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THE RELUCTANT PARSEC AND THE OVERLOOKED LIGHT-YEAR

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The appropriate measure with which to express the distances to the stars (and the greater Universe) is one of those units that took many years to be unanimously agreed upon. Here we trace the origin and seemingly slow acceptance of the distance unit represented by the parsec.

No less august a body than the International Astronomical Union (IAU) declares the parsec (pc) to be the preferred non-SI unit of measure when describing interstellar distances[1]. The light-year (ly) measure of distance, however, is given rather short shrift, "The unit known as the light-year is appropriate to popular expositions on astronomy and is sometimes used in scientific papers as an indicator of distance"[1]. Such comments seem rather divisive, although it appears that the light-year has long been viewed in a somewhat second-class manner. We find, for example, in Volume 2 of the widely read textbook *Astronomy*, by Russell, Dugan & Stewart (published in 1938) the following statements concerning the unit in which stellar distances are measured, "the one used in scientific work is the parsec", to which is added the qualifier that the light-year is used "in more popular discussions".

Even a cursory reading of the astronomical literature reveals that the unit of the light-year existed long before that of the parsec. Sir John Herschel, for example, in his highly read *Outlines of Astronomy*, first published in 1870, notes with respect to stellar distances that, "the only mode we have of conceiving such intervals at all is by the time which it would require light to traverse them". In addition, Herschel notes that, "a parallactic unit of distance from our system of 20 billions of miles, and with a 3¼ years journey of light, may save … ourselves the necessity of covering our pages with such enormous numbers, when speaking of stars whose parallax has actually been ascertained with some approach of

certainty". Such sentiments culminated in Charles Young's definition, given in his *A Text Book of General Astronomy*, published in 1899, "A star with a parallax of 1 [arc second] is at a distance of 3·26 *light years*".

No star has a parallax greater than $P = 0{\cdot}7723$ arc seconds (which corresponds to that deduced for Proxima Centauri[2]), so, one might ask, what is so special about a distance unit corresponding to an angle of parallax of 1 second of arc. Of the stars in the solar neighbourhood only four[2] (two of which form the binary of α Centauri — we take the trinary membership of Proxima Centauri to be presently unproven) have a parallax that might reasonably be expressed as being of order unity, while in excess of 100 stars have parallaxes of order one tenth of an arc second. So, why not introduce a unit of distance based upon a parallax angle of 0·1 arc seconds? Well, of course, such things are really arbitrary. That being said, in 1902 Jacobus Kapteyn[3–5] used a unit distance equivalent to a parallax of 0·1 arc seconds in his definition of absolute magnitude (this distance unit is still used to this very day).

The adoption of 1 second of arc as the angular unit of measure with respect to stellar parallax observations appears to be based upon a statement made by James Bradley (1693–1762). Bradley is predominantly remembered for his highly accurate observations of the star γ Draconis and the first measurement of stellar aberration (amounting to 40 arc seconds) and nutation (amounting to 18 arc seconds). In his 1727 letter to Edmund Halley (later published in the *Philosophical Transactions of the Royal Society*[6]) Bradley comments, "it must be granted that the parallax of the fixed stars is much smaller than hath been hitherto supposed … I am of the opinion, that if it were 1 [arc second] I should have perceived it". Again, we find in Herschel's 1870 *Outlines* the comment, "hitherto we have spoken of a parallax of 1 [arc second] as a mere limit below which that of any star yet examined assuredly, or at least very probably falls, and it is not without a certain convenience to regard this amount of parallax as a sort of unit of reference". Herschel's comments are placed into some form of perspective when it is realized that he was writing thirty years after the first set of publications announcing the successful measurement of stellar parallaxes by Friedrich Bessel, Thomas Henderson, and Friedrich Struve[7].

The impetus to fix a unit of distance based upon stellar parallax measurements, but not cast in terms of the light-year, resulted from a growing interest in the analysis of stellar proper motions. Kapteyn pioneered the study of star streaming in the late 1890s, and the statistical analysis of stellar proper motions became an increasingly important topic during the first several decades of the 20th Century. In England, over the time interval of interest, the research field concerned with large-scale stellar motions was dominated by Frank Dyson, Herbert Hall Turner, and Arthur Stanley Eddington.

Astronomer Royal Dyson can be credited with first use of the term parsec in an actual scientific article, the paper seeing print in the *Monthly Notices* for 1913 March 14. A footnote within that paper[8] reads, "There is need for a name for this unit of distance [corresponding to a parallax of one second of arc]. Mr. Charlier has suggested *Siriometer*, but if the violence to the Greek language can be overlooked, the word *Astron* might be adopted. Professor Turner suggests *Parsec*, which may be taken as an abbreviated form of a distance corresponding to a parallax of one second". In the May 9th issue of the *Monthly Notices*, Carl Charlier comments in another footnote[9], "I have used the term *Siriometer* for denoting a distance equal to a million times the diameter of the Sun from the Earth. I find from *The Observatory* that the Astronomer Royal has objected to this term that it 'suggests

a machine for measuring'. I agree with him herein. But having used this term now nearly two years in my lectures [*i.e.*, he coined the term *circa* 1911], I have found that this suggestion, which I had naturally made myself, is easily obliterated" — in other words, Charlier is not moved by the Astronomer Royal's objections. The word *siriometer* takes its heritage from the star gauges of William Herschel. Indeed, writing in the *Philosophical Transactions of the Royal Society* for 1785, Herschel explains, "the stars of the first magnitude being in all probability the nearest, will furnish us with a step to begin our scale; setting off, therefore, with a distance of Sirius or Arcturus, for instance as unity..."[10]. We now know that Herschel's magnitude argument concerning distance is incorrect, but using modern-day values, Sirius has a measured parallax of 379·2 mas, and it is accordingly $5{\cdot}4 \times 10^5$ AU distant. In terms of Charlier's units, the distance to Sirius is 0·54 *siriometers*.

Charlier makes the comment in his 1913 paper that Dyson disliked the word *siriometer*, and the question arises as to where he acquired his information. The answer to this lies in the 1913 April issue of *The Observatory* in which the discussion at the Royal Astronomical Society meeting for March 14th is transcribed[11]. At that meeting both Dyson and Eddington presented review papers on the topic of the statistical analysis of proper motions and star streaming. It is in the discussion following Dyson's paper that we learn from Turner that "I had the privilege of seeing it in MS., suggesting a short name for that unit which represents the distance of a star with parallax one second of arc. I have myself found that unit much more convenient than the light year, which is about one-third of it; but it has at present a very long name. The Astronomer Royal has made the suggestion that it shall be called *Astron*, and I hope that that or some similar suggestion be adopted. It will not be the least valuable part of the paper if he succeeds in giving us a short name instead of that long one. But I urge that he consider carefully which name he puts forward. The only disadvantage about *Astron* is that it might look like *Astronomical unit*. *Macron* might find favour. The opportunity is an important one, for it might be difficult to go back on a word when he once adopts it". The response by Dyson to Turner's comments run as follows: "Referring to the name I put in the footnote, one feels that the use of light-years has been introduced for lecture purposes, not for operations when your lecture is working with the stars. The name of *Siriometer* has been suggested in this connection. I do not like that; it suggests a machine for measuring. I thought of *macron*, and then thought that the meaning of *micron* might lead to confusion; so I suggested *Astron*. I do not know whether it appeals to people or not". There is no further discussion recorded, however, as to whether other people at the meeting did, or did not like the various terms being proffered. Eddington soon adopted the word parsec and its definition as given by Turner, and we find him expressing the distances to globular clusters with this unit in a paper he presented at the 1913 November 14 meeting of the RAS[12].

Within the discussion between Dyson and Turner we once again find the light-year being dismissed as a serious contender for the unit of distance measure, and discover Dyson's preference for the term *astron*. The March 14th RAS discussion is clearly the source from which Charlier gained his information about Dyson's dislike for the *siriometer*, but true to his comments made in 1913 May, he saw no need to stop using his term. Indeed, we find Charlier continuing to use the *siriometer* in the papers that he published through to 1917. We note specifically that the conversion of 1 *siriometer* ≡ 5 parsecs is given in a review paper published by Charlier in the 1917 November issue of *The Observatory*[13].

An additional unit of distance based upon a parallax measurement was defined by Hugo Seeliger, Director of the Munich Observatory in 1909. His unit of distance, the *siriusweite* (literally the *Sirius distance*) was defined according to one *siriusweite* being the distance at which the parallax is 0·2 seconds of arc[14]. Hence we have 1 *siriusweite* = 5 parsecs = 1 *siriometer* = 16·3 light-years.

On 1914 April 24, Dyson delivered the Friday Evening Discourse at the Royal Institution, and chose to talk on the subject of star streaming. Interestingly, rather than push for his "preferred" unit of the *astron* he adopted the parsec with the explanation that it is "a composite word suggested to me by Prof. Turner. With this unit, a distance of 100 in the diagram [his figure 4] denotes 20 million times the distance of the sun from the earth"[15]. We next find Dyson discussing stellar distances and parallax measurements[16] in the Halley Lecture at Oxford University on 1915 May 20. Within this talk, however, he makes no mention of the *astron* or the parsec, but expresses distances in terms of the Astronomical Unit. Interestingly, Dyson makes reference to Bradley's historical statement[8] that if γ Draconis had moved by so much as one second of arc he would have detected it — here was a golden opportunity, deliberately ignored, presumably, to introduce the parsec or *astron*. Dyson also used the Astronomical Unit to describe stellar distances in a 1917 review paper directly relating to the study of stellar distances[17]. Indeed, we find no specific reference to the unit of the parsec or *astron* in any of Dyson's papers published after 1914 — his death being recorded in 1939. Likewise, Turner appears to have felt no strong attachment to the term he coined. Indeed, in his 1919 January 31 talk at the Royal Institution[18], on 'Giant Suns', we find Turner expressing stellar distances in units of the light-year — Turner died in 1930, spending the majority of his time after *circa* 1920 working on seismography and the study of earthquakes.

Across the Atlantic, far from the meeting rooms of the Royal Astronomical Society, American astronomers predominantly used the light-year to express stellar distances. In a 1917 publication[19], for example, we find Harlow Shapley describing the distance to the globular cluster M 3 in light years, but its diameter in Astronomical Units. Just a year later, however, Shapley uses both the light-year and the parsec to express distances to globular clusters[20]. He feels, however, that it is necessary to add a footnote to explain that a parsec is a distance corresponding to a parallax of one second of arc — no other historical reference to the unit being provided. Edwin Hubble, in contrast, doesn't appear to have used the parsec prior to *circa* 1922. In his paper *A General Study of Diffuse Galactic Nebulae*[21], Hubble explains rather loosely, and again with the aid of a footnote, that a distance of 300 light-years is of order 100 parsecs (the actual conversion is about 92 pc). By 1925 Hubble had switched to using the parsec, but still felt that it was necessary to add a light-year conversion. Writing, for example, in *The Observatory* on *Cepheids in Spiral Nebulae*[22], he includes a footnote to indicate that 285 000 parsecs is equivalent to a distance of 930 000 light-years.

During the first several decades of the 20th Century, Kapteyn was one of Europe's leading theorists on the statistical study of stellar proper motions and star streaming. Indeed, in 1902 Kapteyn introduced the term absolute magnitude[3–5], and based this measure on a distance corresponding to a parallax of 0·1 seconds of arc. He continued to use this '10 parsec equivalent' unit measure until 1920. We know that Kapteyn switched preferential units in this year since he writes[23] in the *Astrophysical Journal* for 1920 July, "different units of distance have been used by different astronomers. That most widely used at present is the parsec. For the sake of uniformity we have resolved henceforth not only to use this unit

but also to use the name, which is very convenient (though very ugly)". Remarkably, Kapteyn also proposes to re-define the absolute magnitude in terms of a standard distance of 1 pc rather than 10 pc. This latter suggestion (understandably) appears to have had no popular support. While Kapteyn suggests that the parsec is being widely used, there is very little evidence for this within the works published by the leading exponents in the field of stellar dynamics.

The first official sanctioning of the parsec as the preferred unit of measure for stellar distances was announced, appropriately enough, at the first General Assembly of the International Astronomical Union, held in Rome in early May of 1922. We are not privy to the details of the discussions held[24], but it is known that Dyson, Turner, and Shapley were at the meeting. The IAU resolution recommended that distances should be cast in terms of the parsec, but allowed for the continuation of Kapteyn's 10-parsec unit of distance when determining absolute magnitude. The decision by the IAU was not universally welcomed or acted upon. Indeed, in 1925, three years after the IAU meeting in Rome, Karl Malmquist described the new recommendation as being, "wholly unnecessary and moreover, inconvenient, and this is another reason not to consider this decision [by the IAU] as the definite one"[25]. In his article Malmquist argues that, "in reality there are only two units to choose between — namely the *siriometer* and the *parsec*". Interestingly, Malmquist makes no mention of the light-year as a possible unit of distance measure. It is a little surprising, perhaps, to find the *siriometer* as the main apparent rival to the parsec, but Malmquist argues, "as a length is most naturally defined through another length it would be most suitable to define the new unit as equal to 10^6 planetary units [*i.e.*, a million AU]"[25]. It is the distance-defining-a-distance feature of the *siriometer* (rather than a distance being defined *via* an angle, as in the case of the parsec) that Malmquist most likes, and he chastises Dyson for his earlier objections to the *siriometer*'s use[8] since it is "*not the name, but the definition that must be final*" [Malmquist's italics]. Malmquist ends his paper with a plea for further discussion, presumably within the open astronomical literature, but within the columns of *The Observatory*, at least, there is no further debate, and the unit of the *siriometer* (along with the *siriusweite*, *astron*, and *macron*) slipped quietly into the storeroom of astronomical history.

Ultimately, perhaps it is simply usage that enables a specific word to become the accepted norm: the more it is seen in print, the more it is used. Historically speaking, one can understand the reasons why the light-year might not have been favoured as the unit for measuring stellar distances. Firstly, the speed of light was, prior to recent times, subject to frequent experimental revision, and second, what year interval is to be used? — there are at least six to choose from[2]. While the light-year is a derived unit (based upon a measure of light speed and a specified time interval), the parsec is based upon an actual astronomical measure, the parallax, and the fundamental (that is directly measurable) Astronomical Unit, which certainly gives the parsec an edge over the light-year with respect to being a fundamental astronomical unit of measure. This all being said, historical precedent certainly favours the light-year, since we find in the letter from Bessel to Sir John Herschel, written from Konigsberg on 1838 October 23, describing the successful measurement of the parallax to 61 Cygni the following comment, "the distance of the star 61 Cygni from the Sun [is] 657700 mean distances of the earth from the Sun: light employs 10·3 years to traverse this distance"[26]. From the very first, therefore, the light-year has been employed as one of the measures of stellar distance.

There is a tendency in present-day popular-astronomy writing to make statements about the exact instance when a specific event happened. There are many

problems in adopting this approach to writing history, not least from the fact that science and scientists rarely ever work in an isolated, step-function-like fashion. In the case of the word *parsec* and its adoption as a unit of distance measure, there is no specific instance when it was first universally adopted. Certainly, the word first appeared in print in the March issue of *The Observatory* for 1913, but the term and its definition were not officially sanctioned or generally accepted for at least a further ten to fifteen years, and even then some astronomers simply chose to ignore the IAU definition. Likewise the originator of the word *parsec*, Turner, felt no great compunction to promote its adoption. Indeed, Turner didn't even use the word in his own publications. Likewise, Dyson, who first used the parsec unit in a scientific publication professed that he preferred another name — the *astron*, although once again he failed to use this term in any of his actual publications. The word *parsec* appears to have become nearly universally adopted within main-stream astronomical literature by *circa* 1930. Interestingly (perhaps inextricably), the divide whereby the light-year is adopted as the measure of stellar distance in 'popular' literature still lingers to this very day.

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