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ClearAll["Global`*"];
SeedRandom[2026]; (* 设定随机种子Or you can leave this seed blank. *)

(* ===== *)
(* Part 1: 物理定义 (手性与极性) *)
(* ===== *)

nodePolarity = <| |>;
SetPolarity[n_, p_] := (nodePolarity[n] = p);
GetPolarity[n_] := Lookup[nodePolarity, n, 0];

(* ===== *)
(* Part 2: 核心演化引擎 (修复自环崩溃版) *)
(* ===== *)

NaturalEvolutionStep[g_Graph] := Module[{edges, activeEdges, candidates, e1, e2, x, y, z, w, pX, pY, pZ, isHetero, neighbors, energyRelease, newActive, newFrozen, newG, reactionType},

edges = EdgeList[g];

(* --- FIX: 严格过滤自环 (u!=v), 防止 Complement 返回空集 --- *)
activeEdges = Cases[edges, UndirectedEdge[u_, v_] /; u != v];

(* --- A. 随机寻找反应用于 --- *)
candidates = {};
Module[{shuffled = RandomSample[activeEdges, Min[Length[activeEdges], 100]], eA, eB}, Label];
Do[
eA = shuffled[[i]];
Do[
eB = shuffled[[j]];
If[Length[Intersection[List @@ eA, List @@ eB]] == 1,
candidates = {eA, eB};
Break[]];
],
];
]
];

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{j, i + 1, Length[shuffled]}
];
If[candidates == {}, Break[]],
{i, 1, Length[shuffled] - 1}
];
];
];

If[candidates == {}, Return[{g, }]];

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

(* --- B. 物理判定 --- *)
pX = GetPolarity[x];
pY = GetPolarity[y];
pZ = GetPolarity[z];

isHetero = (Abs[pX + pY + pZ] < 3) && (pX != 0 && pY != 0 && pZ != 0);

(* 使用括号分组，确保语法安全 *)
If[isHetero,
(
(* 分支 1：湮灭 *)
neighbors = AdjacencyList[g, y];

(* 伽马射线暴优化：尽量生成非自环的边 *)
(* 尝试 3 倍于邻居数量的连接，使用 Select 过滤掉自连 *)
energyRelease = Select[
Table[UndirectedEdge[RandomChoice[neighbors],
RandomChoice[neighbors]], {Length[neighbors] * 3}],
#[[1]] != #[[2]] &
];
newG = VertexDelete[g, y];
newG = EdgeAdd[newG, energyRelease];
reactionType = ;
),
(

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(* 分支 2: 生长 *)
w = Max[VertexList[g]] + 1;
SetPolarity[w, pY];

newActive = {UndirectedEdge[x, z], UndirectedEdge[x, w], UndirectedEdge[w, z]};
newFrozen = {DirectedEdge[x, y], DirectedEdge[y, z]};

newG = EdgeAdd[
  EdgeDelete[g, {e1, e2}],
  Join[newActive, newFrozen]
];
reactionType = ;
}
];
];

Return[{newG, reactionType}];
];

(* ===== *)
(* Part 3: 创世与统计 (Genesis & Statistics) *)
(* ===== *)

RunMatterAntimatterSimulation[steps_] := Module[
  g, nodesM, nodesA, edgesM, edgesA,
  activeCurve = {}, massCurve = {},
  res, status, currentMass
],
(* --- 1. 创世 --- *)
Print@;

(* 物质 +1 *)
nodesM = Range[1, 15];
Scan[SetPolarity[#, 1] &, nodesM];
edgesM = Join[
  UndirectedEdge @@@ Partition[nodesM, 2, 1, 1],
  {UndirectedEdge[1, 5], UndirectedEdge[5, 10], UndirectedEdge[10, 15]}
];
];

(* 反物质 -1 *)

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nodesA = Range[20, 35];
Scan[SetPolarity[#, -1] &, nodesA];
edgesA = Join[
  UndirectedEdge @@@ Partition[nodesA, 2, 1, 1],
  {UndirectedEdge[20, 25], UndirectedEdge[25, 30], UndirectedEdge[30, 35]}
];

g = Graph[Join[nodesM, nodesA], Join[edgesM, edgesA]];

(* --- 2. 接触 --- *)
g = EdgeAdd[g, UndirectedEdge[15, 20]];

Print[, steps, ];

(* --- 3. 循环 --- *)
Monitor[Do[
  res = NaturalEvolutionStep[g];
  g = res[[1]];
  status = res[[2]];

  (* 统计 *)
  AppendTo[activeCurve, Count[EdgeList[g], _UndirectedEdge]];
  currentMass = Total[VertexDegree[g]];
  AppendTo[massCurve, currentMass];

  , {i, 1, steps}],
 Row[{, i, , status, , Last[activeCurve], , Last[massCurve]}]
];

(* --- 4. 可视化 --- *)
Print[];

GraphicsGrid[{
  {
    ListLinePlot[activeCurve,
      PlotLabel -> Style[#, Red, 13],
      PlotStyle -> {Red, Thickness[0.004]},
      Frame -> True, GridLines -> Automatic, ImageSize -> 400],
    ListLinePlot[massCurve,

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    PlotLabel -> Style[, Blue, 13],
    PlotStyle -> {Blue, Thickness[0.004]},
    Frame -> True, GridLines -> Automatic, ImageSize -> 400]
}
], ImageSize -> 800]
]

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(* 运行 400 步 *)

RunMatterAntimatterSimulation[200]

正在初始化正反物质团块...

开始自然演化 (Steps: 200)...

演化完成。生成图表...

Out[64]=

