

KerrGeodesicsC

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1 korb.h

This software describes the generic bound motion of a test mass around a Kerr black hole. There are also functions for calculating r from the tortoise coordinate via root finding. The main function takes inputs: `eccentric` (boolean), `inclined` (boolean), `a` (double), `p` (double), `e` (double), `x` (double), `lambdaSteps` (integer), `lambdaMax` (double), and from those arguments calculates and prints the constants of motion, orbital frequencies, and position at equally spaced Mino times.

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2 Data Structure Index

2.1 Data Structures

Here are the data structures with brief descriptions:

[korb_params](#) 2

3 File Index

3.1 File List

Here is a list of all files with brief descriptions:

[korb.h](#) 8

4 Data Structure Documentation

4.1 korb_params Struct Reference

```
#include <korb.h>
```

Data Fields

- int [eccentric](#)
- int [inclined](#)
- double [a](#)
- double [p](#)
- double [e](#)
- double [x](#)
- double [thmin](#)
- double [E](#)
- double [Lz](#)
- double [Q](#)
- double [B](#)
- double [zm](#)
- double [zp](#)
- double [r1](#)
- double [r2](#)
- double [r3](#)
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- double [p3](#)
- double [p4](#)
- double [Vr](#)
- double [Vth](#)
- double [Yr](#)
- double [Yth](#)

- double [Yphi](#)
- double [Ga](#)
- double [wr](#)
- double [wth](#)
- double [wphi](#)
- double * [dladpsiamps](#)
- int [dladpsinum](#)
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- double * [dpsidlaamps](#)
- int [dpsidlanum](#)
- double * [dchidlaamps](#)
- int [dchidlanum](#)
- double * [Tramps](#)
- int [Trnum](#)
- double * [Tthamps](#)
- int [Tthnum](#)
- double * [Pramps](#)
- int [Prnum](#)
- double * [Pthamps](#)
- int [Pthnum](#)
- double [err](#)

4.1.1 Field Documentation

4.1.1.1 `eccentric`

```
int korb_params::eccentric
```

Boolean to indicate whether the orbit is eccentric

4.1.1.2 `inclined`

```
int korb_params::inclined
```

Boolean to indicate whether the orbit is inclined

4.1.1.3 `a`

```
double korb_params::a
```

specific spin angular momentum divided by black hole mass

4.1.1.4 `p`

```
double korb_params::p
```

Orbital semilatus rectum

4.1.1.5 e

```
double korb_params::e
```

Orbital eccentricity

4.1.1.6 x

```
double korb_params::x
```

$x = \sin(\theta_{\min})$

4.1.1.7 thmin

```
double korb_params::thmin
```

Minimum polar angle

4.1.1.8 E

```
double korb_params::E
```

Specific energy

4.1.1.9 Lz

```
double korb_params::Lz
```

Specific angular momentum

4.1.1.10 Q

```
double korb_params::Q
```

Carter constant

4.1.1.11 B

```
double korb_params::B
```

$\text{Beta} = (1 - E^2) * a^2$

4.1.1.12 zm

```
double korb_params::zm
```

$z_- = \cos^2(\theta_{\min})$

4.1.1.13 zp

```
double korb_params::zp
```

$z_+ =$ other root of polar equation of motion (not directly related to θ_{\max})

4.1.1.14 r1

```
double korb_params::r1
```

r_1 = largest root of radial equation of motion = r_{\max}

4.1.1.15 r2

```
double korb_params::r2
```

r_2 = 2nd largest root of radial equation of motion = r_{\min}

4.1.1.16 r3

```
double korb_params::r3
```

r_3 = 3rd largest root of radial equation of motion (not directly related to a turning point)

4.1.1.17 r4

```
double korb_params::r4
```

r_4 = smallest root of radial equation of motion (not directly related to a turning point)

4.1.1.18 p3

```
double korb_params::p3
```

$p_3 = r_3(1-e)$

4.1.1.19 p4

```
double korb_params::p4
```

$p_4 = r_4(1+e)$

4.1.1.20 Vr

```
double korb_params::Vr
```

Λ_r = radial period in Mino time

4.1.1.21 Vth

```
double korb_params::Vth
```

Λ_{θ} = polar period in Mino time

4.1.1.22 Yr

```
double korb_params::Yr
```

Υ_r = fundamental radial angular frequency in Mino time

4.1.1.23 Yth

```
double korb_params::Yth
```

Upsilon_theta = fundamental polar angular frequency in Mino time

4.1.1.24 Yphi

```
double korb_params::Yphi
```

Upsilon_phi = fundamental azimuthal angular frequency in Mino time

4.1.1.25 Ga

```
double korb_params::Ga
```

Gamma = average rate of t advance in Mino time

4.1.1.26 wr

```
double korb_params::wr
```

Omega_r = fundamental radial angular frequency in t

4.1.1.27 wth

```
double korb_params::wth
```

Omega_theta = fundamental polar angular frequency in t

4.1.1.28 wphi

```
double korb_params::wphi
```

Omega_phi = fundamental azimuthal angular frequency in t

4.1.1.29 dladpsiamps

```
double* korb_params::dladpsiamps
```

Fourier amplitudes of the derivative of Mino time with respect to chi_r

4.1.1.30 dladpsinum

```
int korb_params::dladpsinum
```

number of Fourier amplitudes of the derivative of Mino time with respect to chi_r

4.1.1.31 dladchiamps

```
double* korb_params::dladchiamps
```

Fourier amplitudes of the derivative of Mino time with respect to chi_theta

4.1.1.32 dladchinum

```
int korb_params::dladchinum
```

number of Fourier amplitudes of the derivative of Mino time with respect to χ_θ

4.1.1.33 dpsidlaamps

```
double* korb_params::dpsidlaamps
```

Fourier amplitudes of the derivative of χ_r with respect to Mino time

4.1.1.34 dpsidlanum

```
int korb_params::dpsidlanum
```

number of Fourier amplitudes of the derivative of χ_r with respect to Mino time

4.1.1.35 dchidlaamps

```
double* korb_params::dchidlaamps
```

Fourier amplitudes of the derivative of χ_θ with respect to Mino time

4.1.1.36 dchidlanum

```
int korb_params::dchidlanum
```

number of Fourier amplitudes of the derivative of χ_θ with respect to Mino time

4.1.1.37 Tramps

```
double* korb_params::Tramps
```

Fourier amplitudes of T_r

4.1.1.38 Trnum

```
int korb_params::Trnum
```

number of Fourier amplitudes of T_r

4.1.1.39 Tthamps

```
double* korb_params::Tthamps
```

Fourier amplitudes of T_θ

4.1.1.40 Tthnum

```
int korb_params::Tthnum
```

number of Fourier amplitudes of T_θ

4.1.1.41 Pramps

```
double* korb_params::Pramps
```

Fourier amplitudes of Psi_r

4.1.1.42 Pnum

```
int korb_params::Pnum
```

number of Fourier amplitudes of Psi_r

4.1.1.43 Pthamps

```
double* korb_params::Pthamps
```

Fourier amplitudes of Psi_theta

4.1.1.44 Pthnum

```
int korb_params::Pthnum
```

number of Fourier amplitudes of Psi_theta

4.1.1.45 err

```
double korb_params::err
```

relative error tolerance used to determine convergence of each Fourier series

The documentation for this struct was generated from the following file:

- [korb.h](#)

5 File Documentation

5.1 korb.h File Reference

Data Structures

- struct [korb_params](#)

Typedefs

- typedef struct [korb_params](#) [korb_params](#)

Functions

- int [korb_getparams](#) (int eccentric, int inclined, double a, double p, double e0, double x0, double err, [korb_params](#) *orbpar)
- int [korb_freepar](#) ([korb_params](#) orbpar)
- double [korb_zfromchi](#) (double chi, [korb_params](#) orbpar)
- double [korb_thfromla](#) (double la, [korb_params](#) orbpar)
- double [korb_rfrompsi](#) (double psi, [korb_params](#) orbpar)
- double [korb_dladchi](#) (double chi, [korb_params](#) orbpar)
- double [korb_dladpsi](#) (double psi, [korb_params](#) orbpar)
- double [korb_dchidla](#) (double chi, [korb_params](#) orbpar)
- double [korb_dpsidla](#) (double psi, [korb_params](#) orbpar)
- double [korb_lafrompsi](#) (double psi, [korb_params](#) orbpar)
- double [korb_lafromchi](#) (double chi, [korb_params](#) orbpar)
- double [korb_D](#) (double r, [korb_params](#) orbpar)
- double [korb_Tr](#) (double psi, [korb_params](#) orbpar)
- double complex [korb_Trint](#) (double psi, int n, [korb_params](#) orbpar)
- double [korb_Tth](#) (double chi, [korb_params](#) orbpar)
- double complex [korb_Tthint](#) (double chi, int n, [korb_params](#) orbpar)
- double [korb_Pr](#) (double psi, [korb_params](#) orbpar)
- double complex [korb_Print](#) (double psi, int n, [korb_params](#) orbpar)
- double [korb_Pth](#) (double chi, [korb_params](#) orbpar)
- double complex [korb_Pthint](#) (double chi, int n, [korb_params](#) orbpar)
- double complex [korb_dchidlaint](#) (double chi, int n, [korb_params](#) orbpar)
- double complex [korb_dpsidlaint](#) (double psi, int n, [korb_params](#) orbpar)
- double [korb_dtrfromla](#) (double la, [korb_params](#) orbpar)
- double [korb_dtthfromla](#) (double la, [korb_params](#) orbpar)
- double [korb_psifromla](#) (double la, [korb_params](#) orbpar)
- double [korb_chifromla](#) (double la, [korb_params](#) orbpar)
- double [korb_tfromla](#) (double la, [korb_params](#) orbpar)
- double [korb_dphirfromla](#) (double la, [korb_params](#) orbpar)
- double [korb_dphiithfromla](#) (double la, [korb_params](#) orbpar)
- double [korb_phifromla](#) (double la, [korb_params](#) orbpar)
- int [korb_specint](#) (double complex *amp, double large, int n, [korb_params](#) orbpar, double complex(*func)(double, int, [korb_params](#)))
- int [korb_dft](#) (int *N, [korb_params](#) orbpar, double complex(*func)(double, int, [korb_params](#)), double **amps)
- int [korb_dct](#) (int num, double period, [korb_params](#) orbpar, double(*func)(double, [korb_params](#)), double amps[])
- int [korb_getamps](#) (int *num, double period, [korb_params](#) orbpar, double(*func)(double, [korb_params](#)), double **amps)
- double [korb_drldr](#) (double rm, double a)
- double [korb_rfromrsubtrplus](#) (double rsubtrplus, double a)
- double [korb_rmf](#) (double rm, void *params)
- double [korb_rmdf](#) (double rm, void *params)
- void [korb_rmfdf](#) (double rm, void *params, double *y, double *dy)
- double [korb_rsubtrplusfromrs](#) (double rs, double a)

5.1.1 Typedef Documentation

5.1.1.1 korb_params

```
typedef struct korb_params korb_params
```

This data structure encodes all information needed to reconstruct the position of a test mass orbiting a Kerr black hole at any time via Fourier series. The pointers within will become lists of Fourier coefficients once they are allocated by the function "korb_getparams"

5.1.2 Function Documentation

5.1.2.1 korb_getparams()

```
int korb_getparams (
    int eccentric,
    int inclined,
    double a,
    double p,
    double e0,
    double x0,
    double err,
    korb_params * orbpar )
```

This function gathers all necessary numerical techniques to determine generic orbital trajectories of a test mass around a Kerr black hole. The general strategy involves spectral calculation of Fourier coefficients describing the rate-of-change of position, then the position itself is determined by integrating the Fourier series term-by-term. All necessary information for reconstructing the position at a certain time is encoded in the "korb_params" data structure. It adaptively handles convergence testing and memory allocation (but a separate function is needed to free the allocated memory).

5.1.2.2 korb_freepar()

```
int korb_freepar (
    korb_params orbpar )
```

This function frees the memory allocated by the function "korb_getparams"

5.1.2.3 korb_zfromchi()

```
double korb_zfromchi (
    double chi,
    korb_params orbpar )
```

Find $z = \cos^2(\theta)$ from χ_θ

5.1.2.4 korb_thfromla()

```
double korb_thfromla (
    double la,
    korb_params orbpar )
```

Find θ from Mino time

5.1.2.5 korb_rfrompsi()

```
double korb_rfrompsi (
    double psi,
    korb_params orbpar )
```

Find r from chi_r

5.1.2.6 korb_dladchi()

```
double korb_dladchi (
    double chi,
    korb_params orbpar )
```

Find the derivative of Mino time with respect to chi_theta

5.1.2.7 korb_dladpsi()

```
double korb_dladpsi (
    double psi,
    korb_params orbpar )
```

Find the derivative of Mino time with respect to chi_r

5.1.2.8 korb_dchidla()

```
double korb_dchidla (
    double chi,
    korb_params orbpar )
```

Find the derivative of chi_theta with respect to Mino time from chi_theta

5.1.2.9 korb_dpsidla()

```
double korb_dpsidla (
    double psi,
    korb_params orbpar )
```

Find the derivative of chi_r with respect to Mino time from chi_r

5.1.2.10 korb_lafrompsi()

```
double korb_lafrompsi (
    double psi,
    korb_params orbpar )
```

Find the derivative of chi_r with respect to Mino time from chi_r

5.1.2.11 korb_lafromchi()

```
double korb_lafromchi (
    double chi,
    korb_params orbpar )
```

Find Mino time from chi_theta using a Fourier series

5.1.2.12 korb_D()

```
double korb_D (
    double r,
    korb_params orbpar )
```

Find Delta from r

5.1.2.13 korb_Tr()

```
double korb_Tr (
    double psi,
    korb_params orbpar )
```

Find T_r, which is the radial part of the derivative of t with respect to Mino time

5.1.2.14 korb_Trint()

```
double complex korb_Trint (
    double psi,
    int n,
    korb_params orbpar )
```

This function provides the integrand for calculating Mino time Fourier coefficients of T_r

5.1.2.15 korb_Tth()

```
double korb_Tth (
    double chi,
    korb_params orbpar )
```

Find T_{th}, which is the polar part of the derivative of t with respect to Mino time

5.1.2.16 korb_Tthint()

```
double complex korb_Tthint (
    double chi,
    int n,
    korb_params orbpar )
```

This function provides the integrand for calculating Mino time Fourier coefficients of T_{th}

5.1.2.17 korb_Pr()

```
double korb_Pr (
    double psi,
    korb_params orbpar )
```

Find Psi_r, which is the radial part of the derivative of phi with respect to Mino time

5.1.2.18 korb_Print()

```
double complex korb_Print (
    double psi,
    int n,
    korb_params orbpar )
```

This function provides the integrand for calculating Mino time Fourier coefficients of Ψ_r

5.1.2.19 korb_Pth()

```
double korb_Pth (
    double chi,
    korb_params orbpar )
```

Find Ψ_{θ} , which is the polar part of the derivative of ϕ with respect to Mino time

5.1.2.20 korb_Pthint()

```
double complex korb_Pthint (
    double chi,
    int n,
    korb_params orbpar )
```

This function provides the integrand for calculating Mino time Fourier coefficients of Ψ_{θ}

5.1.2.21 korb_dchidlaint()

```
double complex korb_dchidlaint (
    double chi,
    int n,
    korb_params orbpar )
```

This function provides the integrand for calculating Mino time Fourier coefficients of the derivative of χ_{θ} with respect to Mino time

5.1.2.22 korb_dpsidlaint()

```
double complex korb_dpsidlaint (
    double psi,
    int n,
    korb_params orbpar )
```

This function provides the integrand for calculating Mino time Fourier coefficients of the derivative of χ_r with respect to Mino time

5.1.2.23 korb_dtrfromla()

```
double korb_dtrfromla (
    double la,
    korb_params orbpar )
```

This function returns the integral of T_r with respect to Mino time given the Fourier coefficients of T_r (called `orbpar.Tramps[]`)

5.1.2.24 korb_dtthfromla()

```
double korb_dtthfromla (
    double la,
    korb_params orbpar )
```

This function returns the integral of T_{θ} with respect to Mino time given the Fourier coefficients of T_{θ} (called orbpar.Tthamps[])

5.1.2.25 korb_psifromla()

```
double korb_psifromla (
    double la,
    korb_params orbpar )
```

Find χ_r from Mino time

5.1.2.26 korb_chifromla()

```
double korb_chifromla (
    double la,
    korb_params orbpar )
```

Find χ_{θ} from Mino time

5.1.2.27 korb_tfromla()

```
double korb_tfromla (
    double la,
    korb_params orbpar )
```

Find t from Mino time

5.1.2.28 korb_dphirfromla()

```
double korb_dphirfromla (
    double la,
    korb_params orbpar )
```

This function returns the integral of Ψ_r with respect to Mino time given the Fourier coefficients of Ψ_r (called orbpar.Pramps[])

5.1.2.29 korb_dphithfromla()

```
double korb_dphithfromla (
    double la,
    korb_params orbpar )
```

This function returns the integral of Ψ_{θ} with respect to Mino time given the Fourier coefficients of Ψ_{θ} (called orbpar.Pthamps[])

5.1.2.30 korb_phifromla()

```
double korb_phifromla (
    double la,
    korb_params orbpar )
```

Find phi from Mino time

5.1.2.31 korb_specint()

```
int korb_specint (
    double complex * amp,
    double large,
    int n,
    korb_params orbpar,
    double complex(*) (double, int, korb_params) func )
```

Takes a function pointer and finds a single Fourier coefficient via DFT

5.1.2.32 korb_dft()

```
int korb_dft (
    int * N,
    korb_params orbpar,
    double complex(*) (double, int, korb_params) func,
    double ** amps )
```

Takes a function pointer and finds a set of Fourier coefficients via DFT (including convergence assessment)

5.1.2.33 korb_dct()

```
int korb_dct (
    int num,
    double period,
    korb_params orbpar,
    double(*) (double, korb_params) func,
    double amps[ ] )
```

Takes a function pointer and samples it for DCT via FFTW

5.1.2.34 korb_getamps()

```
int korb_getamps (
    int * num,
    double period,
    korb_params orbpar,
    double(*) (double, korb_params) func,
    double ** amps )
```

Takes a function pointer and calculates DCT coefficients via FFTW (including convergence assessment)

5.1.2.35 korb_drhdr()

```
double korb_drhdr (
    double rm,
    double a )
```

Gives the derivative of the tortoise coordinate with respect to r

5.1.2.36 korb_rsfromrsubtrplus()

```
double korb_rsfromrsubtrplus (
    double rsubtrplus,
    double a )
```

Gives the tortoise coordinate from $r-r_+$

5.1.2.37 korb_rmf()

```
double korb_rmf (
    double rm,
    void * params )
```

Residual between guessing the tortoise coordinate value and the actual value (for root finding)

5.1.2.38 korb_rmdf()

```
double korb_rmdf (
    double rm,
    void * params )
```

Gives the derivative of the tortoise coordinate with respect to r (for root finding)

5.1.2.39 korb_rmfdmf()

```
void korb_rmfdmf (
    double rm,
    void * params,
    double * y,
    double * dy )
```

Gives both the residual between guessing the tortoise coordinate value and the actual value and the derivative of the tortoise coordinate with respect to r (for root finding)

5.1.2.40 korb_rsubtrplusfromrs()

```
double korb_rsubtrplusfromrs (
    double rs,
    double a )
```

Uses various initial guess strategies to efficiently and accurately find $r-r_+$ from the tortoise coordinate via root finding

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