Article

Panpsychism as an Observational Science

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Abstract

The metaphysical concept of panpsychism defines a field of proto-consciousness that is present at all levels in the universe. An observational indication that this concept might be correct is self-organization on all levels from the molecular to the galactic. In 2011, an investigation into the validity of author Olaf Stapledon's concept that a portion of stellar motion is volitional led to a consideration of an observational stellar kinematics anomaly dubbed Parenago's Discontinuity. Data available at the time indicated that cooler, less massive stars (such as the Sun) revolve a bit faster around the center of the Milky Way galaxy than hotter, more massive stars, at least in a sphere with a radius of ~260 light years centered on the Sun. The spectral signature of this discontinuity becomes evident at about the point in the stellar population where molecules can form in stellar photospheres, which supports a published model of molecular consciousness. A mechanistic explanation for Parenago's Discontinuity requires interaction between star fields and dense diffuse nebulae that might drag less massive stars faster than more massive stars. Reference to three major catalogs of deep-sky objects reveals that nebulae large enough to drag stars over a radius of ~260 light years are very rare. In 2016, the European Space Agency (ESA) released the first data set from the Gaia space observatory. It now appears clear that Parenago's Discontinuity is a non-local phenomenon. An unexpected and provocative aspect of the reduced Gaia observations is an indication that stars within >500 light years of the Sun apparently accelerate in the direction of their galactic revolution as they age. Other published supporting work includes a demonstration that certain binary stars are similar in many respects to biological organisms. A well-developed model of quantum consciousness supports the concept that neutron stars are conscious. It has been noted that spiral galaxies such as our Milky Way retain their shape after absorbing smaller satellite galaxies, which also supports panpsychism or self-organization at the highest levels. Another research team has reported that the apparent fractal arrangement of galaxy clusters and voids is also in congruence with some form of universe self-organization. The work of two separate researchers who are contemplating methods of communicating with stellar-level consciousness indicates that experimental astro-panpsychism may be possible as well as observational astro-panpsychism. It is becoming evident that panpsychism may be moving from the realm of metaphysics to the domain of observational astrophysics.

Keywords: Panpsychism, universe self-organization, Parenago's discontinuity, observational science.

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Introduction

In a previous article (Matloff, 2016), it was argued that aspects of panpsychism - The metaphysical doctrine that consciousness permeates the universe at all level of organization - could be tested in the astrophysical realm. As discussed in that article and elsewhere (Matloff, 2012, 2015, 2015a, 2017), the observational support for this thesis resulted from a consideration of stellar kinematics as part of a 2011 symposium at the London headquarters of the British Interplanetary Society to discuss the contributions of Olaf Stapledon, a British philosopher and visionary science-fiction author.

The aspect of Stapledon's work tested in this series of papers was his metaphysical doctrine that stars in a sense are conscious and that a portion of their motion is volitional. Jantsch (1980) has argued that stellar consciousness is to be expected in the context of universal self-organization. A neuronal basis of consciousness utilizing quantum tunneling , as argued by Walker (1970, 1999) and others is impossible for stars. The same is true for theories of consciousness based upon quantum entanglement among microtubules in a brain (Margolis, 2001, Hameroff and Penrose, 2014).

But there is a third possibility. It has been suggested that fluctuations in the quantum foam (also called the quantum vacuum) might be the origin of a proto-consciousness field that permeates the universe (Haisch, 2006). It has been known since 1948 that a significant fraction of the Van der Waal molecular bond is due to vacuum fluctuation pressure - the so-called Casimir Effect (Genz, 1999). The conjecture that consciousness arises from vacuum fluctuations is far from unreasonable - the Big Bang (certainly the most creative incident in the universe) - is thought to have originated from a stabilized vacuum fluctuation.

After selecting the possible conceptual model of how consciousness might enter the upper layers of a star, it was necessary to first determine at what point in the stellar population molecules might form. The next step was to see if any kinematics anomaly appears at or near this point. In other words, do stars with molecules in their upper layers (which might be conscious) move differently from stars too hot to have stable molecules.

As discussed below, observational spectroscopic research dating to the 1930's demonstrated that molecules begin to appear in the outer layers of stars a bit hotter than our Sun. A Soviet-era Russian astronomer, Pavel Parenago, demonstrated that at least for relatively near stars, stars with molecules revolve a bit faster around the center of our galaxy than their hotter sisters.

The Onset of Molecular Signatures in Stellar Spectra

A good place to begin a consideration of molecular signatures in stellar spectra is to discuss spectral classes, surface temperatures and color indices. Deep in the interior of mature main sequence stars, temperatures are uniformly very high due to the conversion of hydrogen to helium and energy. But the stellar surface temperature can vary widely, as presented in Table 1 [Drilling and Landolt (2000), Tokunaga, (2000)].

The hottest stars are of spectral class O, which are bright, blue, massive and comparatively short lived. Low mass, dim, red, long-lived M-class stars are coolest.

Table 1. Surface Temperatures and (B-V) Color Indices For Various Main Sequence Star Spectral Classes

Star Spectral Class	Surface Temperature (degrees Kelvin)	(B-V) Color Index
O5	> 36,000	-0.33
B0	31,500	-0.30
B5	15,400	-0.17
A0	9,480	-0.02
A5	8,160	0.15
F0	7,020	0.30
F5	6,530	0.44
G0	5,930	0.58
G5	~5,680	0.68
K0	5,240	0.81
K5	4,340	1.15
M0	3,800	1.40
M5	3,030	1.64

There are very few spectral lines in the spectra of very hot stars. Spectral lines corresponding to electronic transitions in molecules become more common as star surface temperature decreases.

The (B-V) color index of a star is essentially a comparison of a star's brightness in the blue and yellow ranges of the visible spectrum. It is a quantifying tool in the study of star spectral classes. If , for example, an astronomer determines the (B-V) color index of a particular main-sequence star to be 0.68, she can be reasonably sure that the spectral class of that star is G5. Note that hot stars tend to have negative (B-V) color indices and cooler stars have positive (B-V) color indices. Our Sun is usually classified as a G2 main sequence star. Its surface temperature is 5777 degrees

Kelvin and its (B-V) color index is 0.650 (Livingston, 2000). As discussed in Matloff (2016), observations of the onset of molecular signatures in stellar spectra are discussed by Russel (1934), Renze and Hynek (1937) and Swings and Struve (1932). This early work has been reviewed by Tsuji (1986).

Observations were conducted for more than two dozen stars. These references report that the spectral signature of simple CH and CN molecules begin to appear in stars cooler than spectral class F8 (photospheric temperatures < 6500 Kelvin degrees).

Parenago's Discontinuity

The next step was to search for information regarding a difference in stellar motions between stars hotter than spectral class F8 and those cooler than that class. As discussed in Matloff (2016) and elsewhere, the first indication that such a phenomenon exists was uncovered by the Soviet-era observational astronomer Pavel Parenago (1906-1960). Parenago's observations revealed that at least for stars relatively close to the Sun, cool stars revolve around the center of the Milky Way galaxy a bit faster than hot ones. According to Binney et al. (1997), the sharp difference in stellar velocities, which is referred to as Parenago's Discontinuity, occurs around (B-V) = 0.62, which corresponds to late F or early G stars.

In Matloff (2012, 2015, 2016, 2017), data have been plotted to demonstrate Parenago's Discontinuity for main sequence stars. This plot, which is included as Fig. 1, presents results discussed in Gillmore and Zelik (2000) and Binney et al. (1997).

In Fig. 1, the Binney et al (1997) data is from observations of more than 6,000 main sequence stars by the European Space Agency's Hipparcos space observatory. These stars are all within a sphere with a radius of about 260 light years, centered on the Sun. The ordinate presents variation in star orbital velocity around the center of the Milky Way galaxy.

Note the bulge in the Fig. 1 data points between (B-V) ≈ 0.55 and (B-V) ≈ 0.9. The possible significance of this feature was not recognized by this author in previous papers on this subject. More will be said about this intriguing feature in subsequent sections of this paper.

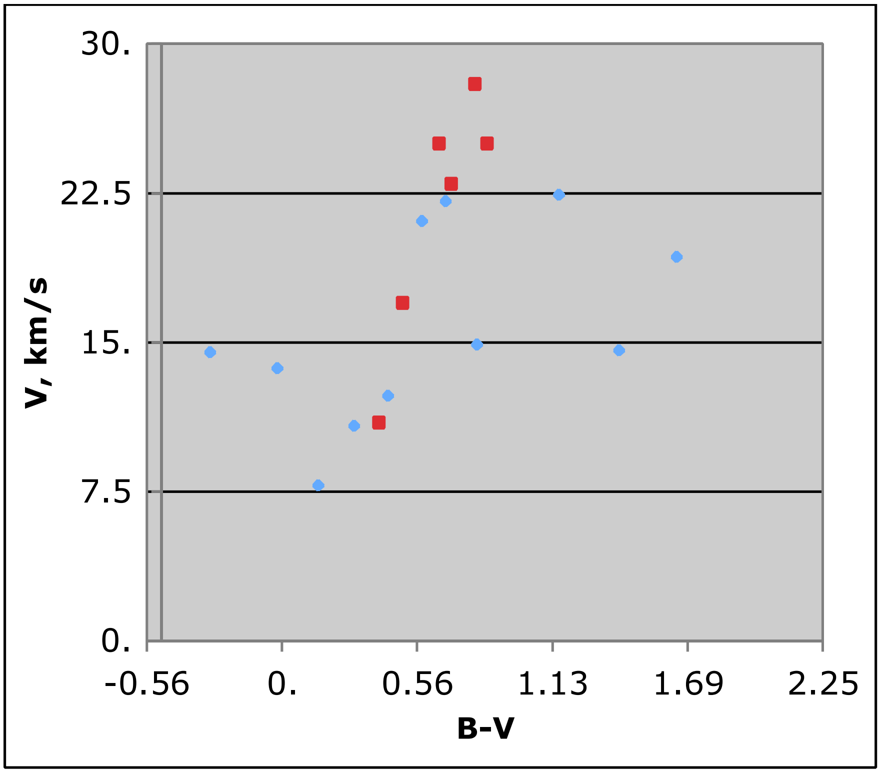

Fig. 1. Parenago's Discontinuity for Main Sequence Stars out to ~260 Light Years. Diamond Data Points are from Gilmore and Zelik (2000). Square Data Points are from Binney et al (1997).

Spiral Arms Density Waves: A Mechanistic Explanation for Parenago's Discontinuity - and Why it Likely Fails

In astrophysics, as in other disciplines, alternative explanations arise to explain observed natural phenomena. The leading mechanistic contender to explain Parenago's Discontinuity is Spiral Arms Density Waves (Binney, 2001 and DeSimone et al., 2004).

Reference to any photograph of a spiral galaxy such as our Milky Way reveals that there are dark patches in the star fields that compose the spiral arms. These are diffuse nebula, that are the nurseries in which infant stars form. The gas/dust density in these galactic clouds is typically more than 1000X greater than in the inter-cloud medium where our Sun resides.

It is not impossible that at various times, a diffuse nebula passes through our Sun's low-density galactic vicinity. According to the Spiral Arms hypothesis, during such an interaction low-mass, high (B-V) stars may be dragged along to a higher galactic-revolution velocity. by the more dense interstellar cloud. The fact that the velocity discontinuity occurs at or very near the point where the signature of stable molecules appears in stellar spectra is a coincidence.

There are two observational objections to the Spiral Arms Density Waves hypothesis. The first of these is a significant observational failure of the Spiral Arms hypothesis. For Spiral Arms to succeed as a hypothesis, there must be a color difference between stars near the leading and lagging edges of spiral arms in spiral galaxies similar to our Milky Way. Foyle et al. (2011) conducted an extensive spectroscopic study of twelve comparatively near spiral galaxies. No such color difference was observed.

The second objection derives from a consideration of the maximum size of catalogued diffuse nebulae. For Spiral Arms to succeed as an explanation of Parenago's Discontinuity from Hipparcos data, as presented in Fig. 1, at least some of these nebulae must have an effective diameter greater than 520 light years.

As discussed in Matloff (2016), three catalogs of deep-sky objects were studied to discover the sizes of the largest known diffuse nebulae in the Milky Way galaxy. These included a modern version of Charles Messier's 1784-vintage catalog of 102 objects (Jones, 1969) ,the much more comprehensive Herschel catalog with >2,500 objects (Mullaney and Tiron, 2011) and an on-line version of the very expansive *New General Catalog* (www.atlasoftheuniverse.com/nebulae.html).

These studies revealed that the median diameter of a diffuse nebula is less than 20 light years. Only 10% of the sample had diameters greater than 100 light years. The largest known diffuse nebula in our galaxy is the Eta Carinae circum-stellar nebula, which has a diameter greater than 400 light years.

The largest known diffuse nebula, 30 Doradus (the Tarantula Nebula) resides in an irregular galaxy (the Large Magellanic Cloud) which is a satellite of our Milky Way and is at a distance of about 200,000 light years. Burnham (1978) estimates the diameter of this object as 800 light years.

When Matloff (2016) was written, it therefore seemed unlikely that a diffuse nebular large enough to drag low mass stars in a sphere with a ~500 light year diameter exists. But because of the existence of one nebula large enough in a neighboring galaxy, it seemed impossible to rule out Spiral Arms.

To demonstrate whether Parenago's Discontinuity is a local or non-local phenomenon, it was necessary to obtain accurate distance and motion data for stars over a larger volume of space than was accomplished using Hipparcos. As discussed in Matloff (2015), the European Space Agency (ESA) launched the Gaia space observatory as a successor to Hipparcos in 2013. The goal of this mission is to determine accurate distances and motions for ~ 1 billion stars in the Milky Way galaxy. Some relevant data from the first Gaia data release are presented below.

Galactic Trajectory Alteration by Minded Stars

There is some discussion in Matloff (2012, 2015, and 2016) of how a minded star might alter its trajectory. One possibility is unipolar jets Emitted by infant stars, which have been observed (Namouni, 2007).

Applying a mass ejection rate consistent with that of young stars in the T Tauri phase (Gomez-de Castro et al. 2003), it was shown in Matloff (2016) that if 20% of a star's initial mass is ejected in a unidirectional jet at 100 km/s for the first billion years of a star's life, the star's velocity will be altered by about 20 kilometers per second.

A much more speculative possibility is also raised in Matloff (2016). If psychokinesis (PK) is scientifically verified, a very weak PK force exerted by a star over a billion-year time interval might be sufficient to alter the star's galactic-revolution velocity.

It was not thought in 2016 that data would soon be available relating to stellar volitional acceleration. But as discussed below, analysis of the first Gaia data release has revealed a very intriguing effect.

The balance of this paper is devoted to new material, in an effort to ascertain whether panpsychism in the celestial realm has emerged as a science. First the predictions in Matloff (2016) will be reviewed in light of the analysis of the first Gaia data release. Next the work of other researchers approaching this subject from multiple directions will be considered. Then, an approach to quantifying panpsychism will be discussed.

Astro-Panpsychism as a Science: Matloff (2016) Predictions Revisited

In the conclusion of Matloff (2016), it was noted that a scientific subject must be subject to experimental or observational validation / falsification. Four questions were listed regarding future observational results that could validate or falsify the concept. Surprisingly (and happily for this author), two of the questions have been answered. The answers of these apparently validate panpsychism. Consideration of a third in light of the first Gaia data release lends support to panpsychism and also leads to the possibility of an equally surprising alternative approach. To the author's knowledge, the fourth question has not been addressed by the scientific community.

Question 1: *Is Parenago's Discontinuity a Non-local, or Universal Phenomenon?*

In 2016, the European Space Agency released the first data release (DR1) from the Gaia space observatory (Gaia Collaboration, 2016 and Lindegren et al., 2016). Contained in Gaia DR1 are astrometric results for more than one billion stars in the Milky Way galaxy brighter than apparent visual magnitude 20.7. For about two million stars in this sample brighter than apparent visual magnitude ~11.5, positions, parallaxes and proper motions were measured with a precision equal to or greater than that of the Hipparcos data set.

This data set was applied by Vityazev et al. (2018) to investigate Parenago's Discontinuity over a much greater volume of space and for many more stars than was done using Hipparcos data (Binney et al, 1997) and Gilmore and Zelik (2000). The Vityazev et al. (2018) sample contains 1,260, 071 main sequence stars and 534,387 red giants. Because of the high luminosity of giant stars, many of these were quite distant. As a star's distance increases, the accuracy of its distance estimate decreases. It was not possible in this study to confirm the assertion of Branham (2011), which is discussed in Matloff (2016), that Parenago's Discontinuity exists for giant stars as well as main sequence stars. Some aspects of the Vityazev et al. (2018) main sequence star sample are presented in Table 2.

Table 2. Vityazev et al.(2018) Sample of Gaia DR1 Main Sequence Stars

Spectral Type	O	B	A	F	G	K	M
Mean (B-V)	-0.37	-0.06	0.19	0.46	0.68	0.96	1.49
Number	91	9165	189560	601577	425150	33843	625
Minimum Estimated Average Distance (kpc)	0.78	0.59	0.59	0.45	0.33	0.14	0.03
Largest Estimated Average Distance (kpc)	2.54	1.15	1.11	0.64	0.40	0.15	0.03
Average Star Age (X 10^9 years)	-	-	-	3.5	8.0	7.7	7.0

Note: 1 kpc = i kiloparsec= 1,000 parsecs or 3260 light years

The most luminous (and rarest) stars in Table 2 are O class. Because of their brightness, they tend to be at a great distance from our solar system. But the spread in average distance estimates for these stars is enormous - 2543 to 8280 light years. Less luminous B and A stars still emit a lot more electromagnetic energy than our Sun and the range in average distance estimates for these stars are less extreme. There are many more B and A stars in the Gaia DR1 main sequence sample than O stars.

Most stars in this population are F, G, and K stars. The spread in average distance estimates for these stars is a lot less than for hotter stars. Average F stars are within 1467 - 2086 light years from the Sun. Average K stars are within about 500 light years of the Sun. Solar-type G stars in this sample are at an average distance of 1085 - 1304 light years from our solar system.

Although the most numerous stellar spectral class is M, these red dwarfs are very dim. Because of the magnitude limitation of Gaia's instruments, there are few M stars in the sample. On average, M stars in the sample are within 100 light years of the Sun.

It is not surprising that the average age of F stars in this sample is 3.5 billion years, since stars in this spectral class do not live as long as our G-class Sun, which is about half-way through its projected 10-billion year life span. But it is very intriguing that most G and K main sequence stars in the Gaia DR1 sample are billions of years older than our Sun.

If intelligent, technological life has evolved and survived on planets orbiting G or K stars in our galactic vicinity, they are likely billions of years in advance of terrestrial civilization. It is humbling to realize that if we encounter extraterrestrials, they will likely be so far in advance of us that we might not even recognize them.

Figure 2 presents galactic revolution velocities for main sequence stars versus (B-V) color index from Fig. 1B of Vityazev et al. (2018). All or most of these 1,260, 071 stars reside in a sphere centered on the Sun with a diameter > 1,000 light years.

Note in Fig. 2 that the bulge in the Fig. 1 data points between (B-V) ≈ 0.55 and (B-V) ≈ 0.9 is clearly present, which indicates that this is a real feature. This interesting feature, which is likely real because it is in both data sets, is discussed in greater detail below.

The data point on the extreme left of the graph, which corresponds to O spectral class stars with an average (B-V) color index of about -0.4 do not likely revolve as fast as indicated. Reference to Fig. 1B of Vityazev (et al. (2016) indicates that the error bars in galactic revolution velocity V are enormous, likely because of the rarity of O stars in the galaxy and the large errors in distance estimates for this class of stars.

Note that Parenago's Discontinuity occurs in this figure at about the same (B-V) value where it occurs in the Fig. 1 data from Hipparcus and *Allen's Astrophysical Quantities* (Binney et al, 1997) and (Gilmore and Zelik ,2000).

Because Parenago's Discontinuity appears in the Fig. 2 data set, for stars > 500 light years from the Sun, it seems very unlikely that Spiral Arms Density Waves is a viable explanation. Parenago's Discontinuity is clearly a non-local phenomenon.

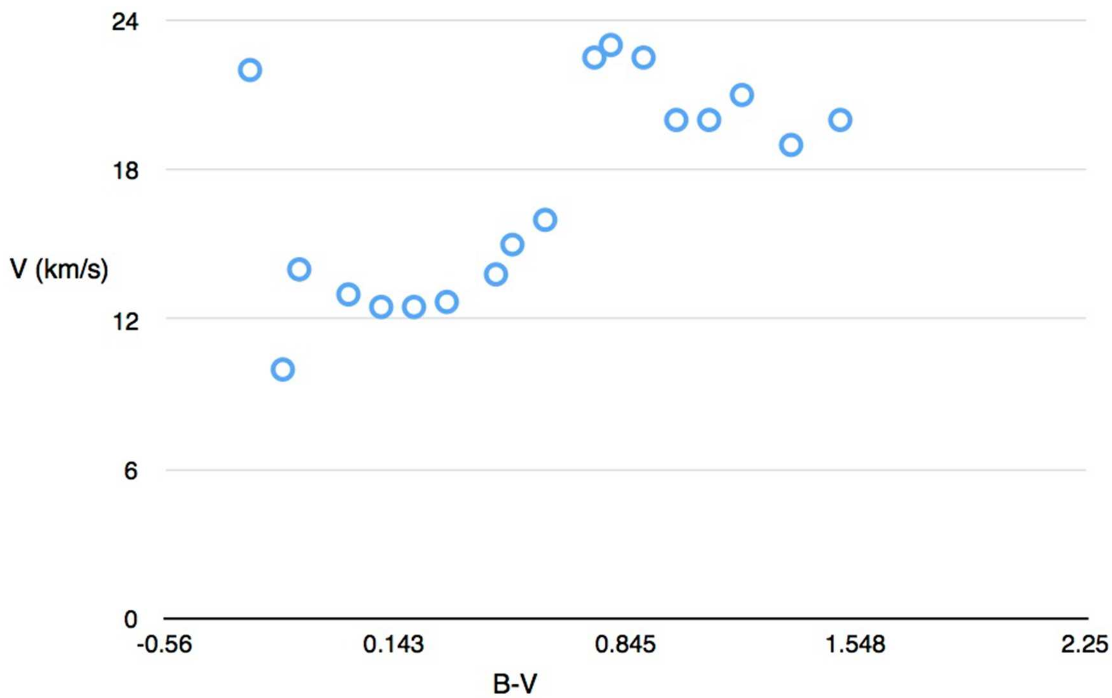

Fig. 2. Relative Star Motion in the Direction of the Sun's Galactic Revolution (V) vs. (B-V) color Index from Gaia DR1 Data (Vityazev, et al. 2018).

When the data sets in Figs 1 and 2 are plotted together, Parenago's Discontinuity is clearly revealed. It is also evident that data points from both data sets line-up rather well. This is presented in Fig. 3.

It shouldn't be concluded that these results entirely rule out a mechanistic explanation for Parenago's Discontinuity. But constructing such a hypothesis will require a great deal of ingenuity. As is the case with Spiral Arms, such a mechanistic hypothesis may not survive future efforts to demonstrate that Parenago's Discontinuity is not merely a non-local phenomenon but a galactic phenomenon. It is also hoped that future researchers attempt to observe Parenago's Discontinuity in the motions of stars in galaxies external to our Milky Way.

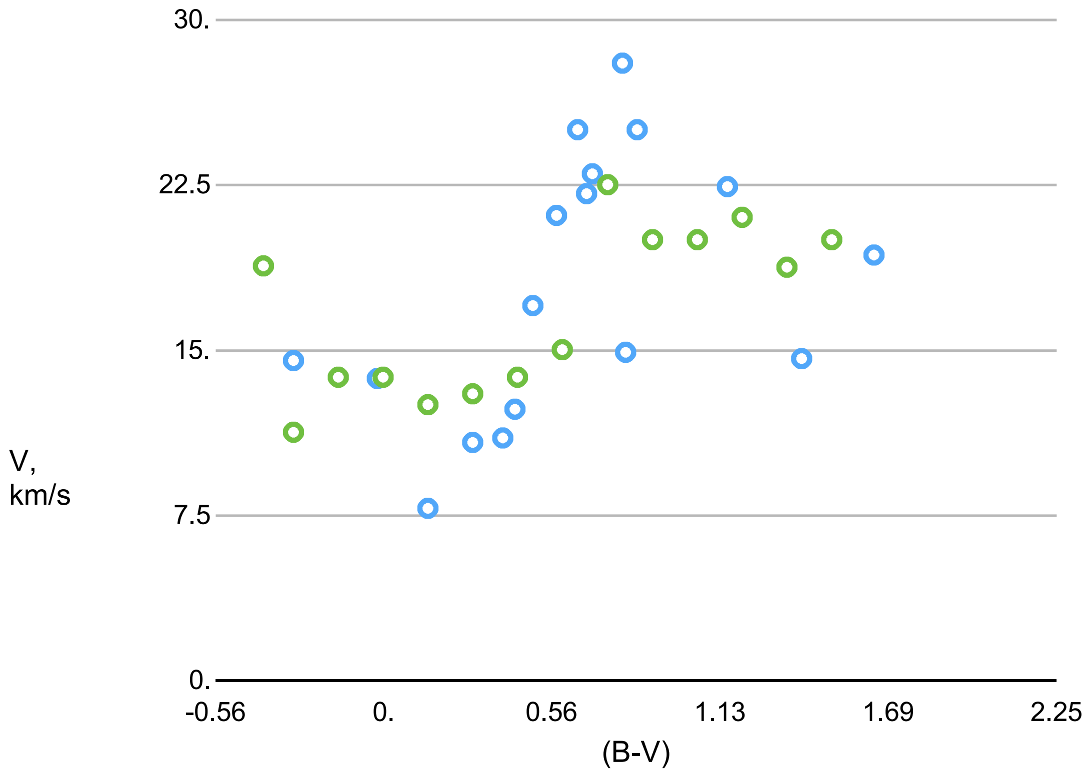

Fig. 3. Combined Plot of Fig. 1 Data (Blue) from Hipparchus and Allen's Astrophysical Quantities with Fig. 2 Gaia DR1 Data (Green).

Question 2: *What is revealed by Further Study of Unipolar Stellar Jets?*

When I posed this question during the preparation of Matloff (2016), I did not expect results anytime soon. As discussed above, the most likely acceleration process for a minded star seemed at the time to be a unipolar jet of material that has been observed to be emitted by infant stars. Might future observation of these jets indicate that they tend to be in a direction opposite to the star's direction of galactic revolution? Might the intensity of the jet vary with an infant star's distance from the galactic center?

But a major result of the very first study of Parenago's Discontinuity using Gaia DR1 data (Vityazev, et al. 2018) is very relevant to the study of minded star acceleration and perhaps as well to considerations of the role of technologically advanced conscious life in the universe.

As well as validating the existence of Parenago's Discontinuity over a much greater volume of space than previous studies could achieve, Vityazev, et al. (2018) were able to investigate the curious bump in Figs. 1-3 between (B-V) ≈ 0.55 and (B-V) ≈ 0.9. They were able to do this because of the large Gaia DR1 star sample and the age estimates for stars in this sample that are presented in Table 2 above.

To my great surprise, the analysis of Vityazev et al. (2018) indicates that mature stars accelerate along the direction of their galactic revolution (and only in this direction) as they age! This is not a tremendous acceleration - it amounts to an increase in galactic revolution velocity of about 1 kilometer per second in every billion years or about 3×10^{-14} meters per second squared. The acceleration of gravity at Earth's surface is about 3×10^{14} times greater than this stellar acceleration!

After the publication of Vityazev et al. (2018), veteran science-journalist Paul Glister decided to devote the April 26, 2019 issue of his well-researched astrophysics/astronautics blog www.centauri-dreams.org to the subject of Parenago's Discontinuity.

My two previous blog contributions on this subject had been organized as a written statement by me followed by a discussion with blog respondents. In this case, Glister decided to conduct the blog entry, which was entitled "Probing Parenago: A Dialogue on Stellar Discontinuity", as a dialogue between me and Alex Tolley (a frequent blog contributor) followed by a discussion with various respondents.

When we debated the apparent acceleration of mature stars, I initially considered mechanisms that the mature, minded star might use to increase its velocity of galactic revolution. These included (but were not limited to) unidirectional electromagnetic radiant output and a directed solar wind. I initially ruled out Coronal Mass Ejections (CMEs), although Kelvin Long (2020) has informed me recently that the velocity of some CME events is higher than 3,000 kilometers per second.

It was a surprise when Tolley, echoed by several blog respondents, suggested an alternative to minded stars to explain this apparent acceleration of mature star. As reviewed in Table 2, most main sequence stars in the Gaia DR1 sample are billions of years older than our Sun. This is sufficient time for even a few very-long-lived extraterrestrial civilizations capable of conducting interstellar colonization missions like those we can envision today to have occupied most or all planetary systems in the galaxy. This concept, which I have considered further in Matloff (2019) leads to the possibility that we live in an occupied and engineered galaxy.

Assuming that further observational research confirms this stellar acceleration, astrophysicists might have to choose between the possibility of minded stars or ET-directed stars, if some mechanistic explanation for this stellar acceleration does not succeed. Either possibility would be humbling to those humans who like to picture themselves as lords of creation.

Question 3: *Does Further Research Support the Conclusion that Molecules are Found in Stars cooler than F8?*

As discussed above and in Matloff (2016), the sample of stars studied in the 1930's to determine the spectral class of stars in which molecular spectral signatures first appear is very small. It is hoped that the much larger library of stellar spectra available today can be accessed to check the conclusion that spectra of stars cooler than spectral class F8 contain signatures of simple molecules such as CH and CN. To my knowledge, results of such studies have not yet been published.

Question 4: *Might There be Observational Signs of Panpsychism or Self-organization at Higher Cosmic Levels?*

In Matloff (2016), I refer to the conjecture of Freeman Dyson that the Mind is present at many levels in the universe (Dyson, 1988). One possible example of self-organization at the galactic level is the observation of Ari Maller (2007) that spiral galaxies such as our Milky Way tend to retain their spiral shapes even after repeatedly absorbing smaller galaxies.

A Romanian philosopher and physicist have collaborated on a study of structures in the universe that are larger than galaxies including galaxy clusters, filaments, and voids. According to their conclusions, the fractal nature of these constructs points towards self-organization on a grand scale (Murdzek and Iftimie, 2008). More recently, Renyue Cen (2014) of Princeton University has found evidence of self-organization in galaxy formation.

An end-of-life stage for stars considerably more massive than our Sun is the compact neutron star. According to D. K. Berry et al. (2016), there is a striking similarity between biological cellular structures and simulated structures in neutron stars. Penrose and Hameroff (2001) speculate that according to their theoretical studies of quantum consciousness, neutron stars may be conscious.

Interacting binary stars are stellar couples so close than one star seems to live off its companion. Clement Vidal (2014, 2016) has conducted a comprehensive analysis of these systems. He concludes that these interacting stellar pairs share many of the properties of biological systems.

Evolutionary biologist Stuart Kauffman (1993) and others have reported evidence for self-organization at much smaller biological levels. It would be nice if a quantitative mechanism could be devoted to consider self-organization at levels from the molecule to the universe.

One person who is addressing this issue is Giulio Tononi (2012a, 2012b). His approach, Integrated Information Theory, treats consciousness as an intrinsic property of any physical system. The consciousness level of any system depends upon the number of interconnections allowing the integration of information. The brain of a human or higher animal has billions of neurons with a vast number of interconnection possibilities. The level of consciousness of such an organism is enormously greater than that of a molecule, which has a small number of interconnection possibilities.

My earlier work on anomalous stellar motions Matloff (2012, 2015, 2015a, 2016, 2017) assumed that stable molecules in or above a star's photosphere have sufficient interconnection possibilities to enable a type of flocking behavior. But there are a lot of molecules in the outer layers of a Sun-like star. So it is certainly not impossible that the consciousness level of such a star is enormous.

Gregory Benford, a physicist affiliated with The University of California at Irvine, has investigated the possibility of god-like stars in a co-authored science-fiction novel (Benford and Eklund, 1977). But could we communicate with a minded star?

One researcher considering modes of establishing a communication link with the Sun is the British biologist Rupert Sheldrake. After receiving his Ph.D. from Cambridge University, Sheldrake worked as a plant physiologist in India. During his stay in India, Sheldrake became acquainted with aspects of Hinduism including Sun mantras and salutations. He speculates whether we could apply such techniques to provoke a solar response, such as a selected sunspot pattern (Sheldrake, 2018).

Van de Bogart (2017, has suggested an alternative possible human-stellar communication mode. Because sound - especially those rhythmic patterns we call songs - are so significant among terrestrial life forms, perhaps stars communicate using subtle variations in their electromagnetic output. Perhaps astrophysicists working in helioseismology could uncover such patterns.

Conclusions: Is Panpsychism Metaphysics or an Observational Science?

We can now discuss the central theme of this paper: Has Panpsychism emerged from metaphysics to enter the realm of science? A number of philosophers and scientists have argued the same point. A recent example is a publication of Philip Goff (2019), a philosopher at Durham University in the UK.

There are several criteria that a discipline must satisfy to be considered scientific. First, can cogent hypotheses be developed to explain physical phenomenon. Second, can these hypotheses be tested by experiment or observation and perhaps evolve into an accepted theory. Next, it should be possible to successfully predict the results of future observations or experiments based upon the hypotheses developed. As the discipline matures, quantitive processes should be developed and applied. Many people should be attracted to the new field and begin to contribute to it. Unexpected significant results should emerge from these studies. Finally, the new scientific discipline should begin to influence the wider culture of our civilization. Based upon the discussion above, we next see how Astro-Panpsychism currently succeeds in satisfying these criteria.

Criteria 1: Development of a Hypothesis related to Astro-Panpsychism

As first described in Matloff (2012) and further discussed in my subsequent work, constructing the hypothesis that a portion of stellar motion is volitional was readily accomplished. A literature search revealed Parenago's Discontinuity, a phenomenon that supported this hypothesis. Further work revealed a molecule-based theory of consciousness and demonstrated that the velocity discontinuity in stellar revolution velocity around the galaxy's center is at or near the point where the signatures of simple molecules appear in stellar spectra.

Criteria 2: Can this hypothesis be tested by further experiment or observation?

An alternative, mechanistic concept to explain Parenago's Discontinuity (Spiral Arms Density Waves) requires large diffuse nebulae interacting with a star field to drag relatively low-mass stars (such as the Sun) more rapidly than more massive stars. At the time that the above hypothesis was generated, Parenago's Discontinuity was observationally evident for main sequence stars within about 260 light years of the Sun. A search of three catalogs of deep sky objects revealed only one diffuse nebula (30 Doradus) large enough to satisfy the requirements of Spiral Arms Density Waves. it was suggested that observations of star positions and motions using the European space Agency's Gaia space observatory could reveal whether 30 Doradus, the largest diffuse nebula known among galaxy neighbors to our Milky Way, would be large enough to explain Parenago's Discontinuity if Gaia results indicated that this phenomenon is non-local.

Criteria 3: It should be possible to successfully predict the result of future observations based upon the hypothesis in Criteria 1

Further observations using the first data release from the Gaia space observatory revealed that Parenago's Discontinuity is observed for main sequence stars over a much greater radius than that of 30 Doradus. This result apparently falsifies Spiral Arms Density Waves, the competing mechanistic hypothesis to the one discussed in Criteria 1.

Criteria 4: Quantitative processes should be developed and applied to any new scientific discipline

The "PHI" approach (Tononi, 2012a, 2012b) is an excellent first step in the quantification of Panpsychism.

Criteria 5: Many people should be attracted to the new discipline and contribute to it

See the cited works by Maller, (2007), Murdzek and Iftimie (2008), Sheldrake (2018, Van de Bogart, (2017), and Vidal (2014, 2016).

Criteria 6: Unexpected significant results should emerge from these studies

See the cited work by Vityazev et al. (2018). As well as the expected result that Parenago's Discontinuity is a non-local phenomenon, this paper presents totally surprising and possibly very significant data demonstrating that main-sequence stars accelerate along their galactic trajectories as they age. This remarkable result, which points to either an engineered or a conscious galaxy, will hopefully be replicated by future observations.

Criteria 7: The new scientific discipline should begin to influence the wider culture of our civilization

The concept of Astro-Panpsychism has long-since entered the genre of science fiction in the cited novel Benford and Eklund (1977). Two more recent science-fiction novels that further explore this concept, as well as presenting a case for stellar acceleration are authored by Gregory Benford and Larry Niven. These are *Bowl of Heaven*, (New York, Tor, 2012) and *Shipstar* (New York, Tor, 2014).

In an equally significant recent publication, Panpsychism is a plot element in a successful techno-thriller. This novel, authored by Julian Gough, is entitled *Connect* (New York: Doubleday, 2018).

Elements of Panpsychism have also appeared in other works of prose and poetry. See for example Alison Hawthorne Deming's *The Edges of the Civilized World: A Journey in Nature and Culture* (New York: Picador, 1999).

Panpsychism clearly satisfies all of the above criteria. So it is hard to argue that it is not emerging as a scientific discipline. It is clearly possible though, that it might ultimately be superseded by some other metaphysical principle. For example,Deepak Chopra and Menas Kafatos argue in *You Are The Universe* (New York: Harmony, 2017) that it will ultimately be replaced by Idealism, in which consciousness is not only present at all universal levels but is dominant over matter and energy.

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We were also visited in New York by Julian Gough, the author of *Connect*. It is hoped that this techno-thriller and other popular publications can successfully communicate the essence of Panpsychism to a mass audience.

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References

Benford, G. and Eklund, G. (1977): *If the Stars are Gods*, New York, Berkley-Putnam.

Berry, D. K., Caplan, M. E., Horowitz, C. J., Huber, G., and Schneider, A. S. (2016.): "Parking Garage Structures in Nuclear Astrophysics and Cellular Biophysics. " in *Physical Review C*, vol. 94, 055801,

Binney, J. J., Dehnen, W., Houk, N., Murray, C. A., Preston, M. J. (1997): "Kinematics of Main Sequence Stars from Hipparcos Data", in *Proceedings ESA Symposium Hipparcos Venice 97, ESA SP-402, Venice, Italy, May 13-16, 1997*, 473-477. Paris, European Space Agency.

Binney, J. J. (2001), "Secular Evolution of the Galactic Disk", in *Galaxy Disks and Disk Galaxies*, eds. F. Bertoli and G. Coyne, ASP Conference Series vol. 230. San Francisco, Astronomical Society of the Pacific.

Branham, R. L.(2011), "The Kinematics and Velocity Distribution of the GIII Stars: *Revisita*

Mexicana de Astronomia y Astrofisica, vol. 47, 197-209.
Burnham, Jr. (1978): *Burnham's Celestial Handbook*, New York: Dover.
Cen, R. (2016), "Temporal Self-Organization in Galaxy Formation." In *Asrophysical Journal Letters*, Vol. 785:L21.
DeSimone, R. S., Wu, X., Tremaine S. (2004): "The Stellar Velocity Distribution in the Stellar Neighborhood" In *Monthly Notices of the Royal Astronomical Society*, vol. 350, 627-643.
Drilling, J. H. & Landolt, A. U. (2000). "Normal Stars", Chap. 15 in *Allen's Astrophysical Quantities, 4th Edition*, ed. A. N. Cox, New York: Springer-Verlag.
Dyson, F. (1988): *Infinite in all Directions*. New York: Harper & Row.
Foyle, K., Rix, H.-W., Dobbs, C., Leroy, A., Walter, F. (2011): "Observational Evidence Against Long-Lived Spiral Arms in Galaxies". In *Astrophysical Journal*, vol. 735, Issue 2, Article ID = 101 (2011).
Gaia Collaboration, A., et al. (2016): "Gaia Data Release 1: Summary of the Astrometric, Photometric, and Survey Properties", in *Astronomy and Astrophysics,* Manuscript no. aa29512-16 (Sept. 19, 2016).
Genz, H. (1999). Nothingness - The Science of Empty Space. Reading, MA: Perseus Books.
Gilmore, G. & Zelik, M. (2000): "Star Populations and the Solar Neighborhood", Chap. 19 in *Allen's Astrophysical Quantities, 4th Edition*, ed. A. N. Cox, New York: Springer-Verlag.
Goff, P. (2019): Galileo's Error: Foundations for a New Science of Consciousness, New York: Penguin/ Random-House.
Gomez de-Castro, A. I., Verdugo, E., Ferro-Fontan, C. (2003): "Wind Jet Formation in T Tauri Stars: Theory vs. UV Observation." In *Proceedings of 12th Workshop on Cool Stars, Stellar Systems and the Sun, July 30-August 3, 2001,* Boulder CO: University of Colorado Press.
Haisch, B. (2006). *The God Theory: Universes, Zero-Point Fields and What's Behind it All*. San Francisco: Weiser Books.
Hameroff, S. & Penrose, R. (2014). "Consciousness in the Universe: A Review of the Orch OR Theory". In *Physics of Life Reviews,* vol. 11, 39-78.
Jantsch. E. (1980): *The Self-Organizing Universe: Scientific and Hunan Implications for the Emerging Paradigm of Evolution*. New York: Pergamon.
Jones, K. G. (1969): *Messier's Nebulae and Star Clusters*. New York: American Elsevier Publishing Company.
Kauffman, S. (1993): *Origins of Order: Self-Organization and Selection in Evolution*. New York: Oxford University Press.
Lindgren, L., Lammers, U., Bastian, U., et al. (2016): "Gaia Data Release 1: Astrometry- One Billion Positions, T0o Million Proper Motions and Parallaxes". In Astronomy & Astrophysics, Manuscript No. aa201628714 (Sept. 15, 2016), arXiv:1609.04303v1 [astro-ph.GA1] 14 Sep 2016.
Livingston, W. C. (2000),:Chap. 14 in *Allen's Astrophysical Quantities, 4th Edition*, ed. A. N. Cox, New York: Springer-Verlag.
Long, K. F. (2020). "Comments on the Volitional Motion of Stars via Self-Thrusting of Stellar Winds and Coronal Mass Ejections." Paper in Draft.
Maller, A, (2007): "Halo Mergers, Galaxy Mergers, and Why Hubble Type Depends on Mass". Presented at *Formation and Evolution of Galaxy Disks*, Vatican Observatory, Rome, October 1-5, 2007.
Margolis, L. (2001): "The Conscious Cell". In *Cajal and Consciousness, Annals of the New York Academy of Sciences*, ed. P. J. Marjian, vol. 929, pp. 55-70.
Matloff, G. L. (2012): "Invited Commentary: Olaf Stapledon and Conscious Stars". In *JBIS*, vol. 65, 5-6.
Matloff, G. (2015): *Starlight, Starbright: Are Stars Conscious?*. Norwich, UK: Curtis Press.

Matloff, G. L. (2015a): "The Nonlocality of Parenago's Discontinuity and Universal Self-Organization". In *Axiom: The Journal of the Initiative for Interstellar Studies*, vol. 1, 14-19. Also presented at both International Academy of Astronautics (IAA) Symposium on the Future of Space Exploration: Towards New Global Programmes, Turin, Italy, July 7-9, 2015.

Matloff, G. L. (2016): "Can Panpsychism Become an Observational Science" In *Journal of Consciousness Exploration and Research*, vol. 7, 524-543.

Matloff, G. L. (March, 2017): "Stellar Consciousness: Can Panpsychism Emerge as an Observational Science", In *EdgeScience*, Number 29, 15-20.

Matloff, G. L., (2019): "Is the Kuiper Belt Inhabited?", *JBIS,* vol. 72, 382-385.

Mullaney J. & Tirion, W. (2011): The Cambridge Atlas of Herschel Objects. Cambridge UK: Cambridge University Press.

Murdzek, R. and Iftimie, O. (2008): "The Self-Organizing Universe", in *Romanian Journal of Physics*, vol. 53, 601-606.

Namouni, F. (2007): "On the Flaring of Jet-Sustaining Accretion Disks". In *Astrophysical Journal,* vol. 659, 1505-1510.

Penrose, R, and Hameroff, S. (2001): "Consciousness in the Universe: Neuroscience, Quantum Space-Time Geometry and the Orch OR Theory.", in *Journal of Cosmology*, vol. 14 (http:/ journalofcosmology.com/Consciousness160.html

Rense, W. A. & Hynek, J. A. (1937): "Photometry of the G Band in Representative Stellar Spectra". In *Astrophysical Journal*, vol. 86, 460-469

Russell, H. R. (1934): "Molecules in the Sun and Stars". In *Astrophysical Journal*, vol. 79, 317- 342.

Sheldrake, R. (2018): "Is the Sun Conscious?". Presented at Electric Universe Society meeting, Bath UK ((July 7, 2018). This lecture can be accessed using YouTube.

Swings, P. & Struve (1932): The Bands of CH and CN in Stellar Spectra" In *Physical Review*, vol. 39, 142-150.

Tokunaga, A. T. (2000): "Infrared Astronomy", Chap. 7 in *Allen's Astrophysical Quantities, 4th Edition*, ed. A. N. Cox, New York: Springer-Verlag.

Tononi, G. (2012a): "Integrated Information Theory of Consciousness". In *Archives Italiennes de Biologie*, vol. 150, 290-326.

Tononi, G. 2012b: *PHI: A Voyage from the Brain to the Sou*l. New York: Pantheon.

Tsuji, T. (1986): "Molecules in Stars". In *Annual Review of Astronomy and Astrophysics,* vol. 24, 197-234.

Van de Bogart, W. G. (2017): "Orchestration of Consciousness: Consciousness and Electronic Music Applied to Xenolinguistics". Presented at Consciousness Reframed Conference, Beijing, China, November 25-27, 2017.

Vidal, C. 2014. *The Beginning and the End: The Meaning of Life in a Cosmological Perspective.* New York: Springer.

Vidal, C. 2016. Stellivore Extraterrestrials: Binary Stars as Living Systems, in *Acta Astronautica*, vol. 128, 251-256.

Vityazev, V. V., Popov, A. V., Tsvetkov, A. S., Petrov, S. D., Trofimov, D. A., and Kiyaev, V. I. (2018): "New Features of Parenago's Discontinuity from Gaia DR1 Data". In *Astronomy Letters*, vol. 44, 629-644.

Walker, E. H., (1970): "The Nature of Consciousness." In *Mathematical Biosciences*, vol. 7, 131-178.

Walker, E. H. (1999): *The Physics of Consciousness*. Cambridge MA: Perseus Books.