Tutorial

August 3, 2018

```
In [2]: import numpy as np
        import galpynamics
        import galpynamics.dynamic_component as dc
        import matplotlib.pyplot as plt
        import warnings
        warnings.filterwarnings("ignore")
```

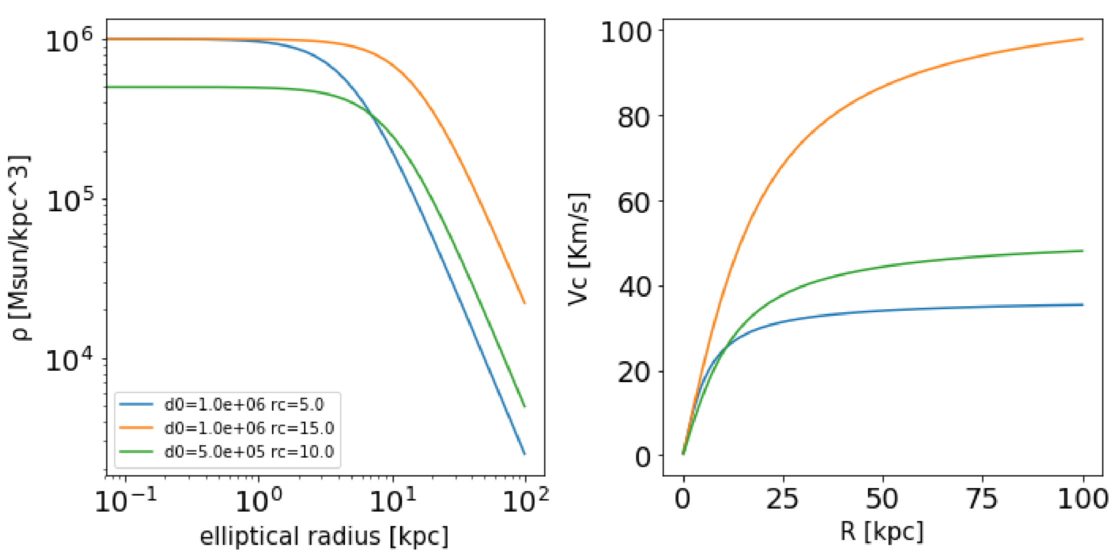
HALO MODELS

```
In [3]: #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()
```

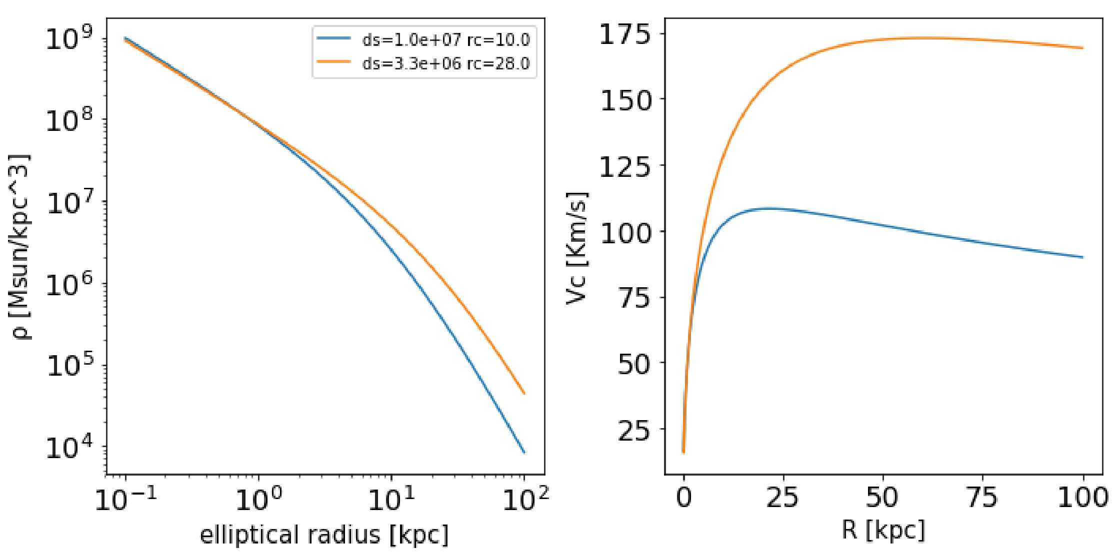
```
Model: Isothermal halo
d0: 5.00e+05 Msun/kpc3
rc: 10.00
e: 0.000
mcut: 100.000
```



```
In [4]: #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 t
        #-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 NF
        #NWF_halo.cosmo(c, V200, H=67, e=0, mcut=100) H is the Hubble constant in km/s/Mpc (67
        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')
```

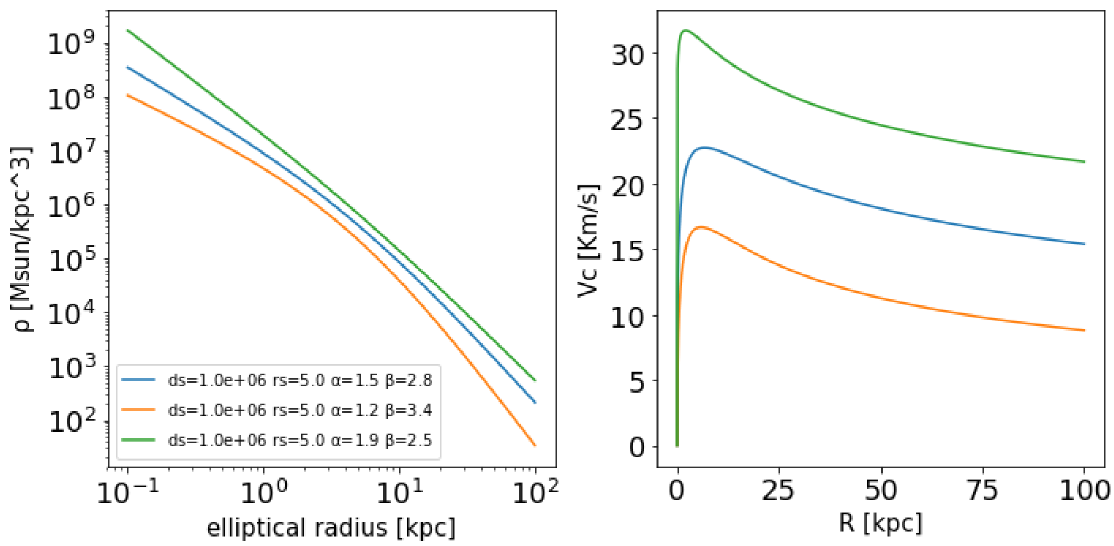
```
        axd.legend()
        plt.show()
```

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



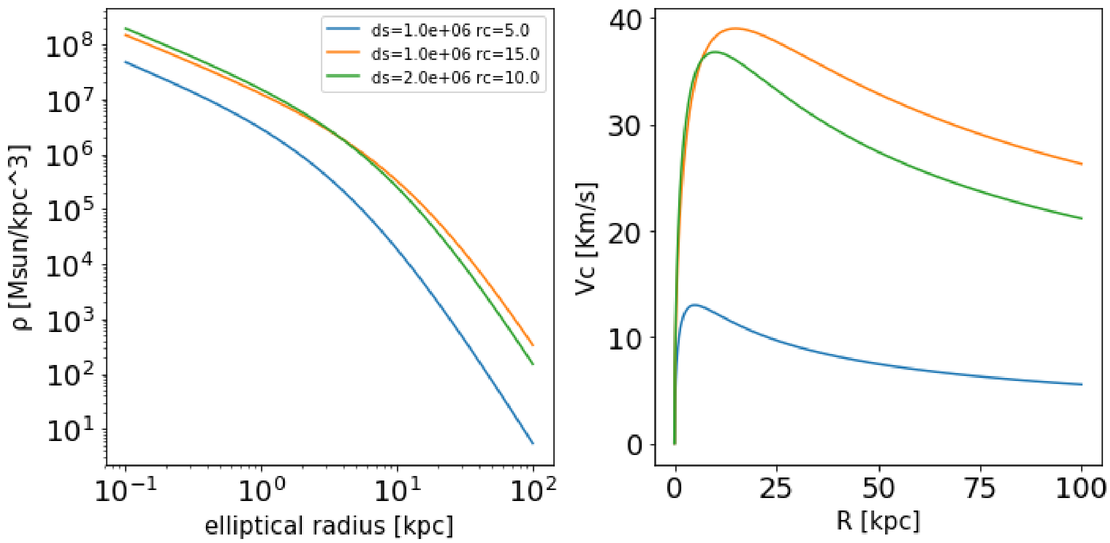

```
In [5]: #alfabeta halo
        R=np.linspace(0,100,1000)
        fig=plt.figure(figsize=(10,5))
        axd=fig.add_subplot(121)
        axv=fig.add_subplot(122)
        R=np.linspace(0,100,1000)
        #d=d0*( (m/rs)^(-alfa) ) * ( (1+m/rs)^(-(beta-alfa)) )
        mcut=100 #radius where d(m>mcut)=0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

```
axv.plot(R,vcirc[:,1],label='ds=%.1e rs=%.1f $\\alpha$=%.1f $\\beta$=%.1f'%(ab_halo.d0

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,a
axv.plot(R,vcirc[:,1],label='ds=%.1e rs=%.1f $\\alpha$=%.1f $\\beta$=%.1f'%(ab_halo.d0

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,a
axv.plot(R,vcirc[:,1],label='ds=%.1e rs=%.1f $\\alpha$=%.1f $\\beta$=%.1f'%(ab_halo.d0

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 [6]:
```
#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()
```

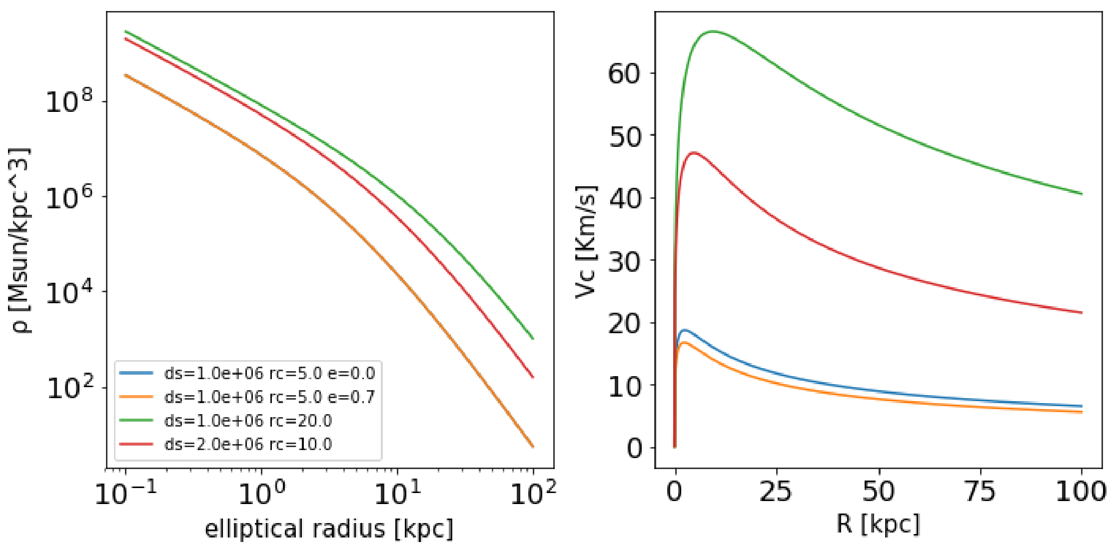
```
Model: Hernquist halo
d0: 2.00e+06 Msun/kpc3
rs: 10.00
e: 0.000
mcut: 100.000
```



In [7]:
```
#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
```

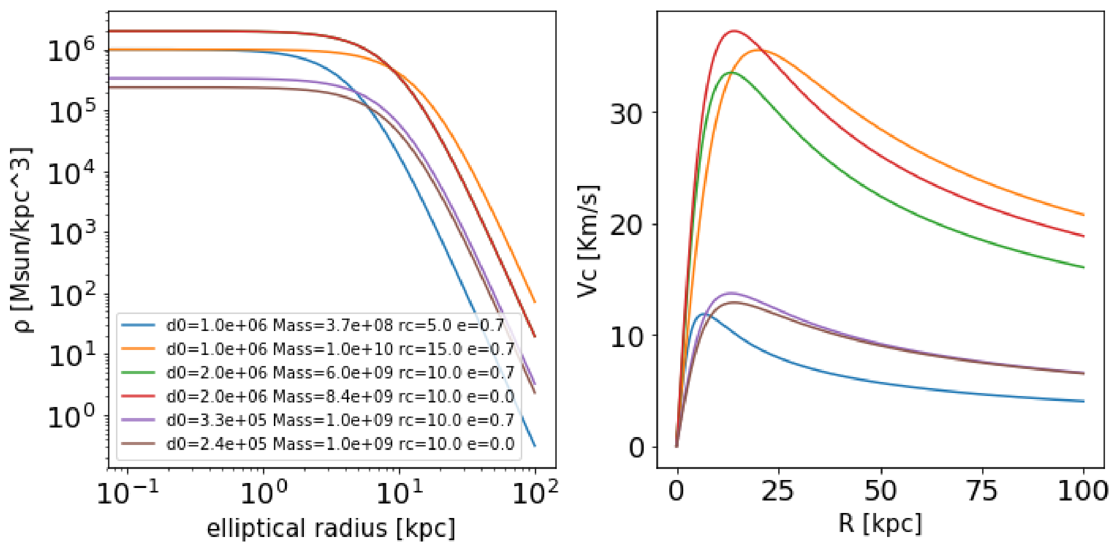


In [8]:
```
#Plummer halo
R=np.linspace(0,100,1000)
fig=plt.figure(figsize=(10,5))
axd=fig.add_subplot(121)
axv=fig.add_subplot(122)
R=np.linspace(0,100,1000)
#d=d0*( (1+m*m/rs*rs)^(-5/2) )
mcut=100 #radius where d(m>mcut)=0
e=0.7 #ellipticity

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
axv.plot(R,vcirc[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%1.f'%(pl_halo.d0,pl_halo.mass

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
axv.plot(R,vcirc[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%1.f'%(pl_halo.d0,pl_halo.mass

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
axv.plot(R,vcirc[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%1.f'%(pl_halo.d0,pl_halo.mas

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
axv.plot(R,vcirc[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%1.f'%(pl_halo.d0,pl_halo.mas

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
axv.plot(R,vcirc[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%1.f'%(pl_halo.d0,pl_halo.mas

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
axv.plot(R,vcirc[:,1],label='d0=%.1e Mass=%.1e rc=%.1f e=%1.f'%(pl_halo.d0,pl_halo.mas




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()
```

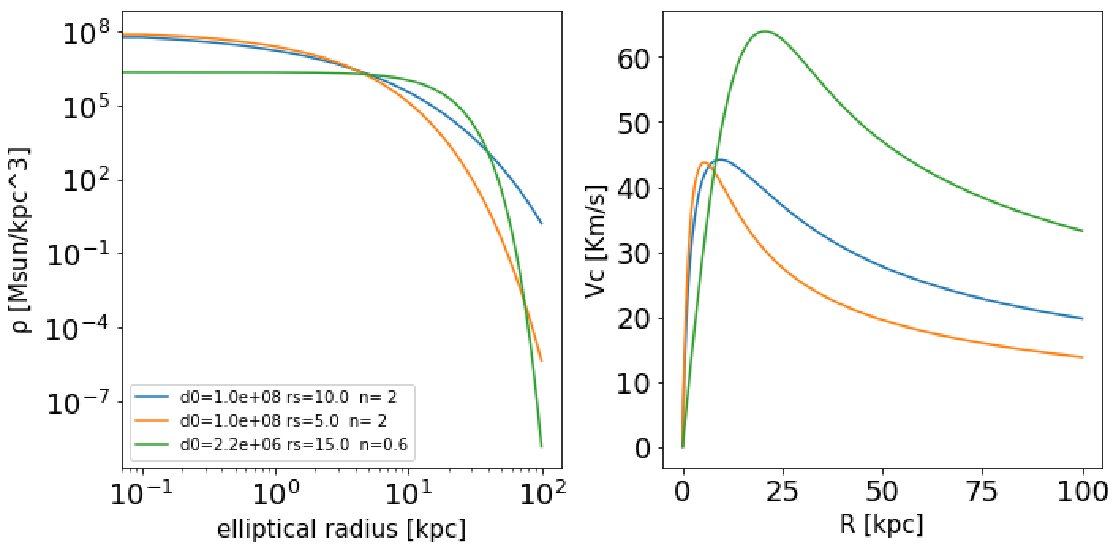
```
Model: Plummer halo
Mass: 1.00e+09 Msun
```

```
d0: 2.39e+05 Msun/kpc3
rc: 10.00
e: 0.000
mcut: 100.000
```



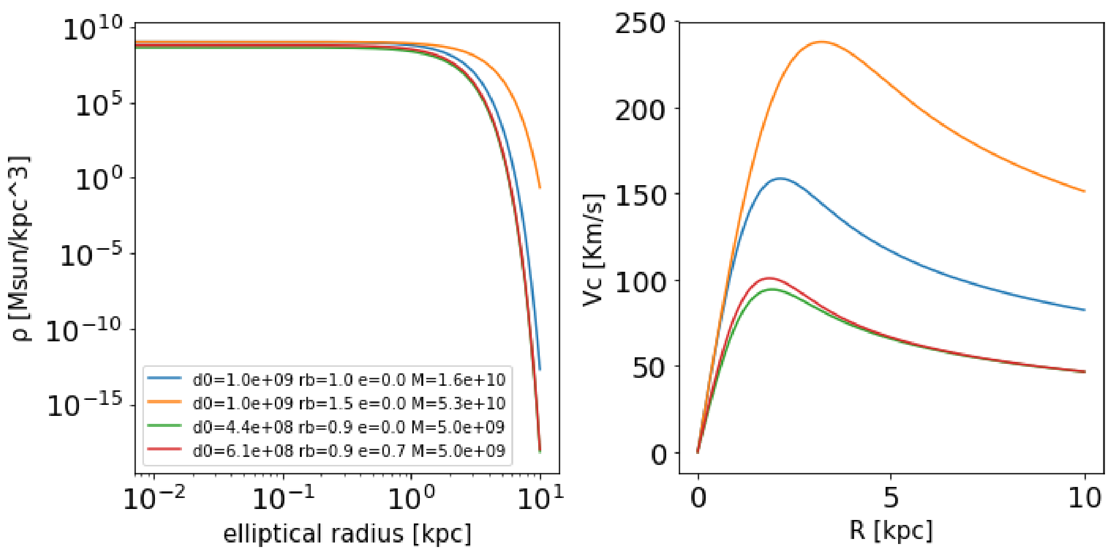
In [9]:
```
#Einasto halo
R=np.linspace(0,100,1000)
fig=plt.figure(figsize=(10,5))
axd=fig.add_subplot(121)
axv=fig.add_subplot(122)
R=np.linspace(0,100,1000)
mcut=100 #radius where d(m>mcut)=0
e=0.0 #ellipticity


#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

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


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

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()
```



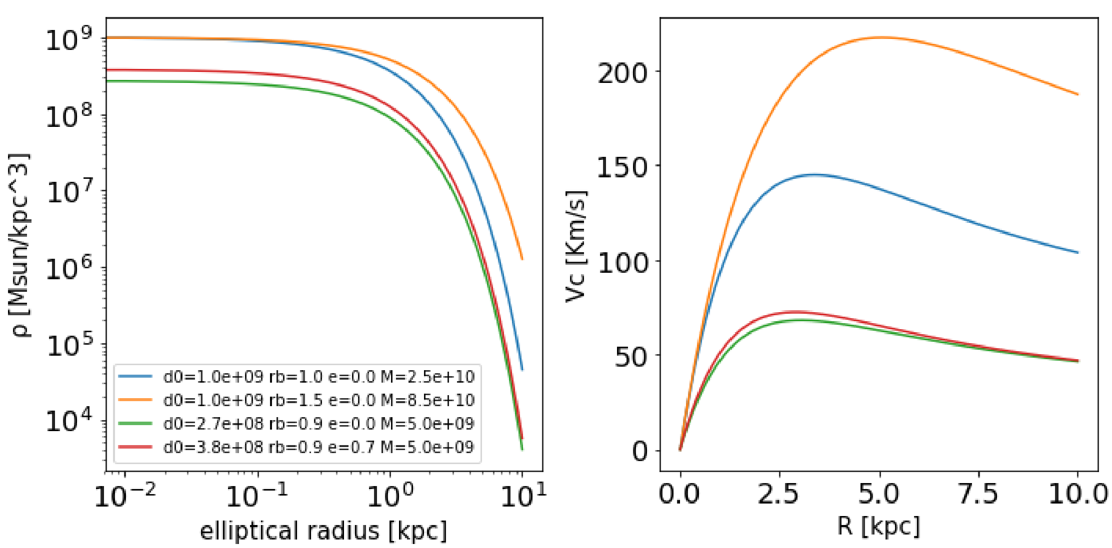

```
In [10]: #Valy halo

         #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_
         axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(vy_halo.d0, vy_halo.rc,v

         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_
axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(vy_halo.d0, vy_halo.rc,v

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_
axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(vy_halo.d0, vy_halo.rc,v

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_
axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(vy_halo.d0, vy_halo.rc,v


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 [11]:
```
#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_
axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(ex_halo.d0, ex_halo.rc,e

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_
axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(ex_halo.d0, ex_halo.rc,e

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_
axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(ex_halo.d0, ex_halo.rc,e

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
axv.plot(R,vcirc[:,1],label='d0=%.1e rb=%.1f e=%.1f M=%.1e '%(ex_halo.d0, ex_halo.rc,


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()
```

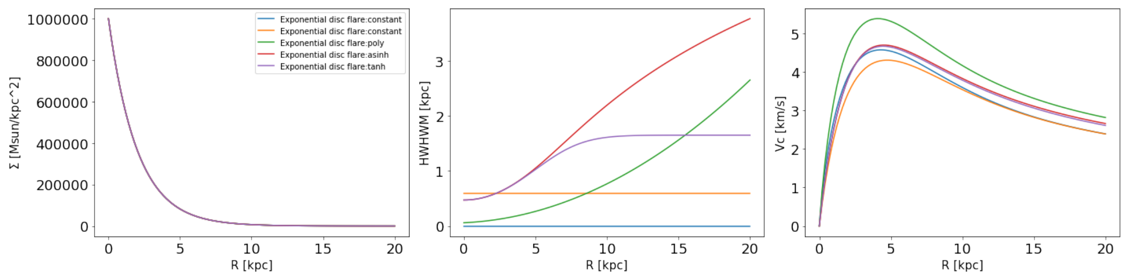


DISC MODELS

In [12]:
```
#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, c
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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=z
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, c
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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+pc
ed=dc.Exponential_disc.polyflare(sigma0=sigma0, Rd=Rd, Rcut=Rcut, zcut=zcut, polycoef
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, c
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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
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, co
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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=
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, co
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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()
```

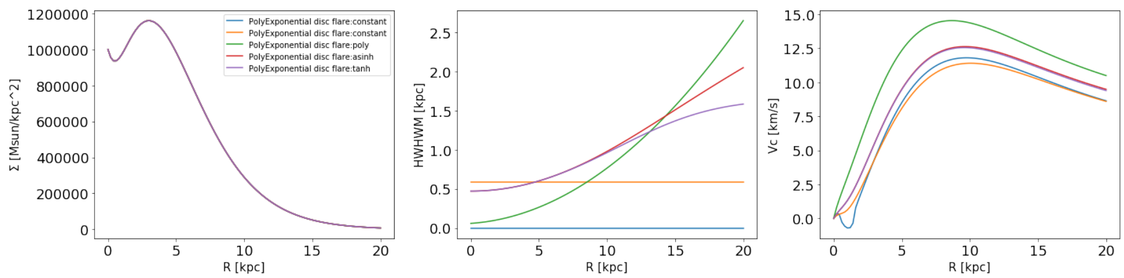
```
Model: Exponential disc
Sigma0: 1.00e+06 Msun/kpc2
Vertical density law: gau
Radial density law: epoly
Rd: 2.000 kpc
Flaring law: tanh
Fparam: 4.0e-01 7.0e+00 1.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00
Rcut: 50.000 kpc
zcut: 20.000 kpc
Rlimit: None
```



In [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



#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
                    #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=
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,
vcirc=epd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the
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=
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,
vcirc=epd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the
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+pc
epd=dc.PolyExponential_disc.polyflare(sigma0=sigma0, Rd=Rd, coeff=Rcoeff, Rcut=Rcut, z
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, c
vcirc=epd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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,
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, c
vcirc=epd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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, z
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, c
vcirc=epd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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
```

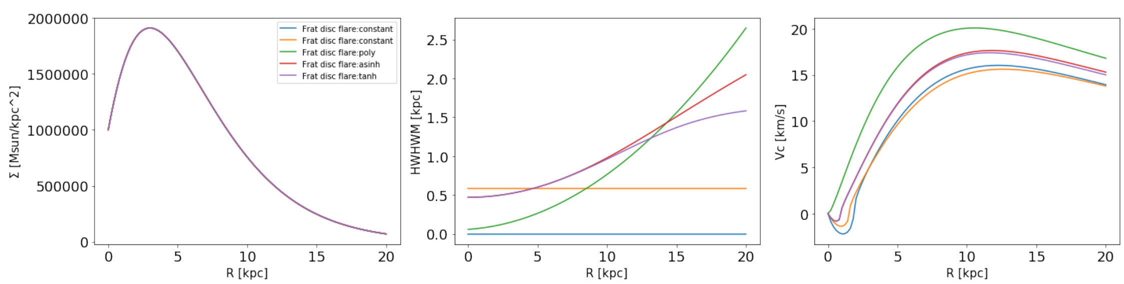


In [14]:
```python
fig=plt.figure(figsize=(20,5))
ax_dens=fig.add_subplot(131)
ax_flare=fig.add_subplot(132)
ax_vcirc=fig.add_subplot(133)
R=np.linspace(0,20,100) #Cylidrincal radii where estimate surface density and flare

#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, c
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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
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, co
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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+pco
ed=dc.Frat_disc.polyflare(sigma0=sigma0, Rd=Rd,Rd2=Rd2,alpha=alfa,  Rcut=Rcut, zcut=zc
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, co
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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=z
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, co
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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=zc
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, co
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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
```

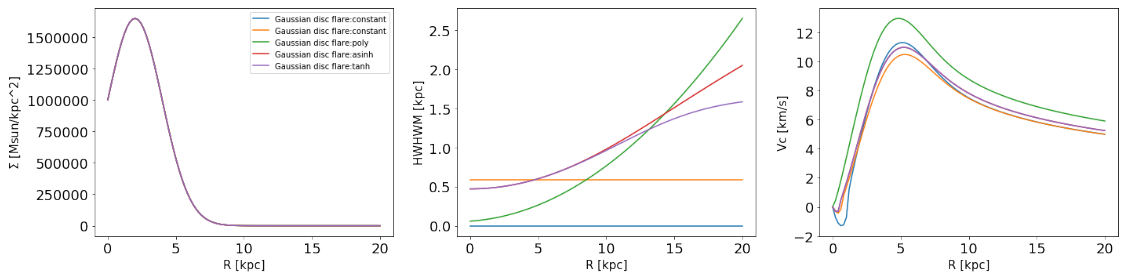



```
In [15]: fig=plt.figure(figsize=(20,5))
        ax_dens=fig.add_subplot(131)
        ax_flare=fig.add_subplot(132)
        ax_vcirc=fig.add_subplot(133)
        R=np.linspace(0,20,100) #Cylidrincal radii where estimate surface density and flare

        #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, c
vcirc=gd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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,z
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, c
vcirc=gd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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+pc
gd=dc.Gaussian_disc.polyflare(sigma0=sigma0, sigmad=sigmad, R0=R0,  Rcut=Rcut, zcut=z
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, c
vcirc=gd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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=z
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, c
vcirc=gd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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=zcu
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, co
vcirc=gd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the p
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 [16]: #We want a razor-thin disc with a exponential surface density law obtained fittig som
         #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,fi
         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 3.1e-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

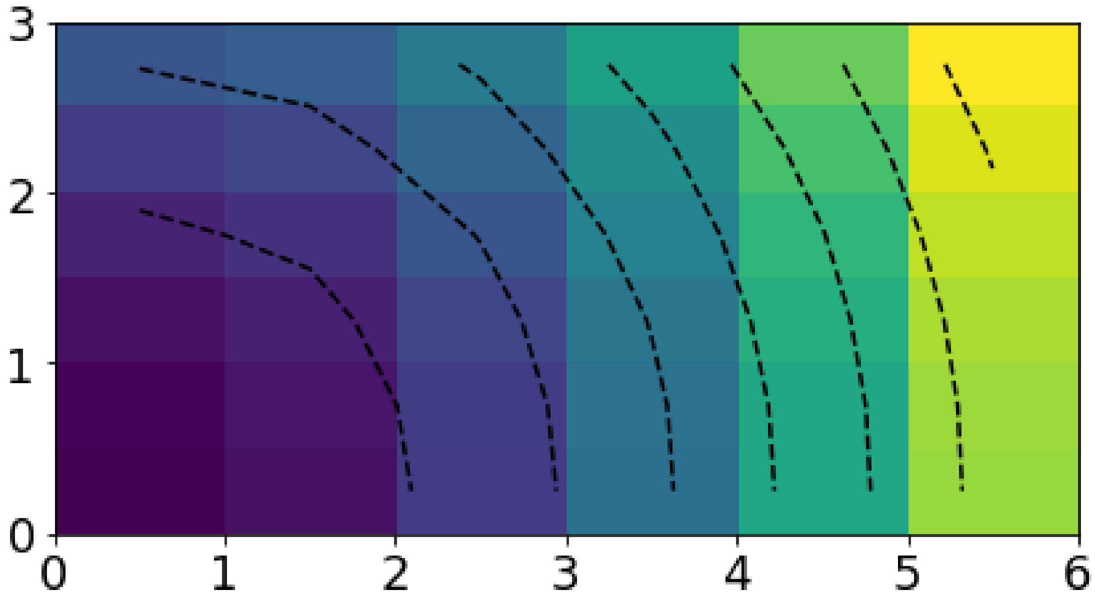
In [17]:
```
#Estimate the potential of a single component

#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 th
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=Tr
#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 conta
    #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
    plt.contour(potential_grid[2].T,origin='lower',extent=(np.min(R),np.max(R),np.min(Z),n


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

```
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[17]: <matplotlib.contour.QuadContourSet at 0x10a1eba20>
```




```
In [19]: #Estimate the potential of a ensemble of dynamic components
         from galpynamics.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, zcu
```

```
#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 th
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
show_comp=False #If show_comp=False return also the estiamte of the potential of all
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=mcu
#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)
#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
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=mcu
#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/My
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)),


#NOTE:
#-1 If show_comp=True, the output contains also the potential of all the i dynamical
#e.g if output=1D, the return array is (ndim,ncomp+4) where ndim=len(R)*len(Z) if gri
#col-0:R, col-1:Z, col-1-ncomp+1: potential of the single components, col-ncomp+2:ext
#The same if output=2D, but the return array is (ncomp+4,len(R),len(Z)). Each slice c
#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 (0.73 s)
Calculating Potential of the 3th component (Hernquist halo)...Done (0.01 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]
```

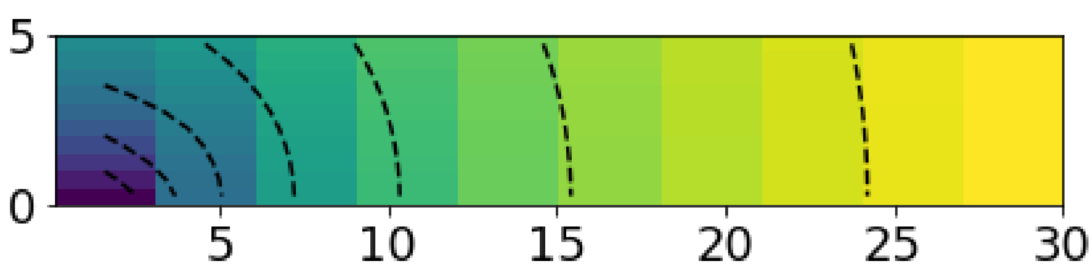
```
[ 1.00666667e+01  4.44444444e+00 -7.07809196e-04]
[ 1.00666667e+01  5.00000000e+00 -7.00559409e-04]
[ 1.33888889e+01  0.00000000e+00 -6.44866819e-04]
[ 1.33888889e+01  5.55555556e-01 -6.44486220e-04]
[ 1.33888889e+01  1.11111111e+00 -6.43471447e-04]
[ 1.33888889e+01  1.66666667e+00 -6.41903537e-04]
[ 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 (0.80 s)
Calculating Potential of the 3th component (Hernquist halo)...Done (0.01 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[19]: <matplotlib.contour.QuadContourSet at 0x10acb73c8>



DENSITY

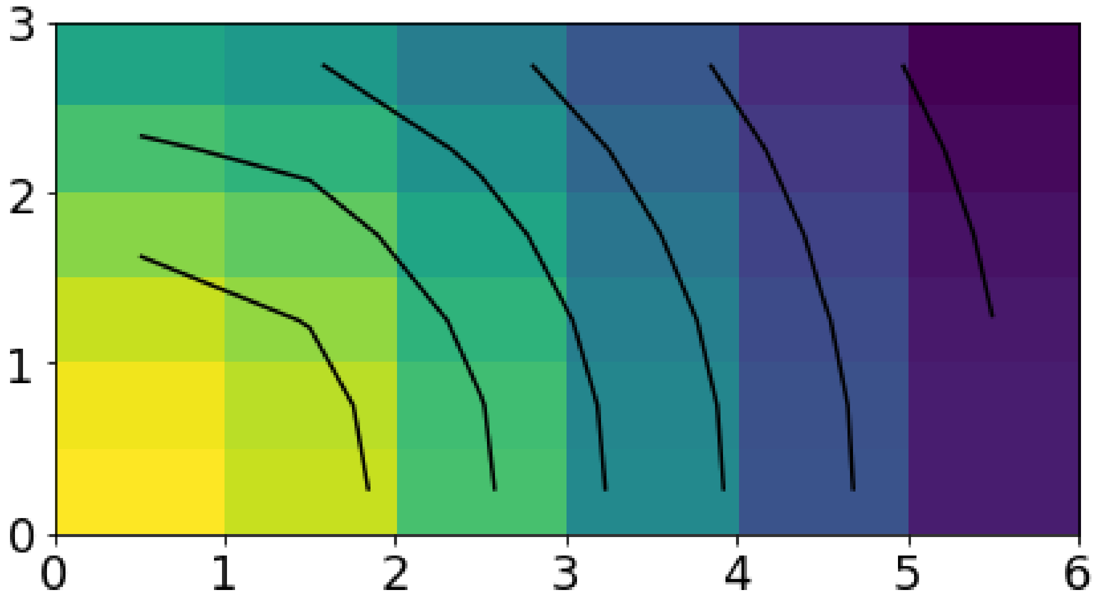
In [20]:
```
#The estimate of the density is similar to the one of the Potential
#1-DENS OF A COMPONENT

#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 th
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
plt.contour(dens_grid[2].T,origin='lower',extent=(np.min(R),np.max(R),np.min(Z),np.ma
```

```
[[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 0x10ad99e80>
```

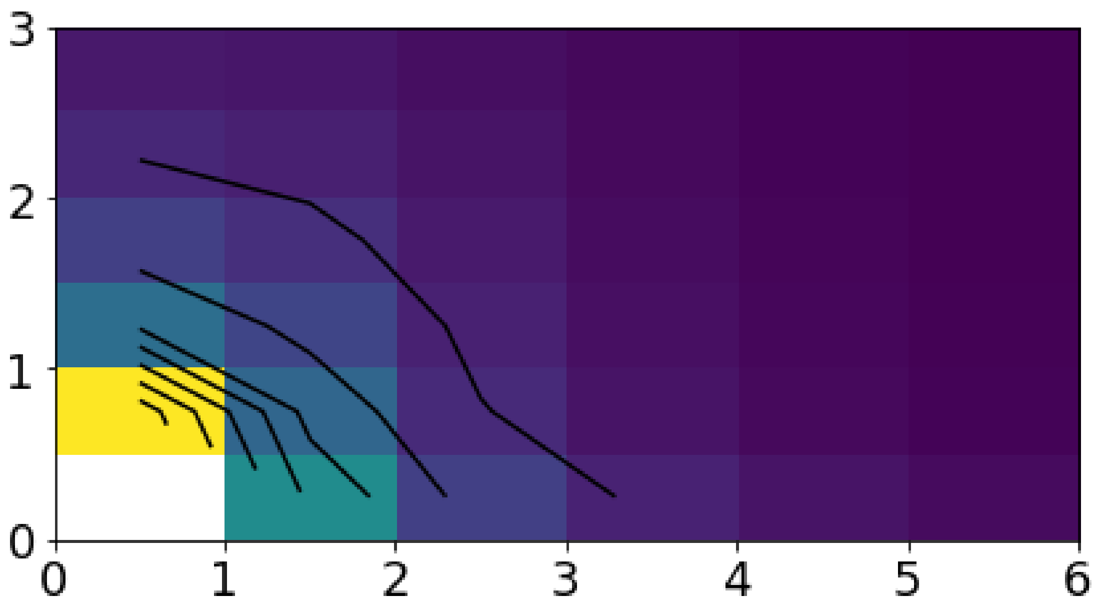



```
In [23]: #2-DENS OF a multicomponent model
         from galpynamics.dynamics import galpotential

         #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, zcu
```

```
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 th
output='1D'
show_comp=False #If show_comp=False return also the estiamte of the potential of all
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 th
output='2D'
show_comp=False #If show_comp=False return also the estiamte of the potential of all
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)),co


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

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

Out[23]: <matplotlib.contour.QuadContourSet at 0x10b2c0ac8>



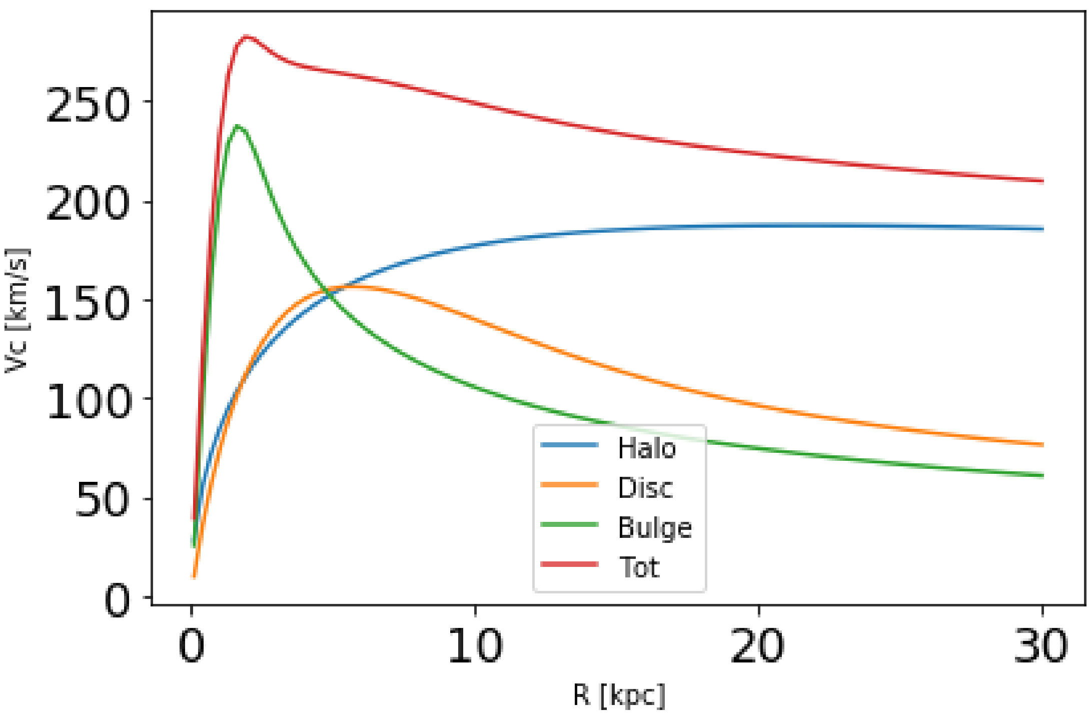
VCIRC FOR MULTIPLE COMPONENTS

```
In [24]: #Estimate the potential of a ensemble of dynamic components
         from galpynamics.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, zcu
```

```python
#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 to
#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

#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 [25]: from galpynamics.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, zcu

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=R
#NB, Here the definition of the flaring model is not important, because then it will
#scale heigth calculation, so the use of thin is useful to avoid to insert useless in

#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
```

```
#Vel dispersion
#Velocity dispersion, we assume that the disc component as an isotropic velocity disp
#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 funct

#R array
#These three quantities define the cylindrical R coordinates that will be used to est
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],Rp
#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 est
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],Zp
#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 th

#The estimate of zd is iterative. The iteration stop when one of the following is Tru
#Number of iteration < Niter
#Maximum Absolute residual between two sequential estiamates of zd lower than flareto
#Maximum Relative residual between two sequential estiamates of zd lower than flareto
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, defaul
zcut=None #If not None, set the zcut of all the disc components to this value, defaul
mcut=None #If not None, set the mcut of all the halo components to this value, defaul
Rlimit='max' #If not None, set a limit Radius for the flaring, i.e. the radius where 
#this could be useful when the flare is fitted with an high degree polynomial that ca
#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
        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 iteration

        final_gas_model, tab_zd,flare_func,fit_func=h.height(flaw=flaw, zlaw=zlaw, polyflare_
```

```
////////////////////////////////////////////////////////////////////////////////
Calculating fixed potential
External potential: Calculating Potential of the 1th component (Hernquist halo)...Done (0.04 s
Calculating Potential of the 2th component (Exponential disc)...Done (7.82 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 0.040 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:
External potential: Calculating Potential of the 1th component (Frat disc)...Done (10.80 s)
**************************************************
```

```
                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 0.034 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-1: Done
Max Absolute residual=1.28e+00
Max Relative residual=1.25e-01
//////////////////////////////////////////////////////////////////////////////

//////////////////////////////////////////////////////////////////////////////
Iter-2:
External potential: Calculating Potential of the 1th component (Frat disc)...Done (9.50 s)
**************************************************
                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 0.030 minutes
Output  data files in gasHeight_res/diagnostic/run1/dat
Output  images in gasHeight_res/diagnostic/run1/image
**************************************************
                 END FITZPROFILE
**************************************************
**************************************************
                  START FITFLARE
**************************************************
Start fitting
Writing table
Save table
```

```
Make plot
Save plot
data in gasHeight_res/diagnostic/run1/flare/fitflare_par.dat
image in gasHeight_res/diagnostic/run1/flare/flare.pdf
**************************************************
                   END FITFLARE
**************************************************
Iter-2: Done
Max Absolute residual=5.39e-02
Max Relative residual=9.96e-03
//////////////////////////////////////////////////////////////////////////////

//////////////////////////////////////////////////////////////////////////////
Iter-3:
External potential: Calculating Potential of the 1th component (Frat disc)...Done (9.45 s)
**************************************************
                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
```

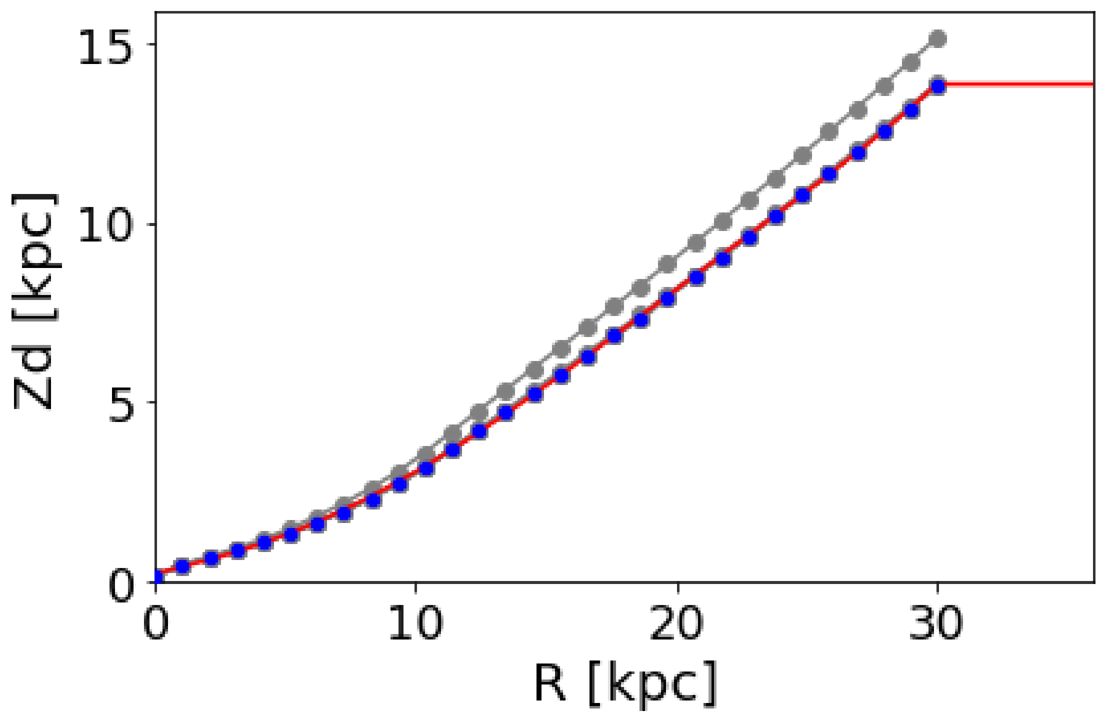
```
Working on radius: 16.56
Working on radius: 17.59
Plotting
Working on radius: 18.62
Working on radius: 19.66
Plotting
Working on radius: 20.69
Working on radius: 21.73
Plotting
Working on radius: 22.76
Working on radius: 23.80
Plotting
Working on radius: 24.83
Working on radius: 25.86
Working on radius: 26.90
Working on radius: 27.93
Working on radius: 28.97
Working on radius: 30.00
Save figures
Writing table
DONE in 0.031 minutes
Output  data files in gasHeight_res/diagnostic/run2/dat
Output  images in gasHeight_res/diagnostic/run2/image
**************************************************
                 END FITZPROFILE
**************************************************
**************************************************
                  START FITFLARE
**************************************************
Start fitting
Writing table
Save table
Make plot
Save plot
data in gasHeight_res/diagnostic/run2/flare/fitflare_par.dat
image in gasHeight_res/diagnostic/run2/flare/flare.pdf
**************************************************
                   END FITFLARE
**************************************************
Iter-3: Done
Max Absolute residual=9.68e-02
Max Relative residual=1.33e-02
//////////////////////////////////////////////////////////////////////////////

//////////////////////////////////////////////////////////////////////////////
Iter-4:
External potential: Calculating Potential of the 1th component (Frat disc)...Done (9.73 s)
**************************************************
```

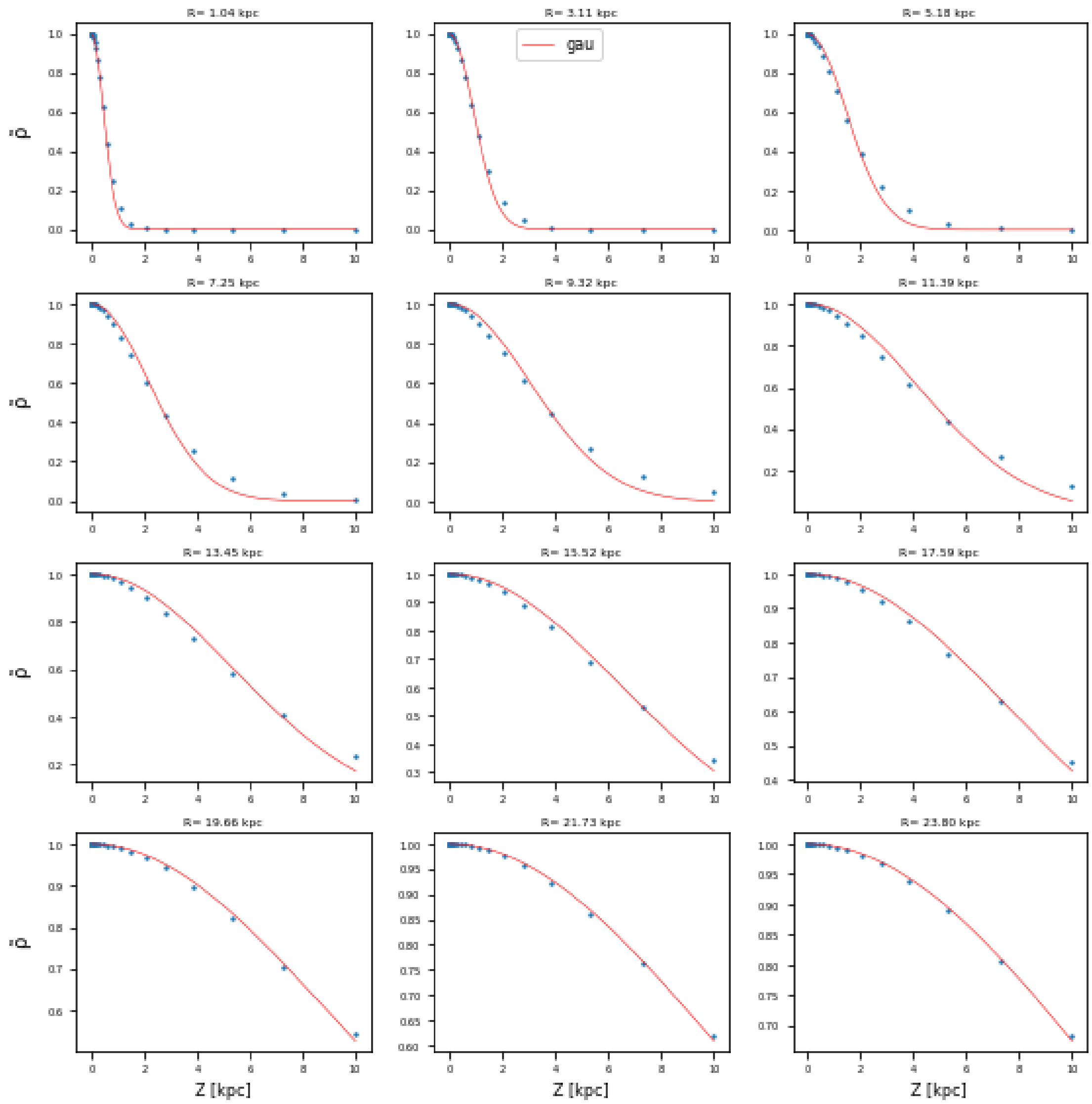
```
                START FITZPROFILE
**************************************************
Number of Radii: 30
Number of Vertical points: 30
Number of the used distributions: 1   ['gau']
1
nplot 2
---Fitting---
Working on radius: 0.01
Working on radius: 1.04
Plotting
Working on radius: 2.08
Working on 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
```

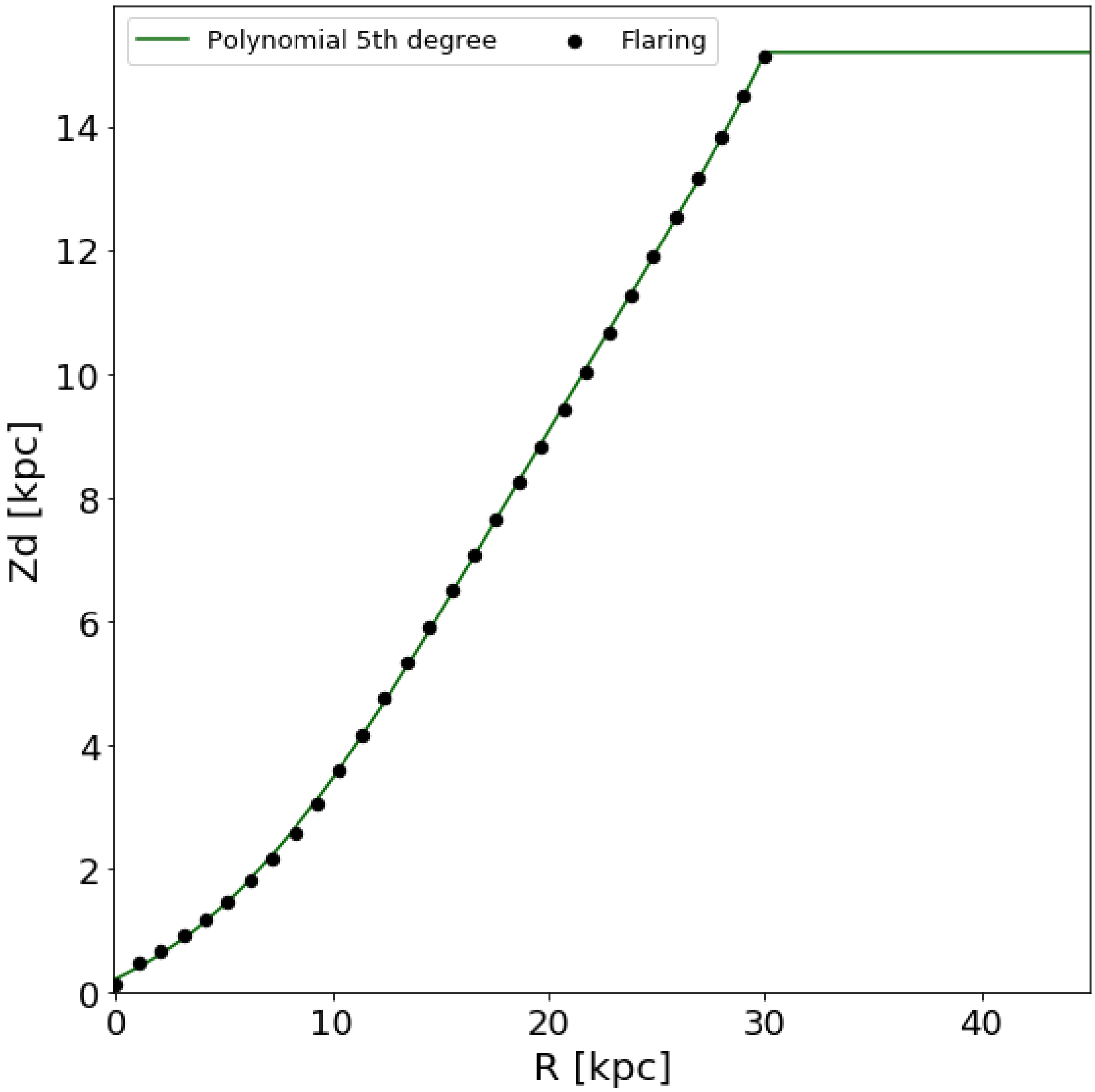
```
Working on radius: 28.97
Working on radius: 30.00
Save figures
Writing table
DONE in 0.032 minutes
Output  data files in gasHeight_res/diagnostic/run3/dat
Output  images in gasHeight_res/diagnostic/run3/image
**************************************************
                 END FITZPROFILE
**************************************************
**************************************************
                  START FITFLARE
**************************************************
Start fitting
Writing table
Save table
Make plot
Save plot
data in gasHeight_res/diagnostic/run3/flare/fitflare_par.dat
image in gasHeight_res/diagnostic/run3/flare/flare.pdf
**************************************************
                   END FITFLARE
**************************************************
Iter-4: Done
Max Absolute residual=1.33e-03
Max Relative residual=1.82e-04
//////////////////////////////////////////////////////////////////////////////

//////////////////////////////////////////////////////////////////////////////
Iter-5:
External potential: Calculating Potential of the 1th component (Frat disc)...Done (9.53 s)
**************************************************
                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
```

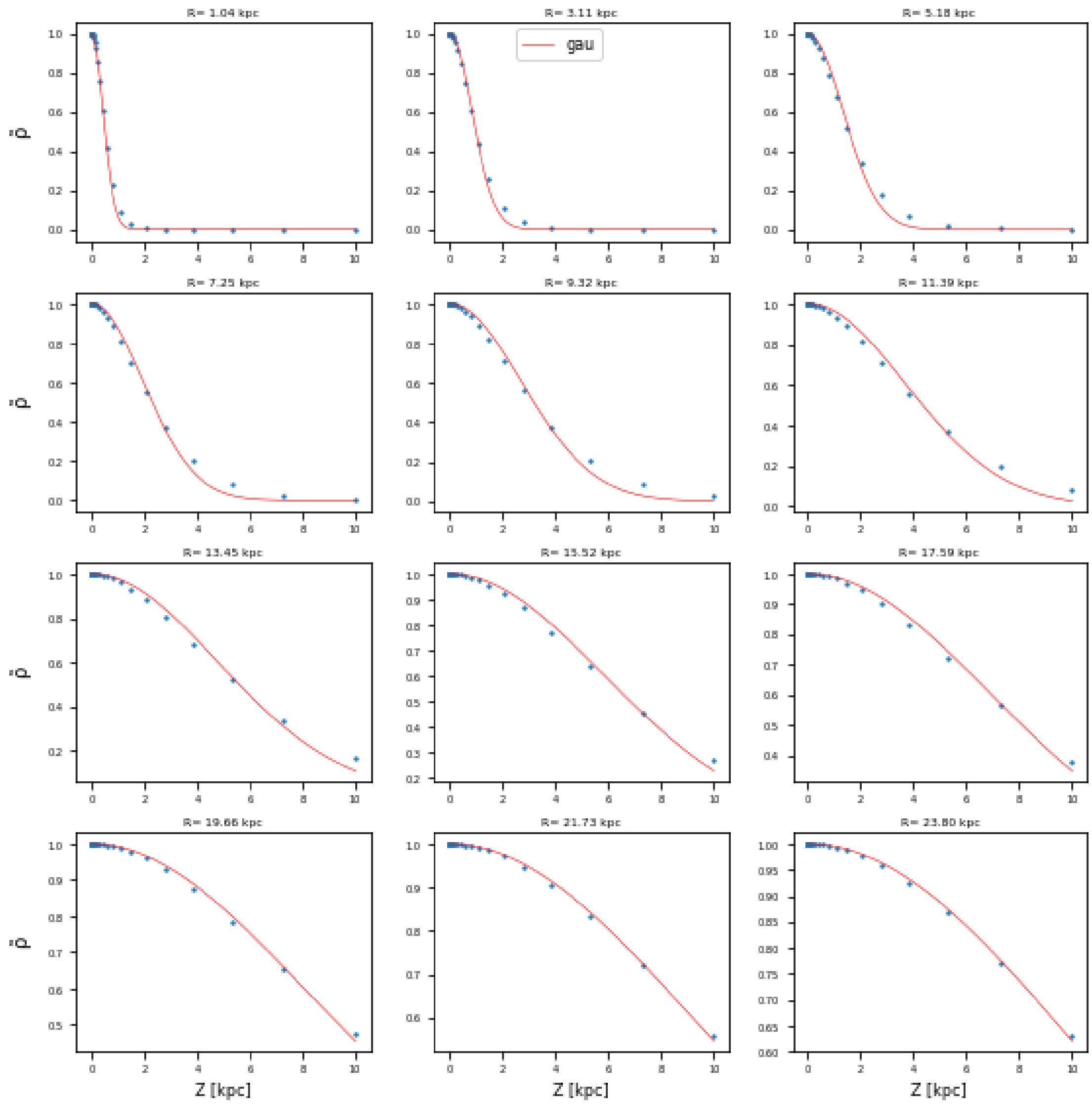
```
Plotting
Working on radius: 6.21
Working on radius: 7.25
Plotting
Working on radius: 8.28
Working on radius: 9.32
Plotting
Working on radius: 10.35
Working on radius: 11.39
Plotting
Working on radius: 12.42
Working on radius: 13.45
Plotting
Working on radius: 14.49
Working on radius: 15.52
Plotting
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 0.028 minutes
Output  data files in gasHeight_res/diagnostic/run4/dat
Output  images in gasHeight_res/diagnostic/run4/image
**************************************************
                 END FITZPROFILE
**************************************************
**************************************************
                  START FITFLARE
**************************************************
Start fitting
Writing table
Save table
```

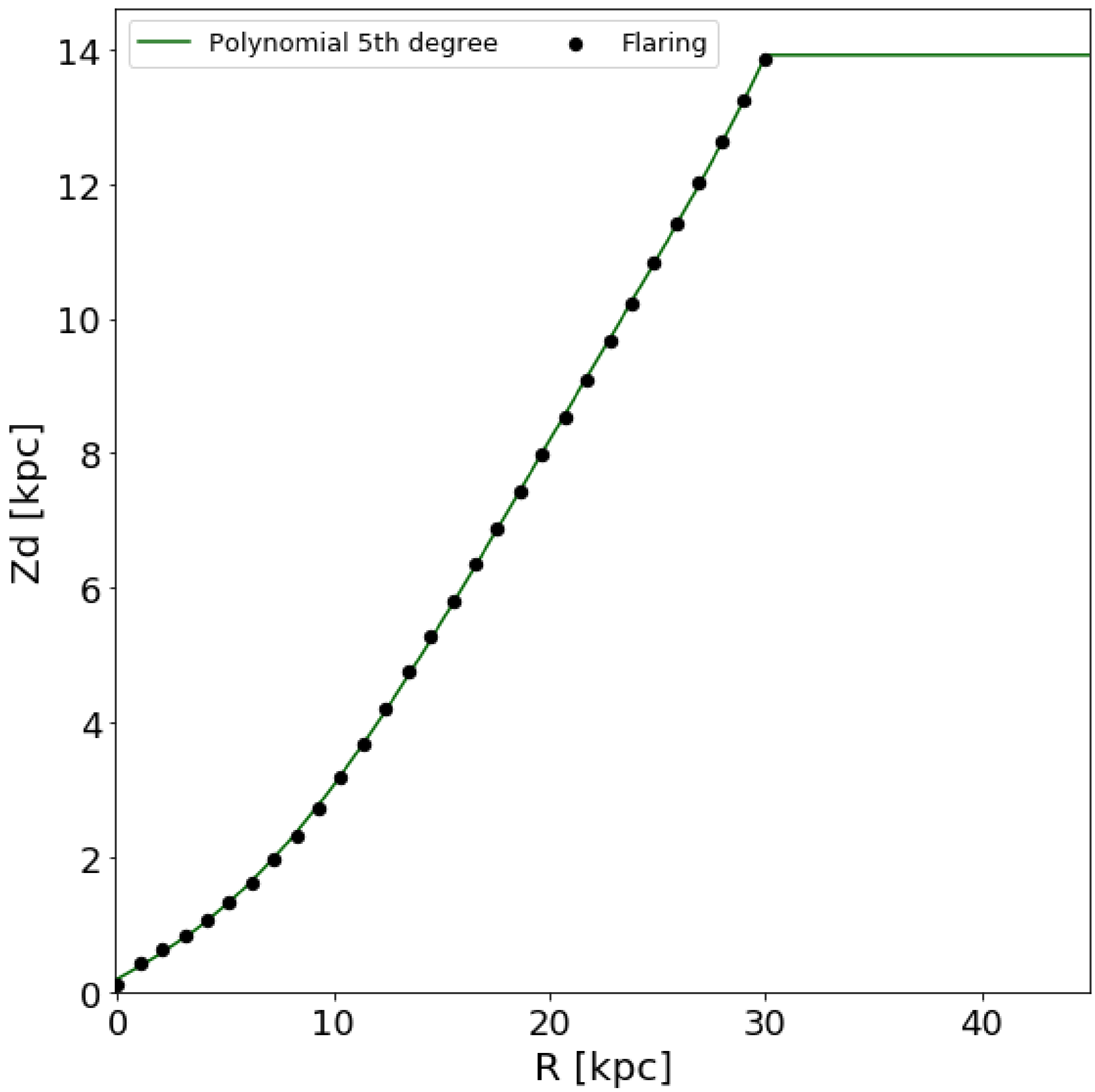
```
Make plot
Save plot
data in gasHeight_res/diagnostic/run4/flare/fitflare_par.dat
image in gasHeight_res/diagnostic/run4/flare/flare.pdf
**************************************************
                   END FITFLARE
**************************************************
Iter-5: Done
Max Absolute residual=6.51e-05
Max Relative residual=8.95e-06
//////////////////////////////////////////////////////////////////////////////
```

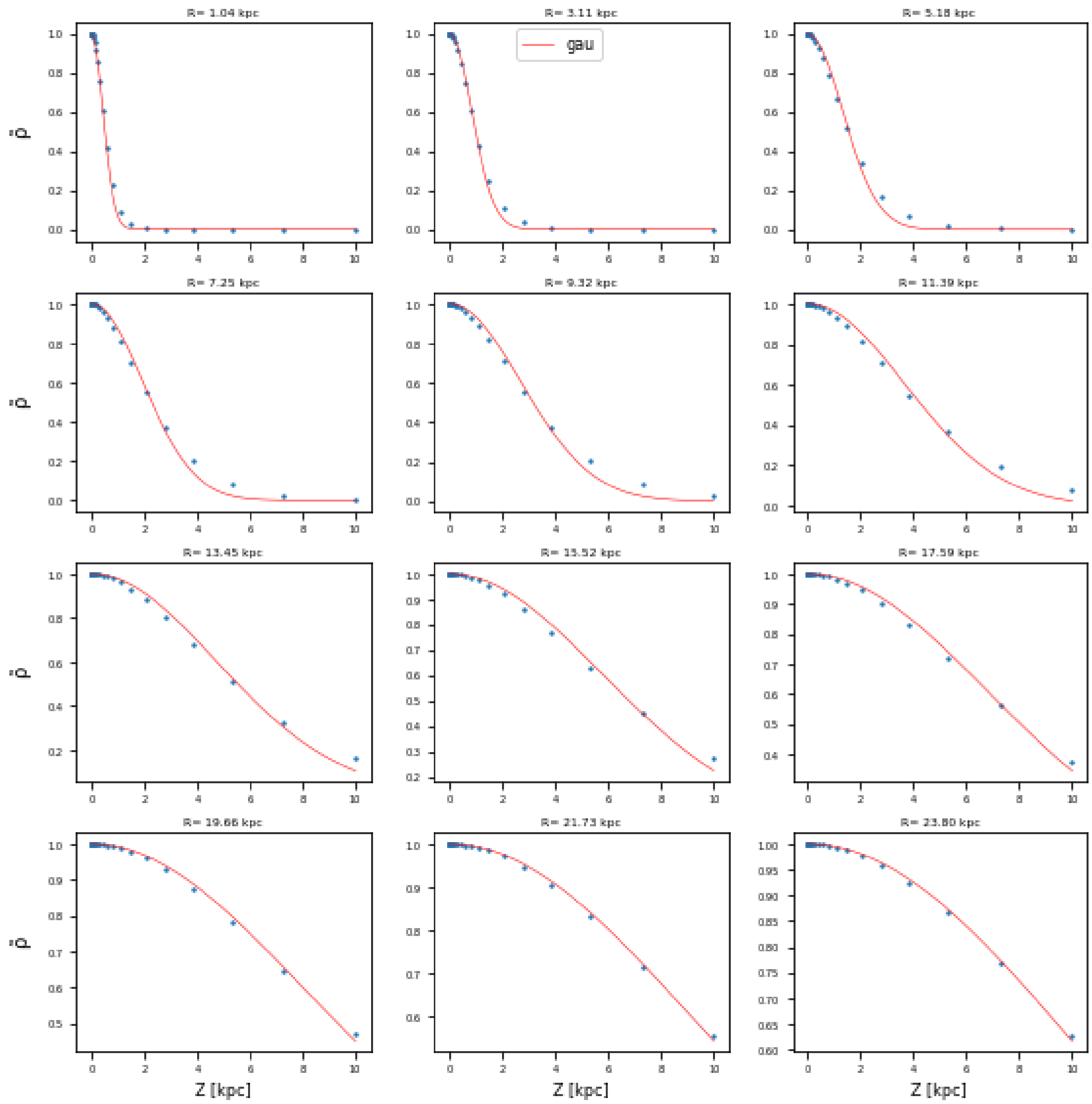


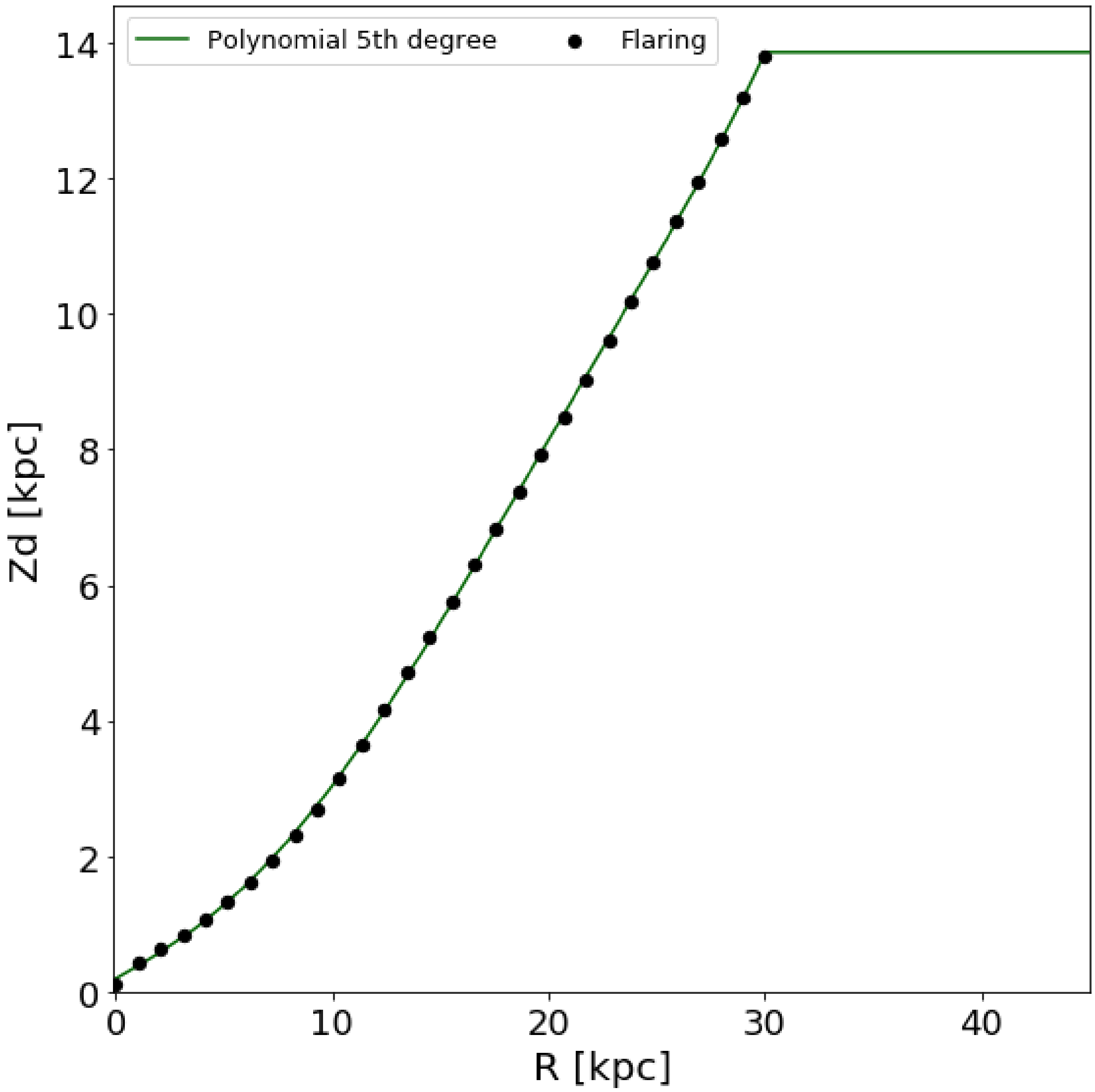

R= 1.04 kpc
R= 3.11 kpc
gau
R= 5.18 kpc
R= 7.25 kpc
R= 9.32 kpc
R= 11.39 kpc
R= 13.45 kpc
R= 15.52 kpc
R= 17.59 kpc
R= 19.66 kpc
R= 21.73 kpc
R= 23.80 kpc
Z [kpc]

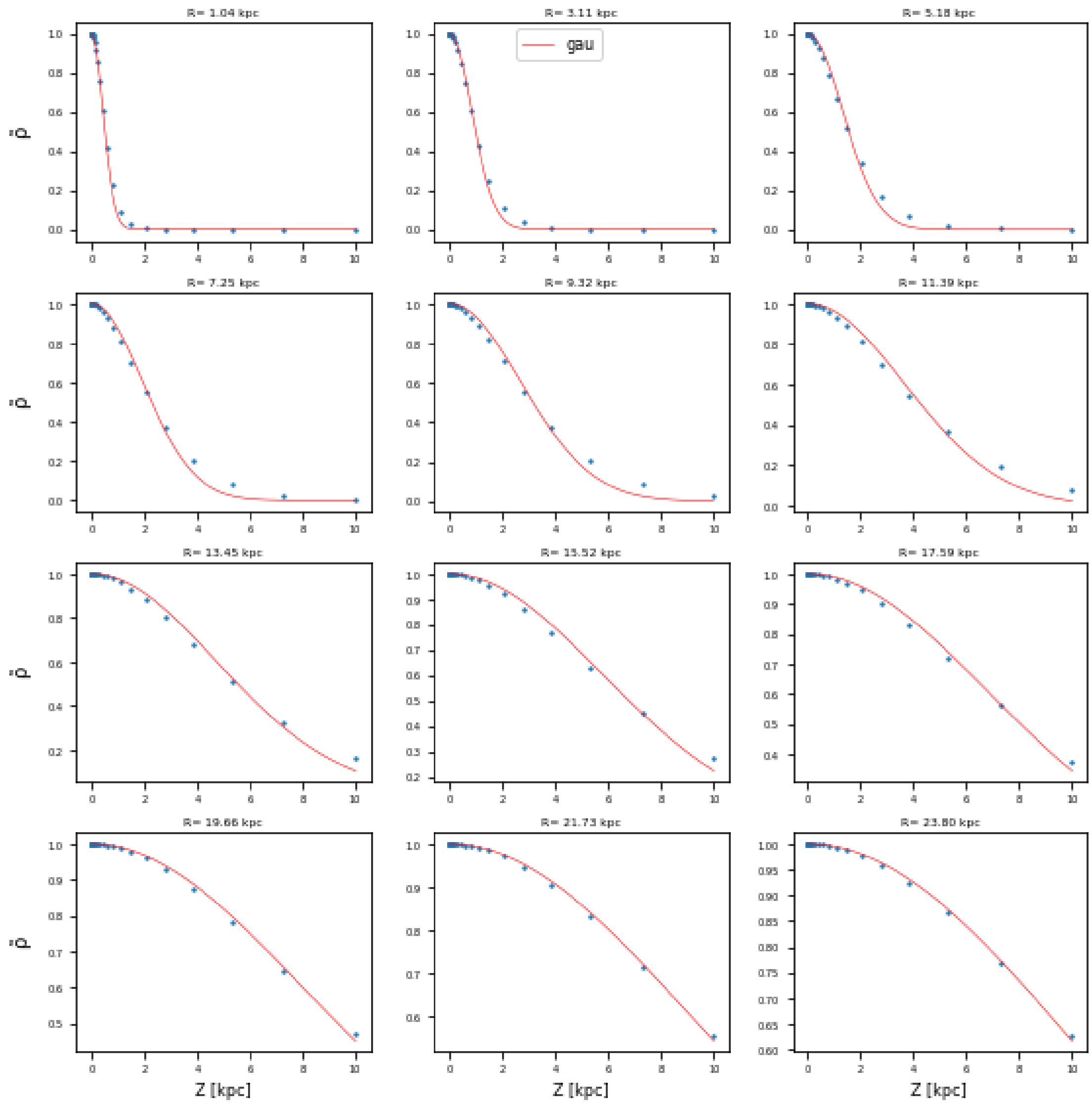

Polynomial 5th degree
Flaring
Zd [kpc]
R [kpc]
0
2
4
6
8
10
12
14
0
10
20
30
40

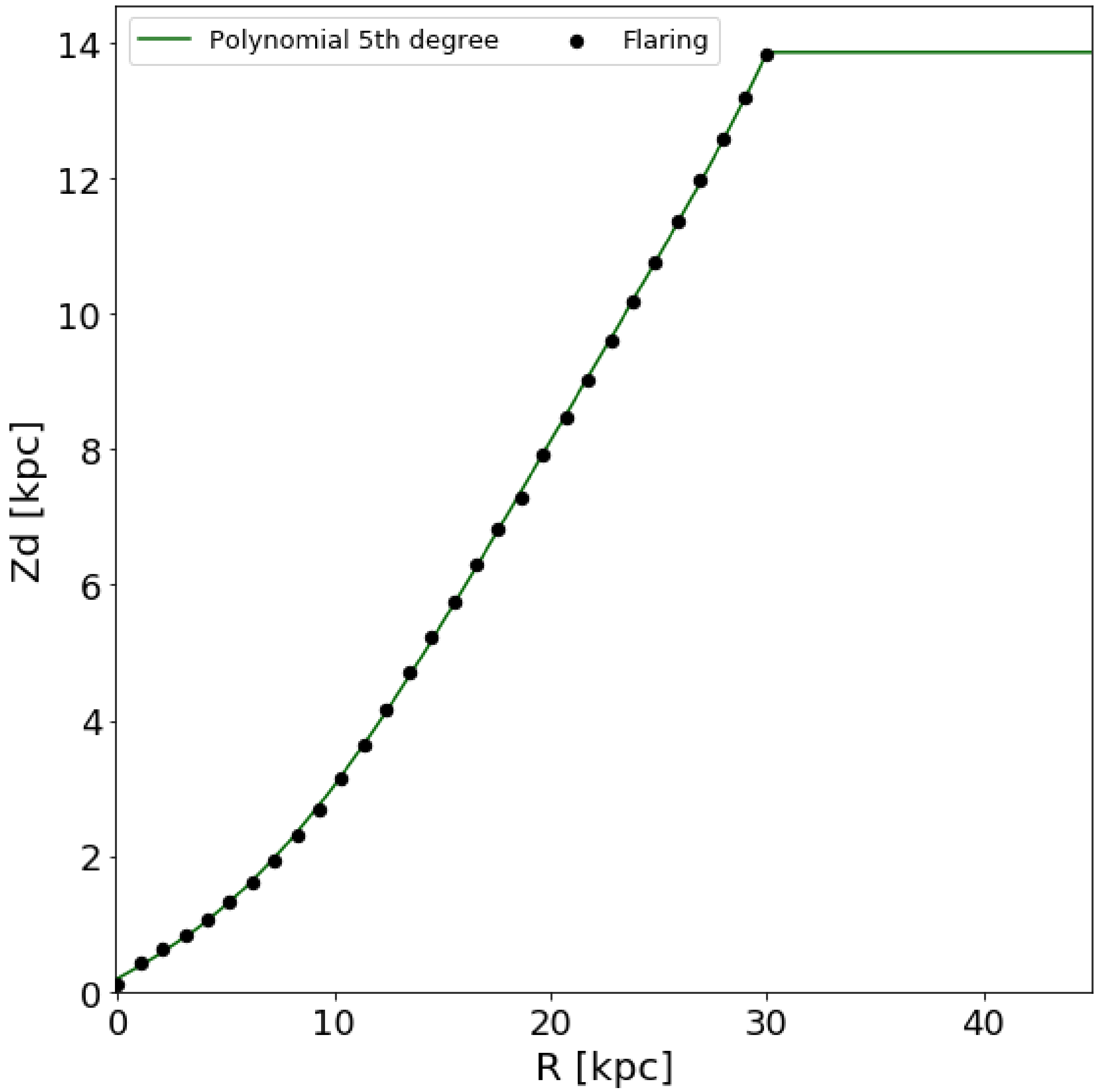

R= 1.04 kpc
R= 3.11 kpc
gau
R= 5.18 kpc
R= 7.25 kpc
R= 9.32 kpc
R= 11.39 kpc
R= 13.45 kpc
R= 15.52 kpc
R= 17.59 kpc
R= 19.66 kpc
R= 21.73 kpc
R= 23.80 kpc
$\tilde{\rho}$
Z [kpc]


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

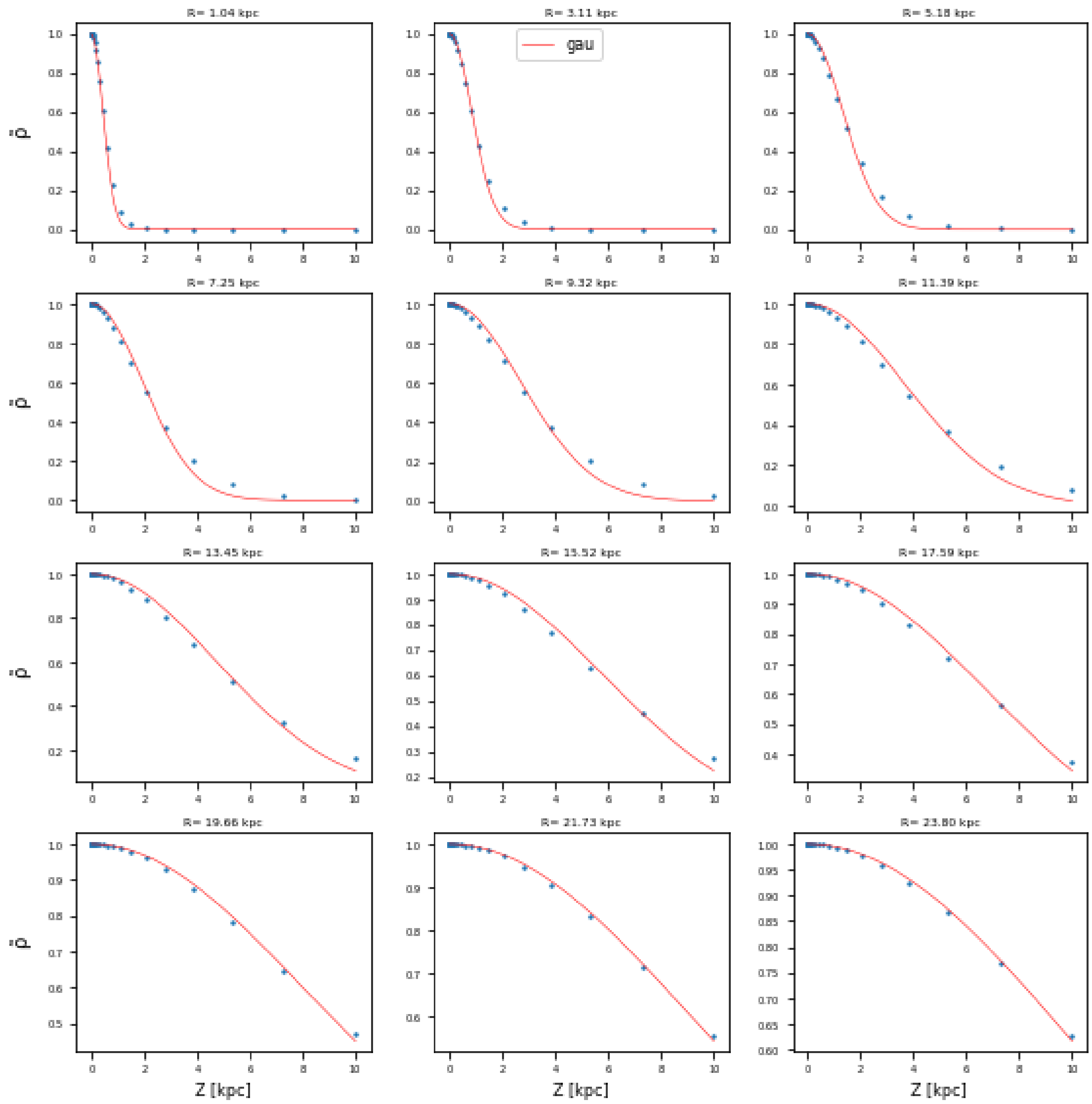

R= 1.04 kpc
R= 3.11 kpc
gau
R= 5.18 kpc
R= 7.25 kpc
R= 9.32 kpc
R= 11.39 kpc
R= 13.45 kpc
R= 15.52 kpc
R= 17.59 kpc
R= 19.66 kpc
R= 21.73 kpc
R= 23.80 kpc
Z [kpc]
Z [kpc]
Z [kpc]

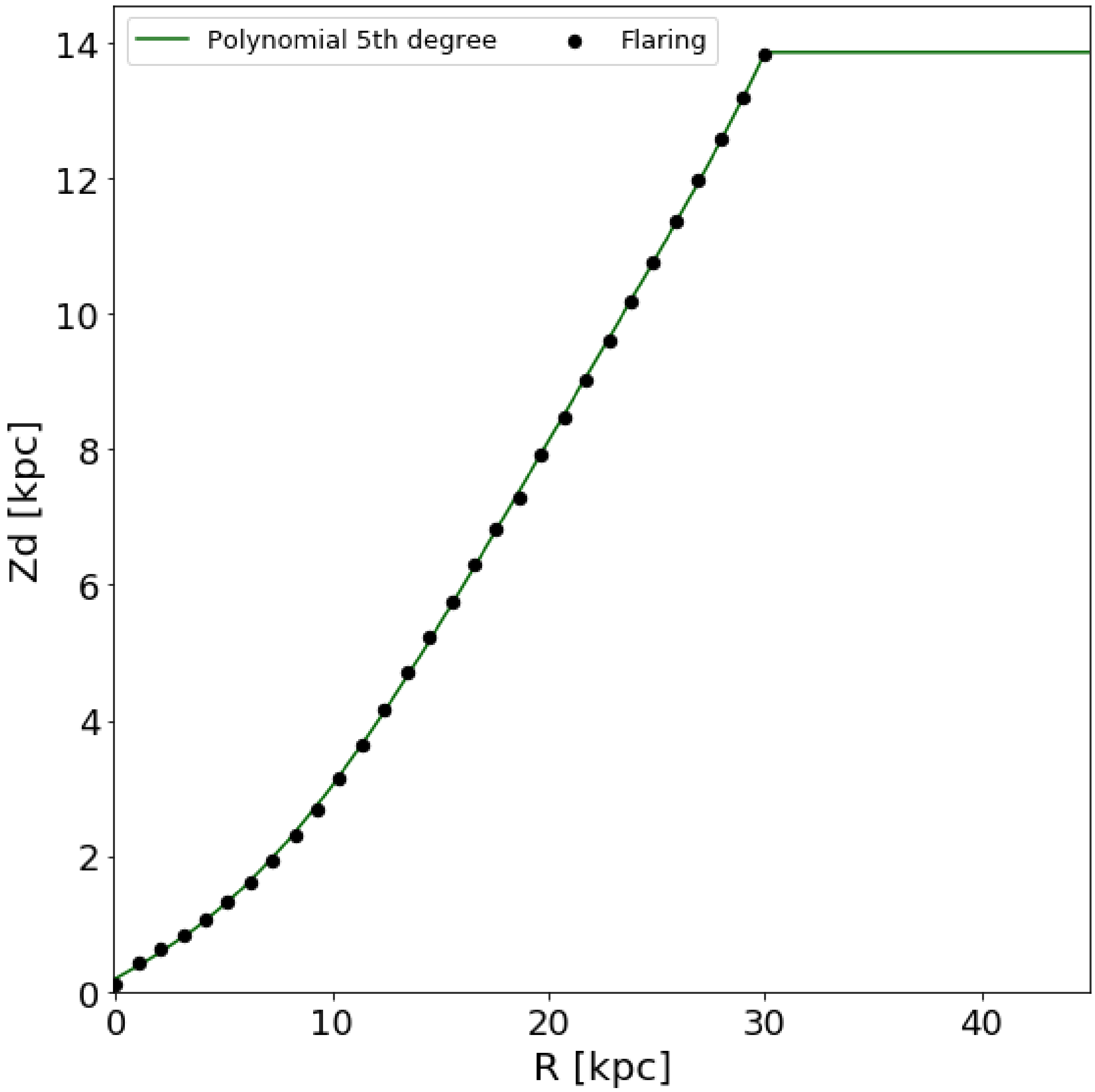

Polynomial 5th degree
Flaring
Zd [kpc]
R [kpc]
0
2
4
6
8
10
12
14
0
10
20
30
40

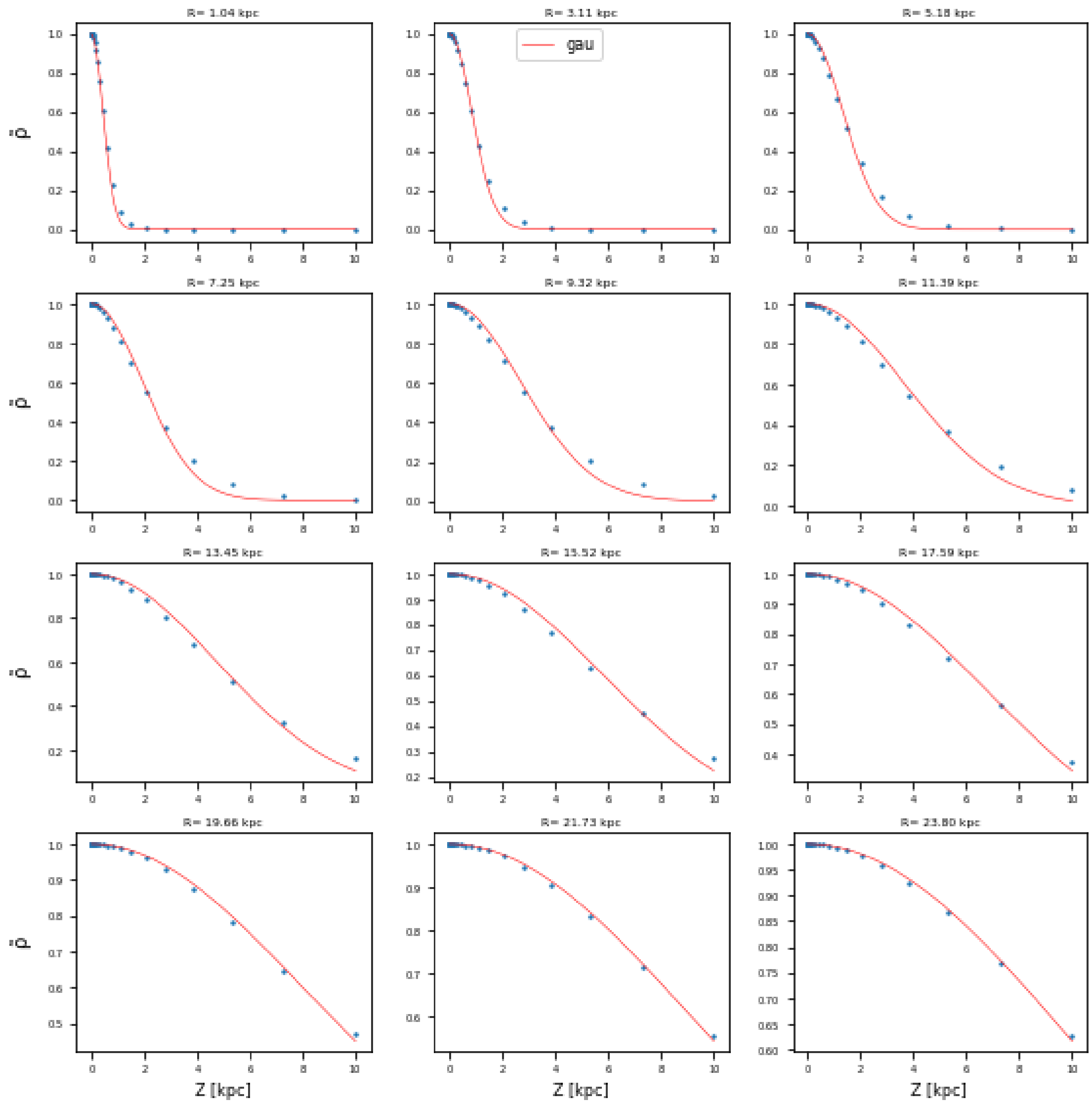

R= 1.04 kpc
R= 3.11 kpc
R= 5.18 kpc
R= 7.25 kpc
R= 9.32 kpc
R= 11.39 kpc
R= 13.45 kpc
R= 15.52 kpc
R= 17.59 kpc
R= 19.66 kpc
R= 21.73 kpc
R= 23.80 kpc
gau
Z [kpc]

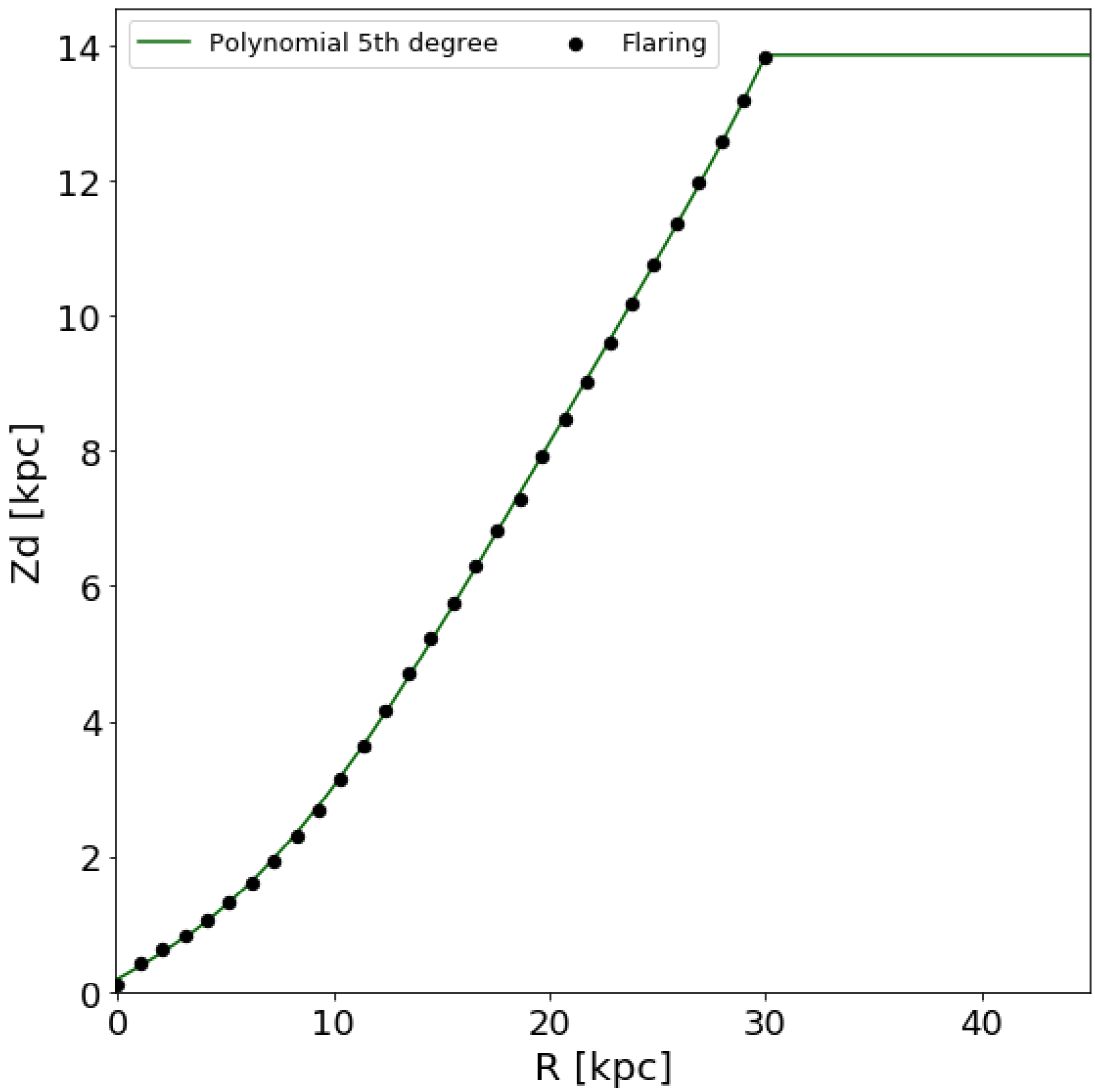


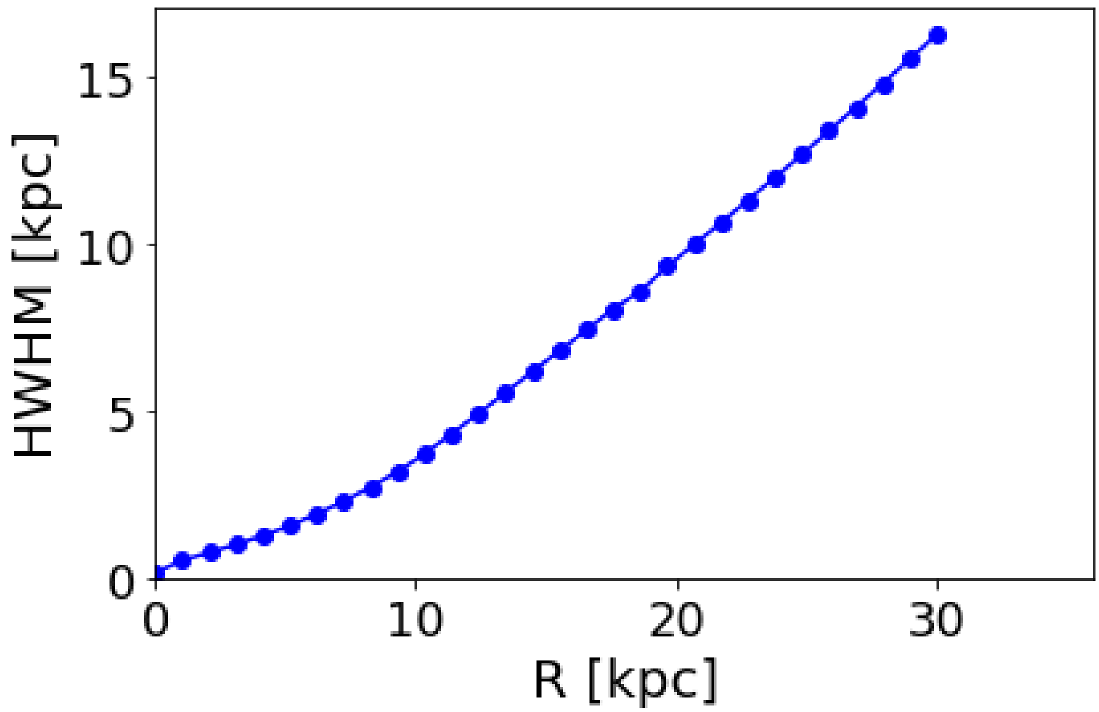
Polynomial 5th degree
Flaring
Zd [kpc]
R [kpc]
0
2
4
6
8
10
12
14
0
10
20
30
40


R= 1.04 kpc
R= 3.11 kpc
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
gau
Z [kpc]


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


R= 1.04 kpc
R= 3.11 kpc
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
gau
$\bar{\rho}$
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

1 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]
```