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In[304]:= ClearAll["Global`*"];
SeedRandom[2025];

(* ===== *)
(* 1. 定义手性探测演化核心 *)
(* ===== *)
(* 我们引入全局变量 chiralityLog 来记录每一步的自旋 *)
chiralityLog = {};

rccRigidStepWithChirality[g_Graph] := Module[{allEdges, activeEdges, candidates, selectedPair, e1, e2, x, y, z, w, nextV, newActive, inertEdges, localSpin},
  },
  allEdges = EdgeList[g];
  activeEdges = Cases[allEdges, _UndirectedEdge];
  If[Length[activeEdges] < 2, Return[g]];
  (* 采样 *)
  candidates = RandomSample[activeEdges, Min[Length[activeEdges], 50]];
  selectedPair = {};
  Do[
    e1 = candidates[[i]];
    Do[
      e2 = candidates[[j]];
      (* 找到共点对 *)
      If[Length[Intersection[List @@ e1, List @@ e2]] == 1,
        selectedPair = {e1, e2};
        Goto["FoundPair"];
      ];
      , {j, i + 1, Length[candidates]}];
    , {i, 1, Length[candidates] - 1}];

  Return[g];
  Label["FoundPair"];
  {e1, e2} = selectedPair;
  y = Intersection[List @@ e1, List @@ e2][[1]];

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

(* === 手性检测探针 (Chirality Probe) === *)
(* 物理定义：利用节点编号(时间戳)定义的拓扑宇称 *)
(* 如果 x(先被选中) < z(后被选中), 定义为 +1 (右手) *)
(* 如果 x > z, 定义为 -1 (左手) *)
(* 这实际上测量了反应路径相对于宇宙膨胀方向的"扭结" *)
localSpin = Sign[z - x];
AppendTo[chiralityLog, localSpin];

(* 继续正常的演化逻辑 *)
w = Max[VertexList[g]] + 1;
newActive = {UndirectedEdge[x, z], UndirectedEdge[x, w], UndirectedEdge[w, z]};
inertEdges = {DirectedEdge[x, y], DirectedEdge[y, z]};

Graph[
Join[VertexList[g], {w}],
Union[Complement[allEdges, {e1, e2}], newActive, inertEdges]
];
];

(* ===== *)
(* 2. 执行演化与检测 *)
(* ===== *)
universe = CycleGraph[3, DirectedEdges → False];
chiralityLog = {} (* 重置日志 *);
steps = 4500;

Print[Style["正在演化并检测手性... (Steps: " <> ToString[steps] <> ")", Blue, Bold, 14]];

(* 使用 Monitor 实时观察手性累积值 *)
Monitor[
Do[universe = rccRigidStepWithChirality[universe], {i, steps}],
Row[{ProgressIndicator[i, {0, steps}], ", i, Total[chiralityLog]}]
];

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];
(* ===== *)
(* 3. 结果分析与可视化 *)
(* ===== *)

(* 计算累积手性 (随机游走路径) *)
cumulativeChirality = Accumulate[chiralityLog];
netChirality = Last[cumulativeChirality];
absBias = N[Abs[netChirality] / steps];

Print["\n===== 手性检测报告 ====="];
Print["Total number of reaction steps: ", Length[chiralityLog]];
Print["Left-handed event (-1): ", Count[chiralityLog, -1]];
Print["Right-handed events (+1): ", Count[chiralityLog, 1]];
Print["Net chirality deviation (Net): ", netChirality];
Print["deviation ratio: ", NumberForm[absBias * 100, {3, 2}], "%"];

(* 判定结论 *)
judgment = If[absBias < 0.05,
  chiral symmetric,
  parity violation];

Print[Style[judgment, Red, Bold, 16]];

(* 绘图 *)
ListLinePlot[cumulativeChirality,
 PlotStyle -> {Thickness[0.003], Orange},
 PlotTheme -> ,
 GridLines -> Automatic,
 Filling -> Axis,
 FillingStyle -> Opacity[0.1],
 AxesLabel -> {, },
 PlotLabel -> Style[, 16],
 Epilog -> {
  Dashed, Blue, InfiniteLine[{{0, 0}, {1, 0}}], (* 零轴 *)
  Text[Style[, Blue, 12], {steps*0.1, Max[cumulativeChirality]*0.8}],
  Text[Style[, Blue, 12], {steps*0.1, Min[cumulativeChirality]*0.8}]
 }
]

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正在演化并检测手性... (Steps: 4500)

===== 手性检测报告 =====

Total number of reaction steps: 3948

Left-handed event (-1): 2001

Right-handed events (+1): 1947

Net chirality deviation (Net): -54

deviation ratio: 1.20%

(random walk) The entire universe is chiral symmetric

Out[324]=

