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STARing the Sky in the Face: Recognizing the Constellations in a Sky Which Does not Have Any

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Abstract The analysis described here attempts to estimate the range within which we use our tendency to see a familiar shape in a disordered pattern (*Pareidolia*). The study starts with the proof that the stars visible to the naked eye are arranged following a Poisson distribution, a concept that I use to understand why, in the works of several artists, the stars appear so clustered that they form an excess in the number of possible constellations. This analysis should be considered only preliminary and will be completed soon by further investigation which I describe at the end of this paper.

1 Introduction

This paper has two "biological parents". One is a concept that has been gathering dust in my head since the period of my bachelor thesis: "In the night sky, the stars visible to the naked eye represent an excellent example of a Poissonian distribution of points".

The other parent is an analysis I could make, thanks to my fairly rich personal library (Adamo 2014), on how some of the most famous cartoonists have represented the night sky in their works.

In these artists' books, I noticed the tendency to draw the stellar points often so close to each other, as to return the idea of a sky which is much more populated by constellations than in real life. A big help to my analysis came from the fact that often in those boards, in addition to stars, the artist represented also the Moon, which has about a half degree angular width. When our satellite is present as in the Fig. 1, we can use it as an indicator of the width of a *pencil beam survey*: it tells us

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Fig. 1 A frame drawed by G. Alessandrini

what the artist's perception of an angular extent of about half a degree is, and thus allows us to measure the relative distances of stellar points drawn in the same board.

Understanding why this happens seemed very challenging to me, and I have found that there are several reasons for the presence of such a trend in many different authors' boards, some easier to understand than others.

An analysis of some of them, for example, has shown that the cartoonist, after drawing a white dot (the star) on a black background (the sky), simply moved his hand fast and slightly. This is indicated by the fact that the stars drawn by those cartoonists often are all of the same magnitude, which tells us how they used the same pen, or a *Photoshop* brush of the same thickness.

I claim this from personal experience and also because other professionals confirmed my idea: usually this happens in the attempt to shorten the delivery time of a work whose primary (or even secondary) purpose certainly was not to educate readers on the true distribution of stars in the sky.

The editorial times are always so tight that the artist is always bound by the mandatory terms under its contract, often at the expense of the quality of some boards, if not of the entire publication.

This does not apply to the famous cartoonist who can afford frequent violations of the terms of his contract, and therefore can spend more time on the effort to represent that piece of the world with a certain realism, with exactly the same zeal with which he has always studied and represented a horse, a palace, the folds of a dress, an airplane, etc. My question "why are you not as keen to correctly depict the stars, which often are the natural background of the scenes you draw?", I think, is more than legitimate, and it would be interesting to investigate what are the artist's mental processes when selecting the elements of a scene—other than the obvious ones such as, for example, the main characters of the story—on which to focus the pictorial attention.

Another possible explanation for this trend to depict an excess of constellations, shown by cartoonists and by some painters, may derive from the real existence of a stronger correlation between the dots in the sky which we scientist have not noticed.

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So it may be that, in the absence of a real analysis of the distribution of stars visible to the naked eye, we tend to believe erroneously that their position on the celestial sphere is random, while the eye of the artists, who I usually trust, spontaneously captures a real correlation between those light points.

It is unlikely that astronomers, who are used to seeing always and only the same constellations, may express the need to see others; but a cartoonist and, in general, an artist who is not also an amateur astronomer, could perhaps experience this kind of impulse and follow it. If so, I would like to understand where this impulse comes from and if, by chance, it can be explained just by the fact that the stars turn out not to be distributed in a random way.

2 Looking for the Real Distribution of Visible Stars

In a search of the literature to see whether an analysis of the distribution of stars in the sky has ever been carried out, I have not found anything significant other than phrases like "assuming a random distribution for the stars" or quick, cryptic references to the fact that things are just as the authors had stated earlier in the paper: according to all the authors I have consulted, stars in the sky occupy positions which follow a Poisson distribution. I then decided to check out this assumption using a program written by Alberto Cappi[1] to calculate the *two points angular correlation function* $w(\theta)$ for groups of galaxies. The choice to use only the *two points angular correlation function* $w(\theta)$ and not the most popular $\xi(r)$, the *spatial two points correlation function* is due to the fact that, observing the sky with the naked eye and seeing the constellations that enter our field of view, we always ignore the distances of those stars from our position.

One should be reminded that the *two points angular correlation function* $w(\theta)$ is a statistical tool which, starting from a point chosen in the ensemble, allows us to calculate the excess of probability of finding coplanar neighbors of the given point, at a previously established angular distance θ. If this function returns an average value of 1, it means that the points are not randomly distributed, presenting quite a strong tendency to cluster. If instead the $w(\theta)$ is, on average, equal or close to zero, it follows that the set of points is distributed at random. Finally, if the correlation function has a negative value, we will say that the whole set is not correlated.

The goal of this analysis is to measure how the constellations are formed by stars with a high probability of being seen as connected because, projected on the sky, they are really close to each other; they could be so close to stimulate in us the belief that they really draw the forms to which we have been referring for about 5000 years when speaking of "astrological signs". Each time it is run, the program applies the procedure starting from each of the N points of the ensemble considered

[1]Osservatorio Astronomico di Bologna (INAF); Laboratoire Lagrange (Observatoire de la Côte d'Azur, Nice).

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and, once the *i-th* analysis is conducted for a certain value θ_i of the angular distance and has ended, starting the $i + 1$ cycle, the program increases the former angular distance θ_i adding to it a fixed quantity chosen by the user. This way the procedure goes on until—and here the analysis ends—it reaches the angular size of the total area occupied by the whole set of points. At each step, the program then applies a comparison with a fictitious catalog of ideal star points distributed in a very random way—this means that sure it has a $w(\theta)$ equal to zero, unambiguous proof of it being a Poisson distribution—on a surface area equivalent to that of the sky. The final calculation of the correlation of the points (stars) belonging to the real catalogue is then performed using the following relationship:

$$\mathrm{w}(\theta) = [\mathrm{N_{SS}}(\theta)/\mathrm{N_{RR}}] - 1$$

where $\mathrm{N_{SS}}$ is the number of star-star pairs separated by a given θ angle, and $\mathrm{N_{RR}}$ is the number of pairs of fictitious star points distributed randomly and separated by the same angle.

3 The Catalogue

I have then asked Alberto Cappi to use his program on a star catalog, the BSC5P, which is the fifth edition of the *Bright Star Catalogue* (Hoffleit and Warren 1991), restricting the analysis to the stars with apparent magnitude less than or equal to 6 (strictly speaking, all and only the stars visible to the naked eye). For the purposes of this first work, I did not need to consider the apparent magnitude differences between the stars of the catalog, focussing my attention only on their position. It is my intention to soon expand this work using this same program which our colleague Federico Marulli has modified, allowing us to weight the correlation with the values of the various known apparent magnitudes and checking whether or not there is a higher correlation between stars of different apparent magnitude.

To perform the analysis, I have considered only the galactic coordinates of any single star, dividing them in the following four different sets:

(1) stars belonging to the northern galactic hemisphere (0° ≤ BII ≤ 90°, total number of objects = 2352, density (N/area) = 0.19600E + 03);
(2) stars south of the galactic plane (−90° ≤ BII ≤ 0°, total number of objects = 2752, density (N/area) = 0.22933E + 03);
(3) stars positioned to the north of the strip of the galaxy (30° ≤ BII ≤ 90°, total number of objects: 942, density (N/area) = 0.78500E + 02) (I have assumed an approximative thickness of the disc of Milky Way as seen from our position equal to 60°, 30° for each hemisphere);
(4) stars south of the galaxy strip (−90° ≤ BII ≤ −30°, total number of objects = 986, density (N/area) = 0.82167E + 02).

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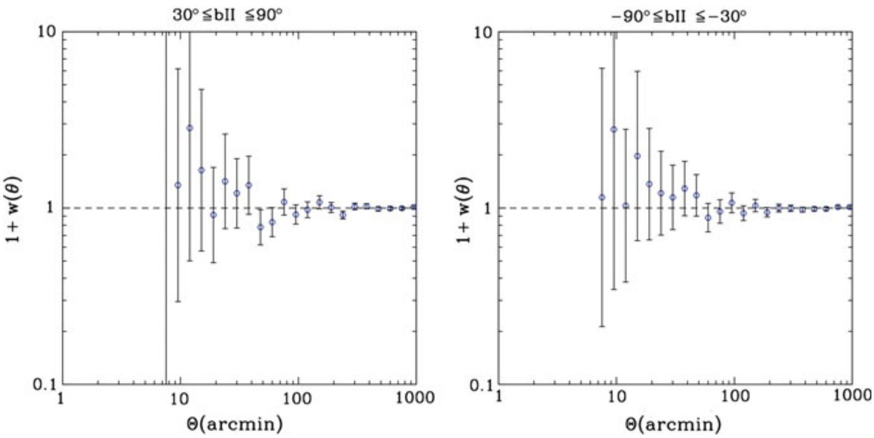

Fig. 2 *Left* correlation of stars positioned to the north of the strip of the galaxy (30° BII ≤ 90°); *Right* correlation of stars south of the galaxy strip (−90° ≤ BII ≤ −30°)

I have done this with the purpose of quantifying the gravitational noise (in this study, I like to regard it this way, but we know that it is a "signal") given by the presence of the galactic plane, especially in the milky band that we see in the sky. It is well known that the Milky Way strip is part of the arm of the galactic disk of stars to which our Sun belongs, observed from a distance that enables us to appreciate its thickness in perspective: an area of the sky crushed in a few degrees of galactic latitude. The very fact that many stars belong to that strip, which is a few tens of degrees thick, causes the eye to see, if not always constellations, at least a correlation among those stars which are really close to each other.

The result of the analysis carried out across the sky, excluding the stars contained in the strip of the Milky Way, can be assessed from the graph shown in Fig. 2. The correlation between the stars is appreciable only at angular distances of the order of a few tens of arc minutes. These are distances similar to the size of the smaller asterisms, many of which do not contain stars of particular brilliance and are also among the most difficult to note: the *Equuleus*, the *Pleiades*, the *Arrow*, the *Dolphin*. As can be seen from the graph, observing how the w(θ) function goes quickly to zero, when I write "appreciable", I simply mean that, even if only slightly, the correlation function assumes non-zero values. As you can see, as the range increases, the sampled correlation decreases rapidly, and already on scales of the order of a degree it is practically zero. Another consideration that emerges from the study of Fig. 2: there is no substantial difference between the two hemispheres above and below the center line that, running through the Milky Way, defines the galactic plane from which I considered stellar positions.

If you decide to include in the correlation analysis also the stars belonging to the galactic plane strip, you get, as expected, a slightly stronger correlation (Fig. 3). In any case, the results do not differ much from the previous case in which the Milky Way had been excluded.

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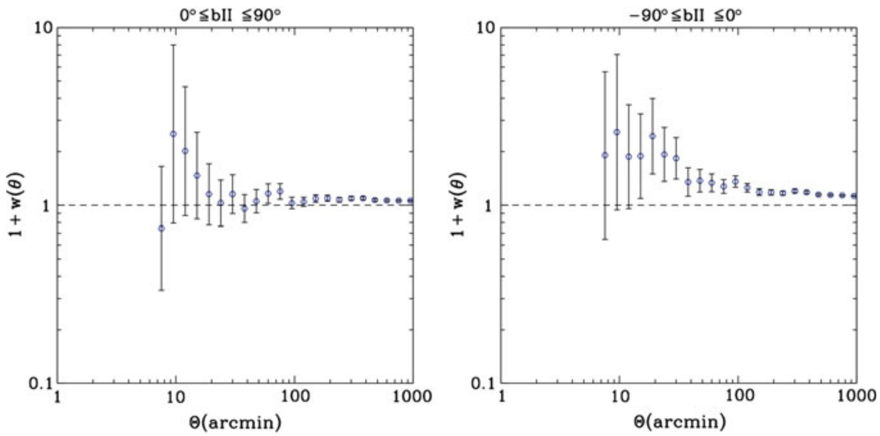

Fig. 3 *Left* correlation 1 + w(θ) of stars belonging to the northern galactic hemisphere (0° ≤ BII ≤ 90°); *Right* correlation 1 + w(θ) of stars south of the galactic plane (−90° ≤ BII ≤ 0°)

By overlaying the results of both correlation studies (Fig. 4), it is easily seen from the graph that at the great angular scales of the order of tenths of degrees that characterize the size of the largest and often more famous constellations, the stars do not appear correlated. This result, obtained starting from the idea of assessing the plausibility of the heavens drawed in some works of cartoonists and painters, tells us that these artists are "victims", like anybody else, of a perceptual error widespread in our species, that leads us to overestimate the correlations between stars in the sky.[2] I now assume that a possible assessment of our ability to see the correlation between points can be approximatively measured using an angle slightly larger than the resolving power of the eye (≈1').

In the past, to understand if you had a sight of 20/20, you would have to try to resolve by naked eye the two stars Mizar and Alcor which, as we now know very well, are 11′48″ apart. As Bohigian in his paper demonstrates (Bohigian 2008), that test is entirely equivalent, if not even more reliable, to the classic Snellen test we face every time we go to an eye clinic. As proof of the fact that, as a species, humans cannot avoid attaching special significance to manifestations of reality that appear significant, we note that various cultures have regarded those two very close

[2]Among those drawn by cartoonists, painters and illustrators, the best skies I found are those for which the artist used a technique that renders a true Poisson distribution of the painted stars. This is an old trick that consists in using a toothbrush previously dipped in a layer of white paint. By suspending it over the dark background meant to represent the night sky, the bristles are rubbed with a thumb, causing a splash of paint drops that will distribute randomly on the paper or canvas. This technique has the added benefit of creating also certain randomness in the distribution of magnitudes of the various points. It is used more by illustrators than by cartoonists, because it requires large areas (the traditional comic strip occupies small spaces), and/or appropriate masking of the other elements of the image on which no drop must fall.

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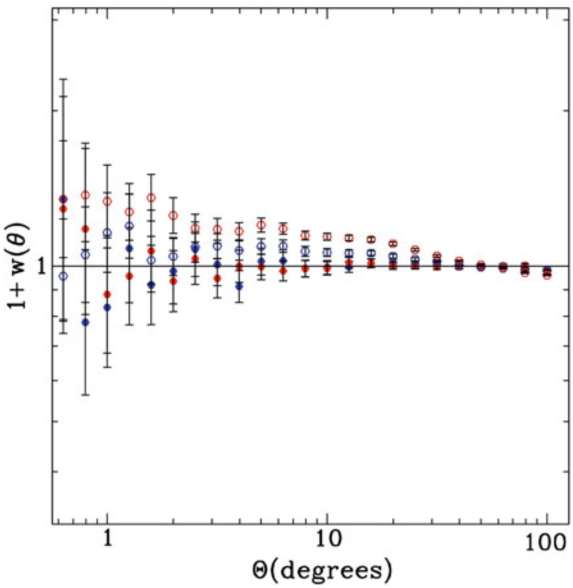

Fig. 4 General correlation $1 + w(\theta)$ between the angular positions of visible stars. *Blue circles* $0° \leq$ BII $\leq 90°$; *blue dots* $30° \leq$ BII $\leq 90°$; *red circles* $-90° \leq$ BII $\leq 0°$; *red dots* $-90° \leq$ BII $\leq -30°$

stars as (a) a squaw with her baby on her shoulders; (b) an indian hunter carrying a saucepan; (c) a small rider on his horse's rump.

Having noted this strong tendency to see histories and meanings even in a minimal segment like the one seen joining the two stars of the so called *Big Dipper*, I was drawn to consider them as important asterisms, as well as the most extensive and well-known constellations. Moreover, the aforementioned *Dolphin* or the *Pleiades*, even if very small stellar clusters, confirm this *attaching tale*-tendency of the human brain. Moreover, if this still is not convincing enough, let us remember that, for example, the constellation of *Aries*, larger than those just mentioned, is built around a simple junction between two very simple segments. This graphic simplicity has never been a problem for those who insisted (and continue to do so) on fleshing out that minimum skeleton, imagining around it the development of a curious cross-breed between a goat and a fish, making it a full sign with astrological meanings ranging well beyond the one expressed graphically.

4 Pareidolia

Considering all the graphs showed before, we also note that at the scale of about one-sixth/one third of a degree they all shows that our eye actually could catch a real correlation doomed to flounder at higher scales. Remembering the meanings given to those two stars and the medical use that ancient people have done of the capability of a human eye to resolve those two stars, I would propose to consider

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that distance between Mizar and Alcor not only as a fairly accurate measure of the resolving power of the human eye, but also as the lower limit of our ability to see shapes arranged in a pattern that, in general, apart from some small deviations, appears rather messy (Poisson): an ability—perhaps I should say a "trend"—I have already studied in the past (Adamo 2009, 2013) which goes by the name of *pareidolia*. There is thus a *geometrical* pareidolia, but also—and perhaps this is the real trend that leads us to discern correlations—a different kind of it that I would call "value pareidolia" or "narrative pareidolia".

At this point, it is necessary to say that, in conducting this analysis, I dealt only with those constellation that we use in our western culture to divide the sky into manageable zones. I know that, for instance, the Chinese constellations can reach a minimum size for the distances between their stars that, they say, are shorter than the Mizar-Alcor angular distance. I could not find reliable data on the size of the asterisms of that distant culture and so I plan to talk about them in a future work when I will find precise data about them.

4.1 Looking for the Range in Which Pareidolia Acts

If you accept my idea of considering at a first approximation the angular distance between Mizar and Alcor as a measure of the minimum distance at which the pareidolia acts, the next question comes in a natural way: what is the maximum size at which our visual system perceives a correlation between related and/or even uncorrelated objects? Studying the literature, I found no answer to this simple question. There are careful studies of how pareidolia acts in the complicated case in which the brain tries to recognize a face to which a pattern of random Gaussian bivariate blobs has been superposed (Andrews et al. 2002; Chauvin et al. 2005; Gosselin and Schyns 2003; Howard and Rogers 1996; Liu et al. 2010, 2014; Rieth et al. 2011). Another trend in these studies concerns how we grasp the differences between the different characteristics of human faces, but I have not found anything quantifying the maximum angular dimension within which our brain creates fictitious correlations between objects that are not related.

At this point, given that (1) humankind never showed a tendency to consider a *meta-constellation* of angular size comparable to that of the portion of the sky visible in a single glance and, by contrast, (2) humans have always shown a marked tendency to see in a large sky field many of constellations of different angular sizes, ideally fragmenting the field of view, in order to understand which is the range of action of our brain while it "sees" in the sky the objects that from Figs. 1 and 2 we know are not real, I will just consider the larger constellations that have a size smaller than or equal to our visual field.

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5 Field of View of the Human Eye

For the non-trivial evaluation of what the extensive human field of vision is, I was advised to read the following passage extracted from the book “Binocular vision and stereopsis”:

> The monocular visual field of the stationary eye extends about 95° in the temporal direction and about 56° in the nasal direction (Fischer and Wagenaar 1954). The total visual field is the solid angle subtended at a point midway between the two eyes by All Those points in space visible to either eye or both. It extends laterally about 190° in humans When the eyes are stationary and about 290° if they are allowed to move. If the head moves on the stationary body, the total visual field extends through almost 360°. The binocular visual field is the portion of the total field Within Which an object must lie to be visible to Both eyes for a given position of the eyes. The binocular visual field is flanked by two monocular sectors Within Which objects are visible to only one eye. Each monocular sector extends about 37° laterally from the temporal boundary of the orbital ridge to the boundary of the binocular field at infinity. Each monocular visual field is the sum of the binocular field and the monocular sector For That eye. The left and right boundaries of the binocular field, formed by the nose, are about 114° apart When the eyes converge symmetrically and less When They converge on an eccentric point. The horizontal extent of the binocular visual field in the 3-month-old human infant Has Been estimated as 60° and that in the 4-month-old infant as 80° (Finlay et al. 1982). With the eyes in a straight ahead position, the upper boundary of the binocular field, formed by the orbital ridges, extends about 50° above the line of sight. The lower boundary extends about 75° below the line of sight. The blind spot, the region where the optic nerve leaves the eye, is devoid of receptors. The projection of the blind spot in the visual field is about 3° in diameter and about 12°–15° falls into the temporal hemifield. Hence, there are two islands Within the monocular binocular field, one on each side of the point of convergence. The field of binocular fixation is the area Within Which binocular fixation is possible by moving the eyes but not the head (Sheni and Remole 1986).

From reading this passage and from a comparison of the numbers mentioned in it, the average amplitude, minimum and maximum of forty-eight ancient constellations, we see clearly how they are perfectly contained in the solid angle subtended by our gaze. To obtain the amplitudes of the constellations, I have used the atlas by Eckhard and Uwe (2006) that for every constellation, gives the coordinates of the “higher star and of the lower star”, as well as of the “rightmost” and “of the leftmost”. By calculating the differences between δ_{Max} and δ_{Min} and between AR_{max} and AR_{min}, multiplying the latter difference by the cosine of δ_{Min}, I found the “real”[3] amplitudes of fifty ancient constellations (originally there were forty-eight, but the *Argo ship,* perhaps considered too big to be seen at a glance, was divided by Nicolas Louis de Lacaille (1713–1762) into three different parts: *Puppis*, *Carina* and *Vela*). The maximum amplitude that occurs in RA is $\Delta AR_{max} = 116.86°$, the minimum is 6.2. The maximum amplitude is $\Delta\delta_{max} = 56.5°$ while the minimum is 5.5. The average sizes instead are $\langle AR \rangle = 36.38$ and

[3]I could not use the areas assigned to each constellation by Dalporte because they exceed the dimensions of the figures drawn in the sky using the stars. For obvious reasons, I am interested only in the areas included in the starry perimeters.

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$\langle\delta\rangle = 28.28°$. There are some exceptions. For instance the *Hydra* constellation, by far the largest one, is not completely visible at a glance because, if one starts observing it at our latitudes, it turns out that it stretches below our horizon, where we just cannot see anything from here. In this case, ancient sailors and merchants have implemented an ideal extension of this constellation that, seen from here, appears to end at the horizon. Travelling south, they realized they could consider *Hydra* larger than previously known, due to the presence of other southern stars that could be easily considered as its extension. In general, a generic constellation is perfectly contained in the visual field of the observer, who often sees more than one simultaneously.

6 Toward the High Limit of Pareidolia

At this point, I would try to propose an upper limit to the physical range within which our pareidolia acts: I propose it is equal to the size of a theoretical constellation that is as wide as the widest of the known ones, 116.86°, and as high as the one which has the largest declination range, 56.5°. If one wishes to consider that not everybody has the same visual skills, one may assume that in reality the upper limit of our ability to see correlations even where there are none, is more or less given by a constellation that has an average size, 36.38° wide in right ascension and 28.28° in declination.

7 Future Developments of the Research: Percolation

It is well known that when we look at a face, at an object, at the sky, etc., even though we are sure to keep our eyes well fixed on what we observe, we make a series of tiny, fast movements called "saccades" which put the different parts of what we observe in correspondence with the *fovea*, the most sensitive part of our inner eye. In other words, what we do is to unite the points of an object on which we focus our attention to reconstruct its general appearance. To understand how our brain works when we are sure to gaze at the constellations, I want to continue the present analysis again thanks to another of Alberto Cappi's programs, that analyzes a set of elements implementing the so-called "percolation": it starts from any point selected in the ensemble and then it moves, by a step of amplitude previously decided by the user, in the direction of the first star that falls within the circle of radius equal to the step itself. Our brain, once the eyes move (saccades) between various stellar points, perform a continuous comparison between the geometry of the brightest star distribution and various mental images that it possesses in its memory. In the case of the ancient constellations these images are bulls, bears, lions, and all the other animals, characters and objects we usually see in the sky. By analogy, using the percolation, the program that I want to use will have to perform a

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comparison between the points of a catalogue and a collection of simple templates such as rectangles, circles and triangles.

Percolation will need to be weighed in the sense that, if two stars of different brightness fall in the circle of radius equal to the step value, the program will choose to go to the brighter one. In this way, what I expect is to find a value of the step (sensitivity) that allows the program to find shapes between the points of a star catalog of sizes comparable to those of ancient constellations listed by Ptolemy in his Almagest. Such a result could have interesting implications in the study of the so-called *pattern recognition problem*, which refers to the problem of figuring out how to make a computer system able to recognize a particular shape. A natural application of this research could then be its implementation in optical systems of industrial machinery.

8 Conclusions

In this paper which more or less travels on the same path traced by Bohigian's, I have used the sky not as an object of study, but as an instrument to understand our "human universe". Perhaps everytime we discover that astronomy could help us in understanding our society, our history, our physiology etc., we can talk of a sort of "medical astronomy" or about a "self-astronomy" or even a "social astronomy".

I have analyzed the possible physical range within which the visual pareidolia occurs, starting from the act of viewing which uses the "eye" medium, a powerful instrument but one which, as we all know, is also affected by some limitations. At this point, I would like to investigate if there is also a "tactile pareidolia" in blind observers, and if so in which range it acts: I suspect that visually impaired people divide the field in which they move in touchable, recognizable and comparable fractions (I would call them "object constellations"). In these space fractions they look for recognizable (archetypal?) patterns of objects the same way we manage the visual field in handy fractions of the sky (constellations) looking for well known shapes.

Continuing by analogy, I believe that we are able to use also a sort of *neural pareidolia* which allows us to connect together apparently unrelated thoughts: sometimes it happens that someone catches a possible correlation between different, distant concepts, while others continue to consider them well separate. This kind of possible *neural pareidolia* clearly merges with the more popular *concept* of *intuition* or in that of *intelligence,* and I strongly trust in the progress of neuroscience that, I hope, will soon tell us which, if any and if measurable, is the upper limit of what we can imagine, perceive, understand of the world in which we all come together. I think that our maximum capability to connect far concepts will be found to be comparable in some way to the measure of our skull dimensions which impose an upper geometrical limit to the maximum distances between brain neurons that, after receiving an external stimulus, activate together or are directly connected to each other by a cause-effect relation. Another possible measure could be in the number density of neurons working together on the same stimuli,

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and a first "proof" of the existence of such a limited capability could be present in our way of designing the chips of our computers, making them more and more dense of "wires", as well as in our tendency to pull the web to extreme distances and local ramifications. This happens maybe because humans tend to group together in the attempt to extend the limited physical size of their individual brain (and thoughts), creating connections between their ideas and opinions that otherwise would be limited by lives spent staying alone. We all share ideas and values and everyone is at the same time a generator, a container, a vehicle and an antenna of concepts. History teaches us that interacting people don't appear always as guided by some form of superior intelligence. Perhaps, like the perception of constellations, there is a maximum size of human ensembles within which one can reasonably hope to see a real growth of the democratic values and of the behaviour of each component. In contrast, exceeding that limit, we always measure a worsening: perhaps the "field of view" of the entire human assembly is too large to work in a good way and we all need to break down the society into states, regions, collectives, families, parties, clubs, etc. If true, this could explain why some are still racist while others simply believe in some form of "federalism".

Perhaps machine evolution one day will frighten us so much to stimulate us to learn how to live in a real democratic way with all other humans on the planet. Another possibility is that we will expand the size of our "democratic field of view" learning to think on a larger social scale only when we will meet an alien civilization: this extraordinary event could stimulate a social dynamic—something similar to a fractal—convincing us to use our Darwinian behaviour against the "others" and not against ourselves. In that case, we will all have a single, well known face but pareidolia will not help us to recognize another specie's face.

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