Simulation Based on Michel Fodje's epr-simple simulation translated from Python to Mathematica by John Reed 13 Nov 2013 and Quaternions Modified by Fred Diether for Completely Local-Realistic Sep 2021 Some parts by Bill Nelson. Includes Joy's S^3 Quaternion Model.

Load Quaternion Package, Set Run Time Parameters, Initialize Arrays and Tables

In[339]:=
```
<< Quaternions`;
β0 = Quaternion[1, 0, 0, 0];
β1 = Quaternion[0, 1, 0, 0];
β2 = Quaternion[0, 0, 1, 0];
β3 = Quaternion[0, 0, 0, 1];
Qcoordinates = {β1, β2, β3};
m = 200000;
trialDeg = 721;
Ls1 = ConstantArray[0, m];
Ls2 = ConstantArray[0, m];
λ1 = ConstantArray[0, m];
λ2 = ConstantArray[0, m];
outAa = Table[{0, 0, 0, 0, 0, 0, 0}, m];
outBb = Table[{0, 0, 0, 0, 0, 0, 0}, m];
plotq = Table[{0, 0}, m];
a1 = ConstantArray[0, m];
b1 = ConstantArray[0, m];
A = ConstantArray[0, m];
B = ConstantArray[0, m];
nPP = ConstantArray[0, trialDeg];
nNN = ConstantArray[0, trialDeg];
nPN = ConstantArray[0, trialDeg];
nNP = ConstantArray[0, trialDeg];
nAP = ConstantArray[0, trialDeg];
nBP = ConstantArray[0, trialDeg];
nAN = ConstantArray[0, trialDeg];
nBN = ConstantArray[0, trialDeg];
ϕ = 3.1; β = 0.32; ξ = -4π/45; (*Adustable parameters for fine tuning*)
```

Generating Particle Data with Three Independent Do-Loops

In[367]:=
```
Do[θ = RandomReal[{-179, 180}]; (*Singlet vector angle*) (*Hidden Variable*)
 λ1[[i]] = β (Cos[θ/ϕ]^2);
 λ2[[i]] = Sign[θ];
 θθ = N[Flatten[{FromPolarCoordinates[{1, θ * π / 180}], 0}]];
 Ls1[[i]] = λ2[[i]] * θθ.Qcoordinates;
 Ls2[[i]] = -Ls1[[i]], {i, m}] (*Conservation of angular momentum*)
```

In[368]:=
```
Do[a = RandomInteger[{-179, 180}];  (*Detector vector angle 1 degree increments*)
 aa = N[Flatten[{FromPolarCoordinates[{1, a * π / 180}], 0}]];
 Da = aa.Qcoordinates;  (*Convert to quaternion coordinates*)
 qa = Da ** Ls1[[i]];
 aq = - (Ls1[[i]] ** Da);
 If[Abs[Re[qa]] < λ1[[i]], C1 = f1, C1 = g1];
 If[Abs[Re[qa]] > λ1[[i]],
  Aa = Re[Da ** Limit[ Ls1[[i]], Ls1[[i]] -> Sign[Re[Da ** Ls1[[i]]]] Da]],
  Aa = λ2[[i]] * Sign[qa[[4]] + ξ]];
 A0 = λ2[[i]] * Sign[qa[[4]] + ξ];
 outAa[[i]] = {a, Aa, i, C1, A0, qa, aq}, {i, m}]
outA1 = Select[outAa, MemberQ[#, g1] &];   (*Split outAa into outA1 and outA2*)
outA2 = Select[outAa, MemberQ[#, f1] &];
```

In[371]:=
```
Do[b = RandomInteger[{-179, 180}];  (*Detector vector angle 1 degree increments*)
 bb = N[Flatten[{FromPolarCoordinates[{1, b * π / 180}], 0}]];
 Db = bb.Qcoordinates;  (*Convert to quaternion coordinates*)
 qb = Ls2[[i]] ** Db;
 bq = - (Db ** Ls2[[i]]);
 If[Abs[Re[qb]] < λ1[[i]], C2 = f2, C2 = g2];
 If[Abs[Re[qb]] > λ1[[i]],
  B = Re[Db ** Limit[ Ls2[[i]], Ls2[[i]] -> Sign[Re[Db ** Ls2[[i]]]] Db]],
  B = -λ2[[i]] * Sign[qb[[4]] + ξ]];
 B0 = -λ2[[i]] * Sign[qb[[4]] + ξ];
 outBb[[i]] = {b, B, i, C2, B0, qb, bq}, {i, m}]
outB1 = Select[outBb, MemberQ[#, g2] &];   (*Split outBb into outB1 and outB2*)
outB2 = Select[outBb, MemberQ[#, f2] &];
```

Matching Events Observed by Alice and Bob using Trial Numbers

In[374]:=
```
list13 = outA1[[All, 3]]; (*Two lists of only trial numbers used for matching*)
list23 = outB1[[All, 3]];
```

Local Detection Analysis of the Events Observed by Alice

In[376]:=
```
listA3 = Select[outA1, Intersection[{#[[3]]}, list23] != {#[[3]]} &];
M1 = Length[listA3];
tna = listA3[[All, 3]];
listA4 = Select[outA1, Intersection[{#[[3]]}, tna] == {#[[3]]} &];
outA1a = Select[outA1, Intersection[{#[[3]]}, tna] != {#[[3]]} &];
outA5 = Table[{0, 0, 0, 0, 0, 0, 0}, M1];
qaaq = ConstantArray[0, M1];
listA36 = listA3[[All, 6]];
listA37 = listA3[[All, 7]];
Do[If[listA4[[i]][[2]] == listA4[[i]][[5]],
  qaaq[[i]] = 1, qaaq[[i]] = Re[listA36[[i]] ** listA37[[i]]]];
 outA5[[i]] = {listA4[[i]][[1]], qaaq[[i]] * listA4[[i]][[2]], listA4[[i]][[3]], f1, listA4[[
     i]][[5]], listA4[[i]][[6]], listA4[[i]][[7]]}, {i, M1}] (*spinorial sign change*)
outA2a = Sort[Catenate[{outA5, outA2}], #1[[3]] < #2[[3]] &]; (*Combine lists and sort*)
outA = Sort[Catenate[{outA1a, outA2a}], #1[[3]] < #2[[3]] &];
a1 = outA[[All, 1]]; (*These results are what Alice observes as defined in Eq.(??)*)
A = outA[[All, 2]];
```

Local Detection Analysis of the Events Observed by Bob

In[390]:=
```
listB3 = Select[outB1, Intersection[{#[[3]]}, list13] != {#[[3]]} &];
M2 = Length[listB3];
tnb = listB3[[All, 3]];
listB4 = Select[outB1, Intersection[{#[[3]]}, tnb] == {#[[3]]} &];
outB1b = Select[outB1, Intersection[{#[[3]]}, tnb] != {#[[3]]} &];
outB5 = Table[{0, 0, 0, 0, 0, 0, 0}, M2];
qbbq = ConstantArray[0, M2];
listB36 = listB3[[All, 6]];
listB37 = listB3[[All, 7]];
Do[If[listB4[[i]][[2]] == listB4[[i]][[5]],
  qbbq[[i]] = 1, qbbq[[i]] = Re[listB36[[i]] ** listB37[[i]]]]];
 outB5[[i]] = {listB4[[i]][[1]], qbbq[[i]] * listB4[[i]][[2]], listB4[[i]][[3]], f2, listB4[[
     i]][[5]], listB4[[i]][[6]], listB4[[i]][[7]]}, {i, M2}] (*spinorial sign change*)
outB2b = Sort[Catenate[{outB5, outB2}], #1[[3]] < #2[[3]] &]; (*Combine lists and sort*)
outB = Sort[Catenate[{outB1b, outB2b}], #1[[3]] < #2[[3]] &];
b1 = outB[[All, 1]]; (*These results are what Bob observes as defined in Eq.(??)*)
B =  outB[[All, 2]];
```

Statistical Analysis of the Particle Data Received from Alice and Bob

In[404]:=
```
θ2 = ConstantArray[0, m];
Do[θ1 = a1[[j]] - b1[[j]] + 361;
 (*All angles are shifted by 361 degrees since θ1 is an index*)
 θ2[[j]] = θ1;
 aliceD = A[[j]]; bobD = B[[j]];
 If[aliceD == 1, nAP[[θ1]] ++];
 If[bobD == 1, nBP[[θ1]] ++];
 If[aliceD == -1, nAN[[θ1]] ++];
 If[bobD == -1, nBN[[θ1]] ++];
 If[aliceD == 1 && bobD == 1, nPP[[θ1]] ++];
 If[aliceD == 1 && bobD == -1, nPN[[θ1]] ++];
 If[aliceD == -1 && bobD == 1, nNP[[θ1]] ++];
 If[aliceD == -1 && bobD == -1, nNN[[θ1]] ++], {j, m}]
```

Calculating Mean Values of A, B, and AB, and Plotting the Results

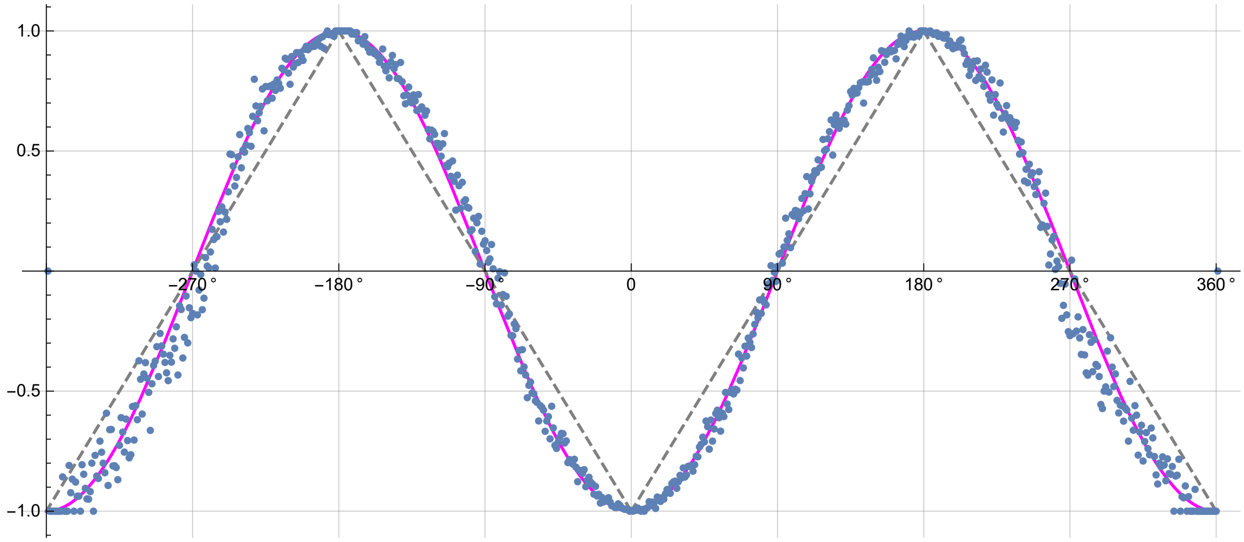
In[406]:=
```
pPP = 0; pPN = 0; pNP = 0; pNN = 0;
mean = ConstantArray[0, trialDeg];
Do[sum = nPP[[i]] + nPN[[i]] + nNP[[i]] + nNN[[i]];
If[sum == 0, Goto[jump],
  {pPP = nPP[[i]] / sum;
   pNP = nNP[[i]] / sum;
   pPN = nPN[[i]] / sum;
   pNN = nNN[[i]] / sum;
mean[[i]] = pPP + pNN - pPN - pNP}];
 Label[jump], {i, trialDeg}]

simulation = ListPlot[mean, PlotMarkers → {Automatic, Tiny}];
negcos = Plot[-Cos[x Degree], {x, 0, 720}, PlotStyle → {Magenta}, AspectRatio → 7 / 16,
   Ticks → {{{0, -360 °}, {90, -270 °}, {180, -180 °}, {270, -90 °}, {360, 0 °}, {450, 90 °},
      {540, 180 °}, {630, 270 °}, {720, 360 °}}, Automatic}, GridLines → Automatic];
p1 = Plot[-1 + 2 x Degree / π, {x, 0, 180}, PlotStyle → {Gray, Dashed}];
p2 = Plot[3 - 2 x Degree / π, {x, 180, 360}, PlotStyle → {Gray, Dashed}];
p3 = Plot[-5 + 2 x Degree / π, {x, 360, 540}, PlotStyle → {Gray, Dashed}];
p4 = Plot[7 - 2 x Degree / π, {x, 540, 720}, PlotStyle → {Gray, Dashed}];
```

Comparing Mean Values with -Cosine Function and Computing Averages

In[415]:=
```
Show[negcos, p1, p2, p3, p4, simulation]
```

Out[415]=



In[416]:=
```
AveA = N[Sum[A[[i]], {i, m}] / m];
AveB = N[Sum[B[[i]], {i, m}] / m];
Print["AveA = ", AveA]
Print["AveB = ", AveB]
PAP = N[Sum[nAP[[i]], {i, trialDeg}]];
PBP = N[Sum[nBP[[i]], {i, trialDeg}]];
PAN = N[Sum[nAN[[i]], {i, trialDeg}]];
PBN = N[Sum[nBN[[i]], {i, trialDeg}]];
PA1 = PAP / (PAP + PAN);
PB1 = PBP / (PBP + PBN);
Print["P(A+) = ", PA1]
Print["P(B+) = ", PB1]
totAB = Sum[nPP[[i]] + nNN[[i]] + nPN[[i]] + nNP[[i]], {i, trialDeg}]
PP = N[Sum[nPP[[i]], {i, trialDeg}] / totAB]
NN = N[Sum[nNN[[i]], {i, trialDeg}] / totAB]
PN = N[Sum[nPN[[i]], {i, trialDeg}] / totAB]
NP = N[Sum[nNP[[i]], {i, trialDeg}] / totAB]
CHSH = Abs[N[mean[[315]]] - N[mean[[225]]] + N[mean[[405]]] + N[mean[[45]]]]
```

AveA = −0.00142

AveB = −0.00388

P(A+) = 0.49929

P(B+) = 0.49806

Out[428]= 200 000

Out[429]= 0.24906

Out[430]= 0.25171

Out[431]= 0.25023

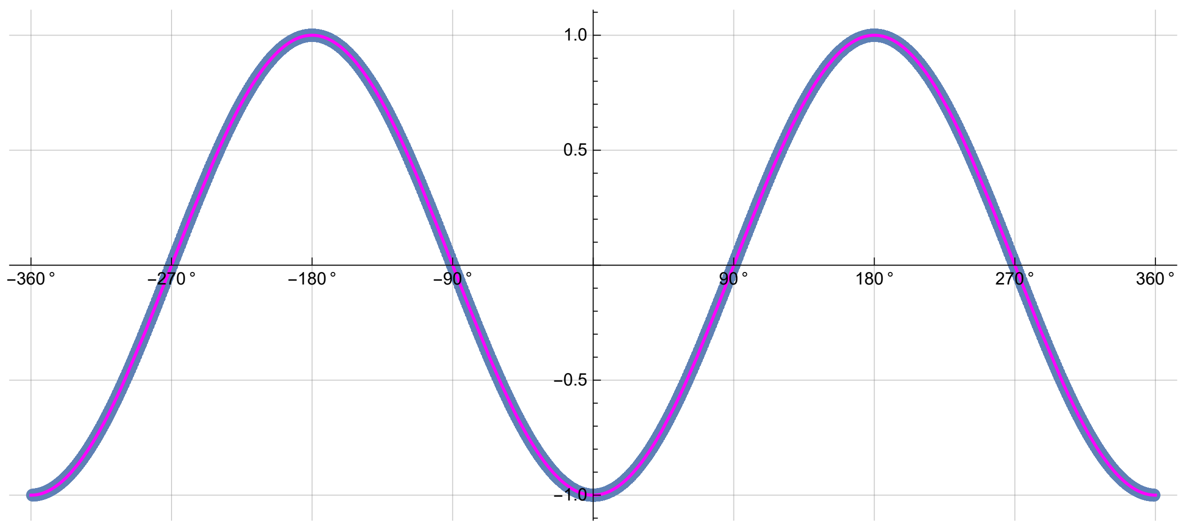
Out[432]= 0.249

Out[433]= 2.85013

Product Calculation

In[434]:=
```
q = 0;
q2a = outA[[All, 6]];
q2b = outB[[All, 6]];
plotq = Table[{0, 0}, m];
angle = ConstantArray[0, m];
Do[If[λ2[[i]] == 1, q = q2a[[i]] ** q2b[[i]], q = q2b[[i]] ** q2a[[i]]];
 angle = θ2[[i]] - 361;
 plotq[[i]] = {angle, Re[q]}, {i, m}]
sim = ListPlot[plotq, PlotMarkers → {Automatic, Small}, AspectRatio → 7/16,
   Ticks → {{{-360, -360 °}, {-270, -270 °}, {-180, -180 °}, {-90, -90 °}, {0, 0 °}, {90, 90 °},
      {180, 180 °}, {270, 270 °}, {360, 360 °}}, Automatic}, GridLines → Automatic];
negcos1 = Plot[-Cos[x Degree], {x, -360, 360}, PlotStyle → {Magenta}];
Show[sim, negcos1]
```

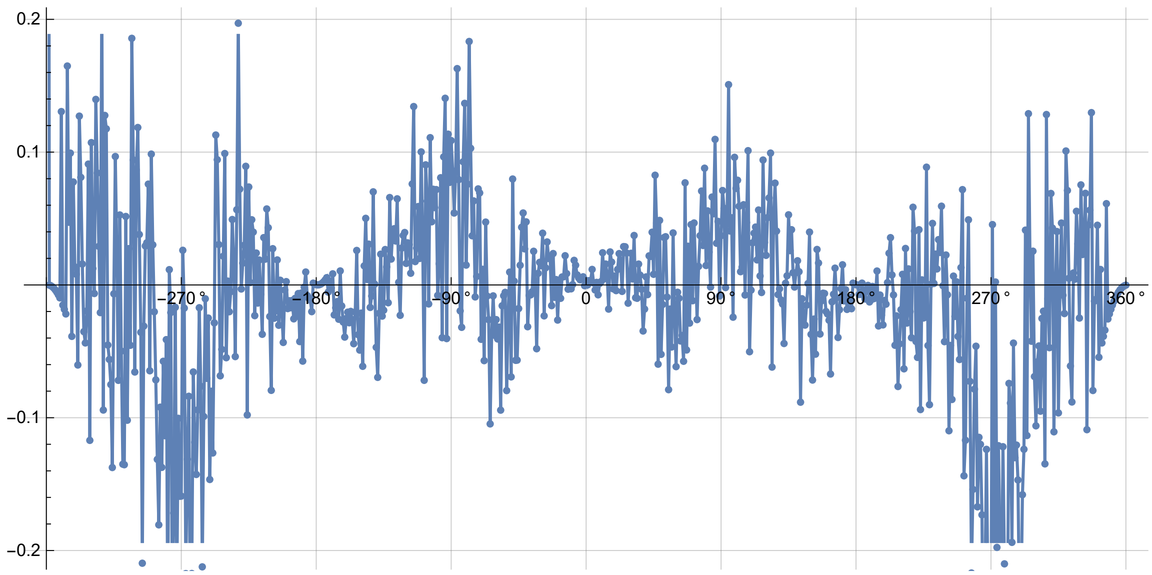
Out[442]=



Blue is the correlation data and magenta is the -cosine curve for an exact match.

In[443]:=
```
dev1 = ConstantArray[2, 720];
dev2 = ConstantArray[2, 720];
dev3 = ConstantArray[2, 720];
Do[dev1 = mean[[i]]; dev2[[i]] = {dev1, i}, {i, 720}]
devang = dev2[[All, 2]] - 361;
Do[dev3[[i]] = mean[[i]] + Cos[devang[[i]] Degree], {i, 720}]
ListPlot[N[dev3], PlotMarkers → {Automatic, Tiny}, Joined → True, AspectRatio → 1/2,
 Ticks → {{{0, -360 °}, {90, -270 °}, {180, -180 °}, {270, -90 °}, {360, 0 °}, {450, 90 °},
    {540, 180 °}, {630, 270 °}, {720, 360 °}}, Automatic}, GridLines → Automatic]
```

Out[449]=



In[450]:=
```
Mean[N[dev3]]
Mean[N[Abs[dev3]]]
```

Out[450]= -0.00707455

Out[451]= 0.0492817