Luminosity for spherical outflow

We use this notebook to generate plots for spherical outflow analysis. This notebook looks at luminosities at different resolutions.

First we import necessary libraries

In [1]:
```
%matplotlib notebook
import processmcrat as pm
import astropy.units as unit
from astropy import constants as const
import matplotlib.pyplot as plt
import matplotlib as mpl
import numpy as np
```

We lead the MCRaT output files, and set our mock observations to be $\theta_{\rm obs}=1^\circ$, $\Delta\theta=4^\circ$, $r_{\rm obs}=10^{14}$ cm and framerate = 5 fps. The spectral fit energy range is $10^{-2}-4\times10^4$ keV.

In [2]:
```
mcrat_sim5_5=pm.McratSimLoad(
    "/Users/josearita-escalante/Documents/GRB-NASA/MCRaT-gits/MCRaT-resolution/CHOMBO/
mcrat_sim5_5.load_frame(2638, read_stokes=False)
observation5_5=pm.MockObservation(1, 4, 1e14, 5, mcratsimload_obj=mcrat_sim5_5)
observation5_5.set_spectral_fit_parameters(spectral_fit_energy_range=[0.01, 40000.0])
spectrum_dict5_5=observation5_5.spectrum(observation5_5.detected_photons.detection_tir
                                         observation5_5.detected_photons.detection_time.ma

mcrat_sim5_4=pm.McratSimLoad(
    "/Users/josearita-escalante/Documents/GRB-NASA/MCRaT-gits/MCRaT-resolution/CHOMBO/
mcrat_sim5_4.load_frame(2638, read_stokes=False)
observation5_4=pm.MockObservation(1, 4, 1e14, 5, mcratsimload_obj=mcrat_sim5_4)
observation5_4.set_spectral_fit_parameters(spectral_fit_energy_range=[0.01, 40000.0])
spectrum_dict5_4=observation5_4.spectrum(observation5_4.detected_photons.detection_tir
                                         observation5_4.detected_photons.detection_time.ma

mcrat_sim5_3=pm.McratSimLoad(
    "/Users/josearita-escalante/Documents/GRB-NASA/MCRaT-gits/MCRaT-resolution/CHOMBO/
mcrat_sim5_3.load_frame(2638, read_stokes=False)
observation5_3=pm.MockObservation(1, 4, 1e14, 5, mcratsimload_obj=mcrat_sim5_3)
observation5_3.set_spectral_fit_parameters(spectral_fit_energy_range=[0.01, 40000.0])
spectrum_dict5_3=observation5_3.spectrum(observation5_3.detected_photons.detection_tir
                                         observation5_3.detected_photons.detection_time.ma

mcrat_sim5_2=pm.McratSimLoad(
    "/Users/josearita-escalante/Documents/GRB-NASA/MCRaT-gits/MCRaT-resolution/CHOMBO/
mcrat_sim5_2.load_frame(2638, read_stokes=False)
observation5_2=pm.MockObservation(1, 4, 1e14, 5, mcratsimload_obj=mcrat_sim5_2)
observation5_2.set_spectral_fit_parameters(spectral_fit_energy_range=[0.01, 40000.0])
spectrum_dict5_2=observation5_2.spectrum(observation5_2.detected_photons.detection_tir
                                         observation5_2.detected_photons.detection_time.ma

mcrat_sim5_1=pm.McratSimLoad(
    "/Users/josearita-escalante/Documents/GRB-NASA/MCRaT-gits/MCRaT-resolution/CHOMBO/
mcrat_sim5_1.load_frame(2638, read_stokes=False)
observation5_1=pm.MockObservation(1, 4, 1e14, 5, mcratsimload_obj=mcrat_sim5_1)
observation5_1.set_spectral_fit_parameters(spectral_fit_energy_range=[0.01, 40000.0])
spectrum_dict5_1=observation5_1.spectrum(observation5_1.detected_photons.detection_tir
                                         observation5_1.detected_photons.detection_time.ma
mcrat_sim4_5=pm.McratSimLoad(
    "/Users/josearita-escalante/Documents/GRB-NASA/MCRaT-gits/MCRaT-resolution/CHOMBO/
mcrat_sim4_5.load_frame(1319, read_stokes=False)
observation4_5=pm.MockObservation(1, 4, 1e14, 2.5, mcratsimload_obj=mcrat_sim4_5)
observation4_5.set_spectral_fit_parameters(spectral_fit_energy_range=[0.01, 40000.0])
spectrum_dict4_5=observation4_5.spectrum(observation4_5.detected_photons.detection_tir
                                         observation4_5.detected_photons.detection_time.ma

mcrat_sim4_4=pm.McratSimLoad(
    "/Users/josearita-escalante/Documents/GRB-NASA/MCRaT-gits/MCRaT-resolution/CHOMBO/
mcrat_sim4_4.load_frame(1319, read_stokes=False)
observation4_4=pm.MockObservation(1, 4, 1e14, 2.5, mcratsimload_obj=mcrat_sim4_4)
observation4_4.set_spectral_fit_parameters(spectral_fit_energy_range=[0.01, 40000.0])
spectrum_dict4_4=observation4_4.spectrum(observation4_4.detected_photons.detection_tir
                                         observation4_4.detected_photons.detection_time.ma


mcrat_sim3_5=pm.McratSimLoad("/Users/josearita-escalante/Documents/GRB-NASA/MCRaT-gits
mcrat_sim3_5.load_frame(659, read_stokes=False)
observation3_5=pm.MockObservation(1, 4, 1e14, 1.25, mcratsimload_obj=mcrat_sim3_5)
observation3_5.set_spectral_fit_parameters(spectral_fit_energy_range=[0.01, 40000.0])
spectrum_dict3_5=observation3_5.spectrum(observation3_5.detected_photons.detection_tir
                                         observation3_5.detected_photons.detection_time.ma


mcrat_sim3_3=pm.McratSimLoad("/Users/josearita-escalante/Documents/GRB-NASA/MCRaT-gits
mcrat_sim3_3.load_frame(659, read_stokes=False)
observation3_3=pm.MockObservation(1, 4, 1e14, 1.25, mcratsimload_obj=mcrat_sim3_3)
observation3_3.set_spectral_fit_parameters(spectral_fit_energy_range=[0.01, 40000.0])
spectrum_dict3_3=observation3_3.spectrum(observation3_3.detected_photons.detection_tir
                                         observation3_3.detected_photons.detection_time.ma


mcrat_sim2_5=pm.McratSimLoad("/Users/josearita-escalante/Documents/GRB-NASA/MCRaT-gits
mcrat_sim2_5.load_frame(329, read_stokes=False)
observation2_5=pm.MockObservation(1, 4, 1e14, 0.625, mcratsimload_obj=mcrat_sim2_5)
observation2_5.set_spectral_fit_parameters(spectral_fit_energy_range=[0.01, 40000.0])
spectrum_dict2_5=observation2_5.spectrum(observation2_5.detected_photons.detection_tir
                                         observation2_5.detected_photons.detection_time.ma


mcrat_sim2_2=pm.McratSimLoad("/Users/josearita-escalante/Documents/GRB-NASA/MCRaT-gits
mcrat_sim2_2.load_frame(329, read_stokes=False)
observation2_2=pm.MockObservation(1, 4, 1e14, 0.625, mcratsimload_obj=mcrat_sim2_2)
observation2_2.set_spectral_fit_parameters(spectral_fit_energy_range=[0.01, 40000.0])
spectrum_dict2_2=observation2_2.spectrum(observation2_2.detected_photons.detection_tir
                                         observation2_2.detected_photons.detection_time.ma

mcrat_sim1_5=pm.McratSimLoad("/Users/josearita-escalante/Documents/GRB-NASA/MCRaT-gits
mcrat_sim1_5.load_frame(164, read_stokes=False)
observation1_5=pm.MockObservation(1, 4, 1e14, 0.3125, mcratsimload_obj=mcrat_sim1_5)
observation1_5.set_spectral_fit_parameters(spectral_fit_energy_range=[0.01, 40000.0])
spectrum_dict1_5=observation1_5.spectrum(observation1_5.detected_photons.detection_tir
                                         observation1_5.detected_photons.detection_time.ma

mcrat_sim1_1=pm.McratSimLoad("/Users/josearita-escalante/Documents/GRB-NASA/MCRaT-gits
mcrat_sim1_1.load_frame(164, read_stokes=False)
observation1_1=pm.MockObservation(1, 4, 1e14, 0.3125, mcratsimload_obj=mcrat_sim1_1)
observation1_1.set_spectral_fit_parameters(spectral_fit_energy_range=[0.01, 40000.0])
spectrum_dict1_1=observation1_1.spectrum(observation1_1.detected_photons.detection_tir
                                         observation1_1.detected_photons.detection_time.ma
```

We now sort them on the type of resolution that is changed.

In [3]:
```
spectrum_dict_spatial=[spectrum_dict5_5, spectrum_dict5_4,
                       spectrum_dict5_3, spectrum_dict5_2, spectrum_dict5_1]

spectrum_dict_temporal=[spectrum_dict5_5, spectrum_dict4_5,
                        spectrum_dict3_5, spectrum_dict2_5, spectrum_dict1_5]

spectrum_dict_mixed=[spectrum_dict5_5, spectrum_dict4_4,
                     spectrum_dict3_3, spectrum_dict2_2, spectrum_dict1_1]

fps=['0.3125','0.625','1.25','2.5','5']

levs=[1,2,3,4,5]

mix = ['(1,0.3125)','(2,0.625)','(3,1.25)','(4,2.5)','(5,5)']
```

We now calculate luminosities and and their respective errors.

In [4]:
```
photon_num_min=10

def luminosity(spectrum_dict):
    lum = np.trapz(spectrum_dict['spectrum'][np.where(spectrum_dict['ph_num']>photon_r
    spectrum_dict['energy_bin_center'][np.where(spectrum_dict['ph_num']>photon_num_mir
    return lum

lum_spatial = []

lum_temporal = []

lum_mixed = []

for i in range(1,6):
    lum_spatial.append(luminosity(spectrum_dict_spatial[-i]))

    lum_temporal.append(luminosity(spectrum_dict_temporal[-i]))

    lum_mixed.append(luminosity(spectrum_dict_mixed[-i]))
```

In [5]:
```
idx_spatial = []

idx_temporal = []

idx_mixed = []

for i in range(5):

    idx_spatial.append(np.where(spectrum_dict_spatial[i]['ph_num']>photon_num_min)[0])

    idx_temporal.append(np.where(spectrum_dict_temporal[i]['ph_num']>photon_num_min)[(

    idx_mixed.append(np.where(spectrum_dict_mixed[i]['ph_num']>photon_num_min)[0])
```

In [6]:
```
lum_err_spatial=[]

lum_err_temporal=[]

lum_err_mixed=[]

for i in range(5):

    alpha_spatial = []

    alpha_temporal = []

    alpha_mixed = []

    spec_err_spatial = spectrum_dict_spatial[i]['spectrum_errors'][idx_spatial[i]]

    spec_err_temporal = spectrum_dict_temporal[i]['spectrum_errors'][idx_temporal[i]]

    spec_err_mixed = spectrum_dict_mixed[i]['spectrum_errors'][idx_mixed[i]]

    for j in range(len(spectrum_dict_spatial[i]['energy_bin_center'][idx_spatial[i]])-
        alpha_spatial.append((spectrum_dict_spatial[i]['energy_bin_center'][idx_spatia
                  spectrum_dict_spatial[i]['energy_bin_center'][idx_spatial[i]][j])/2)

    for j in range(len(spectrum_dict_temporal[i]['energy_bin_center'][idx_temporal[i]]
        alpha_temporal.append((spectrum_dict_temporal[i]['energy_bin_center'][idx_temp
                  spectrum_dict_temporal[i]['energy_bin_center'][idx_temporal[i]][j])/

    for j in range(len(spectrum_dict_mixed[i]['energy_bin_center'][idx_mixed[i]])-1):
        alpha_mixed.append((spectrum_dict_mixed[i]['energy_bin_center'][idx_mixed[i]]
                  spectrum_dict_mixed[i]['energy_bin_center'][idx_mixed[i]][j])/2)

    lum_err_n_spatial = []

    lum_err_n_temporal = []

    lum_err_n_mixed = []

    for k in range(len(alpha_spatial)):
        lum_err_n_spatial.append(((alpha_spatial[k]**2)*(spec_err_spatial[k]**2+spec_e

    for k in range(len(alpha_temporal)):
        lum_err_n_temporal.append(((alpha_temporal[k]**2)*(spec_err_temporal[k]**2+spe

    for k in range(len(alpha_mixed)):
        lum_err_n_mixed.append(((alpha_mixed[k]**2)*(spec_err_mixed[k]**2+spec_err_mi

    lum_n_spatial=0

    lum_n_temporal=0

    lum_n_mixed=0

    for i in lum_err_n_spatial:
        lum_n_spatial+=i

    for i in lum_err_n_temporal:
        lum_n_temporal+=i

    for i in lum_err_n_mixed:
        lum_n_mixed+=i

    lum_err_spatial.append(np.sqrt(lum_n_spatial))

    lum_err_temporal.append(np.sqrt(lum_n_temporal))

    lum_err_mixed.append(np.sqrt(lum_n_mixed))

lum_err_spatial.reverse()

lum_err_temporal.reverse()

lum_err_mixed.reverse()
```

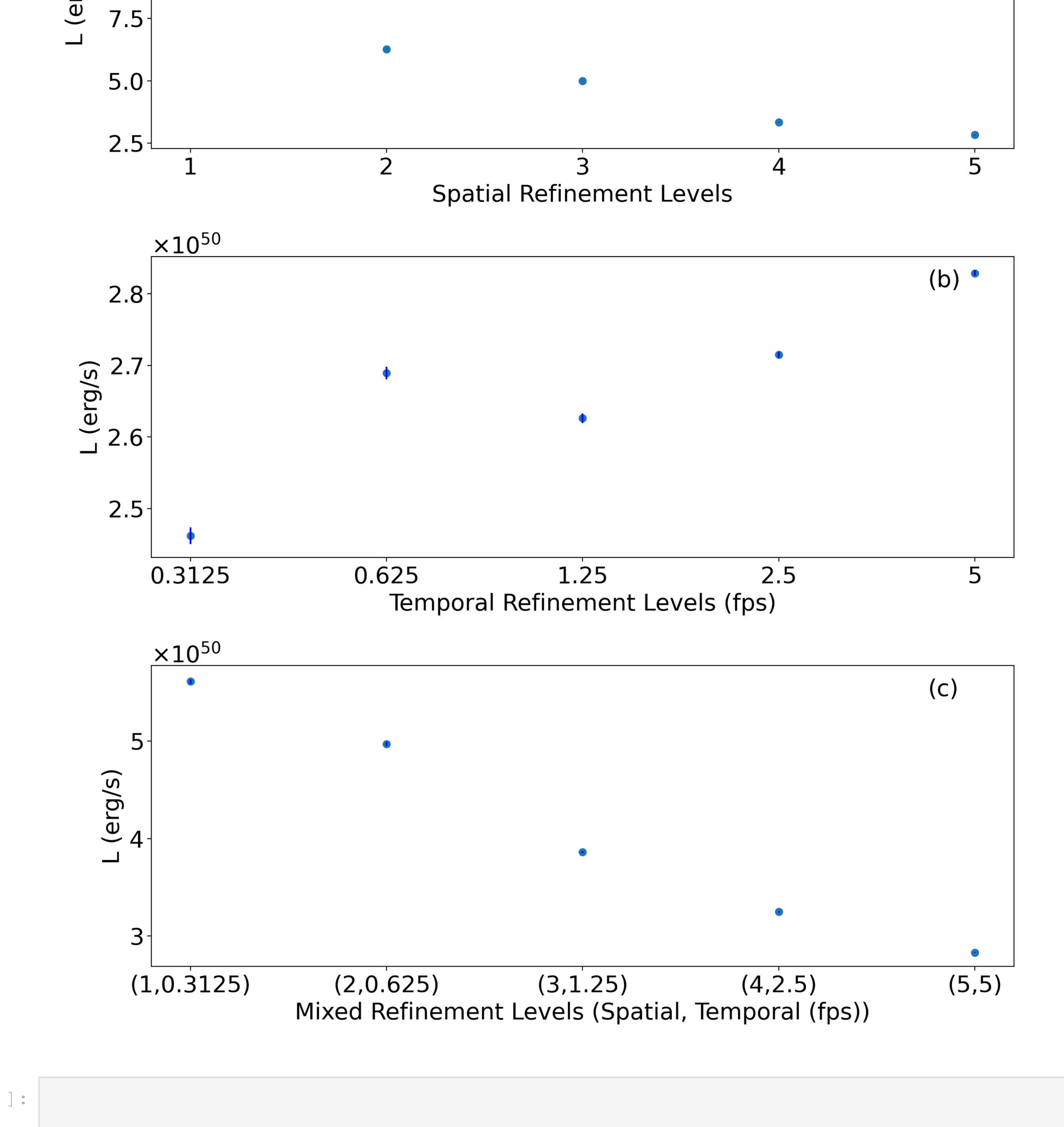
In [7]:
```
print(lum_spatial)
print(lum_temporal)
print(lum_mixed)

print(lum_err_spatial)
print(lum_err_temporal)
print(lum_err_mixed)
```

```
[<Quantity 1.37797801e+51 erg / s>, <Quantity 6.27357143e+50 erg / s>, <Quantity 4.992
59259e+50 erg / s>, <Quantity 3.33385028e+50 erg / s>, <Quantity 2.82892976e+50 erg /
s>]
[<Quantity 2.46218207e+50 erg / s>, <Quantity 2.68939577e+50 erg / s>, <Quantity 2.626
17094e+50 erg / s>, <Quantity 2.71502512e+50 erg / s>, <Quantity 2.82892976e+50 erg /
s>]
[<Quantity 5.61176557e+50 erg / s>, <Quantity 4.97049663e+50 erg / s>, <Quantity 3.859
51769e+50 erg / s>, <Quantity 3.24587811e+50 erg / s>, <Quantity 2.82892976e+50 erg /
s>]
[<Quantity 1.74679675e+48 erg / s>, <Quantity 7.34328396e+47 erg / s>, <Quantity 5.966
10198e+47 erg / s>, <Quantity 4.54527034e+47 erg / s>, <Quantity 3.92742765e+47 erg /
s>]
[<Quantity 1.1664939e+48 erg / s>, <Quantity 8.61404766e+47 erg / s>, <Quantity 6.4988
3383e+47 erg / s>, <Quantity 3.94120008e+47 erg / s>, <Quantity 3.92742765e+47 erg / s
>]
[<Quantity 2.37380378e+48 erg / s>, <Quantity 2.04010158e+48 erg / s>, <Quantity 1.165
37856e+48 erg / s>, <Quantity 5.08046569e+47 erg / s>, <Quantity 3.92742765e+47 erg /
s>]
```

In [8]:
```
lumi_spatial = [ 1.37797801e+51 ,  6.27357143e+50 ,
                4.99259259e+50 ,  3.33385028e+50 ,  2.82892976e+50 ]

lumi_temporal = [ 2.46218207e+50 ,  2.68939577e+50 ,
                 2.62617094e+50 ,  2.71502512e+50 ,  2.82892976e+50 ]

lumi_mixed = [ 5.61176557e+50 ,  4.97049663e+50 ,
              3.85951769e+50 ,  3.24587811e+50 ,  2.82892976e+50 ]

lumi_err_spatial = [ 1.74679675e+48 ,  7.34328396e+47 ,
                    5.96610198e+47 ,  4.54527034e+47 ,  3.92742765e+47 ]

lumi_err_temporal = [ 1.1664939e+48 ,  8.61404766e+47 ,
                     6.49883383e+47 ,  3.94120008e+47 ,  3.92742765e+47 ]

lumi_err_mixed = [ 2.37380378e+48 ,  2.04010158e+48 ,
                  1.16537856e+48 ,  5.08046569e+47 ,  3.92742765e+47 ]
```

We now plot these quantities for each type of resolution.

In [9]:
```
plt.rcParams.update({'font.size': 20})

label_size = 20
mpl.rcParams['ytick.labelsize'] = label_size


f, axarr = plt.subplots(3, sharex=False, sharey=False)
axarr_spex = axarr

f.set_figwidth(12)
f.set_figheight(15)

formatter = mpl.ticker.ScalarFormatter(useMathText=True)
formatter.set_scientific(True)
formatter.set_powerlimits((0, 1))

axarr_spex[0].yaxis.set_major_formatter(formatter)

axarr_spex[1].yaxis.set_major_formatter(formatter)

axarr_spex[2].yaxis.set_major_formatter(formatter)

axarr_spex[0].scatter(levs,lumi_spatial)

axarr_spex[0].errorbar(levs,lumi_spatial, lumi_err_spatial,
  fmt='none', barsabove=True, ecolor='blue')

axarr_spex[0].set_xticks(range(1,6))

axarr_spex[0].set_ylabel(r'L (erg/s)')

axarr_spex[0].set_xlabel("Spatial Refinement Levels")

axarr_spex[1].scatter(fps,lumi_temporal)

axarr_spex[1].errorbar(fps,lumi_temporal, lumi_err_temporal,
  fmt='none', barsabove=True, ecolor='blue')

axarr_spex[1].set_ylabel(r'L (erg/s)')

axarr_spex[1].set_xlabel("Temporal Refinement Levels (fps)")

axarr_spex[2].scatter(mix,lumi_mixed)

axarr_spex[2].errorbar(mix,lumi_mixed, lumi_err_mixed,
  fmt='none', barsabove=True, ecolor='blue')

axarr_spex[2].set_ylabel(r'L (erg/s)')

axarr_spex[2].set_xlabel("Mixed Refinement Levels (Spatial, Temporal (fps))")

#plt.yscale('log')
axarr_spex[0].annotate('(a)',xy=(0.9, 0.9), xycoords="axes fraction")

axarr_spex[1].annotate('(b)',xy=(0.9, 0.9), xycoords="axes fraction")

axarr_spex[2].annotate('(c)',xy=(0.9, 0.9), xycoords="axes fraction")

plt.tight_layout()
#plt.savefig('lum_spherical.pdf',dpi=600, bbox_inches='tight')
plt.show()
```



In [ ]: