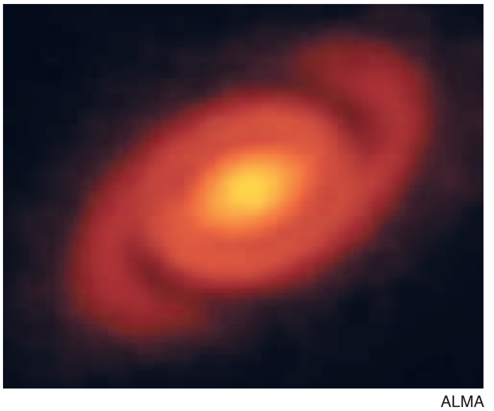
II. Scientific Revolutions Will Shape the Future

The Deep Space Mission that Might Trigger a Multidisciplinary Scientific Revolution

by Judy Hodgkiss

President Trump insists he wants the U.S. to lead the world in scientific and technological development. He instinctively understands that the key to doing that is resuscitating and upgrading the U.S. space program.

As an example of the fundamentals of physical economy, Lyndon LaRouche frequently pointed out how John F. Kennedy's Apollo Project space mission had provided the impetus for explosive growth of the "Silicon Valley," the previously bucolic rural area near San Jose, California, which became America's high-tech center in the 1960s. LaRouche always insisted that space exploration must be the point-on-the-spear in terms of scientific R&D. If the nation's frontier missions in space are appropriately defined and fully-funded, they not only provide spin-off benefits in innovative technologies in obviously related fields, but, even more importantly, they are likely to open up entirely new fields of research of which no one had even dreamed.



ALMA

Proto-planetary disc surrounding the young stellar object, Elias 2-27, 450 light-years away.

This report will explore one of those previously undreamt-of theories that has been brought to life by current research in the space program. We will see how scientists from a wide array of disciplines can be inspired to think in a multidisciplinary way, not only looking to find solutions to certain questions already posed, but being inspired to imagine new questions that, earlier, they didn't even know to ask.

Is There a Fundamental Principle of Development in the Universe?

In 1921, Albert Einstein went beyond his relativity theory, and put forward a theory of the cosmos, what he called the concept of a "finite but unbounded" universe. In a lecture that year before the Prussian Academy of Sciences, he asked the audience to consider a new metaphor: He described the physical universe as a finite number of shadows projected from different kinds of higher-order geometries. He challenged the audience to not only imagine the unseen geometries, but to imagine novel yardsticks that could measure them. Such a universe would be bound only by the principles of development that characterized it.[1]

Einstein would be delighted today to see examples of scientists in such fields as physics, chemistry, or electronics, discovering, to their amazement, that their subject matter might be best measured in a yardstick taken from the higher order geometry of living, growing systems. We start by looking at such developments in the field of planetary science.

The science of how planets—particularly the hard, rocky planets—have coalesced from the disc of clouds of gas and dust surrounding young stars, would not

1. See Hodgkiss, J., "The Finite but Unbounded Universe of Einstein, Planck, and LaRouche," *EIR*, February 15, 2019. https://larouchepub.com/other/2019/4607-the_finite_but_unbounded_unive.html

generally be thought of as a science known for controversies that intrigue the general public. The dry physics of gas cloud formation and dissipation, and the dynamics of solid-body particle collisions has not usually fired up the imagination of the layman

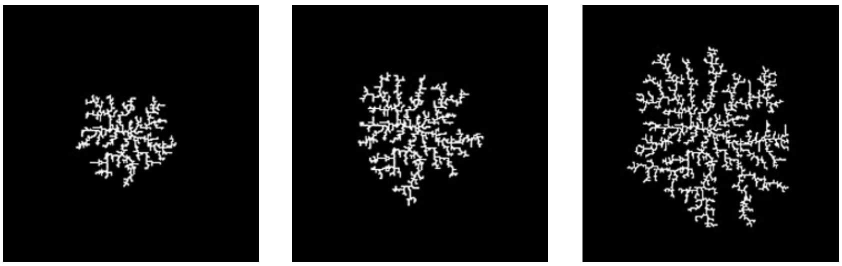
But, over the past few decades, a theory of protoplanetary formation has developed that is quite out of the ordinary; and, as we are now able to observe numerous other solar systems in the universe outside our own, theories of planetary formation are being explored with more urgency.

The formation of planets is not something we can directly observe. We can distinguish only the two extremes of size distribution in the materials surrounding other stars: We can detect young stars that have dust particles swirling within its surrounding disc-shaped gas cloud; and we can observe older stars that are surrounded by fully-formed planets. We can only hypothesize as to what occurs in the in-between stage.

One hypothesis that can be fairly assumed, is that every solid body in the gas cloud that has grown to larger than one kilometer in length or diameter (a little more than a half mile) would be subject to known gravitational effects, and the collisions between any such objects in the cloud would be governed by standard collisional dynamics, whereby larger bodies tend to absorb the smaller ones.

What is a Fractal?

A fractal is a rough or fragmented geometric shape that is characterized by self similarity, meaning that it can be split into parts, each of which is (at least approximately) a reduced-size copy of the whole.

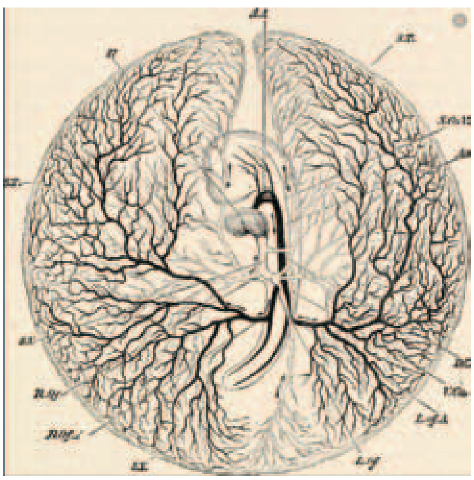


https://commons.m.wikimedia.org/wiki/File:Brownian_tree.gif#mw-jump-to-license

Three images from a simulation of a Brownian-motion fractal in three dimensions.

Kenneth G. Libbrecht

A snowflake builds in a plane.



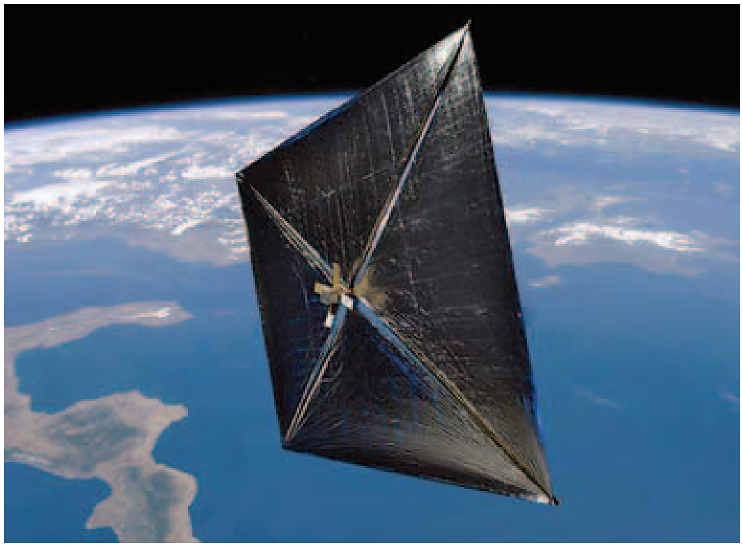
Comparative Anatomy of Vertebrates

Pixabay/Andrew Martin

Living systems grow in three dimensions: a circulatory system branching from the heart (left), and limbs branching from a tree trunk.

But the process of aggregation of dust clusters smaller than that one kilometer has been harder to explain. The motions of such objects would be subject to what are called Brownian motion, and such random motions would be expected to produce more of a tendency for the objects to deflect or to fracture after collisions, rather than to aggregate.

The best theory to answer that question has been that of "fractal" aggregation, whereby the smaller icy dust grains would build up to the one-kilometer size by sticking to each other through a super-efficient, self-developing mechanism, similar to the manner that snowflakes build up complex icy spine structures in a plane around a small crystal core. But, in this case, the dust structure must build up in 3-D. The resulting aggregate would be a complex porous, fluffy object that expresses the maximum area-to-mass ratio.[2]



NASA

Artist's impression of a photon-powered sailcraft in orbit.

This kind of structure allows for several factors that could self-reflexively enable an extraordinary sticking capability: (1) the complex structure maximizes the options for oblique, or soft, collisions to occur; (2) the open structure provides a high collisional cross-section to maximize overall collision probabilities within the gas; and (3) the structure maximizes the "gas-grain coupling," which allows for the separate grains in the gas to have similar velocities—again, enabling softer collisions.

But the idea that such complex, self-organizing structures might develop out of a seemingly random process of individual collisions is an unsettling thought for many physicists and mathematicians. It is a process that is much too life-like, and anti-entropic, for their notions of fixed physical phenomena.

But now, because of recent developments in the U.S. space program, this rather obscure issue of planetary formation might become a hot topic for the general public. The background is the following.

A Visitor from Another Star System

In October of 2017, the first interstellar object was observed flying through our solar system. It was named 'Oumuamua in honor of the Hawaiian observatory tracking it, and was apparently coming from the general direction of the star, Vega.

We only got a fleeting glimpse of it as it flew by the Sun in a hyperbolic arc and shot back out towards the outer reaches of the galaxy. Recent probability calculations indicate that there are many more such objects that we should expect to find.

A proposal was put forward by a group of researchers at NASA, in conjunction with the Harvard Astronomy Department and several private space companies, to speed up the development of the new form of spacecraft, called "sailcraft."[3] The sailcraft is a tremendous technological innovation, which would allow for such high speeds, that, were a swarm of them positioned in orbit on alert for another interstellar interloper like 'Oumuamua to appear, these spacecraft could potentially catch up with the object and photograph, or even take a sample bite of it—presenting us with the opportunity to investigate the composition of an object from outside our solar system.

The sailcraft, itself, is propelled by an unusual power source: the radiation pressure of the Sun, i.e., by the photons from the Sun that impinge on the very thin wings attached to the tiny (loaf-of-bread size) body of the spacecraft. This radiation pressure is enough for the sailcraft, if given a gravity assist around the Sun to accelerate it further, to achieve such a high-energy trajectory that would have allowed it to catch up with 'Oumuamua with only 30-days' notice.

As the data from 'Oumuamua's visit was carefully

2. Here is an animation of a Brownian-motion fractal aggregating (baby planet being born). https://commons.m.wikimedia.org/wiki/File:Brownian_tree.gif#mw-jump-to-license

3. Turyshev, S., et al., "Exploration of the Outer Solar System with Fast and Small Sailcraft." https://arxiv.org/abs/2005.12336

Albrecht Dürer

Dürer's self-portrait in 1493, about the time of his first trip to Italy. Note the resemblance to the student in the de Barbari painting, completed 1495.

analyzed, it became clear that there was an anomaly. The object had an unexplained acceleration as it sped its way out of the solar system, an acceleration that could not be accounted for by known gravitational forces.

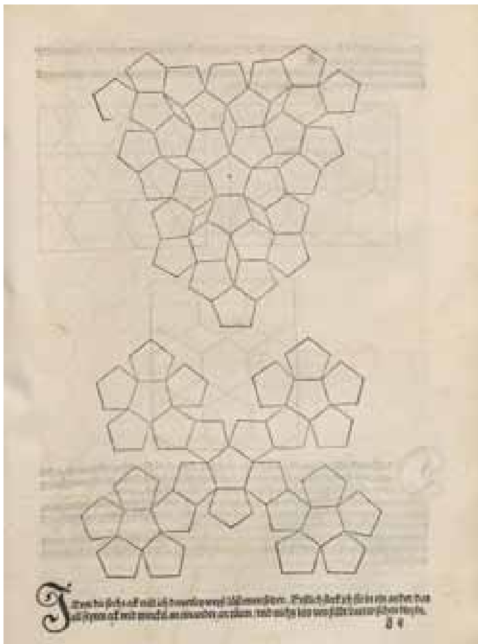
Avi Loeb, head of astronomy at Harvard, who had been intimately involved in the study of the photon-propelled sailcraft technology, did the calculations and, in 2018, wrote an article in which he suggested that 'Oumuamua might be a very thin artificial spacecraft, based, itself, on photon propulsion technology—and, yes, likely built by aliens!

But then, Amaya Moro-Martin, at the Space Telescope Science Institute in Baltimore, produced her study in 2019[4] showing that it was true that all the calculations did indicate that 'Oumuamua was indeed a lightweight sailcraft, but a naturally-formed one, which had likely been expelled in our direction from some nearby young star's proto-planetary disc.

Portrait of Fra Luca Pacioli*, with a young student, painted by Albrecht Dürer's friend, Jacopo de Barbari. Note the pentagon-faced dodecahedron solid sitting on the desk. The dodecahedron is one of the five Platonic Solids that Leonardo da Vinci drew for Pacioli, as illustrations for his 3-volume treatise,* The Divine Proportion.

The ironic, but lawful twist here is that humanity were to produce a sailcraft at the very moment it was needed to catch up to one!

There is a longer story to be told of the exciting interplay between the academic community and the astrophysicists and builders of spacecraft at NASA, but we will return to that in a follow-up article. For now, we will follow the story of the fractal controversy, and explore its implications for a very, very large interdisciplinary community.



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The Dürer pentagon fractal, from The Painter's Manual*, 1505.*

Planetesimals, Quasicrystals, and 5G Broadband

Over the past decade, there have been researchers of all kinds who have not been intimidated by the revolutionary implications of a "fractal" hypothesis.

There were some who set about to replicate the process of sticky-grain aggregation using laboratory and computer simulations, thereby testing the theory. One group. affiliated with Jawaharlal Nehru University in New Delhi, carried out an analog study in 2014, "Fractal Signatures in Analogs of Interplanetary Dust Particles."[5] They noted that mass spectroscopy of tiny cosmic dust aggregates in the Earth's lower stratosphere showed them to be composed of silicates of iron, magnesium, aluminum, and calcium. The scattering of these elements indicated a tendency for them to accumulate in fluffy, loosely structured aggregations. But, it proved difficult to confirm that they were definitely fractal, though it was highly probable.

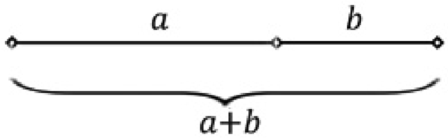
4. Moro-Martin, A., "Could 1I/'Oumuamua Be an Icy Fractal Aggregate?" https://arxiv.org/abs/1902.04100

5. Katyal, N., et al., "Fractal Signatures in Analogs of Interplanetary Dust Particles." https://arxiv.org/abs/1402.7132

Five-Fold Symmetry

Plane figures or solid bodies that demonstrate five-fold symmetry can be connected in a fractal combination, like the Dürer Pentagon Fractal; but they are also capable of becoming fully-packed, i.e., connecting smoothly with certain other figures/shapes in a manner where there will be no gaps or fragments in their growing structure. And these structures are distinct from the shapes of common crystal structures, even though such crystals are also fully-packed, based on their own two-fold, three-fold, four-fold, or six-fold starting unit. The common crystal will replicate its basic unit, over and over again, over a certain period. But growth involving a five-fold or 10-fold symmetry is not precisely periodic, meaning that, as these systems grow, there are always continually slight variations in the way they are connected—and that those variations, themselves, are never repeating in exactly the same way.

That is because the five-fold symmetry has an internal structure that gives rise to a ratio that is an irrational number, that is, one that cannot be expressed as the ratio of two integers, one known by the ancient Greeks as the "golden ratio," or, during the European Renaissance, as the "divine proportion."



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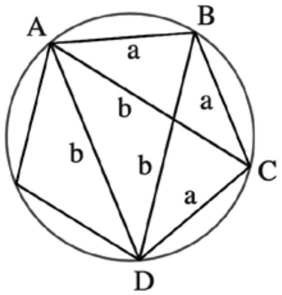
The golden ratio (phi) represented as a line divided into two segments ***a*** *and* ***b****, such that the entire line is to the longer* ***a*** *segment as the* ***a*** *segment is to the shorter* ***b*** *segment. This line can continue to grow to infinity with those proportions, each time taking the* ***a+b*** *as the new* ***a****.*



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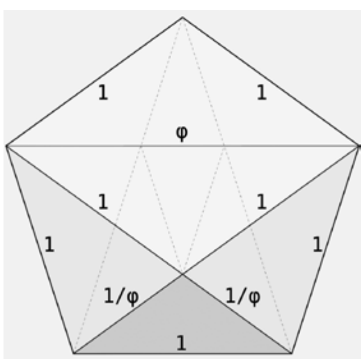
The same golden ratio is inherent in the five-fold symmetry of the pentagon (and, if the sides are doubled, the decagon). The ratio of the sides of the pentagon to its diagonals are in the golden ratio: ***a+b*** *is to* ***a*** *as* ***a*** *is to* ***b****.*



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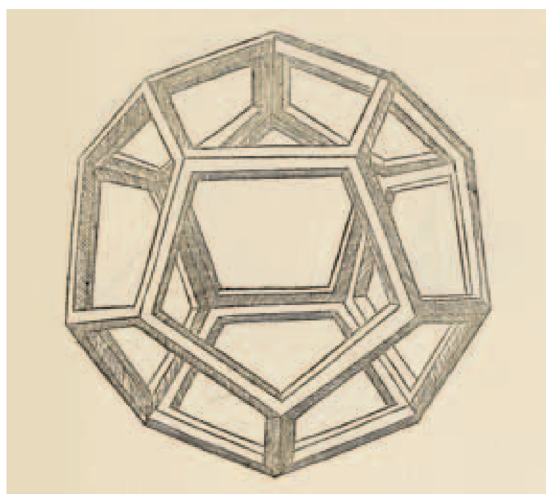
A pentagon drawing demonstrating multiple internal golden ratio triangles that can be used individually or in combinations, to fill in gaps in growing pentagonal or decagonal tilings. Here is an animation demonstrating the principle: https://commons.m.wikimedia.org/wiki/File:RectangleFill.gif#mw-jump-to-license



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The 12 regular pentagonal-faced dodecahedron solid, one of the five Platonic solids, drawn by Leonard daVinci to illustrate Luca Pacioli's The Divine Proportion*, 1509.*

Meanwhile, in another discipline entirely, a group at Mahatma Gandhi University in Kottayam, India, in 2014 presented a paper for an IEEE (Institute of Electrical and Electronics Engineers) international conference on the application of fractal structures for building microstrip antennas for broadband connections, "Microstrip Antenna Based on Durer Pentagon Fractal Patch for Multiband Wireless Applications."[6] As fol-

6. Abraham, J., et al., "Microstrip Antenna Based on Durer Pentagon

low-up, this year, a group at Aditya, India's College of Engineering and Technology presented a study updating that system for 5G communications.

So, what is meant by a "Dürer Pentagon Fractal"? Although fractal antenna structures were not a new idea in 2014, the pentagon (a figure on a plane with five equal sides) structure was. And the reference to the specific pentagon fractal of the Renaissance artist Albrecht Dürer is particularly intriguing.[7] (See box, Five-fold Symmetry.)

Perhaps these individuals in the electronics engineering field were aware of how significant the pentagonal structure was in the shake-up occurring at that time in the field of chemistry. Johns Hopkins University's Dan Shechtman had just been awarded the Nobel Prize in 2011 for his discovery of quasicrystals. The discovery had been made in 1982, but was largely ignored for decades. The quasicrystal is a type of crystal that is not supposed to exist, according to standard chemistry. Instead of having the normal crystal's fixed, repeating structure, the quasicrystal has a pentagonal/decagonal structure that allows for self-similar, but not exactly periodic replication—a growth pattern that is even closer to what occurs in a living system than our fractals.

Quasicrystals are found only in laboratory-created alloys that are produced under conditions of extreme heating, then quick cooling, and also in meteorites that have been exposed somehow to similarly extreme conditions at some point in their history.[8]

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Medieval Islamic architectural tiling patterns. The Baghdad Caliphate of the 12th Century salvaged the Platonic writings from Greece, and later transmitted them to Europe. Here we see a detail from an interior archway in the 15th Century Ottoman Green Mosque, Bursa, Turkey, tiled with pentagons and 10-point stars.

In an hysterical reaction to Shechtman's discovery, the famous chemist, Linus Pauling, had proclaimed: "There are no quasicrystals, just quasi-scientists."

But not all scientists had rejected Shechtman's brilliant insights. Certain physicists built upon them, and carried them over into other disciplines. Physicists Peter Lu of Harvard and Paul Steinhardt of Princeton carried out an amazing study in 2007, "Decagonal and Quasicrystalline Tilings in Medieval Islamic Architecture."[9]

Although their research underplayed the importance of how the Islamic Renaissance was rooted in the ancient Greece of the Pythagoreans and Plato, the effort by these physicists to bring Shechtman's fascinating breakthrough in crystallography over into an appreciation of a mix of art and science is admirable. It is worthwhile to spend an hour watching Peter Lu's lecture here before a Harvard audience.[10]

What Would a New Renaissance Look Like?

Certainly an appreciation of classical culture, as an integrated interaction of science and art, would be at the core of a new Renaissance that could pull the world out of its degenerate state.

We have given a few indications here how such an appreciation can appear naturally when minds are opened up to profound ideas by investigators who dare to push the frontiers.

An upgraded and fully-funded space program is the most obvious immediate step to brute-force such developments—including especially a crash program to bring a fleet of sailcraft on line. Then we could lift the eyes of the world's young people to search the skies, looking for newly-born fluffy fractal creatures coming to visit us from far-distant places.

Fractal Patch for Multiband Wireless Applications." https://ieeexplore.ieee.org/document/7033976

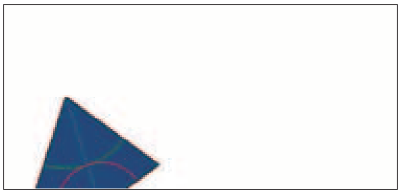
7. A 1993 biography of Dürer suggests that he met with Luca Pacioli (and possibly Leonardo da Vinci) in Italy during his Italian tour of 1494, and that his Italian friend, Jacopo de Barbari, painted him as the student of Pacioli's in the famous 1495, **Portrait of Fra Luca Pacioli**. (See above.) Note in the painting, the pentagon-faced dodecahedron solid sitting on the desk. The dodecahedron is one of the five "Platonic Solids" that Leonardo da Vinci drew for Pacioli, as illustrations for his 3-volume treatise, **The Divine Proportion**.

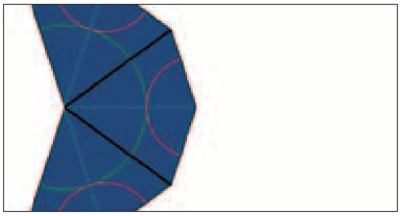
8. Here is an Interview with Dan Shechtman. https://youtu.be/EZRTz-OMHQ4s.

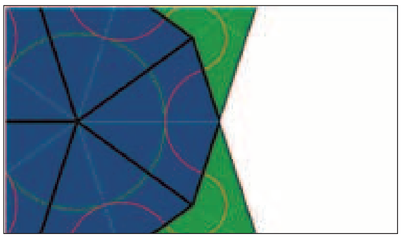
9. Lu, Peter J. and Steinhardt, Paul J., "Decagonal and Quasicrystalline Tilings in Medieval Islamic Architecture." https://semanticscholar.org/paper/24c3a7d58dd9ca7cf14b63de313e36218329b949

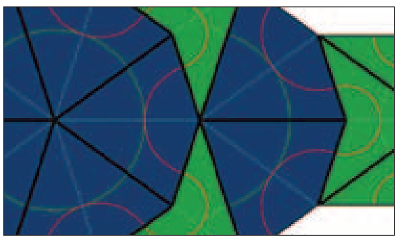
10. Peter Lu's lecture at Harvard. https://youtu.be/rldnu9rNpH8

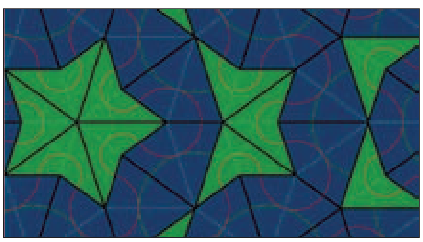
Quasicrystals

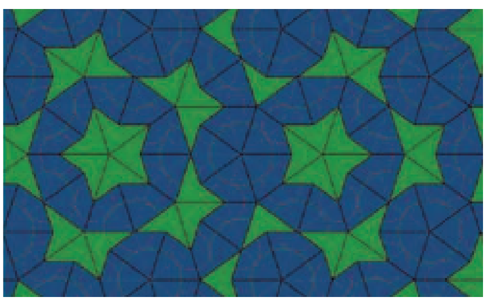




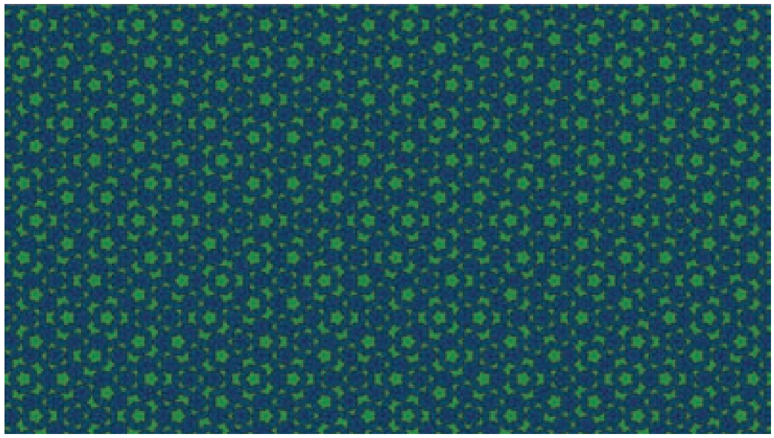








Shown here are consecutive images from an animation of decagonal tiling and an electron-microscopy image. To see the full animation, click here. Note how the image directly below looks very much like the electron microscopy image for quasicrystals. The assumption is that if a higher resolution image of the Khatyrka meteorite fragment were possible, we would see something quite similar to the fully-packed, aperiodic tiling pattern in the previous images.



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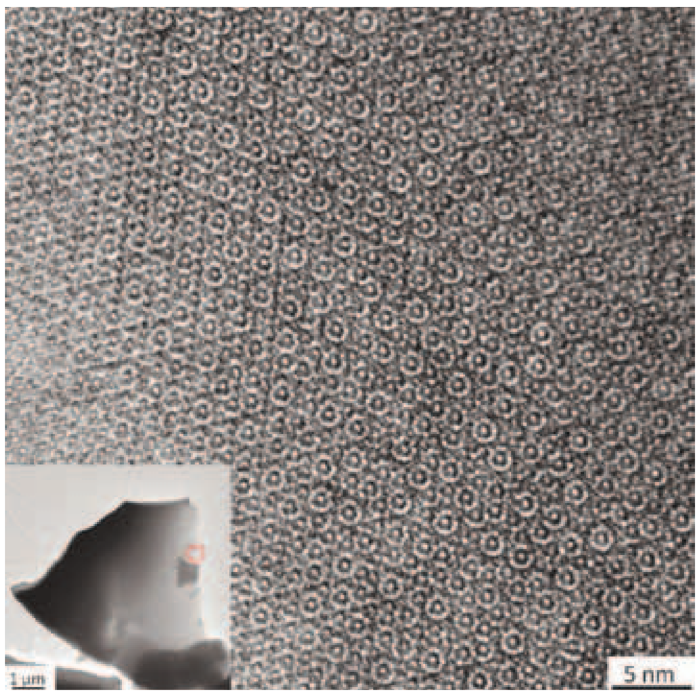

Princeton/Paul Steinhardt

High-resolution electron-microscopy image showing decagonal structure in natural $Al_{71}Ni_{24}Fe_5$ *quasicrystal found in a Khatyrka meteorite.*