

## TOP ARGELANDER STARS: PEDAGOGY & PRIZE

S. R. KULKARNI

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### ABSTRACT

Stellar astronomy, fueled by massive capital investments, advances in numerical modeling and theory, is resurgent and arguably is on the verge of a magnificent renaissance. Powerful time domain optical surveys, both on ground and in space, are producing data on variable stars on an unprecedented industrial scale. Those with deep knowledge of variable stars will stand to benefit from this resurgence. Notwithstanding these developments, in some astronomical communities, classical stellar astronomy has been in the doldrums. I offer a modest proposal to establish a basic level of familiarity with variable stellar phenomenology and an attractive scheme to make research in variable star astronomy visible, alluring and fashionable.

#### 1. A RESURGENCE IN STELLAR ASTRONOMY

Stellar astronomy is now on the rise. *Kepler* with its exquisite photometric precision has revolutionized the field of extra-solar planets and additionally has kick-started the rich field of astero-seismology. The *Gaia* mission is poised to initiate a revolution in astrometry on a scale that astronomers have not seen for nearly a century. This grand expectation is grounded in the large number of stars for which precision astrometric measurements will be obtained by *Gaia*. Pan-STARSS has laid down a deep multi-band photometric grid over three quarters of the sky. Next year, the Zwicky Transient Facility (ZTF) will begin a 3-year survey of the Northern sky, sharply focused on the dynamic optical sky (that is, variable stars, transients and moving objects). In 2018 the TESS mission is expected to start routine observations. TESS will focus on precision photometry of stars brighter than 12 mag. However, full frame images will allow observations of fainter stars over substantial areas of the sky.

One should not discount smaller and nimble investments such as ASAS, ASAS-SN and Evryscope. Many such projects are trail blazers. Finally, it is both gratifying and astonishing, despite the massive capital investment by professional astronomers, that amateur astronomers continue to make serious contributions to stellar and supernova research.

While above we have focused on astrometry and photometry there has been good progress in spectroscopic surveys (e.g. RAVE and the ultra-low resolution spectroscopy of *Gaia*). There is now a (timely) movement to repurpose the massively-multiplexed spectrographs of the Sloan Digital Sky Survey (SDSS) for stellar astronomy.

As can be deduced from the above summary the capital investment in stellar astronomy has been substantial. However, stellar astronomy is a fairly mature field. Thus merely obtaining large volumes of superior data without corresponding superior theoretical framework will not result in realization of the full gains of the capital investments. Fortunately, there has been good progress on the theoretical and modeling fronts. Nowadays, on a routine basis, astronomers undertake multi-dimensional, if not three-dimensional, modeling of stars and related phenomena. Tools such as MESA allow observers and

modelers to compare theory to observations at the few percent (or even lower) level.

The future landscape in stellar astronomy is extremely promising. I justify this statement with just three examples. First is the implication to stellar astronomy arising from the recent findings by LIGO (Abbott et al. 2016) – not only are stellar black hole binaries abundant but the masses of the black holes was surprisingly higher than expected. These two findings are motivating astronomers to explore entirely *new paths of stellar evolution* in which not only low metal abundance but rapid rotation is expected to strongly influence the evolution of stars. Second, several findings over the last few years, from time domain surveys – wild diversity in pre-supernova mass loss, new types of super-luminous supernova – clearly show that massive stars have multifarious evolutionary paths and multifaceted deaths. These advances are still being digested. It is now clear that future textbooks on stellar astronomy will have not one but several chapters on the evolution and endings of massive stars. Finally, it is becoming clear that massive stars in binary systems may play a major role in the ionization history of the early Universe ( $z \sim 6$ ; Ma et al. 2015).

#### 2. F. W. ARGELANDER

With the modern background laid out I now arrive at the primary goal of this writeup – the anticipated resurgence of variable star astronomy. It is by now well known that forecasting the future is difficult<sup>1</sup>. Furthermore, it is almost always wrong.<sup>2</sup> However, it is said that a knowledge of the past helps understand the future better. In that spirit our journey begins with Friedrich Wilhelm Argelander (1799–1875) who is considered as the founding astronomer of the modern era of variable stars.

Argelander was born in what is now Lithuania. He undertook his PhD under the famous German astronomer Friedrich Bessel at the University of Königsberg located in what is now called Kaliningrad.<sup>3</sup> Following his PhD, in 1823, he moved to the Turku Observatory. In 1832 he

<sup>1</sup><http://www.famous-quotes-and-quotations.com/yogi-berra-quotes.html>

<sup>2</sup><http://www.smithsonianmag.com/smart-news/why-experts-are-almost-always-wrong-9997024/?no-ist>

<sup>3</sup>The modern name for this University is Immanuel Kant Baltic Federal University.

moved to Helsinki where he supervised the construction of the then new Helsinki observatory. His primary accomplishment, up until this point, was the investigation of the Sun's motion with respect to other stars. In 1837 he moved to Germany and took up the Directorship of the Observatory of the University of Bonn (which was, at the time, one of the best funded observatories). It was in Bonn, in 1844, he began studies of variable stars. Separately, since 1826, he was a corresponding member of the St. Petersburg Academy of Sciences. Clearly, Argelander was not only energetic but also a pan-European astronomer.

Argelander was an expert in astrometry and photometry. Along with his students and colleagues he was responsible for the famous star catalog, *Bonner Durchmusterung*<sup>4</sup> (BD). This catalog, consisting of 324,188 stars with magnitude brighter than about nine, had an astrometric precision was 0.1' in declination and 0.1 second in Right Ascension (RA). It was the first comprehensive astrometric and photometric catalog of the Northern sky. The catalog, for its time, was considered to have superior photometry.

The BD catalog laid the standard for future photometric and astrometric star catalogs.<sup>5</sup> The BD catalog was re-issued in 1950! Many BD stars serve as absolute photometric standards for ground- and space-based telescopes (e.g. BD +28° 4211, BD +17° 4708). Separately, Argelander founded the *Astronomische Gesellschaft* (Astronomical Society), which in collaboration with many observatories expanded his work to produce the AG catalogs.<sup>6</sup>

### 2.1. Variable Stars & Argelander

A small note in *Popular Astronomy* by Annie J. Cannon of the Harvard College Observatory (Argelander & Cannon 1912) written in 1911 is an excellent gateway to appreciate the role played by Argelander in the development of variable star astronomy. In that note Cannon refers to a chapter on variable stars, entitled *An appeal to the friends of Astronomy*, written by Argelander for the 1844 edition of Schumacher's *Astronomical Year book*. Argelander exhorts fellow astronomers to undertake observations of variable stars and catalog the photometry. Cannon notes "After reading the article, one feels like reviewing the advances in our knowledge of the variable stars since 1844. Instead of 18 variables, as in Argelander's catalogue, we must provide for more than 4000."

Argelander was interested in more than simply amassing data and identifying variable stars. Even with the meager sample of variable stars at his disposal, Argelander in the afore mentioned chapter speculated about the physical origins of variability, making the following prescient suggestions:

*On account of the low state of our knowledge of these stars, nothing in general can at present be offered nor, by any means, can a*

<sup>4</sup>German for "thorough check"

<sup>5</sup>The BD catalog, given the 51° latitude of Bonn, was deficient in Southern stars,  $\delta < -2^\circ$ . This motivated the *Cor-doba Durchmusterung* (CD) and the *Cape Photographic Durchmusterung* (CPD) catalogs.

<sup>6</sup><https://www.britannica.com/biography/Friedrich-Wilhelm-August-Argelander>

*definite theory be given, which can refer the light changes to any one cause. But happily, hypotheses, even if full of error, fail us not. Omitting those which at first glance are seen to be untenable, they resolve themselves into the following three.*

1. *Revolution of the stars on their axes, their surfaces being of different luminosity on the different sides, whereby they would be brighter if they turned towards us the side of greatest illumination, or conversely, darker if the side of less illumination.*
2. *Revolution on their axes, with strongly compressed figure, and considerable variation of angle of the axis of rotation towards the line of sight. If the axis nearly coincides with the line of sight, then the star turns towards us a very extensive surface, sends us much more light, and therefore shines brighter than if they, because of a very large angle, turn their edge, if I may so call it.*
3. *Huge planets revolving around the stars, in the plane of whose orbits the line of sight nearly falls and which, therefore, by inferior conjunction with the star, cut off a large part of the light formerly coming from it to us, so that it seems less bright.*

*The first of these hypotheses seems to be the most plausible and, in general, to explain observed appearances of several of the stars, if we assume that the constitution of these stars is similar to that of our Sun.*

Argelander's suggested phenomena can be summarized as: (1) rotational modulation of star spots<sup>7</sup>, (2) precession of a rapidly rotating ellipsoidal star, and (3) transits of extrasolar planets. Although none of Argelander's eighteen original variables fit his hypotheses<sup>8</sup>, star spots and transiting extrasolar planets are today commonly observed phenomena. Doubtless, Argelander stood on the shoulders of giants; observations of transits within our solar system date back to at least 1631, when Pierre Gassendi recorded the transit of Mercury, while Immanuel Kant and Pierre-Simon Laplace are often credited for suggesting that planets should also exist around other stars just a generation before Argelander<sup>9</sup>. Nevertheless, Argelander's suggestion that transits of extrasolar planets might be observed is apparently the first such mention in the literature. In contrast to his prescience in astronomy, Argelander appears to have been an unsophisticated (simple?) person in real life.<sup>10</sup>

<sup>7</sup>Here Argelander points to the observations of sunspots from Herschel, Schröter, and Sömmerring, though at that time mountain chains were considered a plausible explanation for the spots.

<sup>8</sup>Most are Mira-type pulsators, Cepheids, or semi-detached eclipsing binaries, which do exhibit ellipsoidal modulation though not due to precession of a single star.

<sup>9</sup>Though this idea may even go back to Democritus.

<sup>10</sup>My colleague Prof. Franciscus Wilhelmus Maria Verbunt, University of Nijmegen, The Netherlands, informed me: "There is a nice anecdote about Argelander. I read this in the book on Greek Cultural History by Burckhardt, in the introduction, where it is

I end by noting that this section, for most part, was contributed by graduate student Trevor David and Prof. Lynne Hillenbrand, both of my own department.

### 3. A SCHEME TO NAME VARIABLE STARS

Thanks to Argelander’s enthusiasm for variable star astronomy research and perhaps more importantly to the precision of the photometry in the BD catalog Argelander realized that the sky could be teeming with variable stars. The old scheme of assigning interesting stars (not merely variable) with romanized Latin alphabets had a capacity for 23 stars.<sup>11</sup> In order to accommodate larger populations of variable stars Argelander designed a new naming scheme. The scheme was reformulated several times as the number of cataloged variable stars increased. The reader is referred to Townley (1915) for a historical account of the evolution of the naming framework.

The naming formulation has three steps and is explained below.

- I The designation of a variable star is a prefix to the name of the constellation in which the variable star is located. The first prefix is R.<sup>12</sup> As additional stars were discovered they were assigned prefixes S, T, U, V, W, X, Y and Z. These 9 entries, per constellation, constitute the first (“I”) series. Examples include “R Coronae Borealis” (exotic carbon rich star), “S Andromedae” (supernova of 1885 in the Andromeda galaxy) and “T Tauri” (the archetypical pre-main sequence star).
- II However, by 1881, the number of variable stars in some constellations already exceeded nine. In 1881 Hartwig proposed adding the next series: RR to RZ, SS to SZ, TT to TZ and finally ZZ. Thus series II has  $9+8+7+6+5+4+3+2+1$  stars or a total of 45 stars. For instance, “RR Lyræ” is an exemplar of a class of pulsating variables. “RSCVn” is a prototype of stars with strong magnetic and related activity powered by binarity. “ZZ Ceti” is famous for being the first white dwarf seismological pulsator.
- III By 1904, the number of variable stars had increased (particularly in the Orion constellation) to such an extent that a new series was added: AA through AZ, BB to BZ and end with QQ to QZ. However, as noted earlier, the letter “J” was excluded. The scheme ends with QZ. With some care it can be shown that the number of prefixes in series III is  $25 + 24 + \dots + 11 + 10$  or 280 stars.

Adding the number of entries from series I, II and III leads to 334 prefixes. We will call such stars as “classic” Argelander stars.

told by Kaiser Wilhelm himself(!): Kaiser Wilhelm was in Bonn and decided to visit the observatory. ‘And, my dear Argelander’, he said, “What is new in the starry skies?”. To which Argelander answered: “Does your majesty already know the old?” ”

<sup>11</sup>The romanized Latin alphabets did not include J, U and W. The alphabet I and J are variants and also not pronounced uniformly in European languages. An astute person may have noticed that the “I” column is excluded in airplane seat names. The reader may wish to ascertain this claim the next they fly on an airplane.

<sup>12</sup>Since the previous alphabets of Romanized Latin were already assigned to special stars, e.g. the well known P Cygni and Q Cygni (Nova Cygni 1867).

IV The advent of photography vastly increased the number of variable stars. When the classic 334 prefixes were used up the scheme switches to the “modern” V (for variable) numbering scheme. This scheme was suggested by several astronomers including Townsley (*ibid*). The scheme starts with “V335” and marches to larger numbers. For example the variable after “QZ Cyg” (an “irregular” variable) is “V335 Cyg” (an M1 variable star). Fortunately, mathematicians inform us that there exists an infinite supply of integer numbers. Thus astronomers can safely expect no future reformulation of the scheme to name variable stars.

It is important to note that the Argelander designation was based on optical variability. As a result some super-famous variable stars of our age have lowly Argelander designation. I quote some examples. “V404 Cyg” is a famous X-ray nova and very much in the news since its burst in 2015. Aquila X-1 (V1333 Aql) is a famous soft X-ray transient<sup>13</sup>. SS 433, an exotic and unique, to date, stellar system<sup>14</sup> is merely V1343 Aql.

#### 3.1. Criticism of the Argelander Scheme

In contrast to the effusive praise of Argelander by Cannon Townsley was critical of Argelander for his choice of naming scheme. There is some merit in Townsley’s dislike of the convoluted and idiosyncratic naming scheme described above. However, from personal experience I know that naming schemes (1) rarely have a foundation in some “rational” framework and (2) invoke strong emotional response from otherwise reasonable people. Rather than distract the reader for the main topic of this article I refer the interested reader §A for my experience and thoughts on naming schemes.

Returning to the topic of this article it is simply the case that we can remember short names. It is equally true that we cannot remember long names, even if constructed on a rational basis. Below, I provide one specific example to illustrate this point.

Some time ago I got interested in compact double degenerates. Even within this group of interesting sources the ROSAT source RX J0806.3+1527 (sometimes shortened to RX J0806+15) is extremely interesting. It has an orbital period of only 5.4 minutes. I had a very hard time remembering the name of the source (other than remembering it is an “8-hour” source). Every time I had to look up the literature on this source I would consult a specific paper (which I could remember since one of the authors was my friend) which referred to the source and then passed the ROSAT source name to SIMBAD to find recent papers on the source.

The ROSAT designation, RX J0806.3+1527, was consistently used since discovery (Burwitz & Reinsch 1999; Israel et al. 1999) until 2007 when Barros et al. (2007) used an Argelander designation, HM Cancri. The reader will undoubtedly agree that it is much easier to HM Cnc than RX J0806.3+1527. Thanks to this short name, practically a nemonic to me, I can now query the As-

<sup>13</sup>An object which, in my youth, I intensively observed searching in vain for the disappearance of the accretion disk and emergence of radio pulses.

<sup>14</sup>This system propelled Bruce Margon to stardom.

trophysical Data System (ADS)<sup>15</sup> using the SIMBAD object filer (with name set to HM Cancri) and find all the papers related to this source. The “upgrade” of RX J0806.3+1527 to HM Cancri has increased my productivity!

Finally, as with many other aspects in our culture, conventions once established, however arcane, are hard to uproot and one may as well as celebrate tradition rather than complain.

I end this section by condensing the history of variable star research post Cannon’s era. After the second World War the International Astronomical Union (IAU) gave the responsibility of maintaining the catalogue of variable stars to two groups in the Soviet Union (Moscow University and the Academy of Sciences). The two teams painstakingly maintained the rapidly growing lists of variable stars (with new entries from non-optical bands, particularly X-ray missions). The task involved obtaining the most accurate positions, cross-matching of names and classification (determining to which class each variable belongs to). The “General Catalogue of Variable Stars” (GCVS)<sup>16</sup> was the primary reference for practitioners of stellar variable research. GCVS is now linked primarily to Varbial Star Index (VSX)<sup>17</sup>. However, like many professional astronomers I use SIMBAD<sup>18</sup> because it has links to catalogues (especially those published as accompaniments of papers) and also papers (via ADS).

#### 4. THE TOP ARGELANDER STARS: A PEDAGOGICAL TOOL

Two years ago I taught a course on High Energy Astrophysics. I started the white dwarf teaching module by describing the gradual identification of a curious star (Sirius B) and the puzzle it posed to astronomers, especially to the then doyen of astronomy, Arthur Eddington. This was then followed by the usual discussion of degeneracy pressure, polytropic solutions and the rich and interesting physics of white dwarf cooling.

Inspired by a popular cultural practice<sup>19</sup> of “top ten in the last ten years” I compiled a list of top ten white dwarfs (ranked by the number of papers attributed to them). I then asked the students to read up on the literature<sup>20</sup> and then have each student write up a report and deliver a presentation on the white dwarf that caught their attention or piqued their interest. I believe that the experiment was a success in that the students were able to proceed to the next level of education, namely develop a sound understanding of the phenomenology of the subject. My colleague and good friend E. Sterl Phinney implemented the same scheme for an undergraduate class but for neutron stars. He too reported success.

In the spirit discussed above I decided that rank ordering the Argelander stars would be of some value. After all the Argelander stars are the brightest variable stars in the optical sky. Thus, any astronomer who wishes

TABLE 1  
ARGELANDER STARS (AND QUASI STARS) RANKED BY PUBLICATIONS

Star	Papers	Citations
CM Tau	4346	188271
CW Leo	1941	88253
HU Vel	1815	77437
HZ Her	1801	76800
BL Lac	1772	169329
BW Tau	1663	112243
GP Vel	1247	53917
T Tau	1183	91083
SS Cyg	1141	40155
TW Hya	1063	55204
U Gem	986	42611
AD Leo	973	39306
ZZ Lep	956	40928
DQ Her	907	35728
VY CMa	892	48668
AM Her	879	40961
HL Tau	851	55187
WZ Sge	845	32091
X Per	835	42657
R Leo	829	32662
RS Oph	824	22712
AB Dor	823	43248
RR Lyr	821	90775
DG Tau	819	54421
GK Per	802	27134
AB Aur	781	44379
YY Gem	764	42479
AU Mic	739	32788
UV Cet	737	33829
R CrB	733	23525
QX Nor	713	34919
CH Cyg	710	16842
EZ CMa	707	34578
EV Lac	701	28666
IL Aqr	697	47955
YZ CMi	689	27718
S Mon	688	52156
W Com	684	44964
R Aqr	683	25963
CF UMa	679	56941
AR Lac	677	29520
AU CVn	667	48741
BR Cir	662	28901
RS CVn	657	50874
II Peg	639	26592
GU Mus	637	32034
R Cas	636	23675
UX Ari	633	31696
RW Aur	621	35480
FU Ori	618	34290

Column 1: star name. Column 2: number of papers attributed to object by SIMBAD. Column 3: number of citations attributed to object by ADS.

to undertake research in variable star astronomy would clearly benefit from being familiar with the popular (top ranked) Argelander stars.

#### 4.1. Data Generation & Results

The sky, following an IAU resolution in 1919, is divided into 88 constellations. As noted in §2.1, in a given constellation, there can be up to maximum of 334 variable stars with Argelander prefixes. Thus the total number of classical Argelander stars over the entire sky is  $88 \times 334 = 29,392$ .

I wrote a short program in MATLAB to inquire<sup>21</sup> SIMBAD the details of each of these 29,392 possibilities. Us-

<sup>15</sup><http://www.adsabs.harvard.edu/>

<sup>16</sup>Currently centered at the Sternberg Astronomical Institute of the Lomonosov Moscow State University of Russia; see <http://www.sai.msu.su/gcvs/gcvs/>

<sup>17</sup><https://www.aavso.org/vsx/>

<sup>18</sup><http://simbad.u-strasbg.fr/simbad/>

<sup>19</sup>[https://en.wikipedia.org/wiki/Casey\\_Kasem](https://en.wikipedia.org/wiki/Casey_Kasem)

<sup>20</sup>The wikipedia is usually a good starting point.

<sup>21</sup>The exercise was carried out on 25 September 2016.

ing standard Unix tools I filtered the outputs returned by SIMBAD and extracted the number of papers (“references” in the lingo of SIMBAD) for each classical Argelander star. With the  $88 \times 334$  matrix now populated I was in position to undertake a number of analyses.

I immediately noticed that not all the 29,392 possibilities had SIMBAD entries. For instance, in Antlia there are no Argelander stars beyond CF Ant. We will revisit this issue in §5. Next, no papers were listed in SIMBAD for 991 stars. Examples include AY And, BF And, DD Ara, PP Vul etc. The SIMBAD websites states clearly “Simbad bibliographic survey began in 1950 for stars (at least bright stars) and in 1983 for all other objects (outside the solar system)”. However, a check of AY And shows two references in the GCVS (Ref#00150=N.Florja, Perem Zvezdy 5, 258, 1940; Ref#03188 = M.Doeppner, MVS N575, 1961). Finally, I noticed an anomaly. In a few constellations, there are gaps in the usage of the prefixes, e.g. in Andromeda all prefixes except VV have been used. This puzzle has now been solved, thanks to efforts on the part of some sincere colleagues (see §B).

Once the data gathering was finished I undertook some analysis. The first exercise was to simply sort the stars in descending order of the number of papers. For the top one hundred stars thus ranked I had ADS queried for the citations to each star. Fifty of the stars ranked by the number of papers along with the corresponding number of citations are listed in Table 1. Next, I re-sorted the list of hundred stars, this time by the number of citations. In Table 2 I list the top fifty stars rank ordered by citations and provide the corresponding number of papers. Next, in Table 3, I list the top three stars in each constellation. Perhaps even for an academic this is an artificial exercise since many modern astronomers do not organize their research by constellations. However, the last column in Table 3 is quite interesting and motivated the next section (§5).

#### 4.2. Some Remarks

At this point a reader could reasonably expect a Reader’s Digest summary for each of these stars. However, I specifically avoid doing so because the point of this write up is in fact to motivate (inspire?) young astronomers to pursue a wide knowledge of astronomical phenomenology. Such breadth can only be earned via hard work (plain old curiosity, attending colloquia without texting, reading papers without intermittently checking email and occasionally thinking). I would like to imagine that a student who is interested in stellar astronomy will be puzzled by the top-ranked Argelander star, CM Tau (hint: it is located in Messier 1). More seriously, I hope that a student who has read this writeup will make up his/her deficiency in education by reading key literature on the stars (the number to be decided by the student) listed in the Tables. Alternatively, a scholar could organize a one-day event – “Argelander Jamboree”. On this day earnest neophytes, after having read up on the literature of say thirty stars, meet and hear experts make short presentations on each star.

Despite stating, in the previous paragraph, my desire for reticence I am compelled to make two remarks. The stars listed in Table 1 encompass an astonishing range of astronomical phenomena. The list includes the funda-

TABLE 2  
ARGELANDER STARS (AND QUASI STARS) RANKED BY CITATIONS

Star	Citations	Papers
CM Tau	188271	4346
BL Lac	169329	1772
BW Tau	112243	1663
T Tau	91083	1183
RR Lyr	90775	821
CW Leo	88253	1941
HU Vel	77437	1815
HZ Her	76800	1801
CF UMa	56941	679
TW Hya	55204	1063
HL Tau	55187	851
DG Tau	54421	819
GP Vel	53917	1247
S Mon	52156	688
RS CVn	50874	657
AU CVn	48741	667
VY CMa	48668	892
IL Aqr	47955	697
GG Tau	46093	540
W Com	44964	684
AB Aur	44379	781
AB Dor	43248	823
GM Aur	42856	459
X Per	42657	835
U Gem	42611	986
YY Gem	42479	764
AP Lib	42050	494
AM Her	40961	879
BP Tau	40938	536
ZZ Lep	40928	956
SS Cyg	40155	1141
AE Aur	39624	466
CN Leo	39466	551
RY Tau	39422	580
AD Leo	39306	973
AA Tau	37966	489
DQ Her	35728	907
RW Aur	35480	621
SU Aur	35346	486
QX Nor	34919	713
EZ CMa	34578	707
FU Ori	34290	618
UV Cet	33829	737
AU Mic	32788	739
R Leo	32662	829
WZ Sge	32091	845
GU Mus	32034	637
UX Ari	31696	633
W UMa	30290	602
AR Lac	29520	677

Column 1: star name. Column 2: number of citations attributed to object by ADS. Column 3: number of papers attributed to object attributed by SIMBAD.

mental stellar families (nuclear burning, degenerates and collapsed stars). Next, some stars in Table 1 are extragalactic (AGN, quasar, blazar). Finally the list spans the full life cycle of stars, from nurseries to death (and afterlife).

#### 5. ARGELANDER DESIGNATION AS A PRIZE

In Table 3 I list the number of Argelander designations that have not been assigned (“NA”). Bearing in mind of the improvement in productivity when RX J0806.3+1527 was given an Argelander name (§3.1) and noting the large vacancies in Table 3 an idea emerged in my mind – use the remaining Argelander names for particularly noteworthy sources.

Next, on-going industrial synoptic surveys will un-

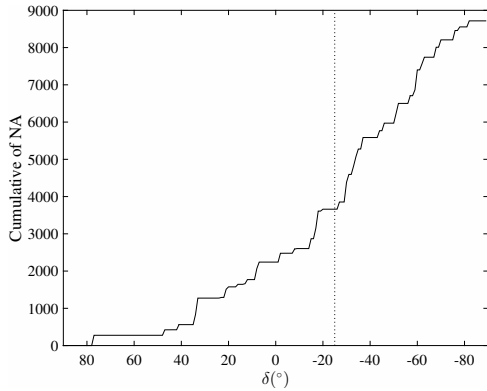


FIG. 1.— The cumulative number of “not assigned” (NA) classic Argelander stars as a function of declination. The vertical line  $\delta = -25^\circ$ . Data drawn from Table 3.

doubtedly discover subclasses and new classes of interesting transients. I specifically suggest that the IAU in cooperation with GCVS hold a contest every year and dole out the remaining classic Argelander designations to to exotic and new subclasses of transients. The contest should be advertised widely and all on-going time domain surveys should be encouraged to send in nominations for spectacular variables uncovered by their surveys. It is well known that prizes catalyze activity (cf. the XPRIZE). Thus the contests will certainly catalyze

research in variable star astronomy and likely have a halo effect and bring attention of the larger astronomical community to stellar astronomy. Perhaps a patron of astronomy could be persuaded to underwrite the annual gala prize ceremony to be held either at Moscow or Bonn!

Observers using Northern facilities may worry that most of the Argelander slots in the Northern constellations have been used up. Fortunately, as can be seen from Figure 1 there still remain significant number of slots that Northern facilities can strive for.

This report grew out of a during-the-dinner conversation at a recently concluded PTF-Theory Network meeting. I am grateful to Edwin Henneken, IT specialist, ADS, Center for Astrophysics, Harvard University for helping me understand the language of machine queries to ADS; Sterl Phinney for excellent comments; Howard Bond for catching a number of embarrassingly elementary errors and typographical mistakes; Lynne Hillenbrand for bringing to my attention the important paper by Townsely; Trevor David for his contribution to §2.1; Anna Ho for a most careful reading; and N. Samus for educating me about GCVS and VSX. I would like to thank Bruce Margon and Virginia Trimble for their enthusiasm for this sort of work and Chris Bochanek for feedback of an earlier version. Finally, this informal article would not have been possible without the selfless work of librarians, software engineers and astronomers at ADS and SIMBAD.

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## APPENDIX

### A. NAMING SCHEMES

The first experience I had with naming scheme was on the eve of the commissioning of the Palomar Transient Factory (Law et al. 2009). This was a project aimed at a systematic study of the variable and transient optical sky. The eponymous project was expected to churn out a large number of transients. The question arose on the naming scheme for PTF discovered transients. The ensuing discussion was intense and emotional. In the end the collaboration voted to continue the existing scheme for supernovae in which the A–Z, AA–AZ, BB–BZ, ..., AAA–AAZ serve as postfixes to the year of discovery (e.g. SN 1987A) except we dropped the number of centuries, e.g. PTF 09uj and iPTF 14atg.

My next experience arose in the field of gamma-ray bursts (GRBs). The traditional naming scheme is GRB *yyymmdd* where *yy* is the last two digits of the year, *mm* is the month number (January=1, December=12) and *dd* is the UT day number (1, 2, .. 31). Astronomers working in this field immediately recognize, for example, GRB 970228, GRB 970508, GRB 98024, GRB 990123 and GRB 030329. This scheme served well for quite some time until the rate of detection of GRBs increased to the point where more than one GRB was discovered in a single UT day. At this point, there were two options: use fractional day to distinguish one GRB from another that happened on the same day or adopt the supernova convention. I voted for the former (and felt strongly about it). In the end the latter convention was adopted.

In retrospect I think the decision that was adopted was the better choice. To start with the GRB rate is probably no more than 1,000 per year (REF) or  $\lambda = 2.73 \text{ day}^{-1}$ . Thus the chance of detecting  $> [2, 4, 6, 8, 10]$  GRBs per day by an *all-sky* detector is  $[0.76, 0.29, 0.06, 0.007, 0.0056]$ , respectively. For a detector which covers say a fourth of the sky but at sufficient sensitivity to probe the faint end (a more reasonable prospect) the probabilities for  $> [2, 3, 4, 5]$  are  $[0.15, 0.03, 0.005, 0.0007]$ , respectively. Thus the adopted scheme has sufficient granularity to accommodate days when the celestial sky is particularly fecund with GRBs. Next, the designation A, B, C is easier to remember, compared to, say, GRB 190304.15.

As noted and expanded below short names are preferred over long names. However, if the sample size is very large then it makes little sense to use short names. For this reason catalogs with large number of entries (e.g. ROSAT catalog, the Sloan Digital Sky Survey) have adopted a logically constructed name (as in RX J0806.3+1527).

My above experiences made me investigate naming schemes in other areas of human activity. I quote two examples for which considerable thought was given to the naming schemes, though with entirely different goals in mind.

#### A1. HURRICANES.

In some regions of the world hurricanes have a major impact. Consequently the National Hurricane center has given considerable thought on how hurricanes are named<sup>22</sup>: “Experience shows that the use of short, distinctive given names in written as well as spoken communications is quicker and less subject to error than the older more cumbersome latitude-longitude identification methods.”

The Center maintains six lists of 21 names (which featured only names of women until 1979) and these are recycled every six years. When the number of hurricanes exceeds 21 the greek alphabets are invoked ( $\alpha, \beta, \dots$ ). Hopefully, global warming will not result in the usage of Sanskrit, Hebrew and Cyrillic alphabets. Fortunately, given the correlation length of hurricanes it is unlikely that we will have to face this particular concern.

#### A2. MOODY’S RATING SCHEME

In the financial world, Moody’s is a well known financial rating company.<sup>23</sup> The adjective “well known” is simply a statement about the perceived standing of Moody’s. The fortunes of companies and even countries are tied to the Moody’s rating. If you come down a notch in the Moody’s rating then you could be losing say a few billion to a few trillion dollars of perceived wealth. In fact, some of my colleagues who planned to retire around 2008 had to rapidly revise their future plans owing to the considerable losses in the market, aided in part by (false) high ratings given to funds based on mortgage funds.

Given the burden carried by Moody’s one would expect great financial and mathematical sophistication on their part. However, one glance at their rating terminology should keep you wondering whether the next global financial meltdown is round the corner.

1. **A series: Aaa, Aa1, Aa2, Aa3, A1, A2, A3.** These ratings include the preferred stocks and bonds ranging from “gilt edged” to favorable investments.
2. **Baa1, Baa2, Baa3, Ba1, Ba2, Ba3 B1, B2, B3.** These range from adequate investments to investments with some risks.
3. **Caa1, Cass2, Caa3, Ca, C.** Poor prospects.

It is one thing for astronomers to revel in DQ Hercules and PTF 11kly but an entirely different thing for the world to trust Moody’s ratings which appear to be based on an arcane and obscure naming scheme.

#### B. VV ANDROMEDAE

Upon my drawing attention to the curious problem of VV And, both Sterl Phinney, California Institute of Technology and Howard Bond, Space Telescope Science Institute, investigated and independently came to the same conclusion. Here is paraphrased report from Phinney: “I believe I have solved the mystery of VV Andromedae. A Google search shows that VV Andromedae was reported in *Popular Astronomy*.<sup>25</sup> VV And is star 110 in the list of newly assigned designations, giving position as 23h 33m 45s +34 59 (max mag 9.7, min mag 10.2).

However a later paper (Pavel 1928) explains why it doesn’t have further data: In this note, to the limits of my German, Pavel (*ibid*) states that someone named Pračka claimed to have discovered an Algol star with a period of 0.959 days, varying between mag 9.7 and 10.2, near ST Andromedae. However Pavel, in 29 exposures with the 40-cm astrograph, was unable to find any variable star down to 13–14 magnitude at or near that position other than ST Andromedae, and concludes that if Pračka observed a variable star at all, it was certainly not in the vicinity of ST Andromedae.

So it seems VV Andromedae was given a name based on Pracka’s data, but was later determined by Pavel to have been some kind of a mistake on Pračka’s part. It is not clear why SIMBAD did not find either of the above (under -either- VV And or ST And!), while Google did.”

I consulted Dr. Nikolai N. Samus who is the head of the group of General Catalogue of Variable Stars, Sternberg Astronomical Institute of Russia. He remarked “The problem of VV And is not unique. There were cases of repeated discoveries of the same stars, giving variable-star names to asteroids, even to images on photographic plates exposed twice.” In fact, GCVS maintains a list of such errant entries.

<sup>22</sup><http://www.nhc.noaa.gov/aboutnames.shtml>

<sup>24</sup>See <http://www.moody.com>.

<sup>25</sup>Popular Astronomy, Volume 21 (1913). Linked to “recently discovered variable stars” from *Astronomische Nachrichten* #4669.

TABLE 3  
TOP THREE ARGELANDER STARS BY CONSTELLATION

Star	Star	Star	Papers	NA
Z And	GX And	RT And	478, 377, 347	1
AG Ant	BW Ant	U Ant	263, 141, 123	227
MY Aps	S Aps	NN Aps	109, 107, 79	-
IL Aqr	R Aqr	AE Aqr	697, 683, 554	13
R Aql	FF Aql	RR Aql	518, 317, 253	-
S Ara	AE Ara	R Ara	84, 65, 63	-
UX Ari	TT Ari	X Ari	633, 398, 236	219
AB Aur	RW Aur	SU Aur	781, 621, 486	-
RX Boo	HN Boo	HP Boo	389, 218, 217	-
RR Cae	R Cae	X Cae	106, 79, 65	309
Z Cam	AX Cam	SV Cam	452, 353, 337	-
RS Cnc	R Cnc	X Cnc	279, 266, 244	64
AU CVn	RS CVn	Y CVn	667, 657, 441	137
VY CMa	EZ CMa	Z CMa	892, 707, 480	-
YZ CMi	CY CMi	BG CMi	689, 284, 189	172
BY Cap	BB Cap	RT Cap	158, 128, 103	212
AG Car	OY Car	HR Car	552, 525, 271	-
R Cas	RZ Cas	SU Cas	636, 416, 389	-
V Cen	BV Cen	XX Cen	217, 162, 152	-
VW Cep	U Cep	VV Cep	499, 447, 411	-
UV Cet	BE Cet	FS Cet	737, 404, 331	112
Z Cha	CU Cha	DX Cha	564, 355, 276	97
BR Cir	BW Cir	AX Cir	662, 151, 108	166
TV Col	TX Col	T Col	278, 126, 85	251
W Com	LS Com	FK Com	684, 392, 327	18
R CrA	TY CrA	S CrA	409, 249, 237	-
R CrB	T CrB	TZ CrB	733, 589, 450	230
TY Crv	R Crv	W Crv	110, 76, 69	281
TV Crt	R Crt	SV Crt	297, 180, 175	265
BP Cru	BZ Cru	S Cru	545, 235, 157	158
SS Cyg	CH Cyg	X Cyg	1141, 710, 414	1
HR Del	NT Del	EU Del	437, 318, 151	17
AB Dor	S Dor	R Dor	823, 307, 213	249
BY Dra	AG Dra	CM Dra	565, 451, 360	-
S Equ	SY Equ	U Equ	116, 78, 54	298
EP Eri	EF Eri	DO Eri	418, 394, 345	51
UZ For	R For	TZ For	223, 164, 89	255
U Gem	YY Gem	OU Gem	986, 764, 207	1
BP Gru	RS Gru	S Gru	97, 85, 66	183
HZ Her	DQ Her	AM Her	1801, 907, 879	-
R Hor	TW Hor	WW Hor	156, 116, 70	270
TW Hya	EX Hya	W Hya	1063, 606, 524	-
VW Hyi	WX Hyi	BL Hyi	583, 186, 184	198
CI Ind	T Ind	CD Ind	112, 75, 70	207
BL Lac	EV Lac	AR Lac	1772, 701, 677	-
CW Leo	AD Leo	R Leo	1941, 973, 829	68
RW LMi	SV LMi	R LMi	343, 309, 297	270
ZZ Lep	R Lep	SS Lep	956, 285, 188	248
AP Lib	HO Lib	KX Lib	494, 424, 403	-
IL Lup	RU Lup	EX Lup	360, 316, 206	-
EI Lyn	RR Lyn	AE Lyn	181, 178, 157	147
RR Lyr	R Lyr	MV Lyr	821, 287, 225	-
TU Men	YY Men	TZ Men	140, 115, 107	251
AU Mic	AT Mic	AX Mic	739, 296, 179	203
S Mon	R Mon	T Mon	688, 474, 414	-
GU Mus	KR Mus	KN Mus	637, 463, 275	-
QX Nor	QV Nor	S Nor	713, 338, 312	-
CL Oct	DR Oct	UV Oct	121, 95, 82	162
RS Oph	U Oph	Y Oph	824, 343, 325	1
FU Ori	U Ori	BM Ori	618, 456, 306	-
AR Pav	S Pav	Y Pav	137, 73, 70	-
II Peg	AG Peg	EQ Peg	639, 466, 390	-
X Per	GK Per	MX Per	835, 802, 345	-
SX Phe	AE Phe	AI Phe	291, 103, 97	203
RR Pic	VZ Pic	AK Pic	289, 230, 108	260
TX Psc	ZZ Psc	WX Psc	415, 384, 370	110
TW PsA	HU PsA	TY PsA	234, 104, 90	275
QX Pup	VV Pup	RS Pup	463, 373, 284	-
T Pyx	TY Pyx	VW Pyx	334, 239, 104	192
R Ret	S Ret	TT Ret	58, 58, 45	286
WZ Sge	QX Sge	QV Sge	845, 605, 516	-
VX Sgr	U Sgr	RY Sgr	510, 404, 346	1
U Sco	AK Sco	RV Sco	413, 183, 161	-
R Scl	BB Scl	VY Scl	253, 130, 128	211
R Sct	RY Sct	EV Sct	276, 259, 210	-



TABLE 3 — Continued

Star	Star	Star	Papers	NA
NP Ser	MQ Ser	MM Ser	558, 291, 275	-
AY Sex	SW Sex	RW Sex	170, 168, 163	237
CM Tau	BW Tau	T Tau	4346, 1663, 1183	-
RR Tel	PZ Tel	QS Tel	496, 199, 108	-
RW Tri	X Tri	R Tri	272, 205, 175	212
KZ TrA	MM TrA	R TrA	480, 196, 152	-
CF Tuc	W Tuc	BS Tuc	205, 88, 79	174
CF UMa	KV UMa	W UMa	679, 615, 602	-
RR UMi	S UMi	U UMi	154, 117, 108	276
HU Vel	GP Vel	IM Vel	1815, 1247, 238	-
GW Vir	CU Vir	EQ Vir	437, 310, 296	-
UY Vol	R Vol	AI Vol	498, 70, 36	268
QZ Vul	SV Vul	ER Vul	380, 372, 323	-

Columns (1-3): Star names. Columns (4): The corresponding numbers of papers which refer to the stars. Column (5): number of classic Argelander designations that have not yet been assigned to variable stars. A “-” indicates that all Argelander designations have been used up.