The Sidereal Center*

Considerations Tending to Indicate That Canopus Occupies This Position

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THE Helium or B type, the so-called "Orion," stars are those which recent studies concur in placing at great distances from our system, while their brighter members, too, appear, according to Prof. Campbell (*Lick Obs. Bul.*, 195) to lie as fully remote as do their fainter. This peculiarity, together with the rapid decrease, with diminishing magnitude, in the numbers of this class, argues a great average luminosity, coupled with great distance. Further, these stars are found by Profs. Campbell and Boss (*Lick Obs. Bul.*, 195; *Astron. Journ.*, 620, 635-6) to be virtually free from that preferential motion, or star-streaming, which seems to be characteristic of the other spectral classes. These stars thus peculiarly invite treatment as of those most truly representing the visible universe, of which they may not unfairly be regarded as the framework.

In a recent study by the writer (*Mon. Not. R.A.S.*, May, 1914) of the distribution of the several spectral classes—particularly of type B—with reference to the galaxy, the relative preponderances of these stars (Oe5 to B5) in galactic latitude and longitude respectively places the apparent center of their system on the 230 degree galactic meridian—or of "galongitude," reckoned from the intersection of the galactic and celestial equators in Aquila—and between 20 degrees and 30 degrees south in galactic latitude, or of "galatitude." This, in other words, is the direction from which our solar system appears to lie eccentric within the universe defined by the helium stars. The relatively small number (706) of these stars involved (as given in *Harvard Annals*, Vol. 56, pt. 2) is largely compensated by the generally remote and therefore comprehensive distribution just referred to of this type's brighter members, of which this number is largely composed, and includes them all. The sidereal center probably lies, therefore, on the line just named, or between α 6 hours 0 minutes, δ -55 degrees, and α 6 hours 55 minutes, δ -52 degrees. The same studies with the work of Kapteyn, Boss, and Campbell further indicate the distance of this center as being in the neighborhood of 400 light-years, or 140 "secpars," to adopt under this name the more useful unit of stellar distance corresponding to 1.0 second parallax.¹

The association of a particular star with the sidereal center would, if established, give coherence to the several lines of study now proceeding in stellar motion and distribution, and enable us to realize more clearly their true significance. Accepting the position line defined, it will be found to lie nearly symmetrically across the splendid star Canopus, and the only star within the prescribed limits of which we have any definite knowledge. This star appears to be the greatest sun of which we know anything, and is referred to by Prof. See as an example of his hypothesis of condensed star-clusters. In view of this remarkable coincidence the further study of this star assumes a peculiar interest as pertinent to the question of a sidereal center.

First, as to the distance of Canopus: the late Sir David Gill found its parallax and proper motion to be insensible with regard to four 8th-magnitude comparison stars, of which the average absolute parallax, according to Prof. Kapteyn's table (*Gron. Pub.*, No. 24) is 0.0065 seconds. Considering, however, the uncertain application of averages to individuals, further evidence is desirable in support or otherwise of this value, and is best afforded by a study of the cross and radial motions in relation to the solar motion in space. The speed of solar motion and its apex appears to vary slightly, according to the spectral class of the stars to which they are referred. Here, as for their general fixity, the helium stars are the chosen reference for the solar position, so in consistence to them also should the direction and speed of solar motion be referred. Prof. Boss (*Astron. Journ.*, 623-4) has derived the solar apex relative to 490 of these stars alone, the mean of his two solutions placing the apex in α 18 hours 17 minutes, δ + 35 degrees 0.4 (as-

suming a solar velocity of 20 kilometers a second); while Kapteyn, Campbell, and Stroobant (assuming apices derived from all spectral types, and but little removed from Boss) derive from the B stars solar velocities ranging from 20.7 to 23.3 kilometers per second; the mean of these (weighted according to the number of stars used) is 21.5 kilometers per second, and is here adopted with Boss Apex, of which the antapex lies therefore in α 6 hours 17 minutes, δ -35 degrees 0.4, a point found to lie 21 degrees 9 minutes south in galatitude (referred to Newcomb's mean north galactic pole in α 12 hours 48 minutes, δ + 27 degrees). The antapex further lies 17 degrees 15 minutes northward from Canopus, the speed of apparent or parallactic drift of which (due to the solar motion) becomes 6.37 kilometers per second towards this antapex. The corresponding radial component (recessional) set up in Canopus is 20.53 kilometers per second, a figure which almost exactly coincides with the observed velocity of Canopus, 20.6 kilometers per second in recession. This indicates Canopus to be stationary with regard to the universe defined by the B type stars.

The annual proper (cross-) motion of Canopus, according to Bos ("Prelim. Gen. Cat.") is 0.0184 seconds

neither of these assumptions is true, yet, being independent and complementary, the truth, in the event of peculiar motion, should fairly lie between them, so that their mean result may be taken as a further index of the distance, and is in striking agreement too with two previous estimates.

In view of the excellent agreement of these entirely independent estimates, the distance of Canopus may fairly be assumed to be 150 secpars, a figure which agrees well too with the order of distance derived for the sidereal center.

As to the luminosity of Canopus, the R. H. P. magnitude is -0.86, while that of our Sun, if removed to a distance of one secpars, may be taken as 0.0 (implying an actual stellar magnitude -26.57); thus Canopus is actually 49,700 times as luminous as the Sun, while its spectrum is class F. Prof. Russell and Dr. Shapley have derived from the known binary systems the surface brightness of the several spectral types, and which should (they state) be fairly constant for each type. They find the surface brightness of the F stars to be 1.1 magnitude, or 2.75 times brighter than the solar (and with a temperature of 7,500 degrees against the solar 5,000 deg. Cent.). The area of Canopus thus becomes 18,000, the

diameter 134, and the volume 2,420,000 times those respectively of the Sun. Russell and Shapley further find that, on a diagram of surface areas (derived from absolute magnitude with unit surface brightness) for different type stars of unit (solar) mass, the F stars segregate compactly just one magnitude larger than our unit Sun, whence follows a relative density of 0.25 the solar. Applying this to the bulk of Canopus, its mass becomes 609,000 times the Sun's. The

chief uncertainty in these values lies in the actual density of such a great sun as Canopus manifestly is. The mutual attraction of so large a volume of gas thus presented would give rise to a set of condition surpassing anything with which we are acquainted; the tendency, however, should be to increase the density and consequently the mass, of which therefore 600,000 times the Sun may be fairly set down as the lower limit.³ A previous estimate, by the late Mr. Gore, of the Canopus mass, based on a parallax of 0.01 seconds, from comparison with Procyon (F5 spectrum), made it a million times the Sun. This estimate, though agreeing well with the present one, rests on one star alone, and that of a spectrum not exactly similar.

Given such a mass, its effect should be evident in the relative motions of the faint stars among which it is situate. In order to apply some such corroborative test, a region was chosen extending from 6 hours 4 minutes to 40 minutes in R.A., and from 50 degrees to 55 degrees in south declination, representing an area some 5 degrees square around Canopus, and all the stars of the Cape and Sydney astrographic catalogues within these limits were plotted. The proper motions of those in the southern belts (below -52 degrees and allotted to Sydney) are, unfortunately, not reduced, so that only those (Cape) stars between -50 degrees and -52 degrees having assigned motions⁴ appear in Fig. 289, supplemented for brighter stars from Boss' "Preliminary General Catalogue." Fig. 289 consequently shows 23 stars (numbered in order of R.A.) in the northern vicinity of Canopus, to which their cross-motions have been reduced relative. Resolving these tangentially and radially, and reckoning their components positive according as they are respectively clockwise around and away from their primary, the mean tangential component

³ One source of uncertainty, that affects some of the quantities derived, is the adopted stellar magnitude of the Sun. Russell adopts one 0.3 magnitude brighter, evidently following the Harvard reduction -26.83. Substituting this for the (unit) -26.57 figure, the luminosity of Canopus reduces to the actual value 39,100, the area to 14,200, diameter to 119, and bulk to 1,691,000 times these solar quantities; the density, on the other hand, increasing to 0.36 the solar, leaves the mass unchanged, and independent therefore of the adopted stellar magnitude of the Sun.

⁴ The four comparison stars used for determining the parallax of Canopus are excluded as being assigned no motion, their mean motion being indistinguishable from that of their primary; a result to be expected in the case of more or less symmetrically placed "satellites," if such at all.

in the direction 57 degrees 0.2, or at 60 degrees 0.4, with the direction of the solar antapex, whither the parallactic component is therefore 0.0091 seconds, while the normal to this line is 0.0160 seconds. Taking the parallactic component to represent the parallactic speed previously derived, the absolute parallax of Canopus becomes 0.0067 seconds. Apart from the inherent uncertainties of these small quantities (considering, too, Gill's failure to detect proper motion), this figure may be affected in either direction by the component of any real motion which Canopus may have crosswise towards or away from the antapex. The absence, however, of peculiar radial velocity argues the probability that any peculiar motion may be entirely absent, and in any case its crosswise component should not be large enough to affect materially the derived parallax. If, on the other hand, we accept the reality of peculiar motion, there is an hypothesis which is strongly supported by the A type stars, and which may be mentioned, of motion parallel to the galactic plane as brought out by Prof. Campbell and applied by Prof. Plummer. This hypothesis usually supplies a good criterion of the distance of an A type star. Since Canopus, however, belongs to type F, a class which affords no definite evidence of galactic planar motion, the application of this method fails, as is evidenced, too, by the parallax (0.077 seconds)² so derived being inadmissibly large in the face of Gill's careful measures.

The peculiar motion (if any) of Canopus would therefore be at random, in which case it may be used in two ways, according to the assumption involved, to derive the parallax. Assuming (i) Boss' average ratio (*Astron. Journal*, 614)

$$\frac{\text{parallactic motion}}{\text{whole motion}} = 0.7$$

to apply in this case, the resulting parallactic motion (0.0129 seconds) yields, with the parallactic speed, an absolute parallax of 0.0096 seconds, or a distance of 104 secpars; (ii) that the speed of motion peculiar to this star be 15.3 kilometers per second, the mean of Campbell's (14.4) and Boss' (16.2) values derived for the F stars, in which case the parallax becomes 0.0050 seconds, giving a distance of 200 secpars. The mean parallax on these two assumptions becomes 0.0073 seconds, while the mean by distances is 152 secpars. Though probably

² Using the general values of solar motion and its apex, as used by Plummer, the parallax reduces to 0.032", a value still too large, however.

* From *Knowledge*.

¹ The name here adopted is the proposed "parsec," with the syllables reversed to meet the objection lately raised to its implication (by English usage of final syllables) of time or pure arc rather than distance.

is found to be 0.0505 seconds (clockwise) as against 0.0344 seconds (outward) mean radial motion. Of the tangential components only two are negative and one zero, while their stated mean represents 83 per cent of the mean whole motion. This, coupled with the fact that the negative radial components confine themselves to one side (west) of their primary, appears to afford evidence of orbital motion enough to justify a closer study in weeding out any stars plainly extraneous to any presumable sub-Canopic system. An inspection of Fig. 289 will eliminate Nos. 10, 13, 17, and 22, as having large proper motion, and apparently sharing the drift of the more rapid of Kapteyn's two-star streams (that towards α 90 degree, δ -12 degrees), their large P.M. arguing a common greater proximity to our system. On this score No. 21, with 0.15 seconds in the opposite direction, should also be excluded.⁵

The relative motions of the remaining 18 stars, as of those at presumably the same order of distance, will remain unaffected by the component of solar motion, and, as possible satellites to Canopus, present the following quantities, which have been derived as simple means as sufficiently approximate, considering the inherent uncertainties of our data:

CANOPIC SYSTEM.	
Mean distance from Canopus.....	D 133 minutes 0.1
Mean tangential component (clockwise).....	T 0.0341 seconds
Mean radial component (outward).....	R 0.0042 seconds
Mean inclination to radius-vector $\tan^{-1} T/R$	θ 83 deg. 0.0
Minimum mass (times the Sun).....	794,000

The angle θ expresses in its approach to 90 degrees that towards the condition of satellites symmetrically placed in a common orbital plane, or of circular motion in a plane normal to the right line. This latter case, if true, would represent the minimum mass $M = DT^2$ when at a distance of 150 secpars, D represents 1,200,000 astronomical units, and T 15 miles a second, or 0.81 of the earth's mean orbital speed. This mass and that previously derived depend alike on the adopted distance of Canopus, of which their mutual relation is consequently independent. Though necessarily provisional, the striking agreement—after due allowance for coincidences—of the two entirely independent estimates of the minimum mass constitutes a somewhat forceful case for the reality of orbital motion for the faint star in the vicinity of Canopus. This of course, cannot be accepted as fact until we have the evidence of such stars of the -52 degree to -55 degree belt in the southern vicinity of Canopus, as may reasonably lie at the same distance. The reduction of these motions is therefore highly desirable, as invested with a peculiar interest.⁶

There is in this connection one point to be observed, namely, that "forward" orbital motions distributed in all planes around their primary will appear "forward" or "retrograde" according as their stars lie on the near or far side of their primary. The settlement of the question thus awaits the development of appliances able to measure the radial velocities of these faint stars.

The actual mass of Canopus will be anything greater than the figure derived, according to the mean orbital inclination (i) to the line of sight. The most reasonable index as to this will follow from the assumption of random orbital inclination, whence integrating $\sin^3 i$ (by the inverse of which the mass varies) gives a mean value 0.589: this, divided into the minimum mass, gives 1,350,000 times the Sun as the probable actual mass of Canopus.

A curious result which follows from this is that such

⁵Other stars, such as Nos. 1, 14, and 15, might further be omitted: such exclusion, however, is scarcely warranted in view of the uncertainties of small P.M.'s, while their exclusion effects no appreciable change in the resultant quantities.

⁶The two stars of known P.M. in this region, δ Pictoris (4.8 magnitude) and γ Carinae (4.4 magnitude), have nearly equal and parallel motions (counter-clockwise), which implies a common drift and considering too their brightness, and being only two in number, they supply no real criterion.

a mass, acting at 150 secpars, would of itself produce in our Sun's motion a tangential component of 3.86 miles or 6.21 kilometers a second. When we consider that the actual crosswise component of solar motion is 6.37 kilometers per second, the striking agreement, which it seems hard to believe entirely coincident, impresses itself in confirmation of the foregoing hypothesis. Again, this agreement of the estimate with the fact supplies an indirect confirmation of the distance of Canopus, since this is ultimately a direct function of the velocity.

The mass necessary at 150 secpars to produce the actual crosswise solar component would be 1,420,000 Suns. The close agreement of these estimates implies that the combined attraction of the lesser suns around us is balanced in this respect—a state of affairs which, if continuous, would indicate for our Sun a highly eccentric hyperbolic orbit in a plane nearly perpendicular to the celestial, and having its "outer" focus distant 160 secpars in the direction α 6 hours 14 minutes, δ -18 degrees, 10 minutes (a degree west of β Canis Majoris), towards which point, therefore, the solar antapex would imperceptibly shift with the lapse of time. As a matter of curiosity—for it assumes continued absence of disturbing forces—the elements of the hyperbola derived are given as follows:

Eccentricity.....	8.52
Angle between asymptotes.....	$166\frac{1}{2}$ degrees
Direct axis.....	10.9 secpars; inclined 13 degrees to galactic plane
Conjugate axis.....	92.3 secpars; inclined 23 degrees to galactic plane
Parameter.....	780 secpars; inclined 23 degrees to galactic plane
"Perihelion" distance.....	41.0 secpars
Epoch since "periastral" passage.....	$.219 \times 10^{12}$ years

Needless to say, the final item is imaginary of the

(a) The objectives (α 90 degrees, δ -12 degrees and α 263 degrees, δ -60 degrees) of Kapteyn's two star-streams (assuming their reality) lie on either side of Canopus at angular distances inversely proportional to their respective speeds, and in nearly the same apparent south galatitide as Canopus.⁷

(b) The solar antapex lies in nearly the same apparent south galatitide.

It will, of course, be clearly understood that none of the foregoing indications are set forth as in any way proving the central position of Canopus, the indication in some cases being within its own limit of error. They nevertheless point consistently in the same direction, though mutually independent, so that, however slender may be each cord in itself, yet, collectively, they assume that comparative strength which the cable bears to its component strands. As a chain of mere coincidences in a common direction, the foregoing indications would be less remarkable than the fact they demonstrate.

Finally, the central position of Canopus may, if established, be used to determine the galactic distances in terms of the Sun-Canopus line, which would thus serve for the sidereal system the purpose served by our astronomical unit (Earth-Sun line) for the solar system. The table summarizes the resultant distances relative to the unit line, and absolutely in secpars

GALACTIC DISTANCES.			
Quantity.	Unital.	Secpars.	Light-years.
Sun to Canopus.....	1.00	150	489
To Galaxy in Cygnus.....	12.98	1,950	6,330
To Galaxy in Argo.....	14.80	2,220	7,220
True Galactic Radius.....	13.88	2,080	6,780
Vertical Displacement of Sun.....	0.422	63.3	206
Lateral Displacement of Sun.....	0.906	136	442

and light-years. The quantities follow from the apparent southward deviation 1.75 degrees, derived by the late Prof. Newcomb for the main galactic stream in connection with the apparent south galatitide 25.1 degrees of Canopus, relative to the plane having its N. pole in α 192 degrees, δ + 27 degrees.⁸

Our eccentricity within the galaxy is therefore vertically 1/33 and horizontally 1/15 of the galactic radius, while the figure derived for this radius, corresponding to a parallax of 0.0005 seconds, follows the trend of recent indications by other methods.

While considering the distance of the galaxy, an independent and rough index of this is supplied from the average actual luminosity in terms of our Sun of the Type II (F, G, K) stars, of which the class Faith's integrated spectrum (*Ap. Journ.*, volume 36, page 362) indicates the galaxy mainly to consist.⁹ According to all the recent studies embodied in Prof. Russell's "absolute magnitude" diagram, these stars average at 0.8 "sunpower," and, taking these to be represented by the average galactic star of apparent magnitude 17, their mean parallax becomes 0.00045 seconds, giving a distance of 2,230 secpars, or 7,250 light-years, which strikingly confirms

the present estimate, and consequently the suggested Canopic hypothesis on which it rests.

There is, to conclude, one factor not to be ignored, and which, though at first sight irrelevant, yet, if established, should be decisive on the question of visible galactic distances, and that is the date of Creation. If the true interpretation of the period named in the inspired account (Genesis i) be six literal days—for which the Hebrew evidence seems strong—and if, again (though the evidence is not so definite), these days apply to the

(Concluded on page 394.)

⁷The galactic meridian of Canopus bisects the remarkable assemblage of helium stars in a belt 10 degrees wide between 200 degrees and 260 degrees in galongitude, and comprising about a quarter of the present count for the whole sky.

⁸This pole seems to give the simplest representation of the truth, being the mean of Newcomb's reductions; Newcomb's pole for the main stream alone lies in α 192 degrees 0.8 minutes, δ +27 degrees 0.2, the deviation of which, however, from that adopted here leaves the mean southward dip unaffected.

⁹This would seem to dispose of Prof. See's exceptional estimate of a million light-years galactic distance, based on the assumption that the galactic stars are type B of nearly one thousand "sun-power."

present creation being then existent! The angular divergence of the asymptotes indicates (in its supplement) that the ultimate deviation of the solar path due to Canopus is $13\frac{1}{2}$ degrees from the straight line.

The several indications in favor of the present hypothesis may now be summarized as follows:

- Canopus occupies the approximate position derived for the center of the stellar system, as defined by the remote helium stars.
- Its distance is of the same order as that indicated for this helium star center.
- Canopus appears to be stationary with reference to these virtually "fixed" helium stars.
- Its predominant luminosity and mass are in character with their suggested significance.
- The relative motions of the faint stars, so far examined, in the vicinity of Canopus indicate an orbital motion confirming the independently derived mass.
- The component of solar motion tangential to Canopus indicates the existence of such a mass at the given distance.

Two other features, which may prove relevant, are: