University Lowbrow Astronomers
Ann Arbor, Michigan

REFLECTIONS / REFRACTIONS

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University Lowbrow Astronomers
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What Will You "A Mount" To?

Always Seize an Opportunity!

By Clayton Kessler

A few weeks ago my day job required me to drive to Rockford IL. I planned to spend the night and attend possibly boring meetings the first thing in the morning. I did not have to think very hard about what else there was to do in the town of Rockford. Rockford is the home of Astro-Physics! While I have seen the crew from AP at NEAF and at the Arizona ASAE show I really did not know how they were set up for visitors at the plant. Oh well – they seem so nice at the shows. The worst that can happen is that they have big guys toss me out the front door.

Astro-Physics manufacturers and sells the very best apochromatic refractors and the fact that folks are willing to wait for years to get one speaks to their quality. They also manufacture a series of computer controlled mounts that run the gamut from small and portable to "Oh My God!!!". All of this is manufactured in this shop in Rockford. As you might expect everyone was more than accommodating to an unexpected arrival and the crew at AP lived up to their public image from NEAF.

I was welcomed to the plant and I had a few equipment questions to ask about. I ended up having a long discussion with a couple of the fellows that regularly attend the larger shows. We talked about a number of things – some related to rings that I am making for customers (they provided great information about dimensions on their equipment!). We also talked about the newer mounts that they are making and showing. The front office had a number of systems set up on display.

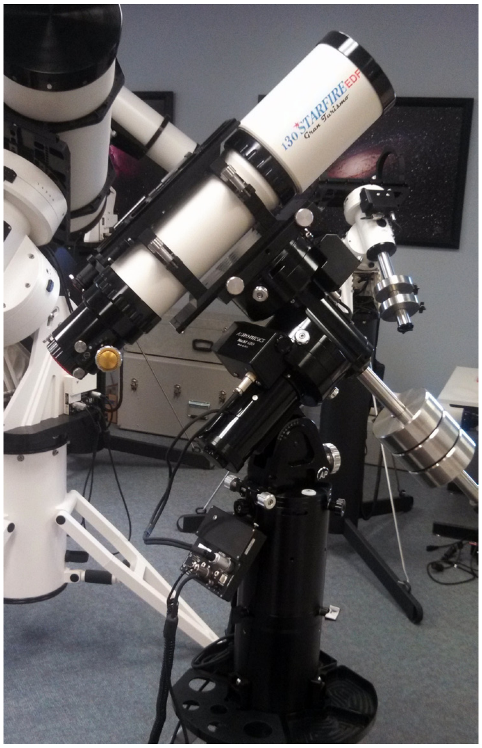
The massive AP 3600 "El Capitan"

All photos by the author.

NOTE: THE JULY 18 LOWBROW MEETING IS IN YPSILANTI!

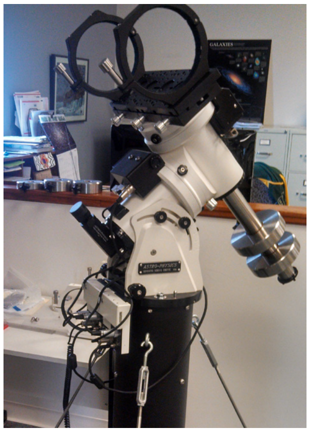
The AP3600 it their largest mount and they call it "El Capitan". It is huge! It has an instrument capacity of a conservative 300 lbs. – there are not very many precision mounts that have this capacity available anywhere. All made in Rockford on precision CNC equipment. This mount is full servo controlled Go-To and has 13" work gears. As with all AP mounts that I have seen the machining and finish is flawless. Of course, the mount itself weighs 247 lbs. – not something to sling in the car to head up to Peach Mountain! The pictures of the mount also show one of the few non-refractors AP makes - a 10" Mak-Cass.

Smaller mounts are also available. AP sports a series of mounts from the Mach-1 with a 45 lb. Instrument capacity. The Mach-1 sports the very popular AP130 "Gran Turismo" refractor – a highly popular refractor.



AP Mach I mount carrying a 130mm Starfire refractor.

The mount below the 3600 in capacity is the AP 1600. This gem (he he he!) sports a 220 lb. capacity and is not so portable at 114 lbs. It is shown with a nice 175mm Apochromatic refractor (well – nice and huge!).



There is also the AP 1100 with a 110 lb. instrument capacity. The 1100 is a "portable" mount at 54 lbs. (less the pier) – so it could head out to Peach.

One of the other questions that I had revolved around an accessory that AP makes. They have a focal reducer that is optimized for systems with a focal ratio of f9 and higher. I had read that this focal reducer is the “favored” one for the 8” f8 RC that I picked up at NEAF earlier in the spring. They were able to answer my questions and configure a focal reducer/camera adapter that held the focal reducer the correct distance from my camera sensor. Naturally I was able to purchase it on the spot and bring it home. Does it work?

Of Course!!

This visit was a lot of fun. It is great to talk about the hobby we all love with new people and to get different viewpoints on the various aspects of that hobby. I even got to come home with a new toy – Bonus!!

I see that I have not mentioned the crazy stuff that happened when I stopped at the camera store that I spotted while driving to Astro-Physics…. But maybe that is a story for later. Remember – Always Seize an Opportunity!

M81 & M82

I took this shot Thursday June 19, using my remote control scope. Tracking was not good for some reason, so I only got about twenty 90-second exposures. So that is half an hour of total exposure. You can barely see the second, ion tail. But boy is it green!

By the time Lowbrows read this, Comet C/2012 K1 (PANSTARRS) will start its passage around Mercury’s orbit and the sun. When it comes back around, it will be tough for us to see because it is heading south. But it should be a bright mag 5.5-6 in the constellation Puppis in October.

Technical details: Canon 5D Mk III camera, 10” f/5 Newtonian, Paramount MX, from Animas NM.

--Brian Ottum

Brian will giving a talk and demonstrating his remotely controlled scope at the November Lowbrow meeting!

Nucleosynthesis

--Part 4--

By Dave Snyder

In this series, I have been discussing nucleosynthesis. If you haven't done so already you may want to read the previous parts: "Nucleosynthesis." Reflections March 2012 (henceforth called "part 1"), "Nucleosynthesis, Part 2." Reflections August 2012 (henceforth called "part 2") and "Nucleosynthesis, Part 3." Reflections October 2013 (henceforth called "part 3").

Nucleosynthesis

As explained earlier, nucleosynthesis is the process where chemical elements such as hydrogen, carbon, iron are formed.

In part 2, I introduced Segrè charts. These charts are not just pretty pictures. As I explained: "Segrè charts can also be used to follow nuclear transitions. For example, nucleosynthesis is a process that involves hundreds of transitions; it can be thought of a series of steps with nuclides moving from one square in a Segrè chart to the next." By properly constructing these transitions, we can understand the entire process of nucleosynthesis. Each transition is one of the following:

- Fusion: where two nuclei merge to form a larger nucleus. Fusion is basically a billiard ball process (see Part 3)[1]. For example hydrogen-1 can fuse with hydrogen-2 to form helium-3. Fusion only occurs at high temperature. Roughly speaking the temperature increases as Z increases (from about 10 million degrees Kelvin for hydrogen, Z=1 to over 3 billion degrees Kelvin for Nickel, Z=28)[2]. Most of the fusion processes we'll encounter are exothermic (that is they release energy), this release of energy is typically through emission of photons, or less commonly emission of neutrons or other particles. However not all fusion reactions are exothermic.

- Photodisintegration: the reverse of fusion. A photon hits a nucleus, and it splits into two nuclei. In most cases, a large nucleus and a small nucleus. As with fusion, photodisintegration only occurs at high temperature (but the relationship between Z and temperature isn't so simple).

- Beta decay: explained in part 3.

- Beryllium-8 decay: Beryllium-8 is highly unstable. It decays in a billiard ball process by splitting into two helium-4 nuclei. This occurs in a tiny fraction of a second; these nuclei decay almost as quickly as they are created. It is an unusual decay; beryllium (Z=4) is very light; billiard ball decays typically occur in much heavier nuclei.

- One of several others as explained below.

Nucleosynthesis can be broken down into these stages:

1) Big Bang Nucleosynthesis: the big bang produces hydrogen, helium and lithium-7.
2) Primary Nucleosynthesis: The first stars form out of this hydrogen/helium and produce most, but not all, of the elements between Z=6 and Z=31.
3) Heavy Element Nucleosynthesis: A group of processes that produce elements Z>31.
4) Secondary Nucleosynthesis: After steps 2 and 3 spread metals (that is elements heavier than helium) through the universe, the next generation of stars can form. These stars produce elements just as the earliest stars do, but there are subtle and not so subtle differences. This is called secondary nucleosynthesis; it produces a number of elements that are not produced efficiently in primary nucleosynthesis.

5) A few light elements are not efficiently produced by any of the previous stages; there are additional processes, not described above, that produce these elements.

Big Bang Nucleosynthesis

The first stage occurs early in the history of the universe. Immediately after the big bang, there are no protons, no neutrons and no atoms. And it is hot, very hot. There are subatomic particles like quarks and electrons, but it is too hot for protons, neutrons or atoms to form.

But things cool off at a known rate. One second after the big bang, it is cold enough to allow protons and neutrons to form. They form in a specific ratio: 6 protons to each neutron (this ratio is important, pay attention to it as it plays an important role in our story)[3].

Nothing more can happen until the universe cools off enough to allow fusion of protons and neutrons. At about 1 minute after the big bang it is cold enough for fusion. Free neutrons (that is neutrons that not part of a nucleus) are unstable and thus the number of neutrons decreases. Over this first minute, the ratio changed: 7 protons to each neutron[4].

It is easier to understand the next steps if we change the 7 to 1 ratio into a 14 to 2 ratio (see figure 1). Two neutrons fuse with two protons to make one atom of helium-4 leaving 12 protons left over (see figure 2, the helium-4 nucleus has 2 protons and 2 neutrons). If we assume the reaction goes as far as possible, we have 12 atoms of hydrogen-1 to each atom of helium-4, or since helium-4 is about 4 times as heavy as hydrogen-1, 75% hydrogen-1 by weight and 25% helium-4 by weight. This ratio hasn't changed much over the past 13.7 billion years.

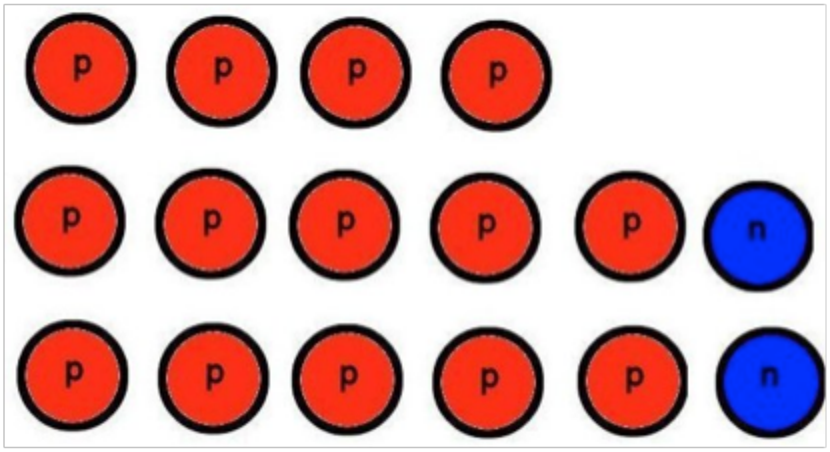
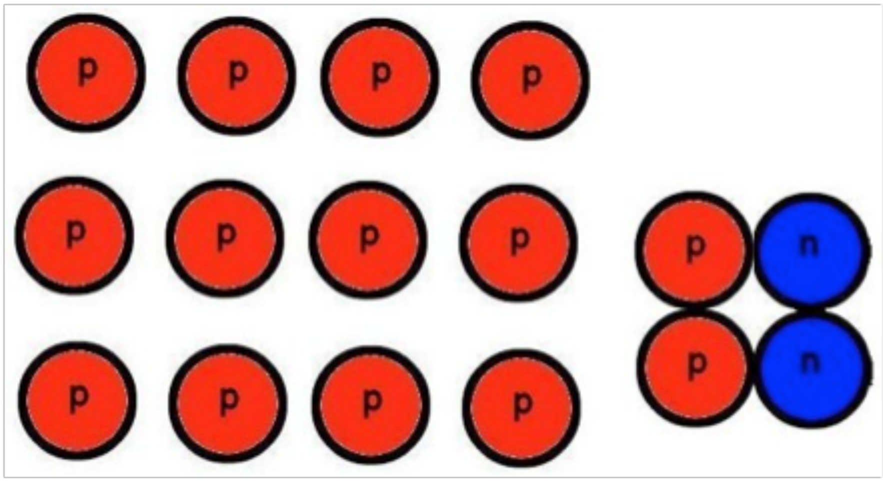


Figure 1:

Before fusion: 14 protons and 2 neutrons

Figure 2:

After fusion: 12 protons and one helium-4 nucleus



This is an oversimplification. While it is approximately correct, the reactions don't take place in one step and they do not go as far as possible. Examining this more carefully we find in addition to hydrogen-1 and helium-4, there is production of hydrogen-2 (known as deuterium), hydrogen-3 (known as tritium) and helium-3. Also not all the neutrons fuse with protons, so there are neutrons left over as well[5].

Formation of heavier elements occurs. By fusing helium nuclei with other helium nuclei you get the isotopes of lithium-7, beryllium-7 and beryllium-8. However there isn't time for fusion to make significant amounts of anything heavier.

Free neutrons are unstable. The isotopes of tritium, beryllium-7 and beryllium-8 are unstable. None of these survive from the big bang to the present day. Deuterium, helium-3 and lithium-7 survive, but in small quantities[6].

Primary Nucleosynthesis

Nothing more happens until the first stars form. These stars consist of hydrogen, helium and a small amount of lithium. Unlike stars found today, there are essentially no heavier elements. After formation of the first stars, primary nucleosynthesis starts. This is a series of hundreds of different reactions (mainly fusion reactions, but other reactions contribute to the overall process).

Primary nucleosynthesis in turn consists of several sub-stages known by the names hydrogen burning, helium burning, carbon burning, neon burning, oxygen burning and silicon burning. I will discuss each of the stages in more detail in this article and in a future article, but first let's look at the overall process.

When gas and dust collapses to form a star, temperatures rise. When the temperature gets hot enough (as I mentioned earlier this temperature is a function primarily of the elements present), fusion starts. Fusion continues until the fuel is exhausted, then collapse occurs, temperatures rise until the next sub-stage. Fusion starts again, until the fuel is exhausted and the cycle repeats. Once the fuel for silicon burning is exhausted, the star collapses until a supernova results, a neutron star forms or a black hole forms. No further fusion is possible.

This is only true for heavy stars.

- Stars 8 times the mass of the sun or less, but at least 4 times the mass of the sun will undergo hydrogen burning, helium burning and carbon burning but not neon burning or any of the other sub-stages.
- Stars 4 times the mass of the sun or less, but at least 0.4 times the mass of the sun will undergo hydrogen and helium burning, but not carbon burning or any of the other sub-stages.
- Stars less than 0.4 times the mass of the sun undergo hydrogen burning, but not helium burning or any other sub-stage.

Note that stars can undergo several of these sub-stages at the same time. And note that fusion can only take place if all the ingredients are present in the right place (a location with a high enough temperature) and this may require mixing of stellar gases. So if gases are not mixed, fusion reactions might not take place, but if the gases are mixed they can.

After formation, stars begin by burning hydrogen. You may have heard the expression "main sequence star." A main sequence star is simply a star that is burning hydrogen (as opposed to stars that burn helium or heavier elements). Hydrogen burning is a very slow process, and stars spend most of their lives on the main sequence. Hydrogen burning can proceed through a set of reactions known as the "proton-proton chain" or through a different set of reactions known as the "CNO cycle." During primary nucleosynthesis, the CNO cycle is generally either non-existent or at most a minor component; it plays a more significant role in secondary nucleosynthesis. The CNO cycle will be discussed in part 5.

Like big bang nucleosynthesis, the main result of hydrogen burning is the conversion of hydrogen-1 to helium-4. There are however important differences. In the big bang there is a ready supply of neutrons. There are no neutrons available in hydrogen burning; this means the reactions are quite different. The events in the big bang happen quickly (3 minutes and it's all over). The events in hydrogen burning take a long time (10 billion years for a star with the mass of the sun).

The big bang produces most of the observed hydrogen and helium in the universe. Hydrogen burning at best slowly alters the quantities of hydrogen and helium, and doesn't contribute anything new[7].

However as we'll see in part 5, the other stages of nucleosynthesis will produce new elements.

Data

Now a simple question. We can write the steps to get from hydrogen to helium and heavier elements, but how do we know that these steps are correct? Here are three approaches to verification.

1) Astronomers are able to detect chemical elements in stars and gas clouds. From this it is possible to calculate the percentage of the universe that is hydrogen, the percentage that is helium and so on. This leads to the following diagram[8].

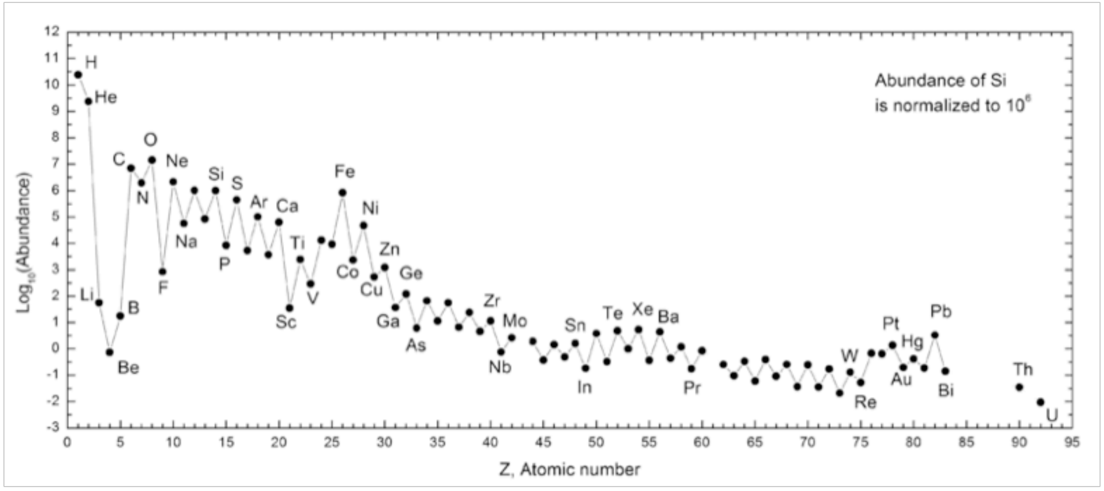


Figure 3

Look carefully at this diagram and note the following features. Hydrogen and helium (H, He) are much more common than anything else. Lithium, beryllium and boron (Li, Be, B) are much less common than other light elements. From carbon (C) to uranium (U) there is a general decrease in abundance with increasing Z. Elements with even Z (such as oxygen, O) are generally more common than elements with odd Z (such as nitrogen, N), resulting in a up and down pattern easily seen on the graph. Hydrogen (H) and beryllium (Be) are exceptions to this pattern. There are other patterns: For example: fluorine (F) is rare compared with similar elements; Iron, Nickel and Lead (Fe, Ni, Pb) are more common than similar elements.

If we assume all the atoms in the universe are the result of nucleosynthesis, we should be able to explain the features of figure 3. As explained earlier, the big bang produces a universe that is 75% hydrogen, 25% helium with a small amount of lithium. So the universe starts out as mostly hydrogen and helium. Subsequent nucleosynthesis processes such as hydrogen burning alters the abundances of elements, but do so very slowly. None of these processes have significantly changed the 75%/25% ratio, even after billions of years. This explains why the universe is still mostly hydrogen and helium. Explanations of other aspects of the graph will have to wait for future articles.

2) For stars of different masses and different metallicities, we can predict how the star should transform chemical elements according to theory. Some of these elements can be found in stellar atmospheres; we can compare the predicted elements with the elements actually observed[9].

3) Finally some of the processes within stars release neutrinos. Unlike photons, neutrinos pass through a star without alteration and can be detected on earth. We can compare predicted neutrinos with the neutrinos actually observed[10].

Next…

In the next part of this series (part 5), I will go through the remaining stages of nucleosynthesis.

(The bibliography and notes to Part Four will be found at the end of the electronic version of Reflections.--Ed.)

Start Your Summer Reading Now!!!

Thumbnail Looks at Books You Should Not Miss

by Christopher Sarnecki

Some older ones, but mostly new. I've read 'em and reviewed 'em so you don't have to. Just pick out one you think you might like and read on.

The Milky Way, An Insider's Guide, by William H. Waller, ©2013, Princeton University Press - If you need to catch up on a current understanding of your home galaxy, the author has compiled this guide as a single source of the latest science on the Milky Way. Not quite a textbook and certainly not a coffee table book, this text includes lots of diagrams, photos, and web links to illustrate the latest information on our host galaxy. Some math included, but nothing that should turn away this group. The author gives a concise run down of current understandings for recent Milky Way subjects such as man's historical understanding of our galaxy, star formation, and life/water formation on Earth.

Longitude, The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time, by Dava Sobel, ©1995, Penguin Books - A short book (175 pages) on smallish pages (4" x 7") yields a very concise story about Englishman John Harrison's invention/creation of a watch that kept precise time on board a ship in the 1700s so as to locate longitude and save untold lives and commerce. Today we take such technology for granted, but in the early 1700's just locating where you were at sea was a calculated guess that could cost you your life and those on board your ship.

Erwin Schrodinger and the Quantum Revolution, by John Gribbin, ©2013, John Wiley and Sons, Inc. - The author, an astrophysicist but probably better known as a prolific author of popular science subjects, presents a detailed human interest story of Schrodinger's life and his work in early quantum physics development. The author obviously knows his stuff, and perhaps, expects his reader to have an extensive historical understanding of the same. OK, quantum physics is where I have to admit, I just don't get it (well at least,I'm honest enough to admit it). The book comes with no illustrations, diagrams, or even photographs; which may be fine as the author does little to explain scientific concepts to the uninitiated. If you want to read about all the late-19th and early to mid-20th century quantum physicists and their inventions, many listed in a single sentence, then this book is for you. I do have to admit the author's ongoing discussion about Schrodinger's interest in the how quantum physics might be connected into biology (think Quantum Chemistry) and the concept of 'conciseness' made me think about issues I would never have imagined. OBTW, for you quantum/astrophysicist reading this, the solution to the dark matter/dark energy conundrum has something to do with 'time'. Like I said, this author makes you think about subjects you never imagined.

Death from the Skies, These are the Ways the World will End..., by Philip Plait, Ph.D., ©2008, Viking Penguin. Written by the author of the 'Bad Astronomy' web site. Plait's main claim to fame is debunking pseudo science promoters and astronomy mis-information heaped upon the general public by the mass media. In this book, the author explores delightful space originated apocalyptic catastrophes to life on Earth such as a coronal mass ejection from our Sun, supernova exposure from an adjacent star, deadly gamma-ray burst, black holes, aliens; and, other topics that may keep you up at night if you don't already have enough fears to do that. Plait also expands on my previous worst fear, an asteroid/comet impacting the Earth. To his credit the author gives his reader some reassurance on the numerical possibilities of anything bad happening to our planet. After reading this book, I'm no more worried about the current generation's well being than before, but very concerned about generations far into the future. Plait guarantees that eventually bad things will happen to the Earth. Don't forget to reacquaint yourself with the fine March 2012 Reflections newsletter article by Norb Vance on a visit Plait made to Eastern Michigan University to discuss this same book - http://www.umich.edu/~lowbrows/private/newsletters/mar-2012.pdf.

INTERMISSION

Barney Flats Oatmeal Stout, **Anderson Valley Brewing** Co., Boonville, CA. - Billed as "pleasantly creamy, rich body", but from my perspective, I'd say this is more of an English style (i.e. - watery) body [not a new world style stout - more syrupy]. Dark notes with slight dry ending.

Kalamazoo Stout, **Bell's Brewery, Inc.**, Comstock, MI. - Brewed with brewers licorice. A crisp and refreshing stout. Nicely drinkable.

Hopslam, **Bell's Brewery, Inc.**, Comstock, MI. - Not an inexpensive brew (read: This IS expensive!), very smooth for a powerful ABV at 10%, this beer is too delicious for words!

COMETS! Visitors from Deep Space, by David J. Eicher, ©2013, Cambridge University Press - Eicher explores great comets throughout history and the modern era, explains in detail comet structure and chemical composition; and, where comets hang out when not passing through the inner solar system. The author has done an excellent job of researching the subjects presented in the book. I never realized the extent of the Ort Cloud and the sizes of Kuiper Belt planetesimals until I read this book. Included in the book are chapters on observing and imaging comets that I found informative. Lots of smallish black and white photos of comets and a few in color. Don't look at this book for it's pictures, but do read it for the latest understanding on the popular subject of comets.

A Palette of Particles, by Jeremy Bernstein, ©2013, The Belknap Press of Harvard University Press - Another smallish book (4" x 7"), 170 pages (not including 30 pages of Appendices), on particle physics. Gosh, I know I've tried to understand elementary particles again and again. Indicated in the introduction the author states "...the level is attended to a general reader with an interest in science", but this author leaves his reader lost without any sense of understanding of the subject. The plot line in the book Catch 22 doesn't get going for the first 50-100 pages. This book doesn't begin to explain to subject matter to it's reader ever (that's right, ever). That does it. I'm swearing off any further attempt to understand elementary particles.

The End of Night, Searching for Natural Darkness in an Age of Artificial Light, by Paul Bogurd, ©2013, Little Brown and Co., - I admit I was concerned about reading an entire book on our growing artificial light problem, but I was pleasantly surprised by the author's dedication to the subject. Chapters include the negative effects of artificial lighting on our sleep patterns and health, human fear of darkness in the modern age, getting to 'know darkness', dark places around the globe, and the recent effort by our National Park System to elevate dark skies to their protection. The text is written in an narrative style that from my perspective makes this book just plain enjoyable to read. If I could recommend one book from this list, this would be it. Now, I think I've finally been inspired to upgrade my exterior lighting to full cut off fixtures.

Brotherhood of the Bomb, The Tangled Lives of Robert Oppenheimer, Ernest Lawrence, and Edward Teller, by Gregg Herken, ©2002, Henry Holt and Company, LLC - Wow, with a title like this, this book is going to be interesting I thought. This book is very well researched, almost too well researched. Reads like a 300 plus page legal deposition mostly about Robert Oppenheimer's accusers into his never ending loyalty hearings. Think this work could have been a more memorable text if the author would have used less facts to illustrate what was a significant story in the lives of these three scientist and the development of the bomb.

NEW DOBSONIAN AT SHERZER

By Norbert Vance
Director, Sherzer Observatory

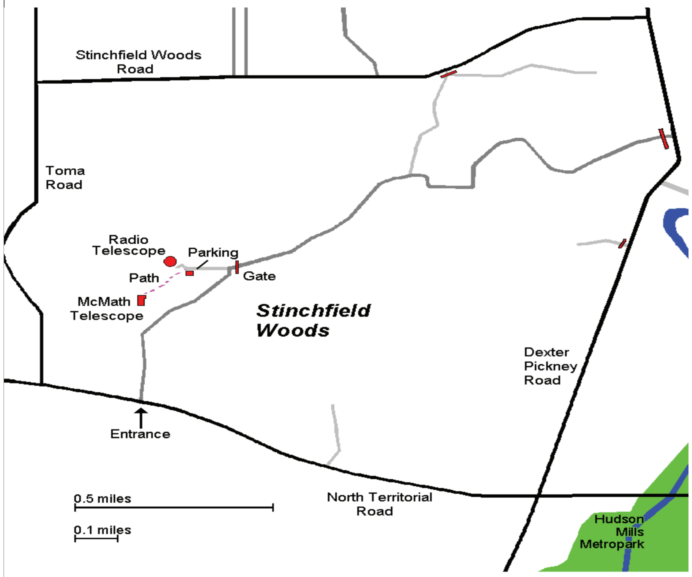
I was able to put our new 16” Orion Dob through the paces tonight and figured you might be interested in a short report. I set the beast up by myself with effort on the south side of the deck. The new lights on Washtenaw still continue to please me, but the brilliant gibbous moon negated any of the benefits- for now. Still, I’m pleased that I was easily pulling many pinpoint stars from the likes of M13, M92, M11, and M3 with a 17mm Baader Hyperion despite the considerable skyglow. Nebulae such as M27 were dampened. The 31mm also performed well but need for a coma corrector is more evident. I’m not complaining. The scope pointed very nicely with the SkySafariPro/iPad2 interface. Occasional star aligns in the region of the sky I was looking improved accuracy such I was getting objects centered with the 17mm. Good cord management is necessary. I found a convenient spot for the iPad atop my step ladder’s paint tray. Saturn and the moon with the 17mm- good focus- but I was truly pleased that the sharpness held even with a 5mm Radian! That was rewarding, especially on Saturn, which filled the field, and Schroter’s Valley. Can’t wait to get this to Fish Lake in a few weeks under a new moon sky. I’ll trust my better students to use the 16” and hone their observing skills with it, and then pass that on to classmates. I typically get 20-24 in my fall observational class.

Doug Scobel sends us this shot of the waxing gibbous moon: ***“Here’s a shot of the moon on the evening of July 9, 2014. Haven’t done much observaytin’ lately, so I took advantage of tonight’s clear if not moon-washed sky. Taken with my Canon 7D DSLR through a 300mm f/4 lens.”***

Places & Times

Dennison Hall, also known as The University of Michigan's Physics & Astronomy building, is the site of the monthly meeting of the University Lowbrow Astronomers. Dennison Hall can be found on Church Street about one block north of South University Avenue in Ann Arbor, MI. The meetings are usually held in room 130, and on the 3rd Friday of each month at 7:30 pm. During the summer months and when weather permits, a club observing session at the Peach Mountain Observatory will follow the meeting.

Peach Mountain Observatory is the home of the University of Michigan's 25 meter radio telescope as well as the University's McMath 24" telescope which is maintained and operated by the Lowbrows. The observatory is located northwest of Dexter, MI; the entrance is on North Territorial Rd. 1.1 miles west of Dexter-Pinckney Rd. A small maize & blue sign on the north side of the road marks the gate. Follow the gravel road to the top of the hill and a parking area near the radio telescopes, then walk along the path between the two fenced in areas (about 300 feet) to reach the McMath telescope building.



Public Open House / Star Parties

Public Open Houses / Star Parties are generally held on the Saturdays before and after the New Moon at the Peach Mountain observatory, but are usually cancelled if the sky is cloudy at sunset or the temperature is below 10 degrees F. For the most up to date info on the Open House / Star Party status call: (734)332-9132. Many members bring their telescope to share with the public and visitors are welcome to do the same. Peach Mountain is home to millions of hungry mosquitoes, so apply bug repellent, and it can get rather cold at night, please dress accordingly.

Membership

Membership dues in the University Lowbrow Astronomers are $20 per year for individuals or families, $12 per year for students and seniors (age 55+) and $5 if you live outside of the Lower Peninsula of Michigan.

This entitles you to the access to our monthly Newsletters on-line at our website and use of the 24" McMath telescope (after some training).

A hard copy of the Newsletter can be obtained with an additional $18 annual fee to cover printing and postage. Dues can be paid at the monthly meetings or by check made out to University Lowbrow Astronomers and mailed to:

The University Lowbrow Astronomers

P.O. 131446

Ann Arbor, MI 48113

Membership in the Lowbrows can also get you a discount on these magazine subscriptions:

Sky & Telescope - $32.95 / year $62.95/2 years

Astronomy - $34.00 / year or $60.00 for 2 years

For more information contact the club Treasurer at:

lowbrowdoug@gmail.com

Newsletter Contributions

Members and (non-members) are encouraged to write about any astronomy related topic of interest.

Call or Email the Newsletter Editor: **Jim Forrester (734) 663-1638 or** jim_forrester@hotmail.com to discuss length and format. Announcements, articles and images are due by the 1st day of the month as publication is the 7th.

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	Dave Jorgenson	
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Lowbrow's Home Page

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Reflections & Refractions

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Lowbrow Calendar

Friday, July 18, 7:30 P.M.: ***Monthly Club Meeting.*** Planetarium, Room 402, Fourth Floor, Mark Jefferson Science Complex, Eastern Michigan University, Ypsilanti, Michigan Norb Vance (Director, Sherzer Observatory, EMU): Planetarium Potpourri at EMU (with some LIVE Saturn thrown in!). ***Note, this meeting will be held on the EMU campus***, not the U-M campus. We plan to have our latest full dome feature "Saturn: Jewel of the Heavens" to show. We'll show the new lighting and $4000 planetarium system upgrades. There will be a short Powerpoint about some happenings on the calendar both here and around the region including Great Lakes Planetarium Association stuff, star parties, etc. And if there's time or the weather isn't 100% we sometimes let the Lowbrows have at the controls to see how Mr. Oz does it. Pizza and pop will be served. Then we will trek over to SEE Saturn, weather permitting in the 10-inch apo refractor using the Ethos and Baader eyepieces along with Mars and a host of other summertime treats. There will other telescopes on deck as well. In other words, there will be fun akin to July meetings in the past.

Saturday, July 19, Sunset: ***Open house at Peach Mountain.*** May be cancelled if cloudy.

Saturday, July 26, Sunset: ***Open House at Peach Mountain.*** May be cancelled if cloudy.

University Lowbrow Astronomers
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Nucleosynthesis

--Part 4--

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Notes

[1] Fusion reactions are of two types, called DI and CN.
DI reactions occur in a single step, for example:
$H^1 + H^2 \rightarrow He^3$ + photon
To satisfy both conservation of energy and conservation of momentum, there must be two items to the right of the arrow. A reaction with only one item to the right, such as $H^1 + H^2 \rightarrow He^3$, doesn't work. Another particle (a photon in this case) is needed to carry away the extra energy. While photons are the most common extra particle, it can be a neutron or any of a number of other particles.
CN reactions occur in two steps, for example:

$O^{16} + O^{16} \rightarrow S^{32*}$
$S^{32*} \rightarrow Si^{28} + He^4$

Note that the first reaction has only one item to the right of the arrow. That's OK, even though it would violate conservation of energy/momentum, it is only a temporary violation (which is allowed in quantum mechanics provided that the time of the violation is short enough). The product (S^{32*}) has an asterisk to denote that it is an excited state of sulfur.

I briefly mentioned excited states in part 3. A given isotope has one ground state, but may have one or more excited states. In most cases excited states have very short half lives. As is typical of most excited states S^{32*} decays quickly and the overall the reaction is

$O^{16} + O^{16} \rightarrow Si^{28} + He^4$

Excited states may decay into the ground state of the same isotope, this usually occurs via a process called gamma emission, though it can occur via other processes (such as IT, internal conversion). Excited states can also decay to other isotopes; such decays are similar to the decays explained in part 3 except that excited state decays are often more "creative" than ground state decays. Since an excited state has lower binding energy, it has more energy available and often will have more decay routes available than the corresponding ground state (that may sound counterintuitive, but it is the case). To give just one example, fusion of $O^{16} + O^{16}$ can have any of the following 7 results:

$Si^{28} + He^4$
$P^{31} + H^1$
$S^{31} + n$
$Si^{30} + 2H^1$
$P^{30} + H^2$
S^{32} + photon
$Mg^{24} + 2He^4$

[2] To determine the temperature needed for fusion, you need to go through a series of steps. (I will not go through all the details, but the following is an outline of the process).

a) Fusion only takes place if two nuclei are within a certain reaction distance (call it r). Traditionally physicists do not talk about reaction distances, but use the term "cross section" symbolized by σ. Cross section and reaction distance are related by the formula: $\sigma = \pi r^2$

b) Two nuclei will repel each other by a force given by Coulomb's law: $F = k_e Z_1 Z_2 e^2/r^2$ (k_e is the coulomb constant, Z_1 and Z_2 are the Z values for the two nuclei and e is the charge on one proton).

c) To force two nuclei within the reaction distance (or cross section), there needs to be enough energy to overcome the Coulomb's repulsion. This value can be calculated as $E_0 = k_e Z_1 Z_2 e^2/r$ (this involves simple physics and a little algebra; essentially the reverse of the calculation needed to determine escape velocity).

d) At the high temperatures where fusion is a possibility, solids and liquids do not exist. All that exist are matter in gas (or plasma) phase. If we assume the gas is an ideal gas, we can use the ideal gas law to relate temperature to the energy of individual atoms. We can calculate a temperature T_0 where the atoms have energy E_0. The average energy in an idea gas is related to temperature by the equation $E = 3k_BT/2$ where k_B is the Boltzmann's constant.

e) Putting these together, these we can calculate T_0. There are complications. The cross section is not a constant, but varies somewhat depending on which nuclei are being fused. Also within a gas at a specific temperature, the atoms have a range of energies, not the specific energy implied above.

f) The calculated T_0 is higher than the observed T_0. This was not understood until it was realized that quantum mechanics allows reactions to take place at lower energies than the explanation above implies. Only by using quantum mechanics do you get the correct temperatures. I will not explain the quantum mechanics calculation which is quite different than the classical calculation given above.

[3] The ratio of protons to neutrons is based solely on a balance between two processes. 1) decay of neutrons into protons and 2) conversion of protons into neutrons. The first happens at high temperatures and low temperatures. The second only happens at the high temperatures found shortly after the big bang. Using simple calculations, it is possible to derive an equilibrium ratio of protons and neutrons.

[4] The bottleneck in big bang nucleosynthesis is the first step, fusion of one proton to one neutron to form deuterium (hydrogen-2). Hydrogen-2 has a low binding energy and is easily broken apart at high temperatures. The temperature must drop enough so hydrogen-2 can exist without being broken apart.

The mean lifetime of a neutron is approximately 15 minutes; however there is some uncertainty in that value. Measurement of the lifetime of a neutron is not easy. Unlike radioactive elements, you cannot accumulate measurable quantities of neutrons and store them in one place as is possible for most radioactive materials. Since neutrons are neutral, it is not possible to manipulate a stream of neutrons with an electric field as is possible for changed particles. Radioactive elements that have short half-lives can be ionized and then manipulated in an electric field, in this way it is possible to determine the properties of these elements (unless the half-life is really short, in which case the best that can be done is to estimate the half-life using the Heisenberg Uncertainty Principle, which I will not explain here).

[5] The main reactions in big bang nucleosynthesis are:
neutron → proton + electron + neutrino
proton + neutron → H^2 + photon
$H^2 + H^2 \rightarrow He^3$ + neutron
H^2 + proton → He^3 + photon
$H^2 + H^2 \rightarrow H^3$ + proton
$H^3 + H^2 \rightarrow He^4$ + neutron
$H^3 + He^4 \rightarrow Li^7$ + photon
$He^3 + He^4 \rightarrow Be^7$ + photon
$He^3 + H^2 \rightarrow He^4$ + proton
He^3 + neutron → H^3 + proton
Be^7 + neutron → Li^7 + proton
$Li^7 + H^3 \rightarrow Be^8$ + neutron + neutron
$Li^7 + He^3 \rightarrow Be^8$ + proton + neutron
$Be^8 \rightarrow He^4 + He^4$

Note, there is a suggestion that a very small quantity of beryllium-9 (the only stable isotope of beryllium) was produced during the big bang. This is not universally accepted, but is an idea that is currently under development (see Maxim Pospelov and Josef Pradler, 23 March 2011).

Using billiard ball thinking, you might think fusion between any two nuclei is possible. You might wonder why some reactions are included and others are not. If we take two nuclei A and B, and attempt to fuse them into a larger nucleus C, giving A + B → C + x, there are a number of issues:

a) Coulomb's law (see note 2(b) above) causes nuclei to repel each other. Ignoring other factors, the repulsion is roughly proportional to Z_1 times Z_2 (the atomic number of nucleus 1 and atomic number of nucleus 2). As the repulsion goes up, it is harder for fusion to take place.
b) Some reactions have a larger cross section (see note 2(a) above) than others. Reactions with a larger cross section are more likely (assuming the same coulomb repulsion). The factors that determine cross section are beyond the scope of this article.
c) If the energy of the reactants (A and B in this case) is close to the energy of the product (C in this case), there is what is known as a "resonance." Resonance reactions are more likely than non-resonant reactions.
d) Reactions that are endothermic (reactions that are not exothermic), cannot take place unless there is adequate energy available. That doesn't mean endothermic reactions are always impossible, rather depending on the circumstances, they may be impossible or they may proceed along with exothermic reactions.
e) If the product (C in this case) is radioactive this may make the reaction less likely. This is true whether or not the product is an excited nuclear state. If the half life of the product is much longer than lifetime of the star or other structure that conducts the fusion reaction, it doesn't matter. If it is much shorter, it may make the reaction unfavorable. As an example, fusion of proton + proton forms a nucleus He^2. He^2 is extremely unstable. In fact many authors do not acknowledge that it even exits. If it does exist, the half-life is extremely short. If it doesn't we can pretend the nucleus exists and has a very short half-life for purposes of this analysis. Either way, fusion of proton + proton is very unfavorable compared to other reactions.
f) Temperature is a factor (as explained in note 2 above).
g) If the two reactants (A and B in this case) are different, A and B must be mixed appropriately for the reaction to take place. How reactants mix (or don't mix) is an important problem that is still not completely understood for all cases and all reactions within nucleosynthesis.
h) Note that fusion reactions A + B + C → something are highly unlikely because getting three nuclei within the reaction distance is improbable.
i) The processes of nucleosynthesis consist of hundreds of reactions, it is reasonable to classify reactions as "important" and "unimportant" to make things more manageable. The problem is how do we classify the reactions? Whether a reaction is important or not depends on the question you are asking. The "important" reactions for supplying energy in stars are different than the "important" reactions for nucleosynthesis.

Note that most of the proton-proton chain reactions that occur in hydrogen burning are DI. Most reactions involving heavier nuclei are CN. Note that fusion of A+B might form an excited state. Many reactions involving reactants heavier than hydrogen form excited states. And such reactions are by definition CN. Determining whether fusion of two nuclei goes to ground state or to an excited state is complicated and beyond the scope of this article. However part of the explanation involves angular momentum.

[6] The abundances of the isotopes (neutron, H^1, H^2, He^3, He^4, Li^7, and Be^7) are dependent on the density of the universe at about 1 minute after the big bang. We can go backward and determine this initial density by asking what value of density produces the observed abundances (after accounting for the fact that the neutron and Be^7 are unstable).

[7] The proton-proton chain proceeds through three steps. Step 1 can occur via either of two reactions (both of which are slow):

Step 1 (main reaction, most common):
proton + proton → proton + neutron + electron + neutrino
proton + neutron → H^2 + photon
Step 1 (pep reaction, less common):
proton + electron + proton → H^2 + neutrino
Step 2: H^2 + proton→ He^3 + photon
Step 3 (there are four different branches. Depending on temperature, one of these will dominate):
The pp I branch:
He^3 + He^3 → He^4 + proton + proton
The pp II branch:
He^3 + He^4 → Be^7 + photon
Be^7 + electron → Li^7 + neutrino
Li^7 + proton → $2He^4$
The pp III branch:
He^3 + He^4 → Be^7 + photon
Be^7 + proton → B^8 + photon
B^8 → Be^8 + positron + neutrino
Be^8 → He^4 + He^4
The pp IV (Hep) branch:
He^3 + proton → He^4 + positron + neutrino

[8] The vertical axis is the percentage of the universe that is composed of the given element by weight.

Abundances of chemical elements are not the same in all locations. There can be processes that deplete an element. For example earth's gravity is not enough to hold onto hydrogen and helium and thus earth has less of these elements than is true in the universe as a whole. And there can be processes that increase an element (such as stellar fusion). So you will get different results depending on where you look. While it is difficult, it is possible take these issues into account to get true universal abundances.

This chart is modified from a chart found within the Wikipedia article "Abundance of the chemical elements." I modified the chart by removing technetium (Z=43), promethium (Z=61). I also removed all the elements heavier than bismuth (Z=83), with the exception of uranium (Z=92) and thorium (Z=90).

Technetium, promethium, bismuth and all elements heavier than bismuth are radioactive (that is they have no stable isotopes). Of these, bismuth, uranium and thorium have isotopes with very long half lives, and thus can found in universe today, though they are less common than elements like carbon and oxygen. These three elements were kept. The other radioactive elements were deleted as they cannot be found in the universe today (except in very small quantities).

[9] By examining the spectra of a star, it is possible to determine which elements are found within the atmosphere. With the exception of hydrogen, it is generally not possible to distinguish one isotope from another. It is generally not possible to determine where the element came from (e.g. did it form within the star, or was the element present before the star formed). It is not possible to determine which elements are present in the star's core.

One notable exception: In 1952, technetium was detected in a stellar atmosphere. Since the most stable isotope of technetium has a half life of 4 million years, the only way the technetium could be present in the atmosphere, was if the star itself formed the technetium. In most other cases detection of an element within the atmosphere does not tell us if the element was formed within the star or came from somewhere else.

[10] Neutrinos. Detection of neutrinos from the sun has been possible for many years. Processes that involve the weak interaction (in particular beta decay) result in neutrinos. Our understanding of the fusion processes within the sun allows us to predict how many neutrinos should be emitted and how many should be detected on the earth. In the case of the sun, fusion of hydrogen-1 to hydrogen-2 involves beta decay and thus release of neutrinos. The number of neutrinos found was less than expected, and the resolution of this discrepancy has led to an improved understanding of neutrinos (though perhaps surprisingly, has not changed our understanding of stellar fusion).

Generally detection of neutrinos from other sources (sources other than the sun) has not been possible (until very recently). One exception was the supernova SN1987A. Neutrinos from this event were detected. This was possible due to its relatively close location in the Large Magellanic Cloud, about 160,000 light years away.

The ability to detect neutrinos is expected to improve. Potential neutrino sources that might be detected in the near future: the big bang (conversion of protons to neutrons; beta decay of neutrons, tritium and beryllium-7), silicon burning (beta decay of several elements), core collapse and formation of neutron stars (this involves changing vast numbers of protons into neutrons through beta decay) and neutron absorption processes (which involve numerous beta decays).