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Zwicky as a Pluralist

Abstract

Fritz Zwicky is best known to the general public for his scientific work. His methodological views are less known and some of his philosophical ideas did not receive favorable reviews. In other reading, however, Zwicky's *principle of flexibility of scientific truth*, which asserts that no scientific statement can be absolute but rather subject to refinements or expansions, shows it as a contribution to epistemic pluralism.

Keywords: *history and philosophy of science, morphology, pluralism, truth, Zwicky*

Zwicky jako pluralista

Abstrakt

Fritz Zwicky jest najbardziej znany opinii publicznej ze swojej pracy naukowej. Jego poglądy metodologiczne są mniej znane,

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a niektóre jego idee filozoficzne nie spotkały się z przychylnymi recenzjami. Jednak z innej perspektywy *zasada elastyczności prawdy naukowej Zwicky'ego* ukazuje ją jako wkład w pluralizm epistemiczny.

Słowa kluczowe: *historia i filozofia nauki*, *morfologia*, *pluralizm*, *prawda*, *Zwicky*

1. Introduction

There are various works about Zwick's life, career and thought (e.g. Maurer 2001, Close-Koenig 2001). "Fritz Zwicky – An Extraordinary Astrophysicist" (Stöckli, Müller 2011) is especially useful since it consists in a long biography with detailed studies about Zwicky's ideas on morphology and his principal scientific merits. However, none of them has entered into Zwicky's notions of philosophy of science, especially in his principle of flexibility of truth: "No truth which is stated in finite terms can be absolute" (Zwicky 1957, p. 12). In order to tackle this issue, in section 2) I will present his principle and one of its criticisms. After having introduced with more detail our main character and his methodology in section 3), I will discuss in section 4) the metaphysical conviction that reposes behind Zwicky's principle.

2. The principle of flexibility of scientific truth

In the first issue of the first volume of the journal of *Philosophy of Science* appeared a letter from Henry Margenau (1901–1977), professor at Yale and later the founding editor of *Foundations of Physics*, critiquing the introduction of a very curious notion, the so-called principle of flexibility of scientific truth (Margenau 1934a). The notion of flexibility of scientific truth first appeared in a short article in the *Physical Review* in 1933 written by the Swiss astrophysicist Fritz Zwicky (1888 –1974). In its first line, one can read:

> From a deeper scrutiny of the foundations of scientific truth it follows that every scientific statement referring to observations should possess a certain minimum degree of flexibility. In other words, no set of two-valued truths can be established with the expectation that this set ultimately will stand the test of experience. Formulations of scientific

> truth intrinsically must (should) be many-valued (Zwicky 1933b, p. 1031).

The scientist also proposed several examples from physics, including the incapacity of the common notion of identity to capture what was happening in the then recently discovered annihilation of an electron-positron pair in gamma rays.

Margenau's (1934a) reply was divided in four steps: I) "The use of a many-valued system with every system of logic so far proposed" (p. 119). II) "Flexibility of scientific truth is incompatible with every system of logic so far proposed" (p. 119). III) "There can be no quarrel with any reasonable attempt of applying new logical systems to our present body of physical evidence. But this cannot be done by questioning present laws and guessing at more general possibilities. These latter activities are the natural rights of any scientist; they derive their justification, not from logic, but from the status of physics as an empirical science" (p. 120). IV) "The examples which Zwicky chooses to illustrate his supposed fundamental principle amount to denials of specific physical laws. They reflect, in part, a sound skepticism but bear no relation to many-value logics" (p. 120).

Two issues later, in the same journal a reply from Zwicky (1934) finally appeared. Without entering into any details about different logics, Zwicky first quoted extensively from his own previous letter and insisted in that, although paradoxical in appearance, the principle of flexibility of truth is "not suicidal", i.e. non-self-refuting:

> This principle is scientific in nature only insofar as the predictions derived from it constitute scientific statements which can be tested by a finite number of experiments. The negation of the principle however is not scientific in nature inasmuch as the verification of this negation would require an infinite number of experiments. Through this double aspect the principle safeguards itself from being annihilated through its own tools after the fashion of Epimenides the Cretan (Zwicky 1934, p. 356).

Finally, after having added some remarks about the very complex structure of thought behind scientific facts and laws, he concluded with the following response to the criticisms of Margenau:

> As the considerations which led me to this principle are still unpublished, Mr. Margenau's criticism perhaps is somewhat premature. He bases his criticism on the following claims. (I) That I am trying to derive my principle from some system of many-valued logic. (2) That there are any number of propositions which are certainly true or false. (3) That the specific applications which I have derived from the said principle refer to difficulties which can be resolved otherwise. Contention (I) is incorrect (…) I have never even suggested that the principle of the flexibility of scientific truth can be derived from any system of many-valued logic […] The so called laws of logic are therefore themselves subject to the flexibility of scientific truth and not vice versa. Contention (2) can perhaps best be answered by the challenge that Mr. Margenau actually produce a proposition which scientifically is certainly true or false […] Contention (3) is hardly subject to any discussion as it is up to future experimentation to decide whether or not the numerous predictions which can be derived from the principle of flexibility of scientific truth will be realized (Zwicky 1934, p. 358).

Margenau published a brief and final response (1934b). There, the philosopher of science correctly concluded that his previous arguments about different logics had not been touched at all by Zwicky's remarks. He accepted the challenge posed by Zwicky and wrote the, so he thought, certainly true or false scientific proposition: "Remarks on the "principle of the flexibility of scientific truth" are printed on pages 354 and 355 of vol. i of *Philosophy of Science*." And finally, he launched a last lunge:

> (3) Mr. Zwicky's proposal may be heuristically very useful, but it is neither new nor a principle of reasoning. In fact, universal doubt has been proclaimed so often that it has become proverbial. And, after all, let us not forget: «Douter de tout et tout croire, ce sont deux solutions egalement faciles» (p. 487).

Margenau did not make explicit the author of the quote, but is easy to recognize Poincaré. In the preface of his *Science and Hypothesis* we find:

> To doubt everything or to believe everything are two equally convenient solutions; both dispense with the necessity of reflection (Poincaré 1905, p. xvii).

Zwicky never replied and the debate simply died. Now, I think that regardless of its elegance the last point in Margenau's critique is not fully correct. Both Poincaré and Zwicky were combating dogmatic views about science: science was neither almighty nor just ruins upon ruins. And also, in agreement with Poincaré, according to Zwicky, science advances by capturing deeper structural relations. Thus, it does not matter that Margenau was completely right about the impertinence of the relation brought by Zwicky between the principle of flexibility of truth and many-valued logics: he failed to see that Zwicky's "profound disrespect for the absoluteness of scientific truth" (Zwicky 1934, p. 355), if not new, was not universal doubt but a *selected and systematic negation*.

Zwicky was in the search of a way to reorganize knowledge on broader basis. He believed that ultimately everything was related with everything. If so, only an infinite statement could attempt to capture the intricateness of a world as such, but such a statement was not scientifically possible. Therefore, "Since all communicable truths must of necessity be formulated in finite terms they are incomplete or flexible in the sense of being again and again capable of expansion and refinement" (Zwicky 1957, p. 12). What was needed, then, was a procedure capable of taking advantage of the flexibility of scientific statements. Zwicky thought in a never-ending method of negation of previous truths and construction of new truths. As he wrote in retrospect:

> The fact that no absolute communicable truth can ever be formulated objectively in finite terms suggests that progress may always be achieved through the application of the morphological procedure of Negation and Construction (Zwicky 1971, p. 9).

3. About Zwicky

Fritz Zwicky (1888–1974) received a PhD from the Federal Institute of Technology Zurich in 1922. Very gifted in mathematics, Zwicky entered Caltech as a research fellow with a Rockefeller grant. From 1927 until

1941, he was an associate professor of physics. In 1942, Zwicky started to work for Aerojet Engineering Corporation. As a result, due to the company's "immeasurable contribution to Air Technical Intelligence in times of war", in 1949 Zwicky was awarded the U.S. Presidential Medal of Freedom. From 1942 until his retirement, he was a Professor in Astrophysics and observational astronomer in the Mount Wilson and Palomar Observatories. After four decades of working at Caltech, he was made professor emeritus in 1968. He compiled a six-volume catalogue of galaxies and galaxy clusters. This influential work contains some 30,000 galaxies and was finished in 1971, shortly before his death on February 8, 1974.

From the beginning of his career, Zwicky was far from being a conventional researcher. In one of his first articles, Zwicky (1929) discussed different theoretical accounts of the observed velocity of recession of the nebula as a function of its distance. Zwicky was far from convinced that these enormous apparent velocities were Doppler effects due to a real motion as almost everybody was already then reading Hubble's law. From among the various options, he favored one with the name *The Gravitational Drag of Light*. The idea is simple. According to the relativity theory, a light quantum has an inertial and gravitational mass. Thus, the light beam will recoil each body that deflect it. But by doing this, it will lose some of its energy, which implies a reddening of its frequency. This idea did not receive much attention, but survived Zwicky under the name of *tired light*. Zwicky died unconvinced about the necessity of the idea of the expansion of the universe.

One of his most important contributions was the study of supernovas. Not only did he discover more than a hundred by himself, he also coined the term in collaboration with Baade and offered the first detailed analysis of their characteristics (Baade and Zwicky 1934). Even further, they thought that cosmic rays were part of the supernova formation and that the remnant should be a star of neutrons. Remarkably, this prediction occurred only one year after the neutron particle was discovered by Chadwick in 1933.

In a paper from 1933, Zwicky used the virial theorem of Clausius to study galaxy clusters and found their speeds did not match the expected mass. He suggested the presence of opaque matter to explain the difference. On page 122 of that article, he claimed that a "dunkle (kelte) Materie" (cold dark matter) could also explain the discrepancy between the theoretical predicted density of the universe by Einstein and De Sitter and the lower observed value found by Hubble (Zwicky 1933a).

In 1936, Einstein published a short paper on gravitational lens where he concluded that the effect could hardly be detected. A year later in another intriguing contribution, Zwicky creatively suggested that galactic systems would be better than stars to identify gravitational lens and that the gravitational lens could be useful to measure the amount of dark matter in galactic systems (Zwicky 1937).

Most people found Zwicky eccentric and he found most people limited. Nonetheless, Zwicky enjoyed wide international recognition, though not as wide as his ambition dictated. In 1972, for "his many distinguished contributions to the understanding of the constituents of the Galaxy and the Universe", Zwicky won the gold medal of the Royal Astronomical Society, the equivalent of the Nobel Prize in astronomy, which carries two mottos: 'Quicquid Nitet Notandum' ("Whatever shines should be observed", Whewell) and 'Nubem Pellente Mathesi' (from Halley's ode to Newton: "the clouds of ignorance dispelled at last by science").

4. The morphological method of negation and construction

Zwicky was convinced that the path of single disciplines with single problems was a dead end and what was required was a theoretical approach capable of an integrated study of the most abstract and general relations between any conceivable objects. Therefore, he tried to design a method to prevent the loss of creative solutions for any problem regardless its complexity. He called it *the morphological approach,* and its results are the most varied; they include the creation of the first artificial meteors and the refilling of European libraries degraded by World War II, just to give a couple of examples.

> The great majority of Fritz Zwicky's publications were in the field of astronomy. Most of the remainder were about his researches in solid state physics and jet propulsion technology. But Zwicky himself always felt that his greatest contributions were in philosophy, specifically in epistemo-

> logy, in the development of new methods of thought and action (Wilson 1974, p. 17).

Zwicky thought and spoke about himself as a morphologist since the very beginning of his career, however, his first academic presentation of this "new philosophical technical principle" was in 1946 during the International Congress for Applied Mechanics in Paris. In the Halley Lecture of 1948, he affirmed that he had tackled almost every single problem from the perspective of morphology. In Zwicky's own words, the morphological approach is just an ordered way of thinking. In this way, it is a real shame that he never gave a definitive fully ordered presentation of it. In the following, I will try to give a summary.

"Morphology" means the study of shapes and focus on structural features. As an example, Zwicky cited Goethe's research of common denominators in the forms of animals and plants. But Zwicky wanted a morphological approach not restricted to any concrete domain, he wanted a door in order to discover structural interrelations between any concrete or abstract objects. Zwicky thought of morphology as a way to enter in a reality where everything is ultimately related. In summary, the main idea of Zwicky's morphological approach was:

> to explore all possibilities and all interrelations among objects, phenomena and concepts that may be relevant for the successful and optimal realization of any scientific, technical or human project (Zwicky 1971, p. 9).

The morphological approach consists in five steps:

1) Formulation of the problem: make an explicit definition or conceptualization of the problem.
2) Analysis of the problem: organize and enumerate the parameters that will be taken into account.
3) Synthesis of valid solutions: combine and create chains of parameters in order to give a complete set of possible solutions.
4) Judgment of these solutions: create a hierarchy for the obtained solutions based on a serious inspection of the context of application.
5) Implementation of the selected solutions.

To Zwicky, the morphologist, eager for innovation and concerned about missing creative solutions, reduces preconceptions to a minimum and discard conventions to the fullest extent. This is why while running the first three steps, no valorizations are accepted; all judgments would be premature. Especially, during the synthesis phase it is important to obtain all possible solutions without any discrimination. To discard any option during the first three phases is simply to let the prejudices amputate the scope of possibilities. And if the chosen solution turns out to be a really bad one, even then the only waste would be to simply discard it.

Bad solutions are valuable for the following reasons:

1) Some 'bad' solutions actually produce results which the 'good' ones do not, and thus may amplify or alter the statement of the problem.
2) A 'bad' solution may induce a 'good' one.
3) Two 'bad' solutions may combine to produce a 'good' one.

> A 'bad' solution may point out the need for more analysis. […] The main difference (between morphology and standard scientific and engineering practices) lies in our attitude about, and treatment of, 'bad' solutions. Experience has taught us their value. We seek them out and treat them with respect (Strong 1964, p. 20).

With his usual lack of modesty, Zwicky proclaimed his morphological approach as the method of "the philosopher's stone". However, this insistence does not agree with the monist for whom there is one and final method and all other should be discarded. The morphological approach is a method of methods, incorporating at least nine distinct morphological techniques within its framework. (*Morphological box, Systematic field coverage, Directed intuition, Negation and construction, Extremes, Integral engineering, Iterative approximation and feedback, Modest morphology, Systematic and positive application of imperfect solutions*) and nothing prevents this number from increasing. Thus, Zwicky spoke about the morphological approach as the best method in so far as it was the most comprehensive one.

> It is basically research into the totality of phenomena. As such it is concerned not only in the totality of all possible solutions to the problem in question, but also to the fundamental relations of these solutions to all vital activities (Zwicky 1969, p. 169).

Instead of giving a recount of the different methods (for a summary see Stökli, Müller 2011, for current uses of morphology see Ritchey 2011), here I prefer to discuss the method of Negation and Construction which was the most important in Zwicky's eyes. According to him, the discovery and development of non-Euclidean geometries was the most vivid example of this method.

> As late as the end of the eighteenth century the great German philosopher Immanuel Kant (1724–1804) thought of having demonstrated in his *Kritik der Reinen Vernunft* that Euclidean space is the only possible, absolute, and a priori given space. Shortly after Kant died, Lobachevsky (1793–1856) and Bolyai (1802–60) proved independently that, as a consequence of denying the absolute truth value of Euclid's fifth axiom and by completely disregarding it, an entirely new Non-Euclidean geometry could be conceived and structurally developed [...] Strangely enough the method of negation and subsequent construction has never been systematically used for the enrichment of our store of knowledge in physics, astronomy, chemistry, biology, in the humanities and technology, nor has it had any serious applications in general human affairs. Only quite recently have the morphologists begun to avail themselves of the most powerful tool of thought and procedure in all fields of human endeavor (Zwicky 1969, pp. 172–173).

Thus is the obvious origin of the method's name because the negation is not that of the dogmatic skeptic nor a simple mechanical rejection; it is a 'no' inspired by a 'yes'. After the denial of a specific principle, one builds an alternative theory using the most appropriate of the other constructive methods trying to generate a general framework where the original theory and the alternatives are just special cases.

> The insights gained as a result of any negation must immediately be made use of for purposes of sound construction. Heeding this advice and following up the well-reasoned negation of apparent truths and some of the so called absolute facts with the constructive use of the vistas that thus open themselves, we may be certain to succeed not only in making sporadic discoveries and inventions but

> actually whole groups and entire classes of them (Zwicky 1969, p. 171).

The discoveries, then, can reach from new types of bodies to the formulation of new laws. What I think should be highlighted is the agenda: testing a model rather than commending it. According to Zwicky, the imperative problem resides in the passive acceptance of widely accepted claims. All of us are prone to cry victory too soon, and, of course, scientists are not exception:

> we note that again and again scientists and technical specialists arrive at stagnation points where they think *they know it all* (Zwicky 1971, p. 4; *his emphasis*).

We can read the commitment to morphology as a way to counter this tendency. In the words of A.G. Wilson, American astronomer and director of the Society for Morphological Research in the 1970s:

> Zwicky believed that if only we could free ourselves from our pedestrian patterns of thought and learn to think morphologically, the future could be shaped by our images – however bold – rather than by the inertias of existing institutions and investments. For Zwicky, the really revolutionary paradigm of morphology consisted in the replacement of one solution by all solutions, one path by all paths, one system by all systems. Only after the complete spectrum of possible solutions, theories, or systems is developed can the full energies of their mutual tensions become available to us (Wilson 1974, p. 17).

In my view, the continual emphasis on morphology as a method to find *all* the solutions to a given problem constitutes, clearly, an exaggeration. The question becomes more interesting if we change 'all' to 'many'. That is, if we focus on the intention of not getting engrossed in finding unique solutions while overlooking possible alternative solutions, the proposal makes a lot more sense and falls squarely on a far-reaching methodological and epistemological pluralism[1].

[1] Pluralism is not singular but, precisely, plural (Ludwig, Ruphy 2021). A concise summary of one of its current branches begins with the 1978 homonym conference,

5. Enter Hamlet

As we have seen, the notion of a flexible truth is, therefore, not simple and abstract skepticism but a concrete constructive pillar that can afford a whole methodology. But what lies behind this principle? It is common to find in Zwicky's writings strong complaints about the attitude that flatters the speaker instead of challenging his assumptions by the creation of new evidence. To him, any scientific claim should be continuously put to test because scientists should be tireless explorers, not tireless sycophants.

> I proceeded first of all on the basis of my conviction that *there are more things in the sky than even the most imaginative human mind can divine* but, that it must be possible to predict at least the existence of some new objects and phenomena through the use of the Morphological Method (Zwicky 1971, p. 4; *my emphasis*).

When Zwicky expressed his conviction that "there are more things in the sky than even the most imaginative human mind can divine", he was making an almost literal use of Hamlet's maxim:

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where Suppes argued that the philosophy of science should abandon the notion, traceable from Kant to Plato, that science approaches eternal truths. Instead, Suppes proposed that science should embrace the notion, in line with American pragmatists, that it is a problem-solving activity. According to this perspective, science never addresses its constant influx of problems in a singular or definitive manner; instead, it consciously and voluntarily draws upon a variety of methods and techniques. A generation later, Kellert, Longino, and Waters wrote a manifesto called "The Pluralist Stance" (2006). Their main argument clarifies the issue: the monist assertion (that the world can be described in a singular and complete way) is, in reality, an open and empirical question. Thus, if the existence of singular descriptions should be investigated and not presupposed, then the aim of science and its philosophy is to empirically explore inherent plurality. Taking it one step further, Hasok Chang (2004; 2012; 2022) argued that pluralism cannot passively accept diversity but must actively work to prevent its diminishment and promote its proliferation. In his pluralist picture, different groups develop their own scenarios, either through spontaneous or enforced mutual toleration. Over time, these scenarios engage in significant interactions, co-opting or integrating the achievements of others and using them as instances for corroboration or refutation. While successful scenarios are retained for whatever they are good at, new scenarios are introduced to establish fresh connections with reality (Chang 2012, p. 224).

> There are more things in heaven and earth, Horatio,
> Than are dreamt of in your philosophy
> *Hamlet* (1.5.167–8).

Was this just rhetoric? It was not and actually it shows how one should accept the principle of flexibility of truth. Hamlet's maxim, as Helmut Heit and Eric Oberheim once pointed out in relation to Feyerabend[2], is not a defense of visionaries but rather an advocacy for the flexible application of scientific knowledge, in full awareness of its possibilities and limitations (Heit, Oberheim 2013, p. 33).

Hamlet did not turn the words of the specter into a dogma. On the contrary, as we learn at the end of the second act, he decided to put the whole event to a new test in order to identify whether the walker of the night was indeed the sad figure of his father or just a diabolical illusion. The message is clear: *conceive*, *perform* and *observe* in order to *have grounds*. The time is out of joint if we keep asserting our tests rather than testing our assertions.

With this new link, I am ready to paint the full portrait of Zwicky's pluralistic thought: an ontological view (*Hamlet's conviction),* followed by an epistemological consideration (*The Principle of Flexibility of Truth),* that lead to a methodological choice (*The Morphological Procedure of Negation and Construction).* In other words, scientific principles relate certain objects in certain ways. If the world is such that there are always more objects and relations than what is already included in any set of principles, then limits and counterexamples to any set of principles should be expected.

[2] Paul Feyerabend (1924–1994) had different times, as did his pluralistic view (Preston 2016). Inherited from his training under Popper, his early works emphasized the concept of testability. If scientific knowledge is distinguished from other forms of knowledge by its falsifiability, then the hallmark of a good scientific theory lies in the quality and quantity of its instances of refutation. However, given that observations are never theory-neutral, isolated good theories do not exist. A science concerned with testability must embrace the proliferation of incompatible theories, as only such a multiplicity of theories will result in an increase in potential refutations (Feyerabend, 1968). In a later stage, Feyerabend realized that from the perspective of science as an activity dedicated to problem-solving, any imposed norm, regardless of its pristine logic or erudition, would be more of an obstacle than an aid. This marked the origin of his epistemic anarchism and his defense of relativism (Feyerabend 1987). Finally, in his last writings, pluralism emerged as a commitment to abundance: facing an ultimately unknowable world, far from restricting our options, we need all the help we can get (Feyerabend 1999).

Thus, the negation of a specific principle opens a path that could lead to objects and relations previously unknown, enabling the construction of a more general and inclusive system of knowledge.

6. Conclusion

The metaphysical assumption of an inexhaustible reality, a relentless source of unexpected objects and relations, and the heuristic notion that a systematic negation of any absolute claim can result in the augmentation of knowledge, constitutes a desirable philosophy of science. Possessed by these convictions, Zwicky, a highly polemical yet successful scientist, placed the focus of his methodological approach on exploring and testing multiple scenarios rather than championing one of them, a pluralistic attitude that seems to be much more responsible and fruitful than the opposite, and could prevent the stagnation of crying victory before time.

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