Tutorial

November 14, 2017

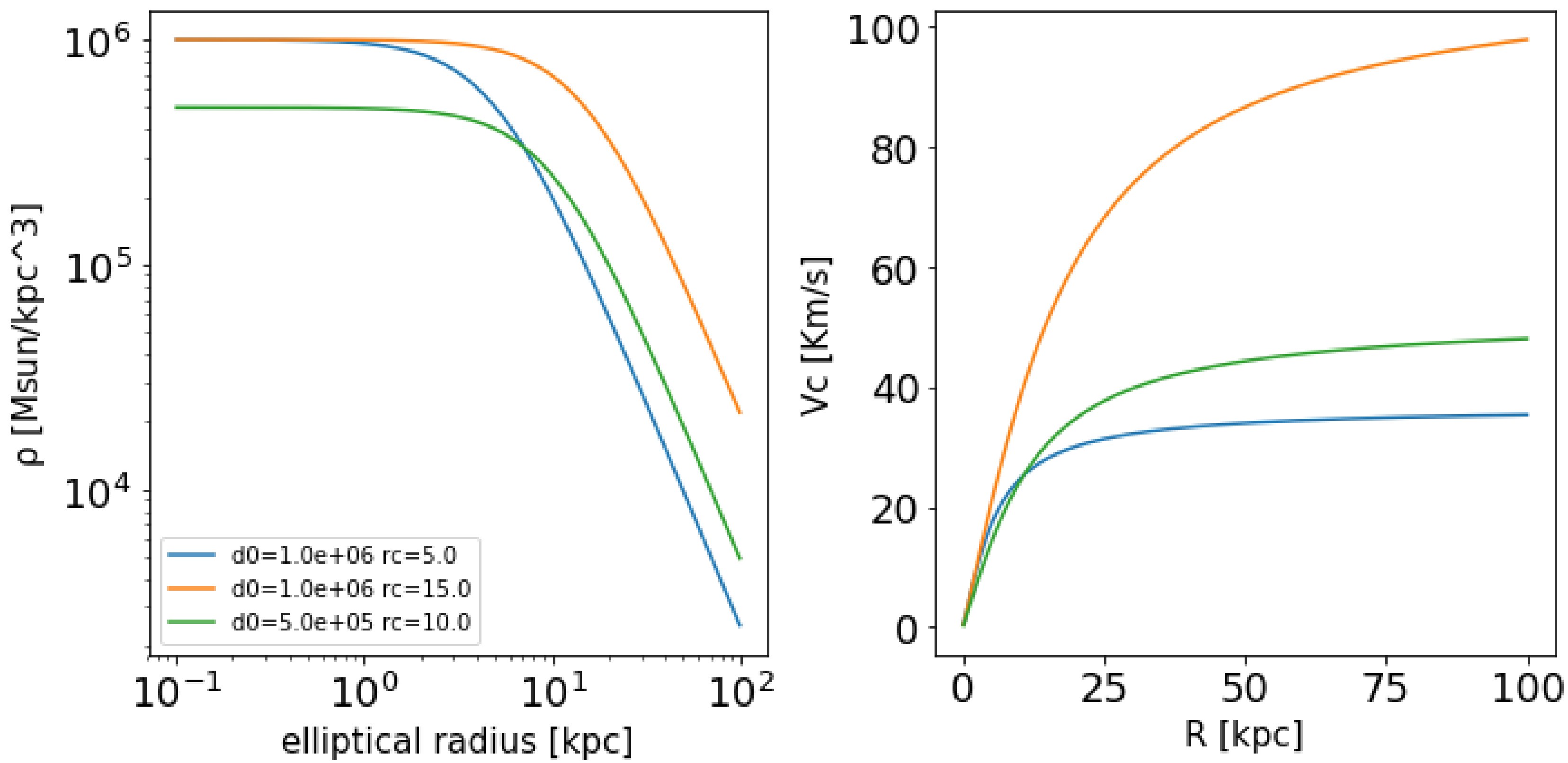
In [12]:
```
import numpy as np
import discH
import discH.dynamic_component as dc
import matplotlib.pyplot as plt
import warnings
warnings.filterwarnings('ignore')
```

HALO MODELS

In [13]:
```
#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))
```

```python
    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
```

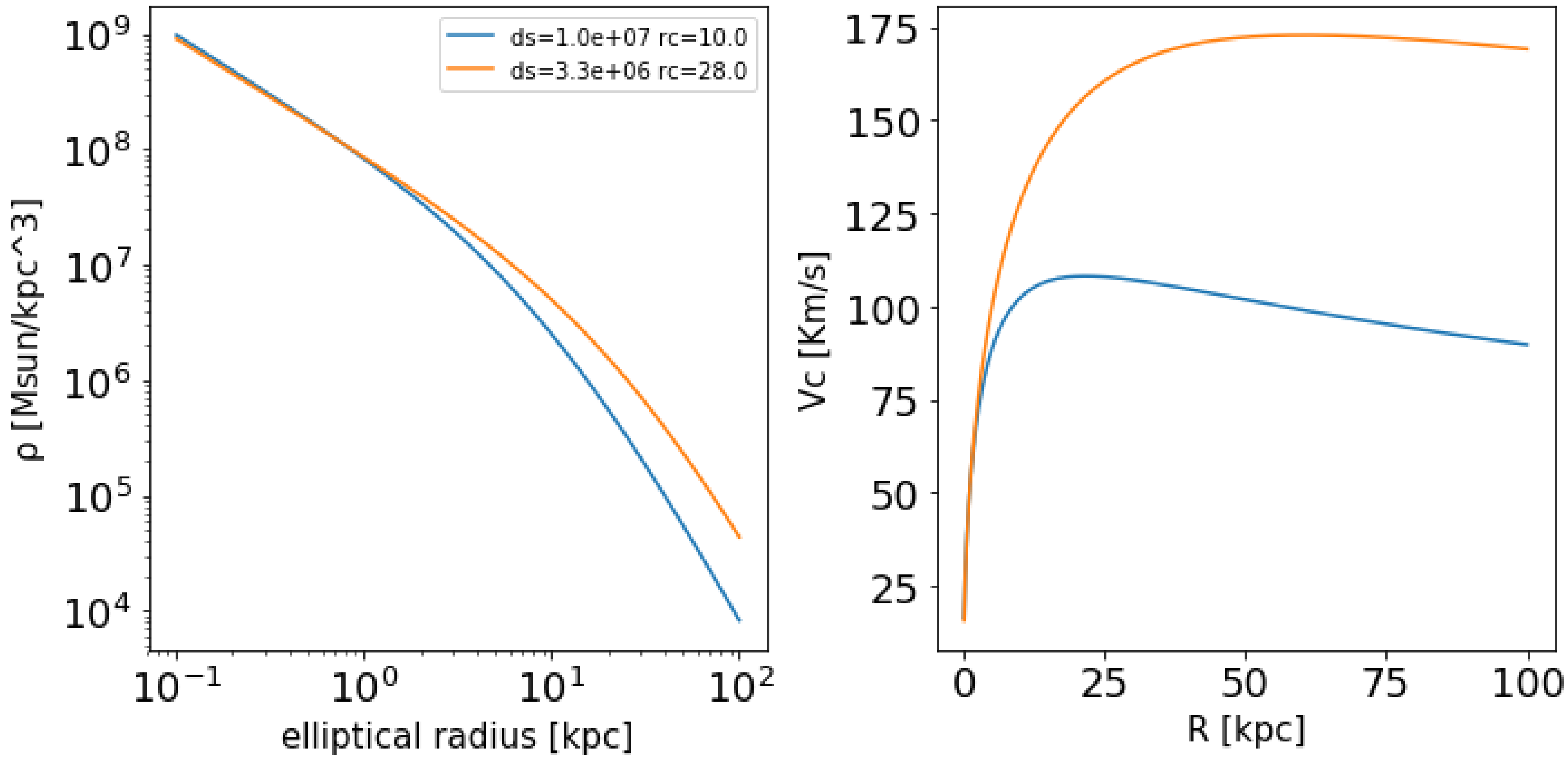


In [14]:
```
#NFW halo
R=np.linspace(0,100,1000)
fig=plt.figure(figsize=(10,5))
axd=fig.add_subplot(121)
axv=fig.add_subplot(122)
R=np.linspace(0,100,1000)
#d=d0*( (m/rs)^(-1) ) * ( (1+m/rs)^(-2) )
mcut=100 #radius where d(m>mcut)=0
```

```python
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 Universe)
#-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()
```

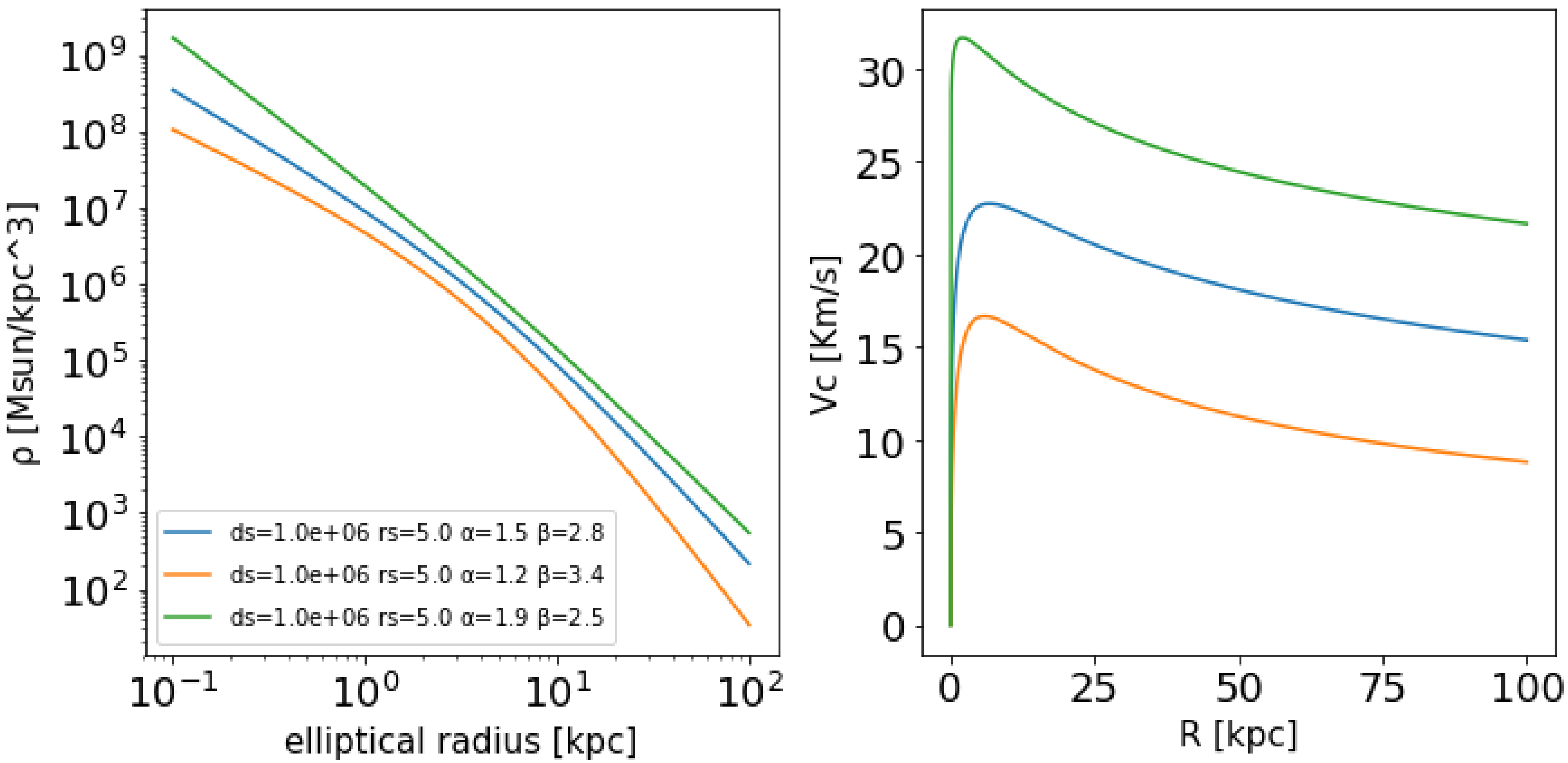
```
Model: NFW halo
d0: 3.26e+06 Msun/kpc3
rs: 27.99
e: 0.000
mcut: 100.000
```




```
In [15]: #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
```

```python
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,alpha=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.beta))
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.beta))

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,alpha=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.beta))
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.beta))

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,alpha=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.beta))
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.beta))

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()
```

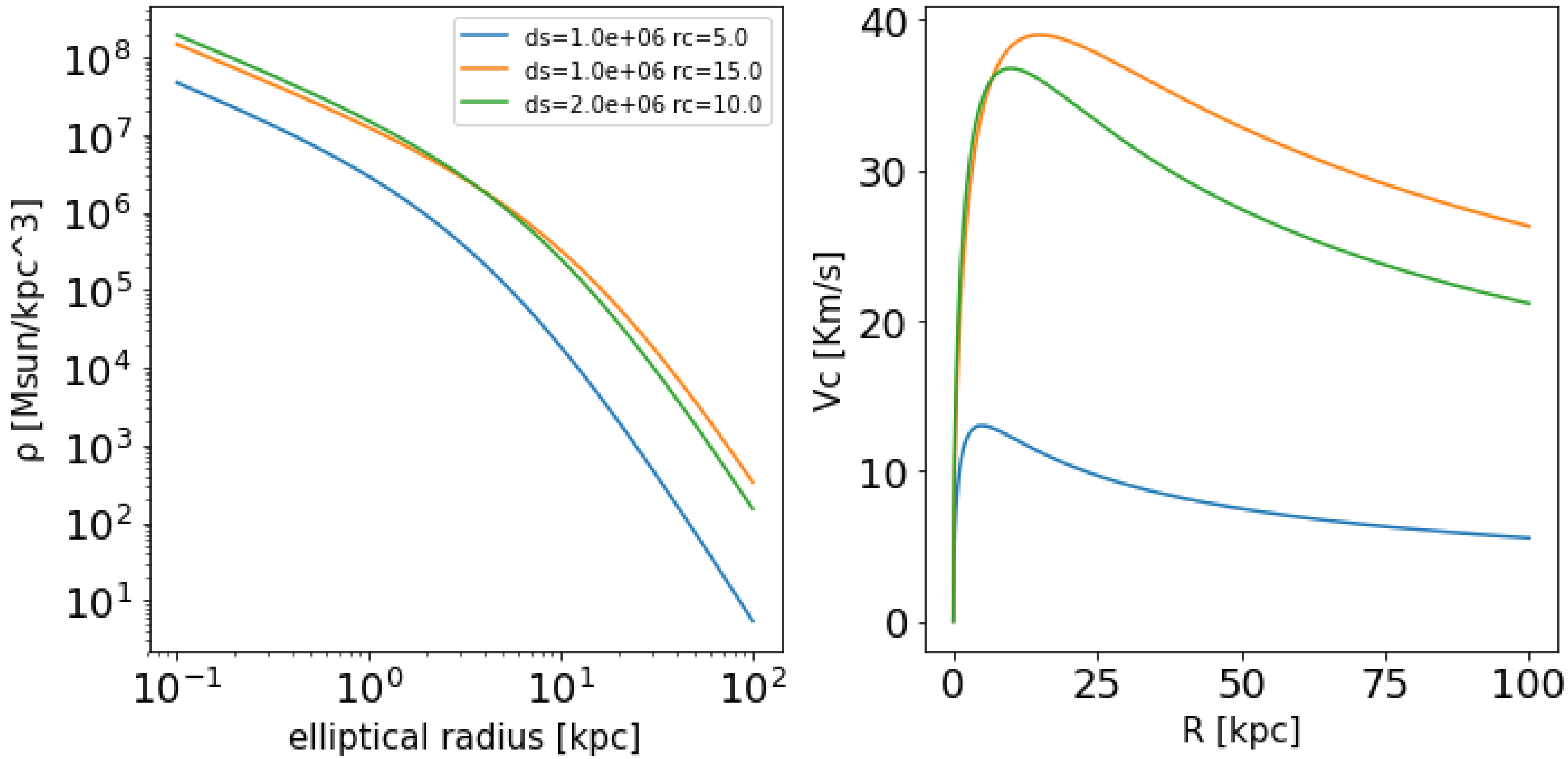



```
In [16]: #hernquist halo
         R=np.linspace(0,100,1000)
         fig=plt.figure(figsize=(10,5))
         axd=fig.add_subplot(121)
```

```
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)
```

```python
        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
```

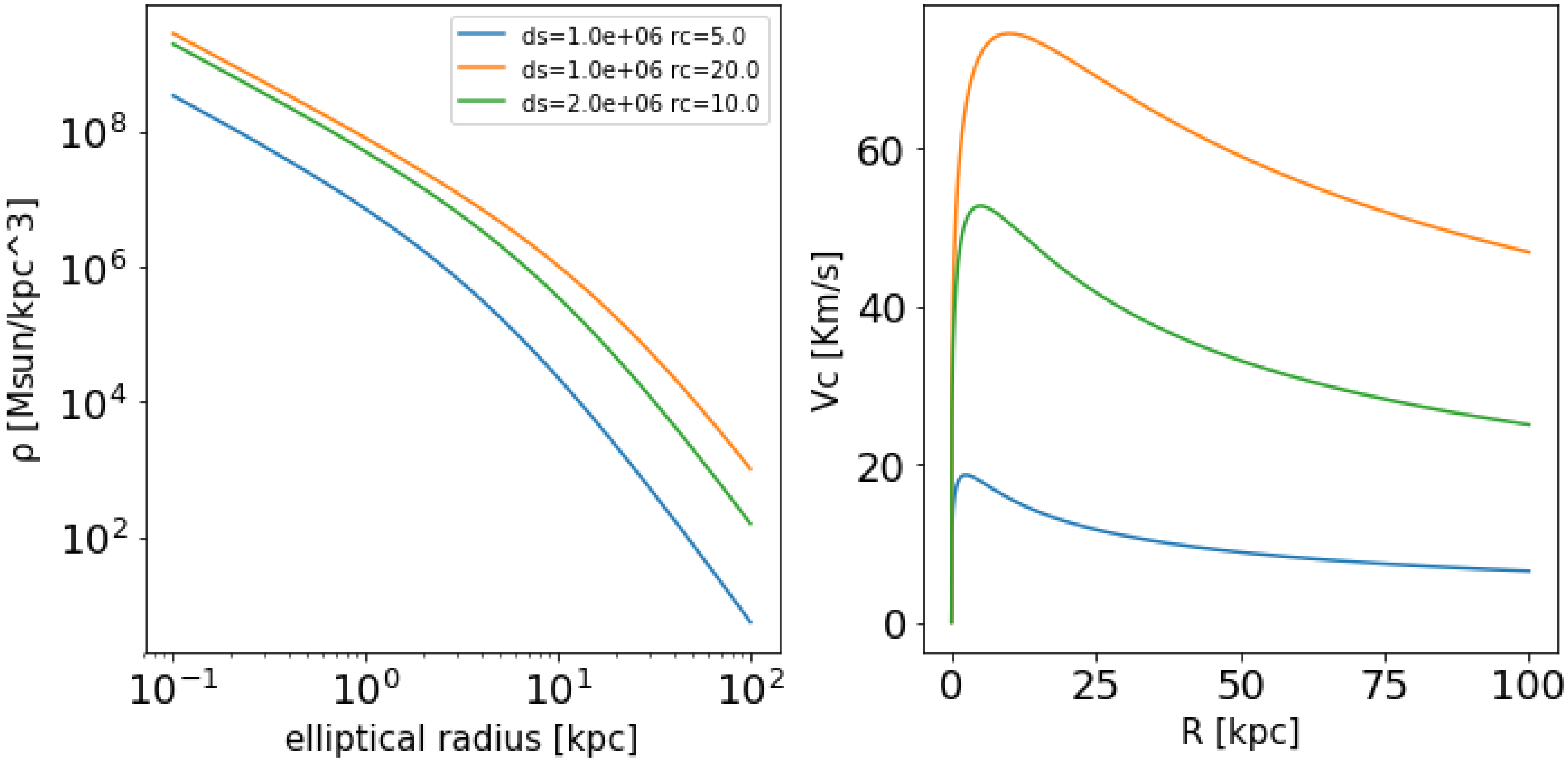



```
In [17]: #deVacouler like halo
         R=np.linspace(0,100,1000)
         fig=plt.figure(figsize=(10,5))
         axd=fig.add_subplot(121)
         axv=fig.add_subplot(122)
         R=np.linspace(0,100,1000)
         #d=d0*( (m/rs)^(-3/2) ) * ( (1+m/rs)^(-5/2) )
         #It is an approximation 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'%(dv_halo.d0,dv_halo.rs))
axv.plot(R,vcirc[:,1],label='ds=%.1e rc=%.1f'%(dv_halo.d0,dv_halo.rs))

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()
```

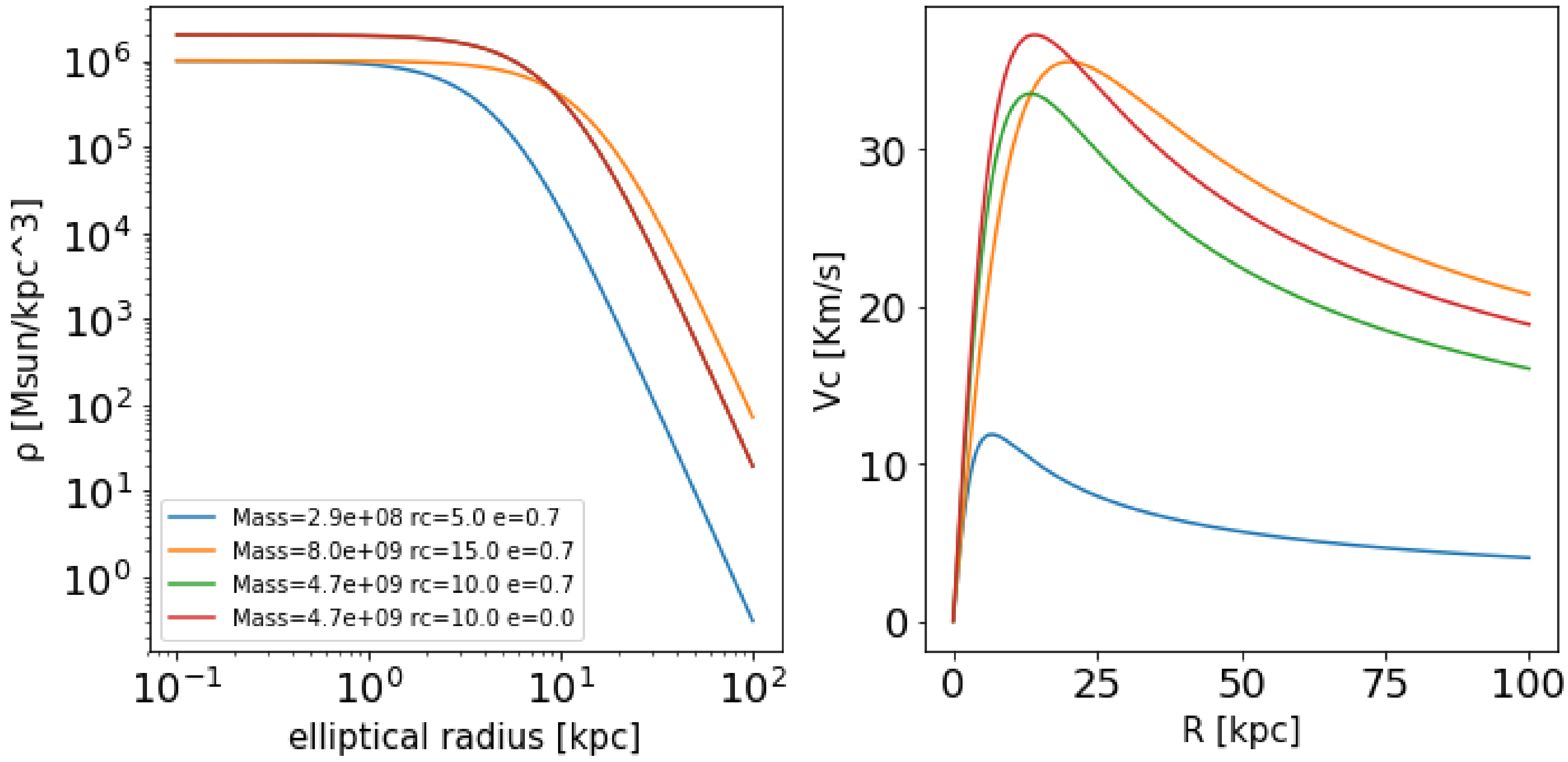
```
Model: deVacouler like halo
d0: 2.00e+06 Msun/kpc3
rs: 10.00
e: 0.000
mcut: 100.000
```



In [18]:
```
#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='Mass=%.1e rc=%.1f e=%.1f'%(pl_halo.mass,pl_halo.rc, pl_halo.e))
axv.plot(R,vcirc[:,1],label='Mass=%.1e rc=%.1f e=%1.f'%(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='Mass=%.1e rc=%.1f e=%.1f'%(pl_halo.mass,pl_halo.rc, pl_halo.e))
axv.plot(R,vcirc[:,1],label='Mass=%.1e rc=%.1f e=%1.f'%(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='Mass=%.1e rc=%.1f e=%.1f'%(pl_halo.mass,pl_halo.rc, pl_halo.e))
axv.plot(R,vcirc[:,1],label='Mass=%.1e rc=%.1f e=%1.f'%(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='Mass=%.1e rc=%.1f e=%.1f'%(pl_halo.mass,pl_halo.rc, pl_halo.e))
axv.plot(R,vcirc[:,1],label='Mass=%.1e rc=%.1f e=%1.f'%(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()
```

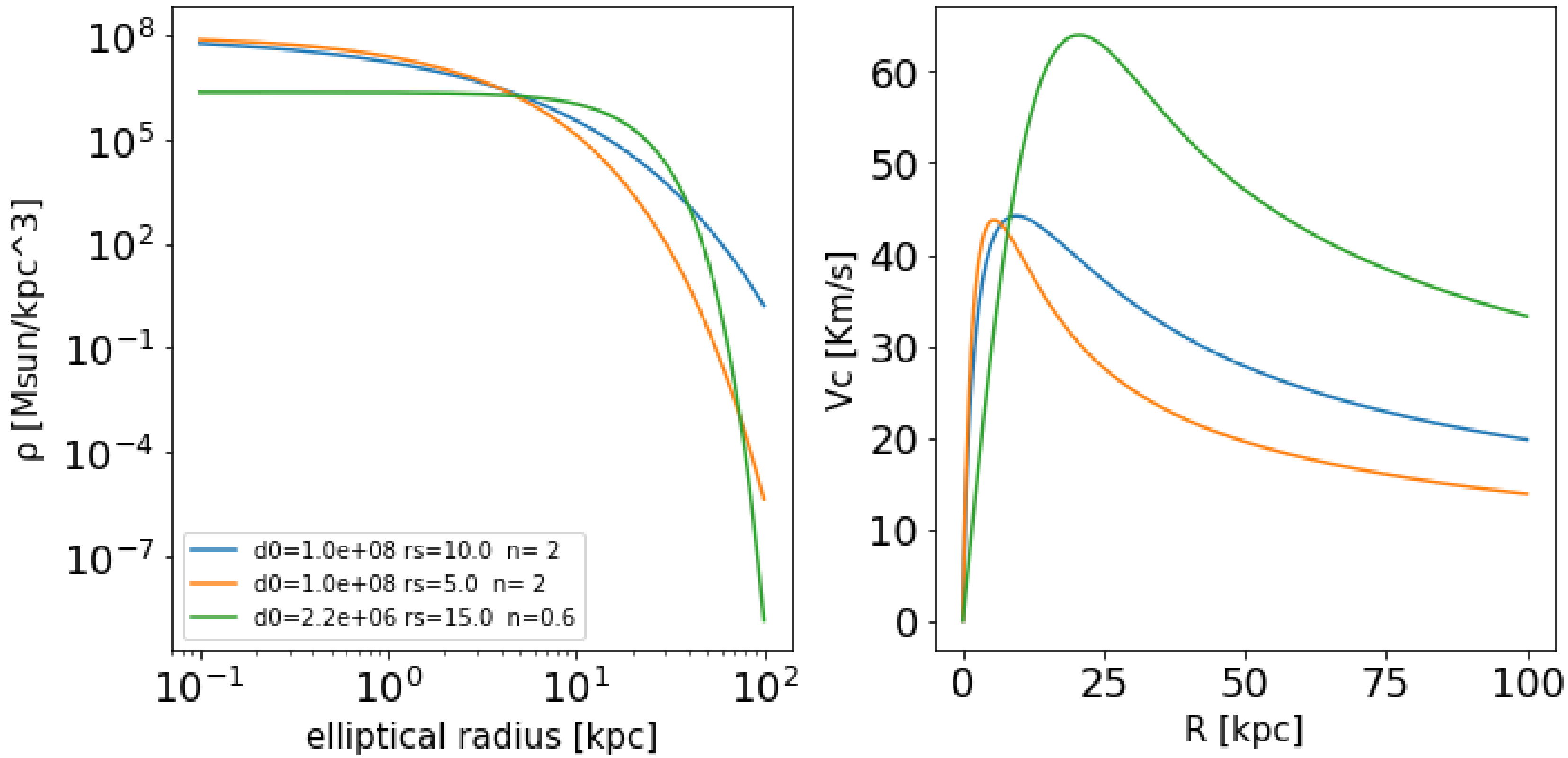
```
Model: Plummer halo
Mass: 4.71e+09 Msun
d0: 2.00e+06 Msun/kpc3
rc: 10.00
e: 0.000
mcut: 100.000
```




```
In [19]: #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
```

```python
#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()
```



DISC MODELS

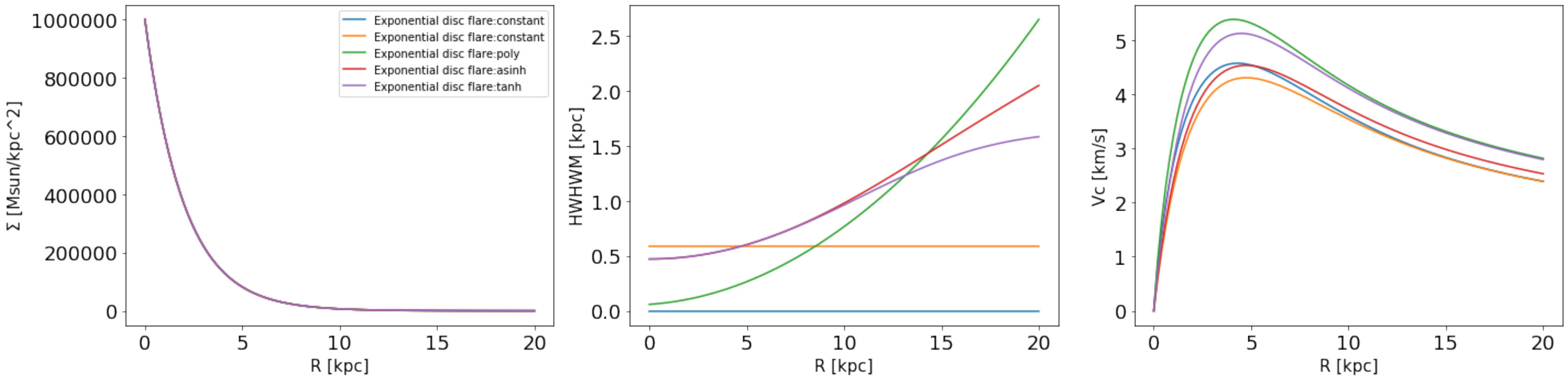
In [20]:
```
#Exponential disc
#Sigma(R)=Sigma0*Exp(-R/Rd)
sigma0=1e6 #Cental surface density in Msun/kpc2
Rd= 2 #Exponential scale length in kpc
Rcut= 50 #Cylindrical radius where dens(R>Rcut,z)=0
zcut= 20 #Cylindrical heigth where dens(R,|z|>zcut)=0
zlaw='gau' #Vertical density law: it could be gau,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

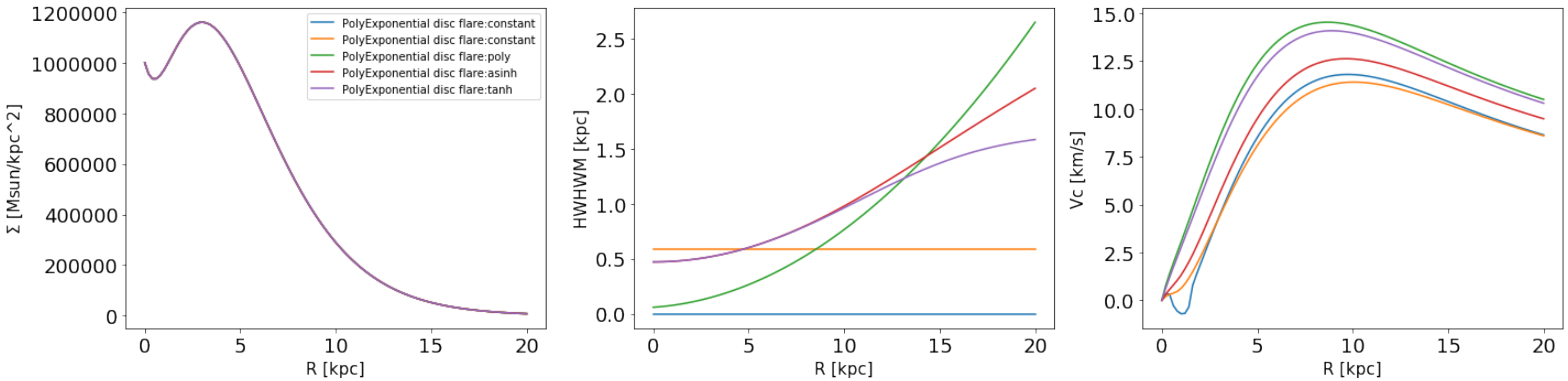


In [21]:
```
fig=plt.figure(figsize=(20,5))
ax_dens=fig.add_subplot(131)
ax_flare=fig.add_subplot(132)
ax_vcirc=fig.add_subplot(133)
R=np.linspace(0,20,100) #Cylidrincal radii where estimate surface density and flare



#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, default=False)
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, default=False)
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=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, default=False)
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, 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, default=False)
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=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, default=False)
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: 1.0e+00 2.0e-01 4.0e-01 0.0e+00 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
```

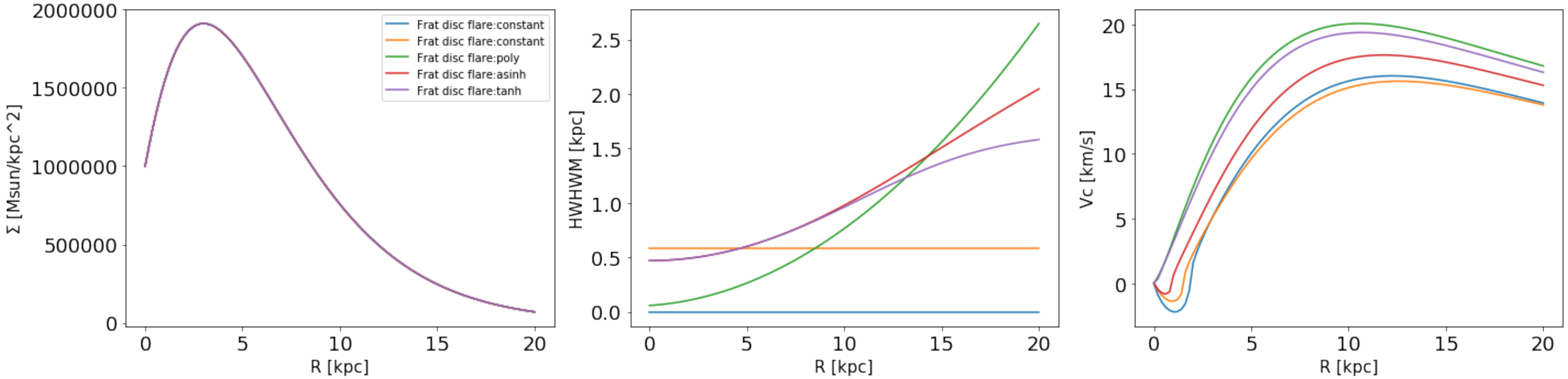


In [22]:
```
fig=plt.figure(figsize=(20,5))
ax_dens=fig.add_subplot(131)
ax_flare=fig.add_subplot(132)
ax_vcirc=fig.add_subplot(133)
R=np.linspace(0,20,100) #Cylidrincal radii where estimate surface density and flare

#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, default=False)
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, default=False)
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, default=False)
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, default=False)
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, default=False)
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
```



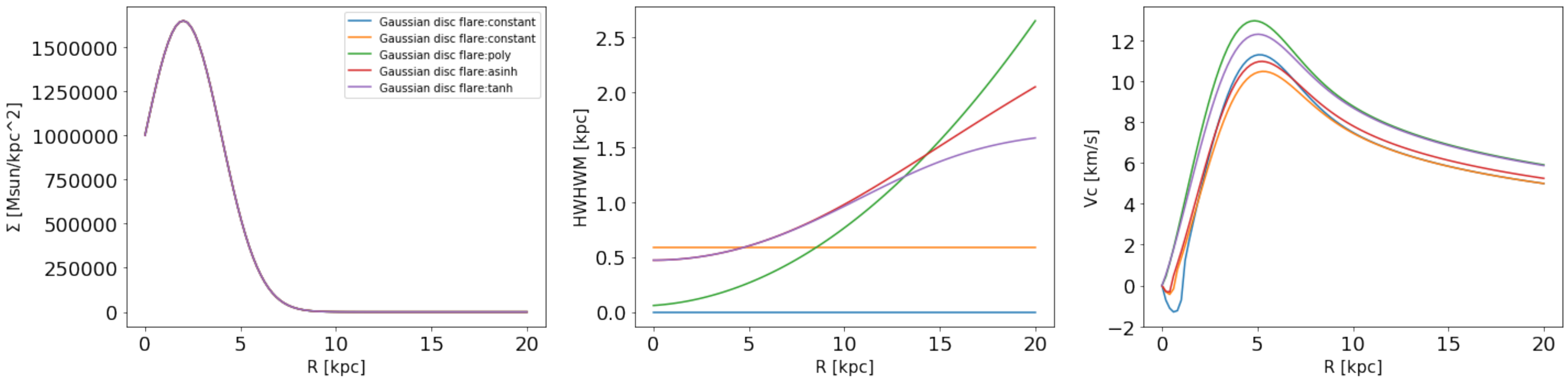
In [23]:
```
fig=plt.figure(figsize=(20,5))
ax_dens=fig.add_subplot(131)
ax_flare=fig.add_subplot(132)
ax_vcirc=fig.add_subplot(133)
R=np.linspace(0,20,100) #Cylidrincal radii where estimate surface density and flare
```

```
#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, default=False)
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, default=False)
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, default=False)
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, default=False)
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, default=False)
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 [24]:
```
#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 [25]: #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=[0.1,2,10] #List with the cylindrical radial coordinates in Kpc
         Z=[0,0.1,1] #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])..ecc
         nproc=2 #Number of proccesors to use for parallel computation
         toll=1e-4 #Relative and absolute Tollerance for the potential integration
         potential_grid=iso_halo.potential(R=R,Z=Z,grid=grid,nproc=2)
         print(potential_grid)
         #First Column -R
         #Second Column -Z
         #Third Column Potenzial in Kpc^2/Myr^2
```

```
[[  1.00000000e-01   0.00000000e+00  -4.23552484e-03]
 [  1.00000000e-01   1.00000000e-01  -4.23543065e-03]
```

```
 [  1.00000000e-01   1.00000000e+00  -4.22621602e-03]
 [  2.00000000e+00   0.00000000e+00  -4.19961401e-03]
 [  2.00000000e+00   1.00000000e-01  -4.19952792e-03]
 [  2.00000000e+00   1.00000000e+00  -4.19109439e-03]
 [  1.00000000e+01   0.00000000e+00  -3.72924475e-03]
 [  1.00000000e+01   1.00000000e-01  -3.72921321e-03]
 [  1.00000000e+01   1.00000000e+00  -3.72609958e-03]]
```

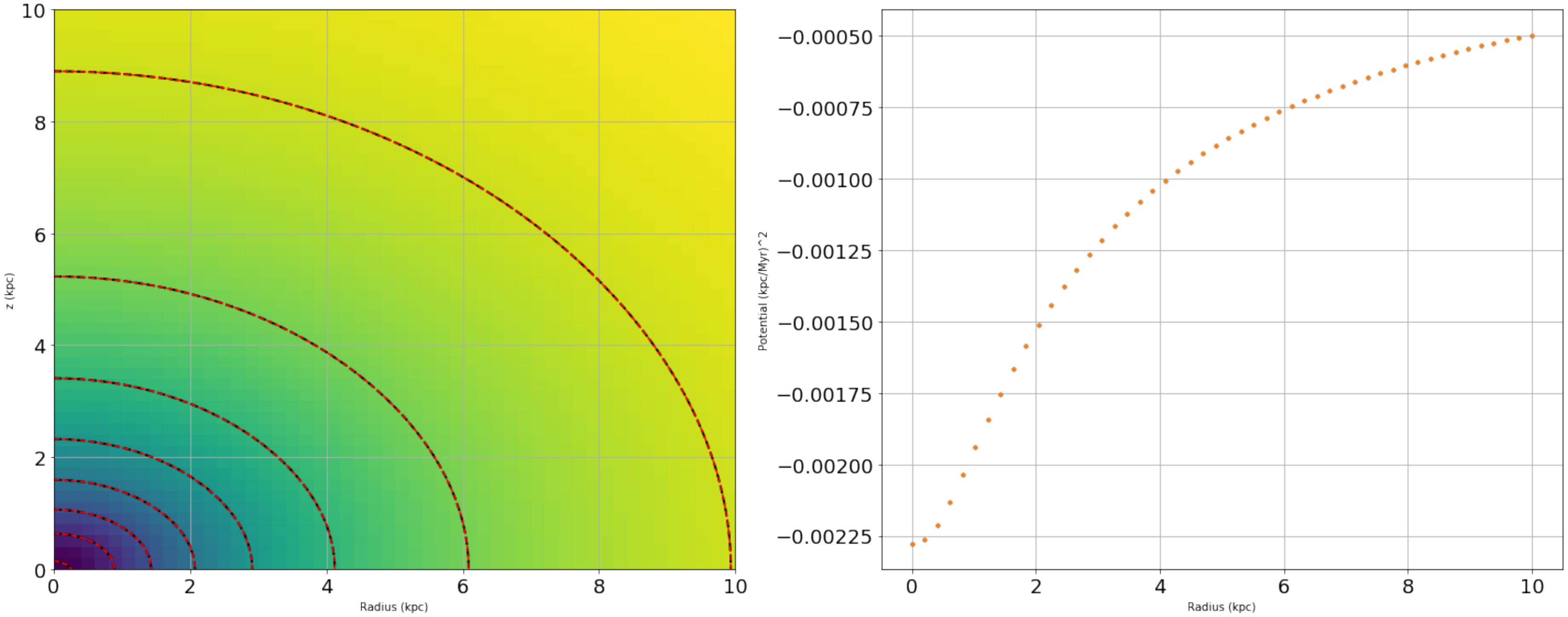
In [26]:
```
# Estimate potential of a triaxial halo

#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,alpha=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()
```

```python
# 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 0x1079bcf28>
```




```
In [27]: #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=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=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])..ecc
nproc=2 #Number of proccesor to use for parallel computation
toll=1e-4 #Relative and absolute Tollerance for the potential integration
```

```python
    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 potential in kpc^2/
    print('##########STEP2###########')
    print('Estimate Potential')
    hp=ga.potential(R,Z,grid=grid, nproc=nproc, toll=toll, Rcut=Rcut, zcut=zcut, mcut=mcut, external_potential=external_potential)
    #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[:5])
    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)
```

```
##########STEP2###########
Components info
Components: 0
Model: NFW halo
d0: 1.00e+06 Msun/kpc3
rs: 1.00
e: 0.000
mcut: 100.000
```

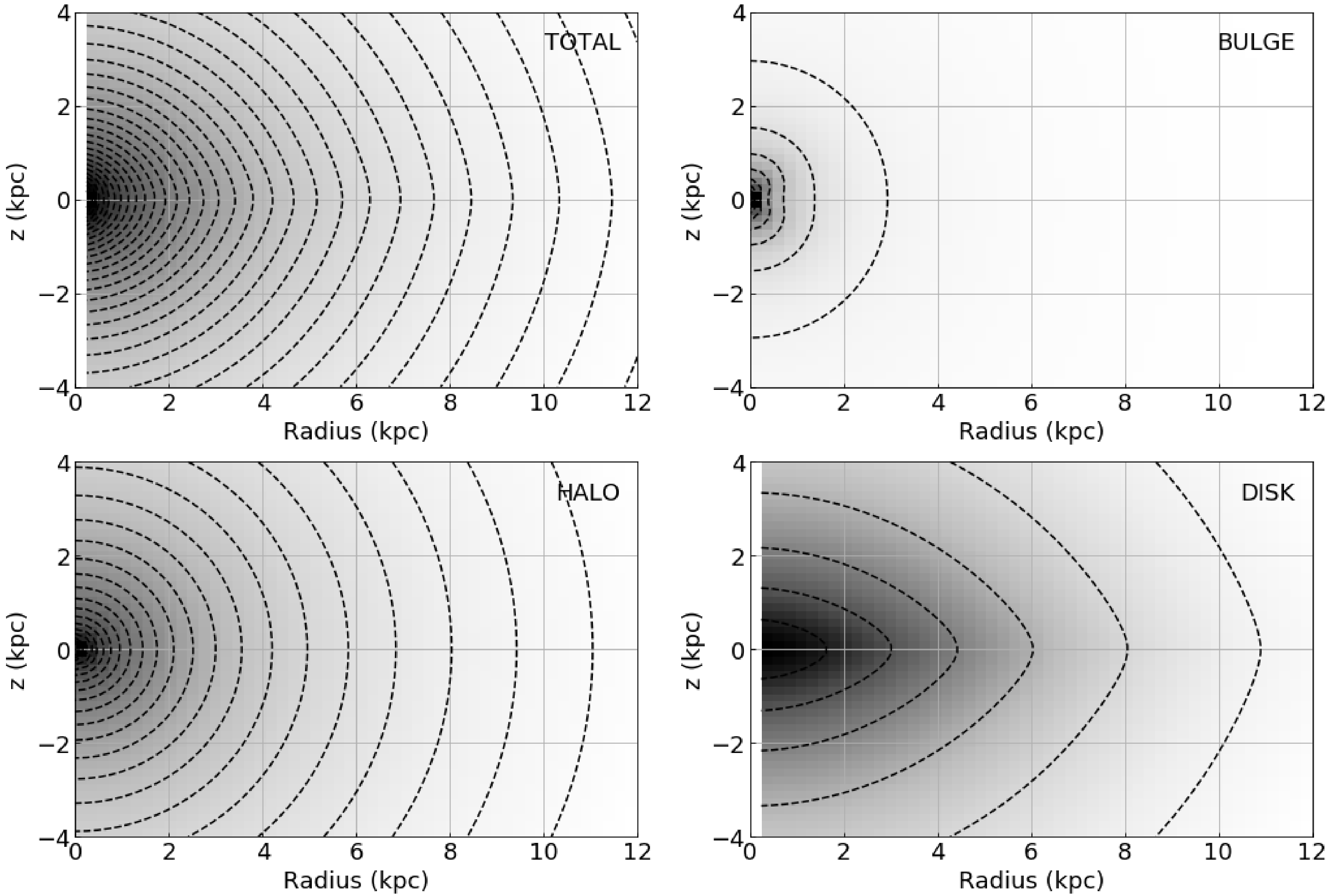
```
Components: 1
Model: Exponential disc
Sigma0: 1.00e+06 Msun/kpc2
Vertical density law: sech2
Radial density law: epoly
Rd: 3.000 kpc
Flaring law: constant
Fparam: 4.0e-01 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00
Rcut: 50.000 kpc
zcut: 30.000 kpc
Rlimit: None

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

###########################
##########STEP2###########
Estimate Potential
External potential: No
Calculating Potential of the 1th component (NFW halo)...Done (0.00 s)
Calculating Potential of the 2th component (Exponential disc)...Done (0.71 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  -1.97041695e-04]
 [  1.00000000e-01   5.55555556e-01  -1.60667195e-04]
 [  1.00000000e-01   1.11111111e+00  -1.33353334e-04]
 [  1.00000000e-01   1.66666667e+00  -1.14923246e-04]
 [  1.00000000e-01   2.22222222e+00  -1.01484332e-04]]
###########################
```

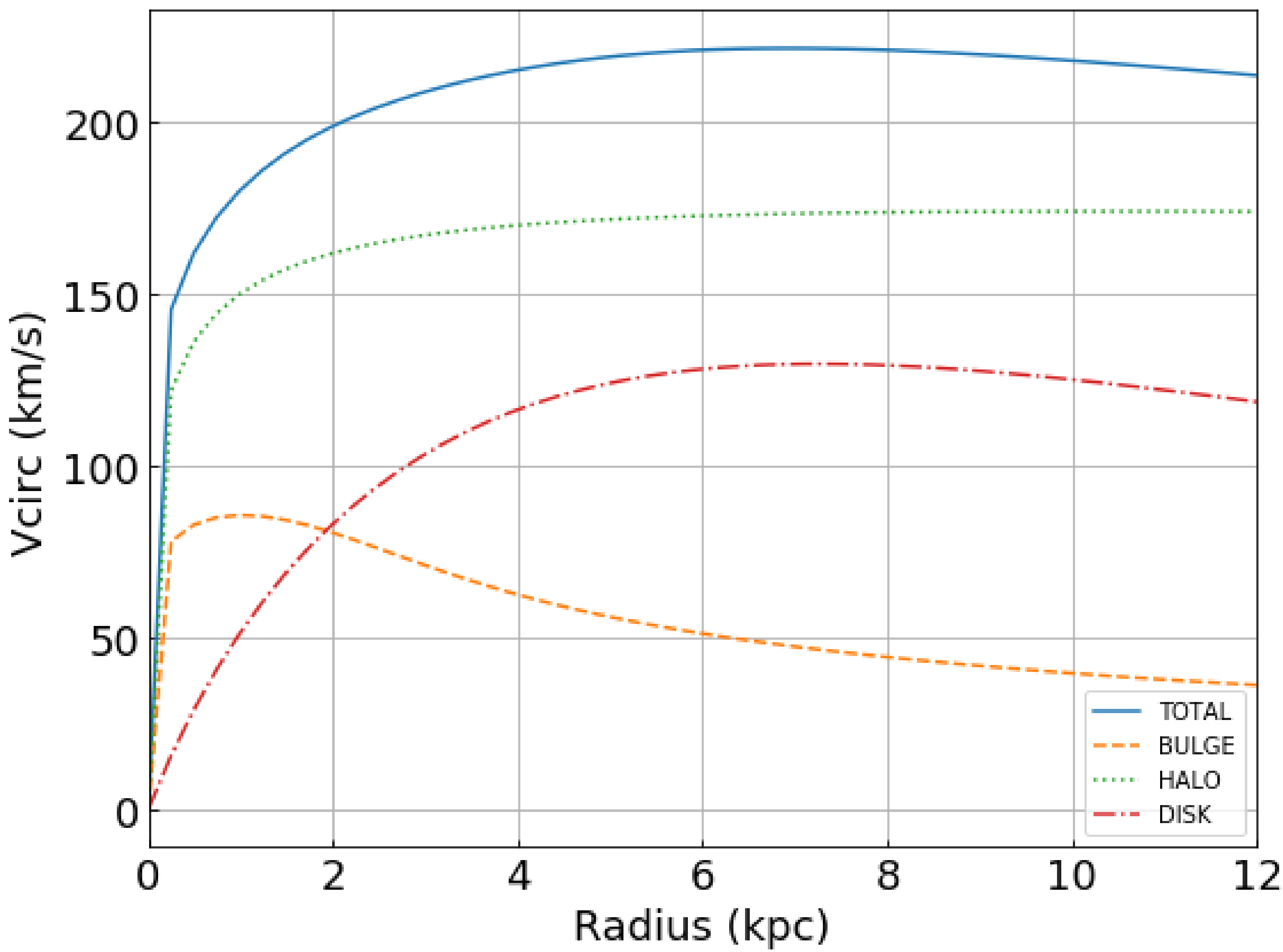
In [30]:
```
# MW Potential
from discH.dynamics import MWpotential
```

```python
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]])
```

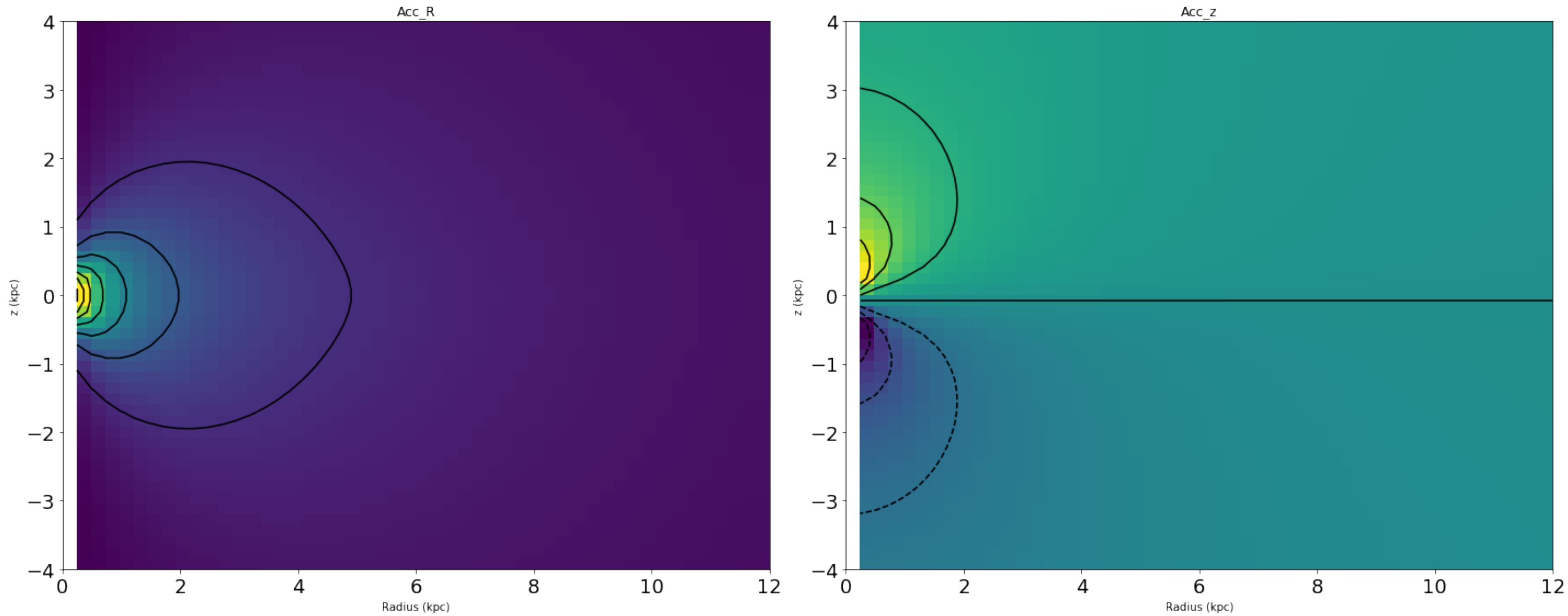
```
        ax2.set_xlabel("Radius (kpc)")
        ax2.set_ylabel("z (kpc)")
        ax2.contour(R,z,az,colors='k')
        ax2.set_title("Acc_z")

        plt.show()
```

```
External potential: No
Calculating Potential of the 1th component (Power law with cut halo)...Done (1.88 s)
Calculating Potential of the 2th component (AlfaBeta halo)...Done (0.40 s)
Calculating Potential of the 3th component (Exponential disc)...Done (29.59 s)
Calculating Potential of the 4th component (Exponential disc)...Done (27.40 s)
```


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



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



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

In [32]:
```
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 properties.

#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_array[0,1] for R<vd

#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.logspace(np.log10(Rr
#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.logspace(np.log10(Zr
#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 outside the used R ra
    #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, Rpoints=Rpoints, Ri

////////////////////////////////////////////////////////////////////////////
Calculating fixed potential
External potential: No
Calculating Potential of the 1th component (Hernquist halo)...Done (0.03 s)
Calculating Potential of the 2th component (Exponential disc)...Done (7.95 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 0.050 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-32-6d53ef0b521e> 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=10, Rpoints=Rpoints,


/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 in height(self, fla
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,external_potential=fix
134


/usr/local/lib/python3.6/site-packages/discH-3.1.0.dev0-py3.6-macosx-10.11-x86_64.egg/discH/src/galpotential/galpotential.py in __init__(sel
 12     def __init__(self,dynamic_components=()):
 13
---> 14         self._check_components(dynamic_components)
 15         if isinstance(dynamic_components,list) or isinstance(dynamic_components,tuple) or isinstance(dynamic_components,np.ndarray):
 16             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/galpotential.py in _check_compo
 31                     raise ValueError('Dynamic components %i is not from class halo or disc'%i)
 32                 i+=1
---> 33         elif isinstance(comp, (disc,halo,triaxial_halo)):
 34             pass
 35         else:


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

#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 [ ]:
```