REFLECTIONS / REFRACTIONS

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University Lowbrow Astronomers

November 2009

Volume 33 Issue 11

Jobs, Jobs, Jobs

By Tom Ryan

The Lowbrows saved my life. They didn't do it by administering first aid when I went into shock when a piece of steel I stepped on went through my foot and came out the top of my shoe. They didn't fish me out of the river when I fell off the railroad trestle over the Huron River. They didn't take me to the hospital to have my face sewn back on after I fell asleep at the wheel and drove into a gasoline tanker truck. They did it by giving me a job. And they did it twice.

In 1979 I had a new house, a terrific girlfriend, and a job where my boss thought I was the best thing since sliced bread. I was making money, I was golden, and nothing bad could ever happen to me. Then, the recession of 1981 hit. The company laid off nearly everyone, including me. My girlfriend left me for very good reasons, and I could no longer afford my house payments. The only job I could find paid half of what I was making when I bought the house. My income fell below my bare minimum living expenses, and I got poorer every day I worked at that place.

The owner of the little gaging company that hired me was happiest when he was making someone else feel bad, and he worked on me for almost two years. My self esteem plummeted. It didn't happen all at once, but every day I faced my evident failure to support myself, and every day I felt a little bit worse. I blamed myself for my situation. I tried to increase my value by taking programming classes at night. The U of M got my money, and I learned Pascal programming. Anybody need a Pascal programmer? No? Gosh, maybe the U of M will give me my money back. No, it doesn't work that way.

I tried to get another job. I tried every day. Unfortunately, by the time I tried this, my self-esteem was so low and I was so desperate for another job that getting down on my knees during interviews and begging to be hired scared off the potential employers.

Then, one of the other guys working with me in that hellhole heard about an astronomy club that was just starting up. I went to a meeting, and the guys there made me Observatory Director.

It is very hard for me to describe how that made me feel. These guys had faith in me. They didn't know that I worked at a really bad job. They didn't know that I couldn't get a job pushing a broom in a shopping mall. They didn't know that I was so poor I had to rent out two of the rooms of my house, and I couldn't pay all of my bills every month. They just gave me a fresh start. They said they needed my help, and it saved my life.

A few months after that, I got a better job. I could once again afford my house payments. I met my future wife at a Lowbrow meeting. And, I was still Observatory Director for the Lowbrows.

Fast forward to 1996. I had been consulting for nine years. I started consulting when the great company that hired me out of Hell was purchased by another company that had the same attitudes toward workers as the gaging company. Rather than subject myself to that again, I started my own company. After nine years of doing excellent work, but no business planning or advertising, my yearly income had finally fallen to the price of a television set.

While we were doing our taxes, my wife looked at the steady decline of income and said, Tom, this isn't working out. You need to get a job.

I thought about working for some evil b*****d again, and I told her I had a job. I just didn't have customers.

Nevertheless, she was right. My business was failing, and so was I.

At the time, I was involved with replacing the electronics and machining a new sidereal drive on the Lowbrow's 24" telescope. Lowbrow Steve Musko asked me if I could machine some hardware at the place he worked, which was Space Physics Research Laboratories. I could and I did, and while I was there, one of the researchers asked me if I could design the optical system of an orbiting satellite. I couldn't (then), but that led to other optical design jobs, and that year, my income was back to where it had been before I started consulting. The wife was happy, and things have been pretty good ever since. This time the Lowbrows (and Steve Musko) saved my career, and consequently, the life that I have now.

We are now deep into another recession. I looked around the table at the after-meeting Lowbrow Pizza and Beer Session and counted about half the Lowbrows present as being out of work. These are all smart people, all hard working people, all in their peak earning years, and half of them are out of work.

This present recession, I believe, will make us long for the days of 1981. I didn't pay any attention to why the 1981 recession occurred, but I have researched this one, and for anyone who would like my opinion on what caused it, and what they can do about it, please feel free to call, email, or grab me after a meeting and I will happily share the sources of my information.

Unfortunately, doing something about the economy, even if that can be accomplished at all in the face of ignorance and opposition, will take years. It only takes a few months of unemployment to destroy a family. There are Lowbrows right now who are out of a job, or are working at a job that is barely getting them to their next payday, or who might be extra ambitious and just want work in addition to what they have now.

I'd like to propose that we, as a club, set aside some area, perhaps on the web site but not in the members-only section, where we post our resumes and any advertisements for more work.

We can help each other. We might change a life. And, if anyone needs an aardvark groomer or a balloon-mender with his own tools, or any of the other skills the Lowbrows might have, they'll know where they can find one, and we can help them, too.

New Life For A Not-So-Old Scope

by Doug Scobel

Most of you reading this are familiar with my 8-inch f/8 homemade Newtonian reflector I call "The Mars Scope". I named it so because I made it specifically for the great Mars opposition of 2003. I used it a lot during that opposition, and made numerous observations and drawings of Mars late that summer. There were times when atmospheric seeing allowed me to push the scope to magnifications of 300 and sometimes even 400 diameters. The views were unforgettable.

Now you may also remember how I had that scope mounted – on an old, homemade (though not by me), equatorial pipe mount. That mount is solid, with very nicely machined bearings, and it steadily supports the weight and almost six-foot tube of the Mars Scope very well indeed.

But that mount has one serious drawback. Yes, it's an equatorial, but it has no tracking capability. At 400 power, objects don't stay in the field of view for very long. At that magnification it doesn't even take half a minute for objects to sweep through the field. So when using the scope for its intended use, namely high-power lunar and planetary viewing, I spend almost as much time recentering the object in the eyepiece as I do actually observing. When trying to eek out as much detail from a high-power view as you can, having the target constantly moving is a distraction at best, and can make you miss detail at worst. The result is that after the 2003 Mars opposition, I've been using the scope less and less. For years I've tried to figure out how to add tracking to that old pipe mount, but never hit on a good way to do it. After all, I'm a woodworker, not a machinist!

All that is about to change. Last winter I had a "Eureka!" moment. Mark Deprest has for years used equatorial tracking platforms for his scopes, and he had purchased a nice, new platform from Equatorial Platforms for his newly acquired PK-457 (18-inch) Dob, which he later refurbished and renamed "Blondie". I thought to myself, if I were to get one of those, I could put my 13-inch Dob "Papa Smurf" on it, and then build a Dob mount for the Mars Scope. I could add tracking to two scopes at once! Brilliant!

Because Equatorial Platforms's platforms are made-to-order, based on your scope's size and weight, I was a little concerned, wondering if one platform would work well with two different scopes. One is short, squat, and heavy, the other is relatively light and tall. Kind of a Mutt and Jeff situation. But after some email correspondence with Tom Osypowski, who runs Equatorial Platforms, my misgivings were relieved and I ordered a platform of my own.

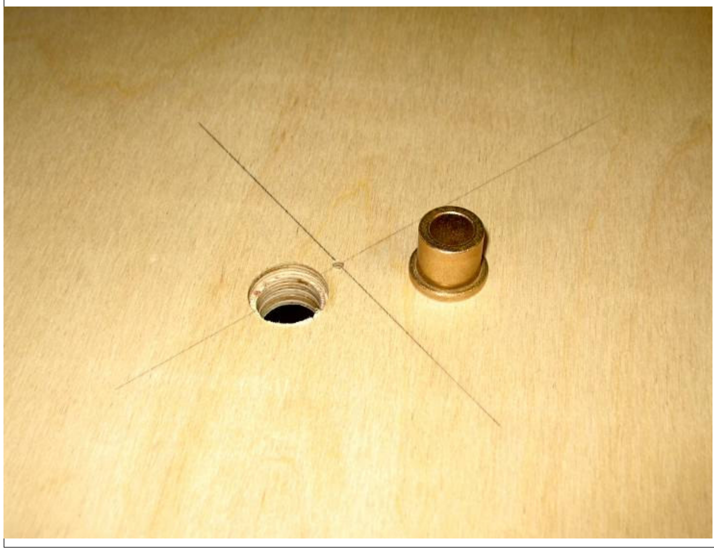
The 13-inch, for which the platform is primarily designed, works splendidly on it. I simply push the scope around like I always have, but when I let go, the object in the eyepiece just sits there. Wow! How did I live without tracking on my scopes for all these years? It's kind of like cruise control on your car. Once you have it, you wonder how you lived without it previously. Mark had always told me "Once you track, you never go back". Now I know first hand what he means.

So now back to the purpose of this article, namely describing how I built the Dob mount for the Mars Scope. It's pretty basic, but with a few little twists that I had to handle along the way. Tom Osy had told me that because the scope is tall, that I need to try to keep the center of gravity as low as possible. While the platform tracks, it can tip as far as seven and a half degrees each way as it runs through its fifteen degrees of travel. Keeping the CG low isn't a problem for Papa Smurf, but it could be for the Mars Scope.

The new Dobsonian-style mount. Everything between the OTA and the equatorial tracking platform are new. The tracking platform doubles as the ground board.

The length of the tube dictated that the rocker box had to be over 30 inches tall, so stiffness was of the utmost. Three-quarter inch Baltic Birch was the obvious choice. But Baltic Birch, which has all hardwood plies, is quite dense and heavy. So I had to build the upper portions as light as I could, without sacrificing stiffness. Still, it's pretty basic Dobsonian construction. Basic box shape. Ebony Star Formica on Teflon bearings. But you won't see any screw heads anywhere. I used biscuits and glue almost exclusively, except where screws can't be seen from the outside. Because of all the dew to which I knew the scope would be exposed, I used Titebond III waterproof glue, stainless steel hardware, and Minwax "Helmsman" marine spar polyurethane on all exterior surfaces to make everything 100% dew-proof.

Biscuits and glue hold it all together. (below)



(left)

Underside of the bottom of the rocker box during construction. The center pivot is offset for better balance. The bronze pivot bushing is captive under the Ebony Star Formica.

As you can see from the pictures, the clamshell-type cradle, which lets me easily reposition the tube for balance or eyepiece access, has a lot of open space. The cutouts in the upper end of the rocker box help keep things lighter up there also. Besides, I think the half-moon shaped altitude trunnions and the circular cutouts are kind of an artistic expression of the scope's lunar and planetary purpose. Okay, maybe not.

Clamshell-style cradle lets me quick and easily re-position the tube when needed.

I really like keeping my eyepieces at hand at the scope, so I made up an eyepiece carrier that sits on the front of the rocker box, similar to the one I made for the 13-inch. Inside there's enough room for six eyepieces, plus four filters. The hinged cover keeps everything dew free while not in use. The bottom compartment holds the battery for running the cooling fan, and the dew control that I intend to add to the scope. At five pounds, having the battery essentially at the bottom of the rocker box helps lower the center of gravity even more. Hanging the weight of the battery and eyepieces on the front of the rocker box makes it a little front-heavy, so I offset the center pivot towards the front to compensate. It sounds a little anal, but with the tracking platform tipping one way and then the other, you really want things balanced as best as you can. A simple center of balance calculation after weighing everything told me how much of an offset I needed. I did the same thing with the altitude trunnions. They're offset up in the cradle a little because the finder and eyepiece are usually going to be above the centerline of the tube. Add a camera and the amount of imbalance becomes potentially significant. Remember, good balance translates into good stability!

Eyepiece and battery holder "hangs" on the front of the rocker box, and helps lower the center of gravity. The 12 volt gel-cell battery lives in the lower compartment, and eyepieces and filters reside in the upper.

So how does it work? As it turns out, wonderfully. All my misgivings about the height making it unstable were unfounded. There's no shakiness, no noticeable tendency to fall over. Just like with Papa Smurf, just point the scope and let go. It's really that simple. It cost me maybe a hundred dollars or so (not counting the tracking platform), but being able to track at up to 400 power or higher is priceless. As Mark says, once you track, you never go back. Now you'll be hearing me say that too. And you'll be seeing the Mars Scope at open houses and observing events more often now too.

The "new and improved" Mars Scope!

Pluto, KBOs and the Definition of "Planet"

By Douglas Warshow

This is the final article relating Dr. Alan Stern's lecture on the importance of the Kuiper Belt and how it helped astronomers to re-examine their views about the Solar System. The rest of this piece concerns one such re-examination that almost everyone has heard about by now: the definition of the word "planet."

In the interest of full disclosure, the author would like to point out that he agrees with Dr. Stern's conclusions and the reader may rightly point to some bias in this piece. Nevertheless, the author will try to present Dr. Stern's train of thought on this matter as dispassionately as possible. The author also asks the reader to refrain from killing the messenger (literally and figuratively); this article is merely a report (with some added background) on the relevant portion of Dr. Stern's lecture.

The term "planet" comes from an ancient Greek word (πλανήτης) meaning "wanderer." This was a reference to the fact that these objects moved through the sky against the background of fixed stars.

Several centuries later, the astronomer Galileo Galilei turned his telescope to Jupiter and saw that there were other bodies that moved with respect to the sky. Although he called them the "Medician stars," he knew that they were actually moons orbiting the King of the Planets.

Other wandering bodies such as Uranus, Neptune, Pluto, the asteroids, comets and the Kuiper belt objects (KBOs) became known to humanity throughout history. As had mentioned in the first of these articles, the size range of the KBOs with respect to Pluto and the other major bodies of the Solar System highlighted the fact that no scientific criteria had ever been assigned to the word "planet." As to augment this point even further, astronomers in the last decade have been discovering many (now well over three hundred) large bodies orbiting other stars. Clearly something had to be done.

A clear consensus on the definition, however, was not in the stars. Debates raged both within and without the astronomical community, especially with respect to the status of Pluto. And although Pluto became the crux of the issue, the outcome would also affect the designations of the KBOs.

In 2006, a gathering of the International Astronomical Union (IAU) debated as to what criteria should be used in order to determine whether or not an object was a planet. In the end, they presented the following definition*:

"A planet is a celestial body that

(a) is in orbit around the Sun,

(b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and

(c) has cleared the neighbourhood around its orbit."

Furthermore, a non-satellite body fulfilling only the first two criteria would be classified as a "dwarf planet," while a non-satellite body fulfilling only the first prerequisite would be termed a "small Solar System body."

Many astronomers (and laypeople) did not consider this definition as successful. And not just for emotional reasons.

As mentioned earlier, there are over three hundred known bodies that are larger than Earth orbiting other stars, so part (a) of the resolution already shows a lack of deep thought on the IAU's part.

The major controversy, however, lies with part (c). First of all, this criterion does not reflect just a characteristic of the body in question, but also where it is with respect to all the other bodies in a planetary system. As one travels away from a star, the larger a world's orbit is. Now add to that the fact that the farther a body is from its primary, the slower the body will travel. This combination means that over the course of any unit of time, the odds of two bodies gravitationally encountering each other decrease with increasing distance from the primary. This, in turn, means that it takes longer period of time for a "planet" to clear its neighborhood. In fact, if you were to place the Earth as far from the Sun as Pluto, then Earth would no longer be considered a planet by criterion (c) since there would be far more bodies in our neighborhood. (Mark, just think of the number of comets you could observe!). So the farther a world is from its primary, the more massive it would have to be to be considered a planet.

Another problem has to do with possible changes in the environment. Should a world's status as planet change with time due to external factors? As an example, if a in bound comet broke up (a la Shoemaker-Levy 9) and some of the surviving fragments settled into an orbit similar to Earth's, would Earth lose its planetary status?

A third problem involves a slight variation of the above: no world in the Solar System has cleared its orbital neighborhood. For instance, there are dozens of bodies, the Trojan asteroids, in the L4 and L5 points of the Jupiter's orbit. By definition, the L4 and L5 points are at the same distance from the primary body (the Sun in this case) as the secondary body (Jupiter). Thus, the Trojans are in the same orbital neighborhood as Jupiter. If a world that is about a thousand times more massive than the Earth is not a planet, then what is? And what's more, just ask the team that runs Project Spaceguard if they think that Earth's neighborhood is clear of debris; their mission is to discover and track near-Earth asteroids in order to determine their potential hazard level for our world. They have compiled quite the list.

Dr. Stern certainly has the right to call foul in regard to the IAU's use of the term "dwarf planet." Stern himself coined the term back in 1991, but he used it to classify a subgroup of planets, much in the same way that dwarf stars are merely a subcategory of stars. (Stern did not mention, however, what he considered to be the upper limit for the dwarf planet subcategory.) He further indicated that the IAU's usage of the phrase would not be considered proper English because of the disjunction in definition.

You are probably wondering why the IAU even proposed the above resolution as a basis for "planet" status. The gist of the answer is an all too familiar one.

The IAU is a bureaucratic organization of about ten thousand professional astronomers. Of these members very few are actually work in field of planetary science. The two committees within the IAU that are in charge of naming Solar System objects are the Committee on Small Body Nomenclature (in charge of naming comets and asteroids) and the Working Group for Planetary System Nomenclature (in charge of naming satellites and other non-asteroid/cometary bodies). (No commission for naming planets exists since it was though that all planets in the Solar System had already been discovered.) The two committees argued which one would get to name the bodies in the Kuiper belt, and the above definition is the result of their compromise. Since the SBN is comprised mostly of planetary dynamicists, the third criterion was added to benefit their group.

Dr. Stern assured the audience that the IAU does not have any authority to enforce their definition and that few (if any) planetary scientists have accepted it. As it is, the planetary scientists are working on their own list of criteria. There is no full consensus yet, but Dr. Stern mentioned some criteria that seem to be widely agreed upon in the planetary science community. This is what is called the Geophysical Planet Definition (GPD):

A planet

(1) does not undergo sustained fusion in its core.

(2) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape.

Notice that the position of the world plays no part in the definition. Using the above criteria, the Solar System contains twenty-five worlds. (The list is given below.)

The first criterion is the key difference between planets and stars. If you look back at part (a) of the IAU resolution, you'll see that if the Sun were part of a binary star system, the stellar companion would be considered a planet.

In the middle ground between stars and planets are the brown dwarfs. These bodies are massive enough to fuse deuterium (also called heavy hydrogen) in their cores, but not normal hydrogen like stars do. Once their deuterium runs out, fusion stops. Since brown dwarfs do undergo sustained fusion (albeit only briefly), they would not be considered planets. Stern joked that most astronomers refer to brown dwarfs as "failed stars," but he would call them "failed planets."

As for the second criterion, you'll note that this is the one criterion proposed by the IAU with which the planetary scientists actually agreed. Some bodies could be rounded by means of meteoroid or comet impacts but if those are the only reason for a body's "roundness", then that world is not a planet.

This begs the question, "How much mass or what minimum size is needed in order for self-gravity to make a round body?" The answer is a resounding, "That depends." Consider: each world is comprised of different materials and in different ratios. Each material possesses a particular yield strength indicating how much pressure it can withstand before it deforms. Imagine a skyscraper built with pumice instead of steel and concrete and that should give you a good feel for the concept.

Additionally, some worlds are more porous than others. (For an extreme example, take a look at a Cassini image of Saturn's wasp's nest of a moon Hyperion.)

Another factor is how much the materials are differentiated within the world. A body that has all its ice in its upper layers will be more malleable under self-gravity than one which has rock interspersed throughout the ice.

Temperature is yet another factor. In general, the warmer a substance is, the easier it succumbs to gravity (like the ice-cream cake that the author once forgot to put back in the freezer).

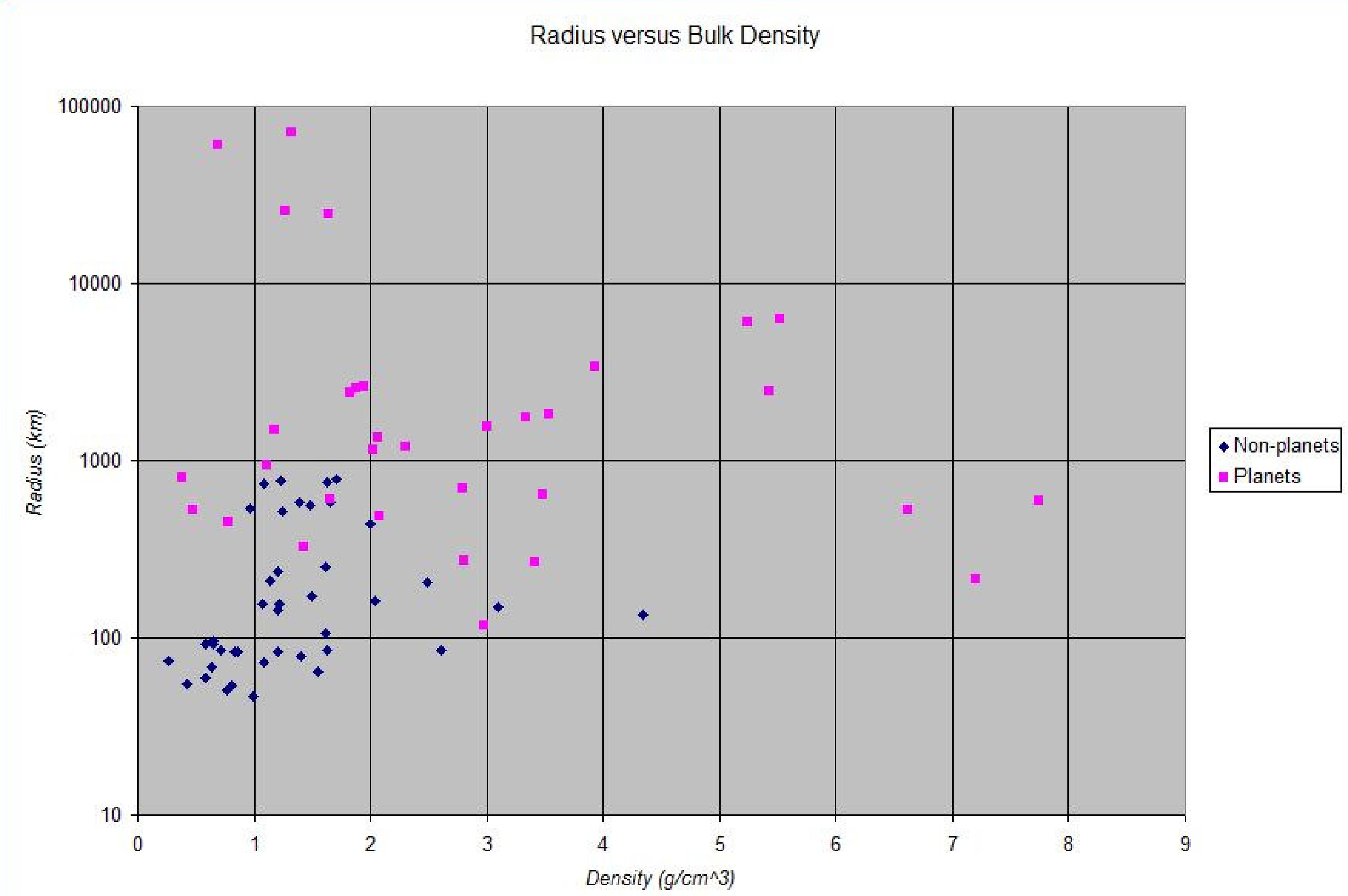
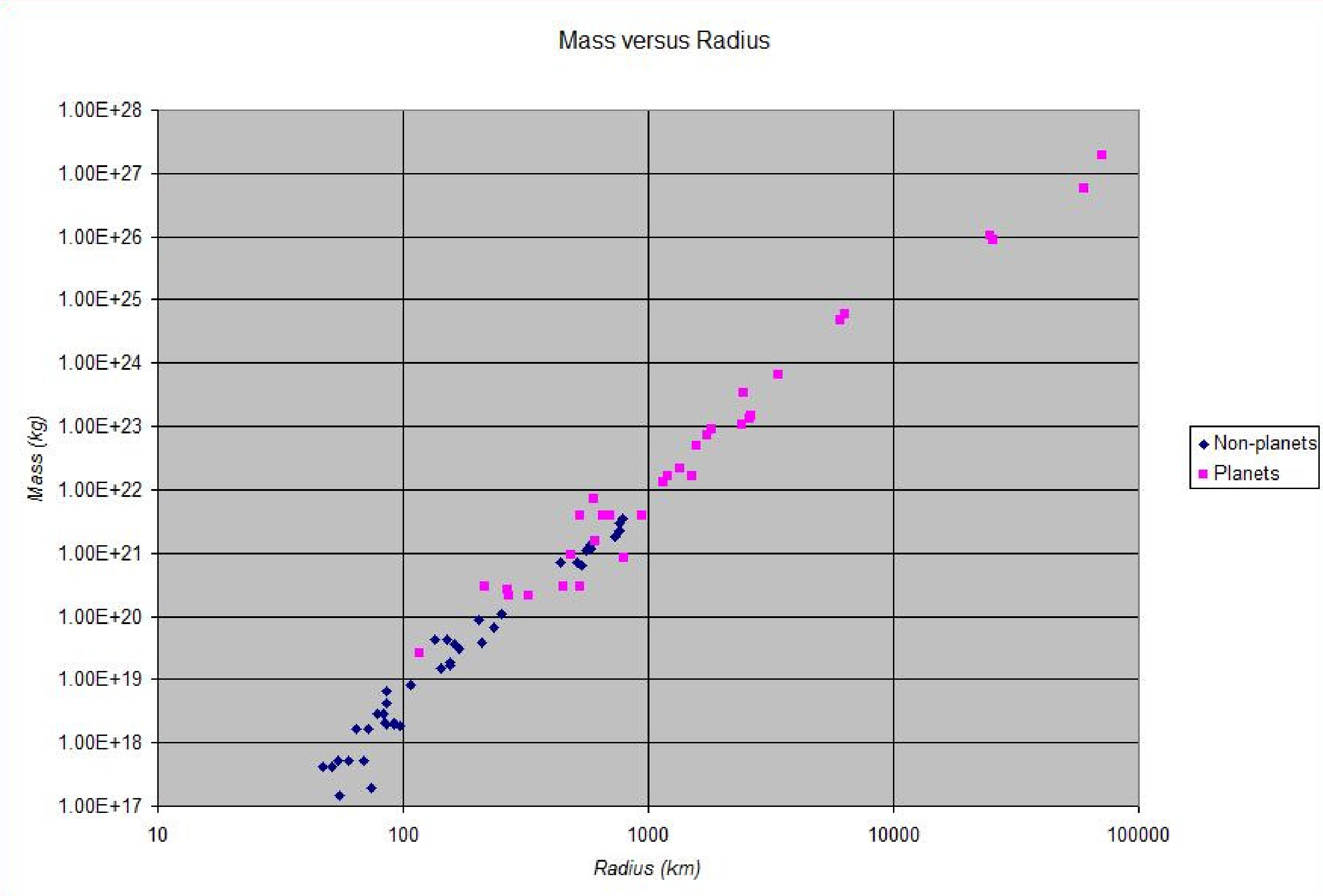


Figure 1 shows a graph of a world's radius versus its density (similar to one shown by Dr. Stern) for several of the larger Solar System bodies. (For some worlds whose size and/or density are not well known, two extreme values are given.) Worlds that qualify as planets as per the GPD are represented by the squares.



You can see a general division between the planets and non-planets in the figure, but when you compare the planets' masses against their radii (as in Figure 2), the differences between the two groups stand out far better.

What if a satellite fulfills the aforementioned prerequisites; should it also be considered a planet? Stern says yes. So if the Earth's moon, Luna, is planet, does that mean that the Earth is a satellite as well? Stern says no by the following reasoning.

Stern said that the definition of a moon is a body that orbits a planet. (The author confesses that he did not think to ask Dr. Stern how he would classify Dactyl, which orbits the asteroid 243 Ida, since neither meets the second criterion of the GPD.) Since all pairs of bodies orbit about their center of mass, i. e., their barycenter, the moon is considered to be orbiting about a planet if the barycenter is located within said planet.

The location of the barycenter can be determined from the following formula:

$$R_{barycenter} = \frac{R_{PrimaryMoon}}{\left(1 + \frac{M_{Primary}}{M_{Moon}}\right)}$$

where $R_{barycenter}$ is the distance from the center of primary body, $R_{PrimaryMoon}$ is the distance between the centers of the primary and the orbiting body and $M_{Primary}$ and M_{Moon} are the respective masses of the primary and orbiting bodies.

For the Earth-Luna system we have:

R_{Earth} = 6,370 km $M_{Earth} = 5.97*10^{24}$ kg

$R_{EarthLuna}$ = 384,000 km $M_{Luna} = 7.35*10^{22}$ kg

→ $$R_{barycenter} = \frac{R_{EarthLuna}}{\left(1+\frac{M_{Earth}}{M_{Luna}}\right)} = \frac{384{,}000km}{\left(1+\frac{5.97*10^{24}kg}{7.35*10^{22}kg}\right)} = 4{,}670km$$ (< R_{Earth})

For the Pluto-Charon system we have:

R_{Pluto} = 1,150 km $M_{Pluto} = 1.31*10^{22}$ kg

$R_{PlutoCharon}$ = 19,600 km $M_{Charon} = 1.52*10^{21}$ kg

→ $$R_{barycenter} = \frac{R_{PlutoCharon}}{\left(1+\frac{M_{Pluto}}{M_{Charon}}\right)} = \frac{19{,}600km}{\left(1+\frac{1.31*10^{22}kg}{1.52*10^{21}kg}\right)} = 2{,}150km$$ (> R_{Pluto})

Figure 3 (on the back page) shows the layouts of the above examples.

Are there any other satellites besides Luna and Charon that would also qualify? You bet: Io, Europa, Ganymede, Callisto, Titan and Triton.

Now why even mention this whole debacle? Well, if we use the GPD instead of the guidelines of the IAU, Pluto retains its planetary status in addition to being a KBO. Several more KBOs can also be considered planets: 136199 Eris, 136472 Makemake and 136108 Haumea along with probable candidates 90377 Sedna, 50000 Quaoar, 28978 Ixion, 90482 Orcus and 20000 Varuna. That makes the total of twenty-five known planets in the Solar System: four terrestrials, four gas giants, nine KBOs and eight satellites. (Note: in Dd. Sterns showed a slide that listed twenty-six planets, but the author noticed when reviewing the recording of the lecture that Charon was listed twice: under both the KBO and satellite categories.)

The Kuiper belt covers a large volume so there is no reason to assume that all of the planet-sized KBOs have been found yet. The portion of the Solar System within Neptune's, meanwhile, has been pretty much mapped out. Thus we can say there is indeed a third planetary region, one that promises to contain far many planets than the other two regions combined.

So to summarize, the discovery of Pluto and the Kuiper belt helped astronomers to re-evaluate in as far which are the most numerous types of bodies in the Solar System, how the Solar system evolved and what is meant when they use the term "planet."

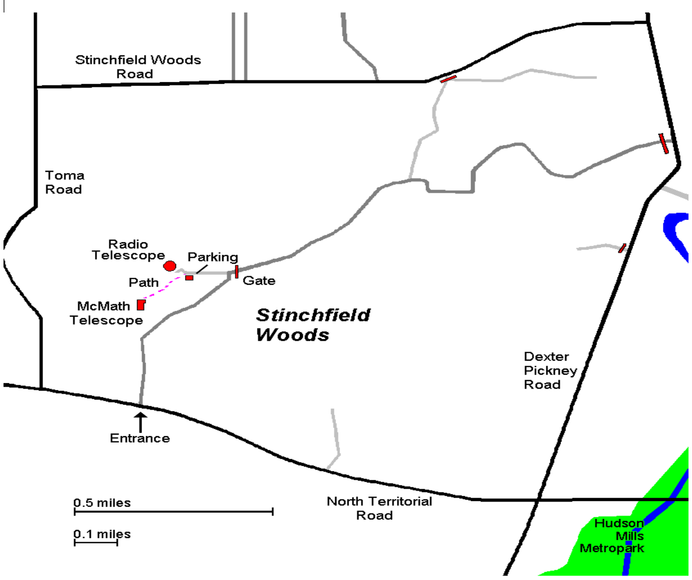
Once again, many thanks to John Causland for providing the author with a DVD of Dr. Stern's lecture.

*IAU Resolution 5A, August 2006

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 $12 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

c/o Liz Calhoun

P.O. 4465

Ann Arbor, MI 48106

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

Sky & Telescope - $32.95 / year

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

For more information contact the club Treasurer. Members renewing their subscriptions are reminded to provide the renewal notice along with your check to the club Treasurer. Please make your check out to: "University Lowbrow Astronomers"

Newsletter Contributions

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

Call or Email the Newsletter Editor: **Mark S Deprest (734)223-0262 or msdeprest@comcast.net** to discuss length and format. Announcements, articles and images are due by the 1st day of the month as publication is the 7th.

Telephone Numbers

President:	Charlie Nielsen	(734) 747-6585
Vice Presidents:	Jim Forrester	(734) 663-1638
	Ken Cook	(734)769-7468
	Bob Gruszczynski	
	Belinda Lee	(313)600-9210
Treasurer:	Liz Calhoun	
Observatory Director:	Mike Radwick	
Newsletter Editor:	Mark S Deprest	(734) 223-0262
Key-holders:	Jim Forrester	(734) 663-1638
	Fred Schebor	(734) 426-2363
	Charlie Nielsen	(734) 747-6585
Webmaster	Dave Snyder	(734) 747-6537

Lowbrow's Home Page

http://www.umich.edu/~lowbrows/

Email at:

Lowbrow-members@umich.edu

University Lowbrow Astronomers

University Lowbrow Astronomers
c/o Liz Calhoun
P.O. Box 4465
Ann Arbor, MI 48106

lizcal@umich.edu

Reflections & Refractions

Website

www.umich.edu/~lowbrows/

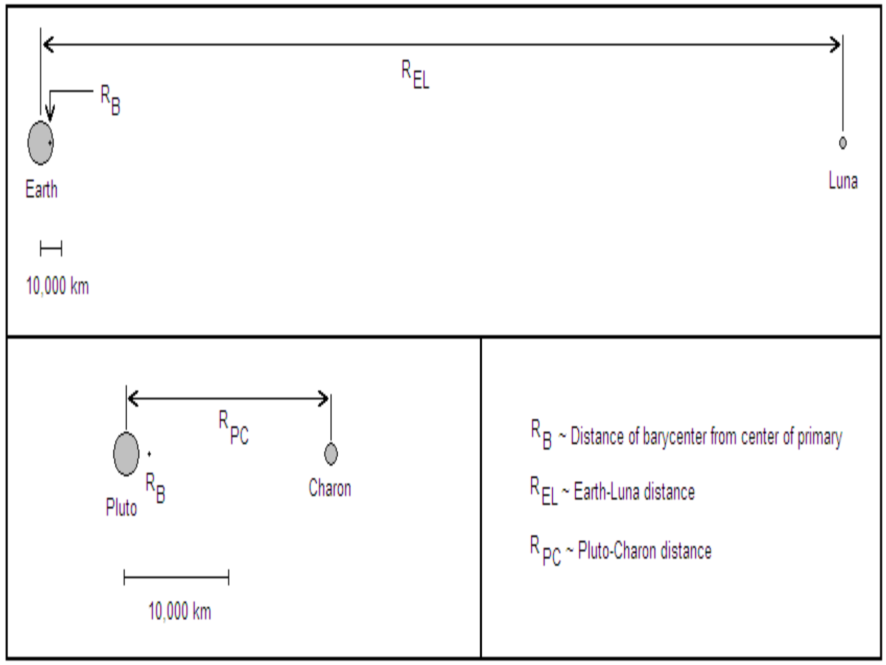


Figure 3: Barycenter locations for the Earth-Luna and Pluto-Charon systems.

University Lowbrow Astronomers
P.O. Box 4465
Ann Arbor, MI 48106

Check your membership expiration date on the mailing label