Information and Causality in Promise Theory

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Abstract—The explicit link between Promise Theory and Information Theory, while perhaps obvious, is laid out explicitly here. It’s shown how causally related observations of promised behaviours relate to the probabilistic formulation of causal information in Shannon’s theory, and thus clarify the meaning of autonomy or causal independence, and further the connection between information and causal sets. Promise Theory helps to make clear a number of assumptions which are commonly taken for granted in causal descriptions. The concept of a promise is hard to escape. It serves as proxy for intent, whether a priori or by inference, and it is intrinsic to the interpretations of observations in the latter.

I. INTRODUCTION

Promise theory describes interactions between generalized agents and their possible outcomes. Promises declare possible causal pathways by defining and documenting ‘outcomes’ as possible boundary states of process graphs. In so doing, they provide scalable definitions of ‘intent without anthropomorphism’ and measurement, based on agents’ assessments of one another. Promise Theory has now been in use for over 15 years and has been applied to many different kinds of process networks [1], [2].

The goal of this letter is to describe the relationship between Promise Theory’s model of agents and promises, and the statistical information passed between them as described by Shannon’s Theory of Communication. Information Theory relies on scale invariant probabilities, whose meanings are inherently ambiguous, but sometimes phenomena are scale dependent. One of the aims of Promise Theory is to move beyond these ambiguities, while suppressing details that are not measurable in practice anyway for many systems.

II. PROBLEM AND NOTATION

Using the standard promise notation from [1], there are three main interaction patterns we need to distinguish and account for: Let A be any agent (on any scale), whose interior structure is unspecified. In this letter, its identity will be closely associated with its role in a particular interaction pattern so we can simplify the notation by taking A ∈ {S, R, I}, for sender, receiver, and intermediate nodes.

Consider three basic cases. The simplest is a unilateral promise declaration of b_S by S, without acceptance by a promisee R:

\[ S \xrightarrow{b_S} R, \]

i.e. the promise meets with ‘deaf ears’. The second is a promise of b_S with partial or complete acceptance b_R by its recipient:

\[ S \xrightarrow{b_S} I \xleftarrow{b_R} R, \]

and the final is the chain propagation of influence by conditional promises, where b_I is promised if and only if b_S is accepted by I:

\[ S \xrightarrow{b_S} I \xleftarrow{b_I} R \]

Since agents make promises only for themselves, these labels S, I, and R play a second role as subscripts to indicate the source of each promised measure. The promise bodies represent the details of what is promised, and these are set-valued measures.

An agent A’ must assess the extent to which a promise \( \pi_A \) made by A has been kept or not. If privy to the interior process states \( \Sigma_A \) for a promised process, this is partly determined by that information, else it’s arbitrary. The assessment by A’ is denoted \( \alpha_{A'}(\pi_A) \), and can take several forms, some of which may involve ‘probabilities’ for certain states \( \sigma_i \in \Sigma_A \), where the Latin indices run over the different symbols in \( \Sigma_A \) (see figure 1). The symbols, which are members of the body sets \( b_A \) take values from the alphabet of interior agent states \( \Sigma_A \), and I assume that every agent speaks a language composed of an alphabet \( \Sigma_c \) for that particular promise type \( \tau^1 \). For a promise:

\[ \pi : A \xrightarrow{b_A} A', \]

the promise body \( b_A \) is a constraint on A, consisting of a type label \( \tau \) and a measure which belongs to the alphabet of the promise language \( \Sigma_\pi \)

\[ b = \langle \tau, \chi \in \Sigma_\pi \rangle \]

1 A further subtlety, which one normally ignores based on an assumption of homogeneity or global symmetry for types \( \tau \), is that the promise body belongs uniquely to its originating agent A, so the alphabets for a promise of type \( \tau \) are really private to each agent—and we should really write \( \tau_A \). However, since non-shared types and alphabets would not result in binding at all, we can effectively ignore those cases where agents speak incompatible languages and absorb such cases into the assessments of promises that are not kept.
The overlap of two promise bodies of the same type of promise\(^2\). Finally, we recall that agents of any type exist in both positive and negative polarities.

An assessment of whether or not a promise is considered kept may be made on a variety of scales and criteria. The symbols \(\alpha_A(x)\) is used for assessments of various kinds, to be detailed in context. The semantic or symbolic assessment of a single sample, for each single promise-keeping event is simple the outcome:

\[
\alpha_A(x(\pi)) : \pi \rightarrow (x \in \chi_{\pi})
\]

where \(x(\pi)\) denotes the sampling of a symbol \(x\) from the channel formed maintained by the keeping of the promise \(\pi\). Alternatively, we could evaluate the semantic average assessment, relative to the promise declaration:

\[
\alpha_A(\pi) : \pi \rightarrow \{\text{KEPT, NOT-KEPT}\}.
\]

A collection of such events leads to a distribution of outcomes, which we can denote either as an average \(\pi()\) or as a pro-forma ‘probability’\(^3\):

\[
\begin{align*}
\sigma_A(\pi) & : \pi \rightarrow \{0, 1\} \\
p_A(\sigma_\pi) & : \sigma_\pi \in \chi_{\pi} \rightarrow [0, 1]
\end{align*}
\]

\(^2\)For example, and agent \(S\) could be a Light Emitting Diode (LED) that promises from within a finite alphabet of red, green, blue (RGB) symbols. The receiver might be a light sensitive detector which can only detect shades of what it calls green (G).

\(^3\)The concept of a probability involves plenty of semantics that are often taken for granted. Here we needn’t take issue with different definitions, as any will do the job.

where the ensemble is defined over a specified set of \(S\) samples

\[
\sum_{i=1}^{N} \frac{\alpha_A(x(\pi) = x)}{N} \rightarrow p_A(x)
\]

These ‘probabilities’ are the quantitative scale ratios, used in definitions of information, according to the Shannon theory of communications \([3],[4]\). How ensembles are constructed is important, but not defined a priori. If one has a controlled environment which can promise repeatable configurations, then there can be spacelike (co-temporal) or frequentist probabilities, and there are timelike (temporal) of Bayesian probabilities, which have different interpretations. In either regime, we have probabilities \(p_A\) assessed by each agent \(A\). However, in order to get to information, we need assessments made by more than one agent: both a sender and a receiver.

We can use these measures to pursue three issues:

- The meaning of autonomy, or causal independence of agents.
- The transmission of intent or expectation as symbols.
- The transmission of observations and assessment from symbols.

These three matters are related but distinct. In related work, considering the concept individuality \([5]\), the authors use mutual information as the criterion by which to define autonomy or causal independence of agents. They show that the assumption of individuality is consistent with immunity from external information propagation. A compatible answer is implicit in Promise Theory, but without the implicit assumptions about probability. Here, the axioms contend that all agents are a priori autonomous or causally independent, and may forego that autonomously, which amounts to a subtle difference. The two viewpoints are entirely consistent where they overlap, but the formulation based on Shannon’s mutual information is not relativistically covariant, whereas a formulation based on promises is. In principle, the promise view is not only simpler but reveals more of the interaction picture than the information view, since the entropy functions are based on ensemble averages. I’ll return to this at the end.

### III. SIMULTANEOUS CHARACTERISTICS

In Shannon’s statistical measures of information, there is no relativity of end points incorporated into the picture, despite the end points being causally distant from one another. Events are assumed simultaneous and therefore form local matrices as viewed by a single ‘godlike’ observer, with infinite and immediate access (figure 2). Promises remain true to a tensorial picture with explicit construction of multi-local behaviours.

A joint probability matrix incorporates the idea that the receiver may get a transmitted symbol wrong with a certain off-diagonal probability, if the non-diagonal elements are non-zero. The joint probability matrix,

![Diagram of simultaneous characteristics](image-url)
which depends on two ends of a causal channel, is defined by:

\[ p_A(\sigma_S, \sigma_R) \equiv p_A(\sigma_S \text{ AND } \sigma_R), \]  
(10)

as used in Shannon’s formulation of informational entropy, is assumed to be observable (by the godlike observer who computes information transfer). It reduces to the lower rank product state \( p_A(\sigma_S)p_A(\sigma_R) \) when \( \sigma_S \) and \( \sigma_R \) are independent variables. As we see below, the existence of this measure assumes coarse graining in a time and space, so its interpretation may be ambiguous. Independently of the definition of measures, the joint matrix represents the agreed ‘probability’ that \( S \) and \( R \) sample common symbols at the same moments. Since the symbols are actually private interior representations of the agents, in Promise Theory, they are assessed autonomously. What this really means is that the observation of a correspondence of symbols at the two ends of the channel \( \sigma_S \sim \sigma_R \), when the symbols coincide in the overlap \( \chi = \chi_S \cap \chi_R \), are therefore ‘equal’ in the sense that they play an invariant role which is understood (independently) by each end of the channel between \( S \) and \( R \). The agents needn’t have a common representation of these symbols, so we cannot say that \( \sigma_S = \sigma_R \), as measured by a godlike third party, but they consistently represent the same information to each party.

IV. SCALAR PROMISE (CASE 1)

An assessment of probability for interaction by any agent (of symbols \( \sigma \in \Sigma_r \) for the promise \( \pi \)), over some ensemble of multiple promise-keeping events, relies on repeated observations under coarse-grained conditions. In the case of a unilateral promise from \( S \), with no acceptance by \( R \), \( R \) makes no assessment of any promise \( \pi \) at all (indeed, it doesn’t even know about it), so we have simply:

\[
\begin{align*}
p_S(\sigma_S, \sigma_R) &= p(\sigma_S) \times 0 \quad (11) \\
p_R(\sigma_S, \sigma_R) &= 0 \times p(\sigma_R) \quad (12)
\end{align*}
\]
i.e. the joint probability is entirely separable, and is identically zero, as the agents are fully independent. Any similarity of symbols, seen only by a privileged third party \( T \) (figure 2), they were able to measure would be entirely coincidental, as they are not able to observe one another. So the mutual information of the agents is identically zero in this case:

\[ I(S; R) = 0. \]  
(13)

Before leaving this elementary case, we should point out the concept of scope, which is a shorthand for a large number of implicit promises.

\[ \pi : S \xrightarrow{+b_S} \Omega \rightarrow \chi \rightarrow R. \]  
(14)

The symbol \( \Omega \) for scope, implies a set of agents to whom the promise of observability has been granted and accepted. In this case, only \( R \) has been offered this information, but this is important for the next two cases. In other words, only agents \( A \in \Omega \) can form assessments of the promise \( \pi \), even though they are not explicitly mentioned in it, and the outcome may not be any of their business per se. These agents in scope are the typical observers in quantum mechanical scenarios, for instance. They are third parties who look upon other agents and calibrate the outcomes according to their own alphabets of states.

V. PROMISE BINDING (CASE 2)

From the foregoing definitions, we can now complete the promises for an information channel, in the Shannon sense, for a single promise with \( b(\pi) = \{\tau, \chi\} \), by adding the acceptance promise, which is normally taken for granted:

\[
\begin{array}{c}
S & \xrightarrow{+b_S} & R \\
R & \xrightarrow{-b_{RS}} & S
\end{array}
\]  
(15)

Here, it’s assumed that \( \tau(b_S) = \tau(b_R) \), i.e. the agents are aligned in their ‘intent’. Now that \( R \) accepts the promise from \( S \),

\[
\begin{align*}
b_S &= \{\tau, \chi_S\} \\
b_{RS} &= \{\tau, \chi_R\}
\end{align*}
\]  
(16)

(17)

and, for a non-zero channel to form, we require the channel overlap of languages to be non-empty:

\[ \chi_{RS} = \chi_S \cap \chi_R \neq \emptyset. \]  
(18)

The subscripts here seem pedantic, but are used to remind us that what is offered \( b_S \) is initiated only by \( S \) and only concerns \( S \)’s interior state (call it \( \sigma_S \)); and, in receiving data from \( S \), \( R \) has its own a choice about what it is willing or able to accept—that choice needs an ‘\( R \)’ annotation to identify it as \( R \)’s ‘intent’. Even though it’s based on data from \( S \), the data are only accepted at \( R \)’s behest. It is not necessary to assume that \( R \) is compelled to accept, by some force. Indeed, we know that this viewpoint is inconsistent [1].

Using the subscript \( R|S \) (\( R \)’s acceptance given \( S \)’s offer), we indicate this implicit causal dependency. Later (in case 3) this dependency will be made explicit when an agent bases a new promised value (sent downstream) on a prior one received from upstream, forming causal chains.
With channel binding now accepted, there is a new issue: for agents to be able to assess one another they must be promised access to information about each other’s interior states, not only a declaration of the promise of expected behaviour. In other words, the promises in (15) are sufficient to enable causal influence, but are not sufficient to be able to assess it from mutual information, since the promises in (15) are not mutual, merely complementary. This is related to the generally assumed observability issue (even for godlike observers). We might treat observability promises as part of ‘scope’ to avoid a proliferation of promises in (15). We have to deal with two kinds of promise bindings:

- A promise of behaviour is something with the status of a ‘charge’, it allows inference of propagated influence. It refers to promises which are locally invariant over the events that confirm them.
- A promise of observational outcome, on the other hand, requires access to private interior states, which is additional information about dynamical changes. The observation of acceptance is an acknowledgment.

Let’s define the alphabet of possible values generated by the set of relevant interior states for $S$ and $R$ by $\sigma_S$ and $\sigma_R$. These states exist at opposite ends of the channel but they can be subject of a promise made by each end to the other:

$$
S \xrightarrow{+\sigma_S} R \quad R \xrightarrow{+\sigma_R} S
$$

In order to be observed, the other end must accept the promised symbols, but they may accept a different set:

$$
S \xrightarrow{-\sigma_S[R]} R \quad R \xrightarrow{-\sigma_R[S]} S
$$

so that what is actually possible to transmit is the overlap:

$$
S \rightarrow R : \sigma_S \cap \sigma_R \leq \sigma_S \quad R \rightarrow S : \sigma_R \cap \sigma_S \leq \sigma_R
$$

This is what we mean by observability. The $\leq$ can also account for noise, but it has a different semantic origin. Noise could always be corrected, as Shannon showed, but the inability or unwillingness to receive certain symbols cannot.

These observability promises are often presumed as ‘bundled’ in our world view, when the first kind of promise has been given, but that’s not strictly necessary. We don’t always have access to observe the outcomes of events. For example, a particle might promise a certain charge, but we have no exterior field or detector to register the forces it may experience.

Over one or more assessments by the two agents, ensembles can be formed to define probability measures from each agent’s independent observational perspectives.

$$
p_S(\sigma_S, \sigma_R) \neq 0 \quad (25)$$
$$p_R(\sigma_S, \sigma_R) \neq 0. \quad (26)
$$

$S$ assesses this as the result of the confirmation it sent and the acceptance of an acknowledgment received. The existence of this matrix now depends on two sets of promise bindings:

- Invariant intent (e.g. ‘charge’ in physics), and
- On-going observability of interior states (events and transitions).

When the alignment of states is merely coincidental, then over ensemble we would observe that

$$
p_S(\sigma_S, \sigma_R) \rightarrow p_S(\sigma_S)p_S(\sigma_R) \quad (27)$$
$$p_R(\sigma_S, \sigma_R) \rightarrow p_R(\sigma_S)p_R(\sigma_R), \quad (28)
$$

which contains non-local information. This assessment cannot be made unless observability promises have been offered, accepted, and kept for the agent assessing the joint states. The mutual information, as used in [5], requires this minimum observability for some observer. Assuming an agent $A$ has such access, then it is the average overlap remaining once the probability of coincidence of random processes is subtracted, as measured by an independent observer $A$:

$$
I_A(S; R) = \sum_{\sigma_S, \sigma_R} p_A(\sigma_S, \sigma_R) \log \frac{p_A(\sigma_S, \sigma_R)}{p_A(\sigma_S)p_A(\sigma_R)},
$$

which is clearly zero when:

$$
p(\sigma_S, \sigma_R) = p(\sigma_S)p(\sigma_R). \quad (29)
$$

We can now consider which promises are required to evaluate the probabilities presumed to be calculable in the informational entropies of a channel.

- A self-assessment $p_A(\sigma_A)$ (e.g. $p_S(\sigma_S)$) can always be obtained ‘immediately’ according to $S$’s interior process and clock.
- A remote assessment $p_A(\sigma_A)$ (e.g. $p_S(\sigma_R)$) is reliant on data being propagated along the information channel, which implies that source and receiver are never simultaneous. This transmission depends on two promises being kept. For the example:

$$
R \xrightarrow{+\sigma_R[S]} S \quad (30)$$
$$S \xrightarrow{-\sigma_R[R]} R. \quad (31)
$$

Looking for a measure of correlation between the symbols at source and receiver still doesn’t discount the possibility that random processes

\footnote{The weakness of treating the agents as random processes is that we have to deal with average causality and probable measures over coarse grained ensembles, when what we really want to deal with individual interactions from the bottom up.}
led to a coincidence of symbols. For the causal information transmission we want the conditional transmission only, which can be excluded statistically over ensemble averages by using the definition for mutual information, but here I want to emphasize that this mutual information is only an average proxy for causal propagation implicit (namely that $S$ signals $R$ and then $R$ acknowledges receipt, as in so-called reliable network protocols, such as TCP/IP):

$$
S \xrightarrow{+\sigma_S} R \quad (32)
$$

$$
R \xrightarrow{-\sigma_R} S \quad (33)
$$

$$
R \xrightarrow{+\sigma_R} S \quad (34)
$$

$$
S \xrightarrow{-\sigma_S} R. \quad (35)
$$

This is the precise statement, on a transactional basis, which is usually coarse-grained to yield common sets of mutual probabilities.

By stating (promising) the mutual information above, we effectively timestamp all events on the interior of a single agent, e.g. $R$ claiming that this is instantaneous for $R$. This is an approximation which is good enough on human scales, but which fails on computational and quantum scales.

On the question of autonomy, or causal independence: regardless of our ability to define probabilistic measures, one sees that the promise in equation (34) is empty if the conditional acceptance of the input in (35) is absent, which is the only one in which an agent is influenced by another agent. So, at a basic level, the agents are always causally independent, but may promise to forego that autonomy by accepting inputs from other agents. It’s the presence of such receptor promises which therefore represent the causal ‘boundary’ for influence. This applies on any scale, since we have not made any assumptions about the interior nature of the agent. It’s a form of Gauss’ law, noted in [6], which may be expressed by saying that what is promised from within a boundary depends a priori only on what is on its interior.

We also see these points reflected in the flow of process time. In a classical Newtonian view, time is a universal and simultaneous quantity that presumes instantaneous access to a single calibrated clock for the entire universe. We know this to be an idealization that fails under many circumstances, and we must instead specify which observer’s clock is being used to count events that we call time [7], [8]. The only things that $S$ and $R$ know about observations of one another is that their receipt comes after the samples were obtained. So, according to either $S$’s clock $t_S$ or $R$’s clock,

$$
t_S(\sigma_S) < t_S(\sigma_{R|S}) \quad (36)
$$

$$
t_R(\sigma_S) < t_R(\sigma_{R|S}) \quad (37)
$$

and similarly,

$$
t_S(\sigma_R) < t_S(\sigma_{S|R}) \quad (38)
$$

$$
t_R(\sigma_R) < t_R(\sigma_{S|R}) \quad (39)
$$

This might seem excessively pedantic for mundane human systems, or biological timescales, but these distinctions are quite important for processes that race one another with split-second timings in computer networks, and sub-atomic physics.

A third party observer watching such a transition from an independent vantage point could calibrate as an impartial arbiter (see figure 2); however, its ability to do so is only uncontested if the promises of observability of $S$ and $R$ by $T$ are much faster than the changes taking place between $S$ and $R$. If we try to parameterize the separation between these causal interactions, then we have a choice about how to represent the partial ordering. Space and proper time can be proxies for that ordering, but since the separation is only a convolution of two autonomous processes, the interpretation is moot. The joint probability has the form of a faithful assessment by a sufficiently fast third party (where ‘fast’ means satisfying the Nyquist law over relevant timescales for $\pi$):

$$
p(S, R) = \alpha_T \left( \pi^{(+)}(S) \text{ AND } \pi^{(-)}(R) \right) \quad (40)
$$

If we assume a vanishing observability delay, then this has the simplified form:

$$
p(+, -) = \int_0^\infty dA \left( \psi^{(+)}(A) \psi^{(-)}(A) \right) \quad (41)
$$

which has the form of a spatial convolution, familiar in quantum mechanics$^6$.

**VI. CAUSAL CHAINS (CASE 3)**

All the elements are now in place for the general case of a causal chain. Note, there is no assumption of a Markov chain, without hysteresis, nor any presumption of a global symmetry. Agents may contain any amount of memory and can incorporate hysteresis, absorption, and so on. They also retain their individuality by default, and must make explicit promises to constrain their behaviour and demonstrate transmission of influence. The question is whether such effects

$^5$This notion is encapsulated in the Shannon-Nyquist sampling law. In classical science, we are used to observing rather slow transitions using light signals which are very fast, so these matters become negligible.

$^6$In a Hilbert space model, which can assume lossless probabilities of a closed system, the + and - are natural Hermitian conjugates.
play a prominent or a negligible role in the observed outcomes.

The main difference in between equation (2) and equation (3) is that there is now a promise with an explicit dependence of a prior outcome from another promise, which is propagated from one agent to another. This was implicitly present in the acknowledgment of observable transmission, but it also carries over into successive interactions (e.g. ‘collisions’ or transmission relays). All the elements are therefore in place, from the discussion of observability, to cover these interactions.

There are two things to note: first, receptor promises \((-b_M)\) are the key to transmission of influence. Influence is not conferred automatically by emission of a signal alone—absorption is an autonomous behaviour too. Next, the foregoing implies that intermediate agents play a key role in forming barriers to transmission (e.g. we can think of the purpose of vaccines to stem disease transmission), as long as they don’t make an independent promise to accept and relay information from a prior agent in the chain with high fidelity. Intermediate agents therefore also serve as the elementary construction for modelling noise and other environmental input channels within a fundamental system. The intermediaries may be:

- Intentionally bad actors.
- Faulty, low fidelity replicators.
- In possession of covert channels that accept information from other sources in the ‘environment’ \(E\):

\[
I \xrightarrow{-b_E} E. \tag{42}
\]

Such influences would impinge on the relay function for propagation from \(S\) to \(R\) if the promise in (3) were replaced by

\[
I \xrightarrow{+b_I | b_S, b_E} \xrightarrow{b}. \tag{43}
\]

The relationship between \(b_E\) and \(b_I\) is of crucial interest in determining faithful propagation along a chain. From a state of initial causal independence, there is no reason why \(S\) and \(I\) should make the same promise, unless they have been calibrated by a ‘global symmetry’ pertaining to all agents. Although such global symmetries exist in nature, from particle physics to biology, the reason for them is unclear and they seem to violate local relativity principles. All such agents appear to have a common origin, or promise to accept causal influence from a common source (see the matroid pattern in [1]):

\[
S \xrightarrow{-b_M} M \quad \tag{44}
\]

\[
I \xrightarrow{-b_M} M \quad \tag{45}
\]

and

\[
S \xrightarrow{+b_I | b_M} A \quad \tag{46}
\]

\[
I \xrightarrow{+b_I | b_M} A'. \quad \tag{47}
\]

In biology, this is indeed the case, where cells are formed by replication from a single source. In particle physics, we simply don’t know what underlying information is at work.

VII. Summary

Comparing Shannon’s statistical theory of communication, commonly known as Information Theory, we find that Promise Theory’s simple partial ordering both simplifies the notations, suppressing probabilities, and thus eliminates the need to define statistical ensembles, with all the attendant assumptions therein. The probabilistic formulae for the various informational entropies are based on statistical ensembles and observations, but the causal concepts are available on a deeper level, as we can see explicitly in Promise Theory. The promise formulation shares something with formalisms like Quantum Field Theory; this is to be expected, given the prominence of agent relativity. The Shannon theory is an absolute spacetime theory, which is adequate for its technical origins, but which is unsuitable for more general processes.

In order for agents to give up their autonomy and become a completely deterministic game piece, within a ballistic model of motion, like a Newtonian system or a Markov chain, they have to be calibrated to the same identical promises (spacetime homogeneity), and they have to completely forego individual autonomy (locality). \textit{A priori} autonomy, or causal independence, is an axiom in Promise Theory, represented by the need for \((-)\) polar promises. This is the natural ‘bare’ state of any agent. The addition of promises may then constrain agents to cooperate. This is consistent with the conclusions reached in [5], which introduce probabilistic considerations, perhaps unnecessarily. The reason is clearly due to the underlying causal ordering implicit in the information channel. This model may also be seen as a deeper structural explication of the Causal Set spacetime model developed for discrete spacetime structure [9]–[13].

Causal independence is not really a pervasive property of an agent, but rather it’s a property of each promise made by an agent. Certain promises may be entirely determined by exterior influence (or at least be indistinguishable from being entirely determined to an external observer), whereas others may appear entirely autonomous. This has as much to do with promise observability as autonomy—which, indeed, is the curse of relativity: being trapped within the rules of the system one aims to observe.

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