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The Dayside : Kissed by a prince

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This week I learned of an interesting bibliometric study by Alessandro Flammini of Indiana University and his colleagues. Published in the *Proceedings of the National Academy of Sciences*, the paper bears a title that might mystify you: "Defining and identifying Sleeping Beauties in science."

The eldritch metaphor is apt. Sleeping Beauties are papers that for decades attract few citations until one day someone discovers their relevance to a current area of research. If the area is active and important, a flood of fresh citations ensues. The paper has awoken!

Flammini did not coin the term Sleeping Beauty himself. The credit belongs to Leiden University's Anthony van Raan, who introduced it in a 2004 *Scientometrics* paper. In their new paper, Flammini and his colleagues present a new and systematic way to find such papers.

Their method does not entail setting arbitrary thresholds for duration of sleep, rapidity of awakening, or height of rising. Rather, it characterizes the shape and scale of a paper's annual citation rate versus time, without adjustable parameters. Essentially, the more concave the plot—that is, the longer the citation rate remains low and flat and the steeper its eventual rise—the highe the paper's beauty coefficient, *B*.

A paper whose citation rate rises linearly with time has a *B* of zero. By contrast, the paper that Albert Einstein wrote with Boris Podolsky and Nathan Rosen in 1935 lay dormant for half a century until experimenters could test its claims and theorists could discuss the experiments' implications. The trio's "Can quantum-mechanical description of physical reality be considered complete" has a *B* of 2258, high enough to place it in Flammini's top 15 in all of science.

Edward Burne-Jones (1833–98) was among the many artists who have depicted the Sleeping Beauty.

Thanks to the enlightened generosity of the American Physical Society (APS), Flammini and his colleagues, like other bibliometric scholars, had access to citation data for the society's journals

dating back to the first issue of *Physical Review* in 1893. The online appendix of the team's paper lists the nine papers in APS journals that have the highest *B* values.

Besides Einstein, Podolsky, and Rosen's 1935 paper, the top nine includes Philip Wallace's 1947 calculation of the band structure of a single layer of graphite&that is, graphene. The paper awoke from a 56-year sleep in 2003 when Andrei Geim and Konstantin Novoselov discovered how to make such layers in the lab. Geim and Konstantin Novoselov went on to receive the the Nobel Prize in Physics for their discovery, which touched off an explosion of interest that has yet to wane.

Five of the other papers in the top nine date from 1951 to 1960. All have to do with the theory of double exchange, a mechanism by which electrons can hop between neighboring ions in ferromagnetic and antiferromagnetic crystals. Those papers were revived in 1994 when a team from Siemens Research Laboratories published its discovery of large room-temperature magnetoresistance in the kind of crystal, perovskite, that those early papers had discussed.

Flammini's paper made me wonder if I had mentioned any Sleeping Beauties in the news stories that I've written for *Physics Today*. One came instantly to mind.

For the magazine's September 2006 issue I reported on the observation by a team from the École Normale Supérieure in Paris of quantized AC conductance in a tiny *RC* circuit. From my interviews with team member Christian Glattli and other physicists who work in the field, I learned about what I now know to be a Sleeping Beauty:

> *The theoretical origin of quantized AC conductance lies in a paradigm-setting 1957 paper by Rolf Landauer. Landauer realized that scattering theory provides a natural and effective way to understand how electrons move in small, cold, clean circuits. According to Landauer, conductance is the manifestation of the probability that electrons—more precisely, their wavepackets—bounce off or pass through constrictions on their way around a DC circuit.*

I also learned about the prince (or princes):

> *Landauer's paper languished after publication. But by the 1980s, experimenters were making devices in which electrons traveled coherently and ballistically. Theorists became interested, too. Then, in 1988, two independent groups—a British group at the University of Cambridge and a Dutch collaboration from Philips Research Laboratories in Eindhoven and Delft University of Technology—made a startling discovery: The conductance of a coherent DC circuit is quantized in units of e^2/h.*

According to Google Scholar, Landauer's paper now has 3058 citations!

What the Sleeping Beauties have in common is that they analyzed physical systems that were beyond the reach of contemporary experiments yet within the reach of conceivable experiments. Publishing a paper that garners lots of citations decades later might not help young physicists gain tenure, but I hope the spotlight shined on Sleeping Beauties inspires them to try.
