Tutorial

March 17, 2018

In [1]:
```
import numpy as np
import discH
import discH.dynamic_component as dc
import matplotlib.pyplot as plt
import warnings
warnings.filterwarnings("ignore")
```

```
/usr/local/lib/python3.6/site-packages/h5py/__init__.py:36: FutureWarning: Conversion of the second argument of issubdtype from
  from ._conv import register_converters as _register_converters
```

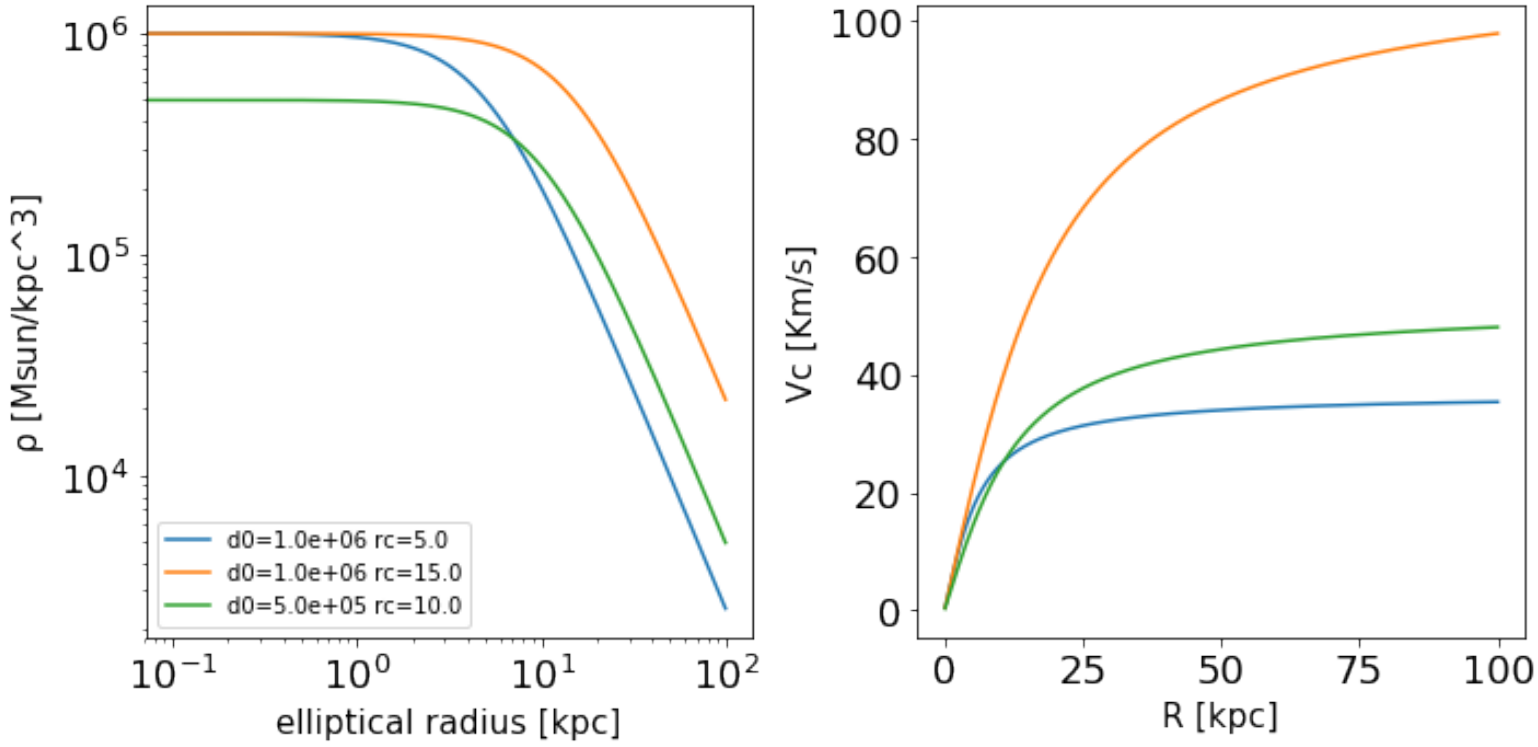
HALO MODELS

In [2]:
```
#Isothermal halo
R=np.linspace(0,100,1000)
fig=plt.figure(figsize=(10,5))
axd=fig.add_subplot(121)
axv=fig.add_subplot(122)



#d=d0*(1+m*m/rc*rc)^(-1)
mcut=100 #radius where d(m>mcut)=0
e=0 #ellipticity
```

```
d0=1e6 #Cental density in Msun/kpc3
rc=5 #Core radius in Kpc
iso_halo=dc.isothermal_halo(d0=d0, rc=rc, mcut=mcut, e=e)
dens=iso_halo.dens(R) #3D dens
vcirc=iso_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e rc=%.1f'%(d0,rc))
axv.plot(R,vcirc[:,1],label='d0=%.1e rc=%.1f'%(d0,rc))


d0=1e6 #Cental density in Msun/kpc3
rc=15 #Core radius in Kpc
iso_halo=dc.isothermal_halo(d0=d0, rc=rc, mcut=mcut, e=e)
dens=iso_halo.dens(R) #3D dens
vcirc=iso_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e rc=%.1f'%(d0,rc))
axv.plot(R,vcirc[:,1],label='d0=%.1e rc=%.1f'%(d0,rc))

d0=5e5 #Cental density in Msun/kpc3
rc=10 #Core radius in Kpc
iso_halo=dc.isothermal_halo(d0=d0, rc=rc, mcut=mcut, e=e)
dens=iso_halo.dens(R) #3D dens
vcirc=iso_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e rc=%.1f'%(d0,rc))
axv.plot(R,vcirc[:,1],label='d0=%.1e rc=%.1f'%(d0,rc))

print(iso_halo)



axd.set_xlabel('elliptical radius [kpc]', fontsize=15)
axd.set_ylabel('$\\rho$ [Msun/kpc^3]', fontsize=15)
axv.set_xlabel('R [kpc]', fontsize=15)
axv.set_ylabel('Vc [Km/s]', fontsize=15)
axd.set_xscale('log')
```

```
        axd.set_yscale('log')
        axd.legend()
        plt.show()
```

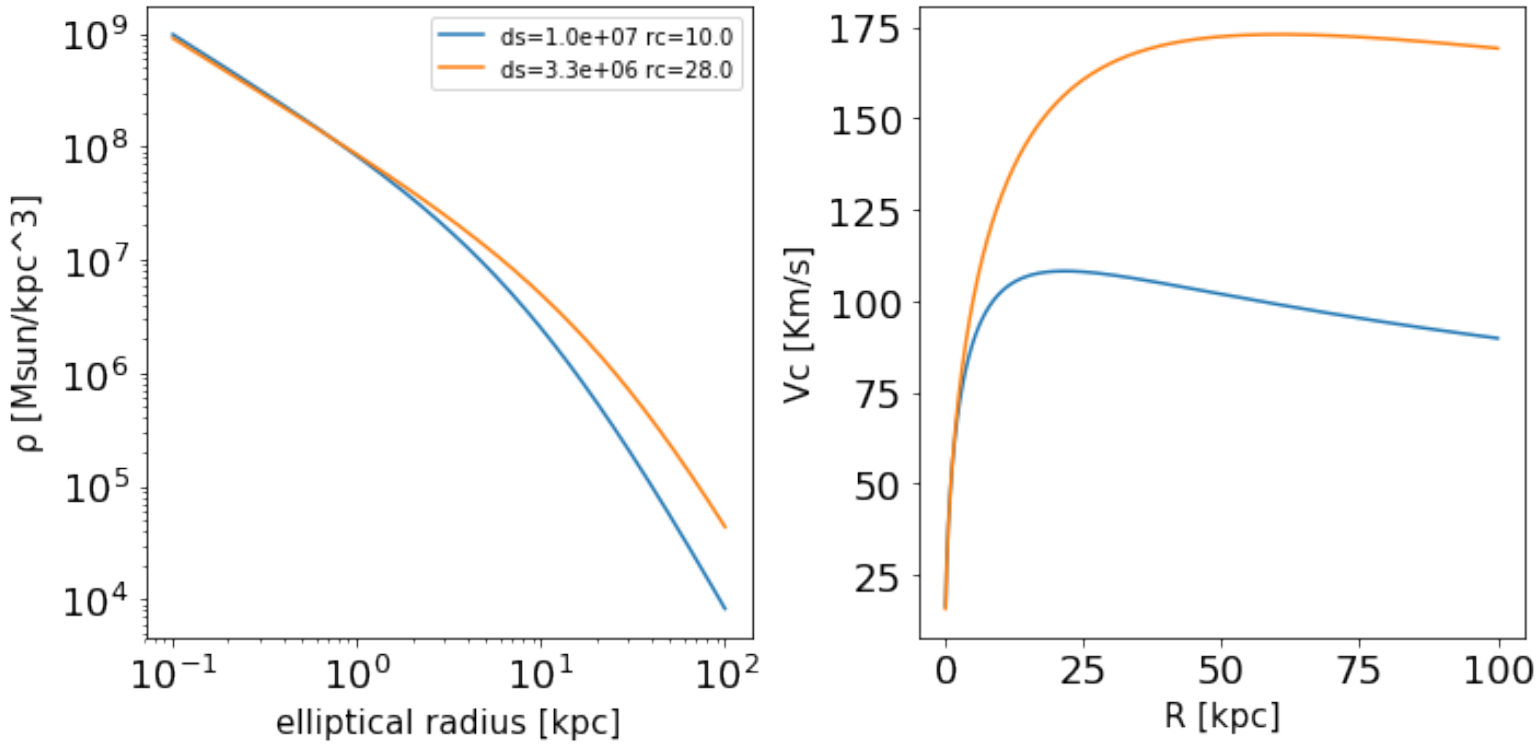
```
Model: Isothermal halo
d0: 5.00e+05 Msun/kpc3
rc: 10.00
e: 0.000
mcut: 100.000
```



In [3]:
```
#NFW halo
R=np.linspace(0,100,1000)
fig=plt.figure(figsize=(10,5))
axd=fig.add_subplot(121)
axv=fig.add_subplot(122)
R=np.linspace(0,100,1000)
#d=d0*( (m/rs)^(-1) ) * ( (1+m/rs)^(-2) )
mcut=100 #radius where d(m>mcut)=0
e=0 #ellipticity

#Primary use: NFW_halo(d0, rs, mcut=100, e=0)
# d=d0/((r/rs)*(1+r/rs)^2)
#-d0 Scale density in Msun/kpc3
#-rs Scale length



#Secondary use: NFW_halo.cosmo(c, V200, H=67  , mcut=100, e=0)
#-c Concentration parameter
#-V200 Velocity (km/s) at virial Radius R200  (radius where the density is 200 times the critical density of the Univers
#-H Hubble constant (km/s/Mpc)

d0=1e7 #Scale density in Msun/kpc3
rs=10 #Scale radius in Kpc
nfw_halo=dc.NFW_halo(d0=d0, rs=rs, mcut=mcut, e=e) #primary method to call NFW halo
dens=nfw_halo.dens(R) #3D dens
vcirc=nfw_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='ds=%.1e rc=%.1f'%(nfw_halo.d0,nfw_halo.rs))
axv.plot(R,vcirc[:,1],label='ds=%.1e rc=%.1f'%(nfw_halo.d0,nfw_halo.rs))


c=8 #Scale density in Msun/kpc3
V200=150 #Scale radius in Kpc
nfw_halo=dc.NFW_halo.cosmo(c=c, V200=V200, mcut=mcut, e=e) #secondary metho do call NFW using coslomogical params:
```

```
        #NWF_halo.cosmo(c, V200, H=67, e=0, mcut=100) H is the Hubble constant in km/s/Mpc (67 default)
        dens=nfw_halo.dens(R) #3D dens
        vcirc=nfw_halo.vcirc(R, nproc=2)
        axd.plot(R,dens[:,1],label='ds=%.1e rc=%.1f'%(nfw_halo.d0,nfw_halo.rs))
        axv.plot(R,vcirc[:,1],label='ds=%.1e rc=%.1f'%(nfw_halo.d0,nfw_halo.rs))

        print(nfw_halo)

        axd.set_xlabel('elliptical radius [kpc]', fontsize=15)
        axd.set_ylabel('$\\rho$ [Msun/kpc^3]', fontsize=15)
        axv.set_xlabel('R [kpc]', fontsize=15)
        axv.set_ylabel('Vc [Km/s]', fontsize=15)
        axd.set_xscale('log')
        axd.set_yscale('log')
        axd.legend()
        plt.show()
```

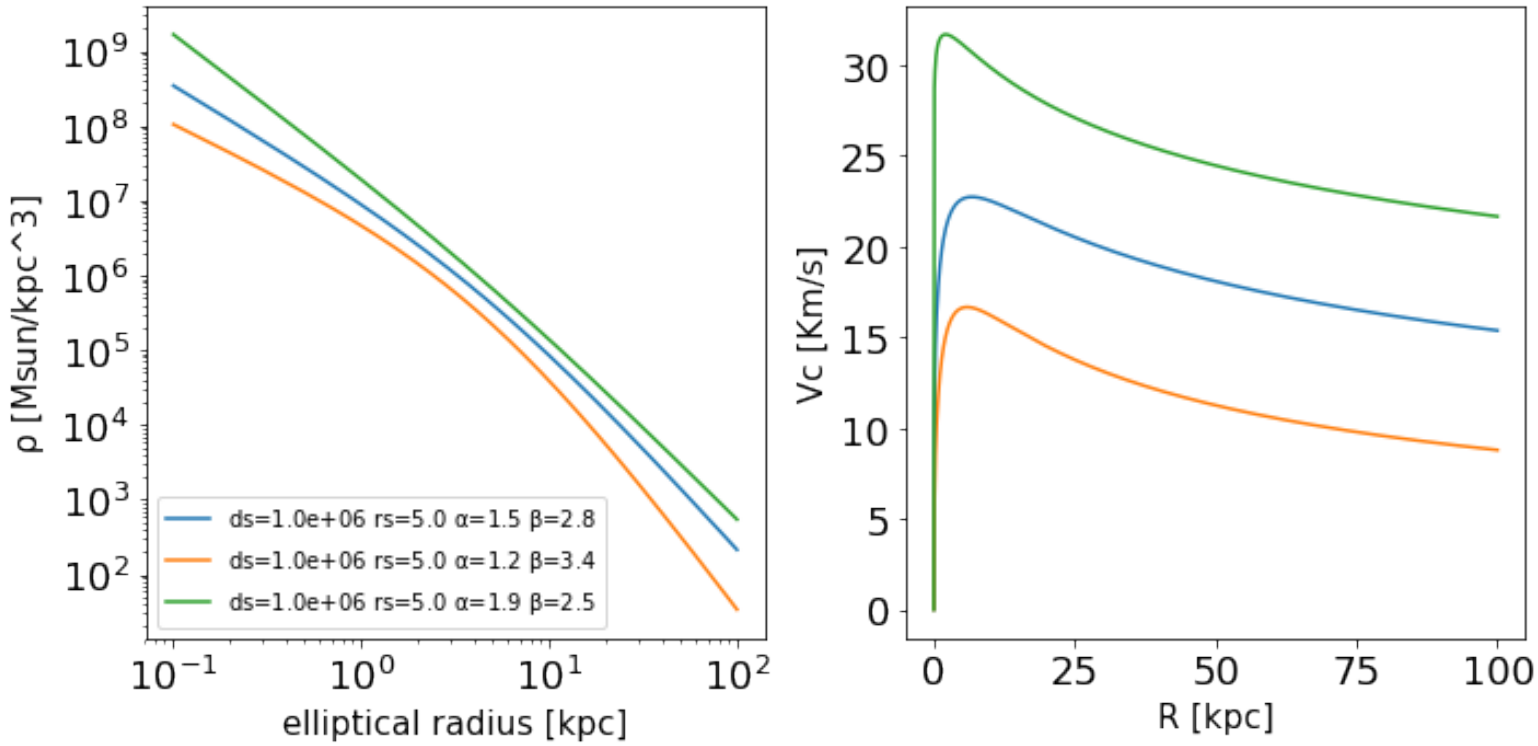
```
Model: NFW halo
d0: 3.26e+06 Msun/kpc3
rs: 27.99
e: 0.000
mcut: 100.000
```



In [4]:
```
#alfabeta halo
R=np.linspace(0,100,1000)
fig=plt.figure(figsize=(10,5))
axd=fig.add_subplot(121)
axv=fig.add_subplot(122)
R=np.linspace(0,100,1000)
#d=d0*( (m/rs)^(-alfa) ) * ( (1+m/rs)^(-(beta-alfa)) )
mcut=100 #radius where d(m>mcut)=0
e=0 #ellipticity
```

```
d0=1e6 #Scale density in Msun/kpc3
rs=5 #Scale radius in Kpc
alfa=1.5 #Inner slope
beta=2.8 #Outer slope
ab_halo=dc.alfabeta_halo(d0=d0,alfa=alfa, beta=beta, rs=rs, mcut=mcut, e=e)
dens=ab_halo.dens(R) #3D dens
vcirc=ab_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='ds=%.1e rs=%.1f $\\alpha$=%.1f $\\beta$=%.1f'%(ab_halo.d0,ab_halo.rs, ab_halo.alfa, ab_halo.
axv.plot(R,vcirc[:,1],label='ds=%.1e rs=%.1f $\\alpha$=%.1f $\\beta$=%.1f'%(ab_halo.d0,ab_halo.rs, ab_halo.alfa, ab_halo

d0=1e6 #Scale density in Msun/kpc3
rs=5 #Scale radius in Kpc
alfa=1.2 #Inner slope
beta=3.4 #Outer slope
ab_halo=dc.alfabeta_halo(d0=d0,alfa=alfa, beta=beta, rs=rs, mcut=mcut, e=e)
dens=ab_halo.dens(R) #3D dens
vcirc=ab_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='ds=%.1e rs=%.1f $\\alpha$=%.1f $\\beta$=%.1f'%(ab_halo.d0,ab_halo.rs, ab_halo.alfa, ab_halo.
axv.plot(R,vcirc[:,1],label='ds=%.1e rs=%.1f $\\alpha$=%.1f $\\beta$=%.1f'%(ab_halo.d0,ab_halo.rs, ab_halo.alfa, ab_halo

d0=1e6 #Scale density in Msun/kpc3
rs=5 #Scale radius in Kpc
alfa=1.9 #Inner slope
beta=2.5 #Outer slope
ab_halo=dc.alfabeta_halo(d0=d0,alfa=alfa, beta=beta, rs=rs, mcut=mcut, e=e)
dens=ab_halo.dens(R) #3D dens
vcirc=ab_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='ds=%.1e rs=%.1f $\\alpha$=%.1f $\\beta$=%.1f'%(ab_halo.d0,ab_halo.rs, ab_halo.alfa, ab_halo.
axv.plot(R,vcirc[:,1],label='ds=%.1e rs=%.1f $\\alpha$=%.1f $\\beta$=%.1f'%(ab_halo.d0,ab_halo.rs, ab_halo.alfa, ab_halo

axd.set_xlabel('elliptical radius [kpc]', fontsize=15)
axd.set_ylabel('$\\rho$ [Msun/kpc^3]', fontsize=15)
axv.set_xlabel('R [kpc]', fontsize=15)
axv.set_ylabel('Vc [Km/s]', fontsize=15)
```

```
axd.set_xscale('log')
axd.set_yscale('log')
axd.legend()
plt.show()
```

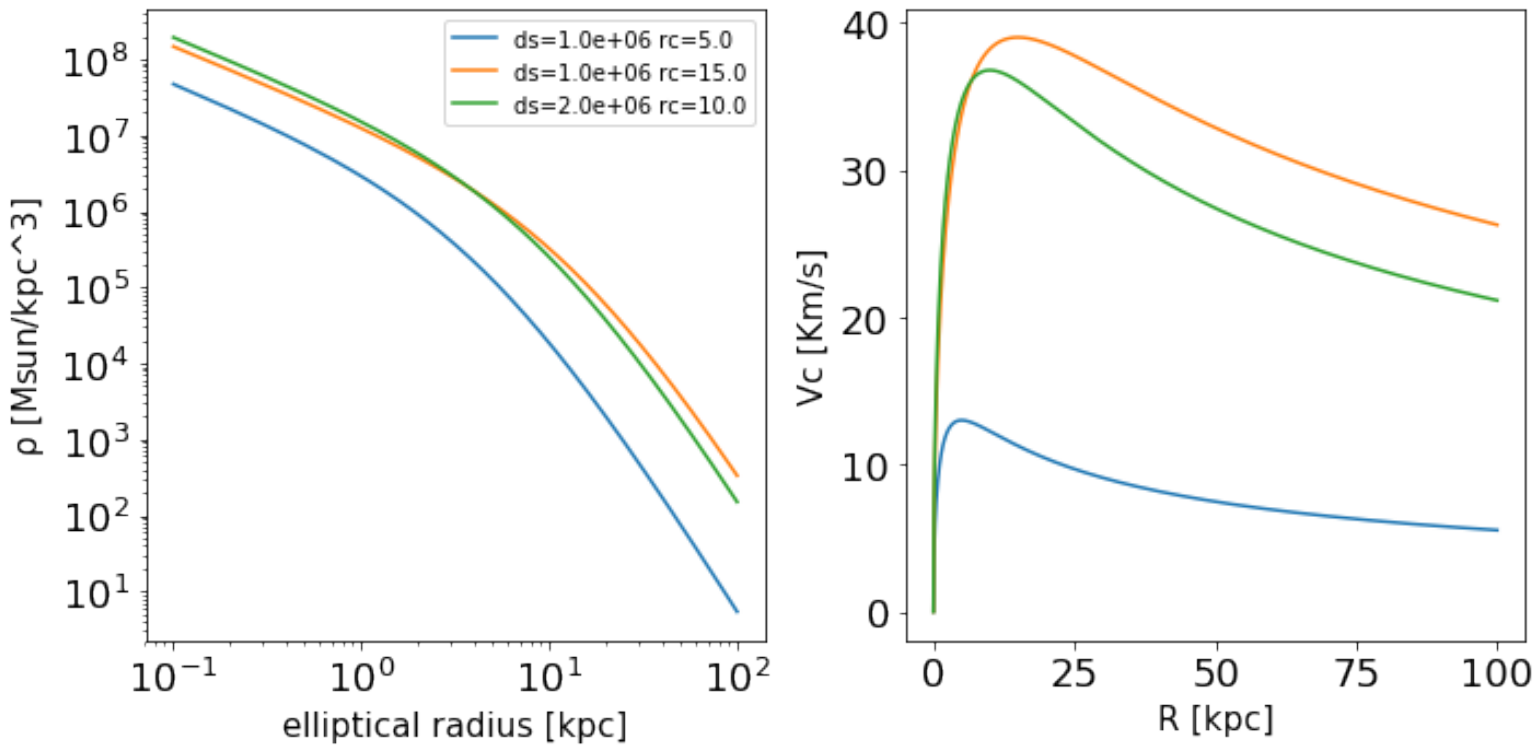


In [5]:
```
#hernquist halo
R=np.linspace(0,100,1000)
fig=plt.figure(figsize=(10,5))
axd=fig.add_subplot(121)
axv=fig.add_subplot(122)
```

```
R=np.linspace(0,100,1000)
#d=d0*( (m/rs)^(-1) ) * ( (1+m/rs)^(-2 )
mcut=100 #radius where d(m>mcut)=0
e=0 #ellipticity


d0=1e6 #Scale density in Msun/kpc3
rs=5 #Scale radius in Kpc
he_halo=dc.hernquist_halo(d0=d0, rs=rs, mcut=mcut, e=e)
dens=he_halo.dens(R) #3D dens
vcirc=he_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='ds=%.1e rc=%.1f'%(he_halo.d0,he_halo.rs))
axv.plot(R,vcirc[:,1],label='ds=%.1e rc=%.1f'%(he_halo.d0,he_halo.rs))

d0=1e6 #Scale density in Msun/kpc3
rs=15 #Scale radius in Kpc
he_halo=dc.hernquist_halo(d0=d0, rs=rs, mcut=mcut, e=e)
dens=he_halo.dens(R) #3D dens
vcirc=he_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='ds=%.1e rc=%.1f'%(he_halo.d0,he_halo.rs))
axv.plot(R,vcirc[:,1],label='ds=%.1e rc=%.1f'%(he_halo.d0,he_halo.rs))

d0=2e6 #Scale density in Msun/kpc3
rs=10 #Scale radius in Kpc
he_halo=dc.hernquist_halo(d0=d0, rs=rs, mcut=mcut, e=e)
dens=he_halo.dens(R) #3D dens
vcirc=he_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='ds=%.1e rc=%.1f'%(he_halo.d0,he_halo.rs))
axv.plot(R,vcirc[:,1],label='ds=%.1e rc=%.1f'%(he_halo.d0,he_halo.rs))

print(he_halo)


axd.set_xlabel('elliptical radius [kpc]', fontsize=15)
```

```
        axd.set_ylabel('$\\rho$ [Msun/kpc^3]', fontsize=15)
        axv.set_xlabel('R [kpc]', fontsize=15)
        axv.set_ylabel('Vc [Km/s]', fontsize=15)
        axd.set_xscale('log')
        axd.set_yscale('log')
        axd.legend()
        plt.show()
```

```
Model: Hernquist halo
d0: 2.00e+06 Msun/kpc3
rs: 10.00
e: 0.000
mcut: 100.000
```

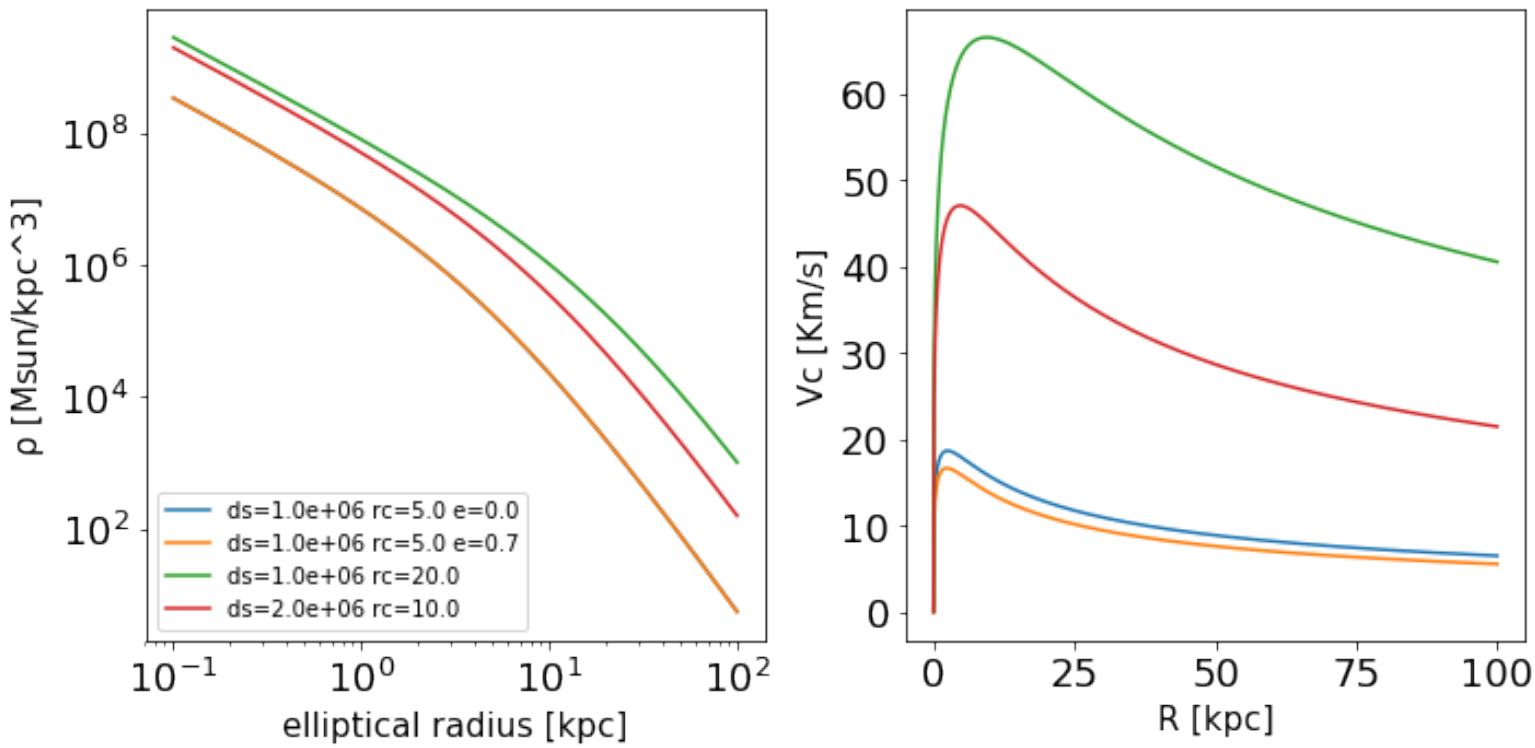


In [6]:
```
#deVacouler like halo
R=np.linspace(0,100,1000)
fig=plt.figure(figsize=(10,5))
axd=fig.add_subplot(121)
axv=fig.add_subplot(122)
R=np.linspace(0,100,1000)
#d=d0*( (m/rs)^(-3/2) ) * ( (1+m/rs)^(-5/2) )
#It is an approximation of the R1/4 law
mcut=100 #radius where d(m>mcut)=0
```

```
e=0 #ellipticity
d0=1e6 #Scale density in Msun/kpc3
rs=5 #Scale radius in Kpc
dv_halo=dc.deVacouler_like_halo(d0=d0, rs=rs, mcut=mcut, e=e)
dens=dv_halo.dens(R) #3D dens
vcirc=dv_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='ds=%.1e rc=%.1f e=%.1f'%(dv_halo.d0,dv_halo.rs,dv_halo.e))
axv.plot(R,vcirc[:,1],label='ds=%.1e rc=%.1f e=%.1f'%(dv_halo.d0,dv_halo.rs,dv_halo.e))

e=0.7 #ellipticity
d0=1e6 #Scale density in Msun/kpc3
rs=5 #Scale radius in Kpc
dv_halo=dc.deVacouler_like_halo(d0=d0, rs=rs, mcut=mcut, e=e)
dens=dv_halo.dens(R) #3D dens
vcirc=dv_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='ds=%.1e rc=%.1f e=%.1f'%(dv_halo.d0,dv_halo.rs,dv_halo.e))
axv.plot(R,vcirc[:,1],label='ds=%.1e rc=%.1f e=%.1f'%(dv_halo.d0,dv_halo.rs,dv_halo.e))

d0=1e6 #Scale density in Msun/kpc3
rs=20 #Scale radius in Kpc
dv_halo=dc.deVacouler_like_halo(d0=d0, rs=rs, mcut=mcut, e=e)
dens=dv_halo.dens(R) #3D dens
vcirc=dv_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='ds=%.1e rc=%.1f'%(dv_halo.d0,dv_halo.rs))
axv.plot(R,vcirc[:,1],label='ds=%.1e rc=%.1f'%(dv_halo.d0,dv_halo.rs))

d0=2e6 #Scale density in Msun/kpc3
rs=10 #Scale radius in Kpc
dv_halo=dc.deVacouler_like_halo(d0=d0, rs=rs, mcut=mcut, e=e)
dens=dv_halo.dens(R) #3D dens
vcirc=dv_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='ds=%.1e rc=%.1f'%(dv_halo.d0,dv_halo.rs))
axv.plot(R,vcirc[:,1],label='ds=%.1e rc=%.1f'%(dv_halo.d0,dv_halo.rs))
```

```
        print(dv_halo)

        axd.set_xlabel('elliptical radius [kpc]', fontsize=15)
        axd.set_ylabel('$\\rho$ [Msun/kpc^3]', fontsize=15)
        axv.set_xlabel('R [kpc]', fontsize=15)
        axv.set_ylabel('Vc [Km/s]', fontsize=15)
        axd.set_xscale('log')
        axd.set_yscale('log')
        axd.legend()
        plt.show()
```

```
Model: deVacouler like halo
d0: 2.00e+06 Msun/kpc3
rs: 10.00
e: 0.700
mcut: 100.000
```



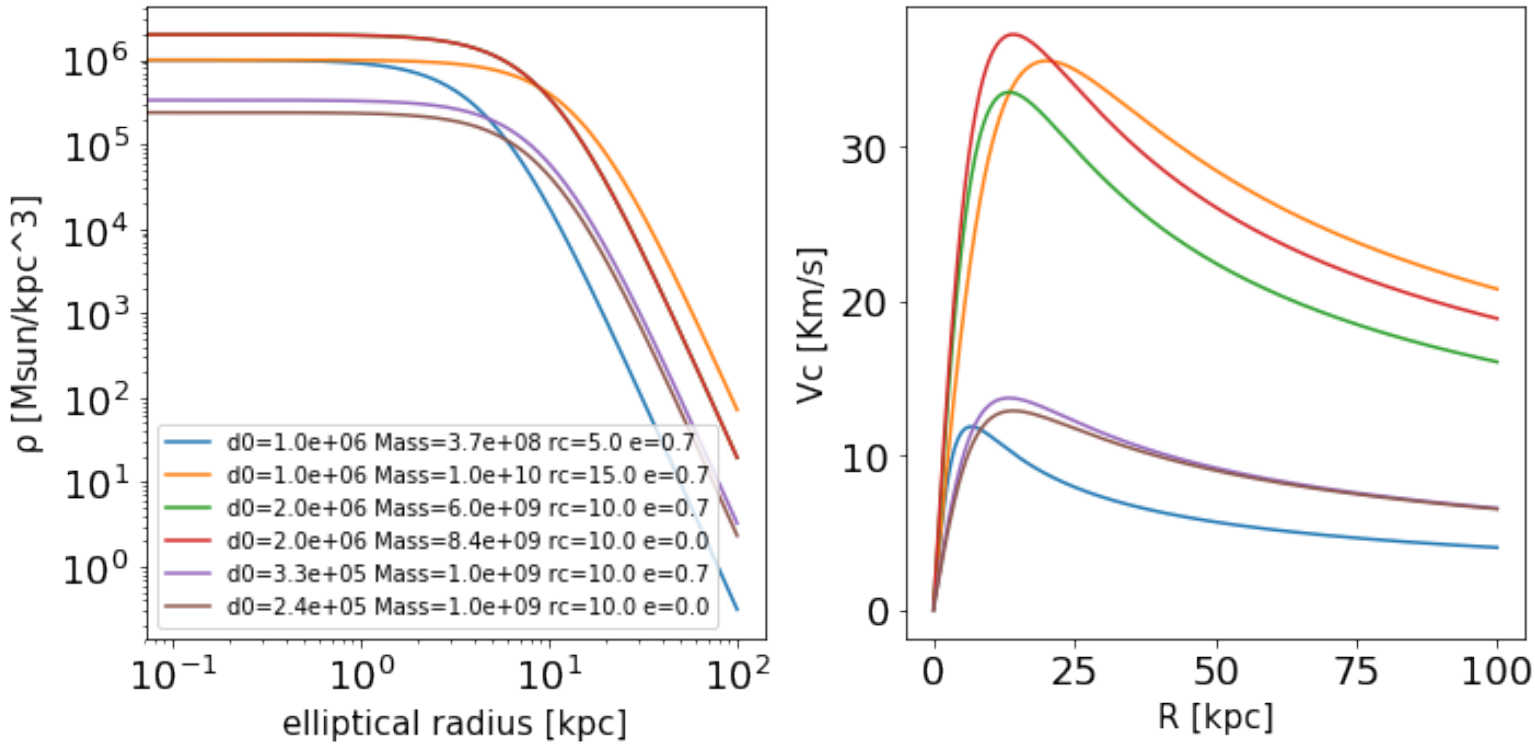
In [7]:
```
#Plummer halo
R=np.linspace(0,100,1000)
fig=plt.figure(figsize=(10,5))
axd=fig.add_subplot(121)
axv=fig.add_subplot(122)
R=np.linspace(0,100,1000)
#d=d0*( (1+m*m/rs*rs)^(-5/2) )
mcut=100 #radius where d(m>mcut)=0
e=0.7 #ellipticity
```

```
d0=1e6 #Central density in Msun/kpc3
rc=5 #Core radius in Kpc
pl_halo=dc.plummer_halo(d0=d0, rc=rc, mcut=mcut, e=e)
dens=pl_halo.dens(R) #3D dens
vcirc=pl_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%.1f'%(pl_halo.d0,pl_halo.mass,pl_halo.rc, pl_halo.e))
axv.plot(R,vcirc[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%1.f'%(pl_halo.d0,pl_halo.mass,pl_halo.rc, pl_halo.e))

d0=1e6 #Central density in Msun/kpc3
rc=15 #Core radius in Kpc
pl_halo=dc.plummer_halo(d0=d0, rc=rc, mcut=mcut, e=e)
dens=pl_halo.dens(R) #3D dens
vcirc=pl_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%.1f'%(pl_halo.d0,pl_halo.mass,pl_halo.rc, pl_halo.e))
axv.plot(R,vcirc[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%1.f'%(pl_halo.d0,pl_halo.mass,pl_halo.rc, pl_halo.e))

d0=2e6 #Central density in Msun/kpc3
rc=10 #Core radius in Kpc
pl_halo=dc.plummer_halo(d0=d0, rc=rc, mcut=mcut, e=e)
dens=pl_halo.dens(R) #3D dens
vcirc=pl_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%.1f'%(pl_halo.d0,pl_halo.mass,pl_halo.rc, pl_halo.e))
axv.plot(R,vcirc[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%1.f'%(pl_halo.d0,pl_halo.mass,pl_halo.rc, pl_halo.e))

d0=2e6 #Central density in Msun/kpc3
rc=10 #Core radius in Kpc
e=0
pl_halo=dc.plummer_halo(d0=d0, rc=rc, mcut=mcut, e=e)
dens=pl_halo.dens(R) #3D dens
vcirc=pl_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%.1f'%(pl_halo.d0,pl_halo.mass,pl_halo.rc, pl_halo.e))
axv.plot(R,vcirc[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%1.f'%(pl_halo.d0,pl_halo.mass,pl_halo.rc, pl_halo.e))

mass=1e9 #Central density in Msun/kpc3
```

```
rc=10 #Core radius in Kpc
e=0.7
pl_halo=dc.plummer_halo(mass=mass, rc=rc, mcut=mcut, e=e)
dens=pl_halo.dens(R) #3D dens
vcirc=pl_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%.1f'%(pl_halo.d0,pl_halo.mass,pl_halo.rc, pl_halo.e))
axv.plot(R,vcirc[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%1.f'%(pl_halo.d0,pl_halo.mass,pl_halo.rc, pl_halo.e))

mass=1e9 #Central density in Msun/kpc3
rc=10 #Core radius in Kpc
e=0
pl_halo=dc.plummer_halo(mass=mass, rc=rc, mcut=mcut, e=e)
dens=pl_halo.dens(R) #3D dens
vcirc=pl_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%.1f'%(pl_halo.d0,pl_halo.mass,pl_halo.rc, pl_halo.e))
axv.plot(R,vcirc[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%1.f'%(pl_halo.d0,pl_halo.mass,pl_halo.rc, pl_halo.e))



print(pl_halo)

axd.set_xlabel('elliptical radius [kpc]', fontsize=15)
axd.set_ylabel('$\\rho$ [Msun/kpc^3]', fontsize=15)
axv.set_xlabel('R [kpc]', fontsize=15)
axv.set_ylabel('Vc [Km/s]', fontsize=15)
axd.set_xscale('log')
axd.set_yscale('log')
axd.legend()
plt.show()
```

```
Model: Plummer halo
Mass: 1.00e+09 Msun
d0: 2.39e+05 Msun/kpc3
rc: 10.00
```

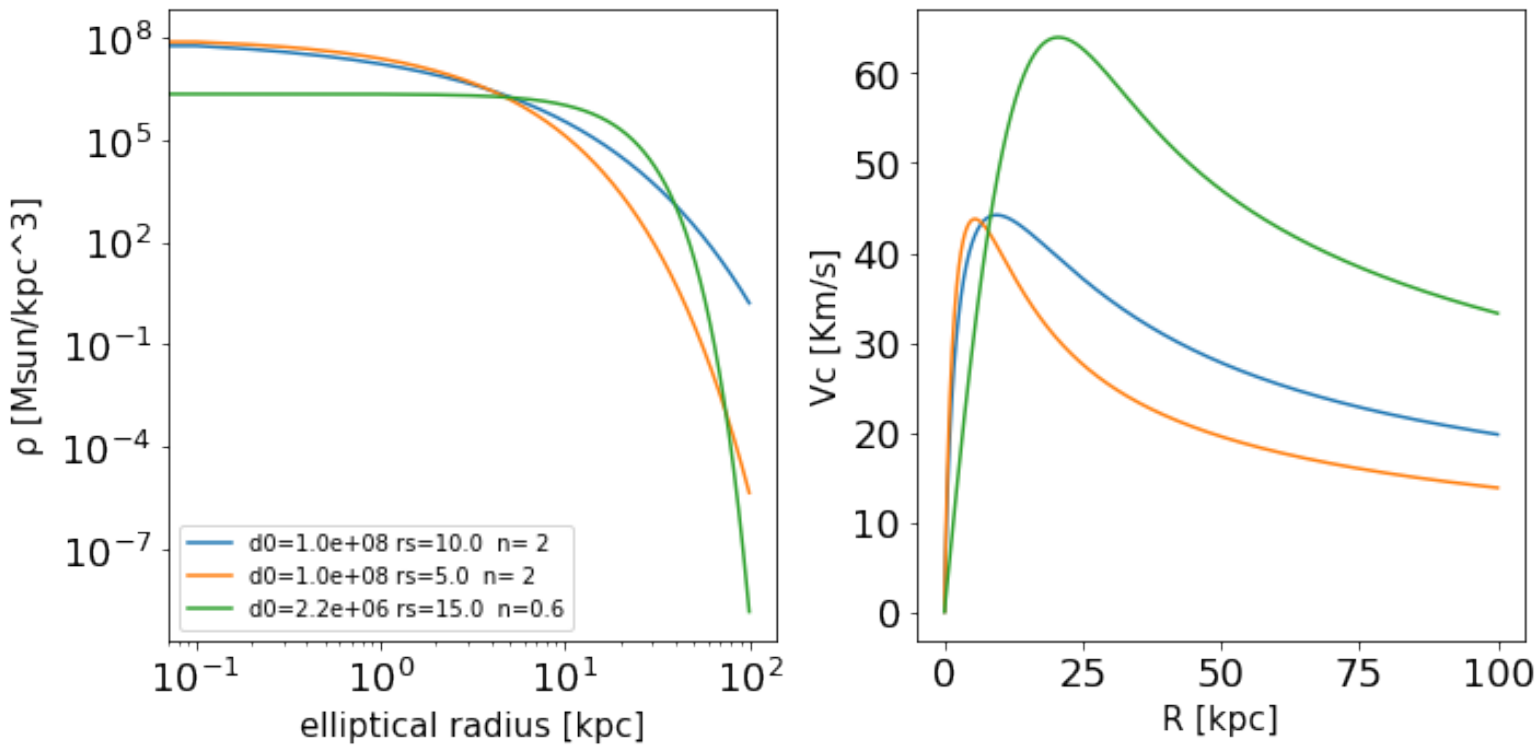
```
e: 0.000
mcut: 100.000
```



In [8]:
```
#Einasto halo
R=np.linspace(0,100,1000)
fig=plt.figure(figsize=(10,5))
axd=fig.add_subplot(121)
axv=fig.add_subplot(122)
```

```
R=np.linspace(0,100,1000)
mcut=100 #radius where d(m>mcut)=0
e=0.0 #ellipticity


#Primary use: einasto_halo(d0, n, rs, mcut=100, e=0)
# d=d0*exp(-dn*(r/rs)^(1/n))
#-d0 Central density in Msun/kpc3
#-n factor n
#-rs radius containing half the total mass of the halo



#Secondary use: einasto_halo.de(de, n, rs, mcut=100, e=0)
# d=de*exp(-2*n*((r/rs)^(1/n) - 1))
#-de Density at rs
#-n factor n
#-rs radius containing half the total mass of the halo



d0=1e8 #Central density in Msun/kpc3
n=2 #Factor n
rs=10 #Radius containing half the total mass of the halo
ei_halo=dc.einasto_halo(d0=d0, n=n, rs=rs, mcut=mcut, e=e)
dens=ei_halo.dens(R) #3D dens
vcirc=ei_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e rs=%.1f  n=%2.f'%(ei_halo.d0, ei_halo.rs, ei_halo.n))
axv.plot(R,vcirc[:,1],label='d0=%.1e rs=%.1f  n=%2.f'%(ei_halo.d0, ei_halo.rs, ei_halo.n))

d0=1e8 #Central density in Msun/kpc3
n=1.5 #Core radius in Kpc
rs=5
ei_halo=dc.einasto_halo(d0=d0, n=n, rs=rs, mcut=mcut, e=e)
```

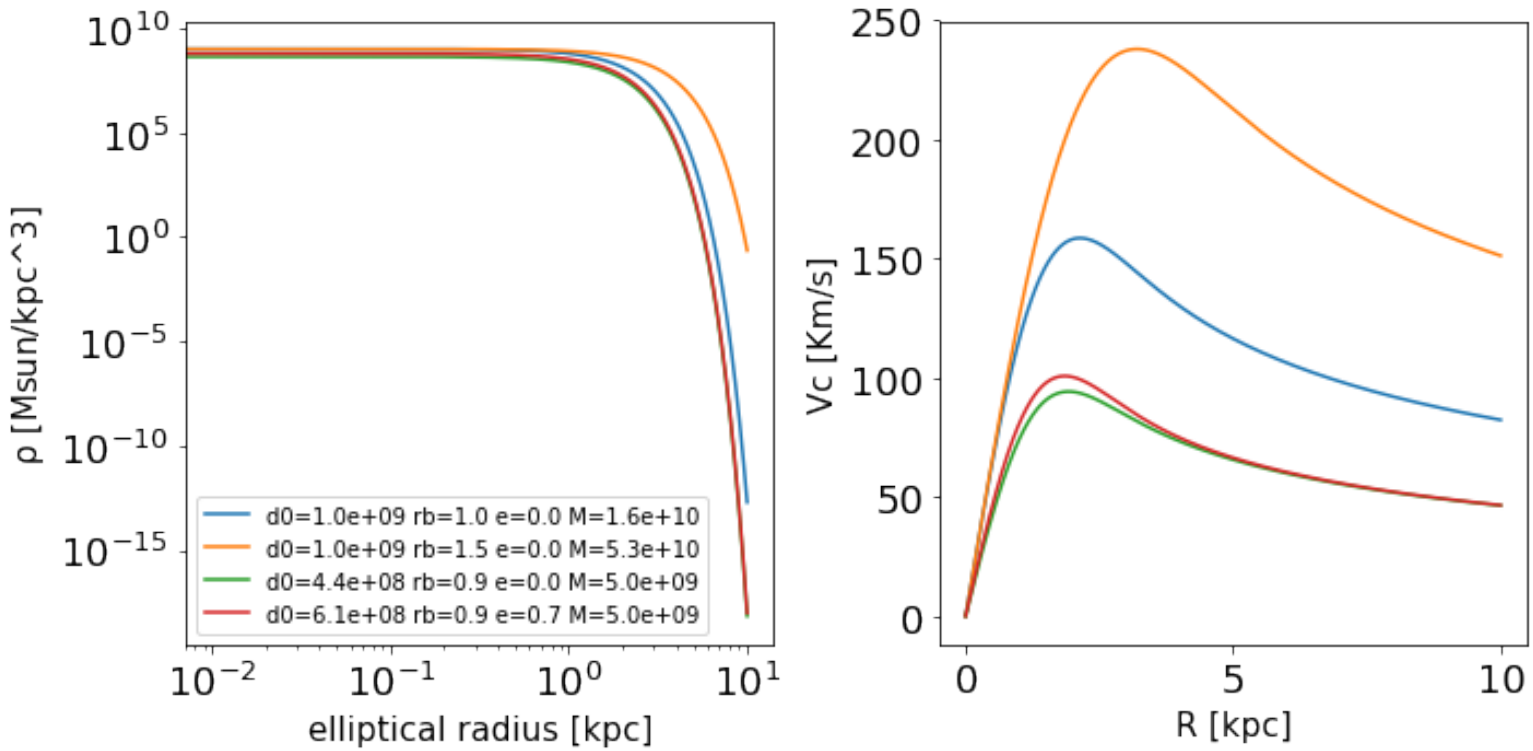
```
dens=ei_halo.dens(R) #3D dens
vcirc=ei_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e rs=%.1f  n=%2.f'%(ei_halo.d0, ei_halo.rs, ei_halo.n))
axv.plot(R,vcirc[:,1],label='d0=%.1e rs=%.1f  n=%2.f'%(ei_halo.d0, ei_halo.rs, ei_halo.n))


de=5e5 #Central density in Msun/kpc3
n=0.6 #Core radius in Kpc
rs=15
ei_halo=dc.einasto_halo.de(de=de, n=n, rs=rs, mcut=mcut, e=e)
dens=ei_halo.dens(R) #3D dens
vcirc=ei_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e rs=%.1f  n=%.1f'%(ei_halo.d0, ei_halo.rs, ei_halo.n))
axv.plot(R,vcirc[:,1],label='d0=%.1e rs=%.1f  n=%.1f'%(ei_halo.d0, ei_halo.rs, ei_halo.n))

axd.set_xlabel('elliptical radius [kpc]', fontsize=15)
axd.set_ylabel('$\\rho$ [Msun/kpc^3]', fontsize=15)
axv.set_xlabel('R [kpc]', fontsize=15)
axv.set_ylabel('Vc [Km/s]', fontsize=15)
axd.set_xscale('log')
axd.set_yscale('log')
axd.legend()
plt.show()
```



In [9]:
```
#Valy halo

#d=d0 * exp(-0.5*m*m/rb*rb)
#where d0=Mb/((2*pi)^1.5 * (1-e*e)^0.5 * rb^3 ) and Mb is the total mass of the halo

R=np.linspace(0,100,1000)
fig=plt.figure(figsize=(10,5))
axd=fig.add_subplot(121)
axv=fig.add_subplot(122)
R=np.linspace(0,10,1000)
```

```
mcut=100 #radius where d(m>mcut)=0


#It can be called using d0, e.g. dc.valy_halo(d0=1e8, rb=2)
#or using the total mass, e.g. dc.valy_halo(mass=1e10, rb=2)

e=0.0 #ellipticity
d0=1e9 #Central density in Msun/kpc3
rb=1 #Radius containing half the total mass of the halo
vy_halo=dc.valy_halo(d0=d0, rb=rb, mcut=mcut, e=e)
dens=vy_halo.dens(R) #3D dens
vcirc=vy_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e'%(vy_halo.d0, vy_halo.rc,vy_halo.e,vy_halo.mass))
axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(vy_halo.d0, vy_halo.rc,vy_halo.e,vy_halo.mass))

e=0.0 #ellipticity
d0=1e9 #Central density in Msun/kpc3
rb=1.5 #Radius containing half the total mass of the halo
vy_halo=dc.valy_halo(d0=d0, rb=rb, mcut=mcut, e=e)
dens=vy_halo.dens(R) #3D dens
vcirc=vy_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e'%(vy_halo.d0, vy_halo.rc,vy_halo.e,vy_halo.mass))
axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(vy_halo.d0, vy_halo.rc,vy_halo.e,vy_halo.mass))

e=0.0 #ellipticity
mass=5e9 #Central density in Msun/kpc3
rb=0.9 #Radius containing half the total mass of the halo
vy_halo=dc.valy_halo(mass=mass, rb=rb, mcut=mcut, e=e)
dens=vy_halo.dens(R) #3D dens
vcirc=vy_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e'%(vy_halo.d0, vy_halo.rc,vy_halo.e,vy_halo.mass))
axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(vy_halo.d0, vy_halo.rc,vy_halo.e,vy_halo.mass))

e=0.7 #ellipticity
```

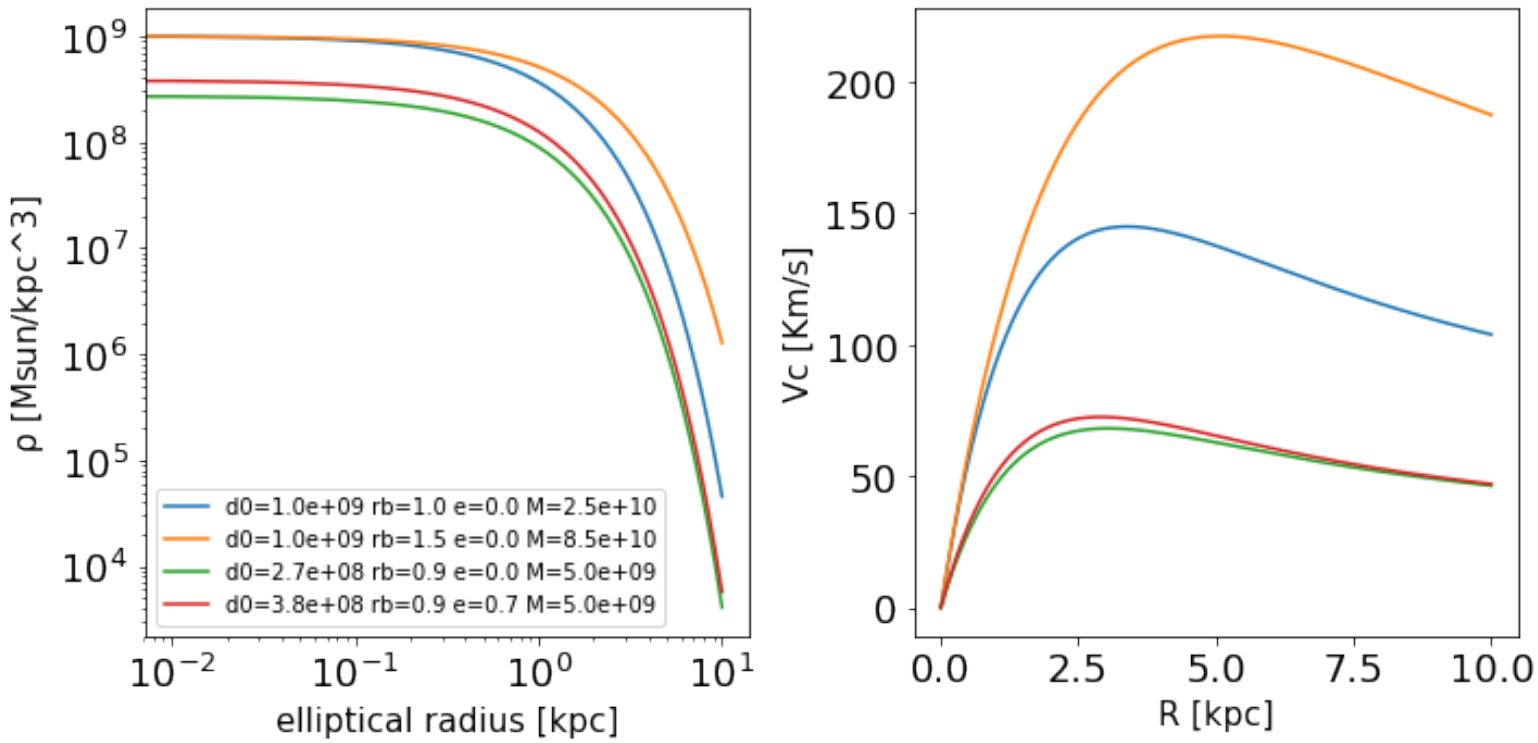
```
mass=5e9 #Central density in Msun/kpc3
rb=0.9 #Radius containing half the total mass of the halo
vy_halo=dc.valy_halo(mass=mass, rb=rb, mcut=mcut, e=e)
dens=vy_halo.dens(R) #3D dens
vcirc=vy_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e'%(vy_halo.d0, vy_halo.rc,vy_halo.e,vy_halo.mass))
axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(vy_halo.d0, vy_halo.rc,vy_halo.e,vy_halo.mass))


axd.set_xlabel('elliptical radius [kpc]', fontsize=15)
axd.set_ylabel('$\\rho$ [Msun/kpc^3]', fontsize=15)
axv.set_xlabel('R [kpc]', fontsize=15)
axv.set_ylabel('Vc [Km/s]', fontsize=15)
axd.set_xscale('log')
axd.set_yscale('log')
axd.legend()
plt.show()
```



In [10]:
```
#Exponential halo

#d=d0 * exp(-m/rb)
#where d0=Mb/((8*pi) * (1-e*e)^0.5 * rb^3 ) and Mb is the total mass of the halo

R=np.linspace(0,100,1000)
fig=plt.figure(figsize=(10,5))
axd=fig.add_subplot(121)
axv=fig.add_subplot(122)
R=np.linspace(0,10,1000)
```

```
mcut=100 #radius where d(m>mcut)=0


#It can be called using d0, e.g. dc.exponential_halo(d0=1e8, rb=2)
#or using the total mass, e.g. dc.exponential_halo(mass=1e10, rb=2)

e=0.0 #ellipticity
d0=1e9 #Central density in Msun/kpc3
rb=1 #Radius containing half the total mass of the halo
ex_halo=dc.exponential_halo(d0=d0, rb=rb, mcut=mcut, e=e)
dens=ex_halo.dens(R) #3D dens
vcirc=ex_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e'%(ex_halo.d0, ex_halo.rc,ex_halo.e,ex_halo.mass))
axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(ex_halo.d0, ex_halo.rc,ex_halo.e,ex_halo.mass))

e=0.0 #ellipticity
d0=1e9 #Central density in Msun/kpc3
rb=1.5 #Radius containing half the total mass of the halo
ex_halo=dc.exponential_halo(d0=d0, rb=rb, mcut=mcut, e=e)
dens=ex_halo.dens(R) #3D dens
vcirc=ex_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e'%(ex_halo.d0, ex_halo.rc,ex_halo.e,ex_halo.mass))
axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(ex_halo.d0, ex_halo.rc,ex_halo.e,ex_halo.mass))

e=0.0 #ellipticity
mass=5e9 #Central density in Msun/kpc3
rb=0.9 #Radius containing half the total mass of the halo
ex_halo=dc.exponential_halo(mass=mass, rb=rb, mcut=mcut, e=e)
dens=ex_halo.dens(R) #3D dens
vcirc=ex_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e'%(ex_halo.d0, ex_halo.rc,ex_halo.e,ex_halo.mass))
axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(ex_halo.d0, ex_halo.rc,ex_halo.e,ex_halo.mass))

e=0.7 #ellipticity
```

```
mass=5e9 #Central density in Msun/kpc3
rb=0.9 #Radius containing half the total mass of the halo
ex_halo=dc.exponential_halo(mass=mass, rb=rb, mcut=mcut, e=e)
dens=ex_halo.dens(R) #3D dens
vcirc=ex_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e'%(ex_halo.d0, ex_halo.rc, ex_halo.e, ex_halo.mass))
axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(ex_halo.d0, ex_halo.rc, ex_halo.e, ex_halo.mass))


axd.set_xlabel('elliptical radius [kpc]', fontsize=15)
axd.set_ylabel('$\\rho$ [Msun/kpc^3]', fontsize=15)
axv.set_xlabel('R [kpc]', fontsize=15)
axv.set_ylabel('Vc [Km/s]', fontsize=15)
axd.set_xscale('log')
axd.set_yscale('log')
axd.legend()
plt.show()
```



DISC MODELS

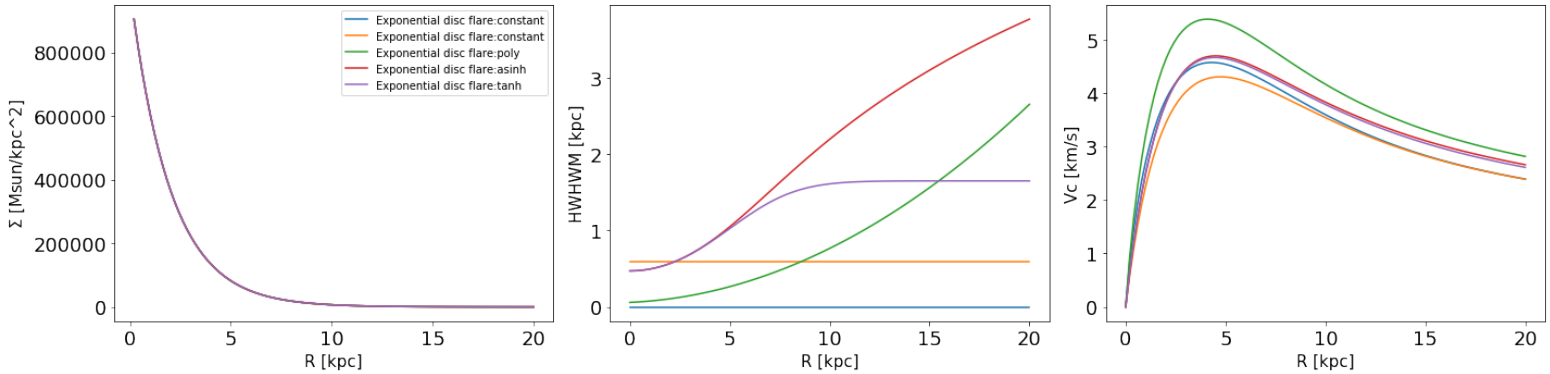
```
In [11]: #Exponential disc
         #Sigma(R)=Sigma0*Exp(-R/Rd)
         sigma0=1e6 #Cental surface density in Msun/kpc2
         Rd= 2 #Exponential scale length in kpc
         Rcut= 50 #Cylindrical radius where dens(R>Rcut,z)=0
         zcut= 20 #Cylindrical heigth where dens(R,|z|>zcut)=0
         zlaw='gau' #Vertical density law: it could be gau, sech2, exp

         fig=plt.figure(figsize=(20,5))
```

```
ax_dens=fig.add_subplot(131)
ax_flare=fig.add_subplot(132)
ax_vcirc=fig.add_subplot(133)
R=np.linspace(0,20,100) #Cylidrincal radii where estimate surface density and flare

#Vertical:
#razor-thin disc
ed=dc.Exponential_disc.thin(sigma0=sigma0, Rd=Rd, Rcut=Rcut, zcut=zcut)
sdens=ed.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=ed.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, def
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=ed.name + ' flare:'+ed.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])

#constant scale-heigth
zd=0.5 #Vertical scale heigth in kpc
ed=dc.Exponential_disc.thick(sigma0=sigma0, Rd=Rd, Rcut=Rcut, zcut=zcut,zd=zd, zlaw=zlaw)
sdens=ed.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=ed.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, def
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=ed.name + ' flare:'+ed.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])

#polynomial flare
pcoeff=[0.05,0.01,0.005] #Coefficent of the polynomial zd(R)=pcoeff[0]+pcoeff[1]*R+pcoeff[2]*R*R+....
ed=dc.Exponential_disc.polyflare(sigma0=sigma0, Rd=Rd, Rcut=Rcut, zcut=zcut, polycoeff=pcoeff, zlaw=zlaw)
sdens=ed.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=ed.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, def
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=ed.name + ' flare:'+ed.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])
```

```
#Asinh flare
#zd(R)=h0+c*(Arcsinh(R*R/Rf*Rf))
h0=0.4 #Cental zd in kpc
c=1 #
Rf=7 #Flaring scale length in kpc
ed=dc.Exponential_disc.asinhflare(sigma0=sigma0, Rd=Rd, Rcut=Rcut, zcut=zcut, h0=h0, c=c, Rf=Rf, zlaw=zlaw)
sdens=ed.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=ed.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, def
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=ed.name + ' flare:'+ed.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])

#Tanh flare
#zd(R)=h0+c*(tanh(R*R/Rf*Rf))
h0=0.4 #Cental zd in kpc
c=1 #
Rf=7 #Flaring scale length in kpc
ed=dc.Exponential_disc.tanhflare(sigma0=sigma0, Rd=Rd, Rcut=Rcut, zcut=zcut, h0=h0, c=c, Rf=Rf, zlaw=zlaw)
sdens=ed.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=ed.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, def
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=ed.name + ' flare:'+ed.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])
print(ed)

ax_dens.legend()
ax_dens.set_xlabel('R [kpc]',fontsize=15)
ax_vcirc.set_xlabel('R [kpc]',fontsize=15)
ax_flare.set_xlabel('R [kpc]',fontsize=15)
ax_dens.set_ylabel('$\Sigma$ [Msun/kpc^2]',fontsize=15)
ax_flare.set_ylabel('HWHWM [kpc]',fontsize=15)
```

```
        ax_vcirc.set_ylabel('Vc [km/s]',fontsize=15)
        plt.show()
```

```
Model: Exponential disc
Sigma0: 1.00e+06 Msun/kpc2
Vertical density law: gau
Radial density law: epoly
Rd: 2.000 kpc
Flaring law: tanh
Fparam: 4.0e-01 7.0e+00 1.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00
Rcut: 50.000 kpc
zcut: 20.000 kpc
Rlimit: None
```



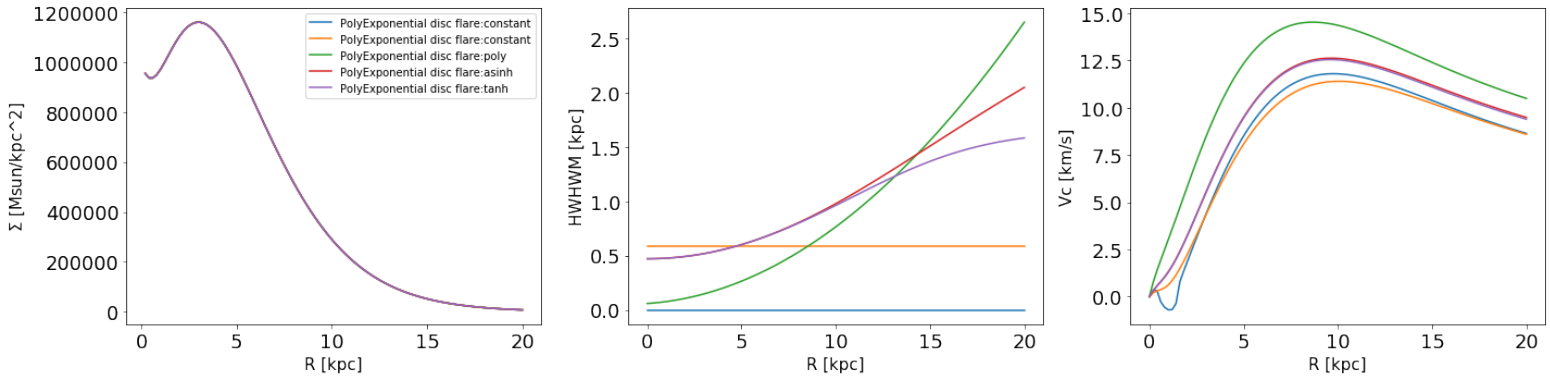
In [12]:
```
fig=plt.figure(figsize=(20,5))
ax_dens=fig.add_subplot(131)
ax_flare=fig.add_subplot(132)
ax_vcirc=fig.add_subplot(133)
R=np.linspace(0,20,100) #Cylidrincal radii where estimate surface density and flare
```

```
#Poly Exponential disc
#Sigma(R)=Sigma0*Exp(-R/Rd)*polynomial(R)
sigma0=1e6 #Cental surface density in Msun/kpc2
Rd= 2 #Exponential scale length in kpc
Rcoeff=[1,0.2,0.4] #Coefficent of the polynomial(R)=Rcoeff[0]+Rcoeff[1]*R+Rcoeff[2]*R*R+....
                    #Rcoeff will be always renormalised to have Rcoeff[0]=1
Rcut= 50 #Cylindrical radius where dens(R>Rcut,z)=0
zcut= 20 #Cylindrical heigth where dens(R,|z|>zcut)=0
zlaw='gau' #Vertical density law: it could be gau, sech2, exp
#Vertical:
#razor-thin disc
epd=dc.PolyExponential_disc.thin(sigma0=sigma0, Rd=Rd, coeff=Rcoeff, Rcut=Rcut, zcut=zcut)
sdens=epd.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=epd.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, de
vcirc=epd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=epd.name + ' flare:'+epd.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])

#constant scale-heigth
zd=0.5 #Vertical scale heigth in kpc
epd=dc.PolyExponential_disc.thick(sigma0=sigma0, Rd=Rd, coeff=Rcoeff, Rcut=Rcut, zcut=zcut, zd=zd, zlaw=zlaw)
sdens=epd.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=epd.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, de
vcirc=epd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=epd.name + ' flare:'+epd.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])

#polynomial flare
pcoeff=[0.05,0.01,0.005] #Coefficent of the polynomial zd(R)=pcoeff[0]+pcoeff[1]*R+pcoeff[2]*R*R+....
```

```
epd=dc.PolyExponential_disc.polyflare(sigma0=sigma0, Rd=Rd, coeff=Rcoeff, Rcut=Rcut, zcut=zcut, polycoeff=pcoeff, zlaw=
sdens=epd.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=epd.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, de
vcirc=epd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=epd.name + ' flare:'+epd.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])

#Asinh flare
#zd(R)=h0+c*(Arcsinh(R*R/Rf*Rf))
h0=0.4 #Cental zd in kpc
c=1 #
Rf=15 #Flaring scale length in kpc
epd=dc.PolyExponential_disc.asinhflare(sigma0=sigma0, Rd=Rd, coeff=Rcoeff, Rcut=Rcut, zcut=zcut, h0=h0, c=c, Rf=Rf, zla
sdens=epd.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=epd.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, de
vcirc=epd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=epd.name + ' flare:'+epd.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])

#Tanh flare
#zd(R)=h0+c*(tanh(R*R/Rf*Rf))
h0=0.4 #Cental zd in kpc
c=1 #
Rf=15 #Flaring scale length in kpc
epd=dc.PolyExponential_disc.tanhflare(sigma0=sigma0, Rd=Rd, coeff=Rcoeff, Rcut=Rcut, zcut=zcut, h0=h0, c=c, Rf=Rf, zlaw
sdens=epd.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=epd.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, de
vcirc=epd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=epd.name + ' flare:'+epd.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])
print(epd)
```

```
        ax_dens.legend()
        ax_dens.set_xlabel('R [kpc]',fontsize=15)
        ax_vcirc.set_xlabel('R [kpc]',fontsize=15)
        ax_flare.set_xlabel('R [kpc]',fontsize=15)
        ax_dens.set_ylabel('$\Sigma$ [Msun/kpc^2]',fontsize=15)
        ax_flare.set_ylabel('HWHWM [kpc]',fontsize=15)
        ax_vcirc.set_ylabel('Vc [km/s]',fontsize=15)
        plt.show()
```

```
Model: PolyExponential disc
Sigma0: 1.00e+06 Msun/kpc2
Vertical density law: gau
Radial density law: epoly
Rd: 2.000 kpc
Polycoeff: 0.0e+00 1.0e+00 2.0e-01 4.0e-01 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00
Flaring law: tanh
Fparam: 4.0e-01 1.5e+01 1.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00
Rcut: 50.000 kpc
zcut: 20.000 kpc
Rlimit: None
```



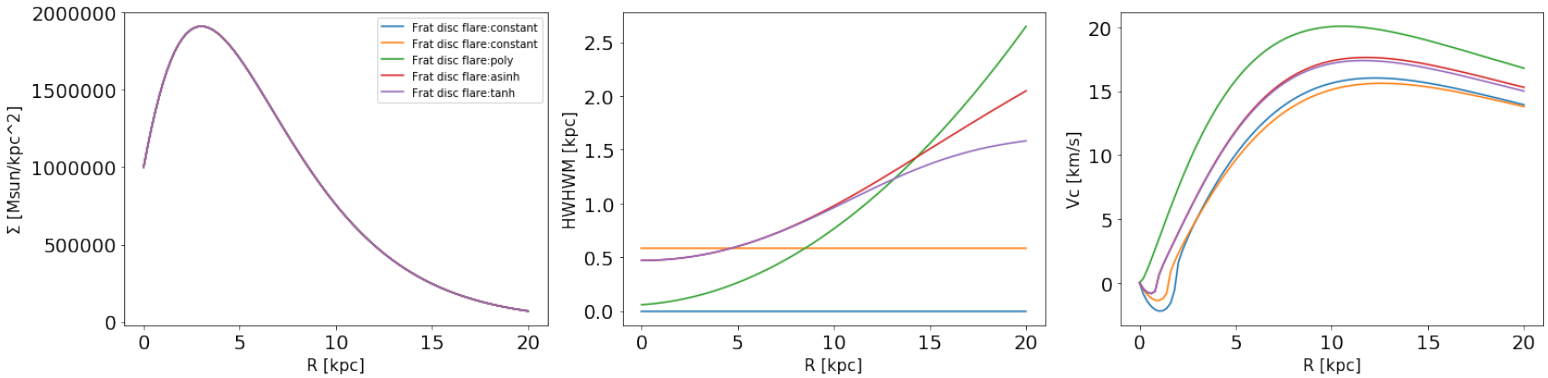
In [13]:
```
fig=plt.figure(figsize=(20,5))
ax_dens=fig.add_subplot(131)
ax_flare=fig.add_subplot(132)
ax_vcirc=fig.add_subplot(133)
R=np.linspace(0,20,100) #Cylidrincal radii where estimate surface density and flare

#Frat disc
#Sigma(R)=Sigma0*Exp(-R/Rd)*(1+R/Rd2)^alfa
sigma0=1e6 #Cental surface density in Msun/kpc2
Rd= 3 #Exponential scale length in kpc
Rd2= 1.5 #Secondary scale length in kpc
alfa= 1.5 #Exponent
Rcut= 50 #Cylindrical radius where dens(R>Rcut,z)=0
zcut= 20 #Cylindrical heigth where dens(R,|z|>zcut)=0
zlaw='gau' #Vertical density law: it could be gau, sech2, exp
#Vertical:
#razor-thin disc
ed=dc.Frat_disc.thin(sigma0=sigma0, Rd=Rd, Rd2=Rd2,alpha=alfa, Rcut=Rcut, zcut=zcut)
sdens=ed.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=ed.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, def
```

```
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=ed.name + ' flare:'+ed.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])

#constant scale-heigth
zd=0.5 #Vertical scale heigth in kpc
ed=dc.Frat_disc.thick(sigma0=sigma0, Rd=Rd,Rd2=Rd2,alpha=alfa, Rcut=Rcut, zcut=zcut,zd=zd, zlaw=zlaw)
sdens=ed.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=ed.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, def
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=ed.name + ' flare:'+ed.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])

#polynomial flare
pcoeff=[0.05,0.01,0.005] #Coefficent of the polynomial zd(R)=pcoeff[0]+pcoeff[1]*R+pcoeff[2]*R*R+....
ed=dc.Frat_disc.polyflare(sigma0=sigma0, Rd=Rd,Rd2=Rd2,alpha=alfa,  Rcut=Rcut, zcut=zcut, polycoeff=pcoeff, zlaw=zlaw)
sdens=ed.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=ed.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, def
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=ed.name + ' flare:'+ed.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])

#Asinh flare
#zd(R)=h0+c*(Arcsinh(R*R/Rf*Rf))
h0=0.4 #Cental zd in kpc
c=1 #
Rf=15 #Flaring scale length in kpc
ed=dc.Frat_disc.asinhflare(sigma0=sigma0, Rd=Rd, Rd2=Rd2,alpha=alfa, Rcut=Rcut, zcut=zcut, h0=h0, c=c, Rf=Rf, zlaw=zlaw
sdens=ed.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=ed.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, def
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
```

```
ax_dens.plot(R, sdens[:,1], label=ed.name + ' flare:'+ed.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])

#Tanh flare
#zd(R)=h0+c*(tanh(R*R/Rf*Rf))
h0=0.4 #Cental zd in kpc
c=1 #
Rf=15 #Flaring scale length in kpc
ed=dc.Frat_disc.tanhflare(sigma0=sigma0, Rd=Rd, Rd2=Rd2,alpha=alfa, Rcut=Rcut, zcut=zcut, h0=h0, c=c, Rf=Rf, zlaw=zlaw)
sdens=ed.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=ed.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, def
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=ed.name + ' flare:'+ed.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])
print(ed)


ax_dens.legend()
ax_dens.set_xlabel('R [kpc]',fontsize=15)
ax_vcirc.set_xlabel('R [kpc]',fontsize=15)
ax_flare.set_xlabel('R [kpc]',fontsize=15)
ax_dens.set_ylabel('$\Sigma$ [Msun/kpc^2]',fontsize=15)
ax_flare.set_ylabel('HWHWM [kpc]',fontsize=15)
ax_vcirc.set_ylabel('Vc [km/s]',fontsize=15)
plt.show()
```

```
Model: Frat disc
Sigma0: 1.00e+06 Msun/kpc2
Vertical density law: gau
Radial density law: fratlaw
Rd: 3.00 kpc
Rd2: 1.50 kpc
alpha: 1.50
```

```
Flaring law: tanh
Fparam: 4.0e-01 1.5e+01 1.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00
Rcut: 50.000 kpc
zcut: 20.000 kpc
Rlimit: None
```



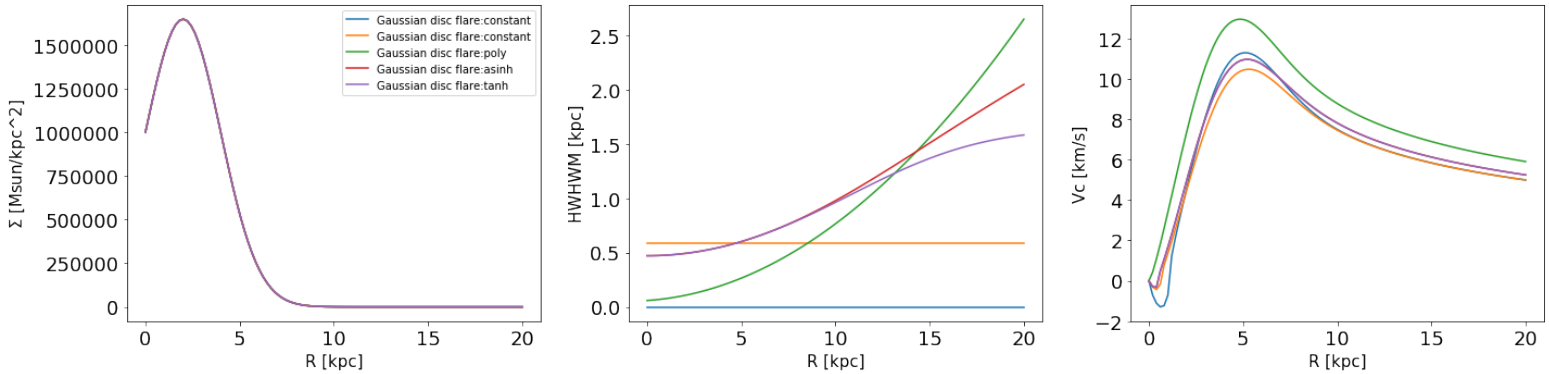
In [14]:
```
fig=plt.figure(figsize=(20,5))
ax_dens=fig.add_subplot(131)
ax_flare=fig.add_subplot(132)
ax_vcirc=fig.add_subplot(133)
R=np.linspace(0,20,100) #Cylidrincal radii where estimate surface density and flare

#Gau disc
#Sigma(R)=Sigma0*Exp(-0.5*((R-R0)/sigmad)^2)
sigma0=1e6 #Cental surface density in Msun/kpc2
R0= 2 #Radius where Sigma reach the peak
sigmad= 2 #Dispersion
Rcut= 50 #Cylindrical radius where dens(R>Rcut,z)=0
```

```
zcut= 20 #Cylindrical heigth where dens(R,|z|>zcut)=0
zlaw='gau' #Vertical density law: it could be gau, sech2, exp
#Vertical:
#razor-thin disc
gd=dc.Gaussian_disc.thin(sigma0=sigma0, sigmad=sigmad, R0=R0, Rcut=Rcut, zcut=zcut)
sdens=gd.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=gd.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, def
vcirc=gd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=gd.name + ' flare:'+gd.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])


#constant scale-heigth
zd=0.5 #Vertical scale heigth in kpc
gd=dc.Gaussian_disc.thick(sigma0=sigma0, sigmad=sigmad, R0=R0, Rcut=Rcut, zcut=zcut,zd=zd, zlaw=zlaw)
sdens=gd.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=gd.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, def
vcirc=gd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=gd.name + ' flare:'+gd.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])


#polynomial flare
pcoeff=[0.05,0.01,0.005] #Coefficent of the polynomial zd(R)=pcoeff[0]+pcoeff[1]*R+pcoeff[2]*R*R+....
gd=dc.Gaussian_disc.polyflare(sigma0=sigma0, sigmad=sigmad, R0=R0,  Rcut=Rcut, zcut=zcut, polycoeff=pcoeff, zlaw=zlaw)
sdens=gd.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=gd.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, def
vcirc=gd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=gd.name + ' flare:'+gd.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])
```

```
#Asinh flare
#zd(R)=h0+c*(Arcsinh(R*R/Rf*Rf))
h0=0.4 #Cental zd in kpc
c=1 #
Rf=15 #Flaring scale length in kpc
gd=dc.Gaussian_disc.asinhflare(sigma0=sigma0, sigmad=sigmad, R0=R0, Rcut=Rcut, zcut=zcut, h0=h0, c=c, Rf=Rf, zlaw=zlaw)
sdens=gd.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=gd.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, def
vcirc=gd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=gd.name + ' flare:'+gd.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])


#Tanh flare
#zd(R)=h0+c*(tanh(R*R/Rf*Rf))
h0=0.4 #Cental zd in kpc
c=1 #
Rf=15 #Flaring scale length in kpc
gd=dc.Gaussian_disc.tanhflare(sigma0=sigma0, sigmad=sigmad, R0=R0, Rcut=Rcut, zcut=zcut, h0=h0, c=c, Rf=Rf, zlaw=zlaw)
sdens=gd.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=gd.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col-1 zd or HWHM (if HWHM=True, def
vcirc=gd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the plane [km/s]
ax_dens.plot(R, sdens[:,1], label=gd.name + ' flare:'+gd.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])


print(gd)


ax_dens.legend()
ax_dens.set_xlabel('R [kpc]',fontsize=15)
```

```
        ax_vcirc.set_xlabel('R [kpc]',fontsize=15)
        ax_flare.set_xlabel('R [kpc]',fontsize=15)
        ax_dens.set_ylabel('$\Sigma$ [Msun/kpc^2]',fontsize=15)
        ax_flare.set_ylabel('HWHWM [kpc]',fontsize=15)
        ax_vcirc.set_ylabel('Vc [km/s]',fontsize=15)
        plt.show()
```

```
Model: Gaussian disc
Sigma0: 1.00e+06 Msun/kpc2
Vertical density law: gau
Radial density law: gau
sigmad: 2.000 kpc
R0: 2.000 kpc
Flaring law: tanh
Fparam: 4.0e-01 1.5e+01 1.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00
Rcut: 50.000 kpc
zcut: 20.000 kpc
Rlimit: None
```



Notes on disc components class.

-Initialize a class with data:
It is possible to define a disc component fitting some data. If we want to fit the surface density we must define a disc model using the parameter rfit_array,while if we want to fit the flaring we must use the ffit_array. In both cases the array should be an array containing the R in the first column the data in the second and if present the data error on the third column. If the chosen flaring law is polynomial we must provide also the degree of the polynomial with the keyword fitdegree. Examples below

```
In [15]: #We want a razor-thin disc with a exponential surface density law obtained fittig some observed data
         #oberserved data
         R=np.linspace(0.1,30,20)
         sigma_o=1e6*np.exp(-R/4)
         observed_data=np.zeros(shape=(20,2))
         observed_data[:,0]=R
         observed_data[:,1]=sigma_o
         #define the model
         ed=dc.Exponential_disc.thin(rfit_array=observed_data)
         print(ed)

         #We want an exponential disc with a polynomial flare
         #flaring data
         zd=lambda R,a1,a2,a3: a1+a2*R+a3*R*R
         zd_o=zd(R,0.4,0.01,0.2)
         observed_dataf=np.zeros(shape=(20,2))
         observed_dataf[:,0]=R
         observed_dataf[:,1]=zd_o
         ed=dc.Exponential_disc.polyflare(rfit_array=observed_data,ffit_array=observed_dataf,fitdegree=3,zlaw='gau')
         print(ed)
```

```
Model: Exponential disc
Sigma0: 1.00e+06 Msun/kpc2
Vertical density law: dirac
Radial density law: epoly
Rd: 4.000 kpc
Flaring law: constant
Fparam: 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00
Rcut: 50.000 kpc
```

```
zcut: 30.000 kpc
Rlimit: None

Model: Exponential disc
Sigma0: 1.00e+06 Msun/kpc2
Vertical density law: gau
Radial density law: epoly
Rd: 4.000 kpc
Flaring law: poly
Fparam: 4.0e-01 1.0e-02 2.0e-01 3.5e-18 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00
Rcut: 50.000 kpc
zcut: 30.000 kpc
Rlimit: None
```

POTENTIAL ESTIMATE

In [16]:
```
#Estimate the potential of a single component

        #Define model
        d0=1e6 #Cental density in Msun/kpc3
        rc=5 #Core radius in Kpc
        mcut=100 #radius where d(m>mcut)=0
        e=0 #ellipticity
        iso_halo=dc.isothermal_halo(d0=d0, rc=rc, mcut=mcut, e=e)

        #Estimate potential
        R=np.linspace(0,6,6) #List with the cylindrical radial coordinates in Kpc
        Z=np.linspace(0,3,6) #List with the cylindrical vertical coordinates in Kpc
        grid=True #If True create a grid from R and Z, otherwise estimate the potentail in the points (R[0],z[0]) (R[1],Z[1])..
        nproc=2 #Number of proccesors to use for parallel computation
        toll=1e-4 #Relative and absolute Tollerance for the potential integration
        output='1D' #It sets the shape of the output data.. see below
        potential_grid=iso_halo.potential(R=R,Z=Z,grid=grid,nproc=2,output=output)
```

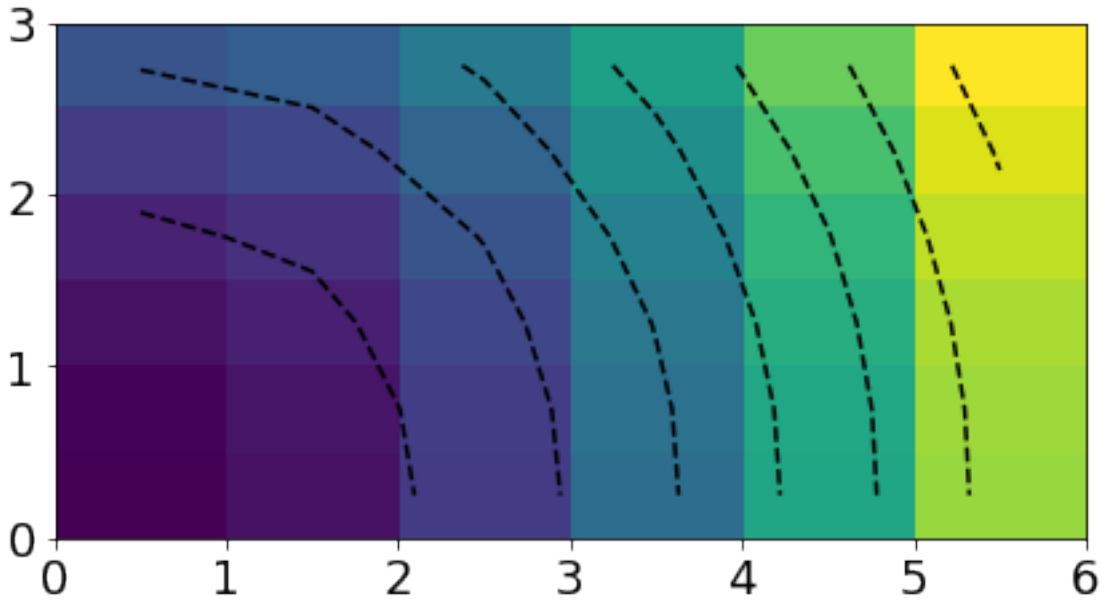
```
print('OUTPUT= 1D')
print(potential_grid)
#If output='1D' potential returns a array with dimension (len(R)*len(Z),3) if grid=True and (len(R),3) if grid=False an
#First Column -R
#Second Column -Z
#Third Column Potenzial in Kpc^2/Myr^2

output='2D'
grid=True
potential_grid=iso_halo.potential(R=R,Z=Z,grid=grid,nproc=2,output=output)
print('OUTPUT= 2D')
print(potential_grid)
#If output='2D' potential returns am array with dimension (3,len(R),len(Z)). It contains a series of three maps with di
#In each map at the map position i,j we have:
#Map 0 (potential_grid[0]) - R coordinates at i,j
#Map 1 (potential_grid[1]) - Z coordinates at i,j
#Map 2 (potential_grid[2]) - Value of the potential  in Kpc^2/Myr^2 at i,j
#Using this format we can pass the output to imshow or contour directly, e.g.:
plt.imshow(potential_grid[2].T,origin='lower',extent=(np.min(R),np.max(R),np.min(Z),np.max(Z)))
plt.contour(potential_grid[2].T,origin='lower',extent=(np.min(R),np.max(R),np.min(Z),np.max(Z)),colors='black')


#NOTE:
#-If len(R)!=len(Z)  and grid=False, grid is automatically set to True. A warning message is printed.
#-output='2D' can be used only if grid=True (or len(R)!=len(Z)) othwerwise an error is raised.
```

```
OUTPUT= 1D
[[ 0.00000000e+00  0.00000000e+00 -4.23561904e-03]
 [ 0.00000000e+00  6.00000000e-01 -4.23224169e-03]
 [ 0.00000000e+00  1.20000000e+00 -4.22227964e-03]
 [ 0.00000000e+00  1.80000000e+00 -4.20621062e-03]
 [ 0.00000000e+00  2.40000000e+00 -4.18473625e-03]
 [ 0.00000000e+00  3.00000000e+00 -4.15867710e-03]
 [ 1.20000000e+00  0.00000000e+00 -4.22227964e-03]
```

```
 [ 1.20000000e+00  6.00000000e-01 -4.21901377e-03]
 [ 1.20000000e+00  1.20000000e+00 -4.20937334e-03]
 [ 1.20000000e+00  1.80000000e+00 -4.19380134e-03]
 [ 1.20000000e+00  2.40000000e+00 -4.17295211e-03]
 [ 1.20000000e+00  3.00000000e+00 -4.14759688e-03]
 [ 2.40000000e+00  0.00000000e+00 -4.18473625e-03]
 [ 2.40000000e+00  6.00000000e-01 -4.18175852e-03]
 [ 2.40000000e+00  1.20000000e+00 -4.17295211e-03]
 [ 2.40000000e+00  1.80000000e+00 -4.15867710e-03]
 [ 2.40000000e+00  2.40000000e+00 -4.13947308e-03]
 [ 2.40000000e+00  3.00000000e+00 -4.11598857e-03]
 [ 3.60000000e+00  0.00000000e+00 -4.12887672e-03]
 [ 3.60000000e+00  6.00000000e-01 -4.12626807e-03]
 [ 3.60000000e+00  1.20000000e+00 -4.11853560e-03]
 [ 3.60000000e+00  1.80000000e+00 -4.10594730e-03]
 [ 3.60000000e+00  2.40000000e+00 -4.08891178e-03]
 [ 3.60000000e+00  3.00000000e+00 -4.06793205e-03]
 [ 4.80000000e+00  0.00000000e+00 -4.06115250e-03]
 [ 4.80000000e+00  6.00000000e-01 -4.05891522e-03]
 [ 4.80000000e+00  1.20000000e+00 -4.05226930e-03]
 [ 4.80000000e+00  1.80000000e+00 -4.04140535e-03]
 [ 4.80000000e+00  2.40000000e+00 -4.02661880e-03]
 [ 4.80000000e+00  3.00000000e+00 -4.00828177e-03]
 [ 6.00000000e+00  0.00000000e+00 -3.98681207e-03]
 [ 6.00000000e+00  6.00000000e-01 -3.98490833e-03]
 [ 6.00000000e+00  1.20000000e+00 -3.97924299e-03]
 [ 6.00000000e+00  1.80000000e+00 -3.96994962e-03]
 [ 6.00000000e+00  2.40000000e+00 -3.95723811e-03]
 [ 6.00000000e+00  3.00000000e+00 -3.94137798e-03]]
OUTPUT= 2D
[[[ 0.00000000e+00  0.00000000e+00  0.00000000e+00  0.00000000e+00
    0.00000000e+00  0.00000000e+00]
  [ 1.20000000e+00  1.20000000e+00  1.20000000e+00  1.20000000e+00
    1.20000000e+00  1.20000000e+00]
```

```
 [ 2.40000000e+00  2.40000000e+00  2.40000000e+00  2.40000000e+00
   2.40000000e+00  2.40000000e+00]
 [ 3.60000000e+00  3.60000000e+00  3.60000000e+00  3.60000000e+00
   3.60000000e+00  3.60000000e+00]
 [ 4.80000000e+00  4.80000000e+00  4.80000000e+00  4.80000000e+00
   4.80000000e+00  4.80000000e+00]
 [ 6.00000000e+00  6.00000000e+00  6.00000000e+00  6.00000000e+00
   6.00000000e+00  6.00000000e+00]]

[[ 0.00000000e+00  6.00000000e-01  1.20000000e+00  1.80000000e+00
   2.40000000e+00  3.00000000e+00]
 [ 0.00000000e+00  6.00000000e-01  1.20000000e+00  1.80000000e+00
   2.40000000e+00  3.00000000e+00]
 [ 0.00000000e+00  6.00000000e-01  1.20000000e+00  1.80000000e+00
   2.40000000e+00  3.00000000e+00]
 [ 0.00000000e+00  6.00000000e-01  1.20000000e+00  1.80000000e+00
   2.40000000e+00  3.00000000e+00]
 [ 0.00000000e+00  6.00000000e-01  1.20000000e+00  1.80000000e+00
   2.40000000e+00  3.00000000e+00]
 [ 0.00000000e+00  6.00000000e-01  1.20000000e+00  1.80000000e+00
   2.40000000e+00  3.00000000e+00]]

[[-4.23561904e-03 -4.23224169e-03 -4.22227964e-03 -4.20621062e-03
  -4.18473625e-03 -4.15867710e-03]
 [-4.22227964e-03 -4.21901377e-03 -4.20937334e-03 -4.19380134e-03
  -4.17295211e-03 -4.14759688e-03]
 [-4.18473625e-03 -4.18175852e-03 -4.17295211e-03 -4.15867710e-03
  -4.13947308e-03 -4.11598857e-03]
 [-4.12887672e-03 -4.12626807e-03 -4.11853560e-03 -4.10594730e-03
  -4.08891178e-03 -4.06793205e-03]
 [-4.06115250e-03 -4.05891522e-03 -4.05226930e-03 -4.04140535e-03
  -4.02661880e-03 -4.00828177e-03]
 [-3.98681207e-03 -3.98490833e-03 -3.97924299e-03 -3.96994962e-03
  -3.95723811e-03 -3.94137798e-03]]]
```

Out[16]: <matplotlib.contour.QuadContourSet at 0x115b03588>

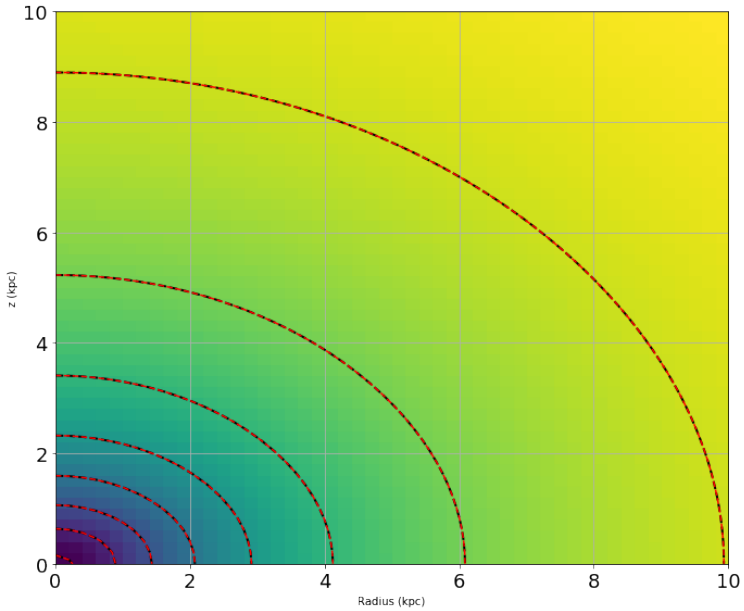


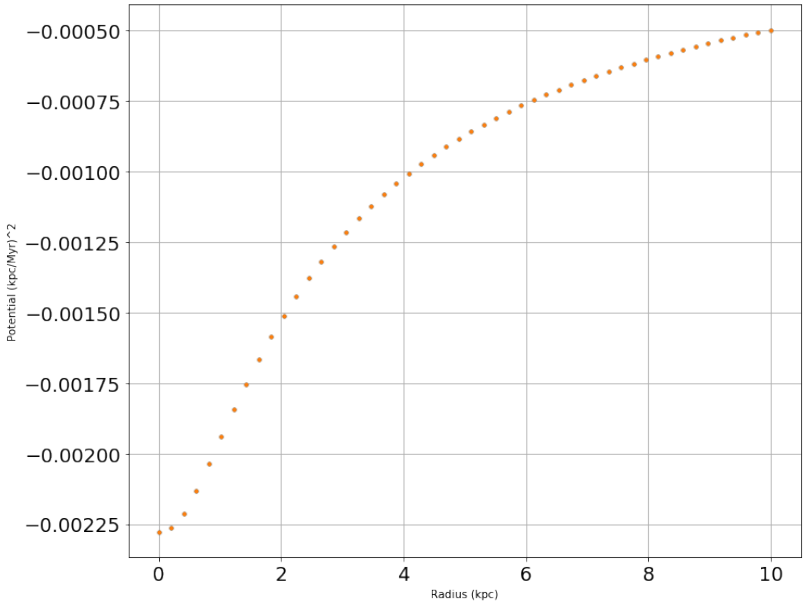
In [17]:
```
# Estimate potential of a triaxial halo

#Define model
d0=0.8E09 #Cental density in Msun/kpc3
rc=1      #Core radius in Kpc
mcut=100 #radius where d(m>mcut)=0
alpha = -1
beta = 4
a,b,c = 1,1,0.5
```

```
e= np.sqrt(1-c*c) #ellipticity
co = 0.00000001

#Defining a grid
x,y,z = np.linspace(co,10,50), np.linspace(co,10,50), np.linspace(co,10,50)
# Triaxial double power-law potential
halo1=dc.triaxial_doublepower_halo(d0=d0,rc=rc,alpha=alpha,beta=beta,a=a,b=b,c=c,mcut=mcut)
print (halo1)
pot1=halo1.potential(x,y,z,grid=True)

# Comparing it with oblate ellipsoid
R = np.linspace(co,10,50)
halo2=dc.alfabeta_halo(d0=d0,rs=rc,alfa=alpha,beta=beta,e=e,mcut=mcut)
print (halo2)
pot2=halo2.potential(R,z,grid=True,mcut=mcut)

pt1 = pot1[:,3].reshape(len(z),len(y),len(x))
pt2 = pot2[:,2].reshape(len(R),len(z)).T
plt.figure()

# Plot triaxial in the plane (x,0,z)
fig=plt.figure(figsize=(20,8))
ax1=fig.add_subplot(121)
ax2=fig.add_subplot(122)
ax1.grid()
ax1.imshow(pt1[:,0,:],origin='lower',extent=[x[0],x[-1],z[0],z[-1]],aspect='auto')
ax1.contour(x,z,pt1[:,0,:], colors='k',linewidths=2)
ax1.set_xlabel("Radius (kpc)")
ax1.set_ylabel("z (kpc)")
# Compare with the oblate
ax1.contour(R,z,pt2,colors='r')

# 1D profile comparison
ax2.grid()
```

```
        ax2.plot(R,pt1[0,0,:],'.')
        ax2.plot(R,pt2[0,:],'.')
        ax2.set_xlabel("Radius (kpc)")
        ax2.set_ylabel("Potential (kpc/Myr)^2")

        plt.show()
```

```
Model: Triaxial Double Power law
Density: d = d0 / ((m/rc)**(alpha) * (1+m/rc)**(beta-alpha))
    with m**2 = x**2/a**2 + y**2/b**2 + z**2/c**2
d0: 8.00e+08 Msun/kpc3
rc: 1.00
alpha: -1.00
beta: 4.00
a: 1.00
b: 1.00
c: 0.50
mcut: 100.000

Model: AlfaBeta halo
d0: 8.00e+08 Msun/kpc3
rs: 1.00
alfa: -1.0
beta: 4.0
e: 0.866
mcut: 100.000



<matplotlib.figure.Figure at 0x115b03f28>
```





In [18]:
```
#Estimate the potential of a ensemble of dynamic components
from discH.dynamics import galpotential

#Step1: Define the components
#Halo
d0=1e6
rs=5
mcut=100
e=0
halo=dc.NFW_halo(d0=d0, rs=rs, mcut=mcut, e=e)

#Bulge
d0=3e6
rs=1
```

```
mcut=10
e=0.6
bulge=dc.hernquist_halo(d0=d0, rs=rs, mcut=mcut, e=e)

#Stellar disc
sigma0=1e6
Rd=3
zd=0.4
zlaw='sech2'
Rcut=50
zcut=30
disc=dc.Exponential_disc.thick(sigma0=sigma0, Rd=Rd, zd=zd, zlaw=zlaw, Rcut=Rcut, zcut=zcut)


#Step2: Initialize galpotential class
ga=galpotential(dynamic_components=(halo,disc,bulge))
#If you want to check the properties of the component:
print('############STEP2############')
print('Components info')
ga.dynamic_components_info()
print('############################')

#Step3
#Calculate potential at R-Z
R=np.linspace(0.1,30,10) #List with the cylindrical radial coordinates in Kpc
Z=np.linspace(0,5,10) #List with the cylindrical vertical coordinates in Kpc
grid=True #If True create a grid from R and Z, otherwise estimate the potentail in the points (R[0],z[0]) (R[1],Z[1])..
nproc=2 #Number of proccesor to use for parallel computation
toll=1e-4 #Relative and absolute Tollerance for the potential integration
Rcut=None #If not None, set the Rcut of all the disc components to this value
zcut=None #If not None, set the zcut of all the disc components to this value
mcut=None #If not None, set the mcut of all the halo components to this value
external_potential=None #If not None, this should be an array matching the dimension of the final grid with an external
show_comp=False #If show_comp=False return also the estiamte of the potential of all the components
```

```
print('############STEP3A############')
print('Estimate Potential: OUTPUT 1D')
output='1D'
hp=ga.potential(R,Z,grid=grid, nproc=nproc, toll=toll, Rcut=Rcut, zcut=zcut, mcut=mcut, external_potential=external_pot
#Return a grid with 0-R 1-Z 2-Total Potential in kpc^2/Myr^2
print('\nReturn a grid 0-R 1-Z 2-Total Potential in kpc^2/Myr^2, e.g.:')
print(hp)
print('############################')

#Step4 Use the results or save them in files:

#The potential information can be accessed with
pot_grid=ga.potential_grid
#Array with col-0: R in kpc, col-1: Z in kpc, col-2: Total potential in kpc^2/Myr^2
pot_grid_complete=ga.potential_grid_complete
#Array with col-0: R in kpc, col-1: Z in kpc, col-i+1: Potential of the single  (i+1)th component
#col-ncomponent+2: External potential col-ncomponent+3: Total potential
#e.g:
pot_disc=pot_grid_complete[:,3]


#To save  in file
complete=True #If True save the pot_grid_complete array (see above), if False the pot_grid array
filename='potential.dat' #File where to store the data
ga.save(filename=filename, complete=complete)


#2D ESTIMATE
print('############STEP3B############')
print('Estimate Potential: OUTPUT 2D')
output='2D'
hp=ga.potential(R,Z,grid=grid, nproc=nproc, toll=toll, Rcut=Rcut, zcut=zcut, mcut=mcut, external_potential=external_pot
#Return a grid with 0-R 1-Z 2-Total Potential in kpc^2/Myr^2
print('\nReturn 3 slice with 2D map:\n 0-R map, 1-Z map, 3-Total Potential in kpc^2/Myr^2')
```

```
print(hp[:])
print('############################')

plt.imshow(hp[-1].T,origin='lower',extent=(np.min(R),np.max(R),np.min(Z),np.max(Z)))
plt.contour(hp[-1].T,origin='lower',extent=(np.min(R),np.max(R),np.min(Z),np.max(Z)),colors='black')


#NOTE:
#-1 If show_comp=True, the output contains also the potential of all the i dynamical components.
#e.g if output=1D, the return array is (ndim,ncomp+4) where ndim=len(R)*len(Z) if grid=True or ndim=len(R) if grid=Fals
#col-0:R, col-1:Z, col-1-ncomp+1: potential of the single components, col-ncomp+2:external potential, col-ncomp+3: tota
#The same if output=2D, but the return array is (ncomp+4,len(R),len(Z)). Each slice contains the map of the single comp
#first two (coordinates) and the last (total potential)
```

```
############STEP2############
Components info
Number of dynamical components:  3
Components: 0
Model: NFW halo
d0: 1.00e+06 Msun/kpc3
rs: 5.00
e: 0.000
mcut: 100.000

Components: 1
Model: Exponential disc
Sigma0: 1.00e+06 Msun/kpc2
Vertical density law: sech2
Radial density law: epoly
Rd: 3.000 kpc
Flaring law: constant
Fparam: 4.0e-01 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00
Rcut: 50.000 kpc
zcut: 30.000 kpc
Rlimit: None
```

```
Components: 2
Model: Hernquist halo
d0: 3.00e+06 Msun/kpc3
rs: 1.00
e: 0.600
mcut: 10.000

############################
###########STEP3A############
Estimate Potential: OUTPUT 1D
External potential: Calculating Potential of the 1th component (NFW halo)...Done (0.00 s)
Calculating Potential of the 2th component (Exponential disc)...Done (0.93 s)
Calculating Potential of the 3th component (Hernquist halo)...Done (0.00 s)

Return a grid 0-R 1-Z 2-Total Potential in kpc^2/Myr^2, e.g.:
[[ 1.00000000e-01  0.00000000e+00 -1.47576916e-03]
 [ 1.00000000e-01  5.55555556e-01 -1.38816058e-03]
 [ 1.00000000e-01  1.11111111e+00 -1.30438838e-03]
 [ 1.00000000e-01  1.66666667e+00 -1.23438805e-03]
 [ 1.00000000e-01  2.22222222e+00 -1.17413109e-03]
 [ 1.00000000e-01  2.77777778e+00 -1.12118979e-03]
 [ 1.00000000e-01  3.33333333e+00 -1.07402497e-03]
 [ 1.00000000e-01  3.88888889e+00 -1.03157323e-03]
 [ 1.00000000e-01  4.44444444e+00 -9.93054410e-04]
 [ 1.00000000e-01  5.00000000e+00 -9.57872425e-04]
 [ 3.42222222e+00  0.00000000e+00 -1.08348714e-03]
 [ 3.42222222e+00  5.55555556e-01 -1.07771386e-03]
 [ 3.42222222e+00  1.11111111e+00 -1.06416982e-03]
 [ 3.42222222e+00  1.66666667e+00 -1.04576715e-03]
 [ 3.42222222e+00  2.22222222e+00 -1.02397894e-03]
 [ 3.42222222e+00  2.77777778e+00 -1.00006640e-03]
 [ 3.42222222e+00  3.33333333e+00 -9.75060346e-04]
 [ 3.42222222e+00  3.88888889e+00 -9.49727081e-04]
```

```
[ 3.42222222e+00  4.44444444e+00 -9.24596663e-04]
[ 3.42222222e+00  5.00000000e+00 -9.00014556e-04]
[ 6.74444444e+00  0.00000000e+00 -8.75515434e-04]
[ 6.74444444e+00  5.55555556e-01 -8.73595077e-04]
[ 6.74444444e+00  1.11111111e+00 -8.69000509e-04]
[ 6.74444444e+00  1.66666667e+00 -8.62485336e-04]
[ 6.74444444e+00  2.22222222e+00 -8.54292021e-04]
[ 6.74444444e+00  2.77777778e+00 -8.44644147e-04]
[ 6.74444444e+00  3.33333333e+00 -8.33779805e-04]
[ 6.74444444e+00  3.88888889e+00 -8.21938396e-04]
[ 6.74444444e+00  4.44444444e+00 -8.09347813e-04]
[ 6.74444444e+00  5.00000000e+00 -7.96215643e-04]
[ 1.00666667e+01  0.00000000e+00 -7.40422940e-04]
[ 1.00666667e+01  5.55555556e-01 -7.39628299e-04]
[ 1.00666667e+01  1.11111111e+00 -7.37627651e-04]
[ 1.00666667e+01  1.66666667e+00 -7.34663250e-04]
[ 1.00666667e+01  2.22222222e+00 -7.30805004e-04]
[ 1.00666667e+01  2.77777778e+00 -7.26116365e-04]
[ 1.00666667e+01  3.33333333e+00 -7.20668698e-04]
[ 1.00666667e+01  3.88888889e+00 -7.14539388e-04]
[ 1.00666667e+01  4.44444444e+00 -7.07809196e-04]
[ 1.00666667e+01  5.00000000e+00 -7.00559409e-04]
[ 1.33888889e+01  0.00000000e+00 -6.44866819e-04]
[ 1.33888889e+01  5.55555556e-01 -6.44486220e-04]
[ 1.33888889e+01  1.11111111e+00 -6.43471447e-04]
[ 1.33888889e+01  1.66666667e+00 -6.41903537e-04]
[ 1.33888889e+01  2.22222222e+00 -6.39807017e-04]
[ 1.33888889e+01  2.77777778e+00 -6.37204980e-04]
[ 1.33888889e+01  3.33333333e+00 -6.34124496e-04]
[ 1.33888889e+01  3.88888889e+00 -6.30595509e-04]
[ 1.33888889e+01  4.44444444e+00 -6.26650669e-04]
[ 1.33888889e+01  5.00000000e+00 -6.22324154e-04]
[ 1.67111111e+01  0.00000000e+00 -5.73155156e-04]
[ 1.67111111e+01  5.55555556e-01 -5.72946582e-04]
```

```
[ 1.67111111e+01  1.11111111e+00 -5.72363178e-04]
[ 1.67111111e+01  1.66666667e+00 -5.71432659e-04]
[ 1.67111111e+01  2.22222222e+00 -5.70164719e-04]
[ 1.67111111e+01  2.77777778e+00 -5.68569195e-04]
[ 1.67111111e+01  3.33333333e+00 -5.66657845e-04]
[ 1.67111111e+01  3.88888889e+00 -5.64443934e-04]
[ 1.67111111e+01  4.44444444e+00 -5.61942403e-04]
[ 1.67111111e+01  5.00000000e+00 -5.59169141e-04]
[ 2.00333333e+01  0.00000000e+00 -5.16933535e-04]
[ 2.00333333e+01  5.55555556e-01 -5.16805225e-04]
[ 2.00333333e+01  1.11111111e+00 -5.16434481e-04]
[ 2.00333333e+01  1.66666667e+00 -5.15831078e-04]
[ 2.00333333e+01  2.22222222e+00 -5.14999241e-04]
[ 2.00333333e+01  2.77777778e+00 -5.13943608e-04]
[ 2.00333333e+01  3.33333333e+00 -5.12669841e-04]
[ 2.00333333e+01  3.88888889e+00 -5.11184471e-04]
[ 2.00333333e+01  4.44444444e+00 -5.09494934e-04]
[ 2.00333333e+01  5.00000000e+00 -5.07609407e-04]
[ 2.33555556e+01  0.00000000e+00 -4.71394392e-04]
[ 2.33555556e+01  5.55555556e-01 -4.71308101e-04]
[ 2.33555556e+01  1.11111111e+00 -4.71054040e-04]
[ 2.33555556e+01  1.66666667e+00 -4.70635817e-04]
[ 2.33555556e+01  2.22222222e+00 -4.70055448e-04]
[ 2.33555556e+01  2.77777778e+00 -4.69315344e-04]
[ 2.33555556e+01  3.33333333e+00 -4.68418457e-04]
[ 2.33555556e+01  3.88888889e+00 -4.67368284e-04]
[ 2.33555556e+01  4.44444444e+00 -4.66168822e-04]
[ 2.33555556e+01  5.00000000e+00 -4.64824562e-04]
[ 2.66777778e+01  0.00000000e+00 -4.33577494e-04]
[ 2.66777778e+01  5.55555556e-01 -4.33515620e-04]
[ 2.66777778e+01  1.11111111e+00 -4.33331670e-04]
[ 2.66777778e+01  1.66666667e+00 -4.33027072e-04]
[ 2.66777778e+01  2.22222222e+00 -4.32602890e-04]
[ 2.66777778e+01  2.77777778e+00 -4.32060465e-04]
```

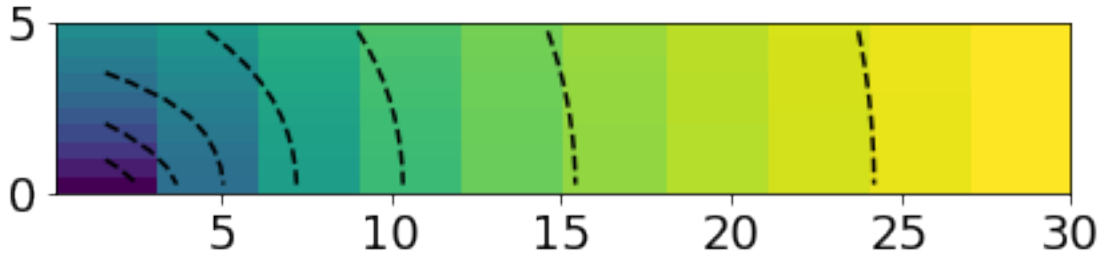
```
 [ 2.66777778e+01  3.33333333e+00 -4.31401471e-04]
 [ 2.66777778e+01  3.88888889e+00 -4.30627946e-04]
 [ 2.66777778e+01  4.44444444e+00 -4.29742148e-04]
 [ 2.66777778e+01  5.00000000e+00 -4.28746678e-04]
 [ 3.00000000e+01  0.00000000e+00 -4.01555070e-04]
 [ 3.00000000e+01  5.55555556e-01 -4.01508654e-04]
 [ 3.00000000e+01  1.11111111e+00 -4.01370007e-04]
 [ 3.00000000e+01  1.66666667e+00 -4.01139785e-04]
 [ 3.00000000e+01  2.22222222e+00 -4.00818550e-04]
 [ 3.00000000e+01  2.77777778e+00 -4.00407121e-04]
 [ 3.00000000e+01  3.33333333e+00 -3.99906508e-04]
 [ 3.00000000e+01  3.88888889e+00 -3.99317922e-04]
 [ 3.00000000e+01  4.44444444e+00 -3.98642769e-04]
 [ 3.00000000e+01  5.00000000e+00 -3.97882639e-04]]
############################
############STEP3B############
Estimate Potential: OUTPUT 2D
External potential: Calculating Potential of the 1th component (NFW halo)...Done (0.00 s)
Calculating Potential of the 2th component (Exponential disc)...Done (0.72 s)
Calculating Potential of the 3th component (Hernquist halo)...Done (0.00 s)

Return 3 slice with 2D map:
 0-R map, 1-Z map, 3-Total Potential in kpc^2/Myr^2
[[[ 1.00000000e-01  1.00000000e-01  1.00000000e-01  1.00000000e-01
    1.00000000e-01  1.00000000e-01  1.00000000e-01  1.00000000e-01
    1.00000000e-01  1.00000000e-01]
  [ 3.42222222e+00  3.42222222e+00  3.42222222e+00  3.42222222e+00
    3.42222222e+00  3.42222222e+00  3.42222222e+00  3.42222222e+00
    3.42222222e+00  3.42222222e+00]
  [ 6.74444444e+00  6.74444444e+00  6.74444444e+00  6.74444444e+00
    6.74444444e+00  6.74444444e+00  6.74444444e+00  6.74444444e+00
    6.74444444e+00  6.74444444e+00]
  [ 1.00666667e+01  1.00666667e+01  1.00666667e+01  1.00666667e+01
    1.00666667e+01  1.00666667e+01  1.00666667e+01  1.00666667e+01
```

```
  1.00666667e+01  1.00666667e+01]
 [ 1.33888889e+01  1.33888889e+01  1.33888889e+01  1.33888889e+01
   1.33888889e+01  1.33888889e+01  1.33888889e+01  1.33888889e+01
   1.33888889e+01  1.33888889e+01]
 [ 1.67111111e+01  1.67111111e+01  1.67111111e+01  1.67111111e+01
   1.67111111e+01  1.67111111e+01  1.67111111e+01  1.67111111e+01
   1.67111111e+01  1.67111111e+01]
 [ 2.00333333e+01  2.00333333e+01  2.00333333e+01  2.00333333e+01
   2.00333333e+01  2.00333333e+01  2.00333333e+01  2.00333333e+01
   2.00333333e+01  2.00333333e+01]
 [ 2.33555556e+01  2.33555556e+01  2.33555556e+01  2.33555556e+01
   2.33555556e+01  2.33555556e+01  2.33555556e+01  2.33555556e+01
   2.33555556e+01  2.33555556e+01]
 [ 2.66777778e+01  2.66777778e+01  2.66777778e+01  2.66777778e+01
   2.66777778e+01  2.66777778e+01  2.66777778e+01  2.66777778e+01
   2.66777778e+01  2.66777778e+01]
 [ 3.00000000e+01  3.00000000e+01  3.00000000e+01  3.00000000e+01
   3.00000000e+01  3.00000000e+01  3.00000000e+01  3.00000000e+01
   3.00000000e+01  3.00000000e+01]]

[[ 0.00000000e+00  5.55555556e-01  1.11111111e+00  1.66666667e+00
   2.22222222e+00  2.77777778e+00  3.33333333e+00  3.88888889e+00
   4.44444444e+00  5.00000000e+00]
 [ 0.00000000e+00  5.55555556e-01  1.11111111e+00  1.66666667e+00
   2.22222222e+00  2.77777778e+00  3.33333333e+00  3.88888889e+00
   4.44444444e+00  5.00000000e+00]
 [ 0.00000000e+00  5.55555556e-01  1.11111111e+00  1.66666667e+00
   2.22222222e+00  2.77777778e+00  3.33333333e+00  3.88888889e+00
   4.44444444e+00  5.00000000e+00]
 [ 0.00000000e+00  5.55555556e-01  1.11111111e+00  1.66666667e+00
   2.22222222e+00  2.77777778e+00  3.33333333e+00  3.88888889e+00
   4.44444444e+00  5.00000000e+00]
 [ 0.00000000e+00  5.55555556e-01  1.11111111e+00  1.66666667e+00
   2.22222222e+00  2.77777778e+00  3.33333333e+00  3.88888889e+00
```

```
  4.44444444e+00  5.00000000e+00]
 [ 0.00000000e+00  5.55555556e-01  1.11111111e+00  1.66666667e+00
  2.22222222e+00  2.77777778e+00  3.33333333e+00  3.88888889e+00
  4.44444444e+00  5.00000000e+00]
 [ 0.00000000e+00  5.55555556e-01  1.11111111e+00  1.66666667e+00
  2.22222222e+00  2.77777778e+00  3.33333333e+00  3.88888889e+00
  4.44444444e+00  5.00000000e+00]
 [ 0.00000000e+00  5.55555556e-01  1.11111111e+00  1.66666667e+00
  2.22222222e+00  2.77777778e+00  3.33333333e+00  3.88888889e+00
  4.44444444e+00  5.00000000e+00]
 [ 0.00000000e+00  5.55555556e-01  1.11111111e+00  1.66666667e+00
  2.22222222e+00  2.77777778e+00  3.33333333e+00  3.88888889e+00
  4.44444444e+00  5.00000000e+00]
 [ 0.00000000e+00  5.55555556e-01  1.11111111e+00  1.66666667e+00
  2.22222222e+00  2.77777778e+00  3.33333333e+00  3.88888889e+00
  4.44444444e+00  5.00000000e+00]]

[[-1.47576916e-03 -1.38816058e-03 -1.30438838e-03 -1.23438805e-03
  -1.17413109e-03 -1.12118979e-03 -1.07402497e-03 -1.03157323e-03
  -9.93054410e-04 -9.57872425e-04]
 [-1.08348714e-03 -1.07771386e-03 -1.06416982e-03 -1.04576715e-03
  -1.02397894e-03 -1.00006640e-03 -9.75060346e-04 -9.49727081e-04
  -9.24596663e-04 -9.00014556e-04]
 [-8.75515434e-04 -8.73595077e-04 -8.69000509e-04 -8.62485336e-04
  -8.54292021e-04 -8.44644147e-04 -8.33779805e-04 -8.21938396e-04
  -8.09347813e-04 -7.96215643e-04]
 [-7.40422940e-04 -7.39628299e-04 -7.37627651e-04 -7.34663250e-04
  -7.30805004e-04 -7.26116365e-04 -7.20668698e-04 -7.14539388e-04
  -7.07809196e-04 -7.00559409e-04]
 [-6.44866819e-04 -6.44486220e-04 -6.43471447e-04 -6.41903537e-04
  -6.39807017e-04 -6.37204980e-04 -6.34124496e-04 -6.30595509e-04
  -6.26650669e-04 -6.22324154e-04]
 [-5.73155156e-04 -5.72946582e-04 -5.72363178e-04 -5.71432659e-04
  -5.70164719e-04 -5.68569195e-04 -5.66657845e-04 -5.64443934e-04
```

```
   -5.61942403e-04 -5.59169141e-04]
  [-5.16933535e-04 -5.16805225e-04 -5.16434481e-04 -5.15831078e-04
   -5.14999241e-04 -5.13943608e-04 -5.12669841e-04 -5.11184471e-04
   -5.09494934e-04 -5.07609407e-04]
  [-4.71394392e-04 -4.71308101e-04 -4.71054040e-04 -4.70635817e-04
   -4.70055448e-04 -4.69315344e-04 -4.68418457e-04 -4.67368284e-04
   -4.66168822e-04 -4.64824562e-04]
  [-4.33577494e-04 -4.33515620e-04 -4.33331670e-04 -4.33027072e-04
   -4.32602890e-04 -4.32060465e-04 -4.31401471e-04 -4.30627946e-04
   -4.29742148e-04 -4.28746678e-04]
  [-4.01555070e-04 -4.01508654e-04 -4.01370007e-04 -4.01139785e-04
   -4.00818550e-04 -4.00407121e-04 -3.99906508e-04 -3.99317922e-04
   -3.98642769e-04 -3.97882639e-04]]]
############################
```

Out[18]: <matplotlib.contour.QuadContourSet at 0x1112ade80>

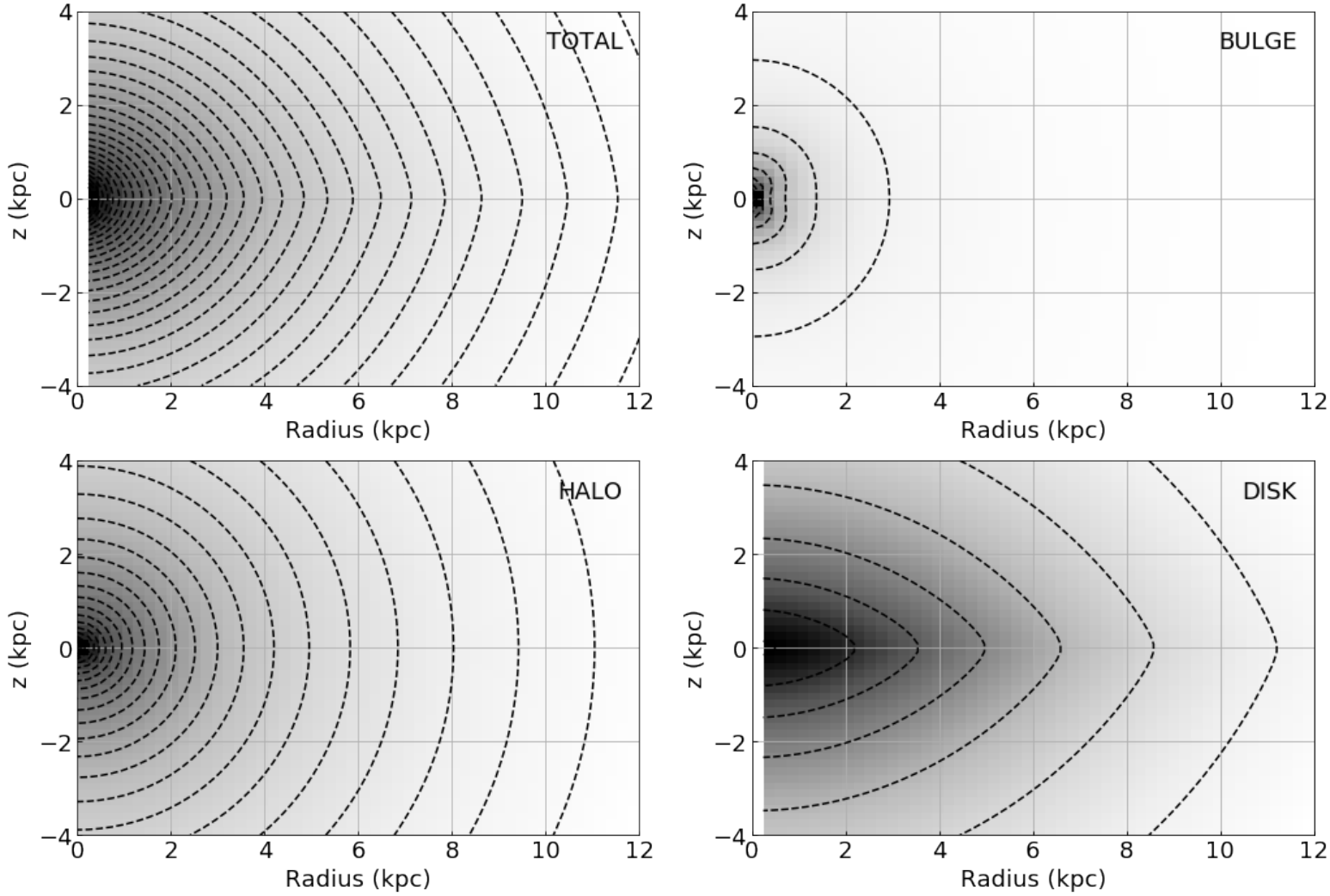


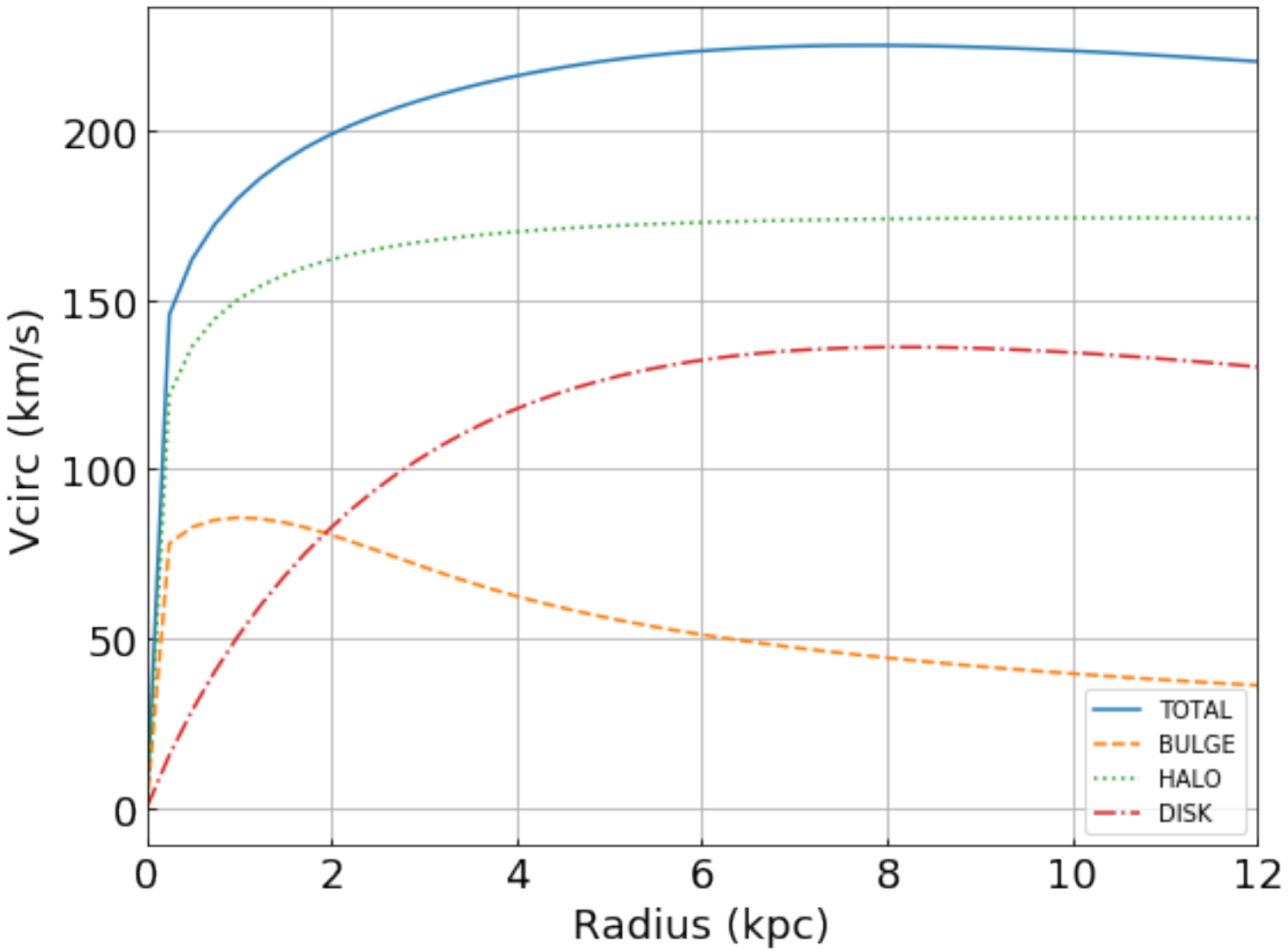
In [19]:
```
# MW Potential
from discH.dynamics import MWpotential
from discH import utils

# Grid and cuts
```

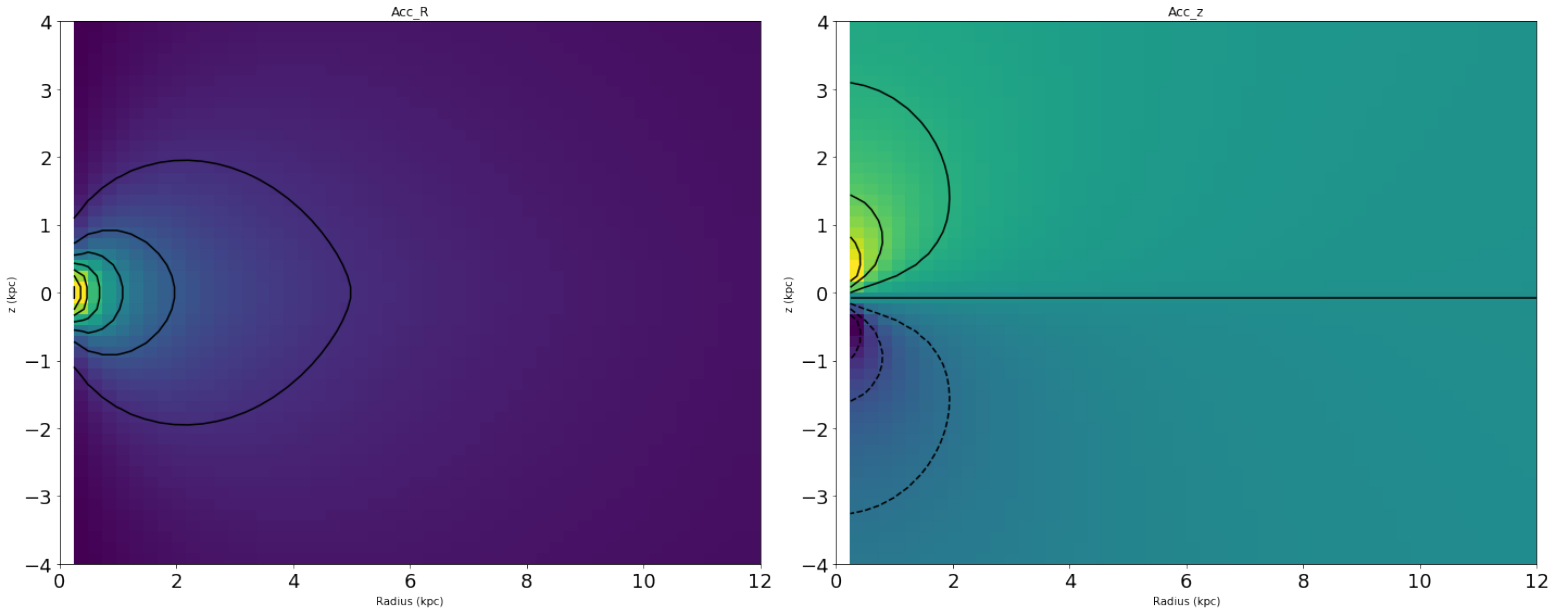
```
mcut, zcut = 100., 50
R,z = np.linspace(0,12,50), np.linspace(-4,4,50)
nproc = 4

# Initializing a MW model: available models are:
# 1) Binney&Tremaine08 (Tab. 2.3) model1 ("BT08_Model1") and model2 ("BT08_Model2")
# 2) Sormani et al. 2017 (see also Ridley+17) ("S+17")
MW = MWpotential('BT08_Model2')
# Calculate potentials
MW.calculate_potential(coordgrid=(R,z),grid=True,Rcut=mcut,zcut=zcut,mcut=mcut,nproc=nproc)
# Write potentials on a FITS file (ext0 is the total, ext1-4 the various components)
# MW.writeFITS("MWpot.fits")
# Write total potential on a HDF5 file
# utils.writeHDF5(MW.potgrid,MW.totalpot,npots=1,"MWpot.h5",)
# Plot potentials (give a fname to plot in a file). Compare with fig 2.21 BT08
fpot = MW.plot_potentials(fname=None)
# Calculate Vcirc
MW.calculate_vcirc(R)
# Plot vcirc (give a fname to plot in a file)
fvc = MW.plot_vcirc(fname=None)

# Calculate accelerations along R and z
aR, az = utils.calculate_acceleration(MW.potgrid,MW.totalpot)
# Plot them
fig = plt.figure(figsize=(20,8))
ax1=fig.add_subplot(121)
ax2=fig.add_subplot(122)
ax1.imshow(aR,origin='lower',aspect='auto',extent=[R[0],R[-1],z[0],z[-1]])
ax1.contour(R,z,aR,colors='k')
ax1.set_xlabel("Radius (kpc)")
ax1.set_ylabel("z (kpc)")
ax1.set_title("Acc_R")

ax2.imshow(az,origin='lower',aspect='auto',extent=[R[0],R[-1],z[0],z[-1]])
```

```
        ax2.set_xlabel("Radius (kpc)")
        ax2.set_ylabel("z (kpc)")
        ax2.contour(R,z,az,colors='k')
        ax2.set_title("Acc_z")

        plt.show()
```

```
External potential: Calculating Potential of the 1th component (Power law with cut halo)...Done (1.89 s)
Calculating Potential of the 2th component (AlfaBeta halo)...Done (0.37 s)
Calculating Potential of the 3th component (Exponential disc)...Done (34.67 s)
Calculating Potential of the 4th component (Exponential disc)...Done (28.78 s)
Calculating Potential of the 5th component (Exponential disc)...Done (35.07 s)
```


TOTAL
BULGE
HALO
DISK
z (kpc)
Radius (kpc)
4
2
0
−2
−4
0
2
4
6
8
10
12


Vcirc (km/s)
Radius (kpc)
0
50
100
150
200
0
2
4
6
8
10
12
TOTAL
BULGE
HALO
DISK



DENSITY

In [20]:
```
#The estimate of the density is similar to the one of the Potential
#1-DENS OF A COMPONENT

#Define model
d0=1e6 #Cental density in Msun/kpc3
rc=5 #Core radius in Kpc
mcut=100 #radius where d(m>mcut)=0
e=0 #ellipticity
iso_halo=dc.isothermal_halo(d0=d0, rc=rc, mcut=mcut, e=e)

#Estimate density 1D
R=np.linspace(0,6,6) #List with the cylindrical radial coordinates in Kpc
Z=np.linspace(0,3,6) #List with the cylindrical vertical coordinates in Kpc
```

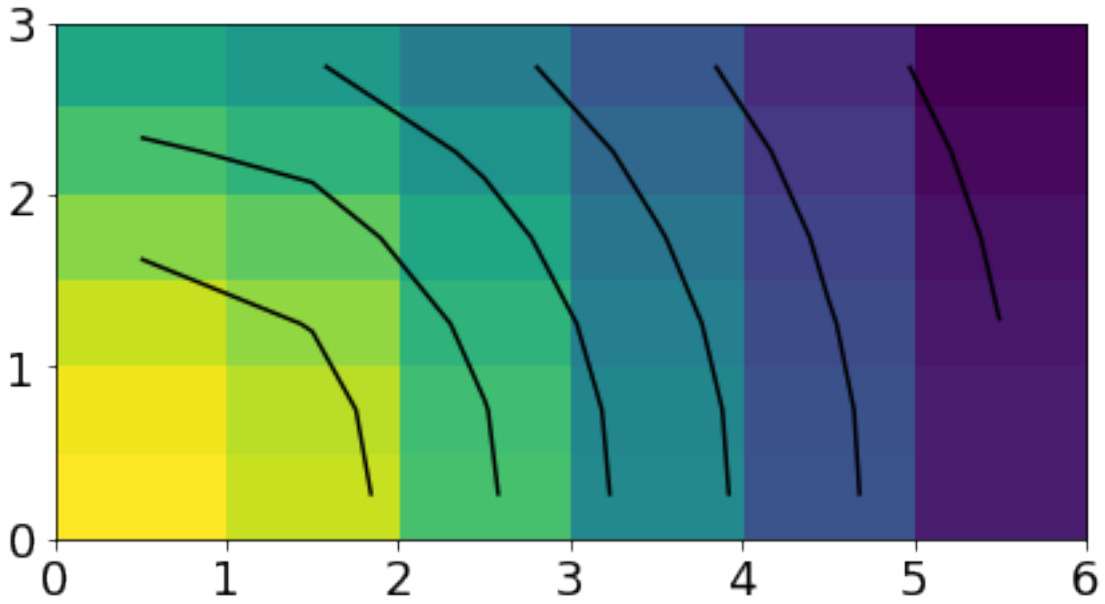
```
grid=True #If True create a grid from R and Z, otherwise estimate the potentail in the points (R[0],z[0]) (R[1],Z[1])..
output='1D' #It sets the shape of the output data.. see below
dens_grid=iso_halo.dens(R=R,Z=Z,grid=grid,output=output)
print(dens_grid)

#Estimate density 1D
output='2D' #It sets the shape of the output data.. see below
dens_grid=iso_halo.dens(R=R,Z=Z,grid=grid,output=output)
print(dens_grid)
plt.imshow(dens_grid[2].T,origin='lower',extent=(np.min(R),np.max(R),np.min(Z),np.max(Z)))
plt.contour(dens_grid[2].T,origin='lower',extent=(np.min(R),np.max(R),np.min(Z),np.max(Z)),colors='black')
```

```
[[0.00000000e+00 0.00000000e+00 1.00000000e+06]
 [0.00000000e+00 6.00000000e-01 9.85804416e+05]
 [0.00000000e+00 1.20000000e+00 9.45537065e+05]
 [0.00000000e+00 1.80000000e+00 8.85269122e+05]
 [0.00000000e+00 2.40000000e+00 8.12743823e+05]
 [0.00000000e+00 3.00000000e+00 7.35294118e+05]
 [1.20000000e+00 0.00000000e+00 9.45537065e+05]
 [1.20000000e+00 6.00000000e-01 9.32835821e+05]
 [1.20000000e+00 1.20000000e+00 8.96700143e+05]
 [1.20000000e+00 1.80000000e+00 8.42318059e+05]
 [1.20000000e+00 2.40000000e+00 7.76397516e+05]
 [1.20000000e+00 3.00000000e+00 7.05417607e+05]
 [2.40000000e+00 0.00000000e+00 8.12743823e+05]
 [2.40000000e+00 6.00000000e-01 8.03341902e+05]
 [2.40000000e+00 1.20000000e+00 7.76397516e+05]
 [2.40000000e+00 1.80000000e+00 7.35294118e+05]
 [2.40000000e+00 2.40000000e+00 6.84556407e+05]
 [2.40000000e+00 3.00000000e+00 6.28772636e+05]
 [3.60000000e+00 0.00000000e+00 6.58587987e+05]
 [3.60000000e+00 6.00000000e-01 6.52400835e+05]
 [3.60000000e+00 1.20000000e+00 6.34517766e+05]
 [3.60000000e+00 1.80000000e+00 6.06796117e+05]
 [3.60000000e+00 2.40000000e+00 5.71820677e+05]
```

```
 [3.60000000e+00 3.00000000e+00 5.32367973e+05]
 [4.80000000e+00 0.00000000e+00 5.20399667e+05]
 [4.80000000e+00 6.00000000e-01 5.16528926e+05]
 [4.80000000e+00 1.20000000e+00 5.05254648e+05]
 [4.80000000e+00 1.80000000e+00 4.87519501e+05]
 [4.80000000e+00 2.40000000e+00 4.64684015e+05]
 [4.80000000e+00 3.00000000e+00 4.38288920e+05]
 [6.00000000e+00 0.00000000e+00 4.09836066e+05]
 [6.00000000e+00 6.00000000e-01 4.07431551e+05]
 [6.00000000e+00 1.20000000e+00 4.00384369e+05]
 [6.00000000e+00 1.80000000e+00 3.89165629e+05]
 [6.00000000e+00 2.40000000e+00 3.74475734e+05]
 [6.00000000e+00 3.00000000e+00 3.57142857e+05]]
[[[0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00
   0.00000000e+00 0.00000000e+00]
  [1.20000000e+00 1.20000000e+00 1.20000000e+00 1.20000000e+00
   1.20000000e+00 1.20000000e+00]
  [2.40000000e+00 2.40000000e+00 2.40000000e+00 2.40000000e+00
   2.40000000e+00 2.40000000e+00]
  [3.60000000e+00 3.60000000e+00 3.60000000e+00 3.60000000e+00
   3.60000000e+00 3.60000000e+00]
  [4.80000000e+00 4.80000000e+00 4.80000000e+00 4.80000000e+00
   4.80000000e+00 4.80000000e+00]
  [6.00000000e+00 6.00000000e+00 6.00000000e+00 6.00000000e+00
   6.00000000e+00 6.00000000e+00]]

 [[0.00000000e+00 6.00000000e-01 1.20000000e+00 1.80000000e+00
   2.40000000e+00 3.00000000e+00]
  [0.00000000e+00 6.00000000e-01 1.20000000e+00 1.80000000e+00
   2.40000000e+00 3.00000000e+00]
  [0.00000000e+00 6.00000000e-01 1.20000000e+00 1.80000000e+00
   2.40000000e+00 3.00000000e+00]
  [0.00000000e+00 6.00000000e-01 1.20000000e+00 1.80000000e+00
   2.40000000e+00 3.00000000e+00]
```

```
  [0.00000000e+00 6.00000000e-01 1.20000000e+00 1.80000000e+00
   2.40000000e+00 3.00000000e+00]
  [0.00000000e+00 6.00000000e-01 1.20000000e+00 1.80000000e+00
   2.40000000e+00 3.00000000e+00]]

 [[1.00000000e+06 9.85804416e+05 9.45537065e+05 8.85269122e+05
   8.12743823e+05 7.35294118e+05]
  [9.45537065e+05 9.32835821e+05 8.96700143e+05 8.42318059e+05
   7.76397516e+05 7.05417607e+05]
  [8.12743823e+05 8.03341902e+05 7.76397516e+05 7.35294118e+05
   6.84556407e+05 6.28772636e+05]
  [6.58587987e+05 6.52400835e+05 6.34517766e+05 6.06796117e+05
   5.71820677e+05 5.32367973e+05]
  [5.20399667e+05 5.16528926e+05 5.05254648e+05 4.87519501e+05
   4.64684015e+05 4.38288920e+05]
  [4.09836066e+05 4.07431551e+05 4.00384369e+05 3.89165629e+05
   3.74475734e+05 3.57142857e+05]]]
```

Out[20]: <matplotlib.contour.QuadContourSet at 0x116120b38>



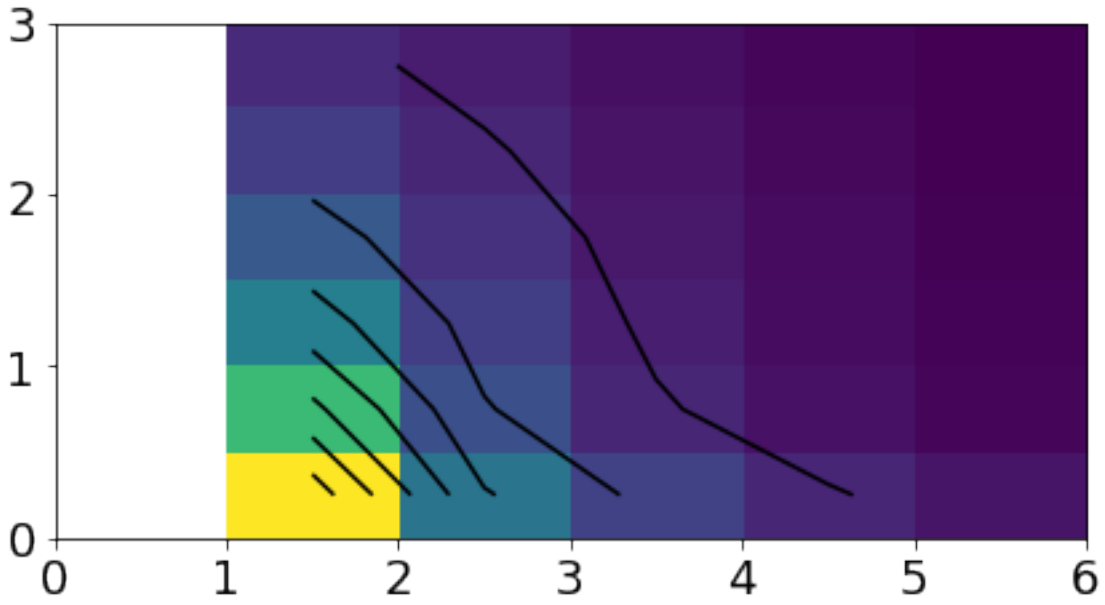
In [21]:
```
#2-DENS OF a multicomponent model
from discH.dynamics import galpotential

#Step1: Define the components
#Halo
d0=1e6
rs=5
mcut=100
e=0
halo=dc.NFW_halo(d0=d0, rs=rs, mcut=mcut, e=e)

#Bulge
d0=3e6
```

```
rs=1
mcut=10
e=0.6
bulge=dc.hernquist_halo(d0=d0, rs=rs, mcut=mcut, e=e)

#Stellar disc
sigma0=1e6
Rd=3
zd=0.4
zlaw='sech2'
Rcut=50
zcut=30
disc=dc.Exponential_disc.thick(sigma0=sigma0, Rd=Rd, zd=zd, zlaw=zlaw, Rcut=Rcut, zcut=zcut)

print('Estimate Density: OUTPUT 1D')
output='1D'
R=np.linspace(0,6,6) #List with the cylindrical radial coordinates in Kpc
Z=np.linspace(0,3,6) #List with the cylindrical vertical coordinates in Kpc
grid=True #If True create a grid from R and Z, otherwise estimate the potentail in the points (R[0],z[0]) (R[1],Z[1])..
output='1D'
show_comp=False #If show_comp=False return also the estiamte of the potential of all the components
hp=ga.dens(R,Z,grid=grid, output=output,show_comp=show_comp)

print('Estimate Density: OUTPUT 2D')
output='2D'
R=np.linspace(0,6,6) #List with the cylindrical radial coordinates in Kpc
Z=np.linspace(0,3,6) #List with the cylindrical vertical coordinates in Kpc
grid=True #If True create a grid from R and Z, otherwise estimate the potentail in the points (R[0],z[0]) (R[1],Z[1])..
output='2D'
show_comp=False #If show_comp=False return also the estiamte of the potential of all the components
hp=ga.dens(R,Z,grid=grid, output=output,show_comp=show_comp)

plt.imshow(hp[2].T,origin='lower',extent=(np.min(R),np.max(R),np.min(Z),np.max(Z)))
plt.contour(hp[2].T,origin='lower',extent=(np.min(R),np.max(R),np.min(Z),np.max(Z)),colors='black')
```

```
        #NOTE:
        #1-See the note on show_comp above.But in this case we do not gave the extra column and the extra slice for
        #external potential
```

```
Estimate Density: OUTPUT 1D
Estimate Density: OUTPUT 2D
```

Out[21]: <matplotlib.contour.QuadContourSet at 0x10f1e9748>



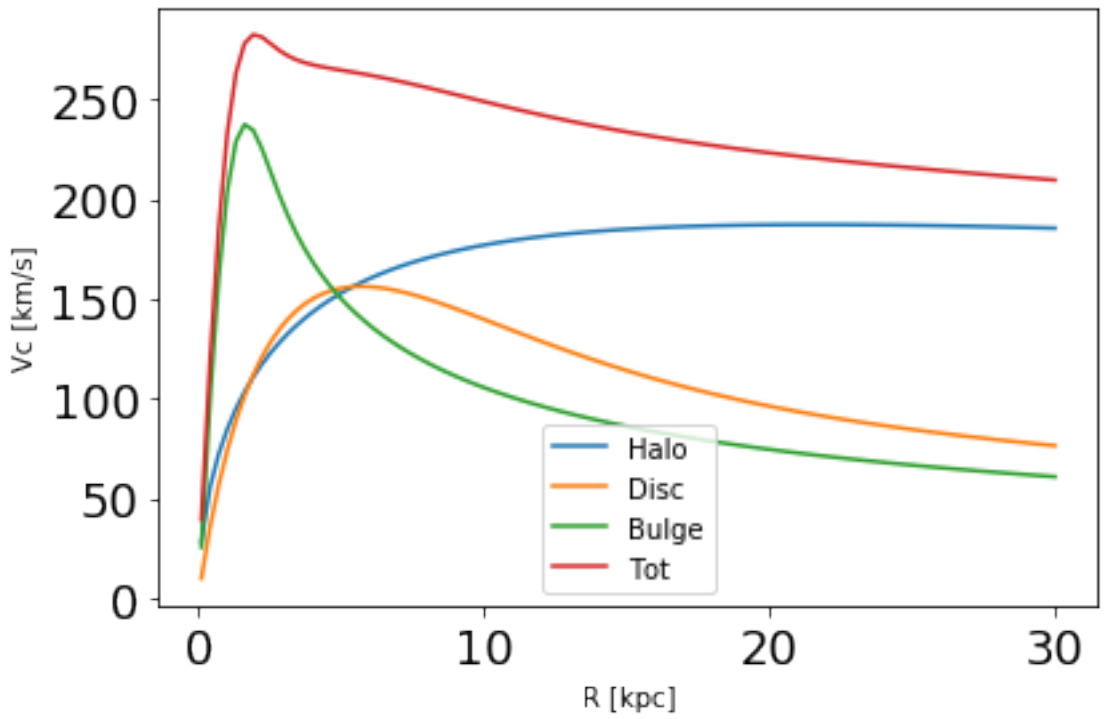
VCIRC FOR MULTIPLE COMPONENTS

In [22]:
```
#Estimate the potential of a ensemble of dynamic components
from discH.dynamics import galpotential

#Step1: Define the components
#Halo
d0=3e7
rs=10
mcut=100
e=0
halo=dc.NFW_halo(d0=d0, rs=rs, mcut=mcut, e=e)

#Bulge
d0=4e9
rb=0.8
mcut=10
e=0.6
bulge=dc.valy_halo(d0=d0, rb=rb, mcut=mcut, e=e)

#Stellar disc
sigma0=1e9
Rd=2.5
zd=0.4
zlaw='sech2'
Rcut=50
zcut=30
disc=dc.Exponential_disc.thick(sigma0=sigma0, Rd=Rd, zd=zd, zlaw=zlaw, Rcut=Rcut, zcut=zcut)


#Step2: Initialize galpotential class
ga=galpotential(dynamic_components=(halo,disc,bulge))
#If you want to check the properties of the component:
print('############STEP2############')
print('Components info')
ga.dynamic_components_info()
```

```
print('############################')



print('###########STEP3###########')
print('Estimate Vcirc')
R=np.linspace(0.1,30,100)
vgrid=ga.vcirc(R,show_comp=True)
print('############################')

#The funciton vgrid returns an array with len(R) row
#the number of column depends on show_comp
#if show_comp=True(default), the 0-column contains R, the last column contains the total velocity and
#the other columns contain the velocity of the ith component
#if show_comp=False, the the 0-column contains R and the 1-column contains the total velocity

#Halo
plt.plot(R,vgrid[:,1],label='Halo')
plt.plot(R,vgrid[:,2],label='Disc')
plt.plot(R,vgrid[:,3],label='Bulge')
plt.plot(R,vgrid[:,4],label='Tot')
plt.legend()
plt.xlabel('R [kpc]')
plt.ylabel('Vc [km/s]')
plt.show()
```

```
###########STEP2###########
Components info
Number of dynamical components:  3
Components: 0
Model: NFW halo
d0: 3.00e+07 Msun/kpc3
rs: 10.00
e: 0.000
mcut: 100.000
```

```
Components: 1
Model: Exponential disc
Sigma0: 1.00e+09 Msun/kpc2
Vertical density law: sech2
Radial density law: epoly
Rd: 2.500 kpc
Flaring law: constant
Fparam: 4.0e-01 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00
Rcut: 50.000 kpc
zcut: 30.000 kpc
Rlimit: None

Components: 2
Model: Valy halo
Mass: 2.58e+10 Msun
d0: 4.00e+09 Msun/kpc3
rb: 0.80 kpc
e: 0.600
mcut: 10.000

############################
###########STEP3############
Estimate Vcirc
############################
```



In [23]:
```
from discH.dynamics import discHeight

##STEP: 1
#Define all the fixed components
#Halo
d0=1e6
rs=5
mcut=100
e=0
halo=dc.NFW_halo(d0=d0, rs=rc, mcut=mcut, e=e)
```

```
#Bulge
d0=3e6
rs=1
mcut=10
e=0.6
bulge=dc.hernquist_halo(d0=d0, rs=rc, mcut=mcut, e=e)

#Stellar disc
sigma0=5e6
Rd=3
zd=0.4
zlaw='sech2'
Rcut=50
zcut=30
disc=dc.Exponential_disc.thick(sigma0=sigma0, Rd=Rd, zd=zd, zlaw=zlaw, Rcut=Rcut, zcut=zcut)

galaxy=(bulge,disc,halo)

#STEP 2: Define the disc model

#Gas disc
g_sigma0=1e6
g_Rd=5
g_Rd2=5
g_alpha=1
Rcut=60
zcut=30
gas_disc=dc.Frat_disc.thin(sigma0=g_sigma0, Rd=g_Rd, Rd2=g_Rd2, alpha=g_alpha, Rcut=Rcut, zcut=zcut)
#NB, Here the definition of the flaring model is not important, because then it will be re-defined in the
#scale heigth calculation, so the use of thin is useful to avoid to insert useless information about the flaring proper

#STEP 3: Initialize the discHeight class
h=discHeight(dynamic_components=galaxy, disc_component=gas_disc)
```

```
#Step 4: Estimat height
zlaw='gau' #Vertical zlaw, it could be 'gau', 'sech2' or 'exp' default=gau
flaw='poly' #Flaring law, it could be 'poly', 'asinh', 'tanh', default=poly
polyflare_degree=5 #If flaw='poly' this is the degree of the polynomial, otherwise it is not used, default=5

#Vel dispersion
#Velocity dispersion, we assume that the disc component as an isotropic velocity dispersion and that is is
#isothermal in the vertical direction, so vdisp=vdisp(R).
#There are different option:
#1-Constant velocity dispersion
vdisp=10
#2-Function of R, e.g.
vdisp=lambda R: 10 + 5/(1+R)
#3-Array of values with col-0 R col-1 v(R)
vdisp_array=np.array([[0,1,4,5,10],[15,12,10,9,8]])
vdisp=vdisp_array
#In this internally, vidsp=vdisp_func(R), where vdisp_func is the interpolating function of the array with vdisp=vdisp_

#R array
#These three quantities define the cylindrical R coordinates that will be used to estimate zd(R)
Rpoints=30 #Number of R points, or list of Rpoints, default=30
Rinterval='linear' #interval type, default=linear
Rrange=(0.01,30)    #Min-max R, default=(0.01,30)
#If Rpoints is a number, the R grid is defined as np.linspace(Rrange[0],Rrange[30],Rpoints) if Rinterval=linear or np.l
#If Rpoints is a list a tuple or np.ndarray use the points inside the list

#Z array
#These three quantities define the cylindrical z coordinates that will be used to estimate the zd at each radius
Zpoints=30    #Number of z points, or list of zpoints, default=30
Zinterval='log'   #nterval type, default=log
Zrange=(0,10) #Min-max z, default=(0,10)
#If Zpoints is a number, the z grid is defined as np.linspace(Zrange[0],Zrange[30],Zpoints) if Zinterval=linear or np.l
```

```
        #If Zpoints is a list a tuple or np.ndarray use the points inside the list
        #NB, Zrange[0] must be always 0 to have a good estimate of the vertical profile of the disc

        #The estimate of zd is iterative. The iteration stop when one of the following is True
        #Number of iteration < Niter
        #Maximum Absolute residual between two sequential estiamates of zd lower than flaretollabs
        #Maximum Relative residual between two sequential estiamates of zd lower than flaretollrel
        Niter=10 #Max number of iteration, default=10
        flaretollabs=1e-4   # default=1e-4
        flaretollrel=1e-4   # default=1e-4

        nproc=2  #Number of proccesors to use for parallel computation, default=2

        Rcut=None #If not None, set the Rcut of all the disc components to this value, default=None
        zcut=None #If not None, set the zcut of all the disc components to this value, default=None
        mcut=None #If not None, set the mcut of all the halo components to this value, default=None
        Rlimit='max' #If not None, set a limit Radius for the flaring, i.e. the radius where zd(R)=zd(Rlimit) for R>Rlimit,
        #this could be useful when the flare is fitted with an high degree polynomial that can have a very strange behaviour ou
        #if 'max', Rlimit=max(R), where R is defined using Rpoints (see above)

        inttoll=1e-4 #Relative and absolute Tollerance for the potential integration, default=1e-4
        external_potential=None #External potential, default=None
        outdir='gasHeight_res' #Folder where to save the outputs, default='gasHeight'
        diagnostic=True #If True, save figures and tables to see all results of the iterations in details, default=True

        final_gas_model, tab_zd,flare_func,fit_func=h.height(flaw=flaw, zlaw=zlaw, polyflare_degree=polyflare_degree, vdisp=10,
```

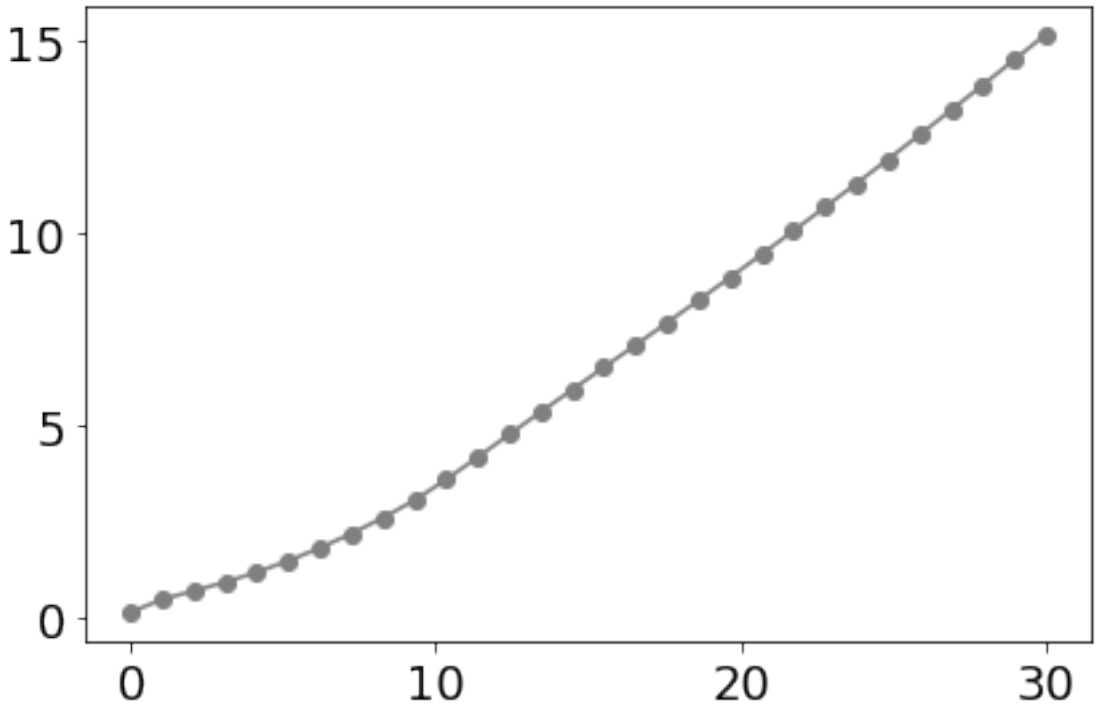
```
////////////////////////////////////////////////////////////////////////////
Calculating fixed potential
External potential: Calculating Potential of the 1th component (Hernquist halo)...Done (0.05 s)
Calculating Potential of the 2th component (Exponential disc)...Done (8.67 s)
Calculating Potential of the 3th component (NFW halo)...Done (0.01 s)
Fixed potential Done
////////////////////////////////////////////////////////////////////////////
```

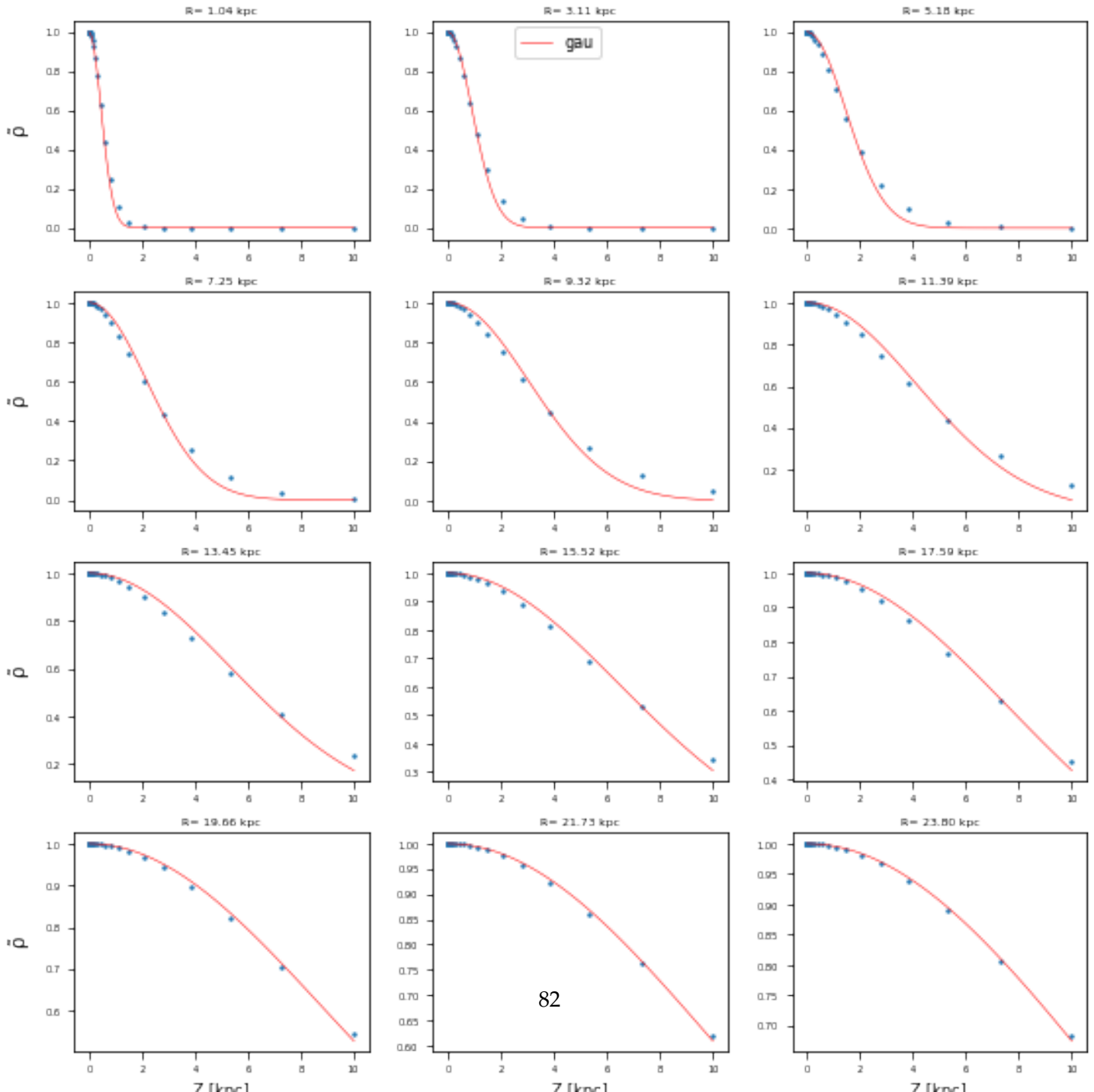
```
////////////////////////////////////////////////////////////////////////////
Iter-0: Massless disc
************************************************
               START FITZPROFILE
************************************************
Number of Radii: 30
Number of Vertical points: 30
Number of the used distributions: 1   ['gau']
1
nplot 2
---Fitting---
Working on radius: 0.01
Working on radius: 1.04
Plotting
Working on radius: 2.08
Working on radius: 3.11
Plotting
Working on radius: 4.15
Working on radius: 5.18
Plotting
Working on radius: 6.21
Working on radius: 7.25
Plotting
Working on radius: 8.28
Working on radius: 9.32
Plotting
Working on radius: 10.35
Working on radius: 11.39
Plotting
Working on radius: 12.42
Working on radius: 13.45
Plotting
Working on radius: 14.49
Working on radius: 15.52
```

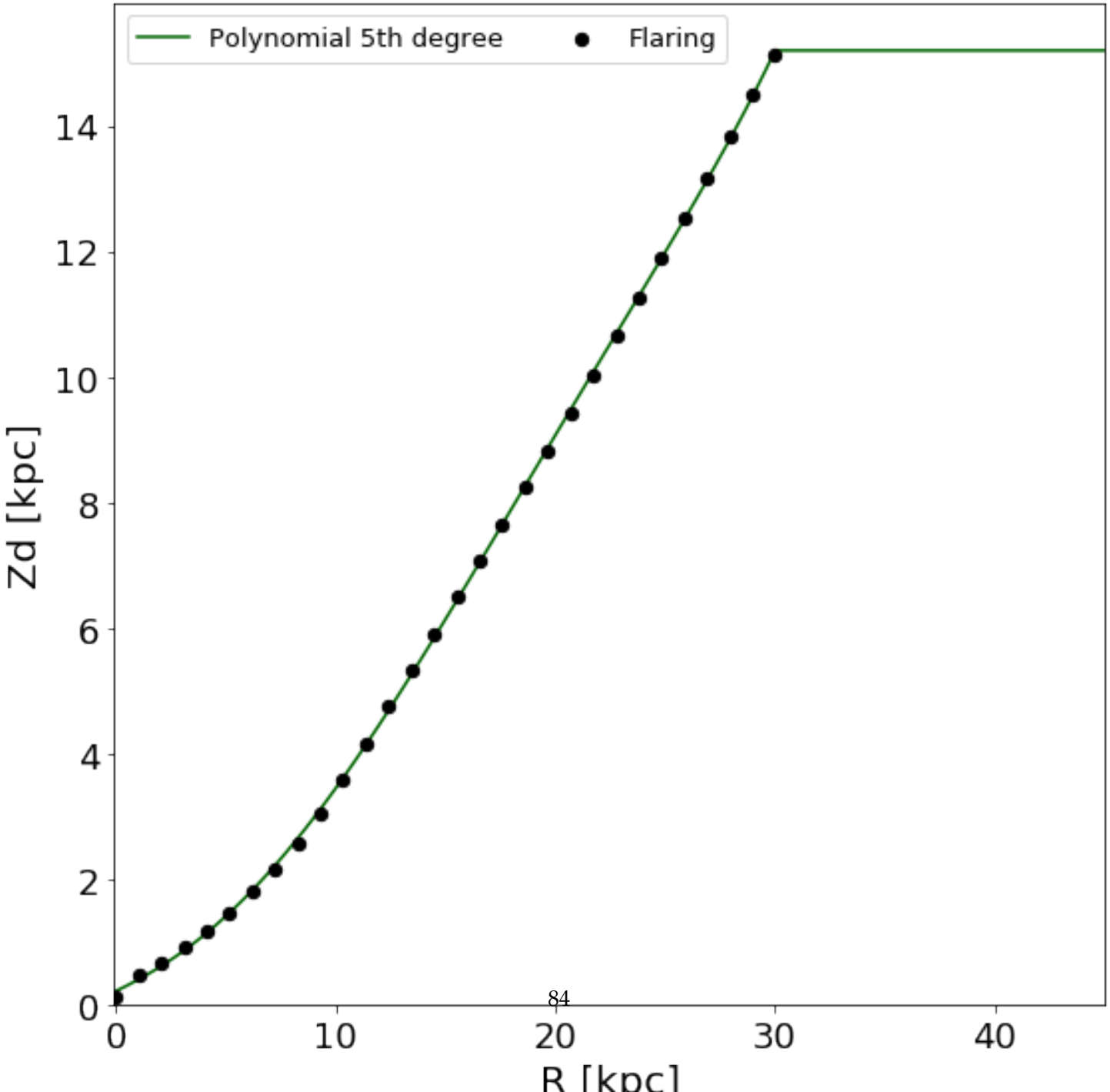
```
Plotting
Working on radius: 16.56
Working on radius: 17.59
Plotting
Working on radius: 18.62
Working on radius: 19.66
Plotting
Working on radius: 20.69
Working on radius: 21.73
Plotting
Working on radius: 22.76
Working on radius: 23.80
Plotting
Working on radius: 24.83
Working on radius: 25.86
Working on radius: 26.90
Working on radius: 27.93
Working on radius: 28.97
Working on radius: 30.00
Save figures
Writing table
DONE in 0.051 minutes
Output  data files in gasHeight_res/diagnostic/run0/dat
Output  images in gasHeight_res/diagnostic/run0/image
************************************************
                END FITZPROFILE
************************************************
************************************************
                 START FITFLARE
************************************************
Start fitting
Writing table
Save table
Make plot
```

```
Save plot
data in gasHeight_res/diagnostic/run0/flare/fitflare_par.dat
image in gasHeight_res/diagnostic/run0/flare/flare.pdf
************************************************
                  END FITFLARE
************************************************
Iter-0: Done
////////////////////////////////////////////////////////////////////////////////

////////////////////////////////////////////////////////////////////////////////
Iter-1:



        ---------------------------------------------------------------------------

        UnboundLocalError                         Traceback (most recent call last)

        <ipython-input-23-6d53ef0b521e> in <module>()
        102 diagnostic=True #If True, save figures and tables to see all results of the iterations in details, default=True
        103
    --> 104 final_gas_model, tab_zd,flare_func,fit_func=h.height(flaw=flaw, zlaw=zlaw, polyflare_degree=polyflare_degree, vdisp=


        /usr/local/lib/python3.6/site-packages/discH-3.1.0.dev0-py3.6-macosx-10.11-x86_64.egg/discH/src/discHeight/discHeight.py
        130             outfolder = '/diagnostic/run%i'%count
        131
    --> 132             df = galpotential(dynamic_components=self.disc_component)
        133             newpotential=df.potential(R, Z, grid=True, nproc=nproc, toll=inttoll, Rcut=Rcut, zcut=zcut, mcut=mcut,ex
        134



        /usr/local/lib/python3.6/site-packages/discH-3.1.0.dev0-py3.6-macosx-10.11-x86_64.egg/discH/src/galpotential/galpotentia
         13     def __init__(self,dynamic_components=()):
         14
```

```
---> 15         self._check_components(dynamic_components)
     16         if isinstance(dynamic_components,list) or isinstance(dynamic_components,tuple) or isinstance(dynamic_compone
     17             self.dynamic_components=list(dynamic_components)


/usr/local/lib/python3.6/site-packages/discH-3.1.0.dev0-py3.6-macosx-10.11-x86_64.egg/discH/src/galpotential/galpotentia
     34                     raise ValueError('Dynamic components %i is not from class halo or disc'%i)
     35                 i+=1
---> 36         elif isinstance(comp, (disc,halo,triaxial_halo)):
     37             pass
     38         else:


UnboundLocalError: local variable 'comp' referenced before assignment
```


15
10
5
0
0
10
20
30


R= 1.04 kpc
R= 3.11 kpc
gau
R= 5.18 kpc
R= 7.25 kpc
R= 9.32 kpc
R= 11.39 kpc
R= 13.45 kpc
R= 15.52 kpc
R= 17.59 kpc
R= 19.66 kpc
R= 21.73 kpc
R= 23.80 kpc
Z [kpc]


Polynomial 5th degree
Flaring
Zd [kpc]
R [kpc]
0
2
4
6
8
10
12
14
0
10
20
30
40

ESTIMATE SCALE HEIGHT The scale heigth of a disc can be obtained using the class discHeight

#Results of the functions:

0-final_gas_model: The final disc model, with the Radial surface density law given in inputr and the vertical profiles obtained in the iterative process

1-tab_zd: A tabel with 0-R [kpc] 1-Zd [kpc]

2-flare_func: The interpolating function of tab_zd, zd(R)=flare_func(R)

3-fit_func: The best-fit function (as defined with flaw) to the last zd estimate.

In the output folder you can find:

-finalflare_zd.pdf: a figure with the zd estimate at each iterative step (gray lines), the last estimate is shown by blue points and the red curve is the last best-fit function

-finalflare_hwhm.pdf: The final zd estimate, but the value in y is the HWHM

-tabflare.dat: 0-Col R[kpc], 1-Col zd[kpc], 2-Col HWHM[kpc]

-tab_fixedpotential.dat: Tab with the potentials of the fixed dynamic components

-tab_totpotential.dat: Tab with the potential of the final disc component

-My suggestion is to use:

```
Rlimit='max'
flaw='poly'
polyflare_degree_degree=5
```

```
In [22]: ##An example of use: estimate of the scale height for the HI disc and H2 disc

         ##Fixed component
         ##halo
         #halo=dc.isothermal_halo(....)
         ##bulge
         #bulge=dc.hernquist_halo(....)
         ##stellar disc
         #disc=dc.Exponential_disc.thick(...)

         ##Observed intrinsic HI surface density
         #HI_tab=[RHI,Sigma_HI]
         #HI_disc=dc.Frat_disc.thin(rfit_array=HI_tab,....)
```

```
##Observed intrinsic H2 surface density
#HII_tab=[RHII,Sigma_HII]
#HII_disc=dc.Frat_disc.thin(rfit_array=HII_tab,....)

#galaxy=(halo,bulge,disc)

#h=discHeight(dynamic_components=galaxy, disc_component=HI_disc)
#HI_disc=h.height(....)[0]

##galaxy_new=(halo,bulge,disc,HI_disc)

#h=discHeight(dynamic_components=galaxy_new, disc_component=HII_disc)
#HII_disc=h.height(....)[0]
```