Feyerabend on the quantum theory of measurement: A reassessment

Daniel Kuby, Patrick Fraser

November 30, 2021

Abstract

In 1957, Feyerabend delivered a paper titled “On the quantum-theory of measurement” at the Colston Research Symposium in Bristol to sketch a completion of von Neumann’s measurement scheme without collapse, using only unitary quantum dynamics and well-motivated statistical assumptions about macroscopic quantum systems. Feyerabend’s paper has been recognized as an early contribution to quantum measurement, anticipating certain aspects of decoherence. Our paper reassesses the physical and philosophical content of Feyerabend’s contribution, detailing the technical steps as well as its overall philosophical motivations and consequences. Summarizing our results, Feyerabend interpreted collapse as a positivist assumption in quantum mechanics leading to a strict distinction between the uninterpreted formalism of unitary evolution in quantum mechanics and the classically interpreted observational language describing post-measurement outcomes. Thus, Feyerabend took his the no-collapse completion of the von Neumann measurement scheme to shows the dispensability of the positivist assumption, leading the way to a realistic interpretation of quantum theory. We note, however, that there are substantial problems with his account of measurement that bring into question its viability as a legitimate foil to the orthodox view. We further argue that his dissatisfaction with the von Neumann measurement scheme is indicative of early views on theoretical pluralism.

1 Introduction

Paul Feyerabend is best known for his work in general philosophy of science, and in particular, ushering in a movement that sought to dismantle purported dogmas of general philosophy of science that remained from the time of the logical positivists. However, long before his methodological pluralism in *Against Method* and his later work ever occurred to him, Feyerabend pursued a career as a philosopher of physics, a philosopher of quantum mechanics in particular. It is this early stage in Feyerabend's career with which we are occupied here.

We can roughly distinguish three phases in Feyerabend's early preoccupation with quantum mechanics: a first phase (1946-1951) during his studies;[1] a second phase (1952-1957), very much influenced by Karl Popper[2]; and, finally, a third phase (1958-1963, 1968-1969) pursuing an autonomous reading of Bohr's contributions to quantum mechanics and its philosophy.[3] At the end of the second phase, Feyerabend was a lecturer at the University of Bristol, where his colleague Stephan Körner and physicist Maurice Pryce were tasked with organizing the Ninth Symposium of the Colston Research Society in 1957. Feyerabend was heavily involved with the planning and organization of the conference, and it led to the publication of what would be his only technical contribution to physics as such in his conference paper entitled "On the quantum theory of measurement."[4] Within this paper, Feyerabend constructs a novel theory of quantum measurement that anticipates many ideas from contemporary decoherence theory and uses this approach to reject seemingly positivist claims about quantum theory made by several physicists involved in the original development of the theory. While this technical paper has been acknowledged in historical scholarship (Jammer (1974, p. 491); Mehra (2012, pp. 27–9)) and physical research (Zeh (1989, p. 81); Auletta et al. (2001, p. 226)), it has not been accounted for in Feyerabend scholarship, until now.

The purpose of our paper is to fill the gap and clarify the transition in Feyerabend's thinking around 1957 as it is made clear in this work. We trace the historical details of his theory of measurement, reconstruct its formal maneuvers, and demonstrate that in it, one finds not only an objection to orthodox quantum theory and the positivist program, but also early signs of theoretical pluralism, a continued defense of methodological realism, and other ingredients that would serve as important stepping stones in the development of his philosophy.

We proceed as follows: In Section 2, we outline the received view of orthodox quantum mechanics as it was understood in 1957 and its purported connection to positivism using the formalism due to von Neumann. We note that, while it is dubious that such a view formed a

---

[1] Of the first phase, not much evidence is available; see Feyerabend (2016) and commentary in Kuby (2016)

[2] See e.g. Feyerabend (2015a, p. 34); Feyerabend (2015b, p. 12).

[3] See Kuby (2021) for a review and assessment of this phase in the context of Feyerabend's general conception of philosophy; cf. also van Strien (2019) for similar conclusions.

[4] The paper was published in English as Feyerabend 1957a; a shorter version, excluding the philosophical discussion, was published in German as Feyerabend 1957b in *Zeitschrift für Physik*.

legitimate orthodoxy, it was unequivocally the target of philosophical analysis and played an important role in actual scientific practice. In Section 3, we reconstruct Feyerabend's novel account of quantum measurement in which all processes are described by unitary evolution (i.e. there is no collapse), and system macroscopicity is accounted for in terms of observer ignorance. We then clarify what he took to be its scientific merits, and assess the extent to which it provides a viable alternative to the von Neumann scheme. In Section 4, we then see how Feyerabend utilizes this account of measurement to launch a principled objection against the classical/quantum distinction in the orthodox account of quantum theory and the closely related positivist observational/theoretical distinction. We discuss how this new account opens the door for realist interpretations of quantum theory, and foreshadows his later work on theoretical pluralism. Our conclusions are summarized in Section 5.

2 The Received View

2.1 Positivism in quantum mechanics

Feyerabend's engagement with the quantum theory of measurement is embedded in the received view that the Göttingen-Copenhagen school of physicists developed quantum mechanics in remarkable concordance with the philosophy of positivism. Although this purported association with positivism is misleading, as we will see, this was a point of agreement between self-declared foes of positivism, like Karl Popper, and friends of positivism, like Philipp Frank.

As a first approximation, positivism here denotes the project aiming to give an account of scientific knowledge as best exemplified by Logical Empiricism: committing to an empiricist account of science rejecting transcendental-idealist accounts involving the *synthetic a priori*, while at the same developing a non-empiricist account of mathematics against earlier empiricists, like Hume or Mill.[5]

As the development of modern physics was propelled by inextricably combining physics and mathematics, the challenge to positivism was to draw a (reliable) distinction between the empirical and non-empirical components of physical theories, such that only the former had

---

[5] It is important to remember that the concept denoted by the German expression "Wissenschaft" and "wissenschaftliche Erkenntnis" is not limited to the natural sciences, but includes humanities and formal sciences, too.

physical meaning. This distinction, some Logical Empiricists thought, could only be set-up by clearly distinguishing between analytic and synthetic sentences in the language of scientific theories. This, in turn, needs to be supplemented by an account of how each theoretical sentence can either be shown to be analytic or its physical content be reduced to synthetic ones or be eliminated altogether. (Let "positivism" denote this more specific task for the remainder of the paper.)

From a contemporary vantage point, the adequacy on the received view is highly dubious, both from an historical and a philosophical perspective: First, the physicists associated with the Göttingen-Copenhagen school did not share a common philosophical view of quantum theory nor, more generally, of physics; and, second, the positions designated as "positivism" were akin to a patchwork of quite different views (Beller 2001). The apparent image of quantum theory as an instance of positivism in practice is therefore something of a caricature of a much more intricate story.

Granting that we cannot take either Frank or Popper as disinterested interpreters of the philosophy of quantum physicists, it is also true that the very same physicists talked at times as if they where endorsing or at least relying on positivist goals. Beller (2001, pp. 55–57) takes some instances of these to be *post hoc* conceptual justifications of results achieved by scientific theorizing—a move which Feyerabend would eventually reverse-engineer to recover the original physical argument which guided the theorizing of Bohr in particular. In this respect Faye et al. (2021, p. 278) argue that Bohr and the Logical Empiricists "did not always share the same premises, though their conclusion seem[ed] to coincide". In short, the appearance of a positivistic consensus among physicists is not so much an indication of genuine positivistic commitments by physicists, but rather a sort of common language of justification deemed permissible (if not literally correct) by the community.

And yet, to understand Feyerabend's philosophical target in his contribution to the Colston Symposium, in this paper we have to take the received view for granted. Karl Popper summarized it as follows:

> Today the view of physical science founded by Osiander, Cardinal Bellarmino, and Bishop Berkeley, has won the battle without another shot being fired. Without any further debate over the philosophical issue, without producing any new argument, the instrumentalist view (as I shall call it) has become an accepted dogma. It may well now be called the 'official view' of physical theory since it is accepted

> by most of our leading theorists of physics (although neither by Einstein nor by Schrödinger). And it has become part of the current teaching of physics. (Popper 1956, p. 360)

The main point inherited from Popper's picture, which Feyerabend (2015a) and Feyerabend (2015b) would draw on, is the picture of the physicists' community as victims of positivism, a philosophical prejudice instilled first and foremost by the main originators of the new quantum theory.

The view targeted by Feyerabend is two-fold: The first part consists in a strict separation between the empirical and the theoretical components in quantum theory. This was chiefly enabled by the demand for elimination of unobservable quantities, a goal subscribed to by many physicists of the Göttingen-Copenhagen school[6], and which became canonical in the first matrix-mechanical formulation given by Heisenberg in his *Umdeutung* paper 1985, customarily seen as the beginning of the new theory of quantum mechanics. Heisenberg (1985, p. 879) opens by programmatically stating a *principle of observability* as follows: "The present paper seeks to establish a basis for theoretical quantum mechanics founded exclusively upon relationships between quantities which in principle are observable."

This makes it possible to isolate an *observational language* that is exhausted by the eigenvalues of Hermitian operators (viewed as labels on measuring devices) and statements about which detectors 'clicked' in various experiments (as well as their aggregate statistics). The "relationships between quantities", on the other hand, constitute the theoretical component. Although Heisenberg's matrix-mechanical formulation soon gave way to Schrödinger's wave-mechanical formulation, the distinction remained intact, the *theoretical language* of QM was now given by Hilbert spaces, state vectors, Hermitian operators, etc., i.e. the mathematical machinery.

The second part of the view Feyerabend targets is a strict separation between classical and quantum description, as advanced primarily by Bohr. As Feyerabend understood Bohr during this time, the observational language of QM can only be interpreted classically. This 'indispensability of classical concepts', as the doctrine has been called, is predicated on the

---

[6] As Faye et al. (2021, p. 264) note:

> Around that time [1927], it was generally assumed that unobservable quantities should be eliminated from physics, a view advocated by Pauli, Born and Jordan, and that Einstein [in 1905], under the influence of Ernst Mach, had been successful in his attempt to meet this demand by first rejecting Newton's notion of absolute simultaneity and then Newton's absolute space and time.

(alleged) fact that “our interpretation of the experimental material rests essentially upon the classical concepts” (Bohr 1928, p. 580). In other words, the physical content of quantum mechanics, insofar it is provided by the observational language, is classical by necessity. Or, to paraphrase Kant, the forms of our sensible intuition are mediated by classical concepts (like space, time, momentum and energy).[7] If quantum phenomena exist, we can only know them as mediated by classical concepts. This leads Bohr to conclude that, since we have no mode of understanding other than classicality, the theoretical concepts of QM are not actually concepts at all, but only provide a “symbolic scheme” Bohr (1949, p. 211): rather than providing concepts which represent the quantum world, “[t]he entire formalism”, i.e. the theoretical language of QM, “is to be considered as a tool for deriving predictions of definite and statistical character [...]. These symbols themselves [...] are not susceptible to pictorial interpretation” Bohr (1948, p. 314).

The conjunction of both parts as well as the specific way the classical-quantum distinction is mapped on to the observational-theoretical distinction in this picture led Feyerabend to the conclusion that the originators really had baked positivism into quantum mechanics.

Feyerabend’s goal in his contribution to the Colston Symposium was to investigate how the positivist treatment of QM had been codified into the standard formulation of quantum mechanics given by von Neumann, in particular its treatment of quantum measurement (see the next subsection), and how it could be excised from it (Section 3).

2.2 The von Neumann Scheme

In his 1957 conference paper, Feyerabend offers first what he takes to be a faithful reconstruction of the traditional von Neumann scheme for quantum measurement, and then offers his own alternative that he takes to be superior. Let us sketch first John von Neumann’s scheme, which in 1957 was (and, to a degree, still is) the standard account of quantum measurement.

According to Feyerabend, von Neumann’s treatment of quantum measurement encodes the positivist view by introducing a strict separation between the theoretical language of quantum states, describing the evolution of the quantum system, and the observational language of measurement outcomes, describing post-measurement processes in classical terms.

---

[7] See e.g. Kaiser (1992), Chevalley (1994), and Cuffaro (2010) for Neo-Kantian interpretations of Bohr’s philosophy.

This separation is secured by postulating a separate, non-unitary process known as the collapse of the wave function which in turn allows for a classical description of measurement outcomes. Let's see how Feyerabend understands von Neumann in more detail.

On the von Neumann measurement scheme, an individual system[8] $\mathcal{S}$ is represented by a unit vector on some Hilbert space $|\phi\rangle \in \mathcal{H}_{\mathcal{S}}$ (equivalently, the density operator $\rho_{\mathcal{S}} = |\phi\rangle\langle\phi|$). An observable property of $\mathcal{S}$ is represented as a self-adjoint operator $\hat{O}$ on $\mathcal{H}_{\mathcal{S}}$ with a real spectrum of eigenvalues $sp(\hat{O}) = \{\lambda_i\}$. For our purposes, we need only consider the case where each λ_i is non-degenerate, i.e. has only one eigenvector $|\phi_i\rangle$ or, equivalently, density operator $\rho_{\phi_i} = |\phi_i\rangle\langle\phi_i|$.

A device $\mathcal{M}$ that measures $\hat{O}$ is represented by a physical system on a Hilbert space $\mathcal{H}_{\mathcal{M}}$ with one macroscopically distinct state $|M_i\rangle$ for each $\lambda_i \in sp(\hat{O})$ (equivalently, $\rho_{M_i} = |M_i\rangle\langle M_i|$); that is, $\{|M_i\rangle\}$ forms a basis of the relevant subspace of $\mathcal{H}_{\mathcal{M}}$ needed for the interactions in question. The human observer may discern with the naked eye which of these states the measuring device occupies, and it is in this way that the state of the measuring device enables the observer to know the measurement outcome. Thus, direct sense-perception may purportedly be connected up with measurement outcomes.

When a measurement of $\hat{O}$ on $\mathcal{S}$ takes place, if $\mathcal{M}$ has an initial (pure) state $|\psi\rangle$ (equivalently $\rho_{\mathcal{M}} = |\psi\rangle\langle\psi|$), then the equations of motion are supposed to evolve the joint system $\mathcal{S} + \mathcal{M}$ by some Hamiltonian $\hat{H}$ via:

$$|\phi\psi\rangle \rightarrow e^{-it\hat{H}/\hbar}|\phi\psi\rangle = \sum_i \langle\phi|\phi_i\rangle|\phi_i M_i\rangle := |\phi'\psi'\rangle. \tag{1}$$

Of course, final states of this form are not the only way a joint system could evolve. Rather, it is the case that for the evolution of the joint system to be called a 'measurement,' this condition must be satisfied.

Next, a non-unitary collapse process is purported to occur which projects the joint system onto a particular eigenstate $|\phi_i M_i\rangle$ with probability $\langle\phi'\psi'|\Pi_i|\phi'\psi'\rangle = |\langle\phi|\phi_i\rangle|^2$ where $\Pi_i := |\phi_i M_i\rangle\langle\phi_i M_i|$ is a projection onto the eigenspace of the eigenvalue λ_i for $\hat{O}$. This probability assignment is the Born rule, and since the collection $\{\Pi_i\}$ forms a projection-valued measure, the probabilities may equivalently be expressed as $\mathbf{tr}(\rho'_{\mathcal{SM}}\Pi_i)$. This collapse process violates the equations of motion, and determines a definite (single) observed measurement outcome. However, the metaphysical considerations as to just how this collapse

---

[8] That is to say, a system in a pure state.

occurs are irrelevant to the received view; it is a fundamentally unknowable process, yet necessary to link the theoretical language of quantum states with the observable language of detector clicks and measurement outcomes.

Feyerabend offers additional clarification on what he takes the salient features of the von Neumann scheme to be: he distinguishes between a *complete* measurement where the result λ_i is known, from an *incomplete* measurement where a collapse has occurred, but the outcome is unknown. While the physical state of affairs is the same in both situations, our knowledge of it is different, and hence how we represent our knowledge in the two cases differs as well. Our *ignorance* of the measurement outcome affects how we describe the evolution of the joint system. Specifically, using density operators from now on, the state prescriptions used by the observer to represent the system after measurement are given by:

$$\begin{aligned} &\text{Incomplete Measurement} \qquad \rho_{\mathcal{S}} \otimes \rho_{\mathcal{M}} \rightarrow \sum_i |\langle\phi|\phi_i\rangle|^2 \rho_{\phi_i} \otimes \rho_{M_i} \\ &\text{Complete Measurement} \qquad \rho_{\mathcal{S}} \otimes \rho_{\mathcal{M}} \rightarrow \rho_{\phi_i} \otimes \rho_{M_i}. \end{aligned} \tag{2}$$

According to Feyerabend, incomplete measurements compel us to treat the state of a system after measurement as a *classical mixture* of eigenstates, rather than the quantum superposition before the measurement. This insight that the statistical features of post-collapse quantum states may be understood as features of the observer's *description* of the system due to their ignorance, and not a feature of the system itself, motivates the alternative theory of quantum measurement which he constructs.

Summarizing the von Neumann scheme in Feyerabend's terms, a quantum observer describes the state evolution of the measured system for a complete measurement as:

$$\underbrace{\rho_{\mathcal{S}} \otimes \rho_{\mathcal{M}}}_{\textit{Initial State}} \rightarrow \underbrace{\sum_{i,j} \langle\phi|\phi_i\rangle\langle\phi_j|\phi\rangle |\phi_i M_i\rangle\langle\phi_j M_j|}_{\textit{Unitary Evolution}} \rightarrow \underbrace{\sum_i |\langle\phi|\phi_i\rangle|^2 |\phi_i M_i\rangle\langle\phi_i M_i|}_{\textit{Collapse (Incomplete Measurement)}} \rightarrow \underbrace{\rho_{\phi_i} \otimes \rho_{M_i}}_{\textit{Complete Measurement}} \tag{3}$$

Here, the mixing probabilities after collapse are subjective;[9] there is already a definite (un-

---

[9] Connecting with Del Santo (2022), the Colston Symposium occurred during a period in which Feyerabend's role with Popper as the sympathetic pupil was beginning to show the first crack. This is made apparent in his contribution in which he defends a subjective account of probabilities directly opposing the propensities view

known) outcome. Transitioning to a complete measurement is hence just a matter of reading off the outcome of an incomplete measurement (which are taken to have already been objectively determined by collapse). After collapse, the evolution of the measuring device is described *classically* as a system whose relevant observables all have definite, determined values.

3 Feyerabend's Theory of Measurement

3.1 Feyerabend's Scheme

Feyerabend took issue with the (apparently) orthodox interpretation of quantum theory, particularly with respect to its reliance on a distinction between classical and quantum levels of analysis and their subsequent partitioning into observational and theoretical fragments. As we shall see, this was tied to his broader dissatisfaction with the positivist program more generally, which heavily influenced this orthodoxy.

More concretely, Feyerabend objects to the cogency of the von Neumann scheme on several grounds. First, it is unsatisfactorily silent about how one connects directly observable features of a macroscopic measuring device to the quantum formalism; the collapse process is necessarily something about which one can have no direct knowledge. Moreover, since collapse projects a state onto a subspace, it is a fundamentally irreversible process that somewhat anomalously opposes the reversibility of unitary evolution. Of course, it was well-known that irreversible processes appear in classical mechanics (which is also governed by reversible dynamics) as well when one considers the evolution of statistical ensembles, but in the classical case, one has compelling explanations for how this irreversibility emerges, e.g. by appeal

---

of Popper, yet is still compelled to cite Popper's propensities account in his bibliography (ref. 18 of Feyerabend 1957a), despite never citing it in the main text. And in a letter sent shorty before the Colston Research Symposium we read:

> [Y]our revision of the usual interpret. of probability is *neutral towards the above problem* [i.e. has the electron definite momentum and definite position at the same time?] which I think is the central problem of any interpretation of QM, and which has led to the "quantum-mess". Hence I must say that, although your paper is most important for probability as well as for the interpretation of the classical statistical disciplines, it does not contain any contribution towards the main problem of quantum-mechanics, mentioned above. Or if it does, this contribution clearly contradicts the Neumann proof *which is not changed* by introducing the propensity-interpretation instead of the usual interpretation in terms of relative frequencies (which von Neumann uses). (Feyerabend to Popper, 27 March 1957, p. 3, reproduced in Feyerabend 2020, p. 254)

See also Collodel (2016) for an extensive analysis of Feyerabend's relation to Popper and his school.

to Boltzmann's H-theorem which was thought to explain how irreversible macroscopic dynamics can emerge from reversible microscopic processes.However, one cannot analogously explain away the irreversibility that arises in the quantum case due to collapse. Taking this strategy from classical statistical physics as inspiration, Feyerabend (1957a) concluded that "the [von Neumann scheme] is correct, but incomplete. What is omitted is the fact that $\mathcal{M}$ is a macroscopic system and that [the observer] cannot discern the finer properties of $\mathcal{M}$" (p. 126).

Feyerabend's primary goal, then, was to develop an alternative theory of quantum measurement—a completion of the von Neumann scheme—that may be fully understood using unitary quantum dynamics (i.e. no collapse) and well-motivated statistical assumptions about macroscopic quantum systems. This new theory does not aim explain why single definite measurement outcomes are observed and hence is not an attempted resolution to the modern measurement problem as such. Rather, the underdetermination of measurement outcomes becomes an artifact of the statistical assumptions about macroscopic systems that agents use when representing them. In this way, Feyerabend apparently needs only to account for incomplete measurement processes using unitary dynamics.

The crucial detail for Feyerabend is how one defines macroscopicity for measurement devices, a notion that he found was already implicit in the von Neumann scheme anyway. He contends that macroscopicity is a feature of an observer's description of a system; it is not a feature of the system itself. In particular, macroscopicity characterizes an observer's ignorance about a system. In the face of this ignorance, the observer loses all hope of an exact microphysical description of events (whereby the determination of *which* measurement outcome will obtain becomes impossible), but may leverage their ignorance to introduce well-motivated statistical assumptions to make approximations that allow for a statistical account of measurement.

For Feyerabend, if a system $\mathcal{X}$ is macroscopic (relative to some observer who is measuring a particular observable), this means that:

(A) With respect to the observable under consideration, the relative phases between components of $\mathcal{X}$ in the eigenbasis of the observable vanish, whence there is no interference between them.[10]

---

[10] Note, this condition on macroscopicity has no bearing on the number of degrees of freedom in question: many-body systems such as superconducting quantum interference devices (SQUIDs) violate assumption (A) with respect to the observers who study them (cf. Ryu et al. 2020) and are therefore not 'macroscopic' in the

(B) The observer cannot distinguish all of the micro-states of $\mathcal{X}$, only certain coarse-grained macro-states, but they are warranted in supposing that all micro-states associated with a given macro-state are equally probable.

The latter point forms what Feyerabend terms the "principle of equiprobability." He notes:

> This assumption, which so far has only been used in connexion with quantum statistics, is an indispensable part of any complete theory of measurement. As opposed to classical theory of measurement the quantum theory of measurement is essentially a statistical theory, i.e. it is a theory which uses, apart from the equations of motion, also further statistical assumptions. (Feyerabend 1957a, p. 126)

It should be stressed that Feyerabend took these assumptions to be implicit and natural features of macroscopic systems as they had already been described by other prominent physicists, for instance, by Jordan (1949) and Ludwig (1953). This is made explicit in an earlier unpublished draft.[11] Indeed, as Bohm writes in his textbook (which Feyerabend also cites), demonstrating the existence of destructive interference of the requisite sort is "a crucial problem that arises in the demonstration of the logical self-consistency of the quantum theory of measurement" (Bohm 1951, p. 600). There is also a 1954 paper by van Kampen which very explicitly adopts similar principle in an attempt to derive macroscopic irreversibility for quantum processes by understanding macroscopicity in terms of vanishing interference terms as in (A) and supposing observational indistinguishability over 'phase cells' associated with the operationally distinguishable eigenspaces, resembling (B).[12]

How should we cache out these assumptions formally? Feyerabend is unfortunately not totally explicit here in his paper. However, we may try to fill in the gaps and offer a rough reconstruction of what he had in mind.[13]

Consider, as Feyerabend did, just the two-dimensional case. Let $\hat{O}$ be the measured observable for a system $\mathcal{S}$ with eigenstates $\{|\phi_1\rangle, |\phi_2\rangle\}$. Let $\mathcal{M}$ be the system that measures $\hat{O}$ for $\mathcal{S}$ and suppose that the initial states of $\mathcal{S}$ and $\mathcal{M}$ are $\rho_{\mathcal{S}}$ and $\rho_{\mathcal{M}}$, respectively (with $|M_i\rangle$ coupling to $|\phi_i\rangle$ for both i). Further, let $\alpha_1 = \langle\phi|\phi_1\rangle$ and $\alpha_2 = \langle\phi|\phi_2\rangle$. Then the unitary evolution of the joint system is

---

requisite sense.

[11] See Paul Feyerabend, "On the quantum-theory of measurement", undated typescript, HF 08-33-24, Herbert Feigl papers, University Archive, University of Minnesota (referenced in Feyerabend 2020, 254, fn 11).

[12] See also van Kampen (1988), where the macroscopicity assumption is applied to quantum measurement.

[13] We thank Jos Uffink for several clarifying remarks and suggestions with this reconstruction.

$$|\phi\psi\rangle \rightarrow |\phi'\psi'\rangle = \alpha_1|\phi_1 M_1\rangle + \alpha_2|\phi_2 M_2\rangle \tag{4}$$

And the expectation value of $\hat{O}$ is:

$$\begin{aligned}\langle\hat{O}\rangle =& |\alpha_1|^2\langle\phi_1 M_1|\hat{O}|\phi_1 M_1\rangle + \alpha_1\overline{\alpha}_2\langle\phi_2 M_2|\hat{O}|\phi_1 M_1\rangle \\ &+ \alpha_2\overline{\alpha}_1\langle\phi_1 M_1|\hat{O}|\phi_2 M_2\rangle + |\alpha_2|^2\langle\phi_2 M_2|\hat{O}|\phi_2 M_2\rangle \\ =& |\alpha_1|^2\langle\phi_1 M_1|\hat{O}|\phi_1 M_1\rangle + (\alpha_1\overline{\alpha}_2 + \alpha_2\overline{\alpha}_1)\langle\phi_1 M_1|\hat{O}|\phi_2 M_2\rangle + |\alpha_2|^2\langle\phi_2 M_2|\hat{O}|\phi_2 M_2\rangle.\end{aligned} \tag{5}$$

What is left out of the von Neumann scheme is that $\mathcal{M}$ is macroscopic. If taken seriously, this expectation value may be further simplified in the following way. One may express $\alpha_k = c_k e^{i\theta_k}$ for some real value $0 \leq c_k \leq 1$ and some real phase $\theta_k \in [0, 2\pi]$. In the two-dimensional case under consideration, Feyerabend somewhat sketchily takes condition (A) on macroscopicity—that relative phases vanish—to mean $\theta_1 - \theta_2 \gg \pi$. Since phases lie on a circle and so have no meaningful absolute magnitude, this is imprecise. However, we may interpret this to instead mean that $\theta_1 - \theta_2 \approx 0$ (or, equivalently, that $\theta_1 - \theta_2 \approx 2\pi$); that is, the relative phase is as far away from π as possible. On this reading, one may easily compute:

$$\alpha_1\overline{\alpha}_2 + \alpha_2\overline{\alpha}_1 = c_1 c_2 \cos(\theta_1 - \theta_2) \approx c_1 c_2 \cos(0) = 0. \tag{6}$$

Hence, when the macroscopicity assumption (A) is met by $\mathcal{M}$, one has that

$$\langle\hat{O}\rangle \approx |\alpha_1|^2\langle\phi_1 M_1|\hat{O}|\phi_1 M_1\rangle + |\alpha_2|^2\langle\phi_2 M_2|\hat{O}|\phi_2 M_2\rangle. \tag{7}$$

Now, if we consider the post-collapse mixed state from the incomplete measurement stage in the von Neumann scheme, we see that the expectation-value is the same. Specifically, after collapse but before the measurement outcome is revealed, the state prescription is:

$$\rho_{S\mathcal{M}} = |\alpha_1|^2\rho_{\phi_1} \otimes \rho_{M_1} + |\alpha_2|^2\rho_{\phi_2} \otimes \rho_{M_2} \tag{8}$$

from which is clear that the expectation value of $\hat{O}$ will be the same as (7). Feyerabend (1957a, p. 127) further extends this by noting that this preservation of expectation values is ensured also for all observables which commute with $\hat{O}$, and so there is a natural sense in which commuting observables allow for 'classically compatible' measurements. This claim is promoted to what Feyerabend calls the '*observer principle*' which states that an observer cannot discern complementarity; if the observer can measure observable $\hat{O}_1$ with a macroscopic device $\mathcal{M}$, they can only also measure another observable $\hat{O}_2$ if $\hat{O}_1$ and $\hat{O}_2$ commute. He claims that this explains the absence of complementarity at the classical level (that is, for macroscopic measurement devices interacting with quantum systems) directly in terms of quantum theory. A more detailed account of a similar perspective is found in van Kampen (1954).

When assumption (B) is also satisfied by the measuring device $\mathcal{M}$, the observer can no longer distinguish at all between the unitary evolution state prescription and the incomplete measurement description. Hence, Feyerabend claims that, once one takes into account macroscopicity, they can substitute the incomplete measurement prescription for the that obtained by unitary evolution. Feyerabend (1957a) puts this as follows:

> ...the assertion that [eigenstates of $\mathcal{M}$] are macroscopically distinguishable, implies, together with the principle of equiprobability, that, *for all practical purposes*, [the unitary evolution description] and [the incomplete measurement description] yield the same results with respect to the properties of $\mathcal{S}$. (Feyerabend 1957a, 126, our emphasis)

We see here that Feyerabend invokes the 'for all practical purposes' (FAPP) clause as a means for asserting that, because of the observer's ignorance about the micro-state of the measuring device, the state prescription obtained from unitary evolution and that obtained from incomplete measurement have the same representational capacity and may thus be used interchangeably. Indeed, we again find agreement with van Kampen who writes "[t]he expectation value of a macroscopic quantity in a pure quantum state can be found as the average of that quantity over a certain classical ensemble" (van Kampen 1954, pp. 612–3).

Unfortunately, Feyerabend does not spell out how the principle of equiprobability (B) is meant to be implemented formally, but in van Kampen's distinct though parallel analysis of macroscopic processes, he remarks that

> The fact that this particular averaging process leads to agreement with observa-

> tions has still to be explained; and for this explanation the argument of randomly varying terms cancelling each other is again essential. In particular it has to be assumed that there is no general trend among the coefficients. (van Kampen 1954, p. 615)

To summarize, Feyerabend's theory of measurement amounts to the realization that the relation between observers and macroscopic measurement devices includes more data than is typically appreciated, and that this data may be leveraged to accommodate a statistical account of quantum measurement that has no collapse. Specifically, if a measuring device is macroscopic, then its state unitarily evolves to one whose statistics very well approximate the incomplete measurement description directly. Hence, the statistics of the von Neumann scheme may be purportedly reproduced without collapse through ordinary unitary evolution.

The crucial claim is that the probabilities assigned to $\rho_{\mathcal{M}_i}$ by the Born rule following unitary evolution will be approximated by the ensemble statistics given by the incomplete measurement prescription. If Feyerabend is right, this explains why the von Neumann scheme reproduces observed statistics (even if it is, for Feyerabend, wrong). It is true that one cannot infer a single measurement outcome from an incomplete measurement—and so his measurement scheme does not solve the measurement problem as such—but since the observer is required to treat the macroscopic measurement device as though it is in a statistical mixture, this is unsurprising. The measurement problem is thus deflated because there is a necessary epistemic limitation from being able to predict a complete measurement due to the imposed statistical assumptions. Importantly, however, there is no collapse process needed to obtain such an account of measurement.

3.2 Merits and Viability

The theory of measurement Feyerabend introduced was clearly not intended to be a serious candidate for overturning actual scientific practice; he presented it in only one paper, published in a conference proceedings, and would never write about it again. Indeed, he says as much himself: "As a satisfactory account of the classical level in terms of QM is still missing, my suggestions will have to be somewhat sketchy — but they may still be useful, at least as an indication of how a more satisfactory theory of measurement may be built up" (Feyerabend 1957a, p. 121). However, it is still valuable to see why he thought his proof of principle demonstration was dialectically valuable to the study of the foundations of quantum mechanics. There are two avenues to pursue, the first being what Feyerabend himself took to be the scientific merits of his work, the second being an independent appraisal of the viability of his proposal.

In the first direction, Feyerabend lists four reasons why his theory of measurement (assuming it is cogent) is to be preferable to the von Neumann scheme:[14]

1. It allows one to explain away collapse as a gap in an incomplete theory (Completeness).
2. All processes are described by the equations of motion (Unity).
3. Unjustified steps in the von Neumann scheme (namely, the omission of certain interference terms during measurement) are provided a rational motivation via the statistical assumptions that describe the observer's relation to the system (Explanatory closure).
4. The 'classical' level of analysis may be subsumed entirely into the strictly quantum level (Reduction).

Given that these sorts of features are valued in scientific practice, there is reasonable grounds upon which accepting the novel theory of measurement would be a progressive move. We thus see why he thought this theory of measurement could serve as a legitimate foil for the von Neumann scheme.

With regard to the viability of Feyerabend's proposal, there are several things to say. The first problem is that many features of the approach are merely sketched, and so filling them in precisely as we have tried to do here introduces challenges. It is not clear, for instance, whether Feyerabend intended to claim that the principle of equiprobability (B) compels the observer to treat the measuring device as though its initial state is a mixture. There is reason to believe this is not a tenable position to hold (for any 'fundamental' description of the measuring device's micro-state should presumably be pure), yet if it is given up, the account is formally incoherent, because the incomplete measurement prescription is certainly a mixed state, but unitary evolution takes pure states to pure states. Moreover, even if the assumption that the measurement device begins in a mixed state is what Feyerabend intended in his rough sketch, results from contemporary decoherence theory illustrate that it is non-trivial

---

[14] The given labels are our own terminology.

to show that the requisite sort of unitary evolution can actually occur, let alone that they are somehow typical.

More broadly, the principle of equiprobability is never formally articulated with any precision. It is merely gestured at as warranting the FAPP substitution of the incomplete prescription for the unitary evolution prescription. But without making this principle precise, the only available conclusion is that the *expectation value* of the relevant observable is preserved by this substitution, but which says nothing about the particular statistics of various measurement outcomes which need not be preserved. Feyerabend may have had in mind some sort of super-selection procedure on viable state descriptions to those which include all possible phases on the micro-states associated with macro-states such that their resulting cross-terms all cancel, but this is merely speculation. This gap would need to be filled in for the theory to be truly feasible. There may even exist cases in which the principle of equiprobability (B) is satisfied, but the interference across macroscopically distinguishable states does not vanish, whence the incomplete measurement description would be unable to recover all of the outcome probabilities as is intended; Bell (1990, p. 38) raised such a concern in response to van Kampen's account which closely resembles Feyerabend's. Hence, it is unclear whether or not the FAPP clause is even satisfied.

Additionally, the deflation of the measurement problem is itself somewhat suspicious. Feyerabend seems to claim that the determination of individual outcomes is not something about which an observer can have knowledge because they are treating the measuring device statistically. This is analogous to the explanation as to why classical statistical mechanics disallows knowledge of the micro-state of an ensemble system. However, the sort of underdetermination in the two cases should not be conflated: if one could give a full-blooded realist interpretation of (or extension to) quantum theory that is compatible with the statistical version described by Feyerabend, then it would need to be able to explain single outcomes. Classical Hamiltonian mechanics is able to do this (in principle) for the micro-state of an ensemble in classical statistical mechanics, but the call for a realist interpretation of quantum theory may be undermined by the measurement problem once more.

Nevertheless, while the technical viability of Feyerabend's approach may be put into question, there are similar alternatives on offer—such as contemporary decoherence theory—that seem to approach measurement as it bears on the interpretation of quantum mechanics with the same intended spirit and perhaps more technical precision. So, with that in mind, we now explore just how Feyerabend hoped such an account of quantum measurement could assist his objection to the classical/quantum distinction and the positivist program more broadly.[15]

4 Philosophical consequences

In the previous Section, we detailed how Feyerabend offers an *indirect* attack on positivism: because collapse is, in Feyerabend's view, motivated by positivism, a criticism of collapse can indirectly contribute to a criticism of positivism. Yet his arguments against collapse proceed on purely scientific and not philosophical grounds. As we have seen, Feyerabend nowhere appeals to philosophical arguments (either as necessary or sufficient grounds) to attack the projection postulate. Similarly, Feyerabend defends his own measurement scheme on its scientific merits and thus has to withstand scientific scrutiny.

In this Section, we switch to a philosophical perspective in order to investigate the interplay between the indirect attack on positivism, Feyerabend's measurement scheme, and his philosophical aims proper. Because the philosophical upshots of his scientific discussion are listed in rapid succession in the conclusion of his paper, we will disentangle them in the following subsections.

4.1 Theory and observation

In the conclusion of his paper Feyerabend briefly recalls the distinction between theory and observation which we associated with positivism in Section 2:

> Within certain schools of philosophy it was, and still is, fashionable to distinguish the level of every-day experience (or the 'observation-language', or the 'everyday-language') from the theoretical level, and to assume that the transition from the first level to the second level is totally different from transitions between parts of either the first, or the second level. (Feyerabend 1957a, p. 129)

He then highlights the kinship between positivism and the way in which the von Neumann measurement scheme relates the observational and theoretical language in quantum mechanics. While we already reviewed in Section 2 the claim that positivism influenced quantum

---

[15] The reader who is fully dissatisfied with Feyerabend's account of measurement may conceivably substitute in their favourite version of decoherence theory in what follows: the philosophical upshot will be the same.

mechanics, here Feyerabend introduces the converse implicature, that quantum mechanics might be interpreted as a vindication of positivism, giving positivism a scientific backing:

> This view is a generalization of the 'orthodox' view about the relation between classical mechanics and QM and it may therefore be called 'scientific'. But this only shows that nowadays scientists are committing a mistake which so far philosophers (notably positivistic, or 'scientific' ones) had the privilege to commit alone. (Feyerabend 1957a, p. 129)

It becomes apparent that Feyerabend's takes his new theory of quantum measurement to have two aims in this respect: Excising and successfully replacing the collapse process shows that the original von Neumann measurement scheme is not a necessary part of quantum mechanics and, therefore, that it cannot be used in more general science-bounded indispensability arguments in philosophy. Conversely, he takes the correctness of his own measurement scheme to be of philosophical import:

> [The new theory of measurement] suggests that, quite in general, *the everyday level is part of the theoretical level* rather than something completely self-contained and independent; and this suggestion can be worked out in detail and leads to a more satisfactory account of the relation between theory and experience than is the account given by Carnap, Hempel and their followers on the one side, and some contemporary British philosophers on the other. (Feyerabend 1957a, 129, our emphasis)

In the same period, Feyerabend would indeed go about to formulate such an account in his landmark article "An attempt at a realistic interpretation of experience" (1958), summarizing the theory of observation sentences he developed in Feyerabend (1951). In the article he defends his *pragmatic theory of observation sentences*, which is best exemplified through 'the detector model of observation': as far as observation is concerned, human observers are detectors, i.e. measuring instruments (Kuby 2018, cf.). Just as a thermometer displays a change in response to its surroundings, so observation sentences are to be modeled as behavioral dispositions of human observers to react in a certain way to events in their surroundings.[16]

---

[16] Feyerabend is not alone in proposing a pragmatic account: For example, Wilfrid Sellars's pragmatic account shares many similarities and would eventually be adopted by Bas van Fraassen. Another pragmatic account can be found in Everett's account of observers in the relative state formalism defined in his long thesis defended

And, just like a measuring instrument has to be *calibrated* in order to be a reliable detector, so a human observer has to be *trained* to react appropriately to some new stimulus to become a reliable observer. The "problem" of observation sentences is reduced to a problem of proper training of observers. Crucially, at this level of analysis observation sentences have no (intrinsic) interpretation: just like the expansion of mercury tells us nothing about the concept of temperature as such, so the utterance of an observation sentence tells us nothing about what is actually being observed.

How do we know what a thermometer actually measures, i.e. temperature? That is, how do we arrive at an interpretation of the behavior of a measuring instrument that informs us about the world? Feyerabend takes the lesson from the detector model of observation to be that nothing in the instrument or in the process of detection mediates this connection. Instead, the pragmatic theory of observation is supplemented with a *contextual theory of meaning* stating that

> the interpretation of an observation-language is determined by the theories which we use to explain what we observe, and it changes as soon as those theories change. (Feyerabend 1958, p. 163)[17]

Human observers do not only utter observation *sentences*, but (interpreted) observation *statements*. And this interpretation, the contextual theory argues, is supplied by the theory (or theories) governing the observational vocabulary. Inverting the positivist view that the physical content of theoretical statements is given by observation statements, the contextual theory claims that the physical content of observation statements is given by our best theory: The physical content of the reading "4° C" on the scale of the thermometer is given by statistical thermodynamics.[18]

This finally leads to "a realistic interpretation of experience". As Feyerabend puts it:

---

in 1957 to promote a realistic interpretation of quantum theory: "…systems which represent observers…can be conceived as automatically functioning machines (servomechanisms) possessing recording devices (memory) and which are capable of responding to their environment"(Everett 2012, p. 77).

[17] Feyerabend's labels this proposition as "thesis I". The term "contextual theory of meaning" appears in (Feyerabend 1960) to denote the idea that "the meaning of our words is a function of the (theoretical) context in which they occur"; and is used in Feyerabend (1962) to denote the idea that "the meaning of a term is not an intrinsic property of it, but is dependent upon the way in which the term has been incorporated into a theory". Preston (1997, pp. 25–30) and Oberheim (2006, pp. 58–63) have variously argued how 'thesis I' and the 'contextual theory of meaning' are related. Since these details do not really matter to our discussion, I equate them here.

[18] This is a much stronger claim than the usual 'theory-ladeness' of observation: as Feyerabend puts it, according to the contextual theory "[l]ogically speaking, all [i.e. everyday-experience and theoretical] terms are 'theoretical'" (Feyerabend 1958, 164. fn 23).

> According to [the contextual theory of meaning], we must distinguish between appearances (i.e. phenomena) and the things appearing (the things referred to by the observational sentences in a certain interpretation). This distinction is characteristic of realism. (Feyerabend 1958, p. 164)

Imagine the following situation: A well-trained physicist utters "I see an alpha-particle track in the cloud chamber" in the appropriate situation. According to the pragmatic theory of observation, we can, at most, infer that there is a *phenomenon*[19], i.e. something "appears" to her that causally prompts her to have this behavioral disposition; this tells us nothing about what is being observed, but, at most, something about the physicist, i.e. that she is a reliable detector. However, once this observation sentence is interpreted by the theory governing the term "alpha-particle" to yield an observation statement, the contextual theory of meaning tells us that the well-trained physicist is directly and non-inferentially *referring to* alpha-particles, i.e. "the things appearing".[20] We see that the contextual theory of meaning aims at justifying a *semantic* realism, i.e. the thesis that theoretical terms refer.

We will now see how this new account of the relationship between theoretical and observation statements is used by Feyerabend to justify a realistic interpretation of quantum theory.

4.2 Realism

In the conclusion to his paper, after proposing his novel account of quantum measurement, Feyerabend notes that it makes way for "a realistic interpretation of the formalism of QM" (Feyerabend 1957a, p. 129). The first way of reading his claim is to look at what this claim would have meant when viewed in its historical context: in the 1950's, discussions of 'realism' in philosophy of science were still focused on the sort of *semantic* realism that was the target of the positivist program, namely, realism about theoretical entities (i.e. the extent to which theoretical terms have semantic content or refer). Recalling the result of his contextual theory of meaning, this is surely the sort of realism Feyerabend was suggesting could be made viable on his account of quantum measurement, and this is easy to see.

Remember that, for Feyerabend, the reason for the introduction of collapse into quantum measurement was the result of positivism as accentuated by Bohr's indispensability thesis:

---

[19] In psychological terms: the proximal stimulus.
[20] In psychological terms: the distal stimulus.

> If we want to understand why [the projection postulate is introduced] we must remember that the current interpretation of quantum-mechanics contains the following philosophical thesis: QM is a tool for producing predictions rather than a theory for describing the world, whereas classical terms have direct factual reference. This thesis implies, of course, that the classical level and the quantum level are entirely distinct and that the transition from the one to the other cannot be further analysed. (Feyerabend 1957a, p. 129)

On the new theory of measurement, claims made about macroscopic systems that were previously viewed as a the 'observational' fragment of quantum theory—statements about measurement outcomes and so forth—are reduced to more fundamental claims about quantum states. That is, the observational language is subsumed entirely within the theoretical language. As such, if any part of the theory is to have semantic content whatsoever, it must be the case that the theoretical language grounds this semantic content, whereby semantic realism obtains:

> Now our analysis, if it is correct, shows that the classical level cannot be regarded as something which is totally distinct from the quantum level; it is rather a (particular) part of that level. Hence, the philosophical thesis, referred to in the last paragraph,[21] must be revised and replaced by a realistic interpretation of the formalism of QM. (Feyerabend 1957a, p. 129)

In (Feyerabend 1958), he spells this claim out in detail:

> Applying [the contextual theory of meaning to the case of quantum mechanics], we may say that if quantum mechanics is correct, then we must interpret all physical magnitudes, classical magnitudes included, as elements of a ring of non-commuting entities. This means that even the familiar properties of objects, such as their position, their momentum, their colour, etc., must be interpreted as Hermitian entities not all of which commute. Now there is *no practical need* to reformulate the language by means of which we describe our experiments or to change its characteristic as the error, committed on the macroscopic level, by the identification of the Hermitian entities of quantum mechanics and the classical

---

[21] Cf. the previous quotation.

> properties, can be shown to be negligible. But although the *smallness* of the error allows us to continue the *use* of the classical practices and of the classical 'forms of perception' on the macroscopic level, the *existence* of the error forbids us to regard this as an indication of the persistence of the classical *interpretation* of those forms. (Feyerabend 1958, p. 162)

The more notable consequence of our analysis, then, is that Feyerabend's measurement scheme is the analogue in physics to his contextual theory of meaning in philosophy.[22]

The second question of interest is: to what extent can we interpret Feyerabend's theory of quantum measurement as offering an avenue for a realistic interpretation of quantum theory where we are now concerned with realism *qua* scientific realism. This is surely not the question Feyerabend had in mind at the time for he, like his fellow empiricists, would have dismissed contemporary notions of scientific realism. It is nevertheless an intriguing (if historically anachronistic) question to consider. We find that the answer in this case depends on how fundamental one takes the new theory of measurement to be.

On the one hand, if one supposes that Feyerabend's new theory of quantum measurement is the final word on the matter, it is hard to see how it could admit a realist interpretation on any contending account of scientific realism. The main reason for this is that it relies so heavily on the observer's ignorance prohibiting their complete knowledge of micro-states, as well as on their privileged epistemic status that enables them to use statistical assumptions to model their ignorance. If no story is provided as to how this ignorance might be remedied, or how the micro-state evolution yielding collapse-like phenomena is possible, the contingent epistemic limitations of the observer would appear to prohibit one from affording the theory a realist interpretation in the modern sense. Moreover, since macroscopicity is itself observer-dependent, different observers will disagree about what sorts of systems are macroscopic,

---

[22] This may suggest a solution to Feyerabend's puzzling claim, which still bestirs scholars, made in the context of the later debate about incommensurability and theory change with Smart, Sellars and Putnam:

> In his paper Professor Putnam creates the impression that I am mainly interested in meanings and that I am eager to find change where others see stability. This is not so. As far as I am concerned even the most detailed conversations about meanings belong in the gossip columns and have no place in the theory of knowledge.

While the claim is not free of hyperbole, the solution to the puzzle is Feyerabend's contention that philosophers working in philosophy of science ("the theory of knowledge") do not help to make progress in the sciences by simply advancing new "theories of meaning" on philosophical grounds. Rather, progress in the sciences can only be had by entering the scientific discourse. (For an interpretation of Feyerabend's philosophy highlighting the aim of improving science, see Oberheim and Hoyningen-Huene (2000, pp. 373–4).) Feyerabend's measurement scheme is such an instance; and here, as we have seen, his contribution involves no "meaning" talk whatsoever.

and so any realistic extension of the theory must somehow account for this apparent intersubjectivity.[23]

As it stands, Feyerabend's account of measurement is, at best, successful in accounting for quantum processes under a FAPP clause. However, as Bell (1990) has argued, the project of interpreting quantum mechanics realistically cannot be achieved merely for all practical purposes. This is because a properly realist interpretation of quantum theory is not something that merely allows us to make successful predictions. Rather, it must be able to describe reality as a whole directly, in full detail, at least in principle. Thus, the theory should be able to accommodate arbitrary physical scenarios irrespective of one's purposes and limited scope of application, something that is impossible if a FAPP clause is invoked to make important theoretical moves. So it seems Feyerabend's account of measurement is insufficient for an interpretation of quantum theory in terms of scientific realism.

If, conversely, one views Feyerabend's approach as a stop-gap theory that suggests its own replacement, then it certainly does gesture towards an approach to quantum measurement that may in principle yield a realist interpretation. To what extent this 'in principle' clause may be satisfied is, however, another point of contention. However, should one view Feyerabend's account as a stop-gap theory—one intended only as a temporary stepping stone towards a more complete theory—one finds a more satisfying state of affairs. Specifically, one finds motivation that interpretations of quantum mechanics that are free from the pathologies of the orthodox view may be possible. In acknowledging the incompleteness of a stop-gap theory, however, Bell's objection against FAPP realist interpretations is a non-issue, for what is on offer is not itself a purported realist interpretation, but rather a guiding template for how one might begin to be constructed in the future.

Feyerabend's text offers clues in both directions: In regarding von Neumann's theory as "correct, but incomplete" because it does not provide an analysis of "the transition to the classical level", he introduces his measurement scheme as the completion yielding such an explanation "in terms of the equations of motion"; indeed, he claims to provide "the outlines of such a *complete* theory" (Feyerabend 1957a, 126, our emphasis). This does not read like the proposal of a stop-gap. On the very same page, however, he also admits that "[t]here is still no satisfactory account available of those approximations" involved in the "transition from the level of QM to the level of classical mechanics" (Feyerabend 1957a, 126, our emphasis),

---

[23] We thank Jos Uffink for raising this point.

implying that his completion has not closed this gap after all. Concluding, the issue boils down to the question whether Feyerabend intended such an account to be "satisfactory" once it attained an 'in principle' explanation, rather than FAPP, or not. The text leaves this question open.

The demand of a realist interpretation of scientific theories was very important for Feyerabend, at least before the development of his pluralist commitments in methodology took root, and consequently played an important role in his understanding of quantum mechanics as we have here seen. At the same time, Feyerabend's measurement scheme allows quantum mechanics to become a rival theory to classical mechanics in the macroscopic realm, thus creating a new competition between the two theories, which the positivist assumption had pacified. Preceding his later formulation of *theoretical pluralism* or of a *pluralistic test-model*, this was perhaps the first instances in which Feyerabend stressed the importance of realistically interpreted *alternative* theories: "we can take refutations seriously and *regard alternative theories* in spite of their unusual character as descriptive of really existing things, properties, relations, etc" (Feyerabend 1958, 168, our emphasis). While Feyerabend in this context came to associate theoretical pluralism with theories which could compete with quantum mechanics in the microphysical realm, such as the de Broglie-Bohm pilot-wave theory, the root can be found in his discussion of the quantum measurement problem. We detail this now.

4.3 Theoretical pluralism

Feyerabend's objection to the positivist approach to interpreting quantum theory may be understood as an objection to a form of naïve theoretical pluralism that one might find there (and, moreover, as a promotion of a different, less naïve form of theoretical pluralism).

Consider, for the moment, the following view which we shall term *instrumental pluralism*: Scientists are warranted in accepting multiple theories at a time if their simultaneous acceptance is of instrumental utility and they are combined to yield consistent predictions. Adopting such a view requires one to enforce limited (and mutually exclusive) domains of applicability for each theory. This sort of theoretical pluralism may be found in the 'positivist' readings of quantum theory: there is instrumental utility in describing pre-measurement processes using quantum mechanics and post-measurement processes using classical mechanics, so we are warranted in accepting both at once, provided we partition the world into 'classical' and 'quantum' parts. The von Neumann measurement scheme then allows one to apply quantum mechanics and classical mechanics in a mutually consistent way.

In his paper, Feyerabend diagnoses this instrumental pluralism in orthodox quantum mechanics. Keeping implicit the fact that both classical and quantum mechanics are simultaneously necessitated by the orthodox account, he notes that "the classical level and the quantum level are entirely distinct" (Feyerabend 1957a, p. 129). He then initiates dissent against this view by noting that "our analysis, if it is correct, shows that the classical level cannot be regarded as something which is totally distinct from the quantum level; it is rather a (particular) part of that level" (Feyerabend 1957a, p. 129).

That is, he objects to instrumental pluralism in orthodox quantum mechanics on the grounds that it allows for the coexistence of incompatible ontological commitments (about which one cannot consistently be a realist). On this reading, Feyerabend's theory of measurement—insofar as it allows quantum mechanics to compete with classical mechanics at the macroscopic level—may be interpreted as a resolution for his dissatisfaction with the use of this instrumental pluralism, for it allows him to recover the possibility of a realistic interpretation.

It appears Feyerabend already thought that early quantum theorists, Bohr *in primis*, prohibited successor theories from being universally applied by requiring classical mechanics to be retained indefinitely. It this respect, Feyerabend may have viewed his own contribution to the theory of measurement as a practical means for getting quantum mechanics back on track, that is, to promote the consideration of progressive interpretive maneuvers that were historically disallowed.

Feyerabend endorses the view that a good successor theory in the microphysical realm is one that should admit a realist interpretation; something impossible for the instrumental pluralist view in which ontologically incompatible theories may be simultaneously accepted due to their instrumental utility by restricting their domain of application. This sets the stage for his *inconsistency-maximizing* theory pluralism that would come a few years later, namely, the view that in order to maximize testability one ought to pursue a variety of *incompatible* theories and adopt a realist reading of each when it is being considered.

In one of the earlier drafts of Feyerabend's paper, we already find the view that the arguably *unanschauliche* consequences of a realistic interpretation of quantum mechanics cannot be simply disengaged by extending the theory in such a way as to recover a classical interpretation of it (as Einstein and Schrödinger sought to do). As Feyerabend laconically puts it: “The attempt to find a classical or semi-classical interpretation of QM looses its point.”[24] The possibility to put quantum mechanics under severe test can only be achieved by building an alternative theory competing with it in the microphysical domain, which would go so far as to eventually violate the quantum of action. This was the motivation for Feyerabend's subsequent interest in De Broglie-Bohm's theory, the only candidate which could deliver a realistically interpreted alternative to quantum mechanics.

5 Conclusions

The Colston Symposium of 1957 marked a turning point in Paul Feyerabend's philosophy. During this symposium, he presented what would be his only technical contribution to physics as such, namely, an extended theory of quantum measurement that sought to eliminate collapse processes and preserve unitary dynamics. The main strategy for this account of measurement was to realize that macroscopic measuring devices have certain features that, on the one hand, prohibit the observer from having total knowledge of their micro-states and, on the other, warrant the observer to use certain coarse-grained statistical assumptions that allow the hypothetical ‘collapsed’ mixed quantum state of the von Neumann measurement scheme to be very well approximated by unitary evolution alone.

The precise formal details underwriting this account of quantum measurement remain ambiguous and were not spelled out by Feyerabend in great detail. There indeed appear to be several problems that such an account of measurement would face if one wanted to make it completely rigorous. Most notably, the purported account relies heavily on an observer-dependent notion of macroscopicity, as well as the use of a ‘for all practical purposes’ clause that, together, limit its utility as a ‘fundamental’ account of the world. Nevertheless, Feyerabend's interest was not in the establishment of a novel theory of measurement *per se*. Rather, he proposed his account as a scientific alternative that would enliven discussions within the physics community about how to interpret quantum theory by motivating interpretative strategies that had been disallowed by the apparent prevailing orthodoxy.

But why did Feyerabend wish to do this? The primary answer lies in his perception of orthodox quantum theory as intimately tethered to the positivist framework in the philosophy of science. On the (historically inaccurate, but nevertheless dominant) received view, the sep-

---

[24] Paul Feyerabend, “On the quantum theory of measurement.” undated manuscript, HF 08-33-26, Herbert Feigl papers, University Archive, University of Minnesota (referenced in Feyerabend 2020, 254, fn 11).

aration between classical and quantum domains in orthodox quantum theory was at once an instance of positivism in practice (insofar as it embodied a form of observational/theoretical distinction by calling 'classical' terms 'observational' and quantum terms 'theoretical'), and also a sort of scientific justification for positivism (insofar as it provided apparently compelling support for the claim that positivist science could be successful). Feyerabend denied the positivist framework on philosophical grounds, and sought to attack it directly at the level of its implementation in scientific practice via quantum mechanics. To do this, he aimed to show that quantum theory could be better accounted for—and better interpreted—without relying on collapse, or the partitioning inherent in the orthodox view into classical/observation and quantum/theoretical terms.

In excising collapse from quantum theory, Feyerabend seem to open the door for a new interpretive strategies that he hopes could enable the development of full-blooded (semantically) realist interpretations of quantum theory. In this, we find early signs of his views that realism is of theoretical and methodological importance in scientific practice. We also identify early signs of theoretical pluralism in his theory of measurement, indicating a historical juncture in his philosophical thinking.

References

Auletta, Gennaro and Giorgio Parisi (2001). *Foundations and Interpretation of Quantum Mechanics: In the Light of a Critical-Historical Analysis of the Problems and of a Synthesis of the Results*. World Scientific.

Bell, John (1990). "Against 'measurement'". In: 3.8, pp. 33–41. DOI: `10.1088/2058-7058/3/8/26`.

Beller, Mara (2001). *Quantum Dialogue: The Making of a Revolution*. University of Chicago Press.

Bohm, David (1951). *Quantum Theory*. New York: Prentice-Hall.

Bohr, Niels (1928). "The Quantum Postulate and the Recent Development of Atomic Theory1". In: *Nature* 121.3050, pp. 580–590. DOI: `10.1038/121580a0`.

— (1948). "On the Notions of Causality and Complementarity". In: *Dialectica* 2.3/4, pp. 312–319.

Bohr, Niels (1949). “Discussion with Einstein on Epistemological Problems in Atomic Physics”. In: *The Library of Living Philosophers, Volume 7. Albert Einstein: Philosopher-Scientist*. Ed. by Paul Arthur Schilpp. Open Court, pp. 199–241.

Chevalley, Catherine (1994). “Niels Bohr’s Words and the Atlantis of Kantianism”. In: *Niels Bohr and Contemporary Philosophy*. Ed. by Robert S. Cohen, Jan Faye, and Henry J. Folse. Vol. 153. Dordrecht: Springer Netherlands, pp. 33–55.

Collodel, Matteo (2016). “Was Feyerabend a Popperian? Methodological Issues in the History of the Philosophy of Science”. In: *Studies In History and Philosophy of Science* 57. Ed. by Ian Kidd and Matthew Brown, pp. 27–56.

Cuffaro, Michael (2010). “The Kantian Framework of Complementarity”. In: *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 41.4, pp. 309–317. DOI: `10.1016/j.shpsb.2010.04.003`.

Del Santo, Flavio (2022). “Beyond Method: The Diatribe between Feyerabend and Popper over the Foundations of Quantum Mechanics”. In: *this issue*.

Everett, Hugh (2012). “Long Thesis: Theory of the Universal Wave Function (1956)”. In: *The Everett Interpretation of Quantum Mechanics: Collected Works 1955-1980 with Commentary*. Ed. by Jeffrey A. Barrett and Peter Byrne. Princeton University Press.

Faye, Jan and Rasmus Jaksland (2021). “Did Logical Positivism Influence the Early Interpretation of Quantum Mechanics?” In: *Logical Empiricism and the Physical Sciences*. Routledge.

Feyerabend, Paul K. (1951). “Zur Theorie der Basissätze”. Dissertation zur Erlangung der Doktorgrades an der philosophischen Fakultät der Universität Wien. Wien: Universität Wien.

— (1957a). “On the Quantum-Theory of Measurement”. In: *Observation and Interpretation: A Symposium of Philosophers and Physicists, Proceedings of the Ninth Symposium of the Colston Research Society*. Ed. by S. Körner and M. H. L. Pryce. London and New York: Butterworths Scientific Pub., pp. 121–130.

— (1957b). “Zur Quantentheorie der Messung”. In: *Zeitschrift für Physik* 148.5, pp. 551–559.

— (1958). “An Attempt at a Realistic Interpretation of Experience”. In: *Proceedings of the Aristotelian Society* 58, pp. 143–170. DOI: `10.2307/4544593`.

— (1960). “Patterns of Discovery”. In: *The Philosophical Review* 69.2, pp. 247–252.

— (1962). “Explanation, Reduction, and Empiricism”. In: *Scientific Explanation, Space, and Time*. Ed. by Herbert Feigl and Grover Maxwell. Vol. 3. Minnesota Studies in the Philosophy of Science. Minneapolis: University of Minnesota Press, pp. 28–97.

Feyerabend, Paul K. (2015a). "Determinism and Quantum Mechanics (1954)". In: *Physics and Philosophy*. Ed. by Stefano Gattei and Joseph Agassi. Cambridge, UK; New York, NY: Cambridge University Press, pp. 25–45.

— (2015b). "Physics and Ontology (1954)". In: *Physics and Philosophy*. Ed. by Stefano Gattei and Joseph Agassi. Cambridge, UK; New York, NY: Cambridge University Press, pp. 9–24.

— (2016). "The Concept of Intelligibility in Modern Physics (1948)". Trans. by Daniel Kuby and Eric Oberheim. In: *Studies in History and Philosophy of Science Part A* 57, pp. 64–66. DOI: `10.1016/j.shpsa.2015.11.016`.

— (2020). *Feyerabend's Formative Years. Volume 1. Feyerabend and Popper: Correspondences and Unpublished Papers*. Ed. by Matteo Collodel and Eric Oberheim. Vienna Circle Institute Library. Vienna-Berlin-Münster: Springer.

Heisenberg, W. (1985). "Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen". In: *Original Scientific Papers Wissenschaftliche Originalarbeiten*, pp. 382–396. DOI: `10.1007/978-3-642-61659-4_26`.

Jammer, Max (1974). *The Philosophy of Quantum Mechanics : The Interpretations of Quantum Mechanics in Historical Perspective*. A Wiley-Interscience Publications. New York [u.a.]: Wiley.

Jordan, P. (1949). "On the Process of Measurement in Quantum Mechanics". In: *Philosophy of Science*. DOI: `10.1086/287049`.

Kaiser, David (1992). "More Roots of Complementarity: Kantian Aspects and Influences". In: *Studies in History and Philosophy of Science Part A* 23.2, pp. 213–239. DOI: `10.1016/0039-3681(92)90033-3`.

Kuby, Daniel (2016). "Feyerabend's 'The Concept of Intelligibility in Modern Physics' (1948)". In: *Studies in History and Philosophy of Science Part A* 57, pp. 57–63. DOI: `10.1016/j.shpsa.2015.11.004`.

— (2018). "Carnap, Feyerabend, and the Pragmatic Theory of Observation". In: *HOPOS: The Journal of the International Society for the History of Philosophy of Science* 8.2, pp. 432–470. DOI: `10.1086/698695`.

— (2021). "Feyerabend's Reevaluation of Scientific Practice: Quantum Mechanics, Realism and Niels Bohr". In: *Interpreting Feyerabend*. Ed. by Karim Bschir and Jamie Shaw. Cambridge, Mass: Cambridge University Press, pp. 132–156.

Ludwig, G. (1953). “Der Meßprozeß”. In: *Zeitschrift für Physik* 135.5, pp. 483–511. DOI: `10.1007/BF01338813`.

Mehra, Jagdish (2012). *The Quantum Principle: Its Interpretation and Epistemology*. Springer Science & Business Media.

Oberheim, Eric (2006). *Feyerabend’s Philosophy*. Berlin: Walter de Gruyter.

Oberheim, Eric and Paul Hoyningen-Huene (2000). “Feyerabend’s Early Philosophy”. In: *Studies in History and Philosophy of Science Part A* 31.2, pp. 363–375. DOI: `10.1016/S0039-3681(00)00007-8`.

Popper, Karl R. (1956). “Three views concerning human knowledge”. In: *Contemporary British Philosophy*. Ed. by Hywel David Lewis. Third Series. London: Allen and Unwin, pp. 357–388.

Preston, John (1997). *Feyerabend: Philosophy, Science, and Society*. Cambridge: Polity Press.

Ryu, C., E. C. Samson, and M. G. Boshier (2020). “Quantum Interference of Currents in an Atomtronic SQUID”. In: *Nature Communications* 11.1, p. 3338. DOI: `10.1038/s41467-020-17185-6`.

van Kampen, N. G. (1954). “Quantum Statistics of Irreversible Processes”. In: *Physica* 20.1, pp. 603–622. DOI: `10.1016/S0031-8914(54)80074-7`.

— (1988). “Ten Theorems about Quantum Mechanical Measurements”. In: *Physica A*.

van Strien, Marij (2019). “Pluralism and Anarchism in Quantum Physics: Paul Feyerabend’s Writings on Quantum Physics in Relation to His General Philosophy of Science”. In: *Studies in History and Philosophy of Science Part A*. DOI: `10.1016/j.shpsa.2019.03.006`.

Zeh, Heinz-Dieter (1989). *The Physical Basis of the Direction of Time*. Springer.