The AstroUtil package

in the astronomy & astrophysics toolbox for MATLAB

Description:

The AstroUtil package contains several sub packages that deals with astrophysical phenomena (e.g., cosmological distances, binary stars).

To view all the functions type: "`AstroUtil.`" followed by <tab>.

To avoid using the "`AstroUtil.cosmo.ad_dist`" syntax, you can use:

```
import AstroUtil.*
help cosmo.ad_dist
```

This file is accessible through "`AstroUtil.manual`".

Credit

If you are using this code or products in your scientific publication please give a reference to Ofek (2014; ascl.soft 07005).

License

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Instellation

This pacakage is available as part of the *Astronomy and Astrophysics toolbox for matlab*. Furthermore, some of the functions in this package use functions in other packages in the toolbox, so full instellation is recomended.

See http://weizmann.ac.il/home/eofek/matlab for instellation instruction and additional documentation.

List of sub packages

The binary star package

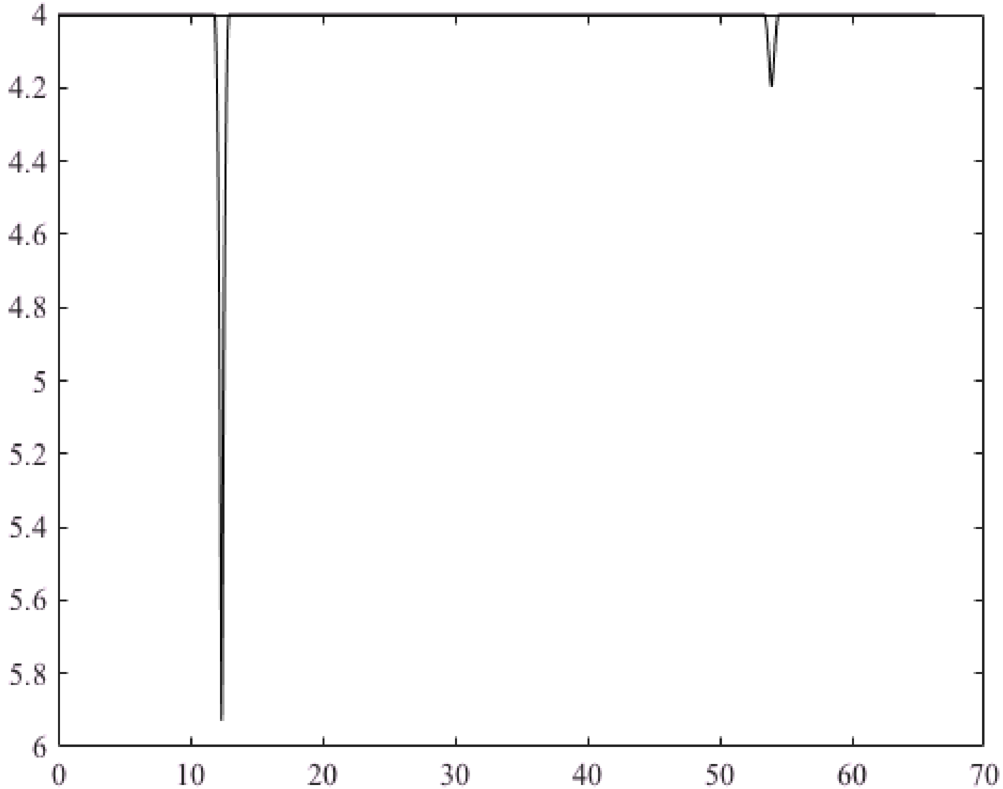
Contains some functions realted to binary stars, including generation of eclipsing binary light curves, radial velocity, and astrometric binaries.

Eclipsing binaries:

The function `AstroUtil.binary.eb_demo` will open a GUI interface to generate eclipsing binary light curves.

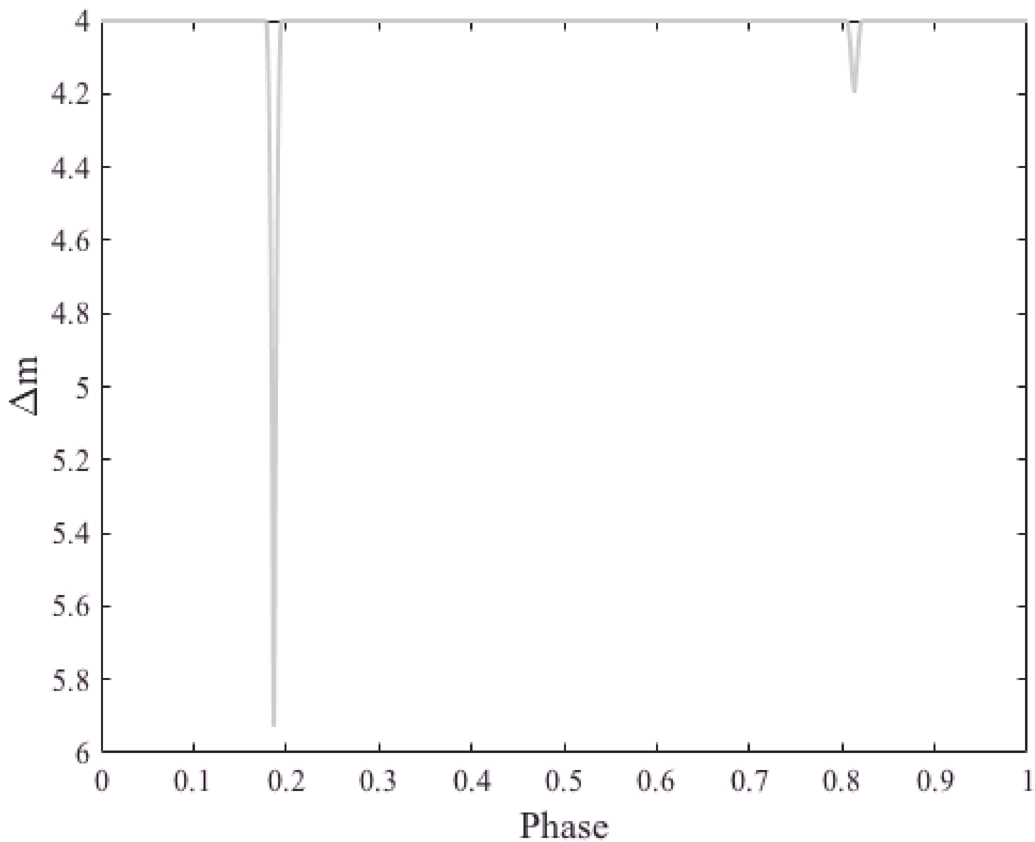
The following example will generate a light curve of eclisping binary:

```
[LC,Period]=AstroUtil.binary.eb_light_curve([100 20],[1 0.6],[0.01 0.01],[0 0.3 0.2 0 0 pi./2]
plot(LC(:,1),LC(:,2),'k-'); invy
```



while the following example will plot the phase folded light curve:

```
AstroUtil.binary.plot_eb_lc_ph([100 20],[1 0.6],[0.01 0.01],[0 0.3 0.2 0 0 pi./2],'AstroUtil.b
```



Additional functions relevant for eclipsing binaries are:

`AstroUtil.binary.binary_reflection_effect` - Calculate reflection effects.

`AstroUtil.binary.limb_darkening` - Calculate limb darkening.

`AstroUtil.binary..obstruction` - Calculate the obstruction for eclipsing binary

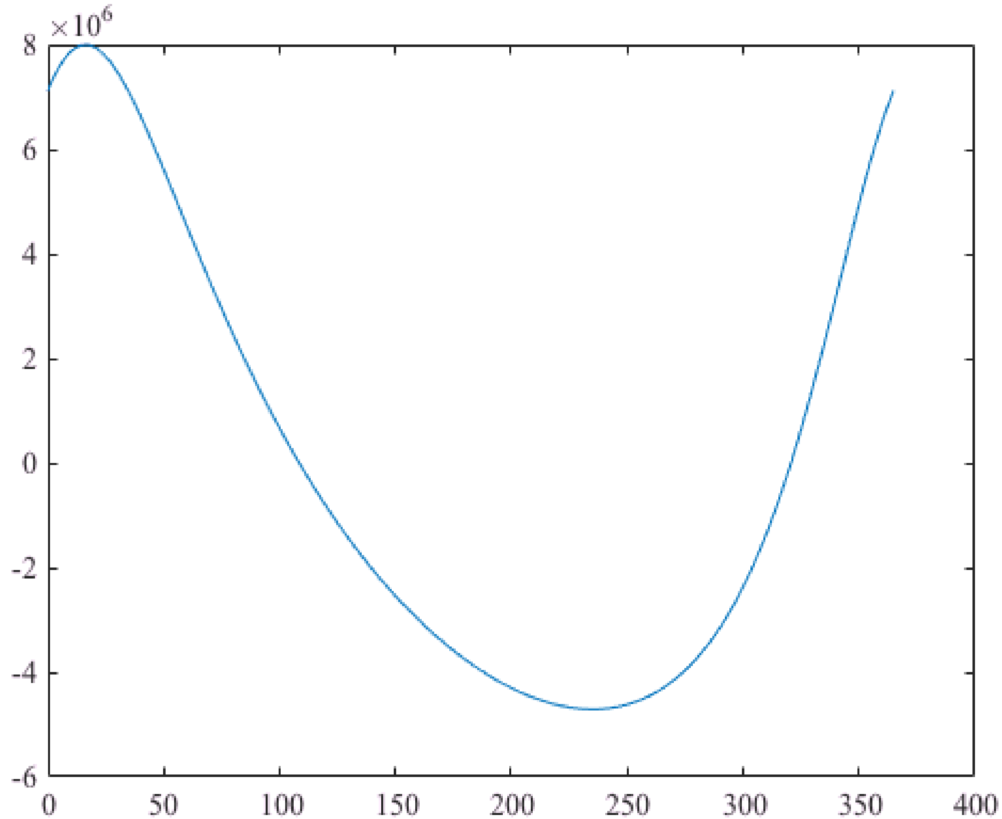
`AstroUtil.binary.plot_eb_lc` - Plot the light curve of eclipsing binary

`AstroUtil.binary.total_light` - Calculate the total light given the limb darkening

Spectroscopic binaries

Use AstroUtil.binary.binary_rv to calculate the radial velocity of a binary.

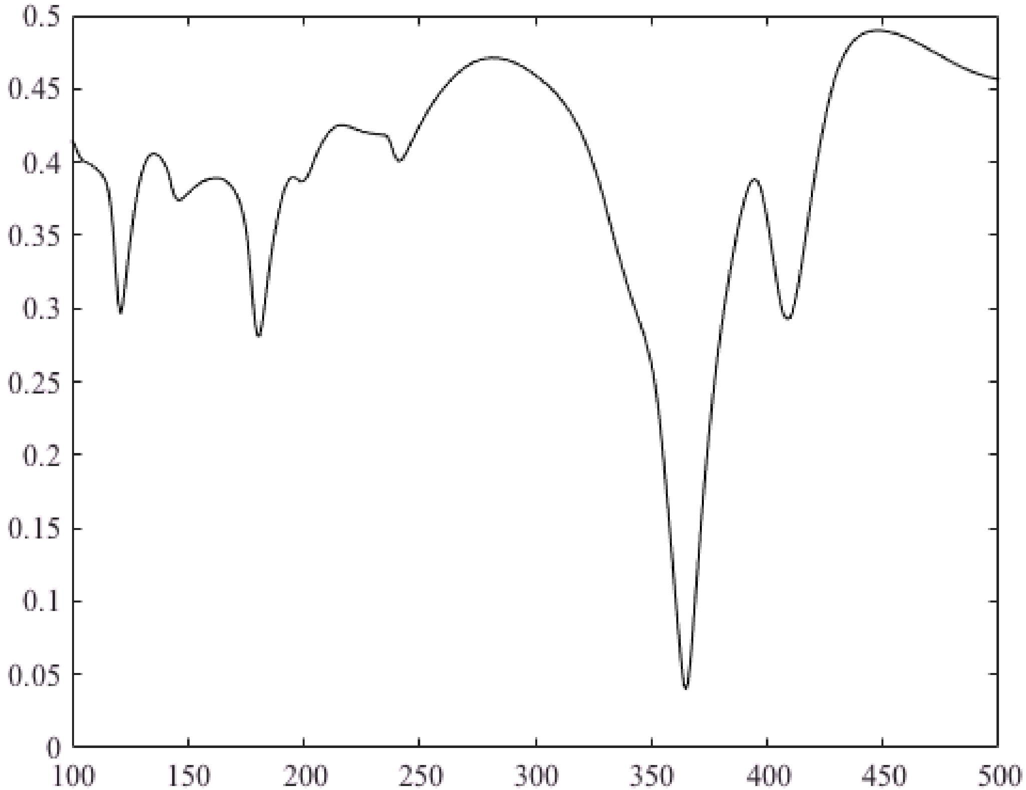
```
t=[0:1:365].';
e=0.3;
a=1;
RAD = 180./pi;
RV=AstroUtil.binary.binary_rv(t,365,0,a./(1-e),e,85./RAD,100);
plot(t,RV)
```



Fitting spectroscopic binaries

The function `AstroUtil.binary.fit_rv_ellipse` can be used to fit radial velocity measurments, and specifically to calculate the periodogram for RV.

```
Time = (1:1:700)';
% define the orbital elements
P    = 365;
T    = 0;
q    = 1;
e    = 0.6;
i    = 1;
omega = 3.9;
Nt = numel(Time);
% generate RV curve
[RV,K2] = AstroUtil.binary.binary_rv(Time,P,T,q,e,i,omega);
RV = RV./1e5;
RV = RV + randn(Nt,1);
% calculate the periogogram
VecP = (100:1:500)';
[Res,FreqVec]=AstroUtil.binary.fit_rv_ellipse(Time,RV,VecP);
% plot the rms vs. the period
plot(VecP,[Res.RMS]','k-');
```

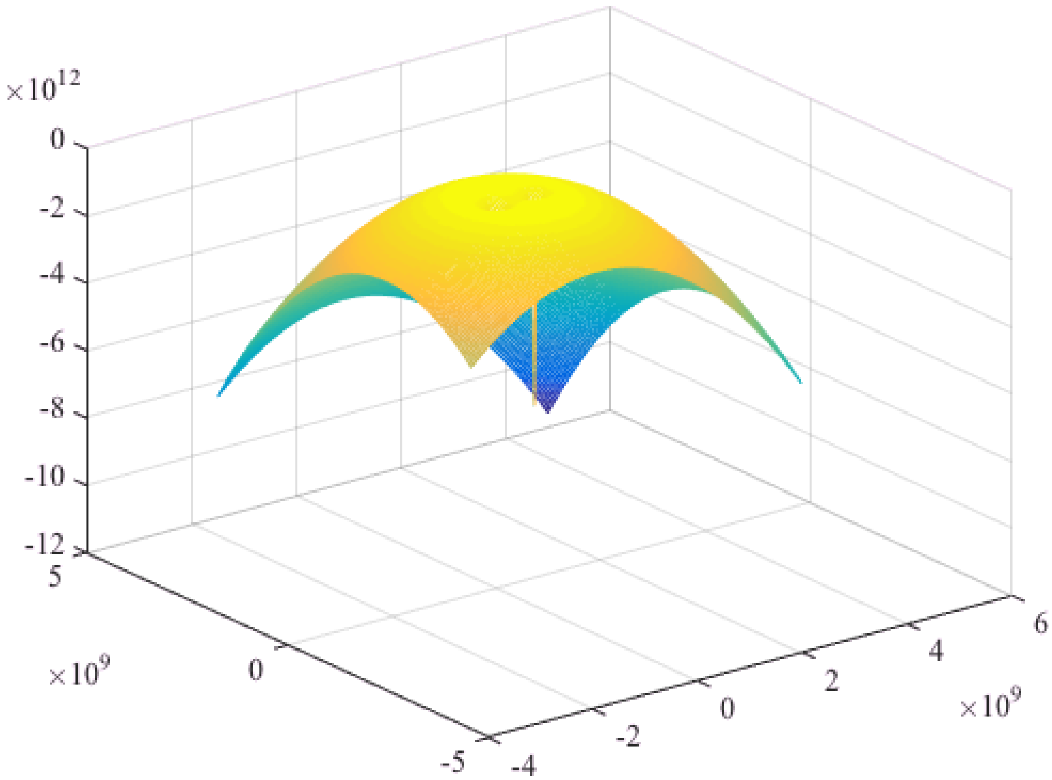


This function uses additional useful functions like: `AstroUtil.binary.rv2ellipse` and `fit_ellipse`.

Equipotentials

The following example plot the equipotential surface for a binary system:

```
[x,y,q]=AstroUtil.binary.equipot(1,0.7,0.7.*1e9,3,50);
mesh(x,y,q);
```

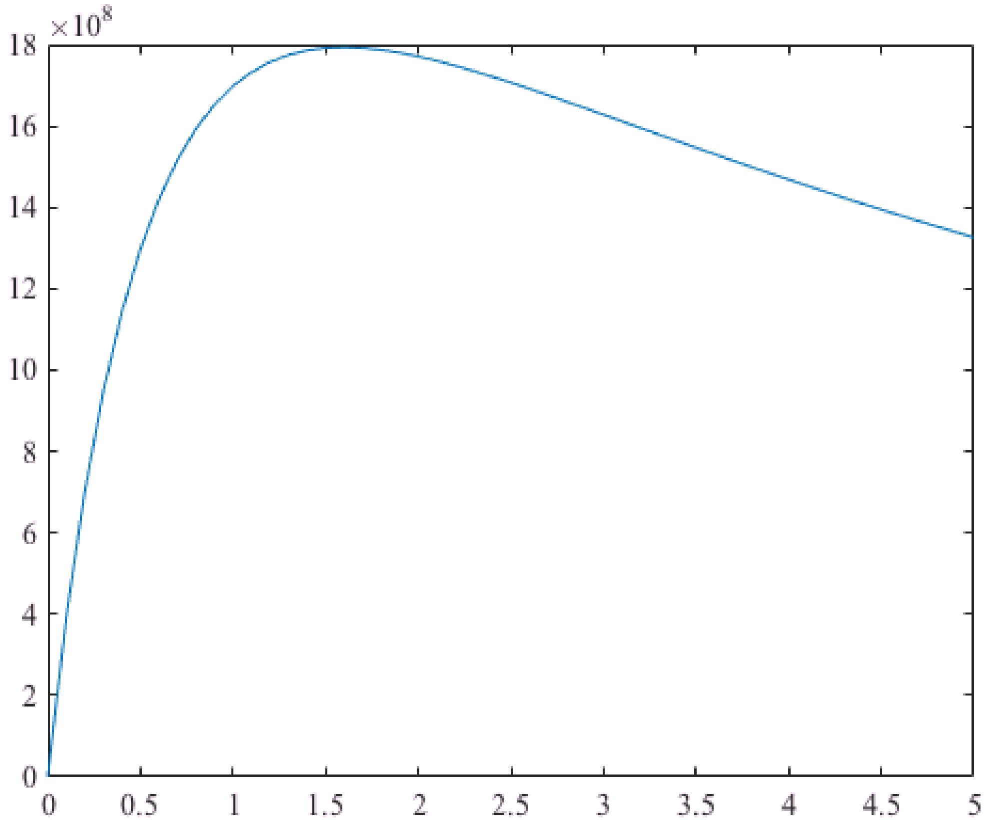


The cosmology package

The `cosmo` package contains function for evaluating cosmological distances and related properties.

Examples related to cosmological distance calculators:

```
import AstroUtil.cosmo.*
z=(0:0.1:5)';
% calculate angular diameter distance
D=ad_dist(z);
plot(z,D)
```



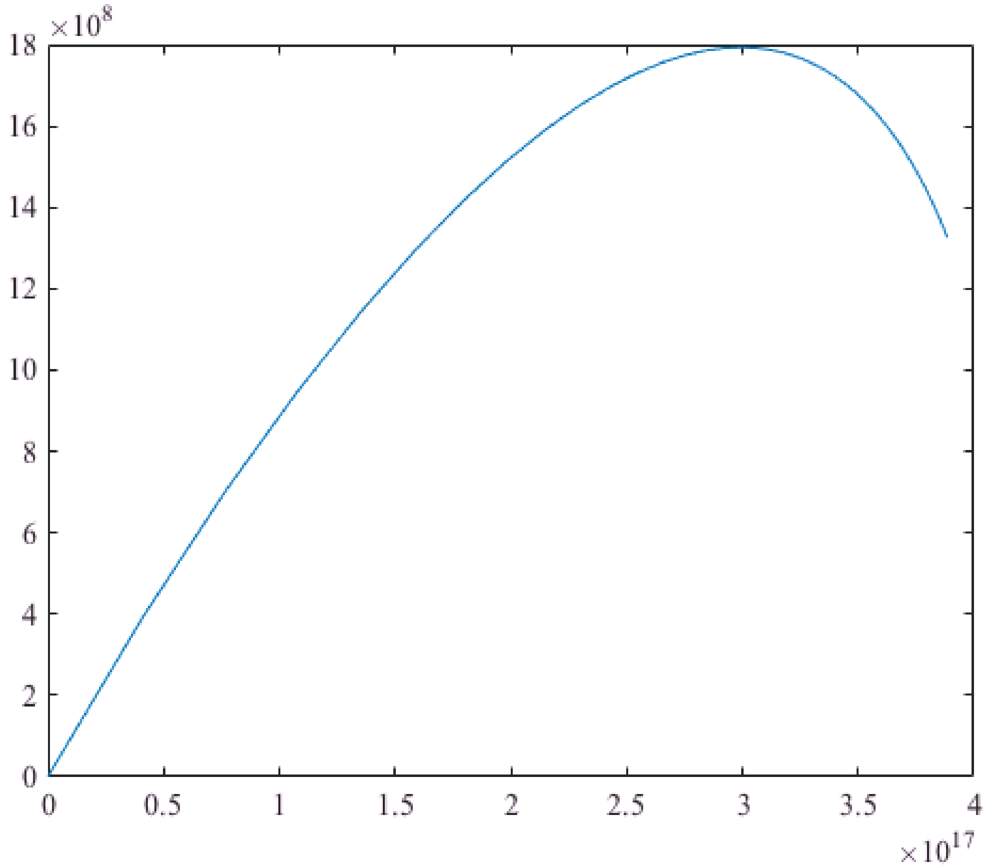

```
% calculate lookback time
T = lookback_time(z);
```

```
Warning: Minimum step size reached; singularity possible.
```

```
% plot angular diameter distance as a function of lookback time [s]
plot(T,D)
```

```
ans =
   6.3872e+08

ans =
   7.2687e+07
```



Functions like `ad_dist` and `lookback_time` support calculations of distances/times between two redshifts:

```
% calculate angular diameter distance [pc] between z1 and z2
z1=1;
z2=2;
ad_dist([z1 z2])
% note this is not the same as:
ad_dist(z2)-ad_dist(z1)
% The last calculation is incorrect and should not be used!
```

Most functions allow to control the cosmological parameters used in the calculations. The function `AstroUtil.cosmo.cosmo_pars` store various cosmological parameters:

```
[Par,ErrPar]=AstroUtil.cosmo.cosmo_pars('planck')
```

```
Par =
          H0: 67.74
      OmegaM: 0.3089
    OmegaRad: 0
      OmegaL: 0.6911
   OmegaB_h2: 0.0223
      sigma8: 0.8159
        z_re: 8.8
         Age: 13.799
```

```
ErrPar = 
           H0: [0.46 0.46]
       OmegaM: [0.0062 0.0062]
       OmegaL: [0.0062 0.0062]
    OmegaB_h2: [0.00014 0.00014]
       sigma8: [0.0086 0.0086]
         z_re: [1.1 1.2]
          Age: [0.021 0.021]
```

```
z=(0:0.1:1)';
D=AstroUtil.cosmo.ad_dist(z,'wmap9');
```

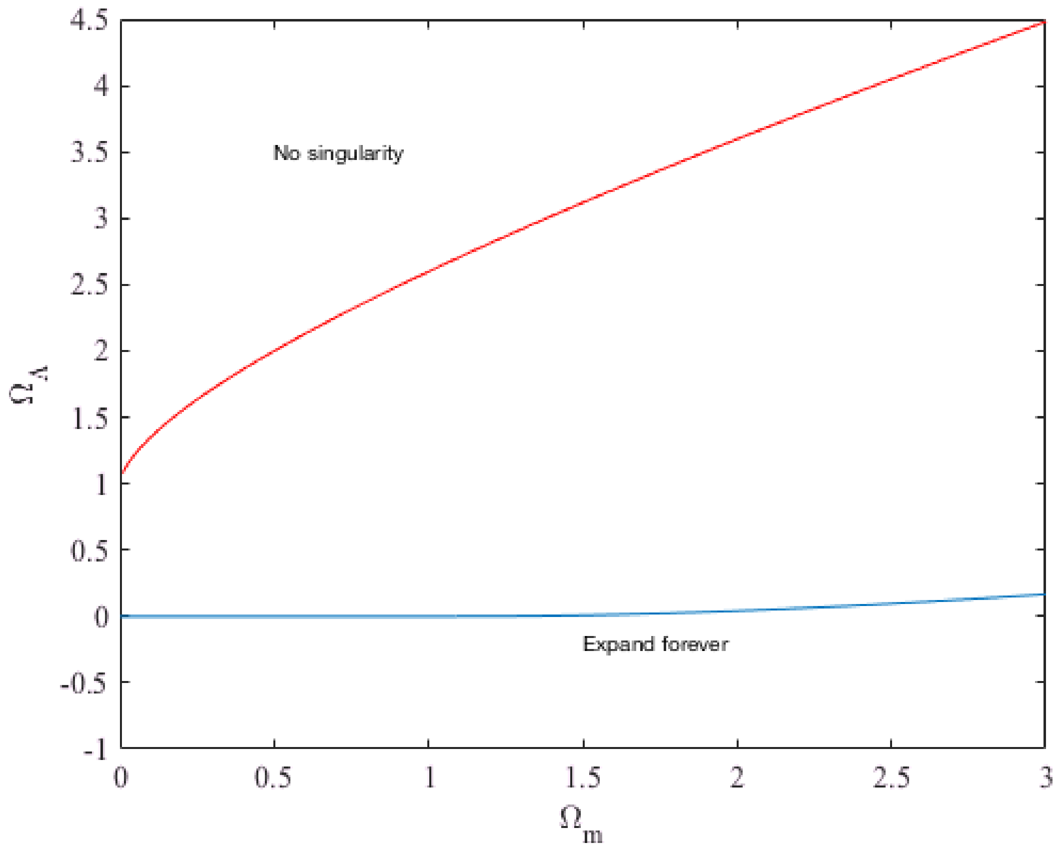
```
D = 
             0
    3.8444e+08
    6.8841e+08
     9.301e+08
    1.1228e+09
    1.2766e+09
    1.3992e+09
    1.4965e+09
    1.5734e+09
    1.6335e+09
      1.68e+09
```

```
% or you can provide the parameters directly:
H0=100;
OmegaM = 0.3;
OmegaL = 0.7;
D=AstroUtil.cosmo.ad_dist(z,[H0,OmegaM,OmegaL]);
```

Additional related functions:

- `AstroUtil.cosmo.lum_dist` - Calculate the luminosity distance
- `AstroUtil.cosmo.inv_lum_dist` - Convert luminosity distance to redshift
- `AstroUtil.cosmo.dist_mod2dist` - Convert distance modulus to luminosity distance
- `AstroUtil.cosmo.comoving_dist` - Calculate the comoving distance
- `AstroUtil.cosmo.hubble_z` - Calculate H0 as a function of redshift
- `AstroUtil.cosmo.comoving_volume` - Calculate comoving volume as a function of redshift.
- `AstroUtil.cosmo.inv_comoving_volume` - Convert comoving volume to redshift
- `AstroUtil.cosmo.crit_surface_density` - Calculate the critical density to lensing
- `AstroUtil.cosmo.delta_vir_z` - Calculate the virial overdensity
- `AstroUtil.cosmo.growth_linear_perturbation` - Calculate the growth function of linear perurbations
- `AstroUtil.cosmo.matter_density` - Calculate the mean matter density in the Universe
- `AstroUtil.cosmo.tran_comoving_dist` - Calculate the transverse comoving distance
- `AstroUtil.cosmo.e_z` - Calculate E(z) cosmological function, which is proportional to the time derivative of the logarithm of the scale factor
- `AstroUtil.cosmo.inv_e_z` - Invert e_z to redshift
- `AstroUtil.cosmo.cdt_dz` - Calculate cdt/dz as a function of redshift
- `AstroUtil.cosmo.omega_z` - Calculate Omega_m as a function of redshift
- AstroUtil.cosmo.omega_m_lambda_lines - can be used to plot selected (spacial) lines in the Omega_m vs. Omega_lambda diagram (e.g., no singularity):

```
OmegaM=[0:0.01:3]';  % define a vector of Omega matter
[OmL_EF,OmL_NS]=AstroUtil.cosmo.omega_m_lambda_lines(OmegaM);
plot(OmegaM,OmL_EF); hold on; plot(OmegaM,OmL_NS,'r');
xlabel('\Omega_{m}'); ylabel('\Omega_{\Lambda}');
axis([0 3 -1 4.5]);
text(1.5,-0.2,'Expand forever'); text(0.5,3.5,'No singularity');
```



The GRB package

The GRB sub package contains Gamma-Ray Bursts related functions.

`AstroUtil.GRB.lorentz_from_flux` - Calculate lower limit on GRB lorentz factor

The lensing package

The `lensing` sub package contains strong gravitational lensing related function including model fitting functions. This package is under development and require additional work.

The microlensing package

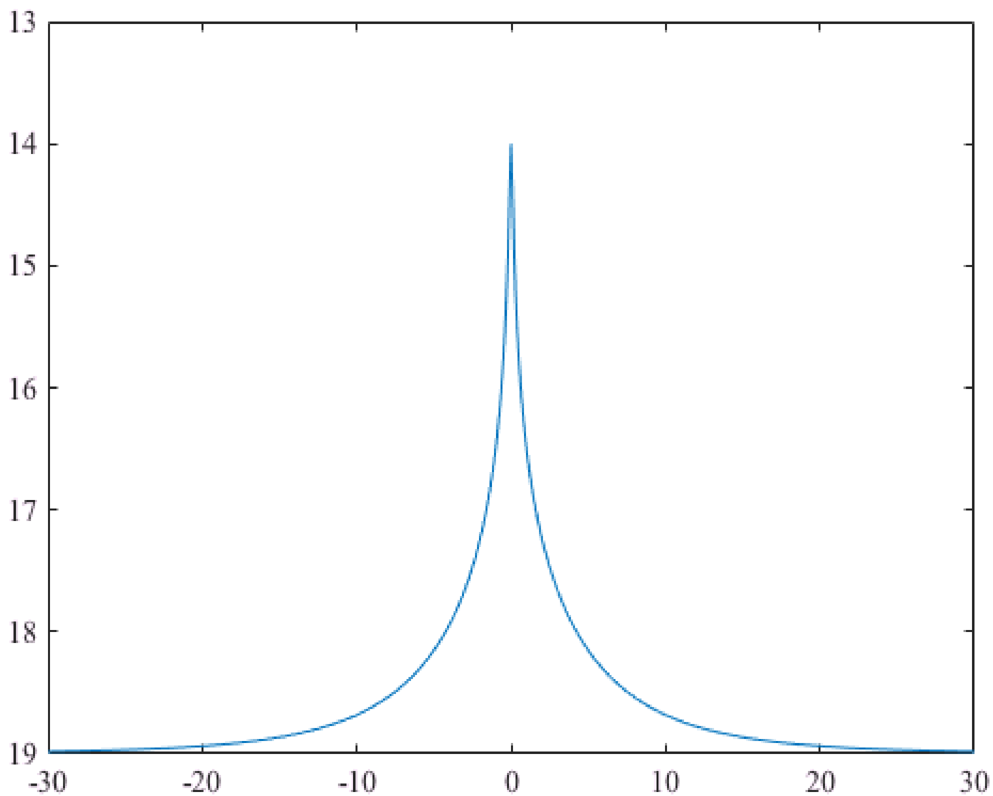
The microlensing sub package contains microlensing related functions.

The `AstroUtil.microlensing.pointsource_lens` can be used to calculate the magnification and images positions:

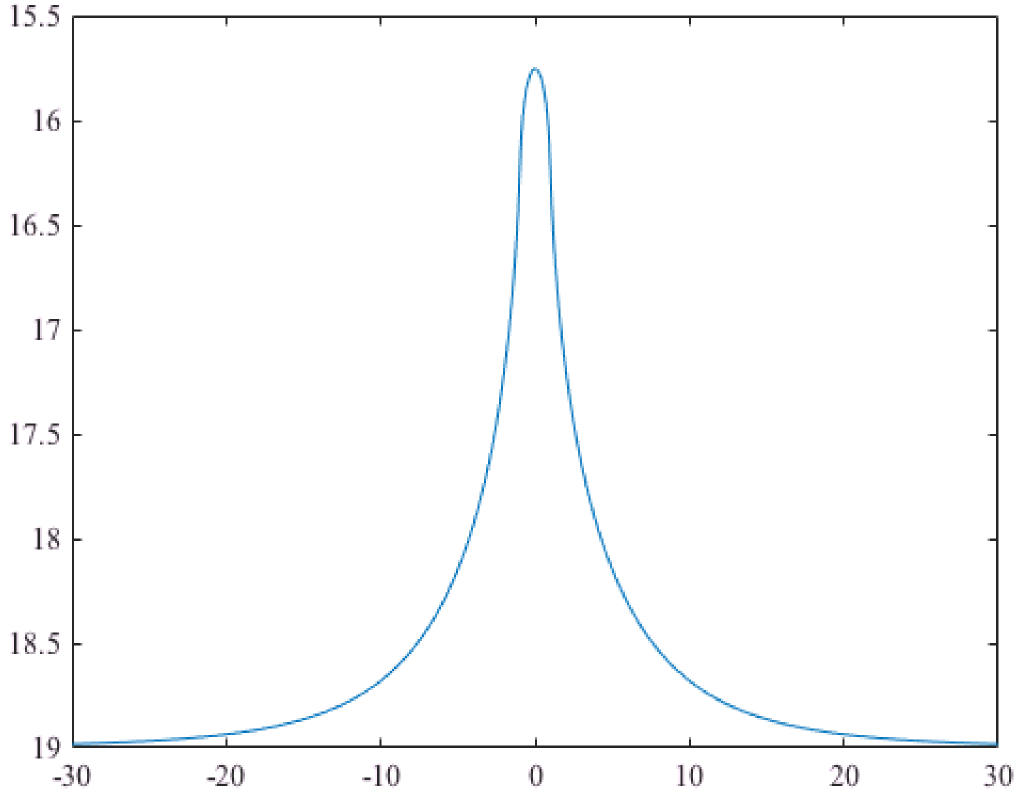
```
RAD = 180./pi;
[ER,T1,T2,Mu1,Mu2,TD1,TD2,Tcm]=AstroUtil.microlensing.pointsource_lens(1,5000,10000,5000,1./(1
```

Alternatively, a more convinient function is `AstroUtil.microlensing.microlens_ps`:

```
% microlensing parameters
Pars.T0   = 0;  % time of min. impact parameter
Pars.Beta = 0.01;  % impact parameters in units of the Einstein radsius
Pars.V    = 0.1;   % velocity [Einstein rdaius per day]
Pars.Alpha = 1;    % blensing parameter
Pars.BaseMag = 19; % Source base magnitude
Time = (-30:0.1:30).';
[Mag,Res]=AstroUtil.microlensing.microlens_ps(Pars,Time);
plot(Res.T,Mag); invy;
```




```
% or similarly with finate source effect
Pars.FS = 0.1;  % source size in units of the Einstein radius
[Mag,Res]=AstroUtil.microlensing.microlens_psfs(Pars,Time);
plot(Res.T,Mag); invy;
```



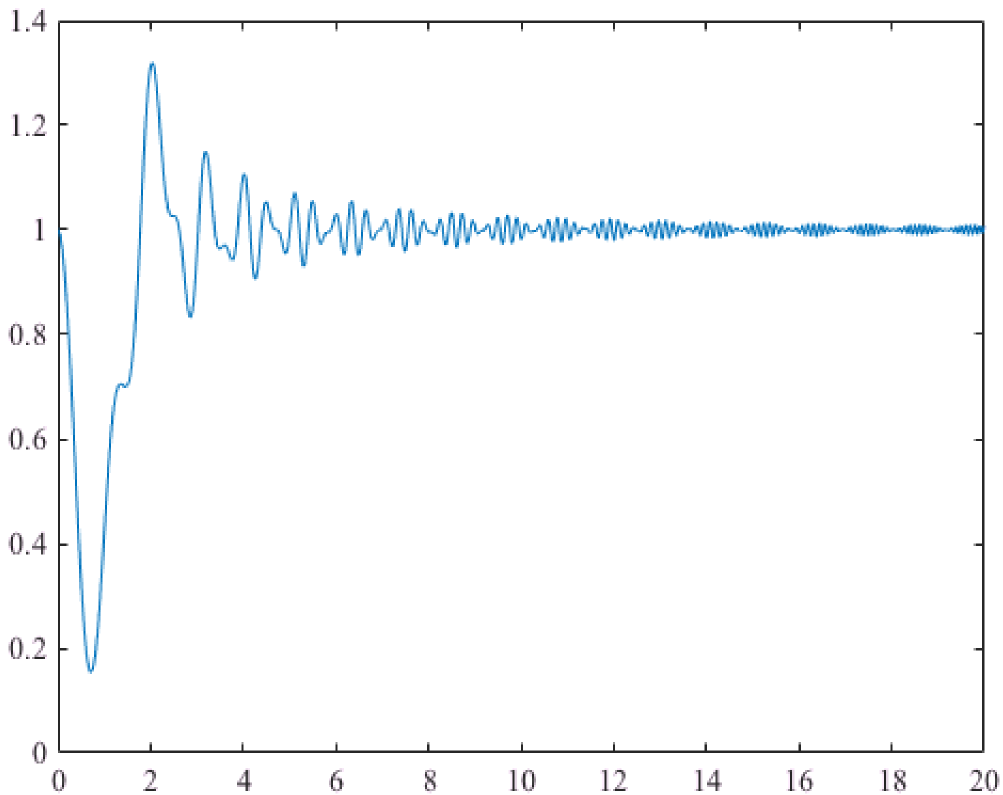
Similarly the function `AstroUtil.microlensing.microlens_psb` gets a list of source-lens distances (in units of the Einstein radius) instead of list of times, while the `AstroUtil.microlensing.microlens_pspar` function take into account the annual parallax.

The Occultations package

The `Occultation` sub package provide some functions to calculate diffractive occultations:

The following example generate the intensity as a function of source-occulter distance (in Units of the Fresnel radii), for occulter which radius is 0.9 the Fresnel scale, assuming a point source and monochromatic light:

```
Dist = (0:0.01:20)';
[I_rho,A_rho]=AstroUtil.Occultation.fresnel_occultation_ps(0.9,Dist);
plot(Dist,I_rho)
```



The function `AstroUtil.Occultation.fresnel_occultation_fs` take into account the finite source size, while the `AstroUtil.Occultation.fresnel_occultation_filt` function deal with finite source and polychromatic light.

The stars package

The stars sub package contains astrophysical stars related functions.

The `AstroUtil.stars.star_ang_rad` function estimate the star angular radius from magnitude and colors.

The function AstroUtil.stars.star_sptype_color calculate the star color index given its spectral type and luminosity class. The following example calculate the SDSS AB *g-r* color index for and A3IV star:

```
[C,E]=AstroUtil.stars.star_sptype_color('A3','IV','SDSS','g','AB','SDSS','r','AB')
```

```
C =
    -0.16608

E =
     0.25165
```

The following example calculate and plot the stellar evolutionary tracks (based on the Geneva stellar tracks):

```
[Ev,UBV]=AstroUtil.stars.stellar_tracks(1,0.04,'c');
```

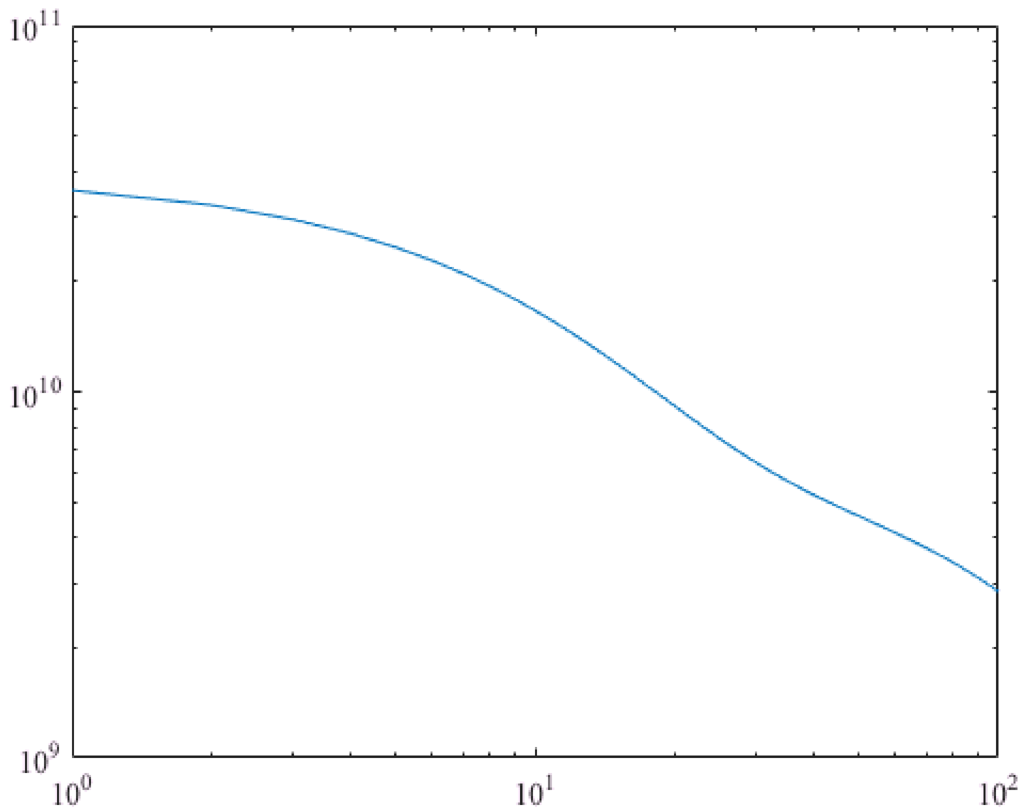
The supernova package

The `supernova` package is a collection of tools for supernovae research.

Several examples:

Calculate the nickel 56 -> Cobalt -> Iron energy production:

```
Time = (1:1:100)';
[E,E_Ni,E_Co]=AstroUtil.supernova.nickel56_decay(Time);
loglog(Time,E)
```



Additional functions contains the Rabinak & Waxman (2011) shock cooling model and more.