# The blochsphere package

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### 1 Introduction

The blochsphere package is used to draw pseudo-3D Blochsphere diagrams, such as that shown in figure 1. It supports various annotations, such as great and small circles, axes, rotation markings and state vectors. It can be used in a standalone fashion, or nested within a tikzpicture environment by setting the environment option nested to true.

### 2 Usage

Using blochsphere is as simple as creating a 'blochsphere' environment.

```
% \begin{blochsphere}[<options>]
% ...
% \end{blochsphere}
```

By default, this will create a blank Bloch sphere ready for annotation. The options can be any of those described in the next section.

 $\drawBall [\langle options \rangle]$ 

This macro draws the basic Bloch sphere, according to the options defined in the next section.

This macro draws latitude and longitude circles at an interval defined by latdegsep and longdegsep respectively.

 $\stDrawingPlane [\langle options \rangle] \{\langle tiltangle \rangle\} \{\langle rotationangle \rangle\}$ 

This macro defines a transformation matrix within TikZ to create the effect of 2D projections of 3D planes, named according to the plane option. This is used internally in all of the drawing commands.

\setLatitudinalDrawingPlane  $[\langle options \rangle]$  { $\langle latitude \rangle$ }

This is a special case of \setDrawingPlane that constructs the transform required to draw a 2D image in a latitudinal plane.

\setLongitudinalDrawingPlane  $[\langle options \rangle]$   $\{\langle longitude \rangle\}$ 

This is a special case of \setDrawingPlane that constructs the transform required to draw a 2D image in a longitudinal plane.

 $\label{lem:circle} $$ \langle contions \rangle = {\langle tiltangle \rangle} {\langle rotationangle \rangle} $$$ 

Draws a circle on the surface of a Bloch sphere around the axis which is tilted by tiltangle from the z-axis and with a rotation of rotationangle about the z-axis.

 $\label{lem:continuous} $$ \operatorname{Circle} [\langle options \rangle] {\langle tiltangle \rangle} {\langle rotationangle \rangle} $$ An alias of \drawCircle.$ 

> Draws a circle on the surface of a Bloch sphere around the axis which is tilted by tiltangle from the z-axis and with a rotation of rotationangle about the z-axis, with an offset along the axis such that it reaches an effective latitude of offsetLatitude.

Draws a circle on the Bloch sphere corresponding to the given latitude.

 $\label{longitudeCircle} $$ \langle options \rangle ] $$ \{\langle longitude \rangle \}$$ 

Draws a great circle on the Bloch sphere corresponding to the given longitude.

Draw a left-handed rotation about the Bloch sphere, titled and rotated as for a circle with the same parameters, with a gap in the line where the arrow should go of clearangle degrees.

\drawRotationRight  $[\langle options \rangle]$  {\langle\} {\langle axisoffset\} {\langle clearangle\}} As above, but a right-handed rotation annotation.

 $\label{eq:drawAxis} $$ (\ordiname{options}) = {\langle tiltangle \rangle} {\langle rotationangle \rangle}$$ 

Draw a line along the axis tilted tiltangle degrees from the z-axis, rotated about the z-axis by rotationangle degrees.

 $\labelPolar \quad [\langle options \rangle] \; \{\langle tikzlabel \rangle\} \; \{\langle tiltangle \rangle\} \; \{\langle rotationangle \rangle\}$ 

Assign a tikz label to the point identified by an angle tiltangle from the z-axis and a rotation rotationangle about the z-axis.

 $\labelLatLon \quad [\langle options \rangle] \; \{\langle tikzlabel \rangle\} \; \{\langle latitude \rangle\} \; \{\langle longitude \rangle\}$ 

Assign a tikz label to the point identified the specified latitude and longitude.

Draw a vector from the origin to the point identified by an angle tiltangle from the z-axis and a rotation rotationangle about the z-axis, which will be labelled tikzlabel.

Draw a vector from the origin to the point identified by the provided latitude and longitude, which will be labelled tikzlabel.

## 3 Package, Environment and Macro options

For convenience, all options at all levels share the same namespace. Therefore, all options passed to the package will be the defaults for all environment, which will in turn be the defaults for all subsequent macro calls.

radius [default = 1.5cm] This option controls the radius of the qubit, and can be specified in any valid  $\LaTeX$ Xunits.

tilt [default = 15] This option controls the tilt (into the page) of the top of the bloch sphere (in degrees).

rotation [default = -20] This option controls the (right-handed) rotation of the Blochsphere around the (potentially tilted) z-axis, also specified in degrees.

color [default = white] This specifies the colour of the drawn ball.

opacity [default = 0.7] This option controls the opacity of the ball, allowing lines drawn

behind the ball to be visible.

- style [default = ] This option controls the current drawing style, and supports any valid tikz styling.
- scale [default = 1] This option allows one to temporarily change the scale of drawn circles/etc, allowing annotations to "hover" over the Bloch sphere.
- plane [default = current plane] The name which should label the current plane being defined, or the plane to be used.
- shift [default = (0,0,0)] The three dimensional offset by which the currently being drawn objects should be shifted.
- ball [default = 3d] Specifies how the ball should be drawn. Options are: 3d, circle, none
- statecolor [default = black] The color with which the state vectors should be drawn.
- statewidth [default = 0.4pt] The width with which state vectors should be drawn.
- axisarrow [default = ] The arrow to use at the end of a drawn axis.
- labelmark [default = false] Whether a black dot should be drawn at the point being labelled.
  - nested [default = false] Whether the blochsphere environment is being nested in a tikzpicture environment. If it is nested, then this should be set to true.

## 4 Example

In this section we provide example code to generate the following diagram:

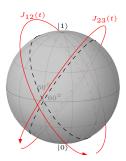


Figure 1: Example Bloch Sphere

1 \begin{blochsphere}[radius=1.5 cm, tilt=15, rotation=-20]
2 \drawBallGrid[style={opacity=0.3}]{30}{30}

4

```
\drawGreatCircle[style={dashed}]{-60}{0}{0}
                               \drawGreatCircle[style={dashed}]{60}{0}{0}
  6
                               \drawRotationLeft[scale=1.3, style=\{red\}]\{-60\}\{0\}\{0\}\{15\}\}
                               \drawRotationRight[scale=1.3, style=\{red\}]\{60\}\{0\}\{0\}\{15\}\}
                               \node at (-0.8, 1.9) {\textcolor{red}{\tiny £J_{12}(t)£}};
10
                               \node at (1.1,1.8) {\textcolor{red}{\tiny £J_{23}(t)£}};
12
                               \labelLatLon\{up\}\{90\}\{0\};
                               \label{latLon} $$ \aligned $
14
                               \node[above] at (up) {{\tiny f\left/1\right>f}};
                               \node[below] at (down) {{\tiny $L \in ft/0 \rightarrow \pounds}};
16
                               \label{latLon[labelmark=false]{d}{15}{90};
                               \node at (d) {\color{gray}\fontsize{0.15cm}{1em}\selectfont \( \frac{60^\circ\frac{1}{3}}{1em} \)};
19
20
                               \labelLatLon[labelmark=falsa]{d2}{5}{78};
21
                               \node at (d2) {\color{gray}\fontsize{0.15cm}{1em}\selectfont £60^\circ£};
               \end{blochsphere}
```

## 5 Implementation

#### 5.1 Preamble

```
1 \NeedsTeXFormat{LaTeX2e}[1994/06/01]
2 \ProvidesPackage{blochsphere}[2015/08/17]
3 \usepackage{tikz,etoolbox,environ,ifthen,kvsetkeys,kvoptions}
4 \usetikzlibrary{decorations.pathreplacing, decorations.markings, calc, fadings}
```

### 5.2 Package/Environment/Macro options

```
Option: radius

5 \define@key{blochsphere}{radius}{%
6 \def\blochsphere@radius{#1}%
7 }
8 \providecommand{\blochsphere@radius}{1cm}

Option: tilt

9 \define@key{blochsphere}{tilt}{%
10 \def\blochsphere@tilt{#1}%
11 }
12 \providecommand{\blochsphere@tilt}{15}
```

```
Option: rotation
                     13 \define@key{blochsphere}{rotation}{%
                     14 \def\blochsphere@rotation{#1}%
                     15 }
                     16 \providecommand{\blochsphere@rotation}{-20}
   Option: color
                     17 \define@key{blochsphere}{color}{%
                     18 \def\blochsphere@color{#1}%
                     19 }
                     20 \providecommand{\blochsphere@color}{white}
 Option: opacity
                     21 \define@key{blochsphere}{opacity}{%
                     22 \def\blochsphere@opacity{#1}%
                     23 }
                     24 \providecommand{\blochsphere@opacity}{0.7}
   Option: style
                     25 \ensuremath{\mbox{\sc define@key{blochsphere}} \{style\} \{\%
                     26 \ensuremath{\mbox{\sc def}\mbox{\sc blochsphere@style}{\#1}\%}
                     28 \verb|\providecommand{\blochsphere@style}{}|
   Option: scale
                     29 \define@key{blochsphere}{scale}{%
                     30 \def\blochsphere@scale{#1}%
                     32 \providecommand{\blochsphere@scale}{1}
   Option: plane
                     33 \define@key{blochsphere}{plane}{%
                     34 \ensuremath{\mbox{def\blochsphere@plane{#1}}\%}
                     35 }
                     36 \providecommand{\blochsphere@plane}{current plane}
   Option: shift
                     37 \define@key{blochsphere}{shift}{%
                     38 \def\blochsphere@shift{{#1}}%
                     40 \providecommand{\blochsphere@shift}\{\{0,0,0\}\}
    Option: ball
```

```
41 \define@key{blochsphere}{ball}{%
                                                                  42 \def\blochsphere@ball{#1}%
                                                                  43 }
                                                                  44 \providecommand{\blochsphere@ball}{3d}
Option: statecolor
                                                                  45 \define@key{blochsphere}{statecolor}{%
                                                                  48 \providecommand{\blochsphere@statecolor}{black}
Option: statewidth
                                                                  49 \define@key{blochsphere}{statewidth}{%
                                                                  50 \def\blochsphere@statewidth{#1}%
                                                                  51 }
                                                                  52 \providecommand{\blochsphere@statewidth}{0.4pt}
   Option: axisarrow
                                                                  53 \define@key{blochsphere}{axisarrow}{%
                                                                  54 \def\blochsphere@axisarrow{#1}%
                                                                  55 }
                                                                  56 \providecommand{\blochsphere@axisarrow}{}
   Option: labelmark
                                                                  57 \define@key{blochsphere}{labelmark}{%
                                                                                      \setboolean{blochsphere@labelmark}{#1}%
                                                                  58
                                                                  60 \newboolean{blochsphere@labelmark}
                                                                  61 \setboolean{blochsphere@labelmark}{false}
             Option: nested
                                                                  62 \ensuremath{\mbox{\sc define@key{blochsphere}} \{nested\} \{\%\} \ensuremath{\mbox{\sc define@key}} \ensuremath{\mbox{\sc
                                                                  63 \ensuremath{\mbox{setboolean}{blochsphere@nested}{\#1}}
                                                                  65 \newboolean{blochsphere@nested}
                                                                  66 \setboolean{blochsphere@nested}{false}
                                                                  67 \ProcessKeyvalOptions{blochsphere}\relax
```

### 5.3 blochsphere Environment

This is the central environment definition. Note that all macros defined below will only be defined within this environment.

#### blochsphere

```
68 \newenvironment{blochsphere}[1][]{
                                       69 \begingroup
                                       70 \makeatletter
                                       71 \ignorespaces\setkeys{blochsphere}{#1}\unskip%
                                       72 \pgfdeclarelayer{back}%
                                       73 \pgfdeclarelayer{front}%
                                       74 \pgfsetlayers{back,main,front}%
                                       75 \pgfkeys{%
                                       76 /tikz/on layer/.code={%
                                       77 \pgfonlayer{##1}\begingroup%
                                       78 \verb| \aftergroup\endpgfonlayer%| \\
                                       79 \aftergroup\endgroup%
                                       80 },%
                                       81 /tikz/node on layer/.code={%
                                       82 \gdef\node@@on@layer{%
                                       83 \setbox\tikz@tempbox=\hbox\bgroup\pgfonlayer{##1}\unhbox\tikz@tempbox\endpgfonlayer\egroup}%
                                       84 \aftergroup\node@on@layer%
                                       85 },%
                                       86 /tikz/end node on layer/.code={%
                                       87 \endpgfonlayer\endgroup\endgroup%
                                       89 }%
                                       90 \def\node@on@layer{\aftergroup\node@@on@layer}%
          \drawBall
                                       91 \newcommand\drawBall[1][]{
                                       92 \begingroup
                                       93 \setkeys{blochsphere}{##1}
                                       94 \end{fter} if strequal \end{fter} bloch sphere @ball} \{3d\} \{ expand after \end{fter} if strequal \end{fter} i
                                       95 \fill[on layer=main,ball color=\blochsphere@color,opacity=\blochsphere@opacity] (0,0) circle (\
                                       97 \expandafter\ifstrequal\expandafter{\blochsphere@ball}{circle}{
                                       98 \draw[on layer=main,color=\blochsphere@color] (0,0) circle (\blochsphere@radius); % 3D lighting
                                       99 }{}
                                     100 \endgroup
                                    101 }%
\drawBallGrid
                                     102 \newcommand\drawBallGrid[3][]{
                                    103 \begingroup
                                    104 \setkeys{blochsphere}{##1}
                                    105 \foreach \phi in {0,##2,...,89} {
                                    106 \drawLatitudeCircle{\phi}
                                    107 \drawLatitudeCircle{-\phi}
                                    108 }
```

```
109 \foreach \theta in \{0, ##3, ..., 179\} {
                                                                                                                            110 \drawLongitudeCircle{\theta}
                                                                                                                            111 }
                                                                                                                            112 \endgroup
                                                                                                                            113 }%
                                                 \setDrawingPlane
                                                                                                                            114 \newcommand\setDrawingPlane[3][]{%
                                                                                                                            115 \setkeys{blochsphere}{##1}
                                                                                                                            116 \pgfmathsetmacro\aphi{##2}
                                                                                                                            117 \pgfmathsetmacro\atheta{##3}
                                                                                                                             118 \pgfmathsetmacro\dot{cos(\aphi)}
                                                                                                                             119 \ifdim\dot pt<0.7 pt\relax%
                                                                                                                            120 \pgfmathsetmacro\norm{cos(asin(\dot))}
                                                                                                                            121 \pgfmathsetmacro\xx{-sin(\aphi)*sin(\blochsphere@rotation - \atheta)} \\
                                                                                                                            \label{locality} 122 \pgfmathsetmacro\xy{sin(\aphi)*sin(\blochsphere@tilt)*cos(\blochsphere@rotation - \atheta)} \\
                                                                                                                            123 \pgfmathsetmacro\yx{-sin(2*\aphi - \blochsphere@rotation + \atheta)/4 - sin(2*\aphi + \blochsphere@rotation + \aphi - \a
                                                                                                                            124 \pgfmathsetmacro\y\{(sin(\aphi)*cos(\blochsphere@tilt) - sin(\blochsphere@tilt)*sin(\blochsphere@tilt) + sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt) + sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*sin(\blochsphere@tilt)*si
                                                                                                                            125 \else
                                                                                                                             126 \pgfmathsetmacro\norm{sqrt(abs(sin(\blochsphere@rotation - \atheta)*cos(\aphi))^2 + abs(sin(\bl
                                                                                                                             127 \pgfmathsetmacro\xx{-sin(\blochsphere@rotation - \atheta)*cos(\aphi)}
                                                                                                                             \label{locality} 128 \pgfmathsetmacro\xy{sin(\blochsphere@tilt)*cos(\aphi)*cos(\blochsphere@rotation - \atheta)} \\
                                                                                                                             129 \pgfmathsetmacro\yx{-cos(\aphi)^2*cos(\blochsphere@rotation - \atheta)}
                                                                                                                            130 \pgfmathsetmacro\y\{(sin(\aphi)*cos(\blochsphere@tilt) - sin(\blochsphere@tilt)*sin(\blochsphere@tilt) + sin(\blochsphere@tilt)*sin(\blochsphere@tilt) + sin(\blochsphere@tilt) + sin(\blochsph
                                                                                                                             131 \fi
                                                                                                                            132 \computeOffset{shift}
                                                                                                                            133 \begingroup\newcommand\tmp[1]{\endgroup\noexpand\relax%
                                                                                                                             134 \tikzset{\blochsphere@plane/.style={cm={\xx/\norm, \xy/\norm, \yx/\norm, \yy/\norm, \unexpanded
                                                                                                                            135 } \tmp{\shift}
                                                                                                                            136 }%
\setLatitudinalDrawingPlane
                                                                                                                            137 \newcommand\setLatitudinalDrawingPlane[2][]{%
                                                                                                                             138 \pgfmathsetmacro\yshift{\sin(\##2)*\the\blochsphere@radius}
                                                                                                                             139 \setDrawingPlane[##1,shift={{0,0,\yshift}}]{0}{0}
                                                                                                                            140 }%
\setLatitudinalDrawingPlane
                                                                                                                             141 \newcommand\setLongitudinalDrawingPlane[2][]{%
                                                                                                                             142 \setDrawingPlane[##1]{90}{##2}
                                                                                                                             143 }%
                                                                      \drawCircle
                                                                                                                            144 \newcommand\drawCircle[3][]{
```

```
145 \begingroup
                      146 \steps{blochsphere}{##1}
                      147 \verb|\setDrawingPlane{##2}{##3}|
                      148 \computeVisibility{##2}{##3}{agamma}{abeta}
                      149 \begingroup\edef\tmp{\endgroup%
                      150 \noexpand\draw[current plane,on layer=back,\unexpanded\expandafter{\blochsphere@style}] \unexpa
                      151 \noexpand\draw[current plane,on layer=front,\unexpanded\expandafter{\blochsphere@style}] \unexp
                      152 } \tmp
                      153 \endgroup
                      154 }%
    \drawGreatCircle
                      155 \newcommand\drawGreatCircle[3][]{
                      156 \drawCircle[##1]{##2}{##3}
                      157 }
    \drawSmallCircle
                      158 \newcommand\drawSmallCircle[4][]{
                      159 \begingroup
                      160 \pgfmathsetmacro\xshift{\sin(\##2)*\cos(\##3)*\blochsphere@radius*\sin(\##4)}
                      161 \pgfmathsetmacro\yshift{\sin(##2)*\sin(##3)*\blochsphere@radius*\sin(##4)}
                      162 \pgfmathsetmacro\zshift{cos(##2)*\blochsphere@radius*sin(##4)}
                      163 \pgfmathsetmacro\radius{\blochsphere@radius*cos(##4)}
                      164 \drawCircle[##1,shift={{\xshift,\yshift,\zshift}},radius=\radius]{##2}{##3}
                      165 \endgroup
                      166 }%
 \drawLatitudeCircle
                      167 \newcommand\drawLatitudeCircle[2][]{
                      168 \begingroup
                      169 \pgfmathsetmacro\yshift{\sin(##2)*\blochsphere@radius}
                      170 \pgfmathsetmacro\radius{\blochsphere@radius*cos(##2)}
                      171 \drawCircle[##1,shift={{0,0,\yshift}},radius=\radius]{0}{0}
                      172 \endgroup
                      173 }%
\drawLongitudeCircle
                      174 \newcommand\drawLongitudeCircle[2][]{
                      175 \begingroup
                      176 \drawCircle[##1]{90}{##2+90}
                      177 \endgroup
                      178 }%
```

\drawRotationLeft

```
179 \newcommand\drawRotationLeft[5][]{
                     180 \begingroup
                    181 \setkeys{blochsphere}{##1}
                    182 \pgfmathsetmacro\xshift{\sin(\#\2)*\cos(\#\3)*\#\4}
                    183 \pgfmathsetmacro\yshift{\sin(\#\2)*\sin(\#\3)*\#\4}
                     184 \pgfmathsetmacro\zshift{cos(##2)*##4}
                     185 \setDrawingPlane[shift={\xshift,\yshift,\zshift}]{##2}{##3}
                     186 \computeVisibility{##2}{##3}{agamma}{abeta}
                     187 \begingroup\edef\tmp{\endgroup%
                     188 \noexpand\draw[current plane,on layer=back,\unexpanded\expandafter{\blochsphere@style}] \unexpa
                     189 \noexpand\draw[<-,current plane,on layer=front,\unexpanded\expandafter{\blochsphere@style}] \unexpanded\expandafter{\blochsphere@style}]
                     190 } \tmp
                     191 \endgroup
                     192 }%
\drawRotationRight
                    193 \newcommand\drawRotationRight[5][]{
                    194 \begingroup
                     195 \setkeys{blochsphere}{##1}
                     196 \pgfmathsetmacro\xshift{\sin(\#2)*\cos(\#3)*\#4}
                     197 \pgfmathsetmacro\yshift\{\sin(\#2)*\sin(\#3)*\#4\}
                     198 \pgfmathsetmacro\zshift{cos(##2)*##4}
                     199 \textbf{ xetDrawingPlane[shift={xshift, yshift, zshift}]{##2}{##3}} \\
                    200 \computeVisibility{##2}{##3}{agamma}{abeta}
                    201 \begingroup\edef\tmp{\endgroup%
                    202 \noexpand\draw[current plane,on layer=back,\unexpanded\expandafter{\blochsphere@style}] \unexpa
                    203 \noexpand\draw[->,current plane,on layer=front,\unexpanded\expandafter{\blochsphere@style}] \unexpanded\expandafter{\blochsphere@style}]
                    204 } \tmp
                    205 \endgroup
                    206 }%
         \drawAxis
                    207 \newcommand\drawAxis[3][] {
                    208 \begingroup
                    209 \setkeys{blochsphere}{##1}
                    210 \pgfmathsetmacro\behind{ifthenelse(-sin(##2)*sin(\blochsphere@rotation - ##3)*cos(\blochsphere@
                    211 \pgfmathsetmacro\newphi{180-##2}
                    212 \pgfmathsetmacro\newtheta{##3+180}
                    213 \ifnum\behind=0\relax
                    214 \labelPolar[scale=1]{blochspheretmpp}{##2}{##3}
                    215 \labelPolar{blochspheretmps}{##2}{##3}
                    216 \labelPolar\{blochspheretmpe\}\{\newphi\}\{\newtheta\}
                    218 \labelPolar[scale=1]{blochspheretmpp}{\newphi}{\newtheta}
                    219 \labelPolar{blochspheretmpe}{##2}{##3}
                    220 \labelPolar{blochspheretmps}{\newphi}{\newtheta}
```

```
222 \begingroup\edef\tmp{\endgroup%
                                        223 \ifnum\behind=0\relax
                                        224 \verb| noexpand draw[ on layer=front, \verb| unexpanded | expandafter{blochsphere@style}, \verb| blochsphere@axisarro| | expandation |
                                        226 \else
                                        227 \noexpand\draw[on layer=front,\unexpanded\expandafter{\blochsphere@style},\blochsphere@axisarro
                                        228 \noexpand\draw[on layer=back,\unexpanded\expandafter{\blochsphere@style}] (blochspheretmps) --
                                        229 \fi
                                        230 } \tmp
                                        231 \endgroup
                                        232 }%
           \labelPolar
                                        233 \newcommand\labelPolar[4][]{%
                                        234 \begingroup
                                        235 \setkeys{blochsphere}{##1}
                                        236 \setLongitudinalDrawingPlane{##4+90}
                                        237 \pgfmathsetmacro\behind{ifthenelse(-sin(##3)*sin(\blochsphere@rotation - ##4)*cos(\blochsphere@
                                        238 \ifthenelse{\boolean{blochsphere@labelmark}}
                                        239
                                                                  {
                                        240
                                                                            \ifnum\behind=1\relax
                                        241
                                                                                     \path[current plane,on layer=back] (90-##3:\blochsphere@radius*\blochsphere@sca
                                        242
                                                                            \else
                                                                                      \path[current plane,on layer=front] (90-##3:\blochsphere@radius*\blochsphere@sc
                                        243
                                                                            \fi
                                        244
                                                                  }
                                        245
                                                                  {
                                        246
                                        247
                                                                            \ifnum\behind=1\relax
                                                                                     \path[current plane,on layer=back] (90-##3:\blochsphere@radius*\blochsphere@sca
                                        248
                                                                            \else
                                        249
                                                                                      \path[current plane,on layer=front] (90-##3:\blochsphere@radius*\blochsphere@sc
                                        250
                                                                           \fi
                                        251
                                                                  }
                                        252
                                        253 \endgroup
                                        254 }%
         \labelLatLon
                                        255 \newcommand\labelLatLon[4][]{%
                                        256 \begingroup
                                        257 \neq 37 
                                        258 \labelPolar[##1]{##2}{\newphi}{##4}
                                        259 \endgroup
                                        260 }%
\drawStateLatLon
```

261 \newcommand\drawStateLatLon[4][]{

```
263 \neq 3 \pgfmathsetmacro\newphi{90-##3}
                264 \drawStatePolar[\#1]{\#2}{\newphi}{\#4}
                265 \endgroup
                266 }%
\drawStatePolar
                267 \newcommand\drawStatePolar[4][]{
                268 \begingroup
                269 \setkeys{blochsphere}{##1}
                270 \labelPolar{##2}{##3}{##4}
                271 \pgfmathsetmacro\behind{ifthenelse(-sin(##3)*sin(\blochsphere@rotation - ##4)*cos(\blochsphere@
                272 \leftarrow 1 = 1 = 1
                273 \tikzset{test/.style={
                274 postaction={
                275 decorate,
                276 decoration={
                277 markings,
                278 mark=at position \pgfdecoratedpathlength-0.5pt with {\arrow[\blochsphere@statecolor,line width=
                279 mark=between positions 0 and \pgfdecoratedpathlength-5pt step 0.5pt with {
                280 \pgfmathsetmacro\myval{multiply(divide(
                281 \pgfkeysvalueof{/pgf/decoration/mark info/distance from start}, \pgfdecoratedpathlength),100)};
                282 \pgfsetfillcolor{\blochsphere@statecolor};
                283 \pgfsetfillopacity\{0.4-\mbox{\em myval/}100*0.2\}
                284 \pgfpathcircle{\pgfpointorigin}{\blochsphere@statewidth};
                285 \pgfusepath{fill};}
                286 }}}}
                287 \else
                288 \tikzset{test/.style={
                289 postaction={
                290 decorate,
                291 decoration={
                292 markings,
                293 mark=at position \pgfdecoratedpathlength-0.5pt with {\arrow[\blochsphere@statecolor,line width=
                294 mark=between positions 0 and \pgfdecoratedpathlength-5pt step 0.5pt with {
                295 \pgfmathsetmacro\myval{multiply(divide(
                296 \pgfkeysvalueof{/pgf/decoration/mark info/distance from start}, \pgfdecoratedpathlength),100)};
                297 \pgfsetfillcolor{\blochsphere@statecolor};
                298 \pgfsetfillopacity{0.4+\myval/100*0.6}
                299 \pgfpathcircle{\pgfpointorigin}{\blochsphere@statewidth};
                300 \pgfusepath{fill};}
                301 }}}}
                303 \path [test,on layer=main] (0,0) -- (##2);
```

262 \begingroup

304 \endgroup 305 }%

#### \computeOffset

\computeVisibility

```
306 \newcommand\computeOffset[2][]{%
307 \setkeys{blochsphere}{##1}%
308 \pgfmathsetmacro{\x}{\blochsphere@shift[0]*cos(\blochsphere@rotation) + \blochsphere@shift[1]*s
 309 \pgfmathsetmacro\y{\blochsphere@shift[0]*sin(\blochsphere@rotation)*sin(\blochsphere@tilt) - \blochsphere@tilt) - \blochsphere@tilt) - \blochsphere@tilt) - \blochsphere@tilt) - \blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere@tilt(\blochsphere))))))) - \block(\blochsphere@tilt(\blochsphere)\blochsphere@tilt(\bl
 310 \expandafter\def\csname ##2\endcsname{(\x pt,\y pt)}%
311 }%
312 \newcommand\computeVisibility[5][]{
313 \setkeys{blochsphere}{##1}
314 \pgfmathsetmacro\aphi{##2}
315 \pgfmathsetmacro\atheta{##3}
316 \pgfmathsetmacro\d{sqrt(blochsphere@shift[0]^2+blochsphere@shift[1]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shift[2]^2+blochsphere@shi
 317 \pgfmathsetmacro\tatheta{\atheta+\blochsphere@rotation}
318 \pgfmathsetmacro\dot{cos(\aphi)}
319 \ifdim\dot pt<0.7 pt\relax%
320 \pgfmathsetmacro\domaintest{if the nelse (and (\blocksphere@rotation - \atheta==0, or (\aphi==0, sin(\aphi==0, sin(\aphi==
321 \left| \text{ifdim} \right|
322 \pgfmathsetmacro\agamma{0}
323 \else
324 \pgfmathsetmacro\agamma{-90+atan(cos(\blochsphere@tilt)*cos(\blochsphere@rotation - \atheta)/(s
325 \fi
326 \else
327 \pgfmathsetmacro\\domaintest\\if thenelse (and (Mod(\bloch sphere @rotation-\atheta, 180) == 90, Mod(\bloch sphere @rotation-\athet
328 \pgfmathsetmacro\domaintesttwo{ifthenelse(Mod(\blochsphere@rotation-\atheta,180)==90,0,1)}
329 \pgfmathsetmacro\domaintestthree{ifthenelse(Mod(\blochsphere@tilt,180)==90,0,1)}
330 \left| \text{ifdim} \right|
331 \pgfmathsetmacro\agamma{360-90*\blochsphere@tilt/abs(\blochsphere@tilt)}
332 \else
333 \ifdim\domaintesttwo pt=0 pt\relax
334 \pgfmathsetmacro\agamma \{360-90*(sin(\aphi)*tan(\blochsphere@tilt)+cos(\aphi)*sin(\blochsphere@tilt)+cos(\aphi)*sin(\blochsphere@tilt)+cos(\aphi)*sin(\blochsphere@tilt)+cos(\aphi)*sin(\blochsphere@tilt)+cos(\aphi)*sin(\blochsphere@tilt)+cos(\aphi)*sin(\blochsphere@tilt)+cos(\aphi)*sin(\blochsphere@tilt)+cos(\aphi)*sin(\blochsphere@tilt)+cos(\aphi)*sin(\blochsphere@tilt)+cos(\aphi)*sin(\blochsphere@tilt)+cos(\aphi)*sin(\blochsphere@tilt)+cos(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(\aphi)*sin(
335 \else
336 \ifdim\domaintestthree pt=0 pt\relax
 337 \pgfmathsetmacro\agamma{360-90*\blochsphere@tilt/abs(\blochsphere@tilt)*cos(\blochsphere@rotati
339 \pgfmathsetmacro\agamma{360-atan( (sin(\aphi)*tan(\blochsphere@tilt)+cos(\aphi)*sin(\blochsphere
340 \fi
341 \fi
342 \fi
343 \fi
344 \pgfmathsetmacro\alpha{acos(-sin(\aphi)*sin(\blochsphere@rotation)*cos(\atheta)*cos(\blochsphere@rotation)*cos(\atheta)*cos(\blochsphere@rotation)*cos(\atheta)*cos(\blochsphere@rotation)*cos(\atheta)*cos(\blochsphere@rotation)*cos(\atheta)*cos(\blochsphere@rotation)*cos(\atheta)*cos(\blochsphere@rotation)*cos(\atheta)*cos(\blochsphere@rotation)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos(\atheta)*cos
345 \pgfmathsetmacro\alphatest{atan(\d/\blochsphere@radius)}
```

 $349 \pgfmathsetmacro\abeta{acos(\d*cot(\aalpha)/\blochsphere@radius)}$ 

 $346 \left( \frac{1}{2} \right)$ 

347 \pgfmathsetmacro\abeta{0}

348 \else

350 \fi

```
351 \pgfmathsetmacro\abeta{ifthenelse(\blochsphere@shift[2]<0,\abeta+2*(90-\abeta),\abeta)}
352 \verb|\expandafter\pgfmathsetmacro\csname ##4\endcsname{\agamma}|
353 \end{small} abeta \end{small} 353 \end{small} abeta \end{small}
354 }%
355 \text{tikzset}
356 \ge  arrows
357 inner sep=0pt,%
358 outer sep=2pt,%
359 mark coordinate/.style={inner sep=0pt,outer sep=0pt,minimum size=3pt,
360 fill=black,circle}%
362 \pgfdeclareradialshading[tikz@ball]{ball}{\pgfqpoint{-10bp}{10bp}}{\label{continuous}} % \propto{-10bp}{\label{continuous}} % \propto{-10bp}{\label{conti
363 color(0bp)=(tikz@ball!30!white);
364 color(9bp)=(tikz@ball!75!white);
365 color(18bp)=(tikz@ball!90!black);
366 color(25bp)=(tikz@ball!70!black);
367 color(50bp)=(black)
369 \ensuremath{\mbox{\sc 1}}{\mbox{\sc 1}
370 \begin{tikzpicture}
371 \drawBall
372 }%
373 }
374 {
375 \ifthenelse{\boolean{blochsphere@nested}}{}{
376 \end{tikzpicture}%
377 }%
378 \endgroup\%
379 }
380 \setminus endinput
```