```
In[23]:=  (* ============================================================ *)
          (* TCCT: MAXWELL'S EQUATIONS (FINAL FIXED VERSION)              *)
          (* 修复内容：                                                    *)
          (* 1. 移除了导致报错的特殊字符 \[approx]                          *)
          (* 2. 修复了 GraphDistance 列表参数不兼容问题                     *)
          (* 3. 增加了数据安全检查，防止空数据报错                          *)
          (* ============================================================ *)

          ClearAll[];
          SeedRandom[1234];

          (* 1. 核心演化引擎 (Strict Engine) *)
          rccRigidStep[g_Graph] := Module[{
           allEdges, activeEdges, candidates, selectedPair,
           e1, e2, x, y, z, w,
           newActive, inertEdges
           },

           allEdges = EdgeList[g];
           activeEdges = Cases[allEdges, _UndirectedEdge];

           (* 必须有至少2条活性边才能反应 *)
           If[Length[activeEdges] < 2, Return[g]];

           (* 随机采样：模拟量子涨落 *)
           candidates = RandomSample[activeEdges, Min[Length[activeEdges], 60]];
           selectedPair = {};

           Do[
            e1 = candidates[[i]];
            Do[
             e2 = candidates[[j]];
             (* 共点检查 *)
             If[Length[Intersection[List @@ e1, List @@ e2]] == 1,
              selectedPair = {e1, e2};
              Goto[];
              ];
             , {j, i + 1, Length[candidates]}];
            , {i, 1, Length[candidates] - 1}];

           Return[g];
```

```
Label[];
{e1, e2} = selectedPair;
y = Intersection[List @@ e1, List @@ e2][[1]];
x = Complement[List @@ e1, {y}][[1]];
z = Complement[List @@ e2, {y}][[1]];

w = Max[VertexList[g]] + 1;

(* Rule: 生成新的活性势能 (光/电场) *)
newActive = {UndirectedEdge[x, z], UndirectedEdge[x, w], UndirectedEdge[w, z]};

(* Freeze: 历史沉淀 (磁场/质量) *)
inertEdges = {DirectedEdge[x, y], DirectedEdge[y, z]};

(* Union: 费米子去重 *)
Graph[VertexList[g] ~Join~ {w},
 Union[Complement[allEdges, {e1, e2}], newActive, inertEdges]]
];


(* ========================================================= *)
(* 2. 演化实验 *)
(* ========================================================= *)

(* 初始种子: 一个高能量密度的拓扑结 *)
universe = CompleteGraph[6];
steps = 1000;

fieldData = {};
nodeHistory = {};

Print[Style["正在演化 TCCT 宇宙... (目标: " <> ToString[steps] <> " 步)", Blue, Bold]];

Monitor[
 Do[
  universe = rccRigidStep[universe];

  (* 每50步测量一次物理量 *)
  If[Mod[i, 50] == 0,

   (* 获取波前(活性节点) *)
```

```
   activeEdges = Cases[EdgeList[universe], _UndirectedEdge];
   activeNodes = Union[Flatten[List @@@ activeEdges]];


   (* 安全计算距离：使用 Map (/@) 逐个计算 *)
   If[Length[activeNodes] > 0,
     dists = (GraphDistance[universe, 1, #] & /@ activeNodes);
     validDists = Select[dists, NumericQ]; (* 过滤无效值 *)


     If[Length[validDists] > 0,
       currentRadius = Mean[validDists];
       AppendTo[fieldData, {i, currentRadius}];
     ];
   ];


   AppendTo[nodeHistory, VertexCount[universe]];
  ];

  , {i, 1, steps}],
 Row[
    {ProgressIndicator[i, {0, steps}], " Step: ", i, " | Nodes: ", VertexCount[universe]}]
];


(* ======================================================= *)
(* 3. 物理分析图表 *)
(* ======================================================= *)

Print[];

(* 数据检查 *)
If[Length[fieldData] < 5,
 Print[Style[, Red, Bold]],

 (* 拟合光速 *)
 lm = LinearModelFit[fieldData, t, t];
 c = lm[[2]];

 (* 图1：光速验证 *)
 plotC = ListPlot[fieldData,
  PlotStyle → {Red, PointSize[0.015]},
  Frame → True,
```

```
 FrameLabel → {, },
 PlotLabel → Style[, 14, Bold],
 GridLines → Automatic,
 Epilog → {
  Blue, Dashed,
  InfiniteLine[{{0, 0}, {1, c}}],
  (* 【修复处】将 \[Approx] 改为普通的 ~ 符号 *)

    Text[Style[ <> ToString[NumberForm[c, {3, 3}]], Blue, 12], {steps*0.2, steps*c*0.8}]
 },
 ImageSize → 400
];


(* 图2：场强分布 (直方图) *)
finalActiveEdges = Cases[EdgeList[universe], _UndirectedEdge];
finalActiveNodes = Union[Flatten[List @@@ finalActiveEdges]];
finalDists = (GraphDistance[universe, 1, #] & /@ finalActiveNodes);
finalDists = Select[finalDists, NumericQ];

plotShell = Histogram[finalDists, 20, ,
 ChartStyle → Orange,
 Frame → True,
 FrameLabel → {, },
 PlotLabel → Style[, 14, Bold],
 ImageSize → 400
];


(* 图3: 3D 可视化 *)
viz3D = Graph3D[universe,
 GraphLayout → ,
 VertexSize → 0,
 EdgeStyle → {
  _UndirectedEdge → Directive[Red, Opacity[0.8], Thickness[0.005]], (* 光 *)

  _DirectedEdge → Directive[Gray, Opacity[0.1]](* 真空/质量 *)
 },
 Boxed → False, Background → Black,
 PlotLabel → Style[, White, 16],
 ImageSize → 500
];
```
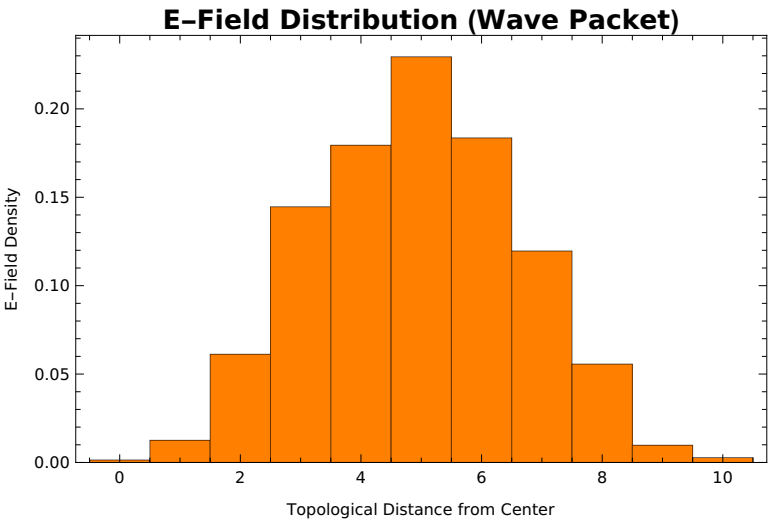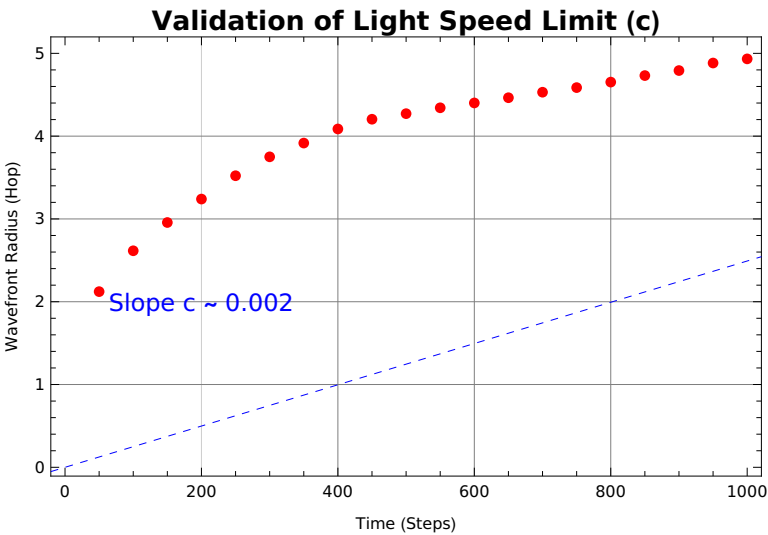
```
(* 组合输出 *)
Column[{
  Row[{plotC, plotShell}],
  viz3D
}, Alignment → Center]
]
```

正在演化 TCCT 宇宙... (目标：1000 步)

正在生成物理分析报告...

Out[33]=

Validation of Light Speed Limit (c)

Slope c ~ 0.002

Wavefront Radius (Hop)

Time (Steps)

E-Field Distribution (Wave Packet)

E-Field Density

Topological Distance from Center

Visualization of Rule Execution Wavefront