Documentation Of GWFrames

Contact: consider opening a GitHub issue or find me at m-melching@web.de.

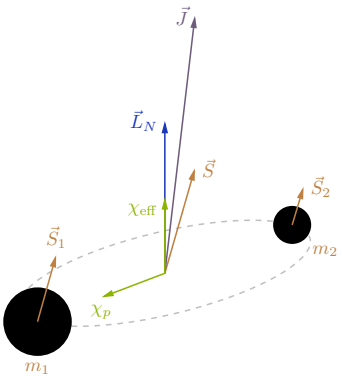
For the most recent version of all the files, see https://github.com/MaxMelching/gw_frames. This file was compiled on October 27, 2025 with git commit hash is 13fc41f (or, in case you need the full one, 13fc41fd2de22e3f2925bd5f9280a84ff9e2d610).

1 Overview

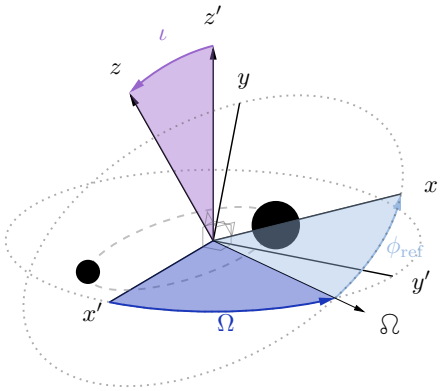
This repository contains three packages, each providing one command:

- cbc_frames_tikz (command \drawframes): Plots a selection of source frame, signal frame, and celestial frame that are used to describe gravitational waves emitted by compact binary coalescences.
- cbc_binary_tikz (command \drawbinary): Plots intrinsic parameters of a system of two compact binary objects. Adapted from code originally written by Jannik Mielke.
- earth_tikz (command \drawearth): Plots one side of the Earth. Mainly intended for usage through \drawframes. Most of the credit for this code goes to Izaak Neutelings, who provided it on https://tikz.net/astronomy_seasons/.

Several examples of how to use this package are shown in the examples folder. Some pictures are also included in Fig. 1.



Visualization of quantities defined in the source frame.



Signal Frame $(x')^\mu$ vs. Source Frame x^μ. The three Euler angles are longAscNodes $= -24 = \Omega - 90, \iota = 30, \phi_{\text{ref}} = 42$.

Figure 1: Examples of frames that can be drawn with the cbc_frames_tikz package: source frame (top) and signal frame (bottom). For more details on how to create such plots, refer to the examples folder.

2 List Of Keyword Arguments

All three packages and their respective commands rely on pgfkeys to pass keyword arguments for customization. More specifically, there is a main /frames family with several subfamilies. Here is a quick primer on how pgfkey families are used throughout the packages: When calling \drawframes[argument=value], you pass argument to /frames; When calling \drawframes[subfamily=argument=value,argument2=value2], on the other hand, argument

is passed to /frames/subfamily. For more details on the usage of sub-families etc. in the actual commands, please refer to the examples folder (especially the tutorials file).

In the following, we list all available keyword arguments for each family, along with their default values and short descriptions. For many of those keywords, there is more than one way in which they can be passed (for the distance argument, for example, there are the keys /frames/distance and /frames/binary/distance, and /frames/distance/value).

Note that certain values cannot be passed to pgfkeys, which is particularly relevant for declaration of labels. If you encounter an issue of this kind, look up the command that this key is stored in (typically something like \cbcframes@<parameter>@Label), and manually set the command. This can be done using \def\cbcframes@<parameter>@Label{<input>}.[1] A practical example would be \def\cbcframes@Omega@Label{$\Omega= \pi/2 + \mathrm{longAscNodes}$}.

Also note that all angles are expected to be given in degrees.

2.1 cbc_frames_tikz

The sub-families introduced here usually accept a family of keyword arguments, i.e. input like \drawframes[sourceframe=mass1=20,mass2=10]. However, for most of them it is also possible to pass a single argument, which is passed on to a sensible keyword of that family (if, for instance, \drawframes[inclination=42] is called, then 42 is passed to /frames/inclination/value; for \drawframes[celestialframe=false], it would be /frames/celestialframe/show, etc.); this keyword is stated at the end of the description of each sub-family.

- /frames/binary family: Properties of the binary system.
  - show: Whether to show the binary system.

    Default = true
  - mass1: Mass of the first compact object, determining its size through multiplication by bhsizepersolmass.

    Default = 20

    (This argument can also be passed via the /frames family.)
  - mass2: Mass of the second compact object, determining its size through multiplication by bhsizepersolmass.

    Default = 20

    (This argument can also be passed via the /frames family.)
  - eccentricity: Determines the circularity of the binary black hole orbit

    Default = 0

    (This argument can also be passed via the /frames family.)
  - separation: Distance of binary companions, in multiples of axislen.

    Default = 0.5
  - distance: Distance of binary center of mass from Earth, in multiples of the axis length axislen.

    Default = 3

    (This argument can also be passed via the /frames family.)

    (This argument can also be passed via the /frames/distance family.)

[1] Depending on where you call that, do not forget to surround this with \makeatletter...\makeatother!

- ❖ bhsizepersolmass: Size of each black hole per solar mass.

  Default = $\frac{0.35}{10}$

  (This argument can also be passed via the /frames family.)

Default keyword: show

- ❑ /frames/sourceframe: (Mostly styling) Properties of the source frame.
  - ❖ show: Whether to show the source frame. Has precedence over other commands for the styling of the source frame, such as sourceframe/axes.

    Default = true
  - ❖ axes: Whether to show the source frame axes.

    Default = true
  - ❖ helperlines: Whether to show the source frame helper lines.

    Default = true

  Default keyword: show

- ❑ /frames/signalframe: (Mostly styling) Properties of the signal frame.
  - ❖ show: Whether to show the signal frame. Has precedence over other commands for the styling of the signal frame, such as signalframe/axes.

    Default = true
  - ❖ axes: Whether to show the signal frame axes.

    Default = true
  - ❖ helperlines: Whether to show the signal frame helper lines.

    Default = true
  - ❖ angles: Whether to visualize the signal frame angles.

    Default = true
  - ❖ showazimuthalangle: Determines if a specific azimuthal angle used in this paper is visualized.

    Default = false

    (This argument can also be passed via the /frames family.)

    (This argument can also be passed via the /frames/azimuthalangle family.)

  Default keyword: show

- ❑ /frames/celestialframe: (Mostly styling) Properties of the celestial frame.
  - ❖ show: Whether to show the celestial frame. Has precedence over other commands for the styling of the celestial frame, such as celestialframe/axes.

    Default = true
  - ❖ axes: Whether to show the celestial frame axes.

    Default = true
  - ❖ helperlines: Whether to show the celestial frame helper lines.

    Default = true

- ❖ angles: Whether to visualize the celestial frame angles.

  Default = true

Default keyword: show

- ❑ /frames/earth: Properties of the Earth drawing.

  Accepts any keyword argument that can be passed to the earth_tikz package (cf. Sec. 2.3). There is a slight change in the defaults, though, radius has a default value of 1.25 here.

  Default keyword: radius

  Note that the Earth is only shown if the celestial frame is shown.

- ❑ /frames/ifo: Properties of the interferometer on Earth.

  - ❖ show: Whether to draw the interferometer.

    Default = true

  - ❖ armlength: Arm length of the interferometer.

    Default = 2

  Default keyword: show

  Note that the interferometer is only shown if the celestial frame is shown.

- ❑ /frames/labels: A centralized way to pass labels for various angles and other quantities. For virtually all of them, there is at least one other way to change the label, namely redefining the corresponding command (which is described in more detail above, at the beginning of this section); for several, there is also a separate keyword sub-family, a list of which is provided further below. Labels in this family are:

  - ❖ inclination
  - ❖ polarization
  - ❖ longascnodes
  - ❖ omega
  - ❖ phiref
  - ❖ ra
  - ❖ dec
  - ❖ lineofsight
  - ❖ distance
  - ❖ ascnode
  - ❖ azimuthalangle

  Default keyword: there is no sensible default

- ❑ /frames/angles: A centralized way to pass values for various angles. For several of them, there is another way to change the value, namely passing it to a separate keyword sub-family, a list of which is provided further below. Angles in this family are:

  - ❖ inclination
  - ❖ polarization
  - ❖ longascnodes

- ❖ phiref
- ❖ ra
- ❖ dec

Default keyword: there is no sensible default

- ❑ axislen: Length of the axes of each coordinate system.

  Default = 3

- ❑ axislabelpad: How far from the axis label is drawn from the axis arrow tip, in multiples of axislen.

  Default = 0.12

- ❑ /frames/inclination
  - ❖ value: Inclination between orbital plane (x-y-plane of the source frame) and sky plane (x-y-plane of the signal frame). This rotation is about the ascending node ☊.

    Default = 0
  - ❖ show: Whether to show the inclination angle.

    Default = true
  - ❖ label: Label for the inclination angle.

    Default = ι

  Default keyword: value

- ❑ /frames/polarization
  - ❖ value: Polarization angle, i.e. rotation of the x-axis in the sky plane (about the line of sight, which coincides with the z-axis of the signal frame).

    Default = 0
  - ❖ show: Whether to show the polarization angle.

    Default = true
  - ❖ label: Label for the polarization angle.

    Default = ψ

  Default keyword: value

- ❑ /frames/longascnodes
  - ❖ value: Determines the angle between x-axis of the signal frame and the ascending node ☊. This angle is $\Omega = 90 + \mathrm{longAscNodes}$.

    Default = 0
  - ❖ show: Whether to visualize the longitude of the ascending node angle.

    Default = true
  - ❖ omegalabel: Label for the angle that is derived from the longitude of the ascending node, i.e. $\Omega = 90 + \mathrm{longAscNodes}$. This is the angle that is actually visualized.

    Default = Ω

  Default keyword: value

- /frames/phiref
  - value: Reference angle ϕ_{ref} that determines the rotation between ascending node and x-axis of the signal frame (about the inclined z-axis of the signal frame).

    Default = 0
  - show: Whether to visualize the reference angle.

    Default = true
  - label: Label for the reference angle.

    Default = ϕ_{ref}

  Default keyword: value

- /frames/ra
  - value: Angle between Earth's x-axis and the projection of the line of sight onto Earth's equatorial plane.

    Default = 0
  - show: Whether to visualize the right ascension.

    Default = true
  - label: Label for the right ascension.

    Default = α

  Default keyword: value

- /frames/dec
  - value: Angle between line of sight and Earth's equatorial plane.

    Default = 0
  - show: Whether to visualize the declination.

    Default = true
  - label: Label for the declination.

    Default = δ

  Default keyword: value

- /frames/distance
  - value: Distance of the binary from Earth, in multiples of the axis length axislen.

    Default = 3
  - show: Whether to visualize the distance.

    Default = true
  - label: Label for the distance.

    Default = D_L

  Default keyword: value

- /frames/lineofsight
  - show: Whether to visualize the line of sight.

Default = `true`

- ❖ `label`: Label for the line of sight.

  Default = $\vec{N}$

Default keyword: `show`

- ❑ `/frames/ascnode`
  - ❖ `how`: Whether to visualize the ascending node.

    Default = `true`
  - ❖ `label`: Label for the ascending node.

    Default = ☊

  Default keyword: `show`

- ❑ `/frames/azimuthalangle`
  - ❖ `show`: Determines if a specific azimuthal angle used in this paper is visualized.

    Default = `false`
  - ❖ `label`: Label for the azimuthal angle.

    Default = `$\pi/2 - $\cbcframes@PhiRef@Label`

  Default keyword: `show`

2.2 cbc_binary_tikz

`pgfkeys` family: `/frames/binary`

- ❑ `mass1`: Mass of the first binary component, in solar masses.

  Default = 20
- ❑ `mass2`: Mass of the second binary component, in solar masses.

  Default = 10
- ❑ `spin1x`: x-component of the dimensionless spin of the first binary component.

  Default = 0
- ❑ `spin1y`: y-component of the dimensionless spin of the first binary component.

  Default = 0
- ❑ `spin1z`: z-component of the dimensionless spin of the first binary component.

  Default = 0
- ❑ `spin2x`: x-component of the dimensionless spin of the second binary component.

  Default = 0
- ❑ `spin2y`: y-component of the dimensionless spin of the second binary component.

  Default = 0
- ❑ `spin2z`: z-component of the dimensionless spin of the second binary component.

  Default = 0
- ❑ `inclination`: Inclination of the orbital plane with respect to the xy-plane. (The orbital plane is the plane in which the two binary components orbit each other.)

Default = 0

- polarization: Angle or rotation in the orbital plane.

  Default = 0

- eccentricity: How eccentric the binary orbit is.

  Default = 0

- separation: How far the binary components are separated.

  Default = 6

- showcombinedquantities: Whether to show quantities like the effective or precessing spin, which are combinations of the properties of both binary components.

  Default = true

Other quantities of interest are the two commands \cbcframes@BHsizepersolmass and \cbcframes@UnitSpinSize, which determine the sizes of black holes and spins, respectively.

2.3 earth_tikz

pgfkeys family: /frames/earth

- radius: Radius of the Earth

  Default = 1

- tilt: Tilt of the Earth

  Default = 0