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Diagrams and alien ways of thinking

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HIGHLIGHTS

- Connects C. S. Peirce's work with recent advances in astronomy and astrobiology.
- Explores the potential of diagrammatic reasoning for METI research.
- Carves out a new moderate option in the great transmission debate.
- Discusses some of the features unique to diagrammatic reasoning.
- Doubles as an introduction to the notation and derivations of Existential Graphs.

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ABSTRACT

The recent wave of data on exoplanets lends support to METI ventures (Messaging to Extra-Terrestrial Intelligence), insofar as the more exoplanets we find, the more likely it is that "exominds" await our messages. Yet, despite these astronomical advances, there are presently no well-confirmed tests against which to check the design of interstellar messages. In the meantime, the best we can do is distance ourselves from terracentric assumptions. There is no reason, for example, to assume that all inferential abilities are language-like. With that in mind, I argue that logical reasoning does not have to be couched in symbolic notation. In diagrammatic reasoning, inferences are underwritten, not by rules, but by transformations of self-same qualitative signs. I use the Existential Graphs of C. S. Peirce to show this. Since diagrams are less dependent on convention and might even be generalized to cover non-visual senses, I argue that METI researchers should add some form of diagrammatic representations to their repertoire. Doing so can shed light, not just on alien minds, but on the deepest structures of reasoning itself.

1. Introduction

Is extraterrestrial intelligence out there? And if so, how would we communicate and reason with it? In 1820, Carl Friedrich Gauss—the mathematician who gave us the Gaussian curve—had the idea of clear-cutting an enormous patch of forest in the shape of a right-angled triangle. His intent was to create a diagrammatic representation of the Pythagorean Theorem so large that it would be seen from outer space, notably from the moon or Mars. The historical accuracy of this story is actually hard to confirm (Crowe, 1986, pp. 204–207). Yet, apocryphal or not, two things stand out. The first is the aspiration to make contact with intelligent aliens. The second is the assumption that the best way to do this is by employing diagrams. Naturally, I find Gauss' approach naive. Still, I want to retain both his interest in aliens and his reliance on diagrams. However, I will be taking my lead, not from Gauss, but from a fellow mathematician who had an unparalleled grasp of semiotics, Charles Sanders Peirce.

Peirce took an active interest in astronomy. In fact, Peirce's early participation in astronomical photography may have fueled his philosophical thinking about diagrams (Hoel, 2016, pp. 63–65). Peirce was a polymath, but he identified principally as a logician. Yet, what Peirce understood by "logic" was much broader than the usual sense, since he equated logic with the study of signs (1931–58, vol. 2, para. 227). His conception of "sign" was in turn quite broad, since he defined the sign as any triadic relation where something stands for something else to something (1931–58, vol. 2, para. 228). Because of this broad conception, Peirce averred that "it has never been in my power to study anything,—mathematics, ethics, metaphysics, gravitation, thermodynamics, optics, chemistry, comparative anatomy, astronomy, psychology, phonetics, economics, the history of science, whist, men and women, wine, metrology, except as a study of semiotic" (in Hardwick, 1977, pp. 85–86).

Those who know Peirce as the founder of American Pragmatism rarely appreciate how closely his pragmatism was tied to his theory of

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signs and logic. As a scientist disinclined to take sceptical doubts seriously, Peirce was fascinated by the undeniable reality of physical happenings. Even so, Peirce saw that some causal events are preceded by deliberation and aimed at a goal. So, even though he took here-and-now practicality to be an essential ingredient of knowledge, he insisted that a full account of the mind and meaning must attend, not just to what *is* done, but also to what *can* be done and what *tends to* be done (Legg & Misak, 2016). A valid logical pattern, for example, is a habit-like tendency that ranges over more than one token instance. Likewise, invalid logical patterns rest on contradictions which cannot be put into practice. Intelligent minds experiment with signs to figure out which combinations of ideas work. So, while logic can be seen narrowly as a clever instrument devised to carry out inferences more efficiently, "[i]n Peirce's hands, logic and cognition become virtually synonymous" (Pietarinen, 2016, p. 121).

All sorts of signs can be used to guide reasoning, but some of the most powerful are diagrams. Diagrams exhibit relations between their parts that match the relations between the parts of their (real or hypothetical) object(s). Hence, a diagram is a "degenerate" icon, since only its relations, not its relata, can be credited with a resemblance (Peirce, 1931–58, vol. 2, para. 277). Think of a timeline. The legend that lets temporal durations be represented geometrically is arbitrary, but we can nevertheless use fixed ratios to infer, say, double durations from double lengths (Champagne, 2016b). Such inferences are deductive, but one of the distinguishing properties of a similarity-based sign like a diagram is that "by the direct observation of it other truths concerning its object can be discovered than those which suffice to determine its construction" (Peirce, 1931–58, vol. 2, para. 279; see however the caveat in Champagne, 2018a, pp. 59–60).

Peirce devised a sophisticated logical system that relied principally on diagrams. I will go over the basics of that system, called Existential Graphs. Peirce held that, "[i]f logicians would only embrace this [diagrammatic] method [...] there would soon be such an advance in logic that every science would feel the benefit of it" (1931–58, vol. 4, para. 571). As we shall see, one surprising upshot of Peirce's account is that it can help us anticipate how intelligent extraterrestrials might think. In current METI research, there are serious questions about message construction and content, so hopefully the present contribution can be of practical use in these efforts. My aim, then, is twofold: I want to demonstrate the independent merit of diagrammatic logic and show how it can advance current METI research.

2. METI and the current state of planetary science

I will be calling on the ideas of a noted pragmatist to forecast how intelligent extraterrestrials might think, but some might view this undertaking as a paradigm case of impracticality. I am not so sure. We know full well that planets orbit our sun, so it takes only a modest induction to infer that other planets orbit other stars too. Planets emit only faint radiation, so traditional astronomical instruments like radio telescopes cannot directly confirm this probable inference. Recently though, scientists have devised several ways to indirectly detect such planets. The radial velocity method, for instance, exploits the fact that a star will wobble slightly because of the gravitational pull of the planet(s) orbiting it (Lovis & Fischer, 2010), whereas the transit photometry method exploits the fact that a star's brightness will dim slightly whenever a planet passes between that star and the Earth (Deeg & Alonso, 2018). Each method has its shortcomings. For one thing, the variations tracked by instruments are truly slight, so any defective calibration and/or computation can lead to false positives. Still, when the results of several methods point to a planet with a same orbital period, we can be confident that those methods are tracking something real.

The term "exoplanet", which is a contraction of "extrasolar planet", was adopted by the International Astronomical Union to capture these new findings. The first exoplanet was confirmed in 1992 (Wolszczan & Frail, 1992). We have since tracked thousands of planets outside of our solar system. The latest research reveals temperate planets relatively near to us (Gillon et al., 2017). This tidal wave of scientific research is (or at least ought to be) reshaping our worldview. We can now tell our children that, for every star one sees, there is at least one planet orbiting it. As a result, "today's planetary scientists refigure the night sky as teeming with *worlds*" (Messeri, 2016, p. 1). For anyone interested in knowing more about nature and our place in it, this is a game-changer.

The confirmation of exoplanets requires multiple validation methods, "[b]ut this approach is expensive because it requires a large amount of ground-based telescope time" (Cameron, 2012, p. 49). The costs of current astronomical research are justified in part by the hope of eventually discovering a habitable planet suitable for human colonization (Seager, 2013). The United States government even held a congressional hearing on "Exoplanet discoveries: Have we found other Earths?" (US Government Publishing Office, 2013). While one can certainly search for a vacant second home, another motivation can be to contact intelligent neighbours. METI—Messaging to Extra-Terrestrial Intelligence—once referred to as "active SETI" (Search for Extra-Terrestrial Intelligence), has thus become an autonomous research program (Zaitsev, 2008).

The results of current planetary science benefit METI research in two ways. First, the sheer number of exoplanets makes the very idea of METI more plausible. To ascertain the likelihood of civilizations capable of emitting detectable electromagnetic signals, we can use a series of fractions proposed by the astronomer Frank Drake in 1961. Although the various numerical values plugged into the Drake Equation remain the object of considerable debate (see Kukla, 2001; Vakoch & Dowd, 2015), one of the first hurdles to be crossed is the number of stars that harbour planetary systems. Naturally, the more exoplanets we find, the more likely it is that "exominds" await our messages. This is in fact where the Drake Equation has recently tilted. It used to be that "rare Earth scepticism" was the best explanation, but things have now changed, so "conclusions reached through bad cosmological input cannot stay the same when the input changes" (Ćirković, 2014, p. 541).

The newfound ability to pinpoint where life-supporting exoplanets are also makes METI more efficient. Just like SETI, "[i]t may take another 40 years, or 400 years, or even 4000 years for this exploratory scientific effort to find what it seeks or to conclude that there is nothing to be found. On the other hand, it could succeed tomorrow, and that tantalizing possibility is why scientists and the lay-public alike remain enthusiastic about the search" (Tarter, 2001, pp. 511–512). Instead of sending signals everywhere, we can now target the worlds most likely to interpret the radio waves they receive. Our growing knowledge of exoplanets thereby decreases wasted efforts and increases the chances of making contact.

From an ethical standpoint, some have argued that it might be unwise to send out messages to recipients who have intentions unknown to us (Gertz, 2016). The astrophysicist Stephen Hawking even made popular headlines by warning against precociously contacting aliens. Given the lack of data, METI seems to be an inkblot onto which each person projects their own hopes or fears. One interesting argument is that the whole issue is a non-issue, since our existing television and radio broadcasts have already let the rest of the universe know that we are present and technologically active. The ethical concerns raised by Hawking and others are nevertheless worth considering. As such, "the great transmission debate" (Denning, 2010) should go on. That said, ethical concerns surrounding METI projects can be provisionally suspended by switching over to what I call "mock-METI", that is, an almost identical research program that stops short of actually sending out the messages it designs. Since it is unlikely that messaging with exominds would be a two-way communication happening in real time, mock-METI ends up being like genuine METI—minus the controversy.

In SETI research, one does not have to worry about the actual content of interstellar messages, since one is working to detect such messages on the receiving end. By contrast, in METI research, one actively takes charge of the emission, so one must make tangible decisions about the content of the message(s). If a surmise about how aliens think turns out to be drastically wrong, then even a message that safely arrives at its destination would amount to little. Reality can be represented in more than one way, so the likelihood that exominds have a cognitive architecture similar to our own is quite slim (Gauker, 1993). This makes METI an epistemically riskier pursuit than SETI, taxing the human imagination to an even greater degree.

When gauging the likelihood of exominds, the big numbers that we feed into the Drake Equation certainly help. Even so, our inferences proceed from a lone instance (Mash, 1993, pp. 204–205). Our epistemic situation is thus less than ideal, since it gives us a target to model but no clue how to model it. As William James noted, a policy of risk-aversion can require that one keep one's mind "in suspense for ever" (1896, p. 339), while a different policy can deem that "the risk of being in error is a very small matter when compared with the blessings of real knowledge" (James, 1896). Clearly, if one is to learn something informative about exominds within one's lifetime, one must adopt the latter attitude. "The probability of success is difficult to estimate", but it is clear that if one does nothing "the chance of success is zero" (Cocconi & Morrison, 1959, p. 846). I for one am too curious about exominds to pass on the whole question.

Although there are presently no well-confirmed tests against which to check the design and transmission of interstellar messages, philosophical reflection can help to narrow the possibilities. Greek atomists, for instance, relied on abstract arguments because they had no other choice. There were no particle accelerators in ancient Greece. Even so, the ancient Greeks were not going to give up on their curiosity solely because they were born in the wrong era. Our current predicament with regards to exominds is essentially the same. We do not have the means to answer our questions, nor do we want to relinquish our thirst for knowledge. It could be argued that, if the ancient atomists had not pursued their interests from the armchair, the particle accelerators would have never come. Likewise, if we do not inquire in advance of the evidence, that evidence might never come. So, like early atomists, it makes sense to enlist philosophical methods.

Academically though, established fields like philosophy have been slow to adapt to the massive changes that are currently happening in planetary science. The non-profit organization METI International states that one of its primary objectives is to "[f]oster multidisciplinary research" that will attract "scholars from the natural sciences, social sciences, humanities, and arts" (http://www.meti.org/). Philosophy can bring truly distinctive ideas and methods to the conversation. We speak of "philosophy of mind" and not "philosophy of *the* mind" so as to not prejudge which mind we are talking about. METI research lets this broad view have tangible applications. Combined with philosophy's stewardship of logic, this puts the discipline in a privileged position.

Consider the problem of what should be the shared starting point for an intelligible exchange between our human minds and exominds. All sorts of things emit electromagnetic waves. Given that "detection of artificially generated electromagnetic waves remains the most likely mechanism of contact" between humans and intelligent extraterrestrials (Shuch, 2011, p. 9), we need to figure out the hallmark(s) of artificiality. In SETI and METI research, it is common to draw inspiration from mathematics or chemistry. Were one to receive a signal containing, say, a series of prime numbers (Pomerance, 2004) or some exact number associated with the atomic constitution of hydrogen (see Dumas, 2011, pp. 406–407), one could rightly infer that this was not a chance occurrence. This is a perfectly sensible surmise. Yet, the enthusiasm for mathematical and chemical starting points tends to occlude their defects.

Take, for example, the prime numbers. We assume that this sequence would stand out because, as far as we know, it does not occur in the natural world. However, it may be that some unknown natural phenomenon produces emissions that conform to the primes (in the same way that some plants and shells realize Fibonacci sequences). If exominds are privy to this phenomenon, then they will dismiss our carefully chosen data, for the same reason that we eventually dismissed the regular intervals we receive from pulsars. Those emissions were initially taken by astronomers to have an artificial origin. So, the lesson to be learned from pulsars is that any promising communicative strategy is always one natural phenomenon away from being converted into a false positive.

The distinctive chemical signature of hydrogen is also not fool proof. The standard argument for appealing to hydrogen is that, because this element is so prevalent, it is liable of having been studied by alien scientists. This inference rests on what is known as the "one world, one science" argument (Kukla, 2008; Rescher, 1985). However, owing to the same prevalence, exominds could just as easily take hydrogen-related patterns as a tell-tale sign that an emission was *not* intentionally emitted, writing off our message as, say, a bizarre but perfectly natural spectroscopy-like imprint (were they to believe that they are alone, this would be a respectable inference to the best explanation). These criticisms are not meant to gainsay the attractive communicative properties of hydrogen and primes—they do stand out. But, hopefully, the glitches I have just highlighted can loosen the hold that those options presently have on researchers' imaginations.

Another strategy—the one I want to promote here—consists in exploiting the basic patterns catalogued by logic. The patterns of logic are different from those of mathematics and chemistry. Even so, the relational motifs that we find, say, in valid deductions, presumably hold everywhere in the universe. Hence, logical inferences demonstrate the same universal scope that makes chemical and mathematical candidates attractive.

I do not want to advocate the pursuit of a logical approach at the expense of other approaches. Though an argument could be made that logic occupies a privileged metaphysical and epistemological position, it might be wiser to embed philosophy's contribution in what Vakoch calls the "dialogic model" of extraterrestrial messaging. In this model, "the goal is not to agree on all details, but to agree to present multiple perspectives" (Vakoch, 1998a, p. 706). Such pluralism is rooted, not in relativism, but in a sober acceptance of fallibilism. The possibility of failure accompanies any epistemic endeavour. In the case of METI, "[t]o claim that we can anticipate with confidence which of these frameworks will be most commensurable across civilizations is unwarranted. […] The inclusion of multiple frameworks thus serves the pragmatic function of increasing the chance that something will be understood" (Vakoch, 1998a, p. 707).

This plurality can be applied to both the content and the medium. Since there is no guarantee that any single approach will achieve the desired coverage, we could send "multiple primers, each constructed to maximize intelligibility using a different decoding strategy" (Vakoch, 1998a, p. 706). Signs couched in the idiom of logic would thus take their place alongside other options, and time alone would tell which surmise proved most fruitful. Limitations in resources might constrain the actual number of messages that can be squeezed into a given emission. But, Vakoch's pluralist model seems especially appropriate for a project of mock-METI that, by design, trades only in simulated messages.

3. METI's search for truly general signs

To the extent that exominds could communicate with us, they would not only be knowledgeable (in a domain-specific way), but rational (in a domain-general way). It thus makes sense to anchor our theorizing about intelligent life to a defining feature of intelligence. Rationality, however, comes in all shapes and sizes. So, while the absence of data seems to give our imagination a wide berth, the reality is that we are operating under a severe constraint. It is hard enough to try and avoid anthropocentrism. In theorizing about exominds, we must avoid being *terracentric*. The term terracentric was coined by James W. Head. Head (1999, p. 154) argues, rightly I think, that "the retreat from human specialness" has been underway in the West since the discoveries of

Copernicus, Tycho Brahe, Kepler, and Galileo (see also Dick, 1980). Clearly, confirming the existence of intelligent exominds would consummate this ongoing retreat from human specialness.

Although it is impossible to get away from the fact that we are what/who we are, one of the most pernicious dogmas that can be brought to METI research is the privileging of sight over other sense modalities. Such privileging is understandable, since many of our most cherished concepts draw on vision. For instance, "[i]n calculus we seek to approximate a given curve at each point by a line. The derivative at that point gives us the slope of that line. Would an alien race with a different evolution think this is natural?" (DeVito, 2011, pp. 447–448). Interestingly, one of the astronomers who spent his career working for the SETI Institute was a blind man by the name of Kent Cullers (who was portrayed in the 1997 science-fiction movie *Contact*, based on the novel by Carl Sagan). As the leader for the Targeted Search Signal Detection Team, Cullers was in charge of developing computer algorithms capable of spotting intentional signals amid galactic radio noise. In a way, Cullers' visual impairment was an asset for this task, since it prevented him from projecting the usual vision-based biases onto his research. To escape terracentrism, we have to rid ourselves of even more pervasive biases.

A step in the right direction, I submit, is to recognize that logical reasoning does not have to be couched in a symbolic notation in order to be regimented (for a tangible illustration of this, see Champagne, 2018b). "Sign" is a broad genus, and one species that deserves consideration is similarity-based signs, most notably diagrams. In symbolic logic, the inferential passage from premise(s) to conclusion(s) is underwritten by coded associations and rules. In diagrammatic logic, the inferences are underwritten by transformations of qualitative sign-vehicles whose parts mimic the relations between the parts of their object (Legg, 2013). Such iconicity or similarity-based reference does not make the problems of noise, bias, and error vanish. Here on Earth, we often have a hard time understanding and agreeing with each other (Ashkenazi, 2017; Peters, 1999, p. 110). Even so, I argue that it is promising for METI researchers to employ some form of diagrammatic reasoning in their message construction. Researchers typically assume that the question of alien communication must be answered before we can address the question of alien reasoning. My hypothesis is that, contrary to this assumption, understanding inference-drawing capacities that are radically unlike us may be the best way to understand sign-interpreting capacities that are radically unlike us.

The only rationality we have ever studied is human or human-derived (in the case of computers, say), so it can be genuinely difficult to envision rational minds operating on entirely different principles. When discussing the realization of life on other worlds, some scientists (e.g., Sagan, 2000, pp. 41–50) are so impressed by the biochemical unity of all known life forms that they think it best to be "carbon chauvinists". They surmise that, while the patterns of reproduction and negentropy distinctive of life on Earth might well realize themselves in, say, silicon-based materials, this possibility is highly unlikely. My concern is with the patterns distinctive, not of life, but of rationality. On Earth, these patterns already realize themselves in natural and artificial systems alike, so it would be simplistic to expect current biology and neuroscience to answer all of our questions about exominds. I nevertheless think that, while notations and other sign-vehicles can vary, the inferential patterns realized in intelligent systems are not up for grabs.

I should note that I am in good company. Leibniz, for instance, thought that logic had a scope so universal that it could bridge, not just the divides between religious and political factions, but also the divides between worlds. Indeed, Leibniz was one of the few Christian thinkers to break with church dogma and write about extraterrestrials (Crowe, 1986, pp. 28–30). According to Leibniz, even God had to contend with the law of non-contradiction. It was this vision of logic as a universal constant that drove Leibniz to pioneer the basic ideas that would eventually blossom into the symbolic logic we know today. Somewhere along the way, though, workers on this grand project took on Leibniz's predilection for symbols uncritically, to the point where it eventually became difficult for anyone to conceive of logic in any other way. It wasn't until the American polymath C. S. Peirce came onto the scene that this began to change.

4. Peirce's eccentric way of looking at things

Peirce wasn't blind like Kent Cullers, but he certainly did not see the world as most of us do. To get a feel for just how different Peirce's logical views were from the mainstream, we can set up a brief contrastive study of disjunction. Let us start with the familiar way of rendering that connective. In most natural languages, two or more items are grammatically listed with a word between them, say "or". A convention is learned that lets this sound or mark signify a disjunction (inclusive or exclusive, as the case may be). So, with the right convention in place, a string of three lexical items like "salt or pepper" is taken to mean that there are two disjuncts. A person uttering this menu of options with a tagline like "There is …" is thus taken to endorse the following disjunction:

"There is salt or pepper."

Since spelling out words is tedious, we can abbreviate the string by writing:

S v P

This, however, is merely a surface alteration, since the algebraic symbols ultimately reflect the linguistic syntax of the ordinary language sentence.

Peirce felt that most systems of logic stuck too close to human ways of reasoning. He saw no reason why such systems should be anthropologically adequate. He thus deplored how most logicians, "after underscored protestations that their discourse shall be of logic exclusively and not by any means of psychology (almost all logicians protest that on file), forthwith become intent upon those elements of the process of thinking which seem to be special to a mind like that of the human race, *as we find it* […]" (1931–58, vol. 4, para. 7; Peirce had in mind the early work of Edmund Husserl, see Stjernfelt, 2007, pp. 141–148). Trying to rectify this bias, Peirce held that "[i]t is one of the chief advantages of Existential Graphs […] that it holds up thought to our contemplation with the wrong side out, as it were; showing its construction in the barest and plainest manner […]" (1931–58, vol. 4, para. 7). Here, then, is how Peirce sees the relation of disjunction that we have just laid out (I will limit myself to the "Alpha" system of Existential Graphs corresponding to the sentential calculus. It should be mentioned, however, that the system of Existential Graphs also involves a "Beta" system, corresponding to a fragment of quantificational logic, and a "Gamma" system, corresponding to modal and higher-order logics).

First, everything will transpire, not in linear strings of typographical characters read in a sequence, but on a two-dimensional space viewed at a glance. This starting canvas has a boundary, but it is meant to be a blank space extending in all directions, as shown in Fig. 1.

Peirce invites us to "regard the ordinary blank sheet of assertion as a

Fig. 1. Sheet of assertion.

Fig. 2. Assertion of a proposition.

film upon which there is, as it were, an undeveloped photograph of the facts in the universe" (1931–58, vol. 4, para. 512). The sheet of assertion thus has a double function: it is both a canvas and an assertion of a tautology. It could be taken to state "All truths obtain" or, in Peirce's words, "the presence of a blank on the sheet of assertion is always permitted" (forthcoming, p. 354fn6; I am quoting from a private prepublication copy, so final pagination may differ). Hence, even if this bare something is currently undifferentiated, logical reasoning begins with a primitive act of assent: Lo, there is something. This minimal commitment to existence is why Peirce called his mature diagrammatic logic Existential Graphs (Roberts, 1973, p. 30; this is especially salient in the Beta system).

If this blank space exists, then it stands to reason that anything on it would exist too. The blank space thus becomes the natural iconic sign of assertion. Suppose, then, that someone adds something more specific to the blank starting point, say X. It would look like Fig. 2.

X is now being claimed. Given the backdrop's default role as a space of assertion, when we cut out an area, the space we obtain becomes a space which is *not* asserted. So, were one to cut the space on which X rests, one would obtain the graph of Fig. 3, which claims that X is not the case.

Note that the shaded area does the work traditionally done by the negation symbol and parentheses (since more than one proposition can figure in a given enclosure). By the same rationale, were we to cut again, this would be akin to double-negation, so the space within would return to an assertion, as shown in Fig. 4.

Although these signs require some learning in order to be properly interpreted, there is something natural about the way that they depict assertion and negation. This naturalness applies, not just to assertion and negation, but to conjunction as well. Suppose that a space is cut for Y in the same way that it was cut for X. This would yield the diagram of Fig. 5.

What we have in Fig. 5 is "Not X and not Y", since visual juxtaposition suffices, in Peirce's graphs, to express logical conjunction. So, if we were to cut the whole graph, we get the following: "It is not the case that not-X and not-Y". Fig. 6 shows this diagrammatic rendering of a disjunction.

Unlike Gauss' deforested geometric patches of land, we should not

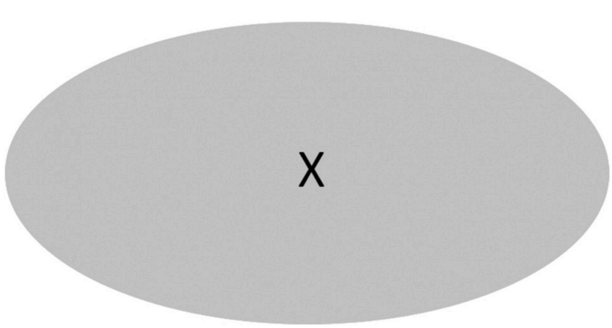

Fig. 3. Negation of a proposition.

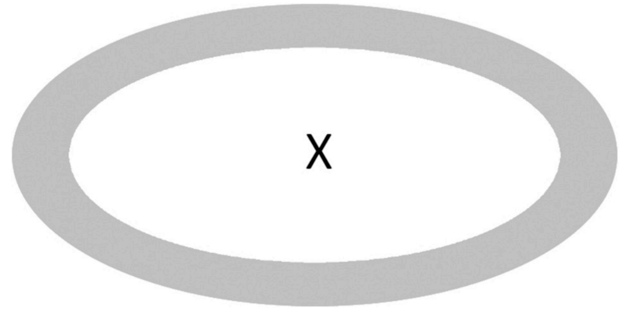

Fig. 4. Double negation.

Fig. 5. Conjunction of negated propositions.

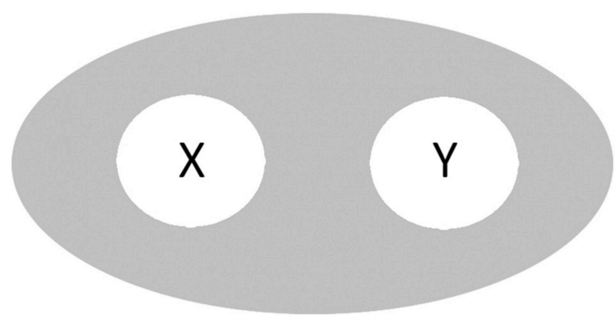

Fig. 6. Disjunction.

assume that anyone would recognize this graph, were they to see it on the surface of a planet. Even so, a system must at some point elect signs that are not further explained or justified. It thus makes sense to search for signs that are self-explanatory. Although logical connectives like disjunction are not obvious at first sight, they can nevertheless be built up from more basic expressions of assertion, negation, and conjunction that aspire to be obvious.

All signs refer, but not all signs refer in the same way. Symbolic and diagrammatic signs differ from one another by their degree of reliance on similarity. A symbol can successfully lead interpretation to its intended object, even if the sign-vehicle used to achieve this—the letter P, for example—bears no resemblance whatsoever to that object. Diagrams employ such conventional signs, but they relate them in a way that aims to mirror the relations between the parts of the diagram's overall object. One can, for instance, use ketchup bottles to diagrammatically represent where world leaders sat at a negotiation table, without thereby implying that those leaders looked like condiments. In the same way, the visual juxtaposition of symbols like P and Q is based on the realization that this arrangement genuinely resembles the relation of conjunction. Symbolic logics of course also juxtapose their symbols, but the fact that Peirce's diagrammatic system makes no use of a conjunction symbol (like &, ∧, or •) shows that the similarity at hand is robust enough to do the required logical work.

Importantly, a diagrammatic vocabulary can give us norms about

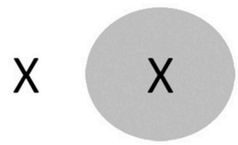

Fig. 7. Contradiction.

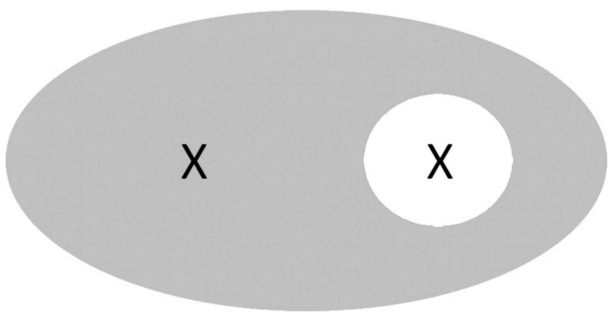

Fig. 8. Tautology.

what to avoid and seek in our inferences. For instance, the sign shown in Fig. 7 should be avoided, since a plan of action involving this conflict could not possibly be implemented (much less grow into a habit). For the same reason, the sign shown in Fig. 8 can safely be regarded as true.

In this way, Peirce's diagrams address "the mystery of elementary logic: *the interior structure of the tautologies*. What forms of utterance are necessarily true, which are contingent on circumstance and which are simply false? All logical systems aim at clarifying this matter. What is important about the existential graphs is that they allow the visual manipulation of complexes of Signs to arrive at the desired answers" (Kauffman, 2001, p. 88; italics in original). The policing of good and bad inferences in the Peircean diagrammatic case comes primarily, not from the violation of socially-instituted norms, but from the impossibility of simultaneously combining certain qualities. The goal of proper reasoning, then, is not simply to avoid committing a contradiction, which is when two tokens have conflicting tones or qualities, but rather to avoid contrapiction—a cognate word adapted from "depiction"—which is when *one* token has two conflicting tones or qualities. The former situation can be encountered in experience (see Fig. 7, for example) while the latter cannot (for more on Peirce's type/token/tone distinction, see Champagne, 2018a, pp. 21–27; for more on contrapiction, see Champagne, 2016a).

Humans can teach each other how to avoid logical blunders, but Peirce held that the activity of thinking "appears in the work of bees, of crystals, and throughout the purely physical world" (1931–58, vol. 4, para. 551). Recent cognitive science and animal studies have not gone as far as Peirce, but the "rationality" of the cephalopod line (octopuses) has been studied relative to the mammalian line (for a survey, see Godfrey-Smith, 2016). Interesting experiments have even been conducted to show how the quorum sensing system of some marine bacteria and the osmosensing system of yeast implement Boolean logical gates (Kothamachu, Feliu, Cardelli, & Soyer, 2015). However, I take rationality to mean, not just an ability to carry out deductive, inductive, and abductive inferences—see the canine syllogism discussed in Champagne (2015a, p. 540)—but also a standing readiness to show/defend how those inferences were carried out (Brandom, 1994), at least in principle. This construal of rationality may look demanding, but it becomes more encompassing when we abandon the assumption that, because humans conduct most of their justifications with language, all rational creatures must do so linguistically as well (Champagne, 2016a).

Peirce's system uses only assertions, negations, and conjunctions. Endorsing this simple foundation, however, does not mean staying at a simplistic level. Since the primitive signs can be compounded, they give rise to novel forms and structures. Indeed, the unpublished papers of Peirce contain diagrammatic representations of increasing sophistication and complexity, like the ones shown in Fig. 9.

Depending on one's propensities (and schooling), Peirce's diagrammatic renderings can seem less intuitive than language-inspired notations. For his part, Peirce wrote that "I do not think I ever *reflect* in words: I employ visual diagrams, firstly because this way of thinking is my natural language of self-communion, and secondly, because I am convinced that it is the best system for the purpose" (1967, manuscript 619, p. 8). However, Willard Van Orman Quine, who was one of the first major figures to familiarize himself with Peirce's work, found the Existential Graphs too cumbersome. Quine wrote that, "[w]hile it is not inconceivable that advances in the diagrammatic method might open possibilities of analysis superior to those afforded by the algebraic method, yet an examination of Peirce's product tends rather […] to confirm one's faith in the algebraic approach" (1935, p. 552). So, if we want to square with our natural reflexes and intuitions, symbolic notations are, for most people, the superior option. The aim of METI research, however, is not to recapitulate how most human minds do think, but to anticipate how some exominds might think. Here, Peirce's alien way of thinking actually becomes a boon.

5. Reasoning as a diagrammatic activity

From Aristotle to the scholastics to Frege, mainstream work in logic has been so wedded to language that it is hard to see how we could drop our linguistic assumptions without dropping the logical apparatus developed in that tradition. Peirce's diagram-based system lets us view reasoning differently. Taken as static snapshots, the Peircean graphs give us a picture of logical relations. But, there is an important sense in which those graphs *move*, so the transformations that Peirce's system

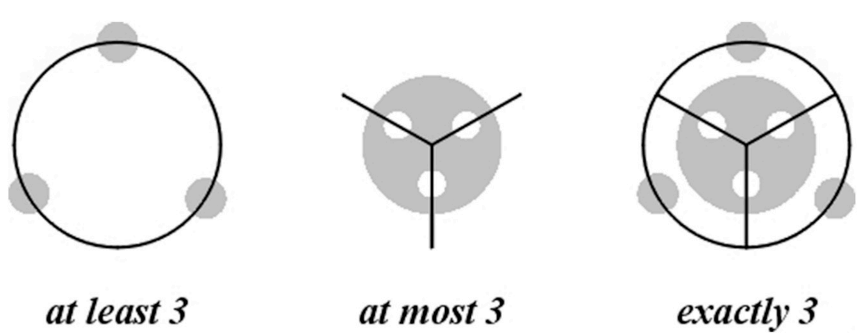

Fig. 9. Notations from Peirce's Beta Graphs (Taken from Sowa, 2011, p. 358).

licenses also give us a fascinating new look at the unfolding of logical inference.

To see this, we can once again contrast Peircean logic with mainstream notation. Normally, the textbook treatment of derivations happens in a line by line format. So, when one is given P as a premise and Q as another premise, an inference rule known as "adjunction" or "conjunction introduction" allows one to deduce the following conclusion:

1. P	(premise)
2. Q	(premise)
Therefore,	
3. P & Q	(1, 2, adjunction)

Similarly, when one is given "P & Q" as a premise, an inference known as "simplification" or "conjunction elimination" allows one to deduce the following conclusion:

3. P & Q	(premise)
Therefore,	
4. P	(3, simplification)

Notice how, whenever an inference is made, a new line is produced. It is as if standard logic is condemned to always write more. Peirce's logic has an eraser. Recall that visual juxtaposition suffices to express logical conjunction. Since no symbol for "and" is needed, the graph of Fig. 10 suffices to convey the claim. In fact, in Existential Graphs, it wouldn't even be possible to give adjunction as a rule. If we want to obtain a single conjunct from a conjunction like the one shown in Fig. 10, then we need only erase the conjunct that we want to discard, resulting in Fig. 11.

Observe that, despite the fact that I have redrawn the diagram—the static format of this publication compels me to—everything could (and should) transpire at the same location. The Peircean view thus regards inferences, not as frozen patterns in some Platonic realm, but as tangible manipulations of signs unfolding in time (see Champagne & Pietarinen, 2018).

Consider how one derives a *modus ponens* in Peirce's Existential Graphs (specifically the Alpha system). Graphically, the starting depiction consists of a sheet of assertion containing a cut space with a propositional variable (say, P), and this cut in turn contains another cut space with another propositional variable (say, Q). The graph of Fig. 12, sometimes called a "scroll", conveys "It is not the case that P is true and that Q is false".

The graph shown in Fig. 12 is the equivalent of a conditional, with the inner variable Q playing the role of consequent and the outer variable P playing the role of antecedent. Once we scribe another token P on a fresh region of the sheet of assertion, as in Fig. 13, we generate all the premise-like materials needed to derive the desired conclusion.

Derivations proceed by transforming an initial layout in any of the following five ways: double-cut, insertion, erasure, iteration and deiteration. Instead of explaining these transformations, we can show them in action, giving a play-by-play narration of how one derives a conclusion in a *modus ponens*. First, the propositional variable P within the

Fig. 10. Conjunction.

Fig. 11. Erasure of a conjunct.

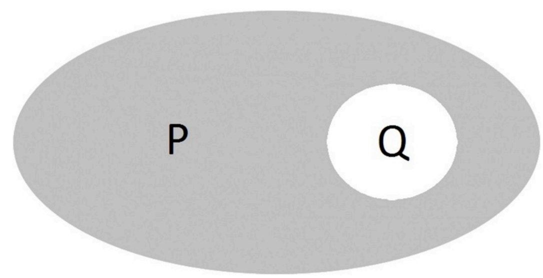

Fig. 12. Conditional.

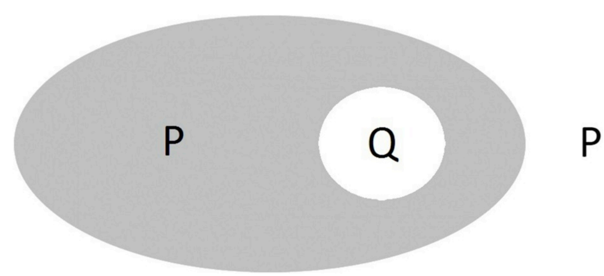

Fig. 13. Starting premises of a *modus ponens*.

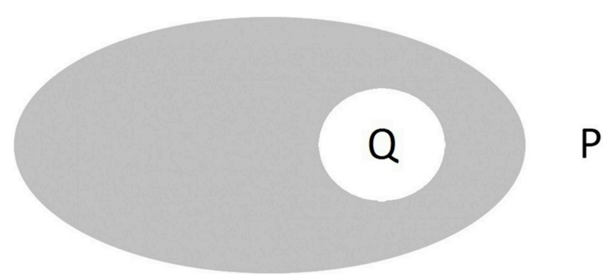

Fig. 14. Second step in the derivation of a *modus ponens*.

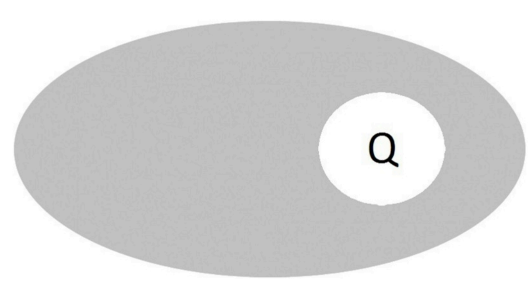

Fig. 15. Third step in the derivation of a *modus ponens*.

cut is deiterated, as shown in Fig. 14.

Second, the remaining P that is not in the cut is erased (see Fig. 15).

Finally, the double-cut that now surrounds the propositional

Fig. 16. Final step in the derivation of a *modus ponens*.

variable Q is removed. Once these three transformations have been performed, we are left with the asserted Q shown in Fig. 16.

In diagrammatic logic, one can point to the self-same properties of the signs in order to justify logical consequences. If one is given the two premises of a *modus ponens*, then rationality recommends the production of a third sign, namely the consequent. Physically, nothing bars the production of an inappropriate or random sign. However, in mainstream symbolic logic, such a production is taken to violate inference rules. As the word "rule" attests, the constraints of symbolic notations are akin to grammar. The constraints of Peirce's logic are closer to geometry—specifically topology, which disregards specific metrics like size and shape (Gardner, 1958, pp. 56–57). So, while rule-following faces a regress (Carroll, 1895), diagrams have the potential to halt this regress, by supplying one with evidence for the appropriateness of a conclusion. As Peirce explained:

> By diagrammatic reasoning, I mean reasoning which constructs a diagram according to a precept expressed in general terms, performs experiments upon this diagram, notes their results, assures itself that similar experiments performed upon any diagram constructed according to the same precept would have the same results, and expresses this in general terms. This was a discovery of no little importance, showing, as it does, that all knowledge without exception comes from observation (Peirce, 1976, pp. 47–48).

Our starting claims (or premises) may be explicit, but when we embody the relations between those claims in diagrams, we can toy with the semiotic surrogates in order to discover or prove what else we are implicitly committed to. For all we know, exominds more naturally think like this.

Peirce was inspired by cinematographic technologies when they first appeared (Pietarinen, 2011, p. 269). This new way of looking at things likely spurred his feeling that inferences are better conceived as a series of transformations (Pietarinen, 2006, pp. 103–180). In his Existential Graphs, those transformations happen in accordance with a handful of diagrammatic modifications designed to preserve the truth of statements and enable derivations. Pursuant with the pragmatist idea that thinking is a kind of action or preparation for action, one shows that one understands a logical relation by intervening in an appropriate way on the diagrammatic layout. Far from being contemplative, the act of grasping an inference always leaves a trace.

There is currently a vibrant debate on the source, if any, of normativity in logic (see Caret & Hjortland, 2015). In a symbolically rendered *modus ponens*, one can nod in assent to the first two premises, but given that the conclusion appears as a new token (on a third line, typically), an extra nod is required. By contrast, in a diagrammatic derivation of a *modus ponens*, one need not assent again. When asking why a given conclusion follows, one prominent answer in the symbolic logic tradition is that the inference rules license it. While a violator of symbolic logic must be lectured about a further claim that they ought to make in virtue of those rules, a violator of Peirce's sign system need only look at the gradual transformation of a claim that they are already making. Commitment to a conditional relation does not, by itself, entail any commitment to the propositions being related. Yet, it turns out that, when a diagram of a conditional and a diagram of that conditional's antecedent are juxtaposed, a latent commitment to the consequent nested in the conditional can be revealed, by stepwise transformations.

There is still a conventional aspect to these diagrams and transformations. Even so, there are good reasons to think that the normativity we find in diagrammatic reasoning is more compelling—or at any rate mobilizes fewer assumptions—than the normativity found in symbolic logics. Considering that METI designs seek to avoid unnecessary assumptions, the diagrammatic approach pioneered by Peirce shows promise.

6. Communication and argumentation

If we ever do carry on a conversation with intelligent extraterrestrials, it will essentially be in one of the following three ways: 1) we can somehow learn their sign system(s), 2) they can somehow learn our sign system(s), or 3) we can co-construct some novel sign system(s) together. In SETI, the first option seems most likely, whereas in METI the second option seems most likely. The third option seems to require some rudimentary success in the first two options, since it is hard to see how two parties could co-construct a novel sign system without a minimal prior grasp of each other's meanings. In any event, the learning curve that all three possibilities must travel can be made less steep by correct anticipations: the more our messages resemble what exominds expect, the less they will have to work to understand us. Likewise, the better prepared we are to receive their messages, the less we will have to struggle to understand them. My proposal can thus be seen as an attempt to narrow the divide between disparate sign systems, thereby advancing the first and second options. Given the generality of diagrammatic signs, it can also serve as a promising blueprint for the third option.

Logic and rational argumentation are so essential to our species' differentia that they should be present in our messages from the get-go, if only in germinal form. Instead of *saying* "We are rational creatures", we can let the diagrammatic transformations *show* our rationality in action (Ambrosio, 2014). If communication and argumentation are taken to be distinct phases, it makes sense to send a sign that conveys "This is a message" before attempting more ambitious signs that convey or call for logical inferences. Parting with this strategy, I suggest that we try to build the rudiments of logic into our very first designs. We are not, after all, dealing with children whose intellectual faculties have yet to come to term, but with exominds presumably capable of sophisticated technological accomplishments (sophisticated enough, at any rate, to detect our emissions). It is true that communication is more basic than argumentation, since making a loud noise can stop someone dead in their tracks without any glimmer of a premise-to-conclusion passage. But, given that argumentation is necessarily a form of communication, when our interlocutor succeeds in justifying a conclusion from a body of premises, we may automatically confirm that communication was effective. If I send you "Q" and you reply "Q", I can confirm that you received what I sent. This is informative, because there are twenty-five additional possibilities in the alphabet (Skyrms, 2010, p. 35). Even so, replying by repeating what was said is not as conclusive as it might seem, since mountain echoes devoid of agency can also do this. If, on the other hand, I send you "If P then Q" and "P" and you reply "Q", then I can confirm not only that you received what I sent, but that you are intelligent to boot. Not only is this sort of reply more informative, it seems to require a distinctive rational faculty. Mountains cannot do this.

One could perhaps object that, if a response to the premises of *modus ponens* would run counter to our expectations—responding to the premises "If P then Q" and "P" with the conclusion "not-Q and R", say—this would mean that the replying mind might be employing a logic that is not classical. The responses of interlocutors are indeed underdetermined in a way that allows for such interpretive leeway.

Even here on Earth, I am free to gloss your blunders either as blunders or as signs of some esoteric genius which I fail to comprehend. However, taking an erroneous *modus ponens* conclusion as evidence of a non-classical commitment comes with a high cost, since it is hard to see what one can do afterward. Which non-classical logic are we dealing with? There is no way to tell. Hence, "if we explain [irrationality] too well, we turn it into a concealed form of rationality; while if we assign incoherence too glibly, we merely compromise our ability to diagnose irrationality by withdrawing the background of rationality needed to justify any diagnosis at all" (Davidson, 2004, p. 184). To strike the right balance between these two unproductive strategies, we have to employ another method that Peirce pioneered, namely pragmatism: start with the most plausible starting point then see what works—modifying only if and when there is real pressure to do so. We cannot anticipate this flow of experience from the armchair, but we can evaluate the potential merits and demerits of different starting points.

In the end, all we have to go by are the signs that our interlocutor(s) put(s) out. This should be enough, though, since in diagrammatic reasoning there is no distinction between inner mental processes and outer manifestations of those processes. Rather, the inferential thinking unfolds in the signs themselves. "By diagramming, humans recruit several systems that are already available for perception and action—such as the visuo-spatial system, the conceptual system, and the motor system—and establish an *external connection* between them, by means of a particular cognitive tool, the role of which is to trigger such a connection thus enhancing inference and reasoning" (Giardino, 2016, p. 98). The perceptual, conceptual, and motor faculties connected by a diagram may be unique to us (or terrestrial species, more generally). Sliding a graph to the left mobilizes innate and habituated patterns in our hands, for instance; just as gazing at a surface calls on our eyes. Still, the idea is that the process of combining these faculties in a coordinated way captures something universal about the activity of thinking, irrespective of whether the thinking agent has hands and/or eyes.

Because tangible modifications of the diagrams are required, my Peircean account links reasoning with sensorimotor capacities, broadly understood. Yet, not only must changes to the diagrams be made, the outcome of those changes must be observed. "Peirce's analysis of mathematical reasoning had convinced him, as early as 1869, that progress in mathematics, as in science, was tied to the use of observation. If it seems strange to speak of mathematics as a science for which observation is relevant, Peirce explains that it is 'observation of artificial objects and of a highly recondite character'" (Roberts, 1973, p. 16). However, there is nothing in my Peircean account that requires the sensorimotor and observational capacities to be like our own. Likewise, the particular realizations of Peirce's diagrammatic system has, in our case, been on paper or a computer screen, but "we are to imagine that there is before the mind of the interpreter a certain field of consciousness […] and suppose it to have a vague analogy with a sheet of paper without definitely supposing it to be confined to two dimensions or to be a visual image […]" (Peirce, forthcoming, p. 333). I submit that this high level of generality makes Existential Graphs a fecund starting point for speculations about alien minds. In fact, recent studies have shown that, while there are lingering difficulties with double-negation (Champagne, 2015b), Peirce's vocabulary is so basic that it could in principle be generalized to cover non-visual senses (Pietarinen, 2010). So long as an exomind fills the placeholder Kant called sensibility, and so long as the creature with that exomind is capable of some measure of causal efficacy, it can (and very likely must) use signs to enable high-level understanding.

Despite his fascination with diagrams, Peirce never privileged one kind of sign over another. True, he made it a point to show that similarity-based signs or icons are structurally simpler than causality-based signs or indices, which are in turn simpler than code-based signs or symbols (see the taxonomy in Champagne, 2015a, pp. 536–541). While I have deliberately played up the contrast between symbolic logics and diagrammatic logics, it should be stressed that, from a Peircean standpoint, "the common-sense, everyday opposition between diagrammatical and symbolic representation systems […] does not hold" in an uncontaminated way, since "even the most formalist, finitist representation systems must conserve some minimum of intuitive representation (e.g., a line subdivided in places that may be occupied by symbols to be manipulated according to rules on that line)" (Queiroz & Stjernfelt, 2011, p. 2). So, in keeping with the pluralistic method endorsed at the outset (Vakoch, 1998a), I want to be clear that the diagrammatic signs I have presented are just one sort among many: "The generality of Peirce's classification [of signs] is thus more suited to situations in which we may presume neither what kind of signs our 'extraterrestrial correspondents' will send or expect to receive nor what kind of conception they may entertain regarding meaningful communication" (Saint-Gelais, 2014, p. 85).

There remains much work to be done: "Nevertheless, if there is no place for the last word in this field, there is still ample place for the first words to be said on many issues" (Ćirković, 2012, p. 4). As far as I know, no one has yet applied the logical ideas of Peirce to extraterrestrial messaging design. Semiotics, which has become a mature field (see the annotated bibliography in Champagne, 2014), would seem to be a mandatory field of study for anyone interested in SETI and METI research (Ulvestad, 2002). Unfortunately, the current situation is so muddled that ideas like icons and the triadic nature of signs are often mentioned without crediting Peirce, the very scientist who crafted those ideas (see for example Vakoch, 1998b). While there is no shortage of high-level exegetic work being done on Peirce, the initiated rarely bother to motivate their preferred topic to the uninitiated. So, while Peirce is widely known as the founder of American pragmatism, few researchers interested in extraterrestrial intelligence are aware of his pioneering contributions to diagrammatic logic. I have thus endeavoured to show how some of Peirce's insights can move those debates forward.

Such a contribution fills a lacuna in scholarship, but in reality, diagrams are not new to METI. Like the right-angled triangle of Gauss, the 1974 Arecibo message composed by Frank Drake relied heavily on diagrams. Drake's stick-man (highlighted in Fig. 17) is a reminder, though, that diagrams have often been deployed in a merely intuitive manner. Peirce's work not only provides principled reasons for why Drake and Gauss were on the right track, it also equips us with a notion of diagram that can go beyond the usual references and into the domain of logic itself. Diagrams can be quaint, but they can accomplish much more.

7. Conclusion

We can infer the presence of exoplanets. This in turn allows us to infer—with decent but by no means conclusive certainty—the presence of exominds. In spite of all the biological and cognitive differences that likely separate us from such minds, there must be a minimal area of overlap for rational exchanges to occur. So, "*to find aliens, we must become the aliens* and understand the many ways they could manifest themselves in their environment and communicate their presence" (Cabrol, 2016, p. 667). Methodologically though, this exercise in speculative empathy faces a challenge. We can reason by analogy from the minds we know, but the only minds we know come from this Earth. Ostensibly, we are tied down to the Earth by more than just gravity. We therefore need some way of escaping the pull of terracentrism. How can this be achieved?

Creative thinking helps, as does paying heed to the musings of eccentric thinkers. The diagrammatic designs that C. S. Peirce developed are so foreign-looking that they almost look like alien writing.

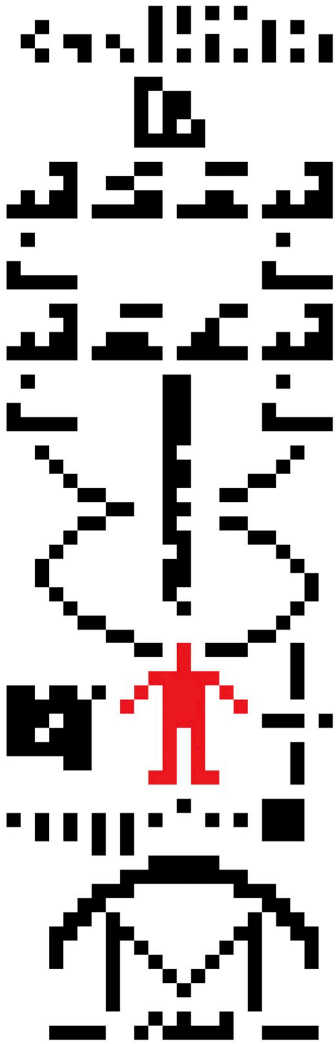

Fig. 17. Message sent from the Arecibo telescope in 1974.
(Taken from Vakoch, 1998b, p. 317)

Interestingly, late in his life, Peirce confessed that he did not feel at home "on this uninteresting planet" (1967, manuscript 302). Whether or not Peirce fully escaped terracentrism, he certainly had a hard time being understood by his peers (Brent, 1998). In fact, scholars have only recently developed the expertise needed to master his difficult writings on logic. Thankfully, we will eventually see the release of *Logic of the Future: Peirce's Writings on Existential Graphs*. At some point in that tome, Peirce asks "whether, in case a given planet were known to be the habitation of a race of high psychical development […] it would be safely presumable that that race was able to reason as Man does" (forthcoming, p. 52). Peirce goes on to discuss diagrams, but he never actually answers his question directly. Even so, my suggestion has been that the alien character of Peirce's Existential Graphs hints at an unforeseen application.

Is it even possible to have a common ground for our knowledge/beliefs, given fundamental uncertainty about the biology and evolutionary history of exominds? I would say yes. We do not come from the same planet. We do, however, come from the same universe. So, on the assumption—entirely plausible, by my lights—that certain logical principles are not Earth-bound conventions, the search for a common ground is not entirely hopeless. We can devise any system of notation we want. However, like Peirce, I have been concerned with evincing "what *must be* the characters of all signs used by a 'scientific' intelligence, that is to say, by an intelligence capable of learning by experience" (1931–58, vol. 2, para. 227). If nothing else, Peirce's Existential Graphs show that logic can be realized in more than discrete symbols strung together in a linear fashion. Not only are some logical relations (like conjunction and negation) more basic than others, some semiotic renderings of those relations are also more basic. My suggestion has been that a diagrammatic conception of logical inference can supply METI researchers with a promising avenue of inquiry.

Of course, given our current lack of contact with aliens, there is no viable empirical test for any of this. Yet, since the topic is too interesting to postpone, I have forged ahead on the assumption that we can nevertheless order proposals, based on their degree of escape from terracentric assumptions. Judged by that standard, standard symbolic notations are too wedded to linguistic syntax to fare well, at least in comparison with diagrammatic logics. Peirce "suggests that the signs we know best, and from which our theory of signs should start, are signs in ordinary communication" (Bergman, 2007, p. 606). We cannot help but start from the languages in use around us. However, "it is clear that common sense is only a starting point; the expansion of semeiotic from familiar signs to cover all signs is an abductive hypothesis" (Bergman, 2007, p. 607).

So, maybe exominds think and reason in a manner akin to the diagrammatic manipulations found in Peirce's Existential Graphs. Naturally, this is an abductive hypothesis. Still, even in mock-METI, some hypotheses are better than others.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.shpsa.2018.09.010.

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