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Translating scientific papers for the public

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Eager to make your research accessible to a general audience without glossing over all the effort that has gone into your work? Try creating "doodle summaries" of your papers.

Communicating scientific results to a general audience is difficult. Communicating the tangle of methods and analysis that support neatly packaged results, not to mention the uncertainties, is even more challenging. To lift the hood on the process, I suggest a method to explain science in the most direct way possible: by doodling annotations on scientific papers.

THE ASTRONOMICAL JOURNAL, 116:1009–1038, 1998 September

Exploding stars tell us the universe is growing really fast

~~OBSERVATIONAL EVIDENCE FROM SUPERNOVAE FOR AN ACCELERATING UNIVERSE AND A COSMOLOGICAL CONSTANT~~

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This took an entire team

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ABSTRACT

TL;DR

We observed some supernovae and found them to be farther away than expected. After some very careful statistics, we're pretty confident that there is something extra out there besides just light and matter.

Some type of energy... that's dark...

It implies that the universe is 14 billion years young. But don't worry, she still has plenty of life ahead of her because our fate is apparently sealed in an eternal expansion.

We present spectral and photometric observa[illegible] 10 Type Ia supernovae (SNe Ia) in the redshift range $0.16 \le z \le 0.62$. The luminosity distances of these objects are determined by methods that employ relations [illegible] om our [illegible] High-z Supernova Search Team and recent results by Riess et al., this expanded set of 16 high-redshift supernovae [illegible] ng cosmological para[illegible] t (i.e., the vacuum energy density, Ω_Λ) [illegible] the universe (t_0). The distances of the high-re[illegible] n expected in a low mass density ($\Omega_M = 0.2$) universe without a cosmological constant. Different light curve fitting methods, SN Ia subsamples, and prior con[illegible] dels with positive cosmological constant [illegible] With no prior constraint on mass density other than $\Omega_M \ge 0$, the spectroscopically confirmed SNe Ia are statistically consistent [illegible] nd 4.0 σ confidence level[illegible] density, Ω_M = 0.2, results in the weakest detection, $\Omega_\Lambda > 0$ at the 3.0 σ confidence level from one of the two methods. For a flat universe prior ($\Omega_M + \Omega_\Lambda = 1$), the spectroscopically confirmed SNe Ia require $\Omega_\Lambda > 0$ at 7 σ and 9 σ formal statistical significance for the two different fitting methods. A universe closed by ordinary matter (i.e., $\Omega_M = 1$) is formally ruled out at the [illegible] 8 σ confidence level for the two different fitting methods. We estimate the dynamical age of the universe to be 14.2 ± 1.7 Gyr including systematic uncertainties in the current Cepheid distance scale. We estimate the likely effect of several sources of systematic error, including progenitor and metallicity evolution, extinction, sample selection bias, [illegible] perturbations in the expansion rate, gravitational lensing, and sample contamination. Presently, none of these effects appear to reconcile the data with $\Omega_\Lambda = 0$ and $q_0 \ge 0$.

Λ

(The term "dark energy" is not used in this paper. This was settled later after a few iterations—including "funny energy".)

[illegible] cosmology: observations — supernovae: general

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BACKGROUND INFO

1. INTRODUCTION

How fast the universe grows depends on the stuff inside it. We know the universe has matter in it (based on the existence of us, bagels, and a few other things). Through gravity, matter slows down the expansion. But if the universe is not slowing down, it would imply there is some other "exotic" component.

This paper reports observations of 10 new high-redshift Type Ia supernovae (SNe Ia) and the values of the cosmological p[illegible] four high-redshift supernovae previously reported by our High-z Supernova Search Team (Schmidt et al. 1998; Garnavic[illegible] the sample of 16 is now large enough to yield interesting cosmological results of high statistical significance. Confidence i[illegible] sample size but on improving our understanding of systematic uncer[illegible]

The time evolution of the cosmic scale factor depends on the composition of mass-energy in the universe. While the universe [illegible] ordinary matter, Ω_M, which decelerates the expansion, its dynamics may also be significantly affected by more exotic forms of energy. Preeminent among these is a possible energy of the vacuum (Ω_Λ), Einstein's "cosmological con-

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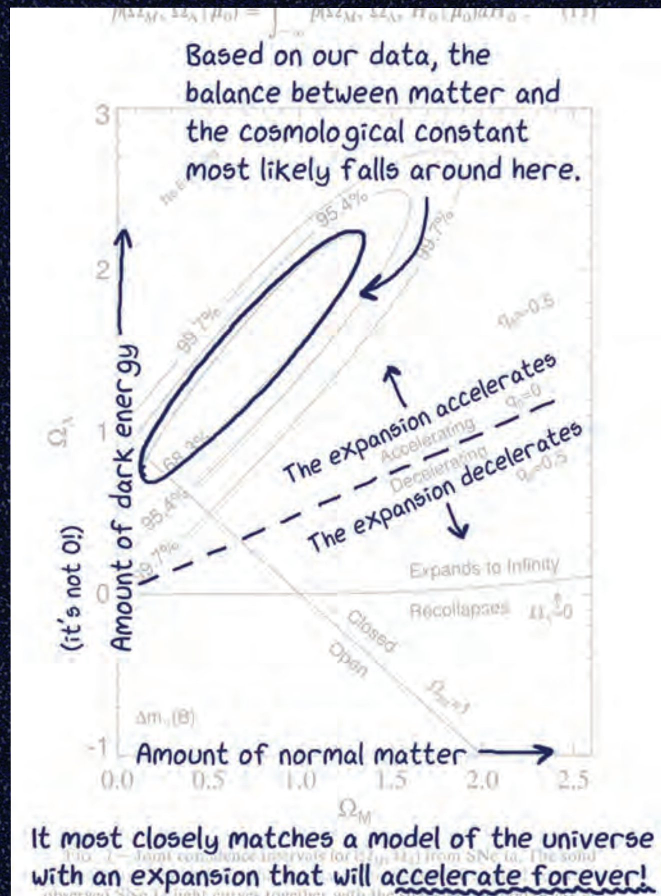
The idea came about two years ago when my mom mentioned that she was excited to read a recent paper of mine. The research was on a subtle systematic effect in cosmological surveys, a topic specific enough that I worried even people in my field would have difficulty understanding it. I wanted to explain the paper in a way that gave my mom a real idea of my work and what went into it.

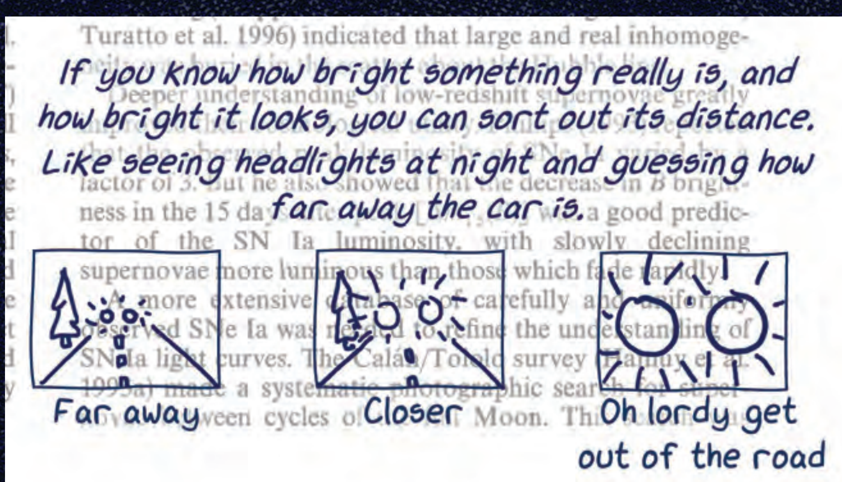
The result was a doodle summary. I placed the PDF version of my paper in PowerPoint and annotated it with text, diagrams, cartoons, and more. I linked to the annotation on the paper's arXiv.org page and received a large, positive reception from other scientists. Several researchers have since made similar summaries of their papers.

The annotated-paper approach is helpful for describing research to colleagues, sharing the content of papers with undergraduates, and explaining to the public what goes into scientific research. It's also a clean way to visually communicate the most important ideas from a paper's plots and tables. I've found that general audiences are often surprised by how much work underlies a single result and how much of a paper scientists may devote to describing all the reasons they may be wrong.

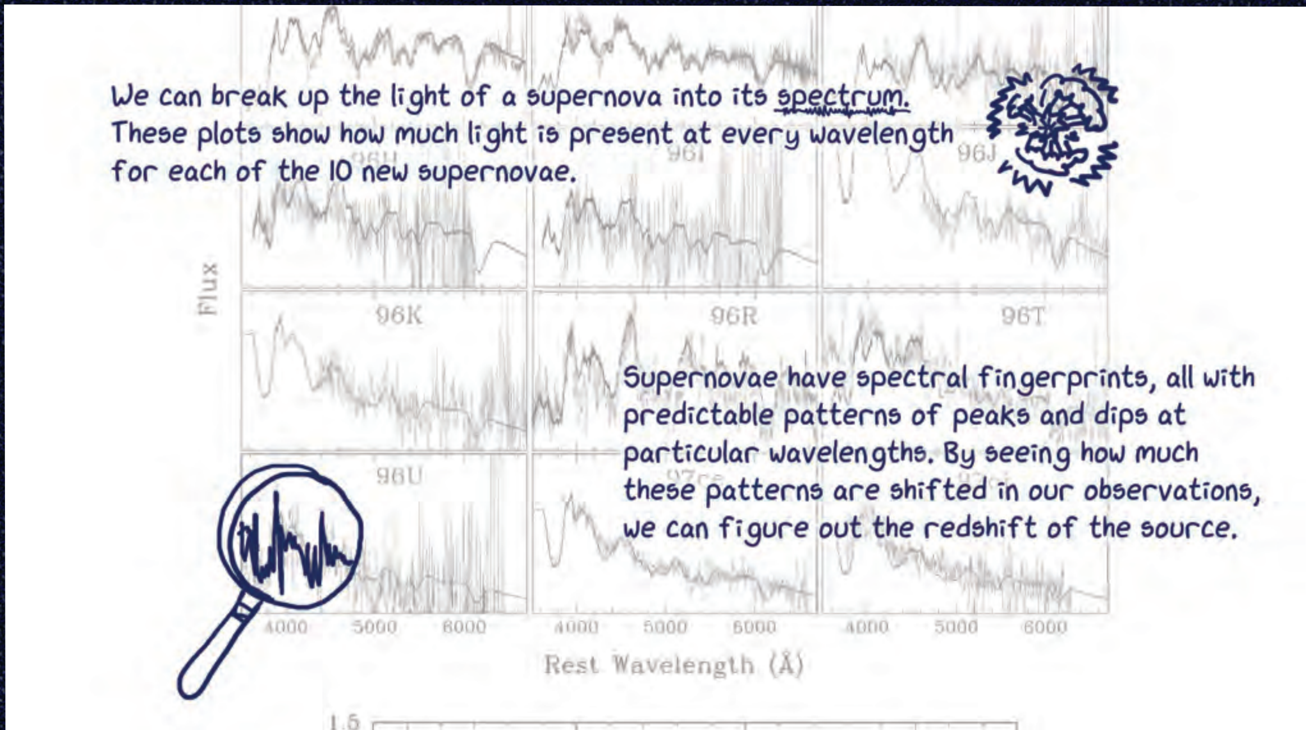
The doodles in this feature annotate the ground-



APPEARING HALFWAY through the 30-page manuscript, this is the pivotal graph that demonstrates the universe's accelerating expansion. A doodle summary highlights a plot's takeaways while de-emphasizing the jargon and symbols. Axis labels are simplified, and helpful context is included.



THIS SET OF CARTOONS is a fun way to illustrate a basic principle for using supernovae at various distances to measure the universe's expansion.



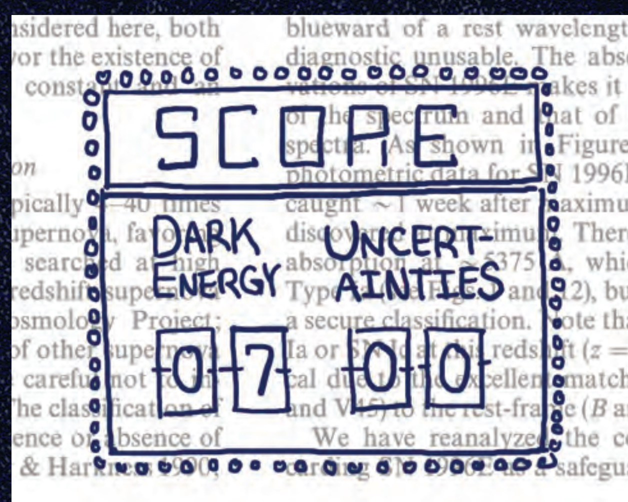
DATA TABLES AND FIGURES are ideal places to explain the background science that underlies the research. In this example, annotations overlaying the spectra of several supernovae explain spectroscopy and how it is used to measure the redshift of cosmic objects.

breaking 1998 *Astronomical Journal* paper by Adam Riess and colleagues, who used observations of supernovae to make a compelling case that the expansion of the universe is accelerating. Combined with research by Saul Perlmutter and collaborators that was published in the *Astrophysical Journal* several months later, it is the most consequential result in modern cosmology, one that was recognized with the 2011 Nobel Prize in Physics.

The snippets illustrate some of what I did to summarize the paper by Riess and colleagues. I encourage readers to try to do something similar with their own research papers.

The annotations use the xkcd font, CC BY-NC 3.0, https://github.com/ipython/xkcd-font. PT

For the full annotation, visit https://physicstoday.org/doodle.



AS MANY RESEARCHERS do in their papers, Adam Riess and colleagues use a significant portion of their manuscript—in this case, 7 of their 30 pages—to address all the possible ways they may be wrong. A doodle summary simplifies each of those factors without glossing over them, like many popular-science articles do. For researchers summarizing their own work, it's a valuable opportunity to describe how much effort goes into producing a piece of peer-reviewed research.