Tutorial

January 16, 2018

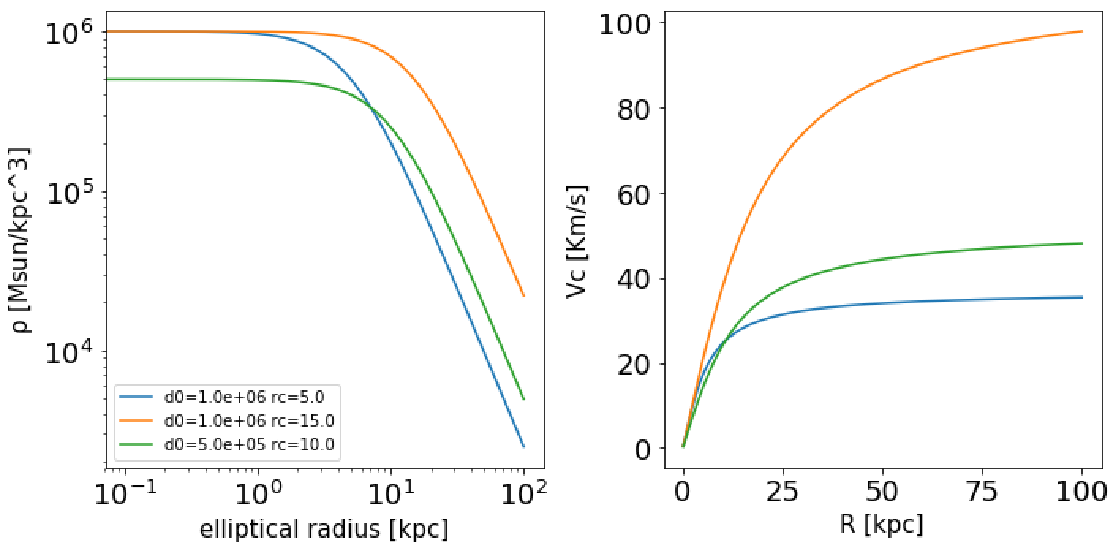
```
In [1]: import numpy as np
        import discH
        import discH.dynamic_component as dc
        import matplotlib.pyplot as plt
```

HALO MODELS

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



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

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


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

        d0=5e5 #Cental density in Msun/kpc3
        rc=10 #Core radius in Kpc
```

```
        iso_halo=dc.isothermal_halo(d0=d0, rc=rc, mcut=mcut, e=e)
        dens=iso_halo.dens(R) #3D dens
        vcirc=iso_halo.vcirc(R, nproc=2)
        axd.plot(R,dens[:,1],label='d0=%.1e rc=%.1f'%(d0,rc))
        axv.plot(R,vcirc[:,1],label='d0=%.1e rc=%.1f'%(d0,rc))

        print(iso_halo)





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

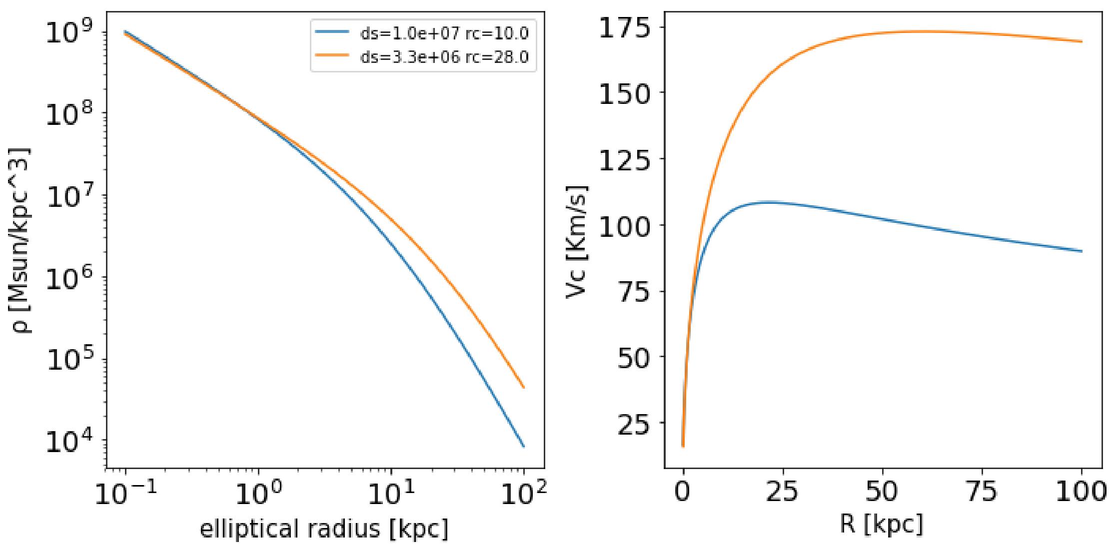
```
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/discH-3.1.0.dev0-py3.6-macosx-10.
  return np.array(vcirc_iso(R, self.d0, self.rc, self.e, toll=self.toll))


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



/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/matplotlib/figure.py:1743: UserWa
  warnings.warn("This figure includes Axes that are not "
```



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

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



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

```python
c=8 #Scale density in Msun/kpc3
V200=150 #Scale radius in Kpc
nfw_halo=dc.NFW_halo.cosmo(c=c, V200=V200, mcut=mcut, e=e) #secondary metho do call NFW
#NWF_halo.cosmo(c, V200, H=67, e=0, mcut=100) H is the Hubble constant in km/s/Mpc (67 d
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()
```

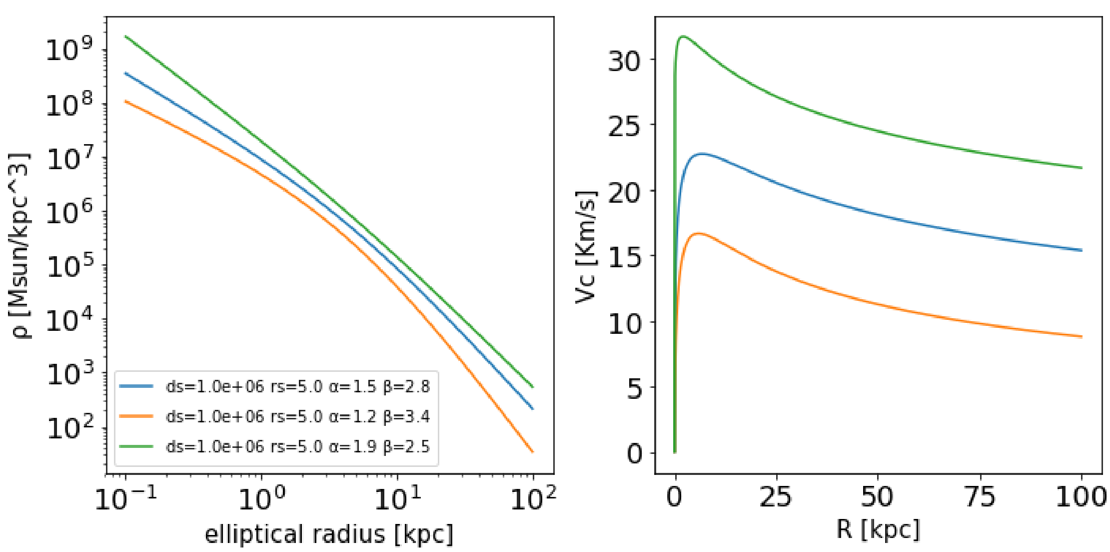
```
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/discH-3.1.0.dev0-py3.6-macosx-10.
  return num / den
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/discH-3.1.0.dev0-py3.6-macosx-10.
  return np.array(vcirc_nfw(R, self.d0, self.rc, self.e, toll=self.toll))
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/discH-3.1.0.dev0-py3.6-macosx-10.
  return np.array(vcirc_nfw(R, self.d0, self.rc, self.e, toll=self.toll))


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



/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/matplotlib/figure.py:1743: UserWa
  warnings.warn("This figure includes Axes that are not "
```




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

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

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

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

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()
```

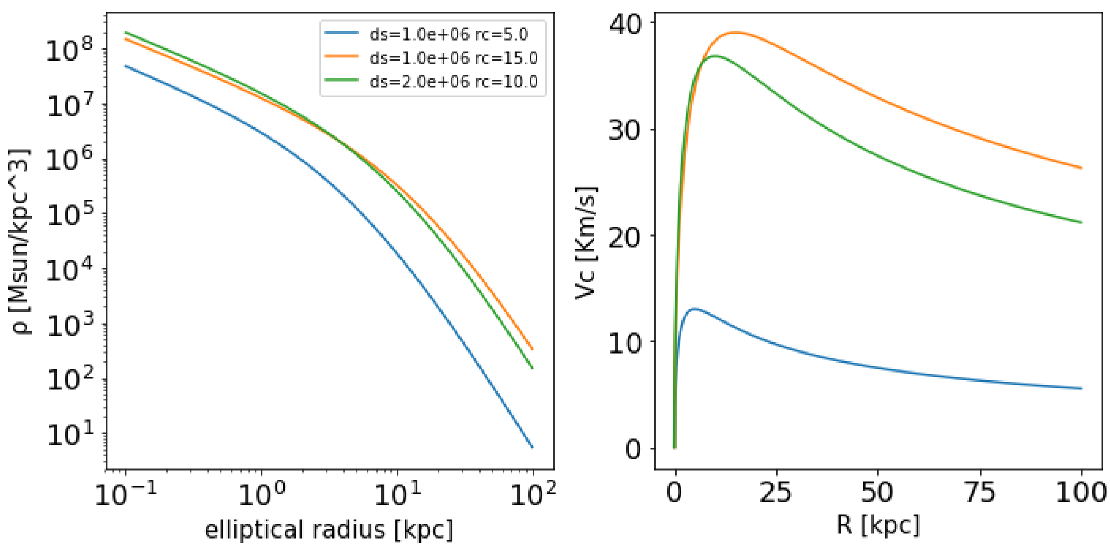
```
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/discH-3.1.0.dev0-py3.6-macosx-10.
  return num / den
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  integration interval.
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/matplotlib/figure.py:1743: UserWa
  warnings.warn("This figure includes Axes that are not "
```



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


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

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

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

print(he_halo)


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

```
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/discH-3.1.0.dev0-py3.6-macosx-10.
```

```
  return num / den
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  integration interval.
  warnings.warn(msg, IntegrationWarning)


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



/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/matplotlib/figure.py:1743: UserWa
  warnings.warn("This figure includes Axes that are not "
```




```
In [47]: #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
```

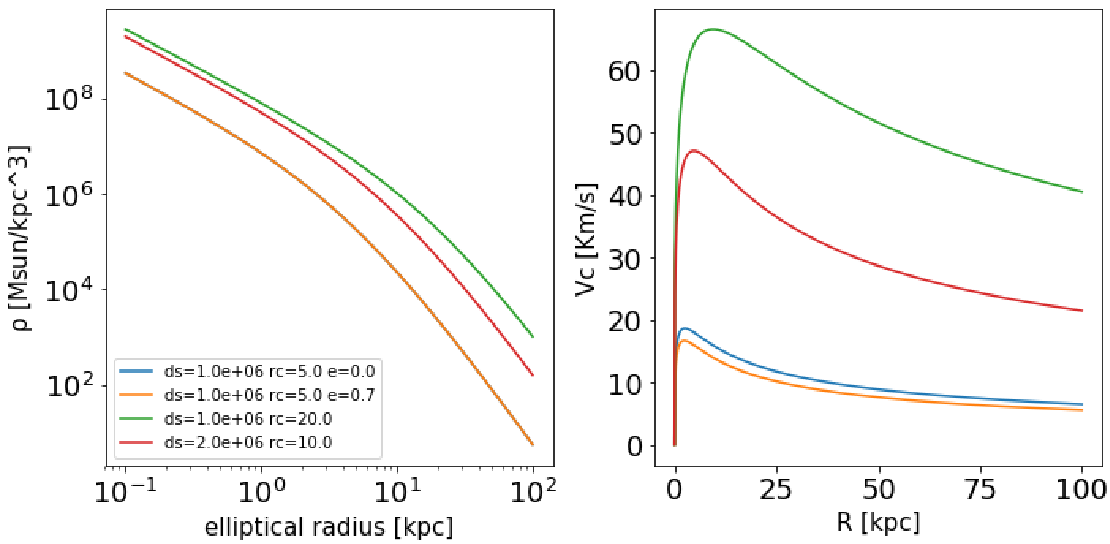
```
d0=1e6 #Scale density in Msun/kpc3
rs=5 #Scale radius in Kpc
dv_halo=dc.deVacouler_like_halo(d0=d0, rs=rs, mcut=mcut, e=e)
dens=dv_halo.dens(R) #3D dens
vcirc=dv_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='ds=%.1e rc=%.1f e=%.1f'%(dv_halo.d0,dv_halo.rs,dv_halo.e))
axv.plot(R,vcirc[:,1],label='ds=%.1e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

```
/Users/Giuliano/anaconda3/lib/python3.6/site-packages/discH-3.3.0.dev0-py3.6-macosx-10.7-x86_64.
  return num / den
/Users/Giuliano/anaconda3/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364: Integrati
  integration interval.
```

```
  warnings.warn(msg, IntegrationWarning)
```

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

```
/Users/Giuliano/anaconda3/lib/python3.6/site-packages/matplotlib/figure.py:2022: UserWarning: Th
  warnings.warn("This figure includes Axes that are not compatible "
```

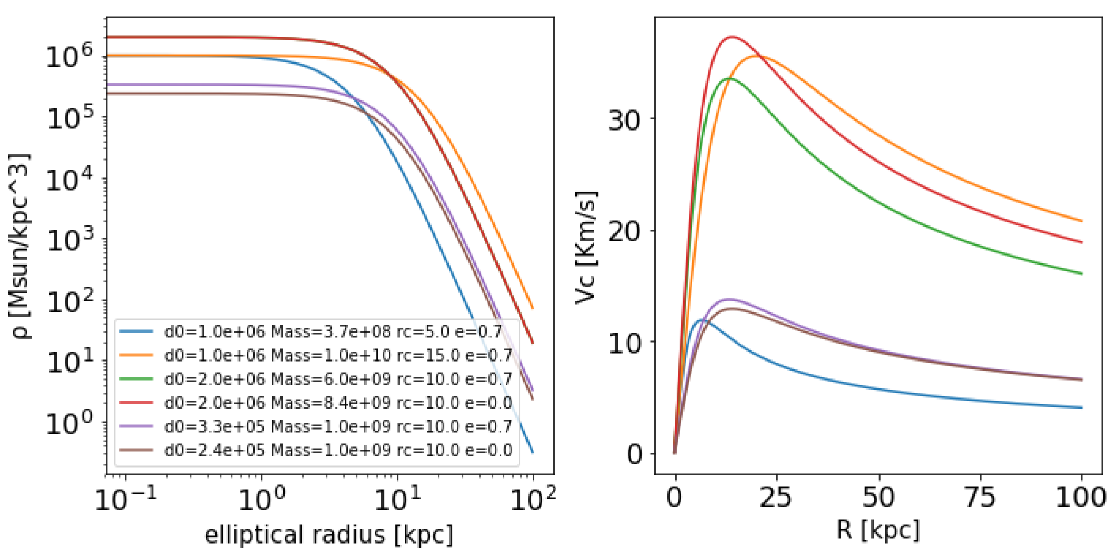


In [4]:
```
#Plummer halo
R=np.linspace(0,100,1000)
fig=plt.figure(figsize=(10,5))
axd=fig.add_subplot(121)
axv=fig.add_subplot(122)
R=np.linspace(0,100,1000)
#d=d0*( (1+m*m/rs*rs)^(-5/2) )
mcut=100 #radius where d(m>mcut)=0
e=0.7 #ellipticity

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

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

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

```python
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()
```

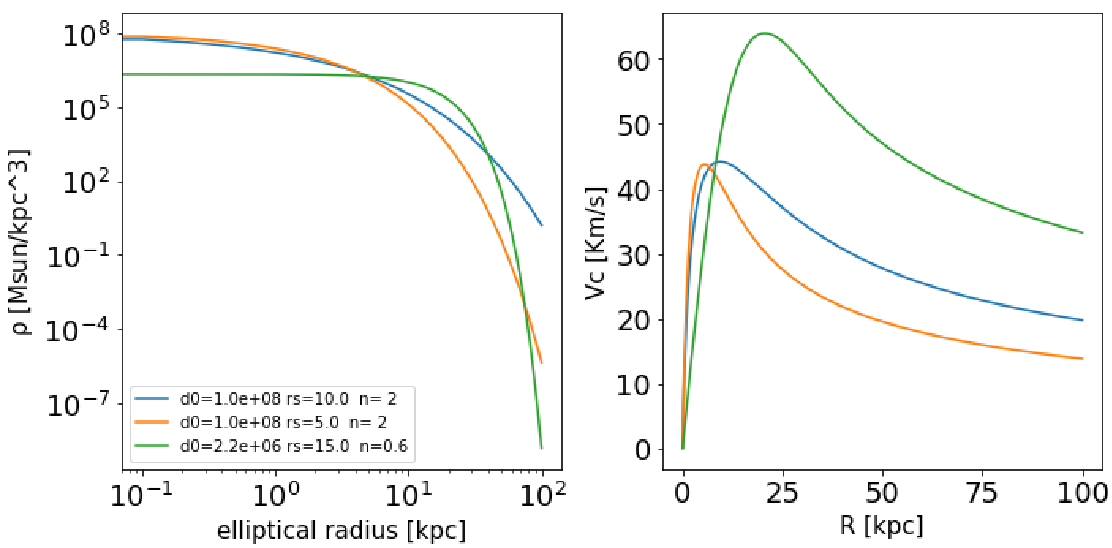
```
/Users/Giuliano/anaconda3/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364: Integrati
  integration interval.
  warnings.warn(msg, IntegrationWarning)


Model: Plummer halo
Mass: 1.00e+09 Msun
d0: 2.39e+05 Msun/kpc3
rc: 10.00
e: 0.000
mcut: 100.000



/Users/Giuliano/anaconda3/lib/python3.6/site-packages/matplotlib/figure.py:2022: UserWarning: Th
  warnings.warn("This figure includes Axes that are not compatible "
```



In [2]:
```
#Einasto halo
R=np.linspace(0,100,1000)
fig=plt.figure(figsize=(10,5))
axd=fig.add_subplot(121)
axv=fig.add_subplot(122)
R=np.linspace(0,100,1000)
mcut=100 #radius where d(m>mcut)=0
e=0.0 #ellipticity


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



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



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

d0=1e8 #Central density in Msun/kpc3
n=1.5 #Core radius in Kpc
rs=5
ei_halo=dc.einasto_halo(d0=d0, n=n, rs=rs, mcut=mcut, e=e)
dens=ei_halo.dens(R) #3D dens
vcirc=ei_halo.vcirc(R, nproc=2)
axd.plot(R,dens[:,1],label='d0=%.1e rs=%.1f  n=%2.f'%(ei_halo.d0, ei_halo.rs, ei_halo.n)
axv.plot(R,vcirc[:,1],label='d0=%.1e rs=%.1f  n=%2.f'%(ei_halo.d0, ei_halo.rs, ei_halo.n


de=5e5 #Central density in Msun/kpc3
n=0.6 #Core radius in Kpc
rs=15
```

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

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

```
/Users/Giuliano/anaconda3/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364: Integrati
  integration interval.
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda3/lib/python3.6/site-packages/matplotlib/figure.py:2022: UserWarning: Th
  warnings.warn("This figure includes Axes that are not compatible "
```

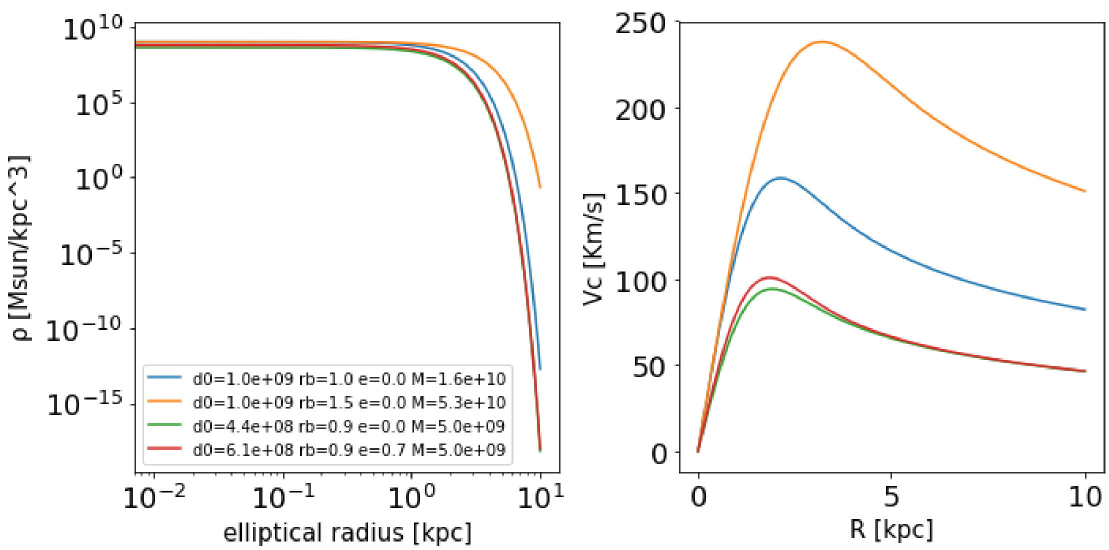



```
In [3]: #Valy halo

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

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

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

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


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()
```

```
/Users/Giuliano/anaconda3/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364: Integrati
  integration interval.
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda3/lib/python3.6/site-packages/matplotlib/figure.py:2022: UserWarning: Th
  warnings.warn("This figure includes Axes that are not compatible "
```

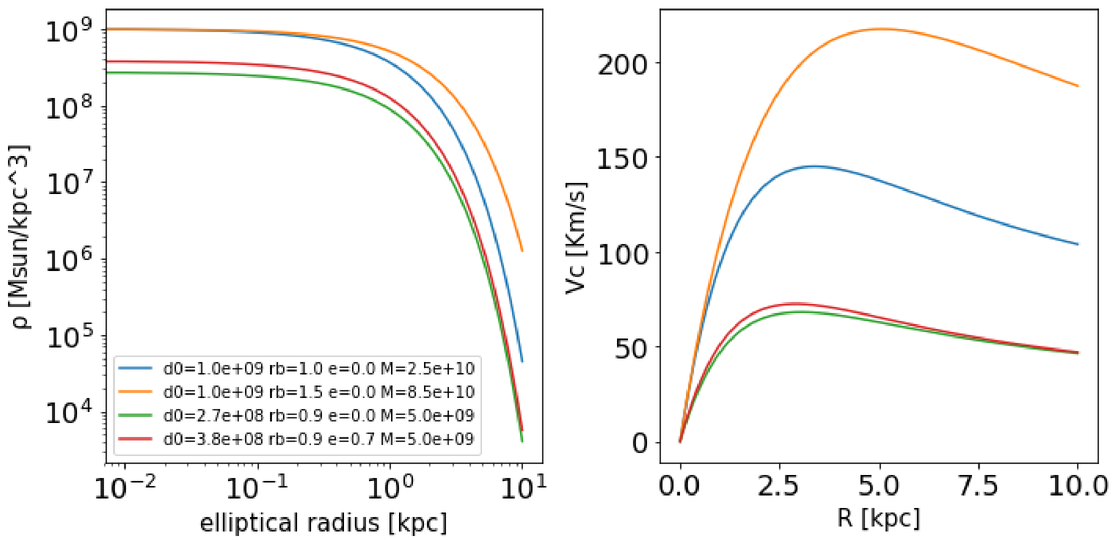



```
In [3]: #Exponential halo

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

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

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

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


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()
```

```
/Users/Giuliano/anaconda3/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364: Integrati
```

```
  integration interval.
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda3/lib/python3.6/site-packages/matplotlib/figure.py:2022: UserWarning: Th
  warnings.warn("This figure includes Axes that are not compatible "
```



DISC MODELS

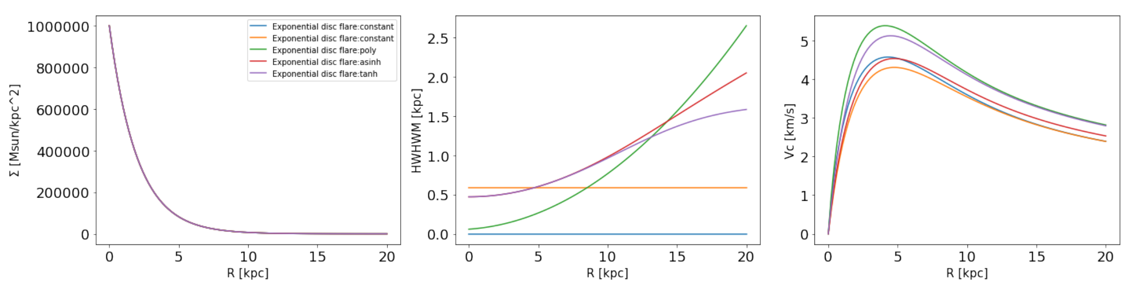
```
In [9]: #Exponential disc
        #Sigma(R)=Sigma0*Exp(-R/Rd)
        sigma0=1e6 #Cental surface density in Msun/kpc2
        Rd= 2 #Exponential scale length in kpc
        Rcut= 50 #Cylindrical radius where dens(R>Rcut,z)=0
        zcut= 20 #Cylindrical heigth where dens(R,|z|>zcut)=0
        zlaw='gau' #Vertical density law: it could be gau, sech2, exp

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

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

```python
ax_vcirc.plot(R, vcirc[:,1])

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

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

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

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

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

```
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/matplotlib/figure.py:1743: UserWa
  warnings.warn("This figure includes Axes that are not "
```




```
In [10]: fig=plt.figure(figsize=(20,5))
         ax_dens=fig.add_subplot(131)
         ax_flare=fig.add_subplot(132)
         ax_vcirc=fig.add_subplot(133)
         R=np.linspace(0,20,100) #Cylidrincal radii where estimate surface density and flare



         #Poly Exponential disc
         #Sigma(R)=Sigma0*Exp(-R/Rd)*polynomial(R)
```

```
sigma0=1e6 #Cental surface density in Msun/kpc2
Rd= 2 #Exponential scale length in kpc
Rcoeff=[1,0.2,0.4] #Coefficent of the polynomial(R)=Rcoeff[0]+Rcoeff[1]*R+Rcoeff[2]*R*R
                    #Rcoeff will be always renormalised to have Rcoeff[0]=1
Rcut= 50 #Cylindrical radius where dens(R>Rcut,z)=0
zcut= 20 #Cylindrical heigth where dens(R,|z|>zcut)=0
zlaw='gau' #Vertical density law: it could be gau, sech2, exp
#Vertical:
#razor-thin disc
epd=dc.PolyExponential_disc.thin(sigma0=sigma0, Rd=Rd, coeff=Rcoeff, Rcut=Rcut, zcut=zc
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, co
vcirc=epd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the pl
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=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, co
vcirc=epd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the pl
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+pcoe
epd=dc.PolyExponential_disc.polyflare(sigma0=sigma0, Rd=Rd, coeff=Rcoeff, Rcut=Rcut, zc
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, co
vcirc=epd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the pl
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, 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, co
vcirc=epd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the pl
ax_dens.plot(R, sdens[:,1], label=epd.name + ' flare:'+epd.flaw)
ax_flare.plot(R, flare[:,1])
```

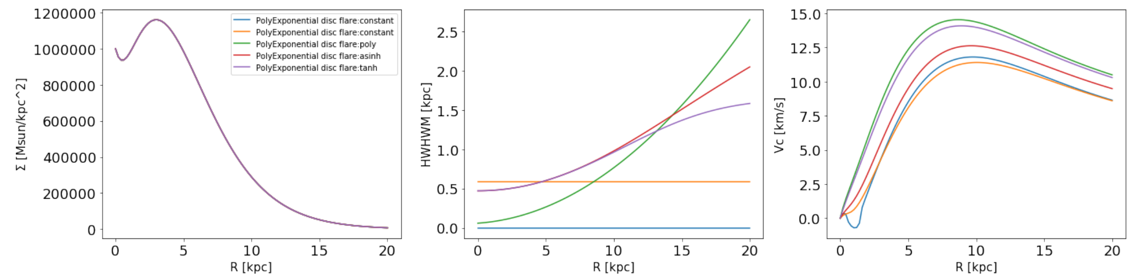
```
    ax_vcirc.plot(R, vcirc[:,1])

    #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, zc
    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, co
    vcirc=epd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the pl
    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()
```

```
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  warnings.warn(msg, IntegrationWarning)
```

```
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
```

```
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/matplotlib/figure.py:1743: UserWa
  warnings.warn("This figure includes Axes that are not "
```




```
In [11]: fig=plt.figure(figsize=(20,5))
         ax_dens=fig.add_subplot(131)
         ax_flare=fig.add_subplot(132)
         ax_vcirc=fig.add_subplot(133)
         R=np.linspace(0,20,100) #Cylidrincal radii where estimate surface density and flare

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

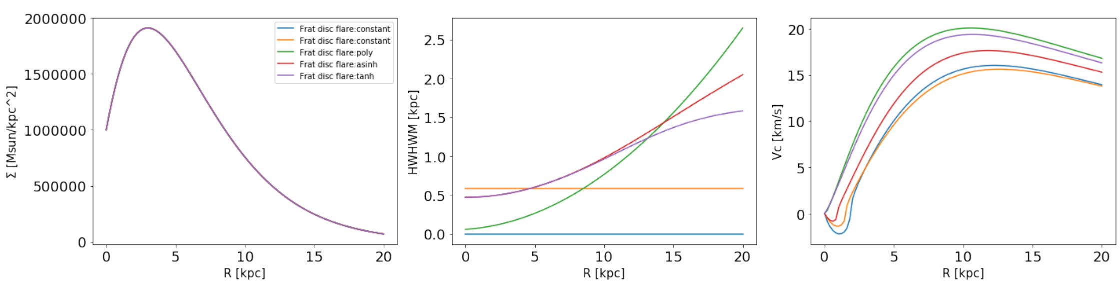
```
sdens=ed.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=ed.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the pla
ax_dens.plot(R, sdens[:,1], label=ed.name + ' flare:'+ed.flaw)
ax_flare.plot(R, flare[:,1])
ax_vcirc.plot(R, vcirc[:,1])

#polynomial flare
pcoeff=[0.05,0.01,0.005] #Coeffficent of the polynomial zd(R)=pcoeff[0]+pcoeff[1]*R+pcoe
ed=dc.Frat_disc.polyflare(sigma0=sigma0, Rd=Rd,Rd2=Rd2,alpha=alfa,  Rcut=Rcut, zcut=zcu
sdens=ed.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=ed.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the pla
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=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, col
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the pla
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=zcu
sdens=ed.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=ed.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col
vcirc=ed.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the pla
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()
```

```
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  warnings.warn(msg, IntegrationWarning)
```

```
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
```

```
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/matplotlib/figure.py:1743: UserWa
  warnings.warn("This figure includes Axes that are not "
```

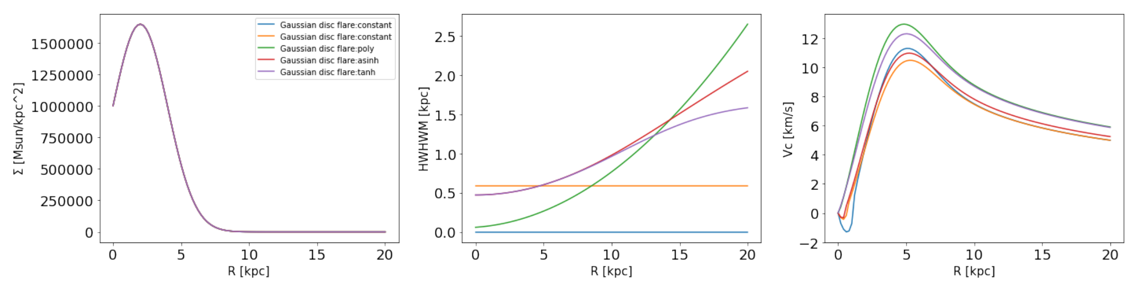


```
In [15]: fig=plt.figure(figsize=(20,5))
         ax_dens=fig.add_subplot(131)
         ax_flare=fig.add_subplot(132)
         ax_vcirc=fig.add_subplot(133)
         R=np.linspace(0,20,100) #Cylidrincal radii where estimate surface density and flare

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


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


#Tanh flare
#zd(R)=h0+c*(tanh(R*R/Rf*Rf))
h0=0.4 #Cental zd in kpc
c=1 #
Rf=15 #Flaring scale length in kpc
gd=dc.Gaussian_disc.tanhflare(sigma0=sigma0, sigmad=sigmad, R0=R0, Rcut=Rcut, zcut=zcut
sdens=gd.Sdens(R) #sdens 2D array: col-0 R, col-1 Surface density at R [Msun/kpc^2]
flare=gd.flare(R, HWHM=True) #radial profile of the vertical scale length: col-0 R, col
vcirc=gd.vcirc(R, nproc=2) #Vcric 2D array: col-0 R, col-1 Circular velocity on the pla
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()
```

```
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
  warnings.warn(msg, IntegrationWarning)
/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/scipy/integrate/quadpack.py:364:
```

```
  warnings.warn(msg, IntegrationWarning)


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



/Users/Giuliano/anaconda/envs/py36/lib/python3.6/site-packages/matplotlib/figure.py:1743: UserWa
  warnings.warn("This figure includes Axes that are not "
```



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 some
         #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,fit
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 -9.4e-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=[0.1,2,10] #List with the cylindrical radial coordinates in Kpc
Z=[0,0.1,1] #List with the cylindrical vertical coordinates in Kpc
grid=True #If True create a grid from R and Z, otherwise estimate the potentail in the
nproc=2 #Number of proccesors to use for parallel computation
toll=1e-4 #Relative and absolute Tollerance for the potential integration
potential_grid=iso_halo.potential(R=R,Z=Z,grid=grid,nproc=2)
print(potential_grid)
#First Column -R
#Second Column -Z
#Third Column Potenzial in Kpc^2/Myr^2
```

```
[[  1.00000000e-01   0.00000000e+00  -4.23552484e-03]
 [  1.00000000e-01   1.00000000e-01  -4.23543065e-03]
 [  1.00000000e-01   1.00000000e+00  -4.22621602e-03]
 [  2.00000000e+00   0.00000000e+00  -4.19961401e-03]
 [  2.00000000e+00   1.00000000e-01  -4.19952792e-03]
 [  2.00000000e+00   1.00000000e+00  -4.19109439e-03]
 [  1.00000000e+01   0.00000000e+00  -3.72924475e-03]
 [  1.00000000e+01   1.00000000e-01  -3.72921321e-03]
 [  1.00000000e+01   1.00000000e+00  -3.72609958e-03]]
```

In [2]:
```
#Estimate the potential of a ensemble of dynamic components
from discH.dynamics import galpotential

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

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

#Stellar disc
sigma0=1e6
Rd=3
zd=0.4
zlaw='sech2'
Rcut=50
zcut=30
```

```
disc=dc.Exponential_disc.thick(sigma0=sigma0, Rd=Rd, zd=zd, zlaw=zlaw, Rcut=Rcut, zcut=z


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

#Step3
#Calculate potential at R-Z
R=np.linspace(0.1,30,10) #List with the cylindrical radial coordinates in Kpc
Z=np.linspace(0,5,10) #List with the cylindrical vertical coordinates in Kpc
grid=True #If True create a grid from R and Z, otherwise estimate the potentail in the p
nproc=2 #Number of proccesor to use for parallel computation
toll=1e-4 #Relative and absolute Tollerance for the potential integration
Rcut=None #If not None, set the Rcut of all the disc components to this value
zcut=None #If not None, set the zcut of all the disc components to this value
mcut=None #If not None, set the mcut of all the halo components to this value
external_potential=None #If not None, this should be an array matching the dimension of
print('##########STEP3##########')
print('Estimate Potential')
hp=ga.potential(R,Z,grid=grid, nproc=nproc, toll=toll, Rcut=Rcut, zcut=zcut, mcut=mcut,
#Return a grid with 0-R 1-Z 2-Total Potential in kpc^2/Myr^2
print('\nReturn a grid 0-R 1-Z 2-Total Potential in kpc^2/Myr^2, e.g.:')
print(hp[:5])
print('###########################')

#Step4 Use the results or save them in files:

#The potential information can be accessed with
pot_grid=ga.potential_grid
#Array with col-0: R in kpc, col-1: Z in kpc, col-2: Total potential in kpc^2/Myr^2
pot_grid_complete=ga.potential_grid_complete
#Array with col-0: R in kpc, col-1: Z in kpc, col-i+1: Potential of the single  (i+1)th
#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_gr
filename='potential.dat' #File where to store the data
ga.save(filename=filename, complete=complete)
```

```
##########STEP2##########
```

```
Components info
Components: 0
Model: NFW halo
d0: 1.00e+06 Msun/kpc3
rs: 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

###########################
##########STEP3###########
Estimate Potential
External potential: No
Calculating Potential of the 1th component (NFW halo)...Done (0.03 s)
Calculating Potential of the 2th component (Exponential disc)...Done (1.03 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]]
###########################
```

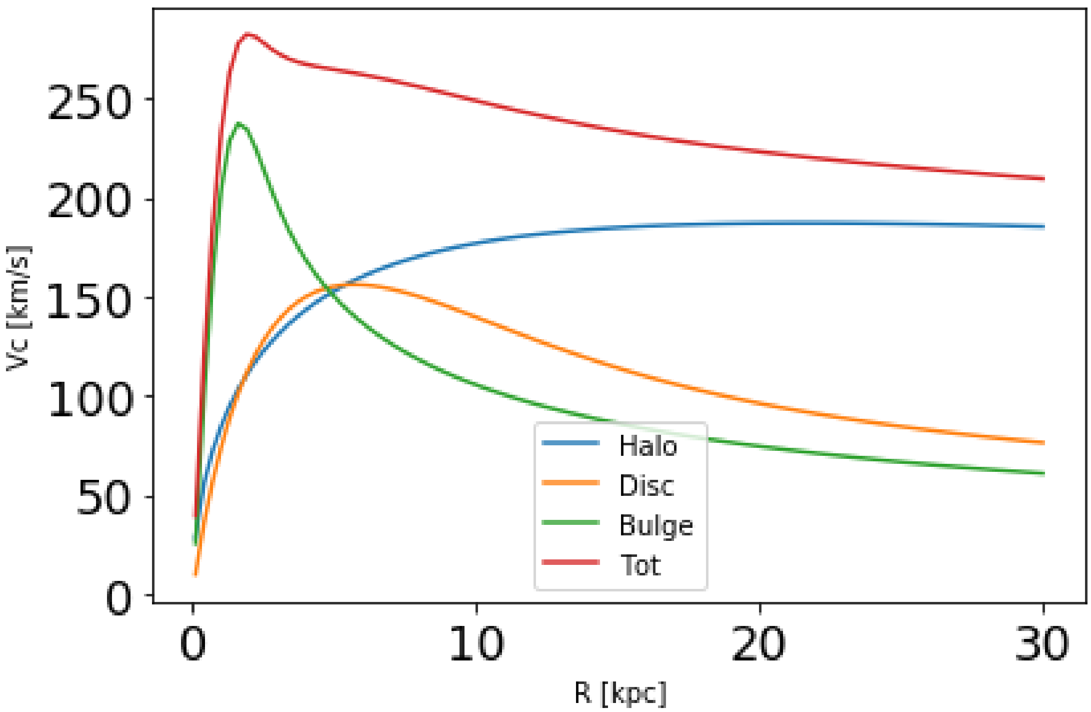
VCIRC FOR MULTIPLE COMPONENTS

In [47]:
```
#Estimate the potential of a ensemble of dynamic components
from discH.dynamics import galpotential
```

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

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

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


#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 tota
#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 ve
```

```python
#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
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
###########################


/Users/Giuliano/anaconda3/lib/python3.6/site-packages/matplotlib/figure.py:2022: UserWarning: Th
  warnings.warn("This figure includes Axes that are not compatible "
```



In [19]:
```
from discH.dynamics import discHeight

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

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

#Stellar disc
sigma0=5e6
Rd=3
zd=0.4
zlaw='sech2'
Rcut=50
```

```
zcut=30
disc=dc.Exponential_disc.thick(sigma0=sigma0, Rd=Rd, zd=zd, zlaw=zlaw, Rcut=Rcut, zcut=

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

#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 i

#Vel dispersion
#Velocity dispersion, we assume that the disc component as an isotropic velocity disper
#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 functio

#R array
#These three quantities define the cylindrical R coordinates that will be used to estim
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],Rpoi
#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 estim
    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],Zpoi
    #If Zpoints is a list a tuple or np.ndarray use the points inside the list
    #NB, Zrange[0] must be always 0 to have a good estimate of the vertical profile of the

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

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

    Rcut=None #If not None, set the Rcut of all the disc components to this value, default=
    zcut=None #If not None, set the zcut of all the disc components to this value, default=
    mcut=None #If not None, set the mcut of all the halo components to this value, default=
    Rlimit='max' #If not None, set a limit Radius for the flaring, i.e. the radius where zd
    #this could be useful when the flare is fitted with an high degree polynomial that can
    #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=1
    external_potential=None #External potential, default=None
    outdir='gasHeight_res' #Folder where to save the outputs, default='gasHeight'
    diagnostic=True #If True, save figures and tables to see all results of the iterations

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

```
////////////////////////////////////////////////////////////////////////////
Calculating fixed potential
External potential: No
Calculating Potential of the 1th component (Hernquist halo)...Done (0.07 s)
Calculating Potential of the 2th component (Exponential disc)...Done (12.36 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 0.083 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: Yes
Calculating Potential of the 1th component (Frat disc)...Done (21.55 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 0.098 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: Yes
Calculating Potential of the 1th component (Frat disc)...Done (19.04 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 0.087 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: Yes
Calculating Potential of the 1th component (Frat disc)...Done (17.09 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 0.091 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: Yes
Calculating Potential of the 1th component (Frat disc)...Done (19.51 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 0.082 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: Yes
Calculating Potential of the 1th component (Frat disc)...Done (17.92 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 0.089 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
//////////////////////////////////////////////////////////////////////////////
```

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]
```