In[325]:=

```
ClearAll["Global`*"];
SeedRandom[2026];

(* ======================================== *)
(* 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]];
```

```
 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]
 }]
```

```
];

(* ======================================== *)
(* 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}]
 }
]
```

正在演化并检测手性... (Steps: 4500)

```
================ 手性检测报告 ================
Total number of reaction steps: 3993
Left-handed event (-1): 1944
Right-handed events (+1): 2049
Net chirality deviation (Net): 105
deviation ratio: 2.33%
```

(random walk) The entire universe is chiral symmetric

Out[345]=