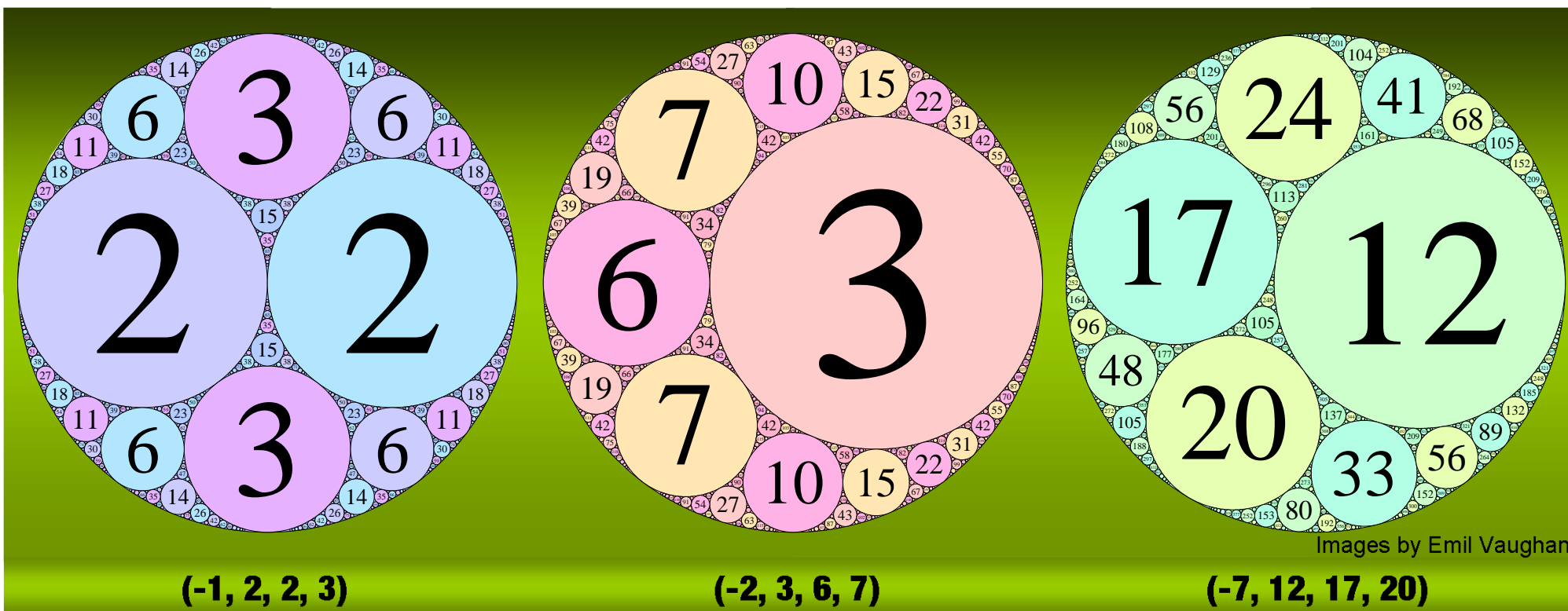




THEOREM OF THE DAY

A Theorem on Apollonian Circle Packings For every integral Apollonian circle packing there is a unique 'minimal' quadruple of integer curvatures, (a, b, c, d) , satisfying $a \leq 0 \leq b \leq c \leq d$, $a+b+c+d > 0$ and $a + b + c \geq d$. This so-called root quadruple completely specifies the packing.



A Descartes configuration consists of four mutually tangent circles. Above right, for example, is a circle of radius $1/7$ containing circles of radius $1/12$, $1/17$ and $1/20$, each of which has a point of contact with the other three. The integers labelling the circles are the *curvatures* (the reciprocals of the radii) and in the root quadruple of curvatures, $(-7, 12, 17, 20)$, the enclosing circle of radius $1/7$ is determined to have negative curvature so that all four circles have disjoint interiors. Any such configuration specifies four more tangent circles — above right, these have curvatures 24, 33, 48, and 105, producing four new configurations $(-7, 12, 17, 24)$, $(-7, 12, 20, 33)$, $(-7, 17, 20, 48)$ and $(12, 17, 20, 105)$. Repeating this process produces a system of infinitely packed circles: an *Apollonian circle packing*. If our initial configuration is integral, as in each of the above examples (which are drawn to different scales), then we will get an *integral packing* with every curvature an integer.

This theorem comes from a series of four pivotal papers by the AT&T team of Ronald Graham, Jeffrey Lagarias, Colin Mallows and Allan Wilks, together with Catherine Yan of Texas A&M University. They further show that all integral Apollonian circle packings may be derived from root quadruples which, like those depicted above, have entries whose gcd is 1.

Web link: www.ams.org/featurecolumn/archive/kissing.html; more advanced: publications.ias.edu/sarnak/section/516 (under 2011). A good guide to creating your own circle packings is Cliff Reiter's article at archive.vector.org.uk/22/4.

Further reading: *Introduction to Circle Packing: The Theory of Discrete Analytic Functions*, by Kenneth Stephenson, CUP, 2005.

