require extraordinary evidence. So the cosmology communi has decided that no such claim can yet be made.

Over the past several decades we've been able to refine th probabilistic arguments associated with the determination likelihood and uncertainty, developing an area of mathemati called Bayesian analysis which has turned the science of dete mining uncertainty into one of the most sophisticated areas experimental analysis. Here we first fold in a-priori estimates c likelihood and then see how the evidence changes our estimate This is science at its best: Evidence can change our minds, an it's better to be wrong rather than to be fooled.

In the public arena, scientists' inclusion of uncertainties h been used by some critics to discount otherwise important result Consider the climate-change debate. The evidence for human induced climate change is neither controversial nor surprisir Fundamental physics arguments have anticipated the observe changes. When the data show that the last sixteen years have bee the warmest in recorded human history, and when measu CO_2 levels exceed those determined over the past 500,000 yea and when the West Antarctic ice sheet is observed to be meltin at an unprecedented rate, the fact that responsible scientists repo many small uncertainties associated with each of these measur ments shouldn't discount the threat we face.

Louis Pasteur once said, "Fortune favors the prepared mind Incorporating uncertainties prepares us to make better-informe decisions about the future. This doesn't obviate our ability t draw rational and quantitatively reliable conclusions on whic to base our actions—especially when our health and secur may depend on them.

EQUIPOISE

NICHOLAS A. CHRISTAKIS

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There's an old word in our language, "equipoise," which has been around since at least the 16th century, when it meant something like "an equal distribution of weight." With respect to science, it's analogous to standing at the foot of a valley and not knowing the best way to climb to the top—poised, that is, between alternative theories and ideas about which, given current information, one is neutral. Use of the word peaked around 1840 and has declined roughly fivefold since then, according to Google Ngram, though it appears to be enjoying a resurgence in the last decade. But attention to equipoise ought to be greater.

The concept found a new application in the 1980s, when ethicists were searching for deep justifications to conduct randomized clinical trials in medicine. A trial was justified, they rightly argued, only when the doctors and researchers doing the trial considered (relying on their medical knowledge) the new drug and its alternative (a placebo, perhaps) as potentially *equally* good. If they felt otherwise, how could they justify the trial? Was it ethical, for the sake of research, to place patients at risk if the researchers suspected that one course of action might be materially better than another?

So *equipoise* is a state of equilibrium in which scientists cannot be sure which of the alternative theories they're contemplatin might be true.

In my view, equipoise is related to that famous Popperia *sine qua non* of science itself: falsifiability. Something isn't scienc if it isn't capable of disproof. We can't even imagine an experiment that would disprove the existence of God—so that's wha makes a belief in God religion. When Einstein famously conjectured that matter and energy warp the fabric of space and tim experiments to test the claim weren't possible but they were a least imaginable, so the theory was capable of disproof. Eventually he was proved right, based on astronomical observations o the orbit of Mercury, and also the bending of light from distan stars, observed during a 1919 solar eclipse—and most recentl by the magnificent discovery by LIGO of gravitational wave from the collision of two black holes over a billion years ago. Ye even if he had been wrong, his conjecture would still have bee scientific.

If falsifiability solves the "problem of demarcation" th Popper identified between science and non-science, equipoi addresses the problem of origin: Where ought scientists to sta from? Thinking about where scientists do—and should—sta from is often lacking. Too often, we simply begin from wher we are. In some ways, therefore, equipoise is an antecedent condition to falsifiability. It is a state we can be in before we hazar a guess that we might test. It's not quite a state of ignorance bu rather a state of quasi-neutrality, when glimmers of ideas ente our mind.

Scientific equipoise tends to characterize fields both earl and late in their course, for different reasons. Early in a field o a new area of research, it's often true that little is known abou anything, so any direction can seem promising and might actually be productive. An exciting neutrality prevails. Late in th

exploration of a field, much is known, so it might be hard to head toward new things—or the new things, even if true, might be small or unimportant. An oppressive neutrality can rule.

Equipoise carries with it aspects of science which are sorely needed these days. It connotes judgment, for it asks what problems are worthy of consideration. It connotes humility, for we don't know what lies ahead. It connotes open vistas, because it looks out at the unknown. It connotes discovery, because, whatever way forward we choose, we will learn something. And it connotes risk, because there are dangers in embarking on unknown journeys.

Equipoise is a state of hopeful ignorance, the quiet before the storm of discovery.

ANSATZ

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"Ansatz" is a fancy way to say that scientists make stuff up.

The most common formulation of physics is based on what are called differential equations, which are formulas that relate the rate at which things change. Some of these are easy to solve, some are hard to solve, and some can't be solved. It turns out that there's a deep reason why there's no universal way to find these solutions, because if that existed it would let you answer questions we know to be uncomputable (thanks to Alan Turing).

But differential equations do have a handy property: Their solutions are unique. If you find *a* solution, it's *the* solution. You can guess a solution, try it out, and fiddle with it to see if you