A List of SETI Targets *by Andrew J. LePage*

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There are moments in everyone's life when you look at a common thing in a totally new way. A particularly memorable example in my life happened one clear spring night when I was age eleven. Every cloudless evening since the previous Christmas I would venture outside with my new three-inch telescope and observe the sky. I would make drawings of Jupiter and its family of Galilean satellites, observe the cratered surface of the Moon, or try to locate some interesting star cluster or nebula.

This particular evening I wanted to take advantage of the unseasonably warm weather, but I was not in the mood to haul my telescope down the hill of the family's backyard to the deck. So with the most ancient of optical instruments, my naked eyes, I headed outside to watch the night sky. After making my standard scan of the horizon, I decided to make myself comfortable and laid down on top of the picnic table on the deck. I just stared straight up at the celestial sphere, trying to locate various constellations and enjoying the view.

After my eyes had become adapted to the dark, not only could I see the brighter stars I would notice in a casual glance, but also dimmer and still dimmer stars. Suddenly, instead of appearing as a bunch of lights shining through some medieval vision of the dome of night, I saw the sky as a three-dimensional object with bright stars close by and dim ones far in the distance. Without the horizon or the dark edge of my telescope's field stop to limit the panorama, I found myself to be among the stars.

Soon they were no longer just stars but huge suns like our own scattered through an immense void. With this leap I began to wonder how our Sun and its family of planets would appear from such a great distance. Finally, it hit me: What if there was someone on a planet revolving around one of those distant suns looking back at me thinking the same thing? And if there was someone out there, which star was its home?

That evening with its new insights and the questions it raised has stuck with me ever since. To this day when I look up into the sky and see all those stars, I wonder which ones are orbited by planets like our own and which of those are the home of a technical civilization. Unfortunately, at present there is no answer. Modern theories of planet formation, infrared observations of circumstellar disks around young stars, and other circumstantial evidence would seem to indicate that planets are common. But despite the best efforts to date, not a single planet around a Sun-like star has been found.

In the Search for Extraterrestrial Intelligence (SETI), knowing where to look is important. With hundreds of millions of potential targets, a short list of candidates would be useful as a starting point. This would be true for either a multi-million dollar effort using an advanced radio telescope or an amateur astronomer making use of a few thousand dollars of equipment in his or her backyard. In this paper I will present a preliminary quantitative rating system for potential SETI targets and list the top 100 candidates.

The Rating System

At the outset of this project, I wanted to develop some sort of rating system that made as few assumptions as possible and used star properties that could either be measured directly or reasonably simulated. One measure that immediately comes to mind is distance. For stars within a couple of hundred light years of the Sun, distances can be accurately measured by means of trigonometric parallax. In addition to being an easily measured stellar property, it has a direct influence on SETI.

SETI typically deals with the detection of electromagnetic signals which fade with distance according to the inverse square law. In many ETI searches, proximity is an important choice in deciding upon a candidate star system [1]. So distance is the first parameter in our rating system:

$$R \propto 1/r^2 \qquad (1)$$

In Equation 1, R is the rating of a candidate star and r is its distance from the Sun. In this formulation, stars with higher ratings are better SETI targets.

The next parameter is, unfortunately, not easily measured. Obviously one would want to observe a candidate star system that has a good chance of harboring a technical civilization. If we had such a probability, it could be incorporated into the rating system as follows:

$$R \propto P \qquad (2)$$

In Equation 2, R is again the rating and P is the probability that a candidate system has a technical civilization capable of interstellar communication. We can combine Equations 1 and 2 and include a proportionality constant, k, as follows:

$$R = kP/r^2 \qquad (3)$$

While at present we have no values for P in Equation 3, we may be able to make a reasonable estimate. If we make the assumption that a technical civilization requires a habitable planet and that all habitable planets have the same likelihood of possessing a technical civilization, we can state the following:

$$P = P_C P_H \qquad (4)$$

Where P_C is the probability a habitable planet has a technical civilization and P_H is the probability a candidate star has a habitable planet.

On the surface it may appear that we traded one unknown, P, for two, P_C and P_H. For the purpose of this rating system, P_C is assumed to be a constant and very small. As will be shown later, its value will not be needed to determine a star's rating

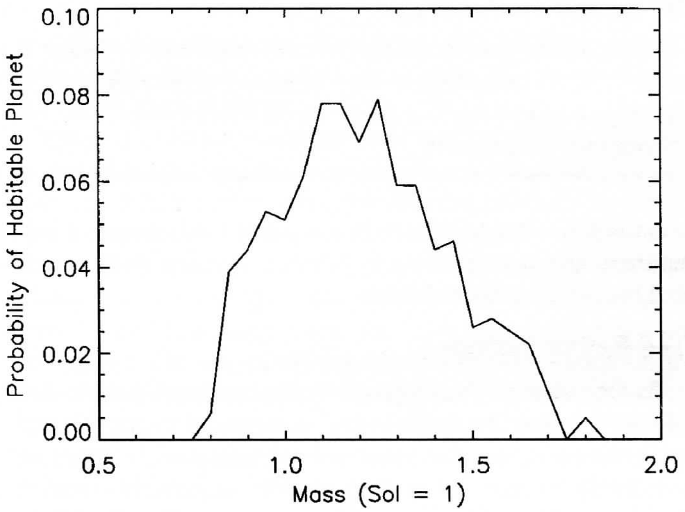

Figure 1: Probability of Habitable Planet versus Stellar Mass

in this system. Fortunately, we do have some recent simulations that can provide a reasonable estimate of P_H [2,3]. These simulations incorporate the latest knowledge of what makes a planet habitable. Unlike previous works, it makes quantitative predictions based on a star's mass.

For the purpose of these simulations, a definition of a habitable planet based on a work by Dole [4] was used. A habitable planet was defined as one that has the following properties: It must be older than one billion years to get past the planetary accretion process to allow life to form. At the same time the planet will only remain habitable as long as its sun is on the main sequence. This would exclude all stars with a mass greater than $1.8M_\odot$, since they would leave the main sequence before the planetary accretion process has finished.

In order to limit extremes in surface temperature, a habitable planet's orbital eccentricity must be less than 0.2, have a period of rotation less than 96 hours, and possess an axial inclination of less than 55 degrees. In order to have a temperate climate, the surface insolation must be greater than $0.94S_\oplus$ and be less than $1.1S_\oplus$. With less insolation, the planet would still be considered biocompatible, but not habitable. Greater levels would result in first a moist greenhouse and later a runaway greenhouse, rendering the planet as sterile as Venus.

Finally, the planet must possess active volcanism and tectonics to regulate the amounts of greenhouse gases such as carbon dioxide. The more massive a planet, the longer it will remain active and habitable. If the planet is no longer active, the carbon dioxide will become locked up in carbonate deposits and the planet will become a global icebox like Mars.

In order to meet these other criteria, the planet's sun must have a mass greater than about $0.75M_\odot$ for a variety of reasons. First, the less massive a star, the dimmer it becomes. In order to maintain the required insolation, a habitable planet must circle closer to its sun. Unfortunately, the effects of tidal braking increase to the point where if the sun's mass is small enough, a potentially habitable planet's rotation rate will be slowed too quickly. Its period of rotation will be greater than 96 hours shortly after the end of its accretion phase, rendering the world uninhabitable. A more subtle reason has to do with the masses of the planets in these systems. Less massive stars would tend to have less massive planets. Less massive planets will remain geologically active for less time. Averaged across its main sequence lifetime, less massive stars would have fewer habitable planets than more massive stars.

These simulations made use of the ACRETE Monte Carlo computer algorithm developed by Dole [5] and expanded upon by Issacman and Sagan [6] to produce realistic solar systems whose properties appear similar to ours. These simulated systems, with ages evenly spaced over the star's main sequence lifetime, were compared with the above criteria as a function of stellar mass.

The probability of a star possessing a habitable planet, P_H, as a function of stellar mass derived from these simulations is shown in Figure 1. As can be seen, P_H increases rapidly with mass starting around $0.80M_\odot$, peaks near $1.25M_\odot$, then slowly declines to zero at $1.80M_\odot$. A star like our Sun with a mass of $1.0M_\odot$ has a 0.051 probability of possessing a habitable planet according to these results. We are obviously fortunate to have beaten these one-in-twenty against odds!

On the whole this result looks reasonable. This range of stellar masses spans spectral types from approximately K3 to A2 and luminosities from about $0.25L_\odot$ to $16L_\odot$. This covers most of the stars that have been traditionally included on lists of potential SETI targets.

Assuming for the moment that these simulations are correct and we have accurate values for P_H, we can combine Equations 3 and 4 as follows:

$$R = kP_CP_H/r^2 \quad (5)$$

For our purposes a relative rating scale would suffice. If we define the rating system to give a sun-like star with a mass of $1.0M_\odot$ at some standard distance r_0 a rating of 1.0, we can obtain a value for kP_C in Equation 5 and combine them as follows:

$$K = kP_C = r_0^2/P_{H\odot} \quad (6)$$

If we assign r_0 a value of 10 parsecs and use a value of P_H for a sun-like star equal to 0.051, K would have a value 1,960 if r is measured in parsecs or 20,800 if r is measured in light years. Finally, by combining Equations 5 and 6, we can obtain the following definition of our rating system:

$$R = KP_H/r^2 \quad (7)$$

This equation as a function of distance and stellar mass is shown in the contour plot in Figure 2. In this figure, each contour is twice as large as the previous one.

Ratings for Multiple Star Systems

In targeted SETI, it is possible that more than one star with a nonzero value of R would be within the primary lobe of a radio antenna or within the field of view of an optical detector. Intuitively, it would seem that this sort of system should have a value of R greater than any of its individual components.

If we take the simple case where we have a binary system,

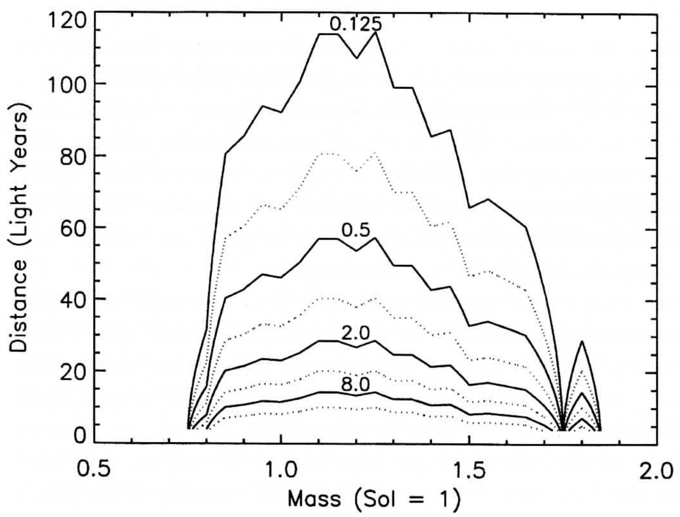

Figure 2: Rating as Function of Distance and Stellar Mass Each contour has twice the R value of the previous one

the probability that it has a technical civilization, P, can be calculated from the value of P for the individual stars as follows:

$$P = 1 - ((1 - P1)(1 - P2)) \quad (8)$$

Expanding this equation and including Equation 4, we can obtain the following:

$$P = P_C P_{H1} + P_C P_{H2} + (P_C^2) P_{H1} P_{H2} \quad (9)$$

Since the probability that a habitable planet has a technical civilization, P_C, is very small, P_C^2 would make the last term of Equation 9 insignificant. With this in mind, we can rewrite Equation 9 as follows:

$$P = P_C(P_{H1} + P_{H2}) \quad (10)$$

With this we can generalize that the value of P for any multiple star system is simply the sum of the individual values of P for all the members of the system. This would be true so long as the total number of members in the system is much less than $1/P_C$. We can therefore state that the rating, R, for any multiple star system is as follows:

$$R = \sum_i R_i = K(\sum_i P_{Hi})/r^2 \quad (11)$$

Here R_i and P_{Hi} are the values for R and P_H respectively of the ith member of a multiple star system.

Physical Significance of Rating

Naturally, when developing a rating system like this, we would want it to have some sort of physical significance. Since my professional background is in optics, I prefer an analogy dealing with optical telescopes. Other analogies are possible and I welcome the reader to write and describe their own.

Let us first break down Equation 7 and see what effects each variable has on our optical system. The first parameter, P_H, is related to the number of objects that must be observed before there is a certain probability of detecting a technical civilization. This can be written as follows:

$$N \propto 1/P_H \quad (12)$$

Here N is the number of stars that must be observed. Another way of looking at it is N is the number of telescopes needed to monitor a group of SETI targets, assuming each target has a telescope dedicated to it for the search.

Our second variable is distance. The further a star is from us, the larger the telescope must be to detect a signal of a given strength. The distance, r, and the area of the telescope, A, are related in the following way:

$$A \propto r^2 \quad (13)$$

By combining Equations 12 and 13, we obtain the following result:

$$NA \propto r^2/P_H \quad (14)$$

The right hand side of Equation 14 is proportional to the reciprocal of our rating R. Therefore we can write:

$$R \propto 1/NA \quad (15)$$

In other words, the rating R is inversely proportional to the total area of the all telescopes needed to perform a search of stars with rating R.

Rating Uncertainty

As in any physical measurement, there is an uncertainty associated with this rating. The two sources of uncertainty are systematic and random errors. Systematic errors in the measurement of any individual star's distance are likely to be quite small. Systematic errors could exist in P_H but they are unknown at this point. Further refinements to the current simulation would help, although simulations using a different method would be ideal for verifying the present results. For the time being, we will ignore systematic errors.

Assuming that the random errors are small, the error in R, ΔR, can be reasonably approximated as follows:

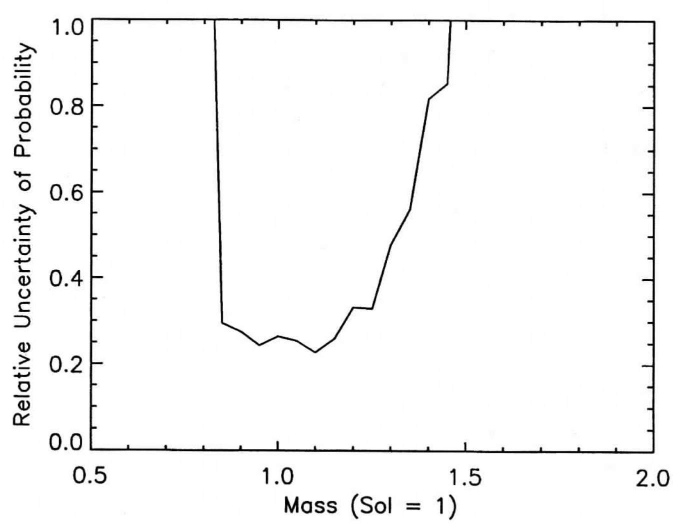

Figure 3: Relative Uncertainty of Probability versus Stellar Mass

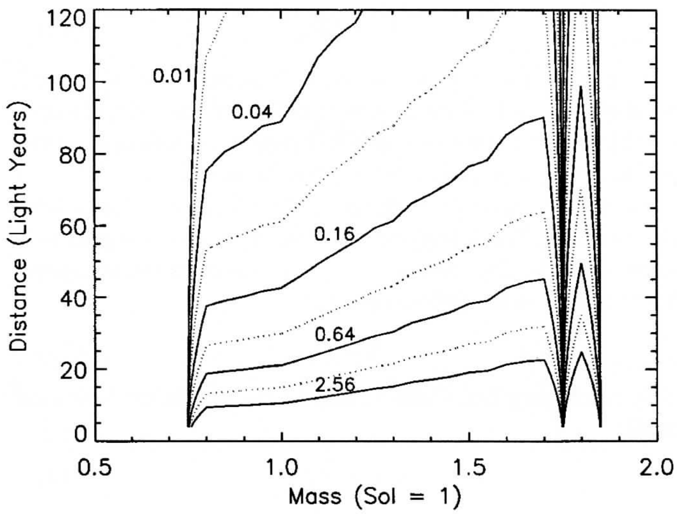

Figure 4: ΔR as Function of Distance and Stellar Mass Each contour has twice the value of ΔR of the previous one

ing, mass transfer between close binaries, or other characteristics that could make the existence of a habitable planet difficult.

Contrary to conventional wisdom, slightly variable stars were included on the list. Recent measurements indicate that our Sun is slightly variable. It is possible that it has experienced periods of enhanced variability in the past. Variability should not automatically disqualify a potential candidate as long as the amplitude is not too large.

Among the criteria for habitable planets it was stated that the maximum allowable orbital eccentricity is 0.2. This would result in a factor of 2.25 variation in surface insolation. That same variation is equivalent to a 0.9 V magnitude amplitude in the star's output. For consideration as a target we will be a bit more conservative and use one-third of that value, 0.3 V, as the maximum allowable amplitude of a variable. If the star's variability or its amplitude was in question, it was included for consideration by default.

The candidate system must obviously have a nonzero value of R. To determine the value of R of a star, its mass must be known in order to obtain P_H. Except for a few well-studied binary systems, the masses of most stars are unmeasured. In these cases the mass was estimated based on the luminosity of the star using the mass-luminosity relationship. Unfortunately, the physics of stars is not so simple and factors other than mass affect the luminosity of a star. The luminosity depends on age, the initial endowment of metals, and many other factors. As a result, many formulations of the mass-luminosity exist and the results are just estimates. Fortunately, except near $0.80M_\odot$, P_H as a function of mass is relatively flat, so the resulting errors in P_H due to uncertainties in the mass estimate would be small compared to errors in P_H previously discussed.

For the purpose of this list, I have used the following relation based on the one used by Fogg [7] which gives a good estimate for a middle-aged main sequence star:

$$M/M_\odot = (L/L_\odot)^{1/4.75} \qquad (18)$$

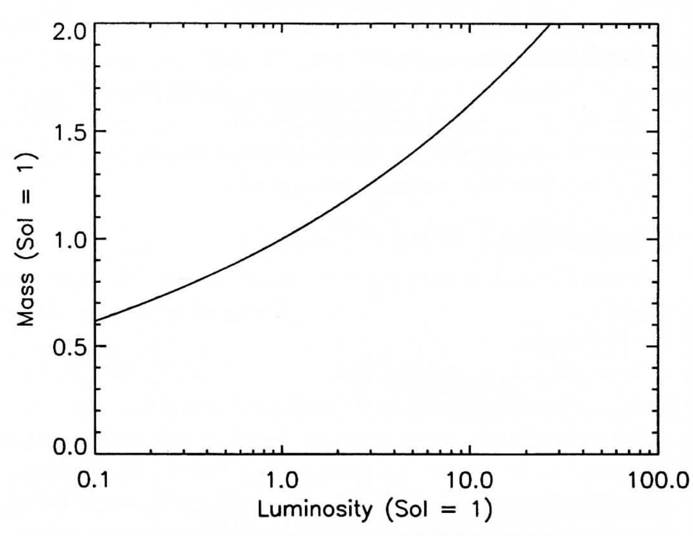

Figure 5: Mass Luminosity Relationship

$$\Delta R = R\sqrt{((\Delta P_H/P_H)^2 + (2\Delta r/r)^2)} \qquad (16)$$

Based on statistical considerations, the relative uncertainty in P_H, $\Delta P_H/P_H$ was calculated with the available information on the simulation used (2). The results of this calculation are shown in Figure 3. As can be seen, the relative uncertainty of P_H is in the 25 to 35 percent range for stars in the $0.80M_\odot$ to $1.20M_\odot$ mass range. Outside this mass range, the relative uncertainty is very large. This violates the assumption in Equation 16 that the random errors be small. Until more accurate simulations with better statistics are available, ratings for these stars must be considered very uncertain. Fortunately, few of the candidate star systems are affected.

The relative uncertainty in P_H for multiple star systems is given by:

$$\Delta P_H/P_H = \sqrt{\sum_i (\Delta P_{Hi}/P_{Hi})^2} \qquad (17)$$

The relative uncertainty in r, $\Delta r/r$, is easier to deal with. It can be calculated based on the measurement error of the system's parallax. Measurement uncertainties for a star's parallax typically are about +/- 5 milliarc seconds. For a star with a parallax of 50 milliarc seconds (i.e., a distance of 20 parsecs or 65 light years), the relative error in distance would be about ten percent.

The effects of these uncertainties are shown in Figure 4. In calculating this contour plot, the relative uncertainties in P_H from Figure 3 are used along with an assumed parallax measurement uncertainty of +/- 5 milliarc seconds. With parallax measurement uncertainties of this size, ΔR is not dominated by them until distances in excess of 160 light years are reached.

Criteria for Target List

The criteria for a candidate target were in keeping with the criteria for a habitable planet. The candidate star had to be a spectral class V or dwarf. Because of the potential uncertainty in spectral classification, transitional stars of class IV-V were also considered. We also did not want any "weird" systems such as those with white dwarfs in close orbits, evidence of massive flar-

Figure 5 shows a plot of this equation.

Multiple star systems have also been included for consideration. There is still a question of whether planets can form in multiple star systems [8,9]. But until the planet and star forming processes are better understood, this will remain an open question. Assuming for the moment that planets can form in multiple star systems, three-body simulations [10] have shown that there are regions where a planet's orbit would be stable. A planet's orbit would be stable if its semimajor axis were three or four times greater than that of a closely orbiting companion, or if the periastron of a distant companion were three or four times larger than the planet's semimajor axis.

For close systems, which would typically be detectable only spectroscopically, the orbit will likely be close to circular and a limit based on the maximum allowable period of revolution can be used. The semimajor axis, period of revolution, and total mass of a binary's orbit are related by Kepler's equation:

$$a_*^3 = (p_*^2)\, M_{TOTAL}/M_\odot \qquad (19)$$

Here a_* is the distance between the two components in astronomical units (AU), p_* is the period of revolution in years, and M_{TOTAL} is the sum of the component's masses.

The size of the semimajor axis of a habitable planet, a_{PLANET}, can be approximated as:

$$a_{PLANET} = \sqrt{(L_{TOTAL}/L_\odot)} \qquad (20)$$

Here L_{TOTAL} is the sum of the components' luminosities. Using the limit discussed above, we can equate the maximum allowable value of a_* compared to a_{PLANET}:

$$a_* < a_{PLANET}/4 \qquad (21)$$

Combining equations 19, 20, and 21, we can obtain the following relation:

$$p_* < ((L_{TOTAL}/L_\odot)^{0.75})/(8\sqrt{(M_{TOTAL}/M_\odot)}) \qquad (22)$$

Typically, we do not know the total mass of the system, M_{TOTAL}. Since we do know the total luminosity of the pair of stars, we can assume a worst-case scenario where most of the mass is in one of the two components and use Equation 18 to calculate the mass. This condition would minimize the total mass of the system and maximize the separation of the components with a fixed value of p_*. Combining Equations 18 and 22, we obtain:

$$p_* < ((L_{TOTAL}/L_\odot{}^{0.64})/8 \qquad (23)$$

So a habitable planet that is in a close binary system that obeys either Equation 22 or 23 would be considered for the list. Suspected close binaries and close binaries whose elements are unknown were included for consideration. Figure 6 shows the maximum allowable period of revolution as a function of stellar luminosity.

The other situation is a binary system with widely separated components. Again we can relate a_{PLANET} and a_*:

$$a_* > 4a_{PLANET} \qquad (24)$$

Equation 20 can be modified as follows:

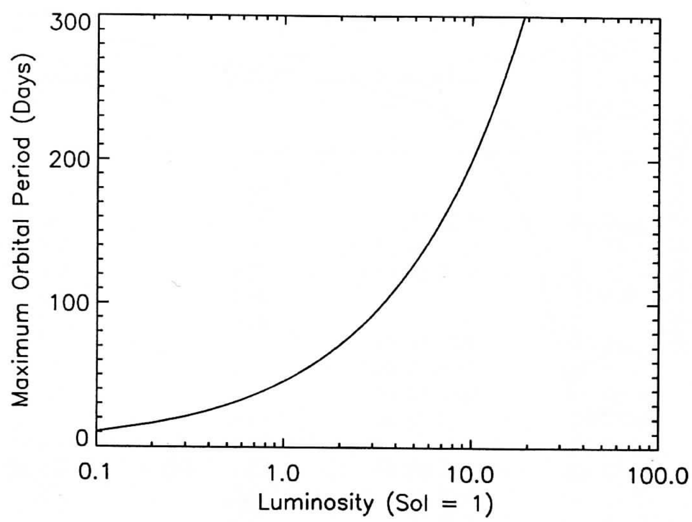

Figure 6: Maximum Period of Revolution versus Total Luminosity for Close Binary Systems

$$a_{PLANET} = \sqrt{(L_l/L_\odot)} \qquad (25)$$

The variable L_l is the luminosity of the planet's sun. Combining equations 19, 24, and 25, we obtain the following:

$$p_* > 8((L_l/L_\odot)^{0.75})/\sqrt{(M_{TOTAL}/M_\odot)} \qquad (26)$$

The value of M_{TOTAL} can be obtained using observed values or estimated using Equation 18. Figure 7 show the minimum allowable p_* as a function of L_l and M_{TOTAL}.

The Target List

To produce this list, the ratings for star systems in several

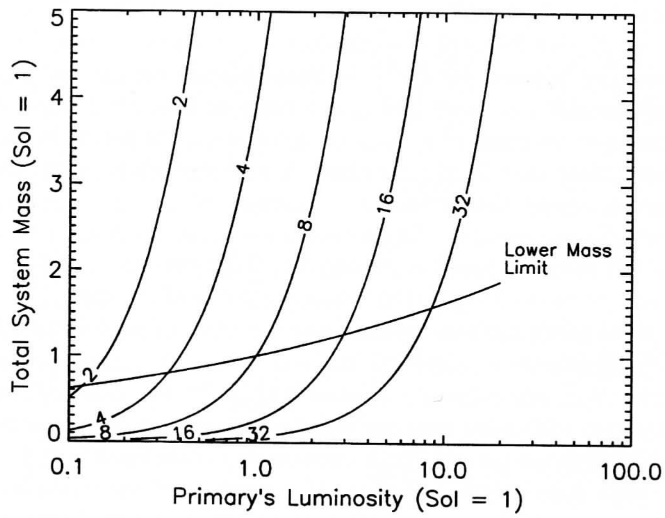

Figure 7: Minimum Period of Revolution as Function of Primary Luminosity and Total System Mass for Widely Separated Binaries (in units of years) Lower Mass Limit line based on Equation 18. Systems much below this line are too luminous for their given mass

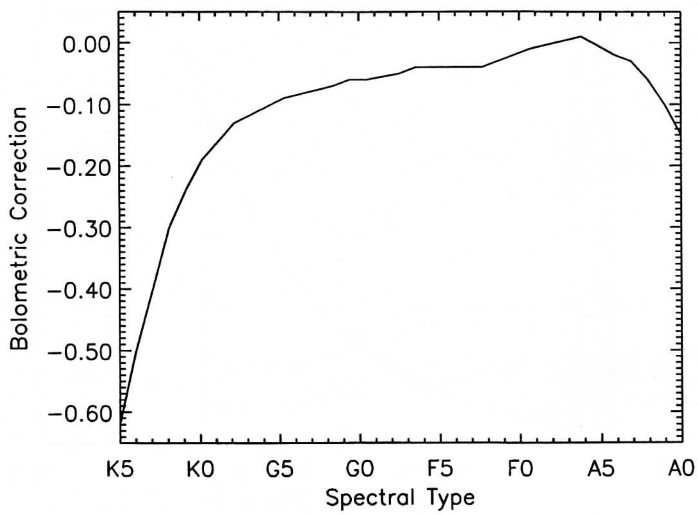

Figure 8: Bolometric Correction versus Spectral Type

star catalogs [11,12,13] were calculated and the top 100 candidates that met the criteria are listed in Table 1. The first column of Table 1 gives the ranking of the system. Multiple star systems are marked with a "+".

The second column gives the name of the individual star or system. Any given star has a multitude of names or catalog numbers, which makes choosing a single appellation difficult. In an effort to minimize this confusion, I have used the following hierarchy of names when choosing the one to be used: If a common name exists, it is used. One example is α Aquilae, for which I used its common name, Altair. If a generally acceptable common name does not exist, the Bayer designation, consisting of a Greek letter and the name of the constellation, is used. An example of this is τ Ceti. If this is not available, the Flamsteed designation is used. This designation includes a number and constellation name such as 70 Ophiuchi.

If all else fails, The Durchmusterung number is used. This number includes the star's declination when the catalog was made and a number taking the form of DM-39 7301, for example. In cases of a multiple star system, the names of the individual stars, if any, are given. If such individual names are not available, the star name is followed by a letter to denote which component it is. An example is α Centauri A and B. As a last resort to avoid confusion, the third column of Table 1 lists the Henry Draper (HD) catalog number of the star.

The fourth and fifth columns give the rating of the system and its uncertainty respectively. In cases where the uncertainty is excessive, this column is marked with a "?". For multiple star systems with more than one component with a nonzero rating, the ratings are given for each component and enclosed by "( )".

The sixth column gives the V magnitude of the individual components. The last two columns give the position of the star system in 2000.0 coordinates.

Table 2 gives additional information on the top star systems. The first three columns are the same as in Table 1.

The fourth column gives the spectral type and class of the star. The fifth column gives the total luminosity of the star calculated from its apparent V magnitude, V, the bolometric correction of the star, BC, and its parallax, π, as follows:

$$\log(L/L_\odot) = 0.4(V_{ABS\odot} - V - BC) - 2 - 2\log\pi \qquad (27)$$

Where $V_{ABS\odot}$ is the absolute bolometric magnitude of the Sun. For this calculation a value of +4.76 was used. The bolometric correction as a function of spectral type used in this calculation [14] is shown in Figure 8.

The sixth column gives the mass of the star. If this mass is marked by "•". the mass was measured [13,14,15]. Otherwise the mass has been estimated using Equation 18. The seventh column gives the system's distance in light years.

Next the parallax in milliarc seconds is given, with its measurement uncertainty enclosed in "( )". Finally, important notes on the star system are included in the final column.

Readers Comments

I realized from the start of this project that formulating a SETI target rating system which would please everyone would be difficult. I invite readers to comment on this rating system so that it can be improved and refined in the future. In addition, some of the sources for system parameters are dated. New information should be available in the future. Readers are invited to supply updates with references.

Finally, while intellectual debates on what makes a good rating system have their place in SETI, it must be remembered that the "S" in SETI stands for "Search." The staff of this magazine and I encourage professional and serious amateur scientists to monitor potential SETI targets for indications of some sort of signal of intelligent origin. Readers who perform such searches are invited to write and detail their observations. Information on the time, date, location, and target monitored, along with data on the equipment used and wavelengths observed, should be included. These observations will be discussed in future issues of *SETIQuest*.

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Table 1: Top 100 Candidate SETI Targets

No.	Name	HD	Rating	Uncertainty	V Mag	Right Ascension h m s (2000 Coordinates)	Declination ° ' "
1+	α CEN A	128620	(75	18)	-0.01		
	α CEN B	128621	(46	13)	1.30		
	α CEN System		121	44		14 39 36.2	-60 50 07
2	τ CET	10700	5.9	1.7	3.50	01 44 04.0	-15 56 15
3+	70 OPH A	165341	3.6	1.0	4.22	18 05 27.2	+02 29 58
4+	γ VIR A	110379	(1.4	0.5)	3.48		
	γ VIR B	110380	(1.5	0.4)	3.50		
	γ VIR System		2.9	1.2		12 41 39.5	-01 26 58
5	1 π (3) ORI	30652	2.4	0.8	3.19	04 49 50.3	+06 57 41
6+	η CAS A	4614	2.3	0.7	3.44	00 49 06.0	+57 48 58
7	ε ERI	22049	2.3	?	3.73	03 32 55.8	-09 27 30
8+	γ LEP A	38393	2.3	0.7	3.60	05 44 27.8	-22 26 54
9	ζ TUC	1581	2.0	0.6	4.23	00 20 04.2	-64 52 30
10+	ξ BOO A	131156	2.0	0.5	4.68	14 51 23.2	+19 06 04
11	Altair	187642	1.8	?	0.76	19 50 46.9	+08 52 06
12	γ PAV	203608	1.7	0.5	4.53	21 26 26.7	-65 21 59
13+	ο (2) ERI A	26965	1.6	?	4.43	04 15 16.3	-07 39 10
14	σ DRA	185144	1.6	0.6	4.68	19 32 21.5	+69 39 40
15+	ζ (1) RET	20766	(0.74	0.23)	5.53	03 17 46.1	-62 34 32
	ζ (2) RET	20807	(0.81	0.24)	5.23	03 18 12.8	-62 30 23
	ζ RET System		1.6	0.6			
16	61 VIR	115617	1.5	0.3	4.74	13 18 24.2	-18 18 41
17	β VIR	102870	1.5	0.5	3.60	11 50 41.6	+01 45 53
18	κ (1) CET	20630	1.2	0.3	4.83	03 19 21.6	+03 22 13
19	α MEN	43834	1.1	0.4	5.09	06 10 14.6	-74 45 11
20	107 PSC	10476	1.1	0.4	5.24	01 42 29.7	+20 16 07
21	ι PER	19373	1.1	0.4	4.05	03 09 04.0	+49 36 48
22	ψ CAP	197692	1.1	0.4	4.14	20 46 05.6	-25 16 16
23+	10 UMA A	76943	(0.71	0.29)	4.11		
	10 UMA B		(0.29	0.11)	6.18		
	10 UMA System		1.0	0.44		09 00 38.3	+41 46 58
24+	γ CRA A	177474	(0.51	0.20)	4.91		
	γ CRA B	177475	(0.48	0.19)	5.01		
	γ CRA System		0.99	0.51		19 06 25.0	-37 03 48
25+	DM-39 7301 A	102365	0.96	0.27	4.90	11 46 31.0	-40 30 01
26	61 UMA	101501	0.95	0.35	5.33	11 41 02.9	+34 12 05
27	DM-37 8437	114613	0.95	0.36	4.85	13 12 03.1	-37 48 11
28+	δ TRI	13974	0.94	0.27	4.87	02 17 03.2	+34 13 28
29+	η CRB A	137107	(0.57	0.15)	5.62		
	η CRB B	137108	(0.37	0.11)	5.89		
	η CRB System		0.94	0.35		15 23 12.2	+30 17 16
30+	ζ TRA	147584	0.93	0.29	4.91	16 28 28.1	-70 05 04
31+	ϑ PER A	16895	0.92	0.34	4.13	02 44 11.9	+49 13 43
32+	36 UMA	90839	0.91	0.24	4.84	10 30 37.5	+55 58 50
33+	DM-22 2345 A	73752	(0.59	0.19)	5.28		
	DM-22 2345 B		(0.29	0.10)	6.80		
	DM-22 2345 System		0.88	0.38		08 39 07.9	-22 39 43
34+	DM+63 238	10780	0.86	0.26	5.63	01 47 44.8	+63 51 09
35	ζ DOR	33262	0.86	0.29	4.72	05 05 30.6	-57 28 22
36+	DM+41 328	10307	0.85	0.24	4.96	01 41 47.1	+42 36 49
37+	DM-25 225 A	3443	(0.42	0.14)	6.35		
	DM-25 225 B		(0.42	0.14)	6.35		
	DM-25 225 System		0.84	0.38		00 37 20.6	-24 46 02
38	μ ARA	160691	0.80	0.25	5.12	17 44 08.6	-51 50 03
39	ν PHE	7570	0.79	0.25	4.96	01 15 11.1	-45 31 54
40+	DM-0 3300 A	158614	(0.41	0.12)	6.00		
	DM-0 3300 B		(0.38	0.11)	6.10		
	DM-0 3300 System		0.79	0.30		17 30 23.7	-01 03 45
41+	DM-43 2906	53705	(0.50	0.15)	5.54	07 03 57.2	-43 36 29
	DM-43 2907	53706	(0.27	0.09)	6.79	07 03 58.8	-43 36 42
	System		0.77	0.32			
42	47 UMA	95128	0.76	0.30	5.05	10 59 27.9	+40 25 49
43	γ SER	142860	0.76	0.41	3.86	15 56 27.1	+15 39 42
44+	9 PUP A	64096	(0.42	0.12)	5.60		
	9 PUP B		(0.33	0.10)	6.20		
	9 PUP System		0.75	0.30		07 51 46.2	-13 53 53
45+	DM-34 4036 A	64379	0.74	0.23	5.08	07 52 15.6	-34 42 19
46+	44 BOO A	133640	0.73	0.20	5.25	15 03 47.3	+47 39 16

No.	Name	HD	Rating	Uncertainty	V Mag	Right Ascension ° ' "	Declination
						(2000 Coordinates)	
47+	τ (1) HYA A	81997	0.70	0.26	4.61	09 29 08.8	-02 46 08
48	ψ (5) AUR	48682	0.69	0.19	4.35	06 46 44.3	+43 34 39
49	54 PSC	3651	0.69	0.21	5.86	00 39 21.7	+21 15 02
50	κ FOR	14802	0.69	0.22	5.19	02 22 32.5	-23 48 59
51+	DM-54 10055 A	211415	0.68	0.22	5.38	22 18 15.4	-53 37 40
52	15 LMI	84737	0.67	0.21	5.10	09 48 35.5	+46 01 15
53+	59 VIR	115383	0.66	0.20	5.22	13 16 46.6	+09 25 27
54	DM-38 10983	147513	0.65	0.22	5.39	16 24 01.2	-39 11 35
55	φ (2) CET	4813	0.63	0.19	5.20	00 50 07.5	-10 38 40
56	λ AUR	34411	0.62	0.23	4.71	05 19 08.4	+40 05 57
57+	26 DRA A	160269	0.61	0.16	5.33	17 34 59.4	+61 52 30
58	DM-51 532	13445	0.61	0.20	6.11	02 10 25.6	-50 49 28
59	χ CNC	69897	0.61	0.20	4.10	08 20 03.8	+27 13 03
60	58 ERI	30495	0.60	0.18	4.92	04 47 36.2	-16 56 04
61+	53 AQR A	212698	(0.30	0.11)	6.30	22 26 34.1	-16 44 29
	53 AQR B	212697	(0.30	0.11)	6.44	22 26 34.3	-16 44 33
	53 AQR System		0.60	0.26			
62+	16 CYG A	186408	(0.34	0.13)	5.95	19 41 48.8	+50 31 31
	16 CYG B	186427	(0.26	0.10)	6.20	19 41 51.8	+50 31 03
	16 CYG System		0.60	0.27			
63	20 LMI	86728	0.59	0.22	5.35	10 01 00.6	+31 55 25
64+	DM-33 4113 A	63077	0.58	0.16	5.36	07 45 34.8	-34 10 23
65+	DM+19 2881	131511	0.58	0.19	6.04	14 53 23.6	+19 09 10
66+	111 TAU	35296	0.58	0.19	5.00	05 24 25.4	+17 23 00
67	DM-23 15935	189561	0.58	0.29	5.96	20 01 23.8	-22 44 14
68	ι PSC	222368	0.58	0.30	4.13	23 39 57.0	+05 37 35
69+	τ OPH A	164765	(0.31	0.19)	5.24		
	τ OPH B	164764	(0.27	0.15)	5.94		
	τ OPH System		0.58	0.35		18 03 04.8	-08 10 50
70	72 HER	157214	0.57	0.17	5.39	17 20 39.5	+32 28 04
71	ι HOR	17051	0.57	0.17	5.40	02 42 33.4	-50 48 01
72	DM-4 2490	76151	0.55	0.17	6.00	08 54 17.8	-05 26 04
73	51 PEG	217014	0.55	0.17	5.50	22 57 27.9	+20 46 08
74+	ι PEG	210027	0.55	0.40	3.76	22 07 00.6	+25 20 42
75	DM-47 13928	207129	0.54	0.17	5.58	21 48 15.6	-47 18 13
76	DM-12 2449	69830	0.53	0.16	6.00	08 18 23.8	-12 37 55
77+	99 HER A	165908	0.53	0.17	5.09	18 07 01.4	+30 33 43
78+	DM-54 5806	121384	0.53	0.19	6.00	13 56 32.9	-54 42 16
79	18 SCO	146233	0.52	0.15	5.49	16 15 37.1	-08 22 11
80	6 CET	693	0.52	0.20	4.89	00 11 15.8	-15 28 05
81	ω SGR	188376	0.52	0.28	4.70	19 55 50.3	-26 17 58
82+	ψ DRA	162003	(0.18	?)	4.58	17 41 56.2	+72 08 56
	DM+72 805	162004	(0.34	0.10)	5.82	17 41 57.8	+72 09 25
	System		0.52	?			
83+	DM+24 2786	130948	0.51	0.15	5.92	14 50 15.8	+23 54 42
84+	ρ (1) CNC A	75732	0.51	0.16	5.97	08 52 35.8	+28 19 51
85+	DM+7 1997 A	72945	(0.32	0.10)	5.99	08 35 50.9	+06 37 12
	DM+7 1997 B	72946	(0.19	0.07)	7.25	08 35 51.2	+06 37 21
	DM+7 1997 System		0.51	0.22			
86+	ϑ BOO A	126660	0.51	0.32	4.06	14 25 11.7	+51 51 03
87	39 TAU	25680	0.49	0.14	5.90	04 05 20.2	+22 00 32
88+	DM-37 10500 A	140901	0.48	0.15	6.02	15 47 28.8	-37 54 59
89	58 OPH	160915	0.48	0.21	4.87	17 43 25.7	-21 41 00
90+	μ (1) CYG	206826	(0.20	?)	4.77	21 44 08.5	+28 44 34
	μ (2) CYG	206827	(0.28	0.09)	6.20	21 44 08.2	+28 44 35
	μ CYG System		0.48	?			
91	ν (2) LUP	136352	0.47	0.14	5.64	15 21 48.1	-48 19 03
92+	DM-59 944 A	65907	0.47	0.14	5.59	07 57 46.9	-60 18 12
93	45 BOO	134083	0.47	0.18	4.93	15 07 18.0	+24 52 09
94+	α COM A	114378	(0.24	?)	5.06		
	α COM B	114379	(0.23	?)	5.08		
	α COM System		0.47	?		13 09 59.2	+17 31 46
95+	1 HYA	70958	0.46	0.13	5.62	08 24 35.0	-03 45 04
96	DM+28 4704	166	0.46	0.15	6.14	00 06 36.7	+29 01 17
97	DM-0 632	25457	0.46	0.15	5.38	04 02 36.7	-00 16 08
98	ρ CRB	143761	0.46	0.16	5.40	16 01 02.6	+33 18 13
99+	σ CRB A	146361	(0.30	0.10)	5.69		
	σ CRB B	146362	(0.16	0.05)	6.72		
	σ CRB System		0.46	0.21		16 14 40.7	+33 51 30
100	DM-21 5081	172051	0.44	0.15	5.88	18 38 53.3	-21 03 07

Table 2: Additional Information on the Top 100 Candidate SETI Targets

No	Name	HD	Type	L/L⊙	M/M⊙	Dist.(ly)	Parallax (milliarc sec)	Notes
1+	α CEN A	128620	G2V	1.5	1.07*			AB: P=79.92y a=17.583"
	α CEN B	128621	K0V	0.50	0.88*			AB/C: Separation=2.2°
	α CEN System					4.35	750 (07)	
2	τ CET	10700	G8V	0.47	0.85	11.8	277 (05)	
3+	70 OPH A	165341	K0V	0.47	0.90*	16.1	203 (04)	AB:P=88.13y a=4.545"
4+	γ VIR A	110379	F0V	3.3	1.18*			One component variable w/ amp=0.02V
	γ VIR B	110380	F0V	3.3	1.13*			A: Spectroscopic Binary
	γ VIR System					33	099 (07)	AB: P=171.37y a=3.746"
5	1 π (3) ORI	30652	F6V	2.6	1.22	25	130 (05)	Variable w/ amp=0.05V
6+	η CAS A	4614	G0V	1.2	0.86*	19.1	171 (03)	A:Spectroscopic binary P=9.209d
								AB: P=480y a=11.994"
7	ε ERI	22049	K2V	0.37	0.81	6.14	393 (03)	
8+	γ LEP A	38393	F6V	2.0	1.16	27	123 (08)	AB: Separation=96.5"
9	ζ TUC	1581	F9V	0.88	0.97	23	140 (08)	
10+	ξ BOO A	131156	G8V	0.59	0.89*	22	153 (04)	AB: P=151.505y a=4.904"
11	Altair	187642	A7V	10.0	1.62	16.5	198 (04)	
12	γ PAV	203608	F6V	1.3	1.06	28	116 (08)	
13+	o (2) ERI A	26965	K1V	0.40	0.82	15.9	205 (04)	A/BC: Separation=83.4"
14	σ DRA	185144	K0V	0.41	0.83	18.5	176 (04)	
15+	ζ (1) RET	20766	G3-5V	0.66	0.92			A: Variable? AB: Separation=310.0"
	ζ (2) RET	20807	G2V	0.87	0.97			
	ζ RET System					37	089 (08)	
16	61 VIR	115617	G6V	0.79	0.95	29	119 (09)	
17	β VIR	102870	F9V	3.0	1.26	33	100 (05)	
18	κ (1) CET	20630	G5V	0.88	0.97	31	107 (06)	Variable w/ amp=0.10 IR
19	α MEN	43834	G6V	0.61	0.90	28	115 (08)	
20	107 PSC	10476	K1V	0.44	0.84	24	134 (06)	Variable?
21	ι PER	19373	G0V	2.8	1.24	38	086 (06)	
22	ψ CAP	197692	F4V	2.8	1.24	39	084 (08)	
23+	10 UMA A	76943	F5V	4.1	1.13*			AB: P=21.85y a=0.619"
	10 UMA B		G5V	0.63	0.84*			
	10 UMA System					48	068 (04)	
24+	γ CRA A	177474	F8V	2.8	1.24			A: Spectroscopic Binary AB:
	γ CRA B	177475	F8V	2.6	1.22			P=120.42y a=1.907"
	γ CRA System					56	058 (06)	
25+	DM-39 7301 A	102365	G5V	1.0	1.00	33	098 (08)	AB: Separation=25.4"
26	61 UMA	101501	G8V	0.45	0.84	27	122 (07)	
27	DM-37 8437	114613	G3V	1.2	1.0	37	089 (13)	
28+	δ TRI	13974	G0V	1.0	1.00	34	097 (07)	Spectroscopic binary P=10.0201d
29+	η CRB A	137107	G1V	1.3	1.10*			AB: P=41.56 a=0.839"
	η CRB B	137108	G3V	1.1	1.00*			
	η CRB System					53	061 (04)	
30+	ζ TRA	147584	F9V	1.1	1.02	35	093 (09)	Spectroscopic Binary P=12.9762d
31+	ϑ PER A	16895	F8V	3.0	1.26	41	079 (05)	A: Variable? AB: P=2720y a=22.289"
32+	36 UMA	90839	F8V	1.6	1.11	39	077 (05)	AB: Separation=46.5' AC: Separation=139"
33+	DM-22 2345 A	73752	G3V	1.8	1.13			A: Spectroscopic Binary
	DM-22 2345 B		K0V	0.46	0.85			AB: P=145.0y a=1.700"
	DM-2345 System					53	062 (06)	
34+	DM+63 238	10780	K0V	0.48	0.86	31	105 (04)	Astrometric binary
35	ζ DOR	33262	F7V	1.9	1.15	44	075 (08)	
36+	DM+41 328	10307	G1.5V	1.2	1.03	38	087 (06)	Astrometric binary P=20y a=0.12"
37+	DM-25 225 A	3443	G7V	0.47	0.85			AB: P=25.00y a=0.670"
	DM-25 225 B		G8V	0.47	0.85			
	DM-25 225 System					44	074 (07)	
38	μ ARA	160691	G3IV-V	0.95	0.99	37	089 (08)	
39	ν PHE	7570	F8V	1.8	1.13	45	072 (07)	
40+	DM-0 3300 A	158614	G9IV-V	1.3	1.14			AB: P=46.4y a=1.02"
	DM-0 3300 B		G8IV-V	1.2	1.08			
	DM-0 3300 System					63	052 (04)	
41+	DM-43 2906	53705	G3V	1.6	1.11			A: Spectroscopic binary
	DM-43 2907	53706	K0V	0.58	0.89			AB: Separation=21.0"
	System					57	057 (06)	AC: Separation=200"
42	47 UMA	95128	G0V	1.5	1.08	44	074 (07)	
43	γ SER	142860	F6V	3.6	1.31	40	081 (08)	Variable?
44+	9 PUP A	64096	G0V	1.0	0.99*			AB: P=23.18y a=0.58"
	9 PUP B		G2V	0.69	0.86*			
	9 PUP System					50	065 (04)	
45+	DM-34 4036 A	64379	F5V	1.4	1.08	45	073 (07)	AB: Separation=3.0"
46+	44 BOO A	133640	F9V	0.95	0.99	39	084 (05)	AB: P=225.0y a=3.772"

No	Name	HD	Type	$L/L_{\odot}$	$M/M_{\odot}$	Dist.(ly)	Parallax (milliarc sec)	Notes
47+	τ (1) HYA A	81997	F6V	2.3	1.19	46	071 (07)	A: Variable spectrum? AB: Separation=65.7”
48	ψ (5) AUR	48682	G0V	1.5	1.10	49	067 (05)	Variable?
49	54 PSC	3651	K0V	0.47	0.85	34	095 (05)	
50	κ FOR	14802	G1V	1.2	1.04	42	077 (08)	
51+	DM-54 10055 A	211415	G3V	0.95	0.99	40	082 (08)	AB: Separation=3.0”
52	15 LMI	84737	G0.5	1.8	1.13	43	066 (06)	
53+	59 VIR	115383	G0V	1.2	1.03	42	077 (06)	AB: Separation=34.3”
54	DM-38 10983	147513	G5V	1.6	1.10	50	065 (08)	Variable w/ amp=0.07V
55	φ (2) CET	4813	F7IV-V	1.7	1.11	51	064 (06)	
56	λ AUR	34411	G2IV-V	2.5	1.21	49	067 (06)	
57+	26 DRA A	160269	G0V	1.4	1.07	48	067 (04)	AB: P=76.00y a=1.52” AB/C: Separation=740”
58	DM-51 532	13445	K1V	0.45	0.85	37	089 (07)	
59	χ CNC	69897	F6V	1.9	1.15	52	063 (06)	
60	58 ERI	30495	G1V	0.92	0.98	42	077 (06)	
61+	53 AQR A	212698	G2V	0.86	0.97			AB: Separation=3.3”
	53 AQR B	212697	G1V	0.78	0.95			
	53 AQR System					60	054 (07)	
62+	16 CYG A	186408	G1.5V	1.6	1.11			AB: Separation=39.2” AC: Separation=70”
	16 CYG B	186427	G2.5V	1.2	1.05			
	16 CYG System					69	047 (07)	
63	20 LMI	86728	G2V	1.2	1.05	47	070 (10)	
64+	DM-33 4113 A	63077	G0V	1.5	1.09	52	063 (05)	AB: Separation=914”
65+	DM+19 2881	131511	K2V	0.54	0.88	39	084 (07)	Spectroscopic Binary
66+	111 TAU	35296	F8V	2.1	1.17	52	063 (05)	A: Spectroscopic binary AB: Separation=720”
67	DM-23 15935	189561	G7V	0.52	0.87	38	085 (18)	
68	ι PSC	222368	F7V	3.7	1.32	46	071 (05)	Variable?
69+	τ OPH A	164765	F5V	1.7	1.12			B: Spectroscopic binary
	τ OPH B	164764	F2V	3.3	1.28			AB: P=280.03y a=1.494”
	τ OPH System					72	045 (08)	
70	72 HER	157214	G0V	1.1	1.02	45	073 (05)	Variable w/ amp=0.4V
71	ι HOR	17051	G0V	1.2	1.04	47	070 (06)	
72	DM-4 2490	76151	G3V	0.47	0.85	38	085 (05)	
73	51 PEG	217014	G5V	1.0	1.01	45	073 (06)	
74+	ι PEG	210027	F5V	4.6	1.38	44	075 (05)	Variable?; Spectroscopic binary P=10.2130d
75	DM-47 13928	207129	G0V	0.94	0.99	45	073 (07)	
76	DM-12 2449	69830	G7.5V	0.58	0.89	41	079 (05)	
77+	99 HER A	165908	F7V	2.1	1.17	54	061 (04)	A: Spectroscopic binary AB: P=55.8y a=1.00”
78+	DM-54 5806	121384	1G6IV-V	0.55	0.88	41	080 (09)	AB: Separation=33”
79	18 SCO	146233	G2V	1.5	1.08	53	061 (05)	
80	6 CET	693	F7V	2.5	1.21	53	061 (06)	
81	ω SGR	188376	G5V	3.16	1.27	53	061 (10)	
82+	ψ DRA	162003	F5IV-V	5.2	1.42			AB: Separation=30.2”
	DM+72 805	162004	G0V	1.8	1.13			
	System					69	047 (04)	
83+	DM+24 2786	130948	G0-2V	0.79	0.95	47	070 (06)	Spectroscopic binary
84+	ρ (1) CNC A	75732	G8V	0.69	0.92	44	074 (07)	AB: Separation=85.0”
85+	DM+7 1997 A	72945	F8V	1.3	1.06			A: Spectroscopic binary P=14.296d
	DM+7 1997 B	72946	G5V	0.46	0.85			AB: Separation=10.3”
	DM+7 1997 System					65	050 (05)	
86+	ϑ BOO A	126660	F7V	4.3	1.36	48	068 (06)	AB: Separation=69.5”
87	39 TAU	25680	G5V	0.80	0.95	47	069 (05)	Variable?
88+	DM-37 10500 A	140901	G6V	0.64	0.91	45	073 (06)	AB: Separation=14.6”
89	58 OPH	160915	F6V	3.0	1.26	57	057 (07)	
90+	μ (1) CYG	206826	F6V	4.8	1.39			AB: P=507.5y a=4.278”
	μ (2) CYG	206827	G2V	1.4	1.07			
	μ CYG System					71	046 (05)	
91	ν (2) LUP	136352	G3-5V	1.1	1.03	50	065 (05)	
92+	DM-59 944 A	65907	G0V	1.3	1.06	53	061 (05)	A: Spectroscopic binary A/BC: Separation=60”
93	45 BOO	134083	F5V	2.8	1.24	58	056 (05)	Variable?
94+	α COM A	114378	F5V	2.8	1.40*			AB: P=25.83y a=0.672”
	α COM B	114379	F5V	2.7	1.46*			
	α COM System					62	053 (04)	
95+	1 HYA	70958	F3V	1.6	1.10	60	054 (05)	Spectroscopic binary P=1.5630d
96	DM+28 4704	166	K0V	0.60	0.90	45	073 (06)	Variable?
97	DM-0 632	25457	F5V	1.9	1.15	59	055 (05)	
98	ρ CRB	143761	G2V	2.0	1.15	59	055 (06)	
99+	σ CRB A	146361	G0V	2.1	1.17			A: Variable w/ amp=0.05V P=1.139789d;
	σ CRB B	146362	G1V	0.86	0.97			Spectroscopic binary P=1.1398d
	σ CRB System					72	045 (04)	AB: P=1000.0y a=6.599”
								AB/C: Separation=633”
100	DM-21 5081	172051	G4V	0.73	0.94	49	066 (08)	