronomy.com/magazine/ask-astro/2019/02/age-of-a-globular-cluster`

`https://astronomy.swin.edu.au/cosmos/s/Stellar+Populations+Of+Globular+Clusters`

Above: M35: NGC 2168. About 110 million years old. An open cluster

Below: M3; NGC5272, 33,900lys distance. Hubble image; 11.4 billion years old

A few weeks ago I read a really depressing short article written by a 27 year old bemoaning about how everything has got worse since the Olympic games in 2012. It was mostly saying how things are going wrong in her life and also her friends. How Covid had made everyone more unhappy with their lot. What a lot of gloomy folk. She thought some nonsense about a couple of footballers wives was the most interesting thing to have happened this year! Hasn't she heard of the Webb Space Telescope?

After I had finished it I thought she should be looking at a different source of news: not all the depressing stories on social media. What about the NASA or ESA websites and see what amazing things have happened in the last 10 years, such as:

2012 saw the Curiosity rover successfully land on Mars on August 6, 2012, with the revolutionary Sky Crain to lower the 2,000 lb rover to the ground. It joined the older rover Opportunity on Mars which had landed in 2004 and lasted until 2018, a bit longer than the 90 days expected. Curiosity is still operational and has covered about 29 km exploring Gale crater. Now we also have InSite (landed in 2018) studying Mars quakes and weather. Perseverance rover with its little helicopter, Ingenuity in 2021. Joined by a Chinese lander Tianwen-1 and a rover Zhurong. In orbit are eight working spacecraft surveying and photographing the Martian surface.

Since 2012 the International Space station has been crewed by numerous nationalities and has been resupplied with Russian Soyuz, both European and Japanese Automated Transfer Vehicles and now new American spacecraft; the Crew Dragon and the Boeing Starliner.

Orbiting around Mercury in 2012 was NASA's Messenger mission which ended in April 2015 when it ran out of fuel.

One of the first missions to the asteroid belt, the space craft Dawn, launched in 2007, Dawn orbited Vesta during 2012 then flew on to Ceres in 2015 and remained in orbit until it ran out of fuel in November 2018.

As of 2012, 700 exoplanets around other stars had been discovered, but that year another 148 was added to the list. In March this year the number of confirmed exoplanets passed 5000.

The Hubble Space Telescope is still fully operational after its 1990 launch and the last Service Mission 4 in May 2009 with the Space Shuttle Atlantis. Where do you start with all the discoveries made by this famous telescope. From the furthest star to the furthest galaxy, to the deepest set of images of the distant ancient universe to the planets in our solar system, its still going strong with another service mission on the horizon to keep it operational for more decades to come. Over 15,000 papers based on Hubble data have been published in peer-reviewed journals with more than 200 added each year. One of the main benefits of the service missions is to return the old equipment modules to earth so they can be examined to see how they copied with the space environment or why they failed and examine the effects of the hostile environment and radiation on equipment. One surprising thing was that the mirrors are still almost as good as new, they were expected to last for only 15 years!

In 2014 the ESA's Rosetta mission to comet 67P/Churyumov-Gerasimenko took wonderful views of the comets nucleus showing gas and dust streaming off its surface.

Missions to the Moon have been continuing conducted by the following nations, the Soviet Union, the United States, Japan, the European Space Agency, China, India, Luxembourg and Israel. Since 2012 there has been 13 missions to the Moon including three landing, one, the Chinese Chang'e 4, soft landed on the Moon's far side in the South Pole-Aitken basin in January 2019 deploying a small rover.

The New Horizons mission to Pluto was launched in 2006 and successfully performed a close flyby of Pluto on July 14, 2015 at a distance of 12,500 km at a speed of 14 km/s. The resulting amazing photographs changed everybody's ideas of what Pluto was and looked like. Later a new target was discovered by the Hubble, 486958 Arrokoth. near to New Horizons flight path. So on 1 January 2019, New Horizons performed a close fly-by of this twin lobed Kuiper Belt Object Arrokoth at 3,500 km. This object is only about 40 km across at its widest point.

The Cassini probe was deorbited in 2017 after spending over 13 years in orbit around Saturn photographing the moons and rings.

The spacecraft Juno was launched in August 2011 and arrived at Jupiter in 2016. Juno is in a 53 day orbit around Jupiter with is closest approach of 4,200 km above the cloud tops to around 8,000,000 km distance. It carries 3 Lego figures representing Galileo Galilei, the Roman god Jupiter and his sister and wife, the goddess Juno. By the end of 2023 it will have completed 57 orbits.

ESA Gaia launched 2013 Astrometry mission measuring positions and distances of over one billion objects in the Milky Way. Solar Orbiter to study the Sun launched February 2020. Older missions still operational include XMM-Newton x-ray space telescope and Integral a gamma ray observatory as well as SOHO from 1995 a real-time solar and space weather mission.

We have seen in 2017 the first image of a black hole by the Event Horizon Telescope in the galaxy M87 and on 12 May 2022, the EHT released the first image of Sagittarius A*, the supermassive black hole at the centre of the Milky Way galaxy.

The ESA and JSA BepiColombo Mercury mission launched in October 2018 is due to get there in 2025.

The Parker Solar Probe is returning fascinating information about the solar corona and the sun.

On 20 October 2020, NASA's OSIRIS-REx successfully touched-down on the asteroid Bennu to collect samples of the surface material which will be returned to Earth in 2023.

Webb Space Telescope launched last year on Christmas day has now begins to show us what it is capable of. The start of fantastic images of the infer-red universe.

The Artemis program is getting ready for its first test flight around the Moon.

While no major new earth bound telescopes have seen first light since 2012, nearly all of them have been upgraded over the last 10 years with new instruments. Around 2027 the 39m Extremely Large Telescope being built as part of ESO in Chile, should see first light.

Funnily there was another article in the same news paper listing how much better things were now. Like life expectancy, if you were born in 1950 it was 65 now a baby born in 2020 can expect to get to 89. In the last 40 years heart disease has almost halved, even dementia has fallen 20% and greenhouse emissions have halved from 1990 to 2020. Lots of good news if you look for it.

Ivor Clarke

George Abell and the End of Humanity

By Mike Frost

A friend of mine, Karen Wilde (Leicestershire County Council's Heritage Development Officer), had an impressive tertiary education, studying at the University of California Los Angeles (UCLA) in the USA. One feature of the American educational system is that students are encouraged to study a variety of subjects in addition to their major. So it was that Karen, a humanities student, came to attend the astronomy course lectured by Professor George Abell of UCLA.

You may know the name Abell, particularly if you are an imager, because he published two catalogues which are full of interesting and beautiful targets. One is a catalogue of galactic clusters, the other a catalogue of planetary nebulae. George Ogden Abell (1927-83) studied as an undergraduate, after military service, at Caltech, and was the first Ph.D student of Donald Osterbrock. He was a lecturer at the famous Griffith Planetarium in Los Angeles (it features in "La La Land", "The Terminator" and many other movies) and then a member of the Palomar Sky Survey team. The all-sky camera survey taken by the Palomar telescope, then the world's largest, was his source for the two catalogues.

In later years Abell was a founder and supporter of CSICOP, the Committee for Scientific Investigation of Claims of the Paranormal, which was a leading debunker of much pseudo-science. He produced a TV lecture course on cosmology and relativity which was part-funded by the Open University, so the OU's observatory (which I have visited) is named for him.

At UCLA, Abell delivered a lecture course in astronomy for 17 years and was regarded as an inspirational lecturer. Karen certainly thought so, and lent me her textbook from the course, "Drama of the Universe". It's a very readable and well-thought-out book, which seeks to place modern-day (for the 70s and 80s) astronomy in a historical and cultural context. There are several appealing idiosyncrasies; for example, as Abell regards the story of astronomy as a drama, he forsakes section and chapters in favour of acts and scenes.

I enjoyed reading the textbook, both straightforwardly as an astronomy textbook, also as a historical record of astronomical thinking in a golden age in American astronomy, when California was the observational capital of the world. But the thing which has stuck with me the most is a single, very precise prediction. In Act V Scene 5, on page 388, Abell calculates that humanity cannot exist after August 20th 2023.

Just in case you were speed-reading, I'll repeat that. George Abell, leading astronomer, proved mathematically that humanity will cease to exist by the middle of next year.

How did he come to this rather startling conclusion? Act V is titled "the search for life" and, after scenes discussing the possibility of life elsewhere in the solar system, and intelligent life elsewhere in the universe, scene 5 returns home to ask: "Is there intelligent life on Earth?". George Abell's thesis is that there isn't, because the one species which shows promise, Homo Sapiens, is busy destroying itself.

The particular thing that he worries about is population growth. Earth's population, he points out, is doubling every 37 years or so, and this means an ever-increasing usage of the Earth's resources.

On page 388, in figure V.39, he plots the land area of the Earth available to each living human being, as a function of time. That plot contains seven data points, from around 1850 to around 1970, and they lie pretty much on a straight line. He then extrapolates that straight line to where it crosses the x-axis, the point at which there is zero land available. Humanity cannot survive beyond this point without doing something about population growth (which hasn't happened) or leaving the Earth (which is not yet fully up-and-running). The slope of the straight line must have some error bars on it – but, for dramatic effect I'm sure, he assumes an exact value and so comes up with August 20th 2023 as the date after which humanity cannot possibly continue to exist.

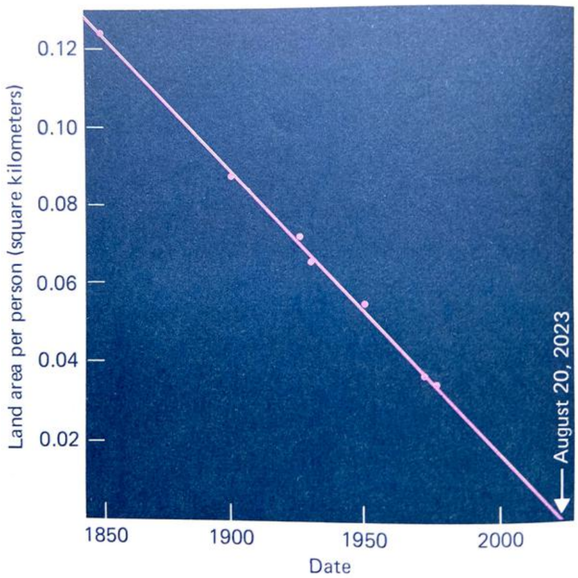


Figure V.39
The land area of the earth available to each living human being, as a function of time.

Now, some of this analysis is quite prescient. For example, he talks about how we are polluting the atmosphere and how increasing levels of carbon dioxide could create a greenhouse effect – global warming before it became fashionable. (He also talks about the possibility of other pollutants causing a drop in temperature and a new ice-age, so he wasn't certain that global warming was going to happen; but knew that climate change probably was). And I am certainly not complacent about the eventual effects of unbridled population growth.

However. . . in addition to being an astronomer, I'm a mathematician. And, mathematically, his analysis simply doesn't make sense. For there to be zero land-area per human being in 2023, Earth's population would have to be infinite. THAT CAN'T HAPPEN! Even if we had "gone at it like rabbits", we would not have gone from 3 billion or so people in 1970 to an infinite number by the mid-2020s.

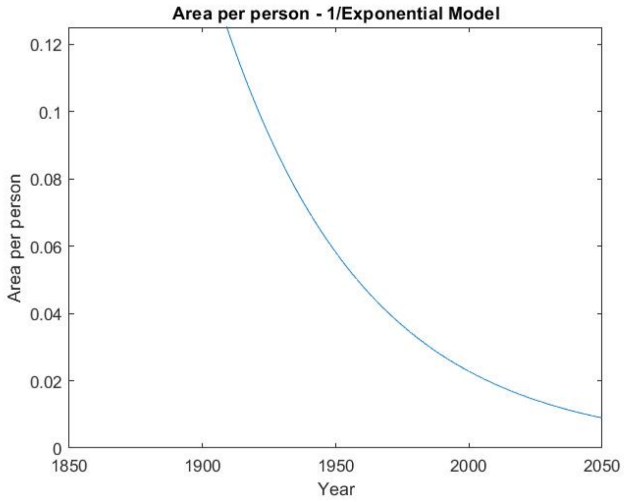
Sorry to introduce equations, but I think they are useful at this point. To a pretty good approximation, the human population of the world is increasing exponentially – doubling every 37 years, as Abell says. It was 4 billion in 1974, so we can model it as

$$\text{Population in year } x = 4\text{Billion} \times 2^{(x-1974)/37}$$

The land area of Earth is 148 million square km, so divide Earth's population into this to get the land area per person.

Land area per person in year x = 148 Million / (4Billion x $2^{(x-1974)/37}$)

It is straightforward to calculate this function, and so we can produce a plot of what "actually" will happen. You can see that the exponential model deviates away from the sloping straight line and approaches zero "asymptotically". That is to say: it never actually gets to zero!



Please, please note that I am not saying there isn't a problem. Earth's population cannot continue to grow exponentially without us hitting a problem at some time, through over-consumption of resources (food, minerals etc). It's just the prediction of August 20th 2023 that I object to. The simple model of exponential growth simply doesn't give a land area per person which decreases to zero as a straight line. It can't.

So, what on Earth was Abell thinking of? In his book, he hedges his bets a little, pointing out that the doubling time has not been constant, and has in fact been decreasing, so that growth is even faster than exponential. But even he, I think, doesn't claim that the doubling time for mankind's population will drop to zero, by next year, which is the implication of his plot.

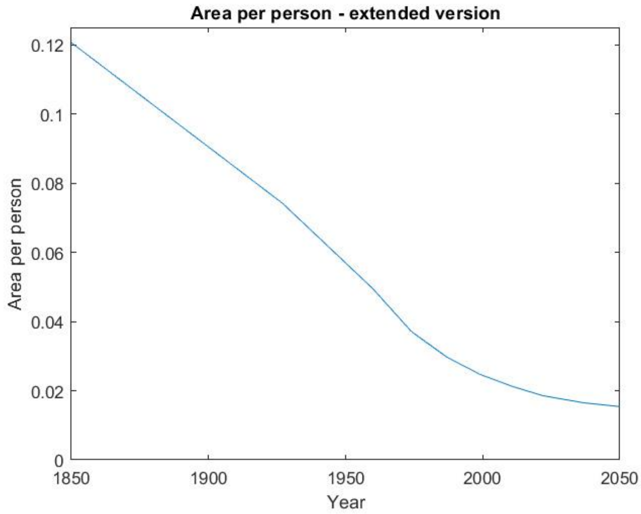
His choice of a calculation of land-area per person is a little curious. Why not just plot population? Well, that's difficult, because it isn't easy to show infinity graphically. Better to plot the reciprocal, one over population, which goes to zero. But, as we've seen, one over an exponential does not go to zero in a finite time.

Surely Abell knew this. He was a straight-A maths and science student, and the mathematics concerned is not particularly complex. Was he playing a rather arcane joke on his students? I'm sure that this isn't the case. There is a long online interview with Abell, in which he re-iterates his grave concerns about population growth, and his insistence that the crunch will come within decades.

On other hand. . . I rather suspect that Abell did know that his model wouldn't drop to zero by 2023, or indeed ever. But I think he did want to make it quite clear that there is a problem coming. I agree with him completely that there is an exponentially growing resource problem, pretty much across the board.

I think that since the 1970s there has been a rather more-nuanced understanding of over-population. It's a small proportion of the Earth's population, the developed world, that consumes most of the resources – but on the other hand the developed world has much smaller population growth rates (negative for some countries). So, there's a complex and perhaps intractable problem to bring un-developed countries up to developed standards and zero population growth. It's difficult, but it could be possible.

We are fifty years on from Abell's prediction – so how have the numbers panned out? We know (to a reasonable accuracy) the Earth's population for this period and can calculate the "actual" land per-person. We can see that the actual curve deviates from a straight line; first more steeply, because the doubling time decreased during the 1970s; and then more shallowly. The levelling out is for two reasons. First, the doubling time has been increasing in recent years; second, because the inverse exponential eventually levels out, as I explained earlier.



In conclusion - I think Abell was a little fast-and-loose with his mathematics. I think he wanted to scare people into doing something. I think he's wrong in the short-term – if we're all dead by August 20th next year, it will be Putin or a Pandemic to blame. But in the long-term, I think he's largely right.

We can't carry on doing what we're doing right now.

Further Reading

"Drama of the Universe", Abell, George Ogden (New York: Holt, Rinehart & Winston, 1978)

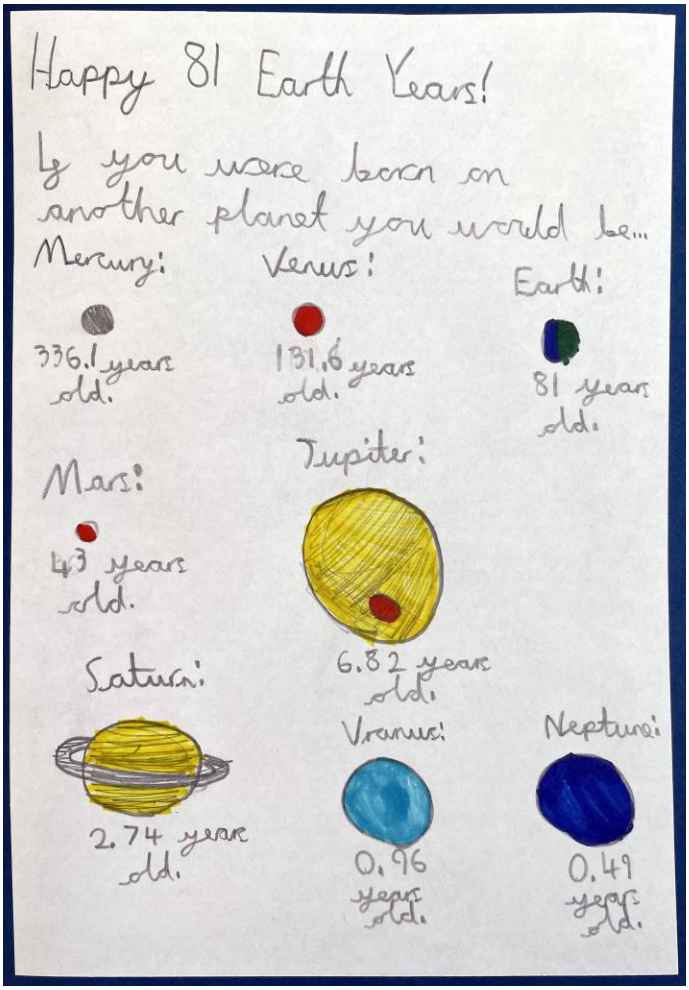
George Abell was interviewed in 1977 as part of the American Institute of Physics' oral history program:
`https://www.aip.org/history-programs/niels-bohr-library/oral-histories/4475`

In a section on exponential growth, he says:
Yes. It [*] can be infinite in a finite time; it's certainly faster than exponential. The human population will become infinite about 2030 at the present rate.
*The "It" isn't the world's population (actually he is talking at this point about the word-count in the Astrophysical Journal) but he quickly moves on to over-population. Note he has slipped back a few years from 2023 in this prediction.

Earth's population over time:
https://en.wikipedia.org/wiki/World_population

1 Billion	1804	2	1927
3	1960	4	1974
5	1987	6	1999
7	2011	8	2022
9	2037 (predicted)	10	2057 (predicted)

My Birthday Card



For my birthday this year I received off my 8 year old grandson a hand made card which had all the solar system planets drawn on it with the age I would have been if I counted their years instead of Earth's. As you can imagine I was delighted with it and for all of hard work he had put into making it.
So how old will you be next if you live on another planet?
Here are a few round figure numbers:

Earth years	50	60	70	80
Mercury	207.64	249.17	290.7	332.23
Venus	81.2	97.46	113.7	130
Mars	26.58	31.9	37.21	42.53
Jupiter	4.21	5.06	5.9	6.74
Saturn	1.69	2.03	2.37	2.71
Uranus	0.59	0.71	0.83	0.95
Neptune	0.3	0.36	0.42	0.48

To work out your age on any of the planets, use the table below. Say you are 57 Earth years old and live on Venus,

57 (Earth years) divide by 0.61562 (for Venus) = 92.589 Venus years.

Mercury	0.2408
Venus	0.61562
Earth	1
Mars	1.8809
Jupter	11.862
Saturn	29.458
Uranus	84.01
Neptune	164.79
Pluto	248.54