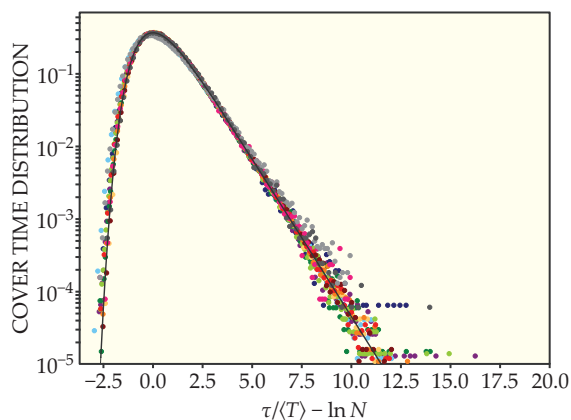


Brownian motion: It can be “persistent,” for instance, weighted toward a particular direction that depends on a previous step; be “intermittent,” stepping between nearest neighbors at one rate and leapfrogging over them at another rate to resume the search elsewhere; or take so-called Lévy flights, which jump from one region to another with step lengths that follow a power-law distribution. (See the article by Joseph Klafter, Michael Shlesinger, and Gert Zumofen, *PHYSICS TODAY*, February 1996, page 33.)

For those and other complex strategies, researchers have focused almost entirely on the time required to reach a single target—the first-passage time T —and have set aside the much harder problem of determining τ . Now CNRS theorists Marie Chupeau, Olivier Bénichou, and Raphaël Voituriez have linked the two quantities and analytically derived the probability distribution of τ for sev-



eral different complex random-walk processes on a finite lattice network.¹ After first writing an expression for τ in terms of a sum of the individual times needed to find each new target

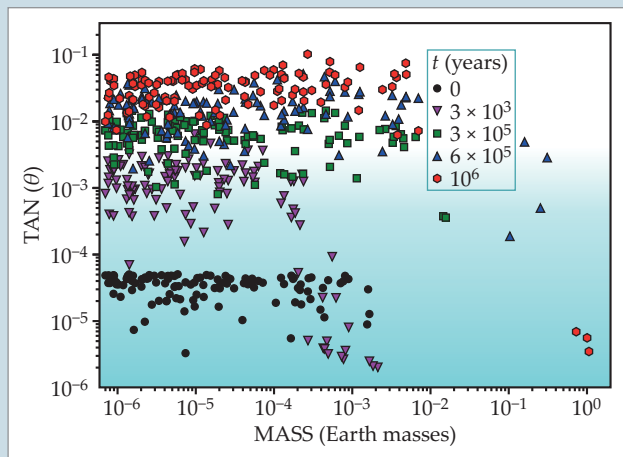
The cover time τ is the time it takes to randomly find all the targets N in a given domain. The theoretical expression for its probability distribution (the black curve) is given by $P(x) = \exp(-x - \exp^{-x})$, where $x \equiv \tau/\langle T \rangle - \ln N$ and $\langle T \rangle$ is the mean first-passage time to a given target site averaged over all starting sites. Provided N is large, the distribution is universally applicable to numerous complex search

among the unfound ones on the lattice, the theorists made a bold hypothesis: Although those individual times depend on the entire random trajectory the walker has taken—and are thus

physics update

These items, with supplementary material, first appeared at <http://www.physicstoday.org>.

Building a solar system pebble by pebble. Broadly speaking, planets form in a gaseous nebula around a star as dusty matter accumulates into ever larger associations. But implementing that evolution in a detailed simulation has proved challenging. In many models, the nebula does not endure long enough for the cores of giant planets to agglomer-



ate. Other models suggest that “pebbles,” perhaps a millimeter to a meter across, are slowed by frictional interactions with the nebular gas and rapidly coalesce into 100- to 1000-km-sized planetary embryos that grow to planet size by accreting remaining pebbles. That mechanism, however, seems too effective; simulations typically produce hundreds of Earth-sized planets in a solar system. Now Harold Levison of the Southwest Research Institute and his colleagues have added a twist to the simulations—a nonzero formation time for pebbles—and obtained a realistic number of rocky and gas-giant planets. As nebular dust coalesces into pebbles, they find, the largest of the massive planetary embryos present at the beginning of the simulation gravitationally scatter their smaller

siblings out of the protoplanetary disk. Thus most embryos are starved of the material needed for further growth; only a few become large enough to form rocky planets or gas-giant cores during the 1 million- to 10 million-year life of the disk. The figure summarizes a representative simulation. The angle θ denotes the inclination of an embryo orbit with respect to the protoplanetary disk, whose angular width is indicated by the blue region. After just 3000 years (purple triangles), a substantial fraction of the embryos initially present (black dots) has already been ejected. By the time the simulation terminates (red hexagons), less than a handful of embryos have grown to Earth size. (H. F. Levison, K. A. Kretke, M. J. Duncan, *Nature* **524**, 322, 2015.) —SKB

The Sun’s tilted axes. As hikers and other navigators know, Earth’s magnetic axis is tilted with respect to its rotation axis. Such misalignment had not been expected in the Sun—but now it’s been seen. NASA’s *Solar Dynamics Observatory* (SDO) has been trained on the Sun for half of the current 11-year cycle of solar activity. Using SDO’s Helioseismic and Magnetic Imager, Adur Pastor Yabar of the Institute of Astrophysics of the Canary Islands and his colleagues created daily maps of the line-of-sight strength and polarity of the Sun’s magnetic field for each of the mission’s first 1700 days. The Sun’s rotation period varies with latitude: It’s 25.5 days at the equator and 34.4 days at the poles. To look for variations *not* associated with differential rotation, Pastor Yabar and his colleagues averaged each map over all longitudes in 1-degree-wide latitudinal belts. When the researchers Fourier-transformed the entire sequence of binned maps, they discovered that a more-or-less monthly oscillation showed up at every latitude on every day. Random sprouting of active regions that rotate in and out of view could conceivably account for the oscillation, but when the researchers excluded active regions, the oscillation persisted. Their latitudinal belts did not sample the same parts of the Sun, as they had assumed, but wobbled up and down over the solar disk—hence the oscillation. Based on that and other lines of evidence, Pastor Yabar and his colleagues concluded that the Sun’s magnetic and rotational axes must