Notes & Considerations on Proposal for Astrosphere Catalog and Baseline Model for Comparison and Reference over Time

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Abstract

The proposition of a catalog for comparing diverse astropause and astrosphere modeling equations and methods is outlined and examined.

1 Introduction

Throughout the field of astrophysics, there lacks a consistency on estimating astropause and astrosphere distances (for brevity's sake both will be referred to as astrosphere for the remainder of the paper). The equations for the estimates themselves differ, and even when the equations are sympathetic, the values assumed and applied differ. As an example, the solar system had been given a range of estimates from at least 74 AU to 150 AU until Voyager 1 reported 121.7 AU. With other systems, we are in absence of Voyager records, and we cannot simply await similar probes for validation.

Presently, there are many factors that cause these differences. A few examples to convey the concept of difference are: one equation working off of mass-loss rate and negating wind speed, another equation factoring in ISM cloud considerations differently, or another factoring in electromagnetic considerations where others do not. There is no simple solution to these problems as the current period of exploration will naturally generate dissimilar approaches and solutions. Further, there is currently no convenient means to find and compare multiple approaches against each other to attempt to discern definition and pattern.

What could be created is a catalog which has a steady and predictable line which estimates can be compared against and kept on file. This would allow estimates to be made and plotted against a predicted model which does not suppose itself to be dependent upon real factors and variables within the equation, but instead works inversely from sample to produce an "ideal" model by which estimates can be lined up against.

The reason for doing so would allow for estimates to be examined in long view against a trend and pattern with a known skeleton model from which they deviate, as opposed to now where estimates are aligned and compared against nothing and we have a lack of direction or focus as to the culmination of these estimates being generated.

2 Construction of Hunt Catalog Foundation

The Hunt catalog is comprised of the baseline, sample estimates, and profiles of those estimates defined by the differences between the estimates and the baseline. What follows are the components to assembling and then employing the Hunt line catalog for an example.

2.1 Brief Definition of "Hunt" variable et al.

In this paper a variable is created for application as outlined. This value is given a name of "Hunt" variable, and all subsequently derived productions from the employment of the Hunt variable adopt the name "Hunt" (e.g. "Hunt line"). The Hunt variable is considered adjustable, as this value is a result of the data's average being applied as a value for approximation in equations outlined later. For clarity, the Hunt variable is given a symbol $\mathcal{H}$. It is referred to as a Hunt since it is employed to approximate a finding of an unknown radius given the related radius opposite of the one calculated to approximate, and implies a direct correlation between the two radii proportionately.
The results of employing the Hunt variable are only considered an approximation because the Hunt variable is only a value from an average from the data collected so far and as such is not specific to a particular objects constituency or definition. No application of the hunt variable should ever be found to be applied in place of typical models and methods. The purpose and application of the Hunt variable are confined to the operations and functions defined within this paper.

Due to the limited quantity of verifiable star astrospheres, the initial Hunt baseline is built from atoms and a few stars. This was done because the atomic data is more readily available in high quantity and good record. Atoms divide the radius of their nucleus by the radius of their covalent bond. Stars divide the radius of the star by the radius of their astrosphere. The average of all results comprises the Hunt variable,
The current "Hunt library" is defined as:

$$\overline{\mathcal{H}} = \left(\left(\frac{R_*}{R_{AP_1}}, \frac{R_*}{R_{AP_2}}, \cdots \frac{R_*}{R_{AP_n}} \right), \left(\frac{R_{nuc_1}}{R_{cov_1}}, \frac{R_{nuc_2}}{R_{cov_2}}, \cdots \frac{R_{nuc_n}}{R_{cov_n}} \right) \right) \tag{1}$$

$\mathcal{H}$="Hunt variable", R_* =Radius of star, R_{AP} =Radius of astropause/sphere, R_{nuc} =Radius of nucleus, R_{cov} =Covalent bond radius.

Once the data was collected and the percent of the energy core of a system determined from the boundary of the whole system, the percent of all samples were averaged, and then tested against that average in a standard deviation, and standard error to test meaningfulness of the determined average. The sample set for stars was 13. The sample set for atoms was 95. For this analysis, the total sample group was 108.

2.2 Initial Data Results

Table 1 shows the resulting combined average ($\sim 0.0039\%$). Table 2 shows each set (stars/atoms) separately to check how different the star set is from the atomic data. The difference between the two sets when separated is a factor of 1.07. This produced a confidence of proportionate relationship close enough to merit relying on atoms to measurably hold up the scaffolding for the core library in the absence of a larger verified star data set (which ideally should replace this starting library at a later date).

Table 1: Summary of all data collected

Average of All Data Samples	0.00003950
Standard Deviation	0.00001073
Standard Error	0.00000103

Table 2: Summary of Stellar and Atomic Systems separated

Average of Only Star Data	0.00004193
Standard Deviation	0.00001963
Standard Error	0.00000103
Average of Only Atomic Data	0.00003916
Standard Deviation	0.00000900
Standard Error	0.00000092

The following figures elaborate upon the results of the sample average data. Figure 1 is a histogram of the sample data. Figure 2 is a plot of each stellar radii as well as atomic nuclear radii.

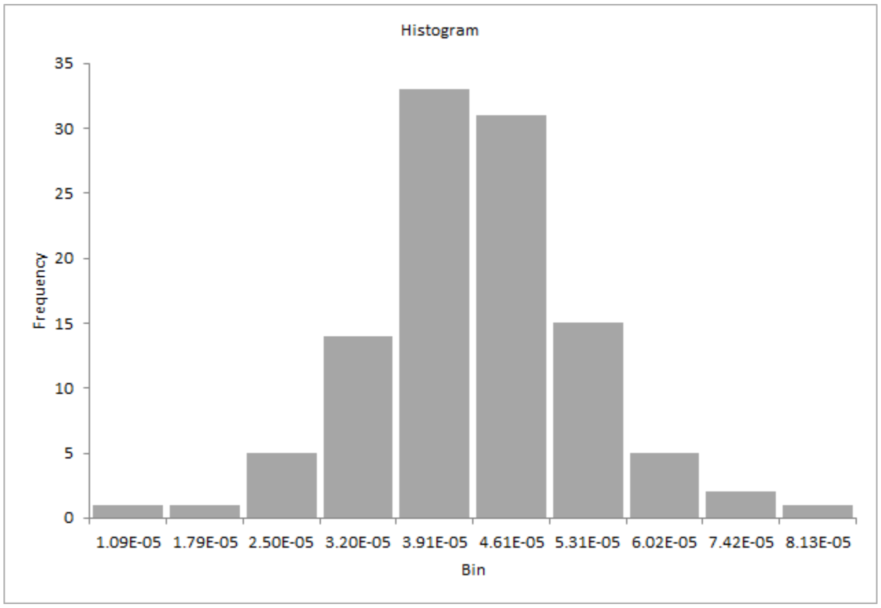

Figure 1: Histogram

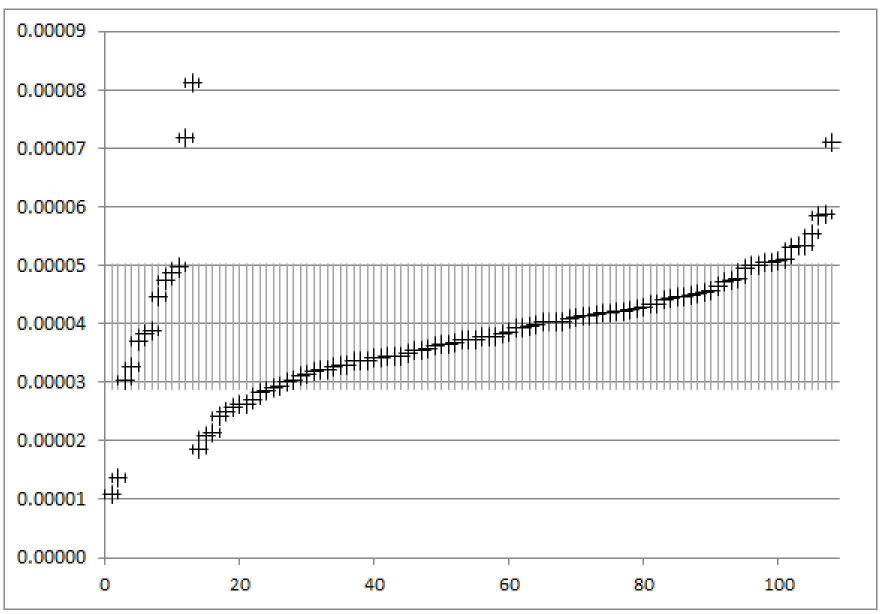

Figure 2: Comparison of Star/Nuc. r to Astrosphere/Cov. Bond r (factor)

2.3 Preliminary Functional Test

To test if the average obtained is sufficient to rely on for generating approximately an average sample representation, the average - as the Hunt variable - was applied in two ways for testing:

To test the ability to reflect the average of the sample in regards to astrosphere and covalent bond radius, equation (2) was used.

$$R_{eff} \approx \frac{R_{nuc}}{\mathcal{H}} \tag{2}$$

To test the ability to reflect the average of the sample in regards to the star and nucleus radius, equation (3) was used.

$$R_{nuc} \approx R_{eff} \cdot \mathcal{H} \tag{3}$$

Where R_{eff} stands for effective radius of the system (i.e. astrosphere/covalent bond), and R_{nuc} stands for the radius of either the star or nucleus.

The results of the equations per sample were compared to the listed values from literature and the difference by factor was derived. All differences by factor were averaged. Table 3 and 4 summarize the resulting averages of applying equations (2) & (3) for testing the Hunt variable.

Table 3: Summary of Hunt Test 1: Cov. Bond/Astrosphere Approx. from Nuc./Star div. by Hunt var.

Average	1.00
Standard Deviation	0.27
Standard Error	0.03

Table 4: Summary of Hunt Test 2: Nuc./Star radius Approx. from product of Cov. Bond/Astrosphere and Hunt var.

Average	1.09
Standard Deviation	0.41
Standard Error	0.04

The following Table 5 is a display of stars with astrosphere listings from literature and values from Hunt equation.

Table 5: Hunt Equation Test - Stars

Star ID	Published Astropause (AU)	$R_{AP} \approx \frac{R_*}{\mathcal{H}}$ Approx. (AU)	Difference (factor)
Kepler-437	290	80.0	0.2760
Kepler-32	180	62.4	0.3466
Kepler-88	140	107.1	0.7651
Kepler-445	30	24.7	0.8240
Kepler-186	59	55.3	0.9377
Sun	121.7	117.7	0.9672
CW Leonis	84000	82398.9	0.9809
Kepler-448	170	191.9	1.1287
HD 210839	2062	2483.7	1.2045
HD 182488	84	103.6	1.2332
HD 14412	72	90.6	1.2589
Kepler-42	11	20.0	1.8192
Kepler-20	54	111.1	2.0578

The following Table 6 is a display of nuclei listings from literature and values from the Hunt equation.

It should be noted that serving to arrive at approximations for covalent bond radii is not the focus; the only focus here of the operation is to serve as a disclosure of a test.

Table 6: Hunt Equation Test - Atoms

Atom	Published Cov. Bond r (pm)	$R_{cov} \approx \frac{R_{nuc}}{\mathcal{H}}$ Approx. (pm)	Difference (percent)
Li	128	60.70	0.4742
K	203	108.00	0.5320
Na	166	90.48	0.5451
Ca	176	108.89	0.6187
Rb	220	139.62	0.6346
Mg	141	92.17	0.6537
Cs	244	162.39	0.6655
Sc	170	113.14	0.6656
Be	96	66.22	0.6898
Ti	160	115.55	0.7222
Sr	195	141.33	0.7248
Fr	260	192.97	0.7422
Y	190	142.02	0.7475
Ba	215	164.17	0.7636
V	153	117.96	0.7710
Al	121	95.44	0.7888
La	207	164.79	0.7961
Ce	204	165.27	0.8102
Pr	203	165.58	0.8157
Zr	175	143.24	0.8185
Nd	201	166.88	0.8302
B	84	70.36	0.8376
Pm	199	167.14	0.8399
Cr	139	118.77	0.8544
Sm	198	169.20	0.8546
Eu	198	169.80	0.8576
Mn	139	120.96	0.8703
Si	111	96.72	0.8714
Gd	196	171.75	0.8763
Ra	221	193.83	0.8771
Nb	164	144.12	0.8788
Tb	194	172.36	0.8884
Ac	215	194.12	0.9029
Dy	192	173.64	0.9044
Ho	192	174.50	0.9089
Fe	132	121.69	0.9219
Tm	190	175.90	0.9258
Er	189	175.32	0.9276
P	107	99.93	0.9339
Mo	154	145.67	0.9459
Yb	187	177.32	0.9482
Th	206	195.53	0.9492
C	76	72.87	0.9588
Cu	132	126.98	0.9620
S	105	101.09	0.9628
Pa	200	195.25	0.9763

Table 7: Hunt Equation Test - Atoms (cont.)

Atom	Published Cov. Bond r (pm)	$R_{cov} \approx \frac{R_{nuc}}{\mathcal{H}}$ Approx. (pm)	Difference (percent)
Co	126	123.83	0.9828
Ni	124	123.66	0.9973
Tc	147	147.16	1.0011
U	196	197.20	1.0061
Ru	146	148.22	1.0152
Hf	175	179.16	1.0238
Cl	102	104.53	1.0248
Ar	106	108.78	1.0262
H	31	31.90	1.0292
Np	190	196.93	1.0365
Ag	145	151.47	1.0446
Rh	142	149.11	1.0501
Zn	122	128.20	1.0508
Ta	170	179.98	1.0587
Pu	187	198.85	1.0634
Cd	144	153.57	1.0665
W	169	180.94	1.0706
Ga	122	130.97	1.0735
N	71	76.70	1.0803
Pd	139	150.79	1.0848
In	142	154.66	1.0891
Am	180	198.58	1.1032
Ge	120	132.75	1.1062
Sn	139	156.39	1.1251
As	119	134.14	1.1273
Sb	139	157.71	1.1346
Se	120	136.52	1.1377
Br	120	137.05	1.1421
I	139	159.91	1.1504
Xe	140	161.73	1.1552
Te	138	160.20	1.1608
Cm	169	199.67	1.1815
Re	151	181.70	1.2033
Kr	116	139.80	1.2052
O	66	80.18	1.2148
At	150	189.13	1.2609
Os	144	183.00	1.2709
Bi	148	188.83	1.2759
Rn	150	192.68	1.2845
Pb	146	188.29	1.2897
Ti	145	187.43	1.2927

Table 8: Hunt Test 1: Cov. Bond Approximating (cont.)

Atom	Published Cov. Bond r (pm)	Hunt Variable Cov. Approx. (pm)	Difference (percent)
Ir	141	183.64	1.3024
Po	140	188.83	1.3488
Pt	136	184.55	1.3570
Au	136	185.14	1.3613
Hg	132	186.27	1.4111
F	57	84.91	1.4896
Ne	58	86.63	1.4936
He	28	50.52	1.8044

The following figures elaborate on the Hunt Test results. Figure 3 shows a plot of Table 3. Figure 4 shows a plot of Table 4. Figures 5 and 6 show raw value plots of astrosphere and covalent bond radii generated by employing the Hunt variable equation (2). Figure 7 and 8 show raw value plots of star and nucleus radii generated by employing the Hunt variable equation (3).

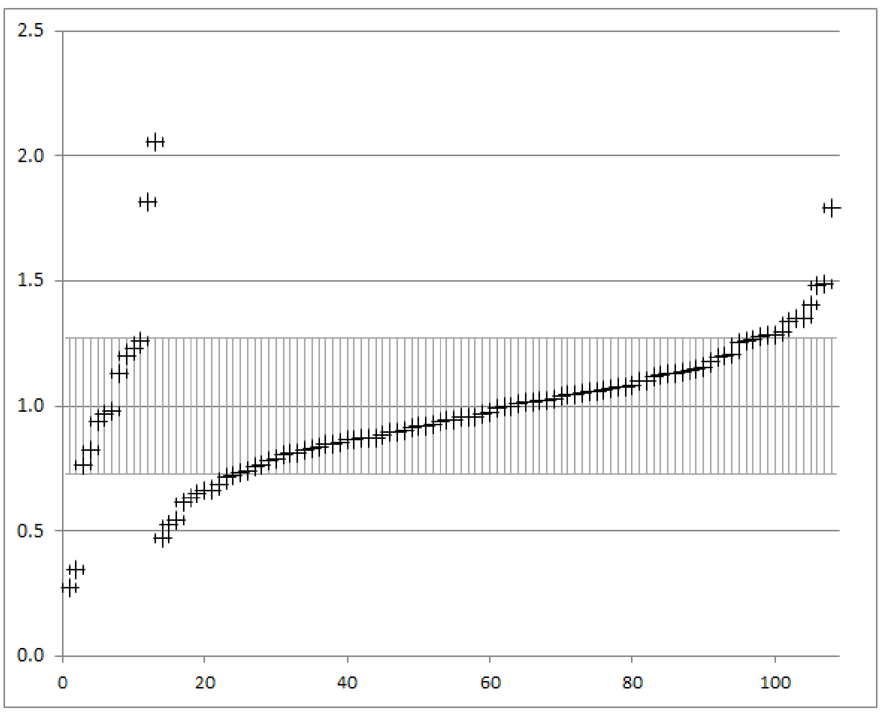

Figure 3: Hunt Test 1: Cov. Bond/Astrosphere Approx. from Nuc./Star div. by Hunt Var. (factor)

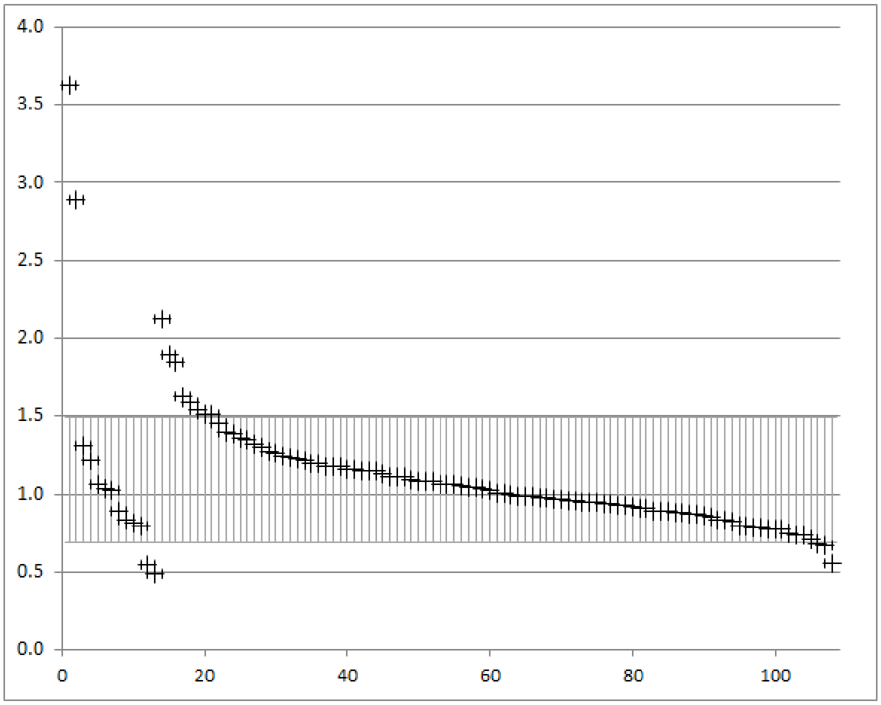

Figure 4: Hunt Test 2: Nuc./Star r Approx. from product of Cov. Bond/Astrosphere and Hunt var. (factor)

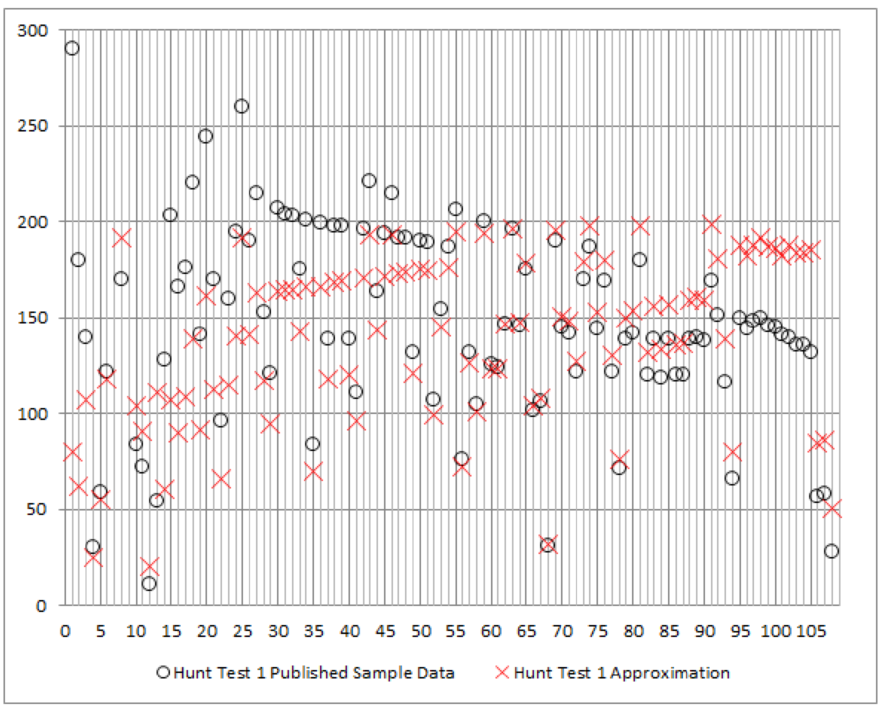

Figure 5: Hunt Test 1: Astrosphere (AU) & Cov. Bond values (pm) - CW Leonis Not Shown

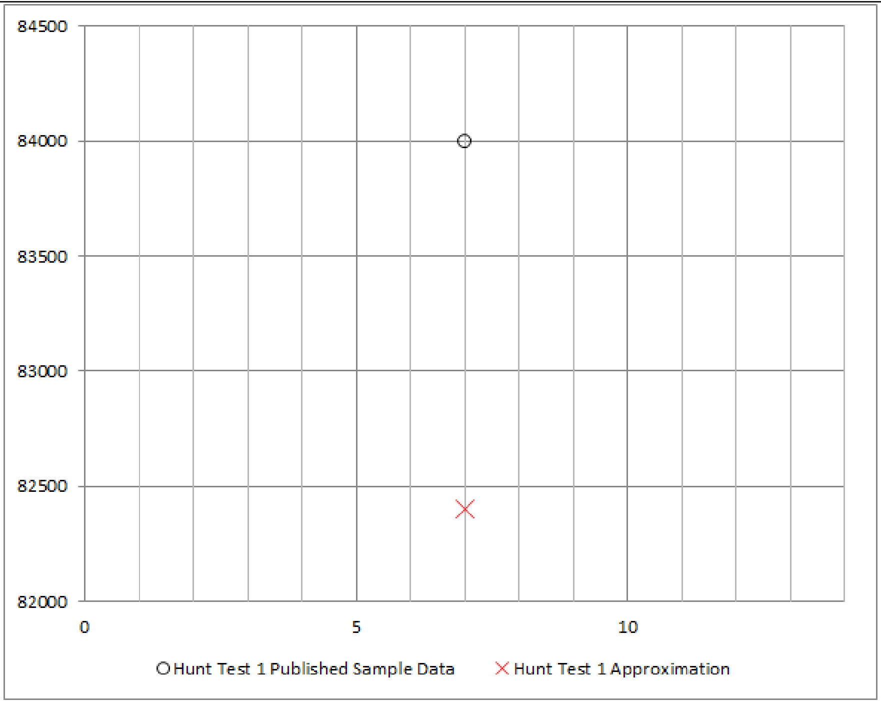

Figure 6: Hunt Test 1: Astrosphere values of CW Leonis results.

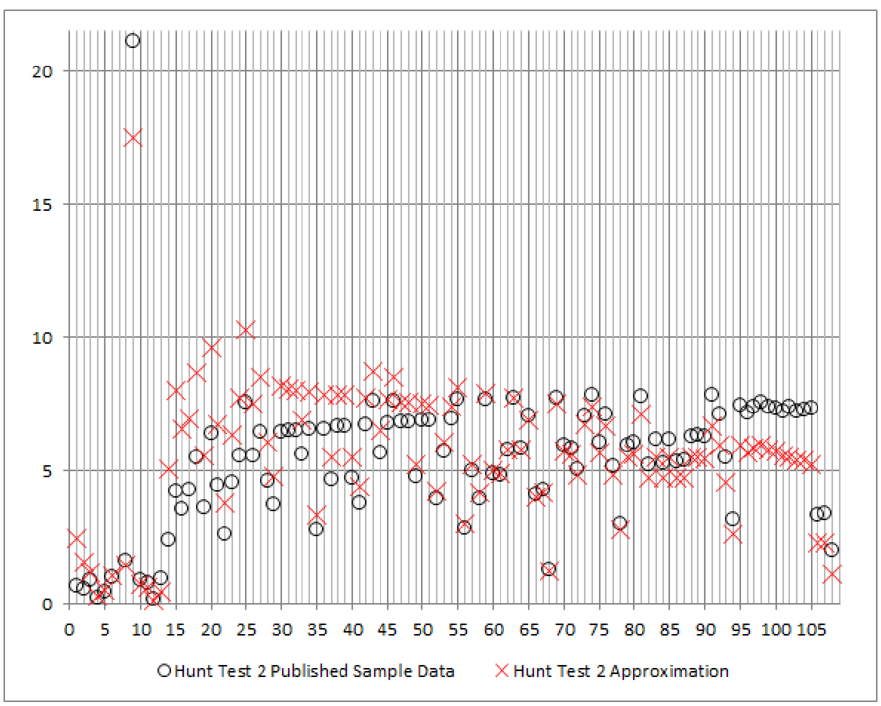

Figure 7: Hunt Test 2: Star radius values (Mag. of Sun) & Nuc. radius values (fm) - CW Leonis Not Shown

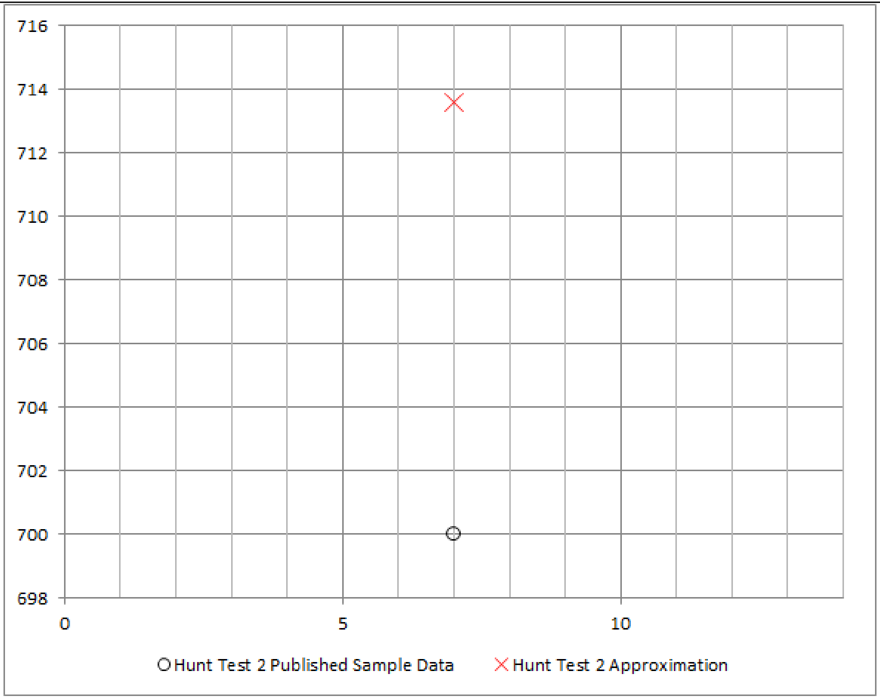

Figure 8: Hunt Test 2: Star radius for CW Leonis results.

2.4 Review of Exploration

The results showed that the average relation between a given star or nucleus of an atom and its astrosphere or covalent bond would typically be that the star or nucleus' radius would account for $\sim$0.0039% $\pm$ 0.0010 of the total system size (when counting the "system" as that which is from the astrosphere to star; for atomic structures, the total "system" was the covalent bond radius juxtaposed against the nucleus' radius).
When the stars were separated from the atomic data, the average became $\sim$0.0041% $\pm$ 0.0019 for the stars.
The concept of sampling both stars and atoms to approximate a scaffolding from which to employ as the foundation to build upon appears statistically valid at this point; employing the atoms as a crutch to balance estimates upon a known measure of proportion for a system which has an energy core freely in space and a consequent system. The sampled average does indeed inversely produce approximations representative of an average from the sample from which it was produced from.

2.5 Disclaimer

It needs to be mentioned that the sampling of atoms and stars in this manner is purely functional in application only for this paper's purpose as described and does not extend to supporting any claims regarding the relationships between atoms and stars in any manner.
It also needs to be reminded that this data is the kind belonging to sample averages and does *not* claim to model an aspect of physical nature itself.

3 Assembling the "Hunt Line"

We can now build a line which has any given possible star radius and derive from that an average astrosphere radius if all systems were reflective of the ideal system (which, it should be remembered that all systems are *not* reflective of the ideal).
This line is referred to as the "Hunt line".
The means for building the Hunt line is a sequential application of equation (2) along a scale.
This operation and method produces a straight line at angle correlated in increase between any given star radius magnitude and the radius of the astrosphere.
The results create a plot line which looks like that in the following figure:

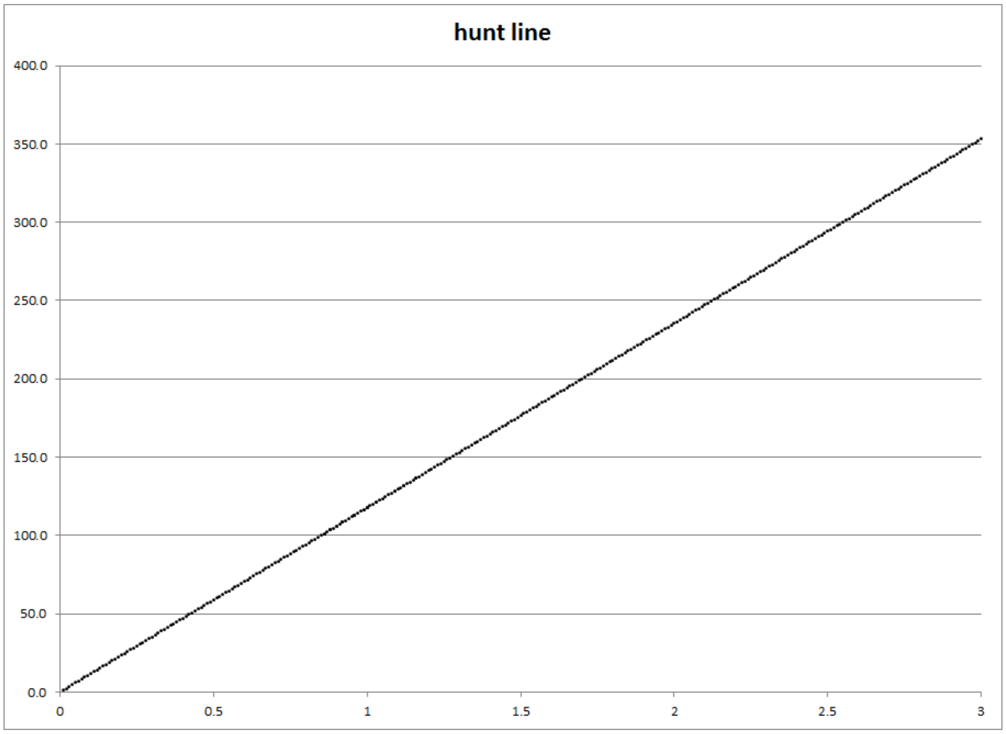

Figure 9: Hunt Line.

Y-axis: Astrosphere AU. X-axis: Radial Magnitude of Sun.

It should be noted that the Hunt line is not considered to be an authoritative reference by which to make corrections to estimates. It is only a reference line for generating profiles and catalog.

3.1 Plotting Against the Hunt Line

We can now place estimates made by researchers along the Hunt line for the purposes of examining the overall trend of a given set by its deviation from the steady Hunt line. Because the Hunt line is driven by a relationship between star radius and astrosphere radius, it is immediately clear how a given set of estimates relates to the concept of any correlation between star radius and astrosphere radius.
The following figure (10) is an example of concept of what the visual appearance of the Hunt Line employment could look like.

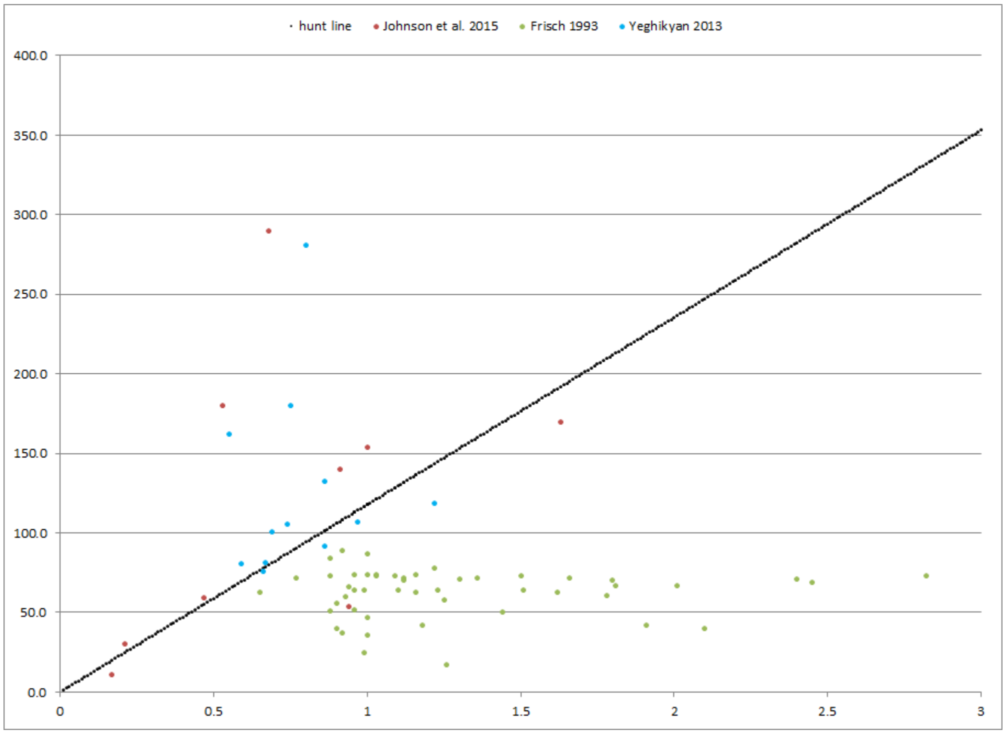

Figure 10: Hunt Line Example

4 The Hunt Profile

From plotting against the Hunt line we can now create a cataloged profile for any given estimate set by its deviation from the Hunt line.
The Hunt profile is a five-part profile that is unlikely to be exactly alike between two different sets.
The five attributes are the mean of the difference by factor of the set from the Hunt line, the maximum difference by factor of astrosphere values in the set, the minimum difference by factor of astrosphere values in the set, the P value of a two-tail T-Test between the estimate set and the Hunt line, and the P value of an F-Test between the estimate set and the Hunt line.

4.1 Creating a Hunt Profile

The first step in creating the Hunt profile is to assemble the astrosphere estimates and their related star radii, and to place the Hunt line approximations for the same astrosphere estimates along side of the estimates. Then we divide the set's astrosphere estimates from the Hunt line approximations to derive the difference by factor. We then find the mean of that difference by factor.
We then note the maximum difference and the minimum difference in the set.
Next we perform a standard two-tail T-Test and an F-Test between the set and the Hunt line approximations. These are ran on the raw values and not on the difference by factor. An example of what such a profile looks like is the following:

Table 9: Example Hunt Profiles

Set Number	Estimate Set	A	B	C	D	E
1	Johnson et al 2015	1.48	3.62	0.49	2.28E-01	1.64E-01
2	Frisch 1993	0.46	0.82	0.11	1.79E-14	1.13E-15
3	Yeghikyan 2013	1.43	2.99	0.83	7.60E-02	2.54E-03

A: Mean difference from Hunt line by factor, B: Max difference from Hunt line by factor
C: Minimum difference from Hunt line by factor D: T-Test between set and Hunt line P value
E: F-Test between set and Hunt line value

4.2 Interpreting the Profile

To interpret the meaning of the profile, we understand that the closer to 1 the mean is, the closer to having the same mean as the Hunt line the set is. The more positive the P value beyond 0.05 the T-Test is, the more the given set has a correlation between star radius and astrosphere radius. This means the stronger that correlation is, the more it is that it can be said that the given set has a condition which produces a larger astrosphere based in some relation upon the size of the star's radius. The further the P value is below 0.05, the less of a correlation is found to exist in the set. The more positive the P value is beyond 0.05 of the F-Test, the more the given set shares a similar variance as the Hunt line contains between different astrosphere sizes. Because of this, it becomes simple to see information about sets from a simple plot of these attributes.
For example, if we take the three sets which were plotted against the Hunt line previously and put them into a Hunt profile plot, we see the following:

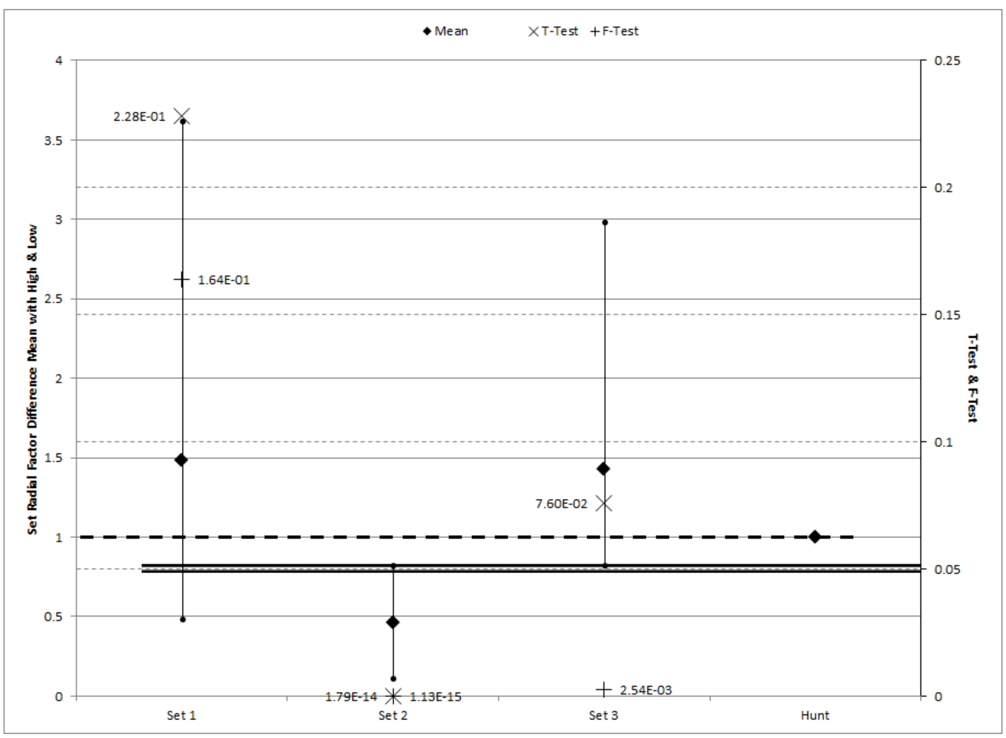

Figure 11: Hunt Profiles

We can easily see that the further "north" the T and F-Test P values are, the more correlation is found between the given set and the Hunt line assumption (i.e. a strong correlation between star radius and astrosphere radius). The further "south" the T and F-Test P values are, the less correlation is found.
As such, we can quickly spot that Johnson et al 2015 contains a strong correlation with the Hunt line assumption, Yeghikyan 2013 contains a marginal correlation, and Frisch 1993 contains absolutely no correlation. We can also quickly see that Johnson et al 2015 and Yeghikyan 2013 contain a mean of difference by factor closer to the Hunt line mean of difference by factor (which will always be 1) than Frisch 1993. Further we can quickly spot that Johnson et al 2015 and Yeghikyan 2013 tend to produce estimates which are equal to and greater than the Hunt line, while Frisch 1993 tends to produce estimates much lower than the Hunt line.
In the Hunt line and Hunt profile figures, the data should also include the equation used by the set as well as the assumed values influencing the equation (if any), as well as basic attributes of the given star.
For example, the equations of the example 3 sets of estimates are:

Johnson et al 2015

$$r_a = \frac{1}{V}\Big((M_*, t_*)\frac{v_0 \dot{M}_{\odot}}{4\pi n m}\Big) \tag{4}$$

Frisch 1993

$$\frac{P_{SW}}{R_A^2} = \alpha\frac{B^2}{8\pi} + 2\beta n_e kT + \gamma n_e m_H u^2 + \delta\beta n_H kT + \delta\beta n_H m_H u^2 + \epsilon P_{CR} \tag{5}$$

Yeghikyan 2013

$$R_A = \sqrt{\frac{\dot{M}V_w}{4\pi P_{ISM}}} - \frac{1}{\sqrt{P_{ISM}}}\ \left(\frac{M}{R}V_{rot}\right)^{2/3} \tag{6}$$

Note: The equation from Yeghikyan 2013 is one of two equations employed in Yeghikyan's estimates. Yeghikyan supplied two possible estimates by employing two separate equations. Here in this paper, only one of Yeghikyan's equations are used. Both would be documented in the actual Hunt catalog and treated as two separate estimate sets.

5 Generation of the Hunt Catalog

The Hunt catalog could be an online catalog which researchers could access and input their respective data, along with a copy of their publication and contact information for questions from the data analysts. That data would be analyzed by an analyst of submitted data and properly appropriated into the Hunt catalog.
The Hunt catalog would be capable of being scaled by the user, as well as permitting the user to search the catalog for various parameters including authors, star id's/names, constellations, distances from Earth, sizes of stars, classes of stars, sizes of astrosphere, various data attributes of classification, and by similarity of Hunt profile or similarity of the model's equation.
This paper serves as an blueprint for the Hunt catalog which would be built online.

6 Addendum

The following is an addendum to section 2.2 above. Further data was accumulated from papers after the original data research and analysis within section 2.2 was conducted. A further update will be merited in light of the additional material. For the time being, the rough outline of the data has been added here for awareness. Table 10 consists of star data, and Figure 12 shows a revised histogram, mean, standard deviation, and T-test between atoms and stars in like fashion as relevant to section 2.2 above.

Table 10: Addendum Star Data

A	B	C	D	E
118236360	1.6456E+12	0.00007185	Kepler-42	1
146056680	4.488E+12	3.25438E-05	Kepler-445	1
326888760	8.8264E+12	3.70353E-05	Kepler-186	1
368619240	2.6928E+13	1.36891E-05	Kepler-32	1
382529400	2.42144E+13	1.57976E-05	ξ Boo B	2
410349720	1.20344E+13	3.40981E-05	36 OphB	2
459035280	1.13607E+13	4.04054E-05	61 Cyg A	2
465990360	1.21254E+13	3.84309E-05	70 Oph B	2
472945440	4.3384E+13	1.09014E-05	Kepler-437	1
479900520	1.50384E+13	3.19116E-05	36 OphA	2
514675920	1.57485E+13	3.2681E-05	ϵ Ind	2
521631000	2.69454E+13	1.93588E-05	ϵEri	2
556406400	4.20566E+13	1.32299E-05	ξ Boo A	2
598136880	1.36912E+13	4.36878E-05	α Cen B	2
598136880	1.98449E+13	3.01406E-05	70 Oph A	2
632912280	2.0944E+13	3.02193E-05	Kepler-88	1
653777520	8.0784E+12	8.09291E-05	Kepler-20	1
674642760	1.60216E+13	4.21084E-05	61 Vir	2
695508000	2.30384E+13	3.01891E-05	Sun	1
848519760	1.77694E+13	4.77518E-05	α Cen A	2
1133678040	2.5432E+13	4.45768E-05	Kepler-448	1
4.86856E+11	1.25664E+16	3.87426E-05	CW Leonis	3

A: Star Radius in Meters from Simbad Database, B: Published Astropause/sphere Estimates in Meters,
C: A as factor of B, D: Star Name, E: Publication (1: Johnson et al. 2015, 2: Yeghikyan 2013, 3: Sahai 2010)

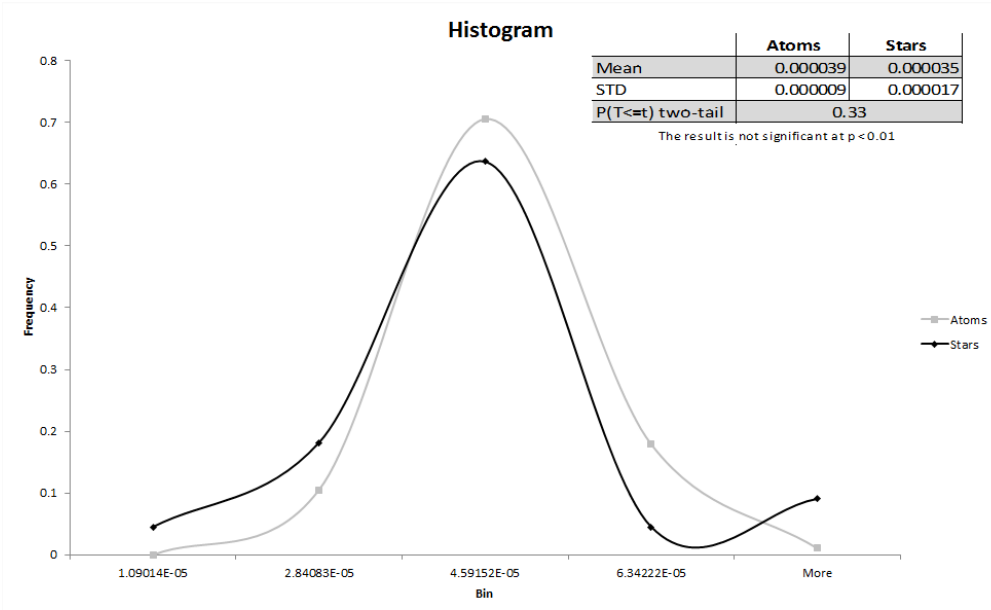

Figure 12: Addendum Histogram

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