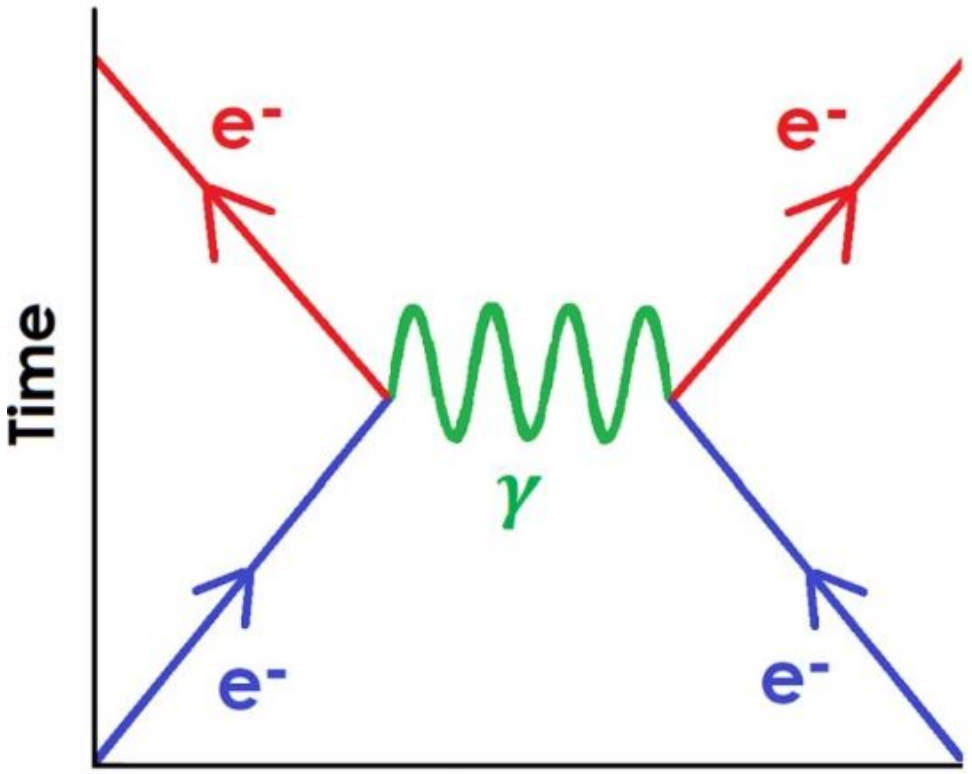
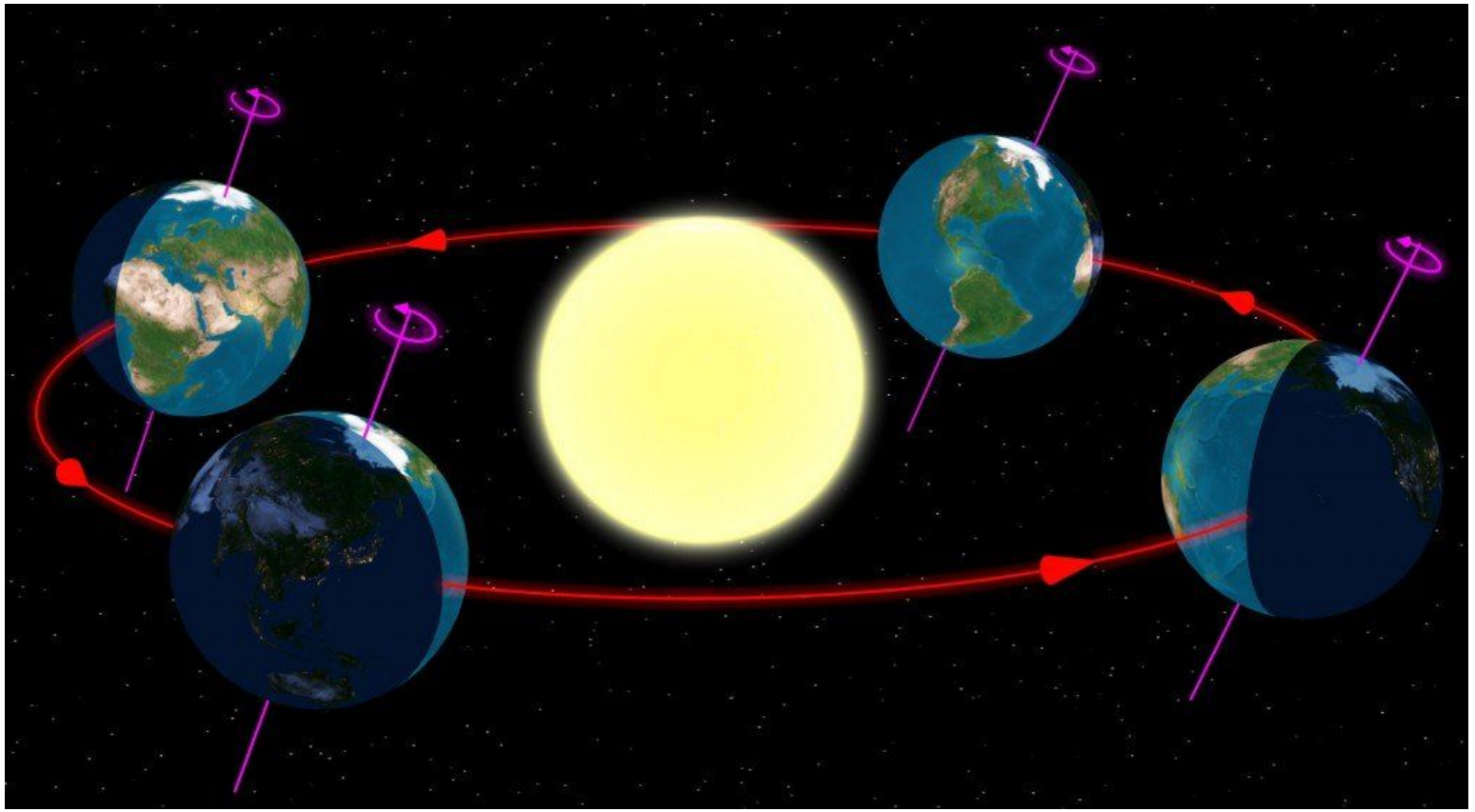
Foundations Work: Time and Space



$e^- + e^- \rightarrow e^- + e^-$

The Copenhagen Interpretation

Meaningful Time - Cycles

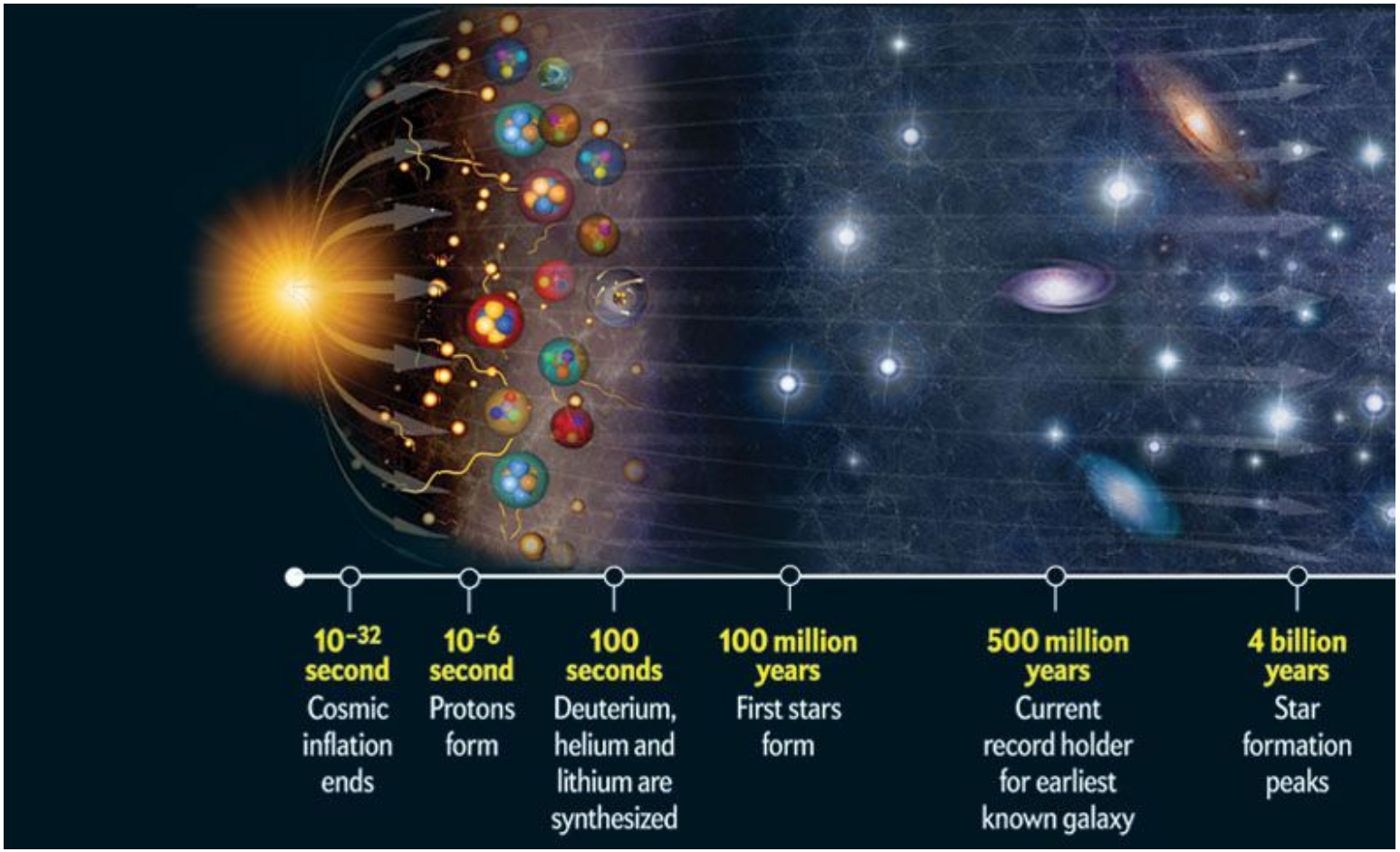


Circular Definition

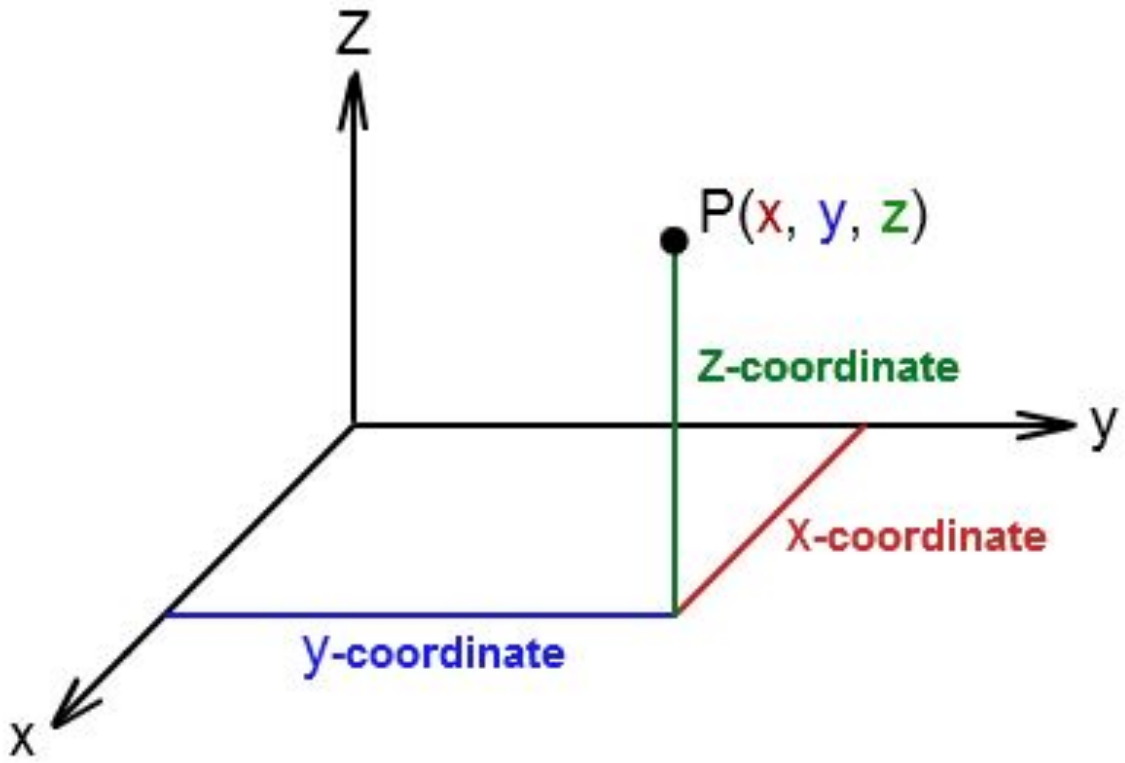
Janna Levin from Barnard College/Columbia University in a short excerpt from *The Illusion of Time*:

"We would like to corner time as a thing, but it defies that completely by being momentary. By only having definitions that harken back to the notion of time itself."

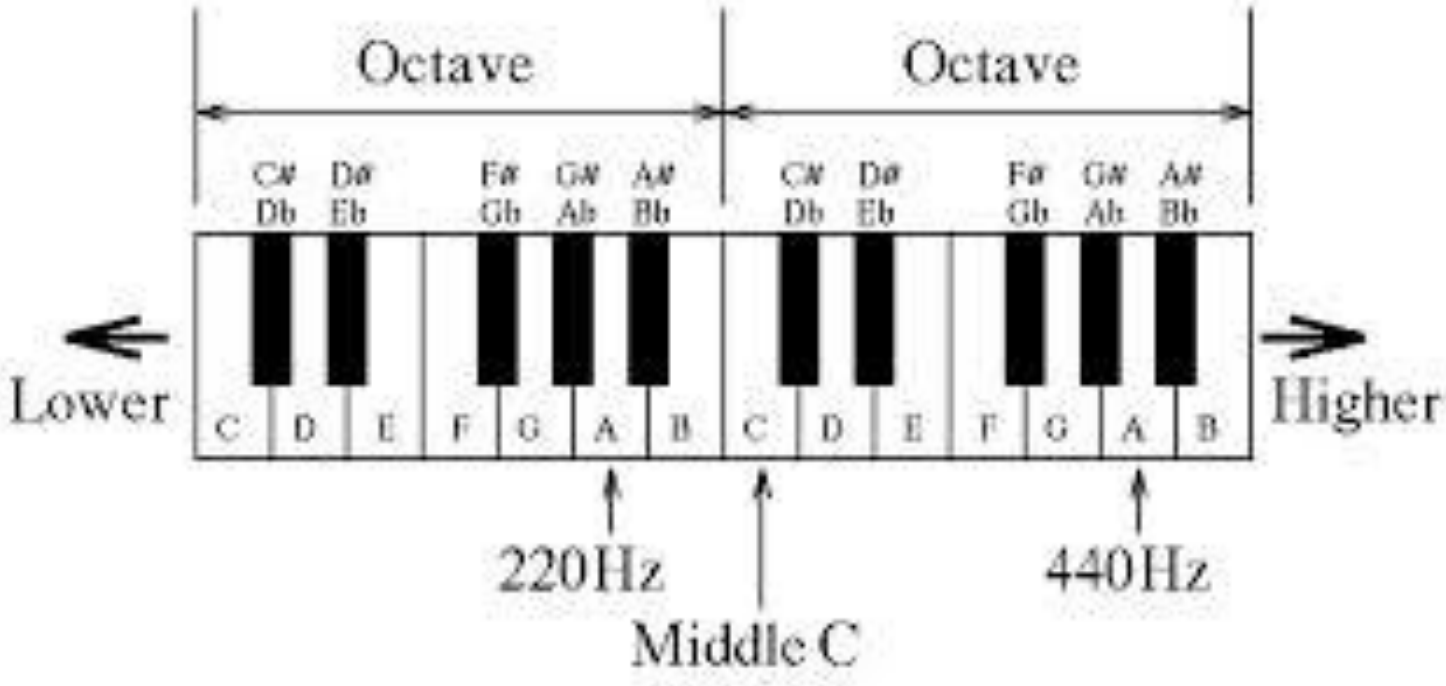
The Age of the Universe



Multifractals and Manifolds



Useful Frequency Intervals



Black Hole Scalar Distribution

Nasa.gov:

“Black holes can be big or small. Scientists think the smallest black holes are as small as just one atom.”

“The largest black holes have masses that are more than 1 million suns together.”

“Scientists think the smallest black holes formed when the universe began.”

Scalar Turbulence

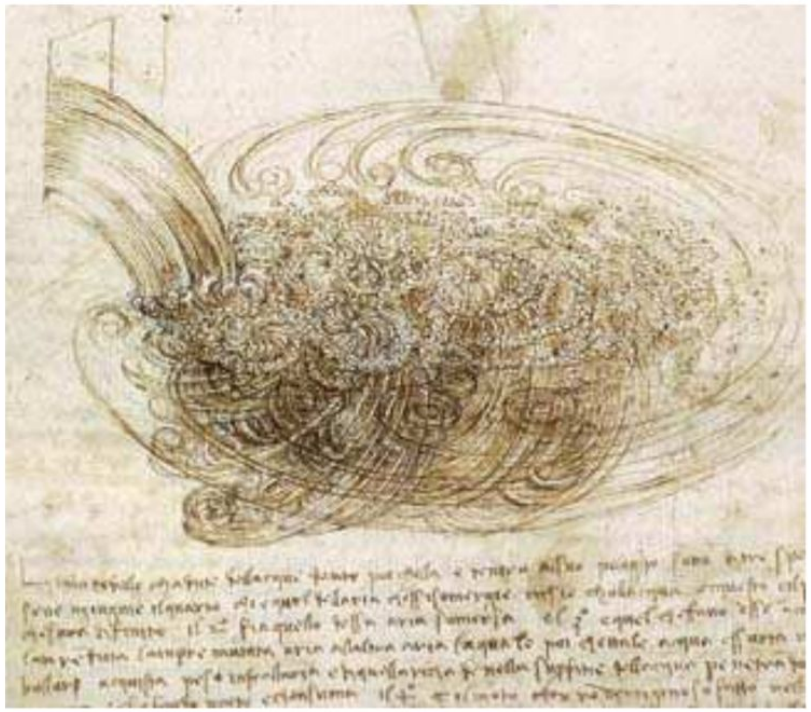
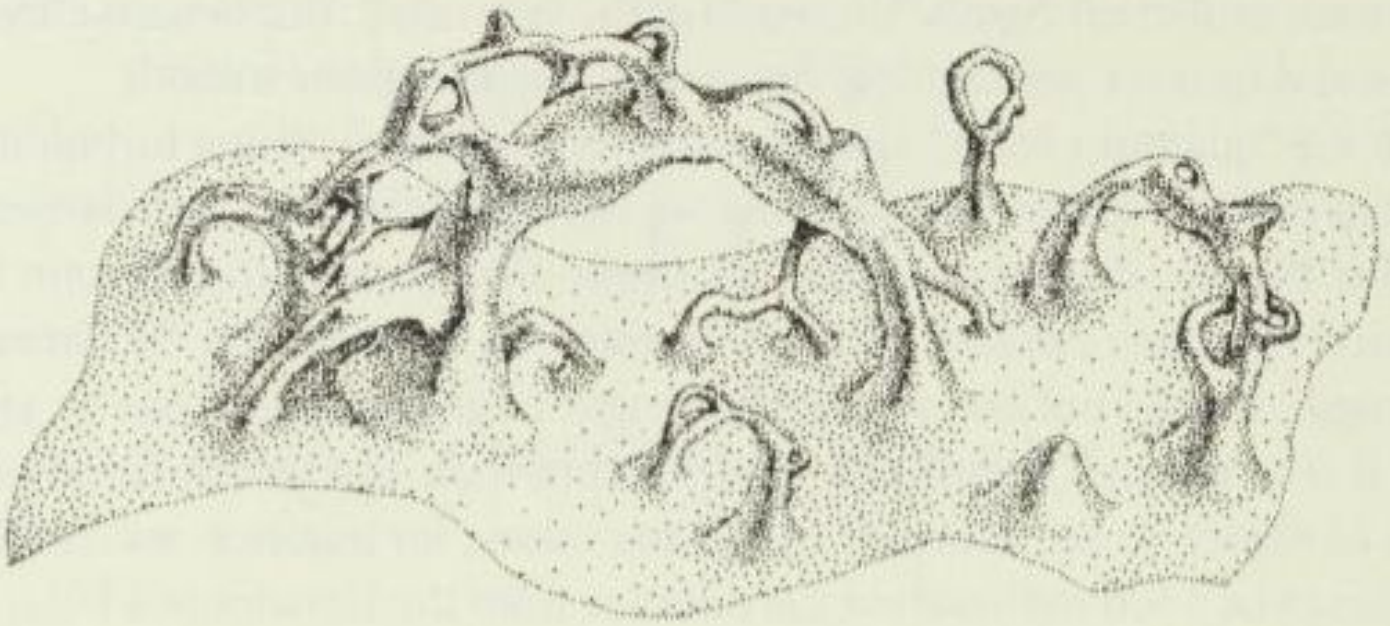


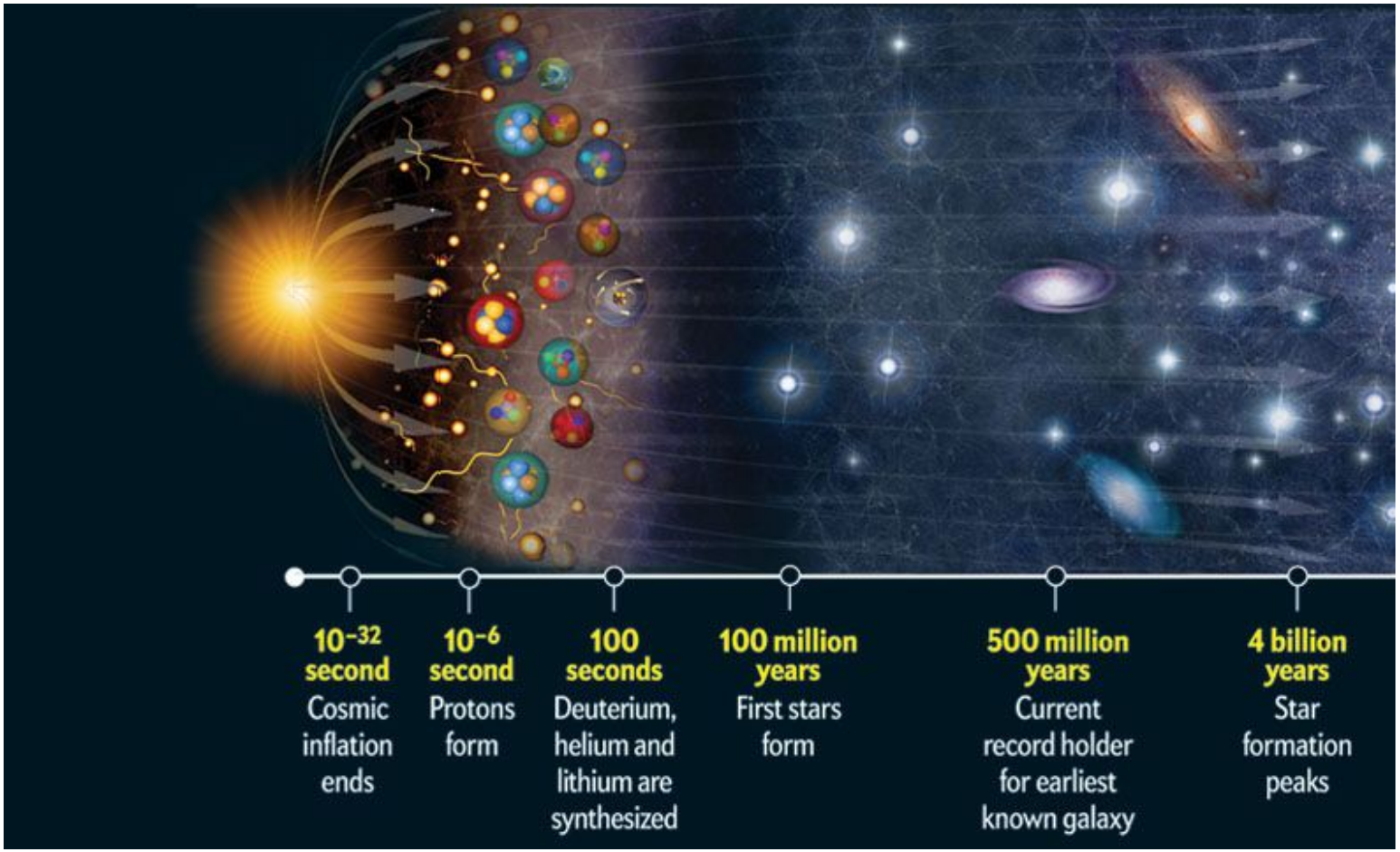
Figure 8.1: Drawing of a turbulent flow by Leonardo da Vinci (1452–1519), who recognized that turbulence involves a multitude of eddies at various scales.

Quantum Turbulence

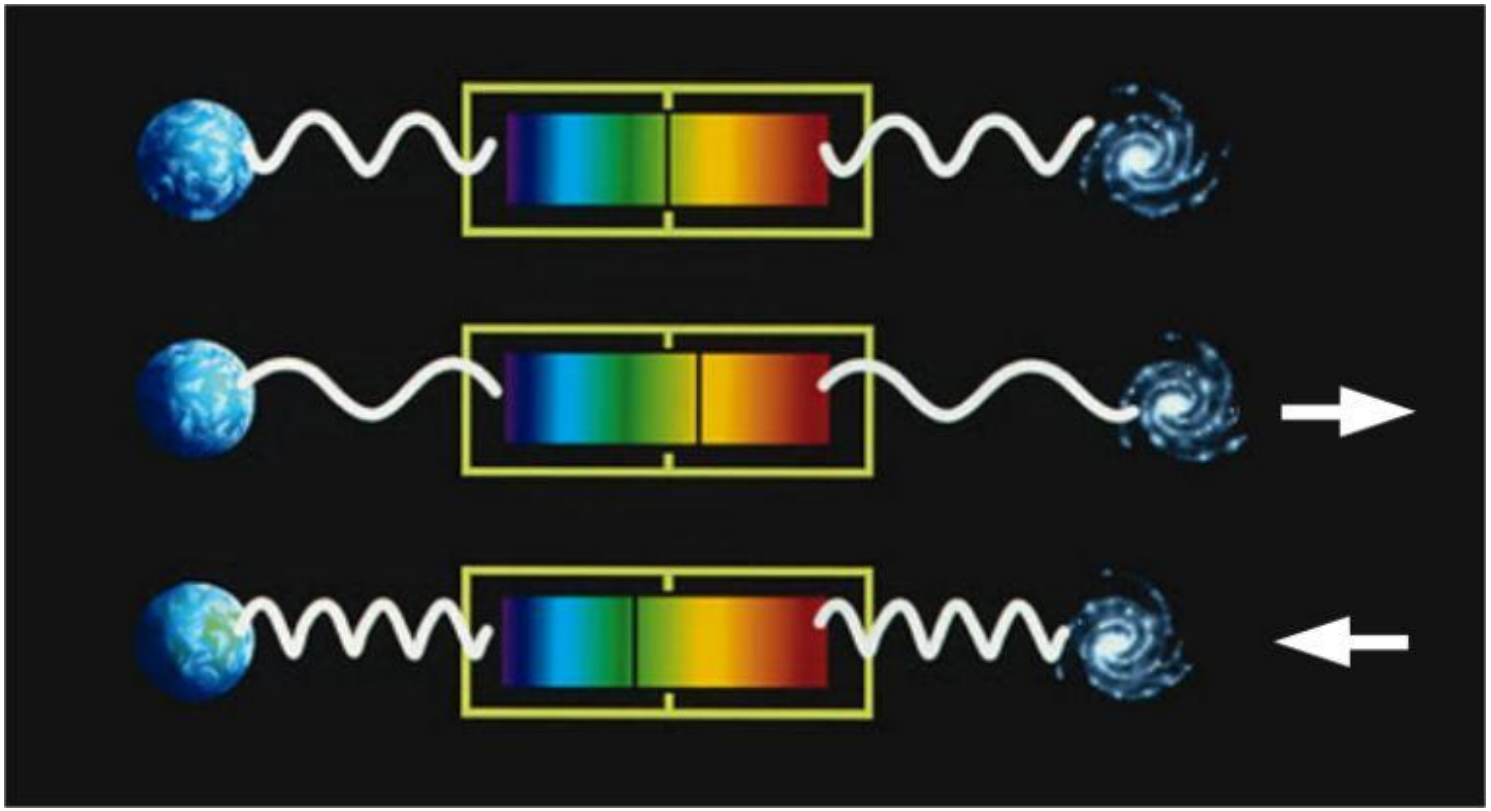


Quantum foam.
(*Reprinted with permission from Fig. 13.7c in Kip Thorne*, Black Holes and Time Warps: Einstein's Outrageous Legacy [*New York: W. W. Norton, 1994*], *p.* 478.)

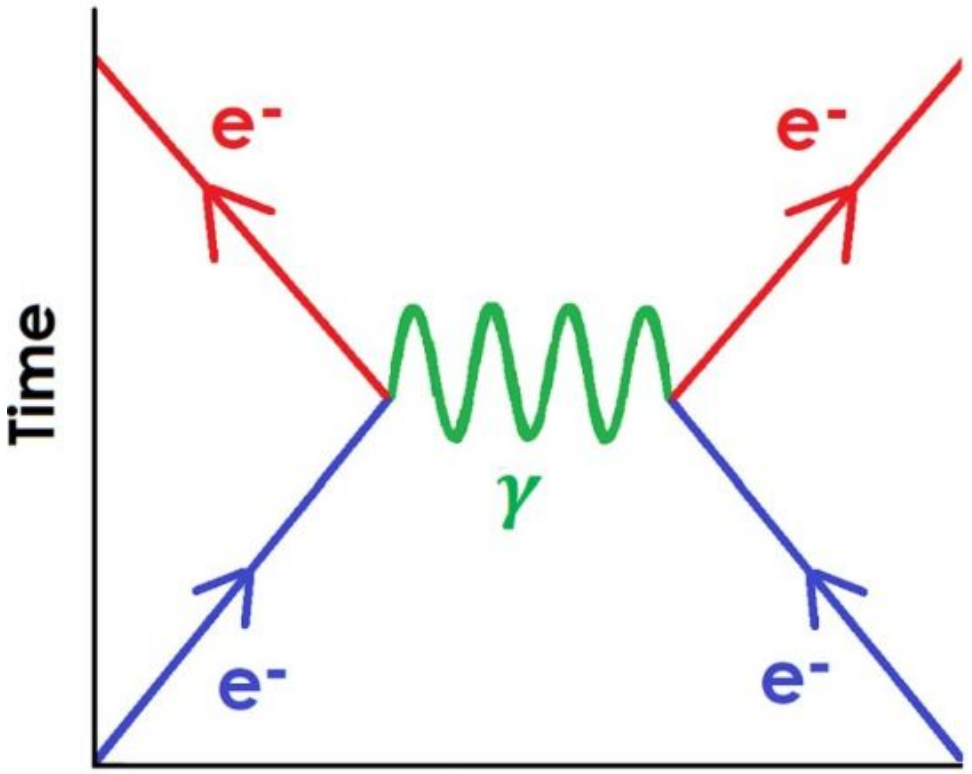
The Age of the Universe



Interpreting the Red Shift Data

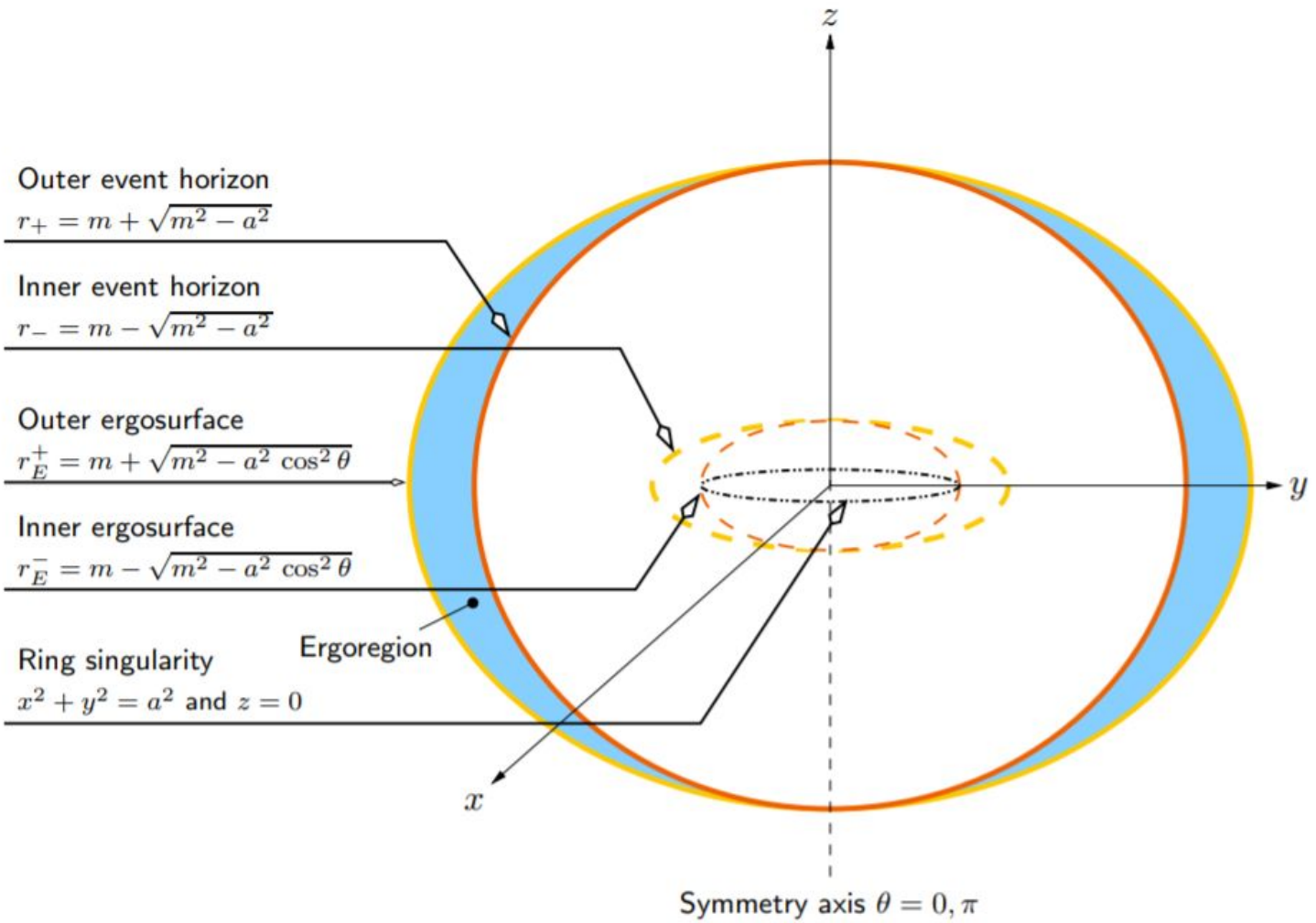


Feynman Diagrams



$e^- + e^- \rightarrow e^- + e^-$

Event Horizons - Photon Spheres



Mirror Force Reversal

SUMMARY

We show that inside the circular photon orbit in the Schwarzschild geometry all the dynamical effects of rotation reverse direction. In particular, for particles and test fluids orbiting the centre on circular (in general non-geodesic) orbits the following occur.

(i) *The centrifugal force reverses its direction.* The centrifugal force *attracts* orbiting particles toward the centre: the faster a particle orbits, the more strongly is it pushed towards the centre.

(ii) *The Rayleigh stability criterion is reversed.* For a stable angular-momentum distribution, the specific angular momentum *decreases* with increasing distance from the axis of rotation.

(iii) *The direction of the viscous torque is reversed.* For a fluid with constant angular-momentum distribution, angular momentum is transported *inwards* by viscous torque.

Mirror Force Reversal

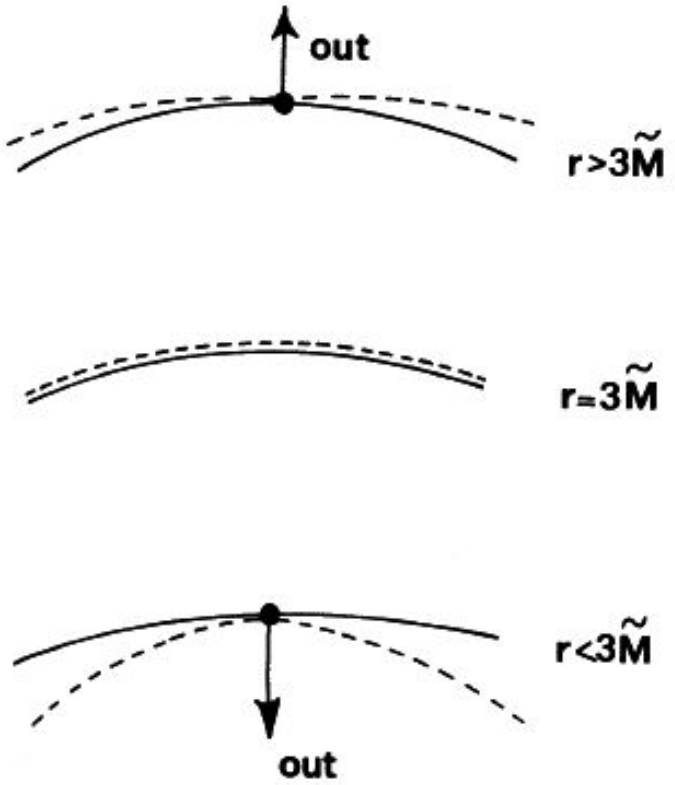


Figure 2. The reverse in sense of the outward and inward directions at the circular photon orbit $r = 3\tilde{M}$. Circles $r = constant$ are shown by solid lines and photon trajectories by broken lines.

Eddy Black Holes

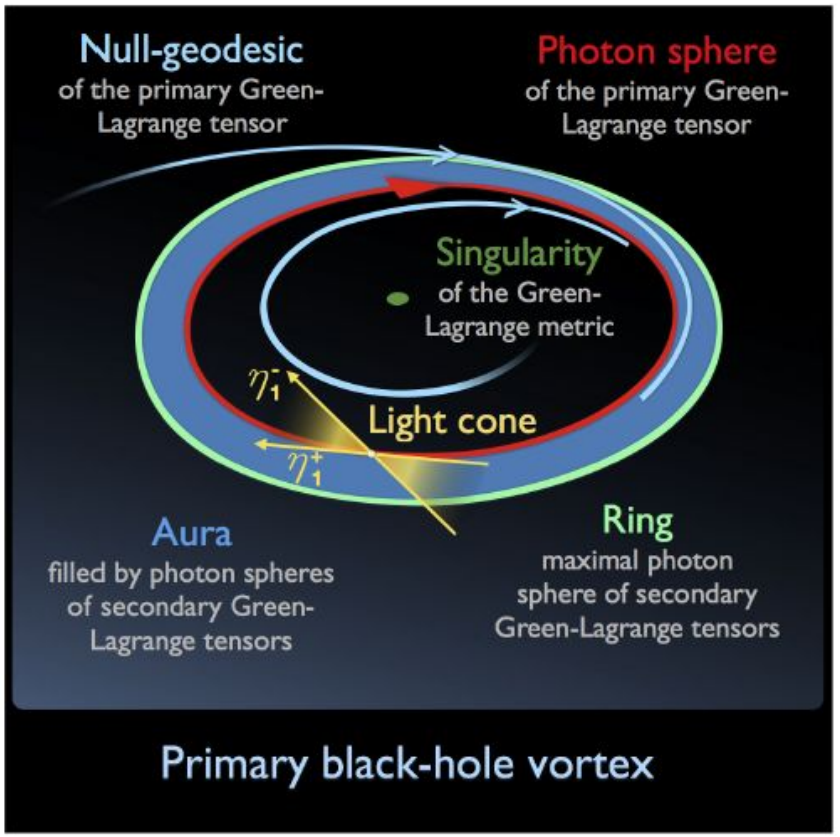
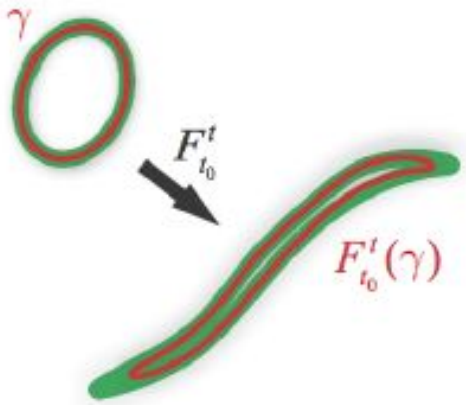
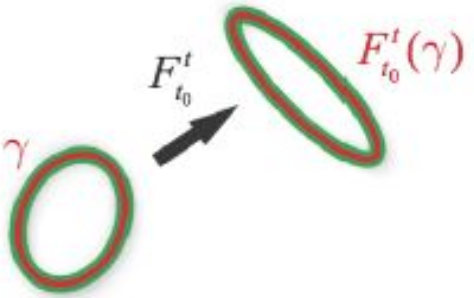


FIGURE 2. Mathematical equivalence between coherent Lagrangian vortices and black holes.

Harry Clarke's illustration for
"A Descent into the Maelström"
by Edgar Allan Poe (1841)



Typical material belt



Coherent material belt

FIGURE 1. Edgar Allan Poe's maelstrom and material belts in turbulence. A closed material curve γ (red) at time t_0 is advected by the flow into its later position $F^t_{t_0}(\gamma)$ at time t. The advected curve remains coherent if an initially uniform material belt (green) around it shows no leading-order variations in stretching after advection.

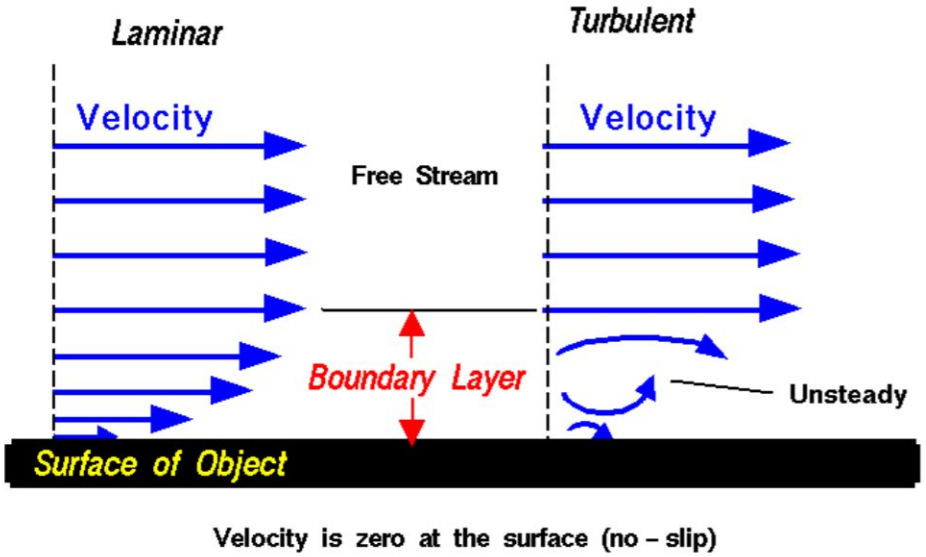
or maelstroms, in popular fiction. An early example can be found in Edgar Allan Poe's short story entitled *A Descent into a Maelström*:

> "The edge of the whirl was represented by a broad belt of gleaming spray; but no particle of this slipped into the mouth of the terrific funnel..."

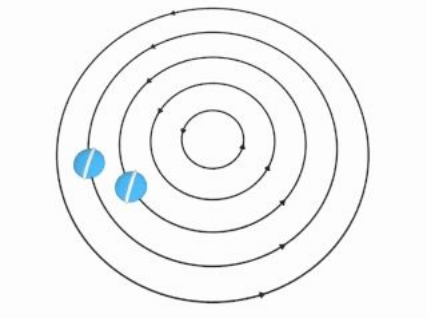
This literary account depicts a belt-like vortex boundary that keeps particles from entering its interior (Figure 1). Altogether, Poe's view on vortices is Lagrangian, and resonates with our intuition for black holes in cosmology.

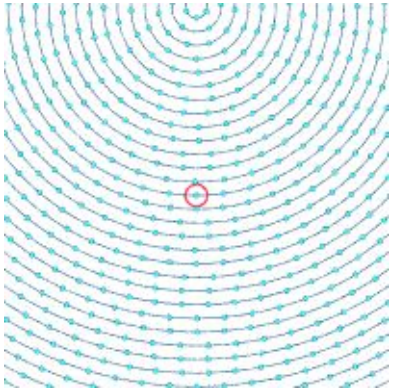
As we show below, this view turns out to have some merit. When appropriately modeled, Poe's coherent belt becomes mathematically equivalent to a photon sphere, *i.e.*, a surface on which light encircles a black hole without entering it. This analogy yields computational advantages, which we exploit in locating material eddy boundaries in the South Atlantic Ocean. Using satellite altimetry-based velocities from this region, we uncover super-coherent Lagrangian vortices, and derive estimates for coherent material transport induced by the Agulhas leakage.

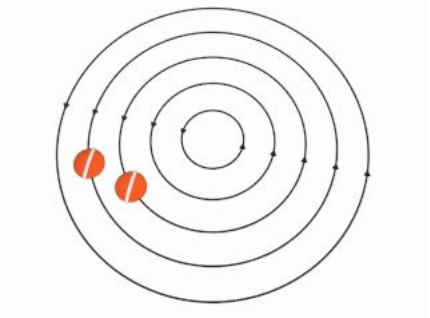
Rotational and Irrotational Vortices

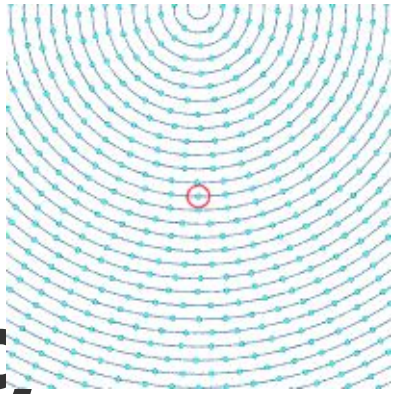


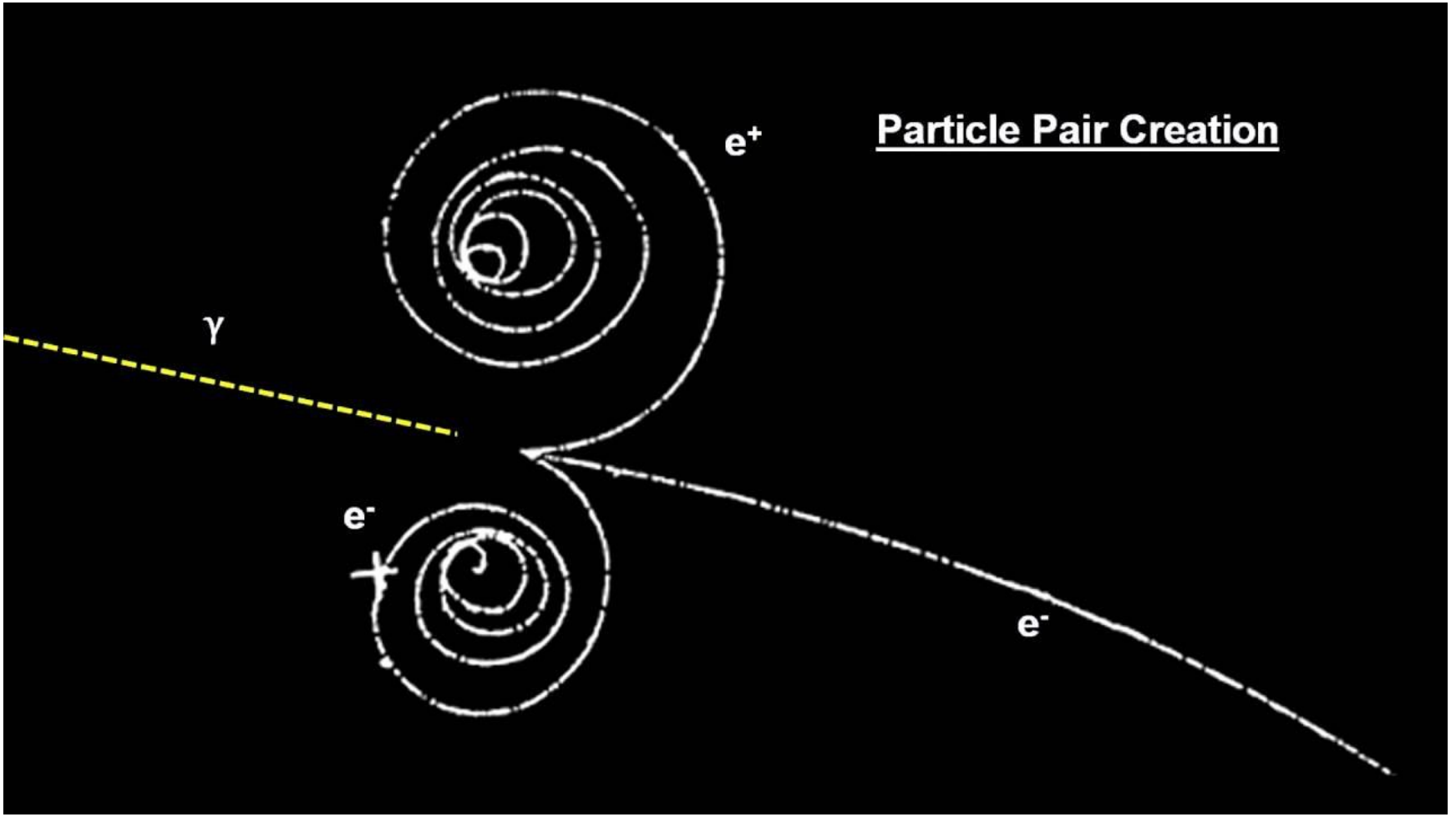
Velocity is zero at the surface (no – slip)










Particle Pair Creation
e+
γ
e-
e-

Space to Time Transition Across an Event Horizon

"One thing that happens to an observer crossing the event horizon is that once it is crossed the singularity lies in the future. To the outside observer, the black hole (and inside it, the singularity) forms a world-tube -

a world tube traces out a three-dimensional volume for every moment in time.

- but to the inside observer, the singularity is now a hypersurface (in your future)."

Foundations Work: Time and Space