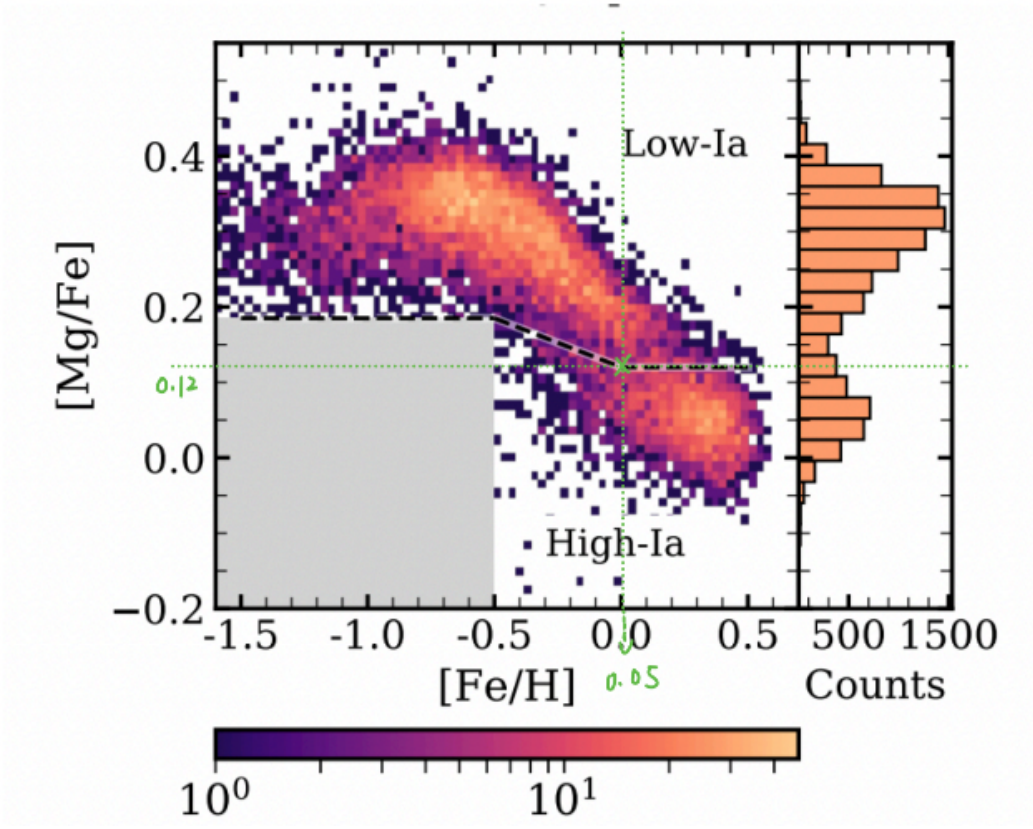
Target plnaet: TRAPPIST-1 b

Section 1, elements of host star(Task 1 in Project Description)

Based on NEA (https://exoplanetarchive.ipac.caltech.edu/overview/TRAPPIST-1), for TRAPPISST-1:

[Fe/H] :0.05350

Based on Griffith et al., 2020



[Mg/Fe] :0.12

Note that: $[N/M] = \log \frac{N/M}{N_\odot/M_\odot}$

$[Mg/Fe] = \log Mg - \log Fe - (\log Mg_\odot - \log Fe_\odot)$

$= -(\log Mg_\odot - \log Fe_\odot - (\log Mg - \log Fe))$

$= -[Fe/Mg]$

[Fe/Mg] :-0.12

$$[Mg/Fe] = \log Mg - \log Fe - (\log Mg_{\odot} - \log Fe_{\odot})$$

$$[Fe/H] = \log Fe - \log H - (\log Fe_{\odot} - \log H_{\odot})$$

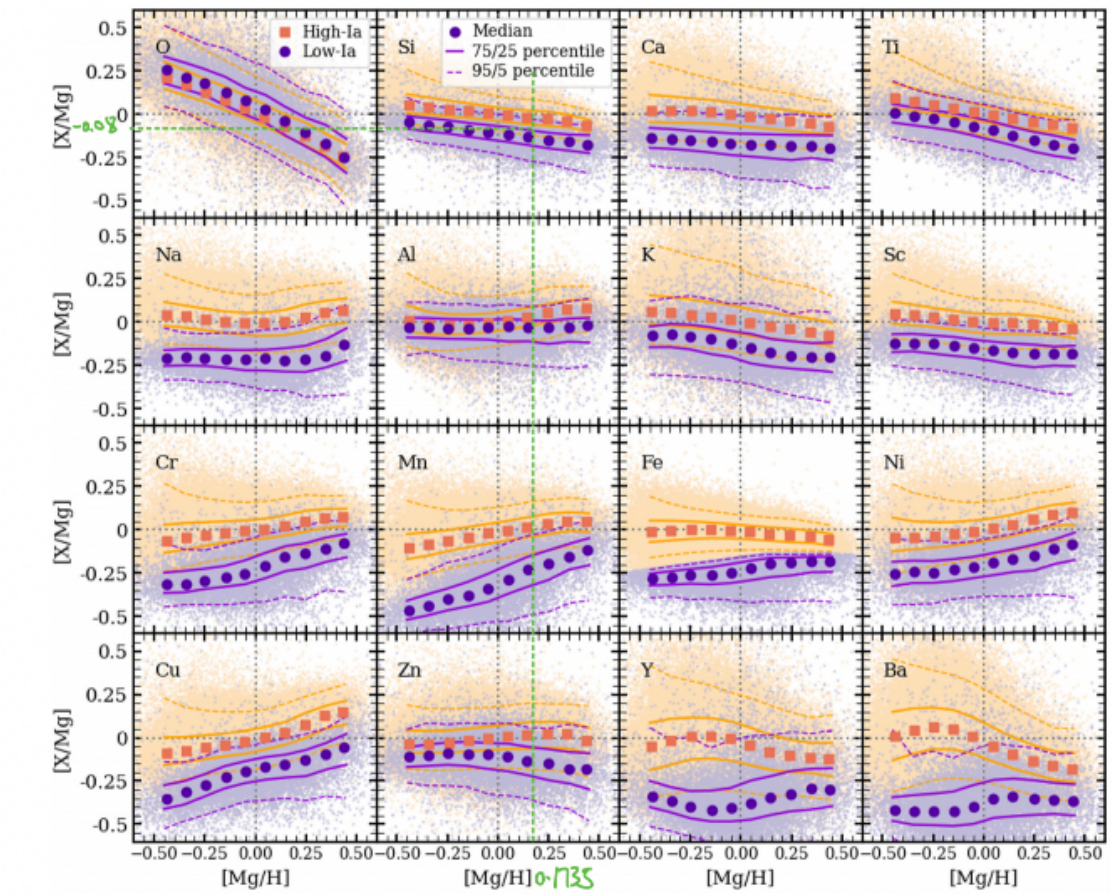
$$[Mg/H] = \log Mg - \log H - (\log Mg_{\odot} - \log H_{\odot})$$

$$= [Mg/Fe] + [Fe/H]$$

$$= 0.1735$$

[Mg/H] :0.1735

Based on Griffith et al., 2022,



[Si/Mg] :-0.08

Now find the mole ratio of Si/Mg, Fe/Mg

$$[N/M] = \log \frac{N/M}{N_{\odot}/M_{\odot}}$$

$$N/M = N_{\odot}/M_{\odot} \cdot 10^{[N/M]}$$

Based on [this (http://hyperphysics.phy-astr.gsu.edu/hbase/Tables/suncomp.html)]

$$Fe_{\odot}/Mg_{\odot} = 0.78947$$

$Si_{\odot}/Mg_{\odot} = 1.18421$

Si/Mg=0.984983

Fe/Mg=0.598877

Section 2(Task 2 in Project Description)

In [1]:
```
import os
import sys
import numpy as np
# hack to allow scripts to be placed in subdirectories next to burnman:
if not os.path.exists('ExoPlex') and os.path.exists('../ExoPlex'):
    sys.path.insert(1, os.path.abspath('..'))
Pressure_range_mantle_UM = '1000 1400000'
Temperature_range_mantle_UM = '1400 3000'

Pressure_range_mantle_LM = '1000000 7500000'
Temperature_range_mantle_LM = '2200 5000'

core_rad_frac_guess = 1.
water_rad_frac_guess = 0.1
water_potential_temp = 300.

combine_phases = True
use_grids = True
import ExoPlex as exo
```

In [2]:
```
if __name__ == "__main__":

    Mass_planet = 1.374 # in Earth masses
    #create filename to store values

    Output_filename = 'high_wFEO'
    #Next user must input the ratios by mole (Earth is Ca/Mg = .07, Si.
    CaMg = 0.07
    SiMg = 0.984983
    AlMg = 0.09
    FeMg = 0.598877


    #How much water do you want in your planet? By mass fraction.
    wt_frac_water = 0.0

    #Don't forget that if you have water you need to add water layers
    number_h2o_layers = 0

    #Now we can mix various elements into the core or mantle
    wt_frac_Si_core = 0. #by mass <1
    wt_frac_O_core = 0. #by mass
    wt_frac_S_core = 0. #by mass
    mol_frac_Fe_mantle =0.0#by mole

    #What potential temperature (in K) do you want to start your mantle
    Mantle_potential_temp = 1600

    #Input the resolution of your upper mantle and lower mantle composi
    #These are input as number of T, P points. 50 50 = 2500 grid points,
    #5 minutes to calculate. Lower mantle resolution does not need to b
    #mostly ppv.
    resolution_UM = '50 50'
    resolution_LM = '20 20'

    #lastly we need to decide how many layers to put in the planet. Thi
    #the mass-radius sampling.
    num_mantle_layers = 500
    num_core_layers = 600



    number_of_runs = 1
    Output_radii = []
    Output_mass = []


    ######### Initalize and run ExoPlex


    compositional_params = [wt_frac_water,FeMg,SiMg,CaMg,AlMg,mol_frac_
                            wt_frac_O_core,wt_frac_S_core,combine_phases,

    if use_grids == True:
        filename = exo.functions.find_filename(compositional_params)
    else:
        filename=''
```

```
structure_params =  [Pressure_range_mantle_UM,Temperature_range_mant
                     Pressure_range_mantle_LM, Temperature_range_mar
                     core_rad_frac_guess,Mantle_potential_temp,wate


layers = [num_mantle_layers,num_core_layers,number_h2o_layers]

#This is where we actually run the planet. First PerPlex grids of m
#Cp and alpha are calculated and stored in the Solutions folder. If
#(in name, not necessarily in composition), then PerPlex is not run

Planet = exo.run_planet_mass(Mass_planet,compositional_params,struct

#Planet is a dictionary containing many parameters of interest:
#Planet.get('radius') = list of the radial points from calculation
#Planet.get('mass') = list of the cumulative mass at each radius po
#Planet.get('density') = list of densities from calculation (kg/m^3
#Planet.get('temperature') = list of temperature points from calcul
#Planet.get('gravity') = list of gravity points from calculation (S
#Planet.get('pressure') = list of pressure points from calculation
#Planet.get('alpha') = list of values of thermal expansivity points
#Planet.get('cp') = list of values of specific heat points from calc
#Planet.get('phases') = list of phases and their molar fractions
print()
print("Mass = ", '%.3f'%(Planet['mass'][-1]/5.97e24), "Earth masses"
print("Radius = ", '%.3f'%(Planet['radius'][-1]/6371e3), "Earth radi
print("Core Mass Fraction = ", '%.2f'%(100.*Planet['mass'][num_core_
print("Core Radius Fraction = ", '%.2f'%(100.*Planet['radius'][num_c
print("CMB Pressure = " ,'%.2f' % (Planet['pressure'][num_core_layer

print("number of oceans:",'%.2f' % (wt_frac_water*Planet['mass'][-1
#If you'd like the full output, uncomment out these lines!
Output_filename = Output_filename + '_Radius_'+ str('%.2f'%(Planet[
exo.functions.write(Planet,Output_filename)
```

```
Core composition:  {'Fe': 100.0, 'Si': 0.0, 'O': 0.0, 'S': 0.0}
Mantle composition:  {'FeO': 0.0, 'SiO2': 54.79812765, 'MgO': 37.3190
4665, 'CaO': 3.63457148, 'Al2O3': 4.24825422}
Mantle Fe# -0.0
Core Mass Percent =  23.644

Your closest grid filename is:  0.07CaMg_0.00FeMg_0.09AlMg_1.0SiMg_0.
0NaMg_0.00Fe_U/LM_results.txt


Core composition:  {'Fe': 100.0, 'Si': 0.0, 'O': 0.0, 'S': 0.0}
Mantle composition:  {'FeO': 0.0, 'SiO2': 54.79812765, 'MgO': 37.3190
4665, 'CaO': 3.63457148, 'Al2O3': 4.24825422}
Mantle Fe# -0.0
Core Mass Percent =  23.644

The Upper mantle .tab already exists, please wait briefly for solutio
n

../Solutions_Small/0.07CaMg_0.00FeMg_0.09AlMg_1.0SiMg_0.0NaMg_0.00Fe
The Lower mantle .tab already exists, please wait briefly for solutio
n

iteration # 1
iteration # 2
iteration # 3
iteration # 4
iteration # 5
iteration # 6
iteration # 7
iteration # 8
iteration # 9
iteration # 10
iteration # 11
iteration # 12
iteration # 13
iteration # 14
iteration # 15

Mass =  1.374 Earth masses
Radius =  1.117 Earth radii
Core Mass Fraction =  23.80
Core Radius Fraction =  46.35
CMB Pressure =  204.07 GPa
number of oceans: 0.00

Detailed data file written to: high_wFEO_Radius_1.12.txt
```

Planet Mass = 1.374 Earth masses

Planet Radius = 1.117 Earth radii

Based on the luminosity of TRAPPIST-1 b, we could find the surface irradiation(flux) of TRAPPISR-1 b

luminosity have two section.

The luminosity of TRAPPIST-1 b:

1. thermal luminosity
2. reflective luminosity

thermal luminosity

$L_t = 4 \cdot r^2\pi \cdot \sigma_{SB} \cdot T^4$, based on this (https://www.astronomy.ohio-state.edu/thompson.1847/1144/Lecture9.html#:~:text=L%20%3D%20F%20x%20Area%20%3D

T: temperature of planet

σ_{SB}: Stefan-Boltzmann constant

r: radius of planet

L_t: thermal luminosity of planet

The temprature of our planet are the same as TRAPPIST-1 b(since we choose TRAPPIST-1 b as simulation target):

397.6K based on NEA (https://exoplanetarchive.ipac.caltech.edu/overview/TRAPPIST-1)

In [3]:
```
import os
import sys
import numpy as np
import astropy.constants as c
import astropy.units as u
```

In [4]:
```
tl = (4 * np.pi *(1.117*c.R_earth)**2 * c.sigma_sb * (397.6 * u.K)**4).t
print(tl)
```

```
9.038494498528959e+17 W
```

reflective luminosity

$L_s = 4 \cdot r_s^2\pi \cdot \sigma_{SB} \cdot T_s^4$

L_s: luminosity of star

r_s: radius of star

T_s : temprature of star

star: TRAPPIST-1

$$L_p = \frac{L_s}{4\pi a^2} \cdot \pi r^2$$

a: semi-major axis of our planet, here a equals to the semi-major axis of TRAPPIST-1 b

In [5]:
```
lf = (((4 * np.pi *(0.1192*c.R_sun)**2 * c.sigma_sb * (2566 * u.K)**4) 
print(lf)
```

```
9.045056577232369e+17 W
```

the flux of our planet on its surface:

$$F = \frac{L_s + L_p}{4\pi r^2}$$

In [6]:
```
f = ((lf+tl)/(4 * np.pi * (1.117*c.R_earth)**2 )).to(u.W/u.m**2)
print(f)
```

```
2835.2075627065533 W / m2
```

Section 3（Task 3 in Project Description）

The mass of TRAPPIST-1 b:

Max: 1.443 mass of earth

Min: 1.305 mass of earth

Max mass:

In [7]:
```
if __name__ == "__main__":

    Mass_planet = 1.443 # in Earth masses
    #create filename to store values

    Output_filename = 'high_wFEO'
    #Next user must input the ratios by mole (Earth is Ca/Mg = .07, Si.
    CaMg = 0.07
    SiMg = 0.984983
    AlMg = 0.09
    FeMg = 0.598877


    #How much water do you want in your planet? By mass fraction.
    wt_frac_water = 0.0

    #Don't forget that if you have water you need to add water layers
    number_h2o_layers = 0

    #Now we can mix various elements into the core or mantle
    wt_frac_Si_core = 0. #by mass <1
    wt_frac_O_core = 0. #by mass
    wt_frac_S_core = 0. #by mass
    mol_frac_Fe_mantle =0.0#by mole

    #What potential temperature (in K) do you want to start your mantle
    Mantle_potential_temp = 1600

    #Input the resolution of your upper mantle and lower mantle composi
    #These are input as number of T, P points. 50 50 = 2500 grid points,
    #5 minutes to calculate. Lower mantle resolution does not need to b
    #mostly ppv.
    resolution_UM = '50 50'
    resolution_LM = '20 20'

    #lastly we need to decide how many layers to put in the planet. This
    #the mass-radius sampling.
    num_mantle_layers = 500
    num_core_layers = 600



    number_of_runs = 1
    Output_radii = []
    Output_mass = []


    ######### Initalize and run ExoPlex


    compositional_params = [wt_frac_water,FeMg,SiMg,CaMg,AlMg,mol_frac_
                            wt_frac_O_core,wt_frac_S_core,combine_phases,

    if use_grids == True:
        filename = exo.functions.find_filename(compositional_params)
    else:
        filename=''
```

```
structure_params =  [Pressure_range_mantle_UM,Temperature_range_mant
                     Pressure_range_mantle_LM, Temperature_range_mar
                     core_rad_frac_guess,Mantle_potential_temp,wate


layers = [num_mantle_layers,num_core_layers,number_h2o_layers]

#This is where we actually run the planet. First PerPlex grids of m
#Cp and alpha are calculated and stored in the Solutions folder. If
#(in name, not necessarily in composition), then PerPlex is not run

Planet = exo.run_planet_mass(Mass_planet,compositional_params,struct

#Planet is a dictionary containing many parameters of interest:
#Planet.get('radius') = list of the radial points from calculation
#Planet.get('mass') = list of the cumulative mass at each radius po
#Planet.get('density') = list of densities from calculation (kg/m^3
#Planet.get('temperature') = list of temperature points from calcul
#Planet.get('gravity') = list of gravity points from calculation (S
#Planet.get('pressure') = list of pressure points from calculation
#Planet.get('alpha') = list of values of thermal expansivity points
#Planet.get('cp') = list of values of specific heat points from calc
#Planet.get('phases') = list of phases and their molar fractions
print()
print("Mass = ", '%.3f'%(Planet['mass'][-1]/5.97e24), "Earth masses"
print("Radius = ", '%.3f'%(Planet['radius'][-1]/6371e3), "Earth radi
print("Core Mass Fraction = ", '%.2f'%(100.*Planet['mass'][num_core_
print("Core Radius Fraction = ", '%.2f'%(100.*Planet['radius'][num_c
print("CMB Pressure = " ,'%.2f' % (Planet['pressure'][num_core_layer

print("number of oceans:",'%.2f' % (wt_frac_water*Planet['mass'][-1
#If you'd like the full output, uncomment out these lines!
Output_filename = Output_filename + '_Radius_'+ str('%.2f'%(Planet[
exo.functions.write(Planet,Output_filename)
```

```
Core composition:  {'Fe': 100.0, 'Si': 0.0, 'O': 0.0, 'S': 0.0}
Mantle composition:  {'FeO': 0.0, 'SiO2': 54.79812765, 'MgO': 37.3190
4665, 'CaO': 3.63457148, 'Al2O3': 4.24825422}
Mantle Fe# -0.0
Core Mass Percent =  23.644

Your closest grid filename is:  0.07CaMg_0.00FeMg_0.09AlMg_1.0SiMg_0.
0NaMg_0.00Fe_U/LM_results.txt


Core composition:  {'Fe': 100.0, 'Si': 0.0, 'O': 0.0, 'S': 0.0}
Mantle composition:  {'FeO': 0.0, 'SiO2': 54.79812765, 'MgO': 37.3190
4665, 'CaO': 3.63457148, 'Al2O3': 4.24825422}
Mantle Fe# -0.0
Core Mass Percent =  23.644

The Upper mantle .tab already exists, please wait briefly for solutio
n

../Solutions_Small/0.07CaMg_0.00FeMg_0.09AlMg_1.0SiMg_0.0NaMg_0.00Fe
The Lower mantle .tab already exists, please wait briefly for solutio
n

iteration # 1
iteration # 2
iteration # 3
iteration # 4
iteration # 5
iteration # 6
iteration # 7
iteration # 8
iteration # 9
iteration # 10
iteration # 11
iteration # 12
iteration # 13
iteration # 14
iteration # 15
iteration # 16

Mass =  1.443 Earth masses
Radius =  1.133 Earth radii
Core Mass Fraction =  23.80
Core Radius Fraction =  46.30
CMB Pressure =  213.63 GPa
number of oceans: 0.00

Detailed data file written to: high_wFEO_Radius_1.13.txt
```

Min Mass:

In [8]:
```
if __name__ == "__main__":

    Mass_planet = 1.305 # in Earth masses
    #create filename to store values

    Output_filename = 'high_wFEO'
    #Next user must input the ratios by mole (Earth is Ca/Mg = .07, Si.
    CaMg = 0.07
    SiMg = 0.984983
    AlMg = 0.09
    FeMg = 0.598877


    #How much water do you want in your planet? By mass fraction.
    wt_frac_water = 0.0

    #Don't forget that if you have water you need to add water layers
    number_h2o_layers = 0

    #Now we can mix various elements into the core or mantle
    wt_frac_Si_core = 0. #by mass <1
    wt_frac_O_core = 0. #by mass
    wt_frac_S_core = 0. #by mass
    mol_frac_Fe_mantle =0.0#by mole

    #What potential temperature (in K) do you want to start your mantle
    Mantle_potential_temp = 1600

    #Input the resolution of your upper mantle and lower mantle composi
    #These are input as number of T, P points. 50 50 = 2500 grid points,
    #5 minutes to calculate. Lower mantle resolution does not need to b
    #mostly ppv.
    resolution_UM = '50 50'
    resolution_LM = '20 20'

    #lastly we need to decide how many layers to put in the planet. Thi
    #the mass-radius sampling.
    num_mantle_layers = 500
    num_core_layers = 600



    number_of_runs = 1
    Output_radii = []
    Output_mass = []


    ######### Initalize and run ExoPlex


    compositional_params = [wt_frac_water,FeMg,SiMg,CaMg,AlMg,mol_frac_
                            wt_frac_O_core,wt_frac_S_core,combine_phases,

    if use_grids == True:
        filename = exo.functions.find_filename(compositional_params)
    else:
        filename=''
```

```
structure_params =  [Pressure_range_mantle_UM,Temperature_range_mant
                     Pressure_range_mantle_LM, Temperature_range_mar
                     core_rad_frac_guess,Mantle_potential_temp,wate


layers = [num_mantle_layers,num_core_layers,number_h2o_layers]

#This is where we actually run the planet. First PerPlex grids of m
#Cp and alpha are calculated and stored in the Solutions folder. If
#(in name, not necessarily in composition), then PerPlex is not run

Planet = exo.run_planet_mass(Mass_planet,compositional_params,struct

#Planet is a dictionary containing many parameters of interest:
#Planet.get('radius') = list of the radial points from calculation
#Planet.get('mass') = list of the cumulative mass at each radius po
#Planet.get('density') = list of densities from calculation (kg/m^3
#Planet.get('temperature') = list of temperature points from calcul
#Planet.get('gravity') = list of gravity points from calculation (S
#Planet.get('pressure') = list of pressure points from calculation
#Planet.get('alpha') = list of values of thermal expansivity points
#Planet.get('cp') = list of values of specific heat points from calc
#Planet.get('phases') = list of phases and their molar fractions
print()
print("Mass = ", '%.3f'%(Planet['mass'][-1]/5.97e24), "Earth masses"
print("Radius = ", '%.3f'%(Planet['radius'][-1]/6371e3), "Earth radi
print("Core Mass Fraction = ", '%.2f'%(100.*Planet['mass'][num_core_
print("Core Radius Fraction = ", '%.2f'%(100.*Planet['radius'][num_c
print("CMB Pressure = " ,'%.2f' % (Planet['pressure'][num_core_layer

print("number of oceans:",'%.2f' % (wt_frac_water*Planet['mass'][-1
#If you'd like the full output, uncomment out these lines!
Output_filename = Output_filename + '_Radius_'+ str('%.2f'%(Planet[
exo.functions.write(Planet,Output_filename)
```

```
Core composition:  {'Fe': 100.0, 'Si': 0.0, 'O': 0.0, 'S': 0.0}
Mantle composition:  {'FeO': 0.0, 'SiO2': 54.79812765, 'MgO': 37.3190
4665, 'CaO': 3.63457148, 'Al2O3': 4.24825422}
Mantle Fe# -0.0
Core Mass Percent =  23.644

Your closest grid filename is:  0.07CaMg_0.00FeMg_0.09AlMg_1.0SiMg_0.
0NaMg_0.00Fe_U/LM_results.txt


Core composition:  {'Fe': 100.0, 'Si': 0.0, 'O': 0.0, 'S': 0.0}
Mantle composition:  {'FeO': 0.0, 'SiO2': 54.79812765, 'MgO': 37.3190
4665, 'CaO': 3.63457148, 'Al2O3': 4.24825422}
Mantle Fe# -0.0
Core Mass Percent =  23.644

The Upper mantle .tab already exists, please wait briefly for solutio
n

../Solutions_Small/0.07CaMg_0.00FeMg_0.09AlMg_1.0SiMg_0.0NaMg_0.00Fe
The Lower mantle .tab already exists, please wait briefly for solutio
n

iteration # 1
iteration # 2
iteration # 3
iteration # 4
iteration # 5
iteration # 6
iteration # 7
iteration # 8
iteration # 9
iteration # 10
iteration # 11
iteration # 12
iteration # 13
iteration # 14
iteration # 15

Mass =  1.305 Earth masses
Radius =  1.101 Earth radii
Core Mass Fraction =  23.80
Core Radius Fraction =  46.41
CMB Pressure =  194.52 GPa
number of oceans: 0.00

Detailed data file written to: high_wFEO_Radius_1.10.txt
```

Mass = 1.443 Earth masses, Radius = 1.133 Earth radii

Mass = 1.374 Earth masses, Radius = 1.117 Earth radii

Mass = 1.305 Earth masses, Radius = 1.101 Earth radii

In [9]:
```
def density(R,M):
    """
    R: radius of planet
    M: mass of planet
    """
    D=(M/(4/3 * np.pi * R**3)).to(u.g/u.cm**3)
    return D
```

In [10]:
```
print("the density of planet with max mass:",density(1.133*c.R_earth,1.
print("the density of planet with normal mass:",density(1.117*c.R_earth
print("the density of planet with min mass:",density(1.101*c.R_earth,1.
```

```
the density of planet with max mass: 5.451876714447971 g / cm3
the density of planet with normal mass: 5.4174715372404405 g / cm3
the density of planet with min mass: 5.3730140924676 g / cm3
```

Section 4 Make a Planet（Task 4 in Project Description）

In [11]:
```
import os
import sys
import numpy as np
# hack to allow scripts to be placed in subdirectories next to burnman:
if not os.path.exists('ExoPlex') and os.path.exists('../ExoPlex'):
    sys.path.insert(1, os.path.abspath('..'))
Pressure_range_mantle_UM = '1000 1400000'
Temperature_range_mantle_UM = '1400 3000'
```

In [12]:
```
Pressure_range_mantle_LM = '1000000 7500000'
Temperature_range_mantle_LM = '2200 5000'
```

In [13]:
```
core_rad_frac_guess = 1.
water_rad_frac_guess = 0.1
water_potential_temp = 300.
```

In [14]:
```
combine_phases = True
use_grids = True
import ExoPlex as exo
```

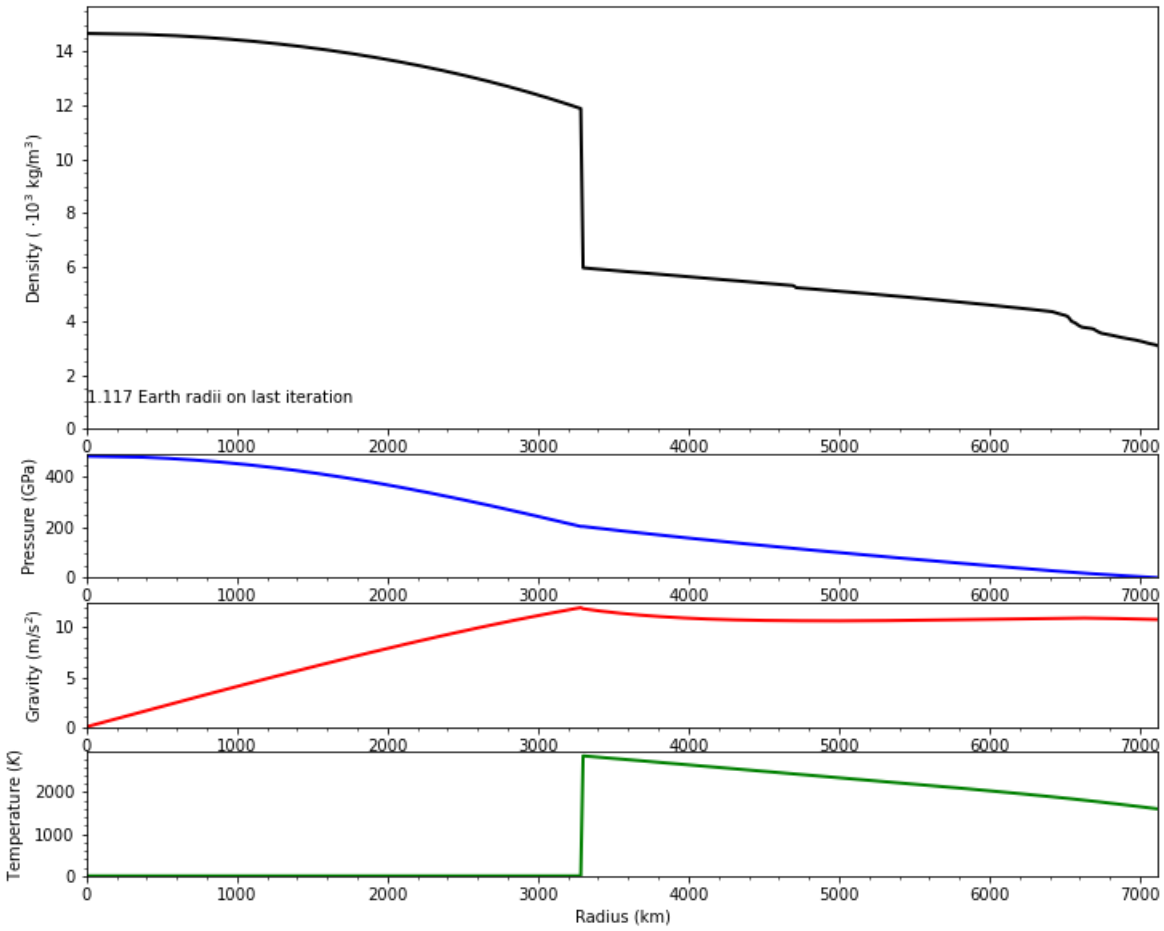
Mass of **TRAPPIST-1 b: 1.374 Earth Mass** based on NEA (https://exoplanetarchive.ipac.caltech.edu/overview/trappist-1)

In [15]:
```
if __name__ == "__main__":

    Mass_planet = 1.374 # in Earth masses
    #create filename to store values

    Output_filename = 'high_wFEO'
    #Next user must input the ratios by mole (Earth is Ca/Mg = .07, Si.
    CaMg = 0.07
    SiMg = 0.984983
    AlMg = 0.09
    FeMg = 0.598877


    #How much water do you want in your planet? By mass fraction.
    wt_frac_water = 0.0

    #Don't forget that if you have water you need to add water layers
    number_h2o_layers = 0

    #Now we can mix various elements into the core or mantle
    wt_frac_Si_core = 0. #by mass <1
    wt_frac_O_core = 0. #by mass
    wt_frac_S_core = 0. #by mass
    mol_frac_Fe_mantle =0.0#by mole

    #What potential temperature (in K) do you want to start your mantle
    Mantle_potential_temp = 1600

    #Input the resolution of your upper mantle and lower mantle composi
    #These are input as number of T, P points. 50 50 = 2500 grid points,
    #5 minutes to calculate. Lower mantle resolution does not need to b
    #mostly ppv.
    resolution_UM = '50 50'
    resolution_LM = '20 20'

    #lastly we need to decide how many layers to put in the planet. This
    #the mass-radius sampling.
    num_mantle_layers = 500
    num_core_layers = 600



    number_of_runs = 1
    Output_radii = []
    Output_mass = []


    ######### Initalize and run ExoPlex


    compositional_params = [wt_frac_water,FeMg,SiMg,CaMg,AlMg,mol_frac_
                            wt_frac_O_core,wt_frac_S_core,combine_phases,

    if use_grids == True:
        filename = exo.functions.find_filename(compositional_params)
    else:
        filename=''
```

```
structure_params =  [Pressure_range_mantle_UM,Temperature_range_mant
                     Pressure_range_mantle_LM, Temperature_range_mar
                     core_rad_frac_guess,Mantle_potential_temp,wate


layers = [num_mantle_layers,num_core_layers,number_h2o_layers]

#This is where we actually run the planet. First PerPlex grids of m
#Cp and alpha are calculated and stored in the Solutions folder. If
#(in name, not necessarily in composition), then PerPlex is not run

Planet = exo.run_planet_mass(Mass_planet,compositional_params,struct

#Planet is a dictionary containing many parameters of interest:
#Planet.get('radius') = list of the radial points from calculation
#Planet.get('mass') = list of the cumulative mass at each radius po
#Planet.get('density') = list of densities from calculation (kg/m^3
#Planet.get('temperature') = list of temperature points from calcul
#Planet.get('gravity') = list of gravity points from calculation (S
#Planet.get('pressure') = list of pressure points from calculation
#Planet.get('alpha') = list of values of thermal expansivity points
#Planet.get('cp') = list of values of specific heat points from cal
#Planet.get('phases') = list of phases and their molar fractions
print()
print("Mass = ", '%.3f'%(Planet['mass'][-1]/5.97e24), "Earth masses"
print("Radius = ", '%.3f'%(Planet['radius'][-1]/6371e3), "Earth radi
print("Core Mass Fraction = ", '%.2f'%(100.*Planet['mass'][num_core_
print("Core Radius Fraction = ", '%.2f'%(100.*Planet['radius'][num_c
print("CMB Pressure = " ,'%.2f' % (Planet['pressure'][num_core_layer

print("number of oceans:",'%.2f' % (wt_frac_water*Planet['mass'][-1
#If you'd like the full output, uncomment out these lines!
Output_filename = Output_filename + '_Radius_'+ str('%.2f'%(Planet[
exo.functions.write(Planet,Output_filename)

#Now let us plot
import matplotlib.pyplot as plt

figure = plt.figure(figsize=(12, 10))

ax1 = plt.subplot2grid((6, 3), (0, 0), colspan=3, rowspan=3)
ax2 = plt.subplot2grid((6, 3), (3, 0), colspan=3, rowspan=1)
ax3 = plt.subplot2grid((6, 3), (4, 0), colspan=3, rowspan=1)
ax4 = plt.subplot2grid((6, 3), (5, 0), colspan=3, rowspan=1)

ax1.plot(Planet['radius'] / 1.e3, Planet['density'] / 1.e3, 'k', lin
ax1.set_ylim(0., (max(Planet['density']) / 1.e3) + 1.)
ax1.set_xlim(0., max(Planet['radius']) / 1.e3)
ax1.set_ylabel("Density ( $\cdot 10^3$ kg/m$^3$)")
ax1.minorticks_on()
text = '%.3f' % (Planet['radius'][-1] / 6371e3) + ' Earth radii on T
ax1.text(0.05, 0.95, text)

# Make a subplot showing the calculated pressure profile
ax2.plot(Planet['radius'] / 1.e3, Planet['pressure'] / 1.e4, 'b', li
ax2.set_ylim(0., (max(Planet['pressure']) / 1e4) + 10.)
```

```
    ax2.set_xlim(0., max(Planet['radius']) / 1.e3)
    ax2.set_ylabel("Pressure (GPa)")
    ax2.minorticks_on()

    # Make a subplot showing the calculated gravity profile
    ax3.plot(Planet['radius'] / 1.e3, Planet['gravity'], 'r', linewidth=
    ax3.set_ylabel("Gravity (m/s$^2)$")
    ax3.set_xlim(0., max(Planet['radius']) / 1.e3)
    ax3.set_ylim(0., max(Planet['gravity']) + 0.5)
    ax3.minorticks_on()

    # Make a subplot showing the calculated temperature profile
    ax4.plot(Planet['radius'] / 1.e3, Planet['temperature'], 'g', linew
    ax4.set_ylabel("Temperature ($K$)")
    ax4.set_xlabel("Radius (km)")
    ax4.set_xlim(0., max(Planet['radius']) / 1.e3)
    ax4.set_ylim(0., max(Planet['temperature']) + 100)
    ax4.minorticks_on()

    plt.show()
```

```
Core composition:  {'Fe': 100.0, 'Si': 0.0, 'O': 0.0, 'S': 0.0}
Mantle composition:  {'FeO': 0.0, 'SiO2': 54.79812765, 'MgO': 37.3190
4665, 'CaO': 3.63457148, 'Al2O3': 4.24825422}
Mantle Fe# -0.0
Core Mass Percent =  23.644

Your closest grid filename is:  0.07CaMg_0.00FeMg_0.09AlMg_1.0SiMg_0.
0NaMg_0.00Fe_U/LM_results.txt


Core composition:  {'Fe': 100.0, 'Si': 0.0, 'O': 0.0, 'S': 0.0}
Mantle composition:  {'FeO': 0.0, 'SiO2': 54.79812765, 'MgO': 37.3190
4665, 'CaO': 3.63457148, 'Al2O3': 4.24825422}
Mantle Fe# -0.0
Core Mass Percent =  23.644

The Upper mantle .tab already exists, please wait briefly for solutio
n

../Solutions_Small/0.07CaMg_0.00FeMg_0.09AlMg_1.0SiMg_0.0NaMg_0.00Fe
The Lower mantle .tab already exists, please wait briefly for solutio
n

iteration # 1
iteration # 2
iteration # 3
iteration # 4
iteration # 5
iteration # 6
iteration # 7
iteration # 8
iteration # 9
iteration # 10
iteration # 11
iteration # 12
iteration # 13
iteration # 14
iteration # 15

Mass =  1.374 Earth masses
Radius =  1.117 Earth radii
Core Mass Fraction =  23.80
Core Radius Fraction =  46.35
CMB Pressure =  204.07 GPa
number of oceans: 0.00

Detailed data file written to: high_wFEO_Radius_1.12.txt
```



Section 5 Mantle Mineralogy Compare to the Earth（Task 5 Project Description）

mineralogy of Earth(from example)

'FeO': 0.0,

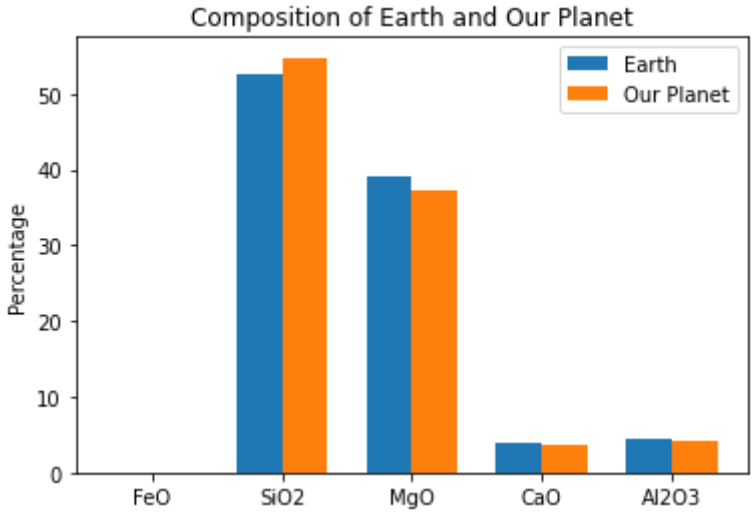
'SiO2': 52.55497015,

'MgO': 39.17101638,

'CaO': 3.81493827,

'Al2O3': 4.45907521

In [16]:
```
import matplotlib.pyplot as plt
import numpy as np

earth = [0.0, 52.55497015, 39.17101638, 3.81493827, 4.45907521]
our_planet = [0.0, 54.79812765, 37.31904665, 3.63457148, 4.24825422]

labels = ['FeO', 'SiO2', 'MgO', 'CaO', 'Al2O3']

x = np.arange(len(labels))

width = 0.35

fig, ax = plt.subplots()

ax.bar(x - width/2, earth, width, label='Earth')

ax.bar(x + width/2, our_planet, width, label='Our Planet')

ax.set_ylabel('Percentage')
ax.set_title('Composition of Earth and Our Planet')
ax.set_xticks(x)
ax.set_xticklabels(labels)
ax.legend()

plt.show()
```



In [ ]:

In [ ]:

In [ ]: