In [1]:
```
import numpy as np
import os
from astropy.io import fits
from astropy import units as u
from astropy.modeling.polynomial import Polynomial1D
from astropy.modeling.models import Gaussian1D, Linear1D
from astropy.modeling.fitting import LinearLSQFitter
from IPython.display import Image
# astroquery provides an interface to the NIST atomic line database
from astroquery.nist import Nist
from IPython.display import Image
import glob
```

In [2]:
```
from PIL import Image
import numpy as np
import pylab as pl
pl.style.use('dark_background')
```

Dark subtract, do the tracing, then use star or jupiter traces to extract spectra from other images, fit line solution, measure spectral features

Load in Files

In [3]:
```
scatteredsun_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct
scatteredsun1_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oc
scatteredsun2_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oc
scatteredsun3_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oc

scatteredsun_30s_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\

dark_5m_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th20

dark_30s1_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th
dark_30s2_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th
dark_30s3_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th

dark_60s1_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th
dark_60s2_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th
dark_60s3_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th

alb_a_30s1_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5t
alb_a_30s2_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5t
alb_a_30s3_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5t
alb_a_30s4_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5t
alb_a_30s5_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5t

alb_a_60s1_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5t
alb_a_60s2_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5t
alb_a_60s3_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5t

alb_b_60s1_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5t
alb_b_60s2_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5t
alb_b_60s3_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5t

alb_b_300s_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5t

altair_30s1_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5
altair_30s2_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5
altair_30s3_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5
altair_30s4_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5
altair_30s5_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5

europa_30s1_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5
europa_30s2_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5
europa_30s3_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5

he_20s_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th202
he_20s_1_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th2

io_10s1_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th20
io_10s2_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th20
io_10s3_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th20

io_30s1_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th20
io_30s2_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th20
io_30s3_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th20

jupiter_10s1_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct
jupiter_10s2_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct
```

```
jupiter_10s3_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct

ne_20s_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th202

ne_30s1_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th20
ne_30s2_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th20
ne_30s3_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th20

ring_5m1_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th2
ring_5m2_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th2
ring_5m3_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th2
ring_5m4_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th2

vega_30s1_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th
vega_30s2_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th
vega_30s3_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th
vega_30s4_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th
vega_30s5_filename = "\\Users\\Sydnee O'Donnell\\OneDrive\\UF\\Obs Tech 2\\Oct5th
```

In [4]:
```
flat_1min_image_data =  (np.mean([fits.getdata(x) for x in glob.glob("\\Users\\Sy
                        axis=0)
              - np.mean([fits.getdata(x)
                         for x in glob.glob("\\Users\\Sydnee O'Donnell\\OneDrive\
                        axis=0)
             )


alb_a_30s_image_data =  (np.mean([fits.getdata(x) for x in glob.glob("\\Users\\Sy
                        axis=0)
              - np.mean([fits.getdata(x)
                         for x in glob.glob("\\Users\\Sydnee O'Donnell\\OneDrive\
                        axis=0)
             )

alb_a_60s_image_data =  (np.mean([fits.getdata(x) for x in glob.glob("\\Users\\Sy
                        axis=0)
              - np.mean([fits.getdata(x)
                         for x in glob.glob("\\Users\\Sydnee O'Donnell\\OneDrive\
                        axis=0)
             )

alb_b_60s_image_data =  (np.mean([fits.getdata(x) for x in glob.glob("\\Users\\Sy
                        axis=0)
              - np.mean([fits.getdata(x)
                         for x in glob.glob("\\Users\\Sydnee O'Donnell\\OneDrive\
                        axis=0)
             )

alb_b_300s_image_data =  (np.mean([fits.getdata(x) for x in glob.glob("\\Users\\S
                        axis=0)
              - np.mean([fits.getdata(x)
                         for x in glob.glob("\\Users\\Sydnee O'Donnell\\OneDrive\
                        axis=0)
             )

altair_30s_image_data =  (np.mean([fits.getdata(x) for x in glob.glob("\\Users\\S
                        axis=0)
              - np.mean([fits.getdata(x)
                         for x in glob.glob("\\Users\\Sydnee O'Donnell\\OneDrive\
                        axis=0)
             )

europa_30s_image_data =  (np.mean([fits.getdata(x) for x in glob.glob("\\Users\\S
                        axis=0)
              - np.mean([fits.getdata(x)
                         for x in glob.glob("\\Users\\Sydnee O'Donnell\\OneDrive\
                        axis=0)
             )

## don't have darks for these so using 30 s - if hot pixles are sensitive then th
he_20s_image_data =  (np.mean([fits.getdata(x) for x in glob.glob("\\Users\\Sydne
                        axis=0)
              - np.mean([fits.getdata(x)
                         for x in glob.glob("\\Users\\Sydnee O'Donnell\\OneDrive\
                        axis=0)
```

```
            )

## don't have darks for these so using 30 s - if hot pixles are sensitive then th
io_10s_image_data =  (np.mean([fits.getdata(x) for x in glob.glob("\\Users\\Sydne
                      axis=0)
             - np.mean([fits.getdata(x)
                        for x in glob.glob("\\Users\\Sydnee O'Donnell\\OneDrive\
                       axis=0)
            )

io_30s_image_data =  (np.mean([fits.getdata(x) for x in glob.glob("\\Users\\Sydne
                      axis=0)
             - np.mean([fits.getdata(x)
                        for x in glob.glob("\\Users\\Sydnee O'Donnell\\OneDrive\
                       axis=0)
            )

## don't have darks for these so using 30 s - if hot pixles are sensitive then th
jupiter_10s_image_data =  (np.mean([fits.getdata(x) for x in glob.glob("\\Users\\
                      axis=0)
             - np.mean([fits.getdata(x)
                        for x in glob.glob("\\Users\\Sydnee O'Donnell\\OneDrive\
                       axis=0)
            )

## don't have darks for these so using 30 s - if hot pixles are sensitive then th
ne_20s_image_data =  (np.mean([fits.getdata(x) for x in glob.glob("\\Users\\Sydne
                      axis=0)
             - np.mean([fits.getdata(x)
                        for x in glob.glob("\\Users\\Sydnee O'Donnell\\OneDrive\
                       axis=0)
            )

ne_30s_image_data =  (np.mean([fits.getdata(x) for x in glob.glob("\\Users\\Sydne
                      axis=0)
             - np.mean([fits.getdata(x)
                        for x in glob.glob("\\Users\\Sydnee O'Donnell\\OneDrive\
                       axis=0)
            )


ring_5m_image_data =  (np.mean([fits.getdata(x) for x in glob.glob("\\Users\\Sydr
                      axis=0)
             - np.mean([fits.getdata(x)
                        for x in glob.glob("\\Users\\Sydnee O'Donnell\\OneDrive\
                       axis=0)
            )

vega_30s_image_data =  (np.mean([fits.getdata(x) for x in glob.glob("\\Users\\Syd
                      axis=0)
             - np.mean([fits.getdata(x)
                        for x in glob.glob("\\Users\\Sydnee O'Donnell\\OneDrive\
                       axis=0)
            )
```

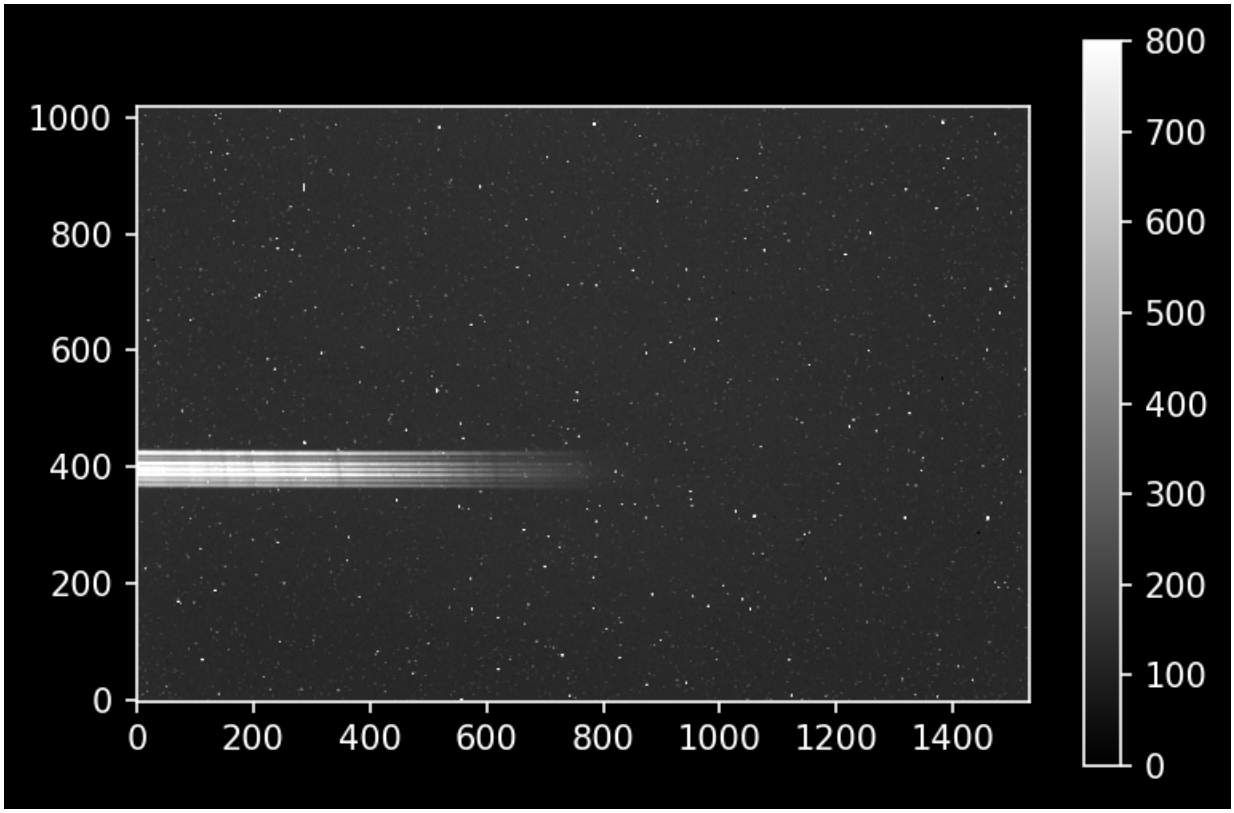
```
C:\ProgramData\Anaconda3\lib\site-packages\numpy\core\fromnumeric.py:3372: Ru
```

```
ntimeWarning: Mean of empty slice.
  return _methods._mean(a, axis=axis, dtype=dtype,
C:\ProgramData\Anaconda3\lib\site-packages\numpy\core\_methods.py:170: Runtim
eWarning: invalid value encountered in double_scalars
  ret = ret.dtype.type(ret / rcount)
```

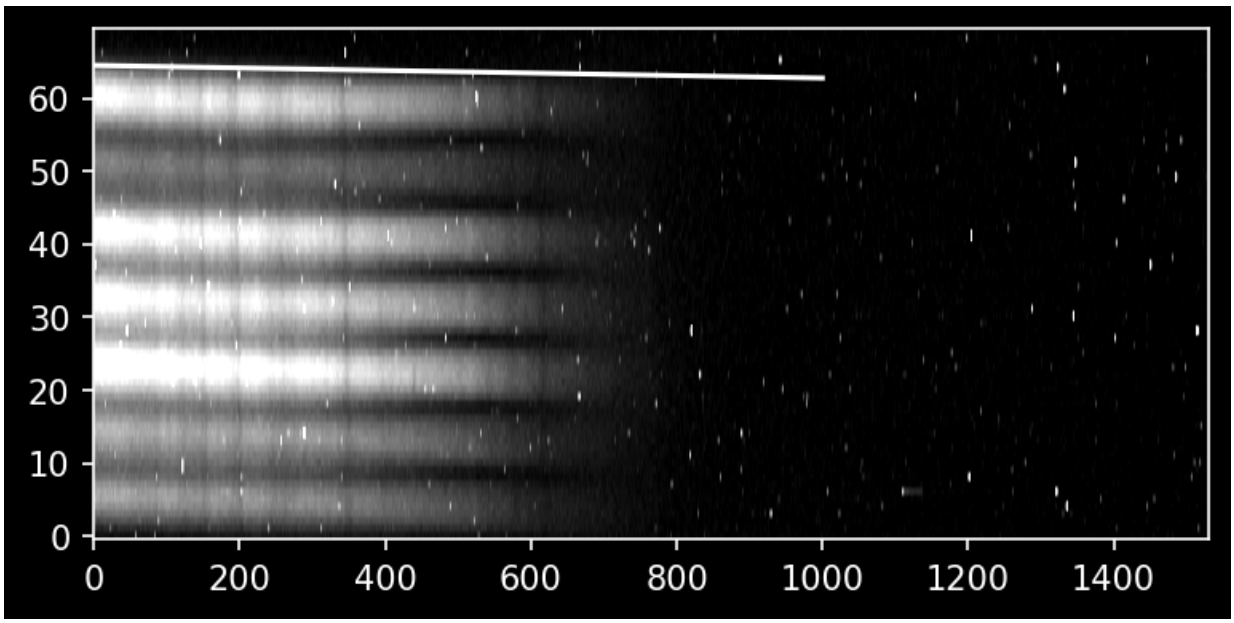
Flats & getting a trace

In [5]:
```
%matplotlib inline
import pylab as pl
pl.rcParams['image.origin'] = 'lower'
pl.rcParams['figure.dpi'] = 150
pl.matplotlib.style.use('dark_background') # Optional!
pl.imshow(flat_1min_image_data, cmap='gray', vmax=0, vmin=800)
pl.colorbar()
```

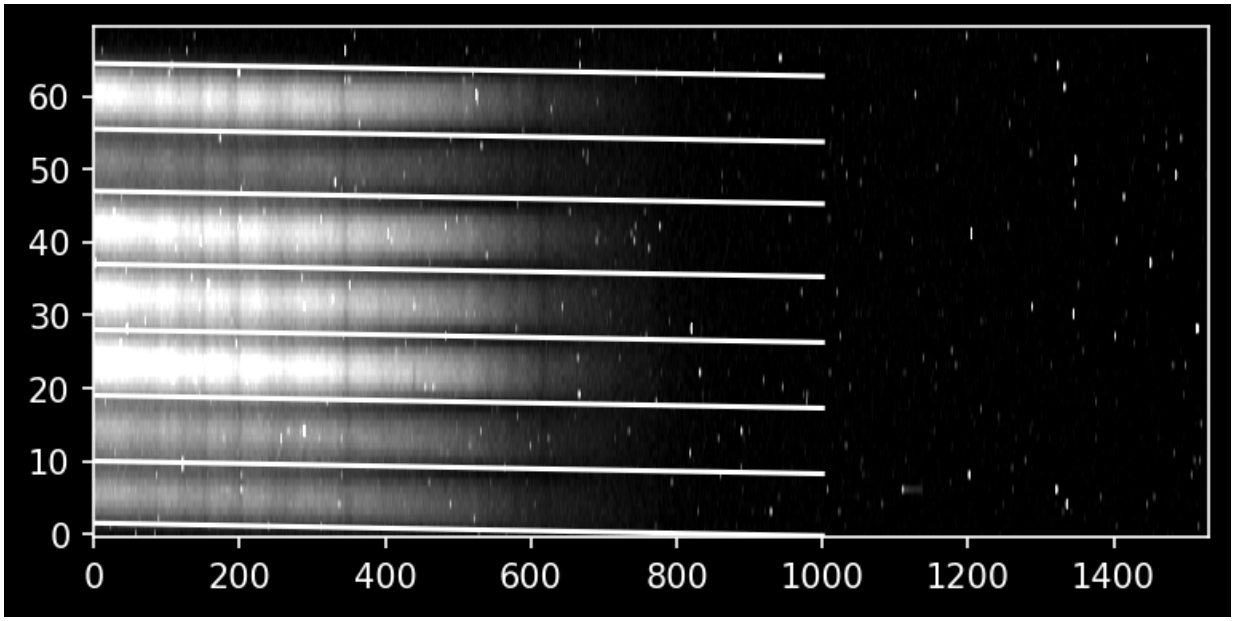
Out[5]:
```
<matplotlib.colorbar.Colorbar at 0x1f69e0fc4c0>
```



In [6]:
```
dy = -1.5
dx = 860
slope = dy/dx

ystart = 365
yend = 435

flat_array = np.array(flat_1min_image_data)
flat_array = flat_array - np.median(flat_1min_image_data)
pl.imshow(flat_array[ystart:yend,:], cmap='gray', vmax=800, vmin=0)
pl.plot([0,1000], 64.5 + np.array([0,1000]) * slope, color='w')
pl.gca().set_aspect(10)
```



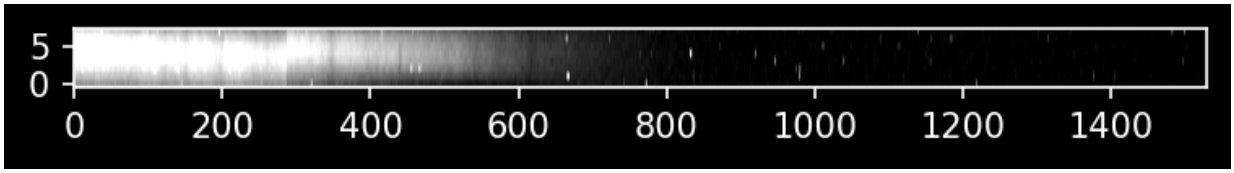
In [7]:
```
intertrace_cuts = np.array([1.5, 10, 19, 28, 37, 47, 55.5, 64.5])
flat_array = np.array(flat_1min_image_data)
flat_array = flat_array - np.median(flat_array)
pl.imshow(flat_array[ystart:yend,:], cmap='gray', vmax=800, vmin=0)
pl.plot([0,1000], intertrace_cuts + np.array([0,1000])[:,None] * slope, color='w'
pl.gca().set_aspect(10)
```



In [8]:
```
npixels_to_cut = 4 # very conservative - we'll see why below
xvals = np.arange(flat_array.shape[1])
trace_center = ystart+(intertrace_cuts[2] + intertrace_cuts[3])/2 + xvals * slope
cutout_trace = np.array([flat_array[int(yval)-npixels_to_cut:int(yval)+npixels_to
                         for yval, ii in zip(trace_center, xvals)]).T
cutout_trace.shape
```

Out[8]: (8, 1530)

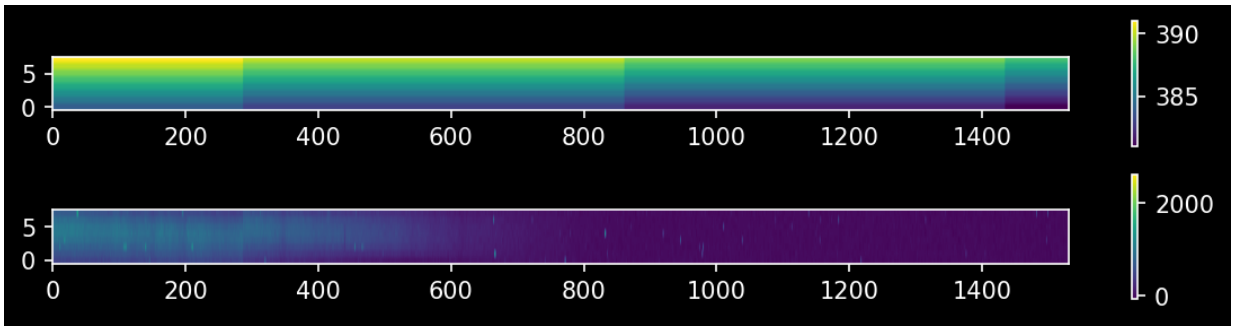
In [9]:
```
pl.imshow(cutout_trace, cmap='gray', vmax=800, vmin=0)
pl.gca().set_aspect(10);
```



moment analysis

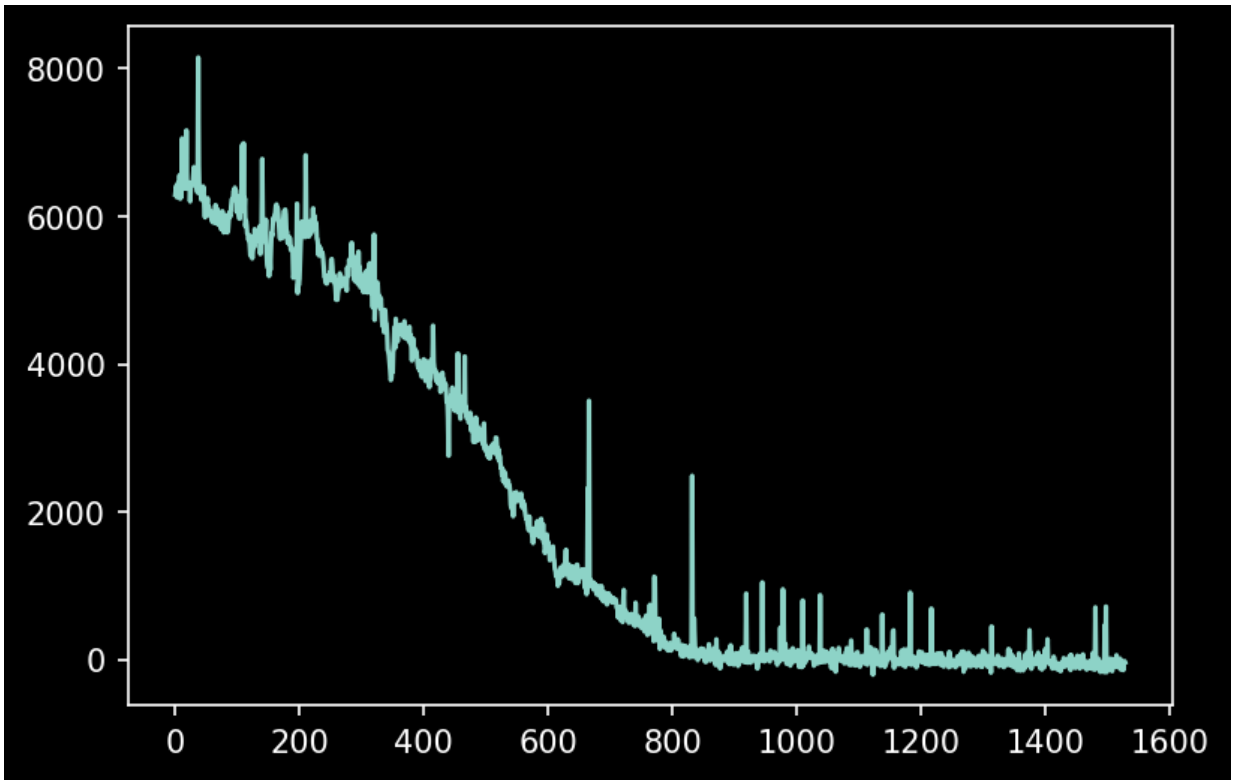
In [10]:
```
# to get the y-axis values corresponding to each part of our cutout trace, we do
yaxis_full = np.arange(flat_array.shape[0])
yaxis = np.array([yaxis_full[int(yval)-npixels_to_cut:int(yval)+npixels_to_cut]
                  for yval, ii in zip(trace_center, xvals)]).T
```

In [11]:
```
pl.figure(figsize=(8,2))
im = pl.subplot(2,1,1).imshow(yaxis)
pl.colorbar(mappable=im)
pl.gca().set_aspect(10);
im = pl.subplot(2,1,2).imshow(cutout_trace)
pl.colorbar(mappable=im)
pl.gca().set_aspect(10);
pl.tight_layout();
```



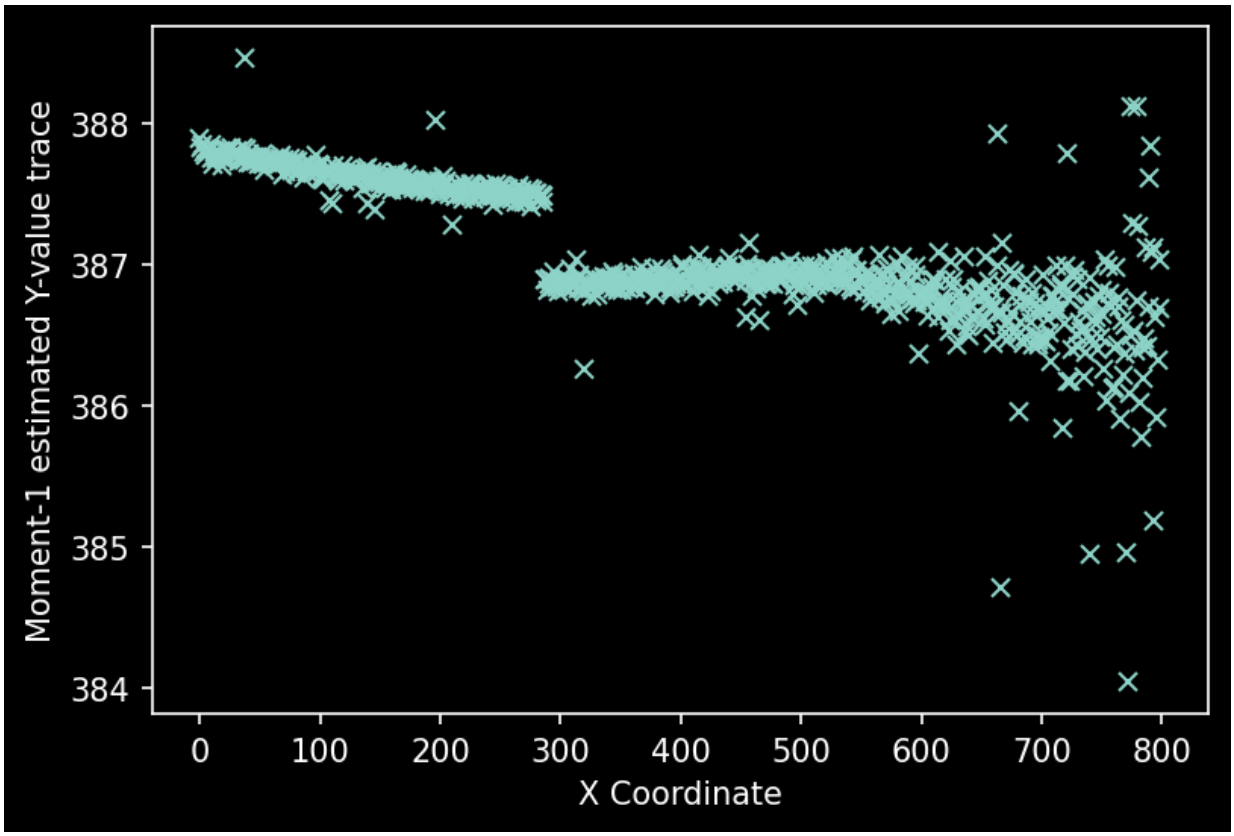
In [12]:
```
pl.plot(cutout_trace.sum(axis=0))
```

Out[12]:
```
[<matplotlib.lines.Line2D at 0x1f69e18ce50>]
```

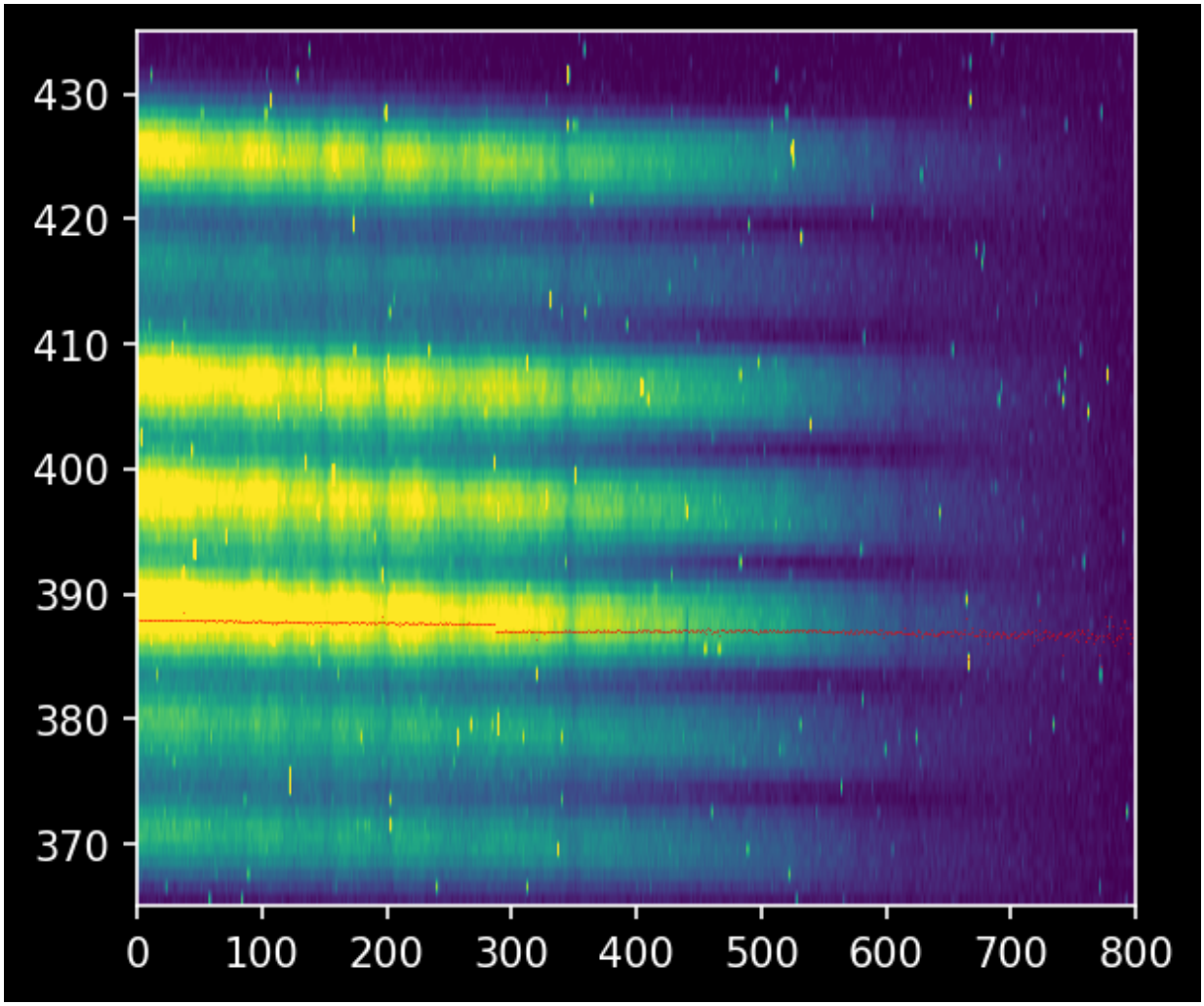


In [13]:
```
# moment 1 is the data-weighted average of the Y-axis coordinates
xend = 800
weighted_yaxis_values = np.average(yaxis[:,:xend], axis=0,
                                   weights=cutout_trace[:,:xend])
```

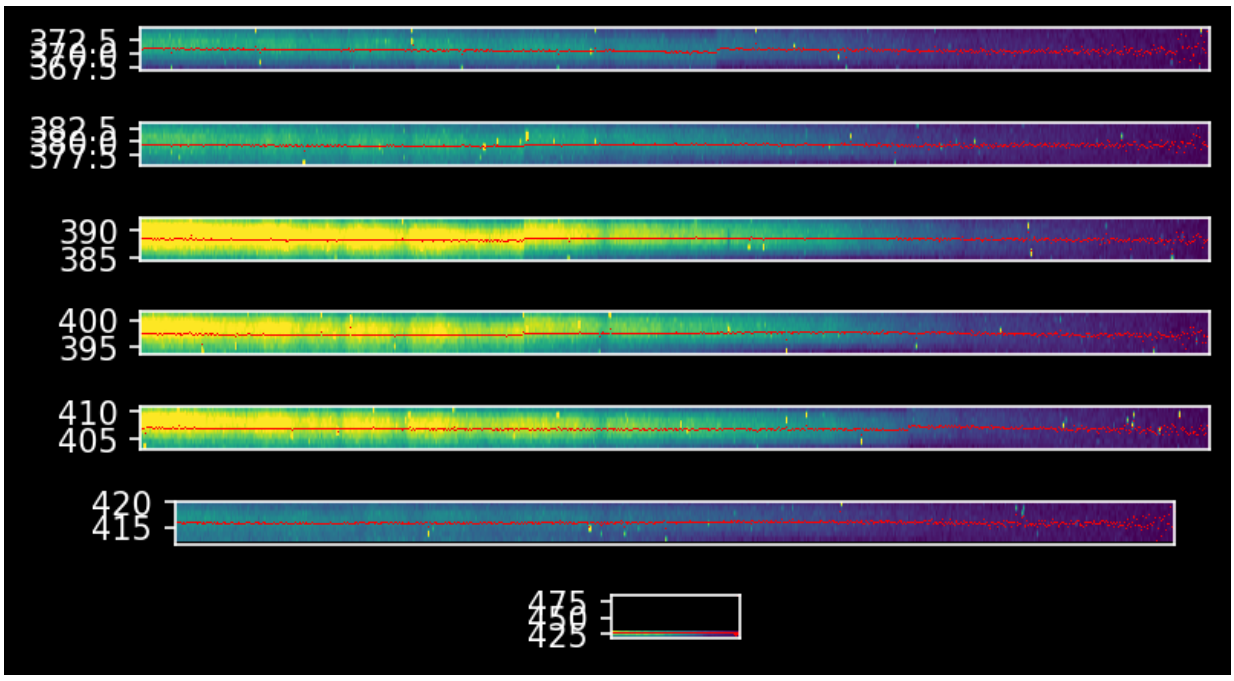
In [14]:
```
_=pl.plot(xvals[:xend], weighted_yaxis_values, 'x')
_=pl.xlabel("X Coordinate")
_=pl.ylabel("Moment-1 estimated Y-value trace")
```



In [15]:
```
# we need to use the 'extent' keyword to have the axes correctly labeled
_=pl.imshow(flat_array[ystart:yend, :xend],
            extent=[0,xend,ystart,yend], vmax=800, vmin=0)
_=pl.gca().set_aspect(10) # we stretch the image out by 10x in the y-direction
_=pl.plot(xvals[:xend], weighted_yaxis_values[:xend], 'r,', alpha=0.5)
_=pl.axis((0,xend,ystart,yend))
```

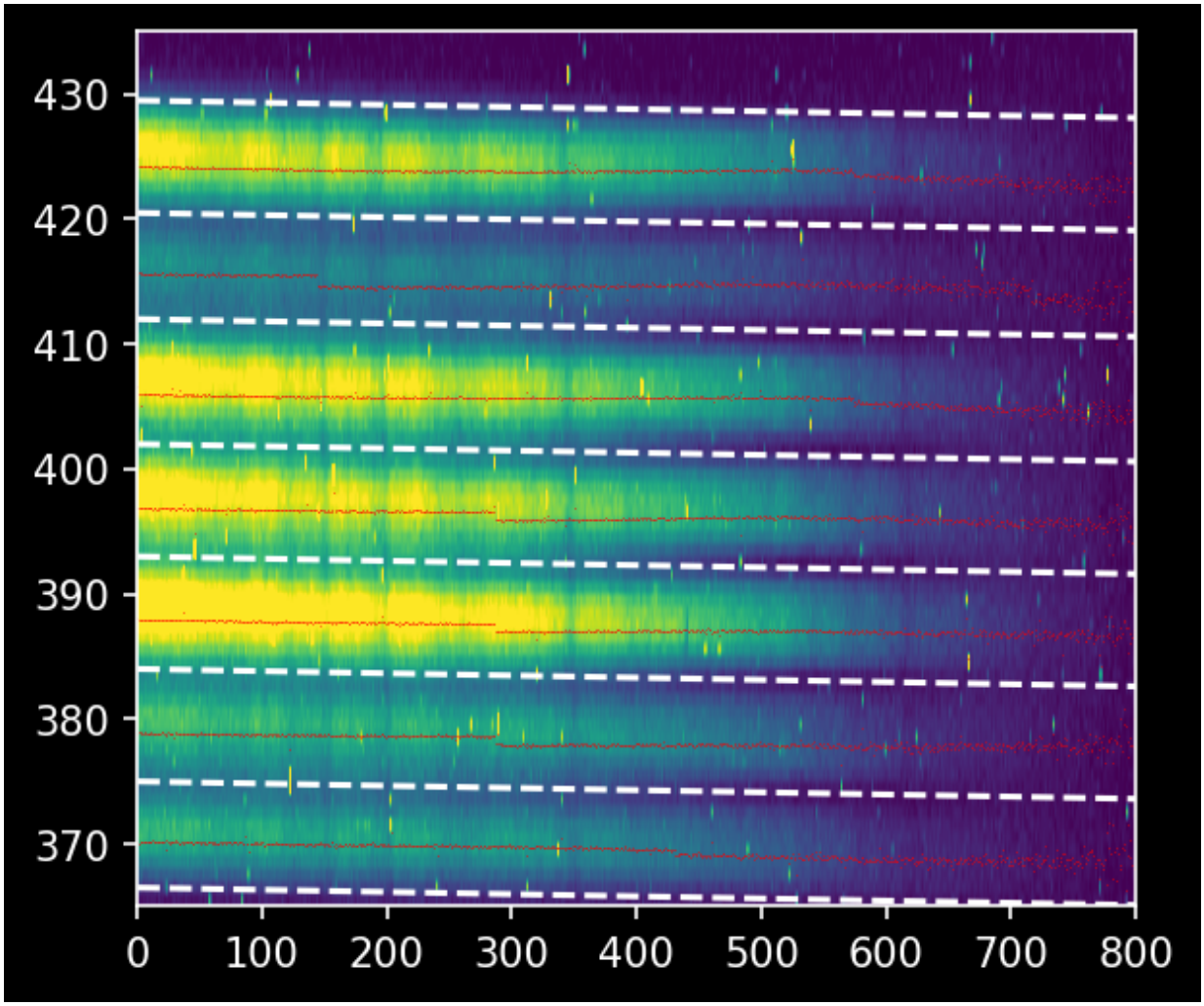


In [16]:
```
pl.figure(figsize=(8,3))
traces = {}
for trace_index in range(len(intertrace_cuts)-1):
    yoffset = ystart + (intertrace_cuts[trace_index] + intertrace_cuts[trace_inde
    trace_center = yoffset + slope * xvals

    cutout_trace = np.array([flat_array[int(yval)-npixels_to_cut:int(yval)+npixel
                         for yval, ii in zip(trace_center, xvals)]).T
    yaxis = np.array([yaxis_full[int(yval)-npixels_to_cut:int(yval)+npixels_to_cu
                      for yval, ii in zip(trace_center, xvals)]).T
    weighted_yaxis_values = np.average(yaxis[:,:xend], axis=0,
                                       weights=cutout_trace[:,:xend])

    # it takes a little mental gymnastics to get to this, but: to show the trace
    # we need to calculate the local version
    local_weighted_yaxis_values = np.average(np.arange(npixels_to_cut*2)[:,None]
                                             axis=0, weights=cutout_trace[:,:xend

    traces[trace_index] = weighted_yaxis_values
    ax = pl.subplot(7, 1, trace_index+1)
    ax.imshow(cutout_trace[:,:xend], extent=[0, xend, yoffset-npixels_to_cut, yof
    ax.plot(xvals[:xend], yoffset - npixels_to_cut + local_weighted_yaxis_values[
    ax.set_aspect(4)
    ax.set_xticks([])
pl.tight_layout()
```



In [17]:
```
# then we can plot the "global" version here
pl.imshow(flat_array[ystart:yend, :xend],
          extent=[0,xend,ystart,yend], vmax=800, vmin=0)
pl.plot([0,xend], ystart + intertrace_cuts + np.array([0,xend])[:,None] * slope,
pl.gca().set_aspect(10)
for trace in traces.values():
    pl.plot(xvals[:xend], trace[:xend], 'r,', alpha=0.5)
pl.axis((0,xend,ystart,yend))
```

Out[17]: (0.0, 800.0, 365.0, 435.0)



Fitting Trace Profile

In [18]:
```
from astropy.modeling.polynomial import Polynomial1D
from astropy.modeling.fitting import LinearLSQFitter
```

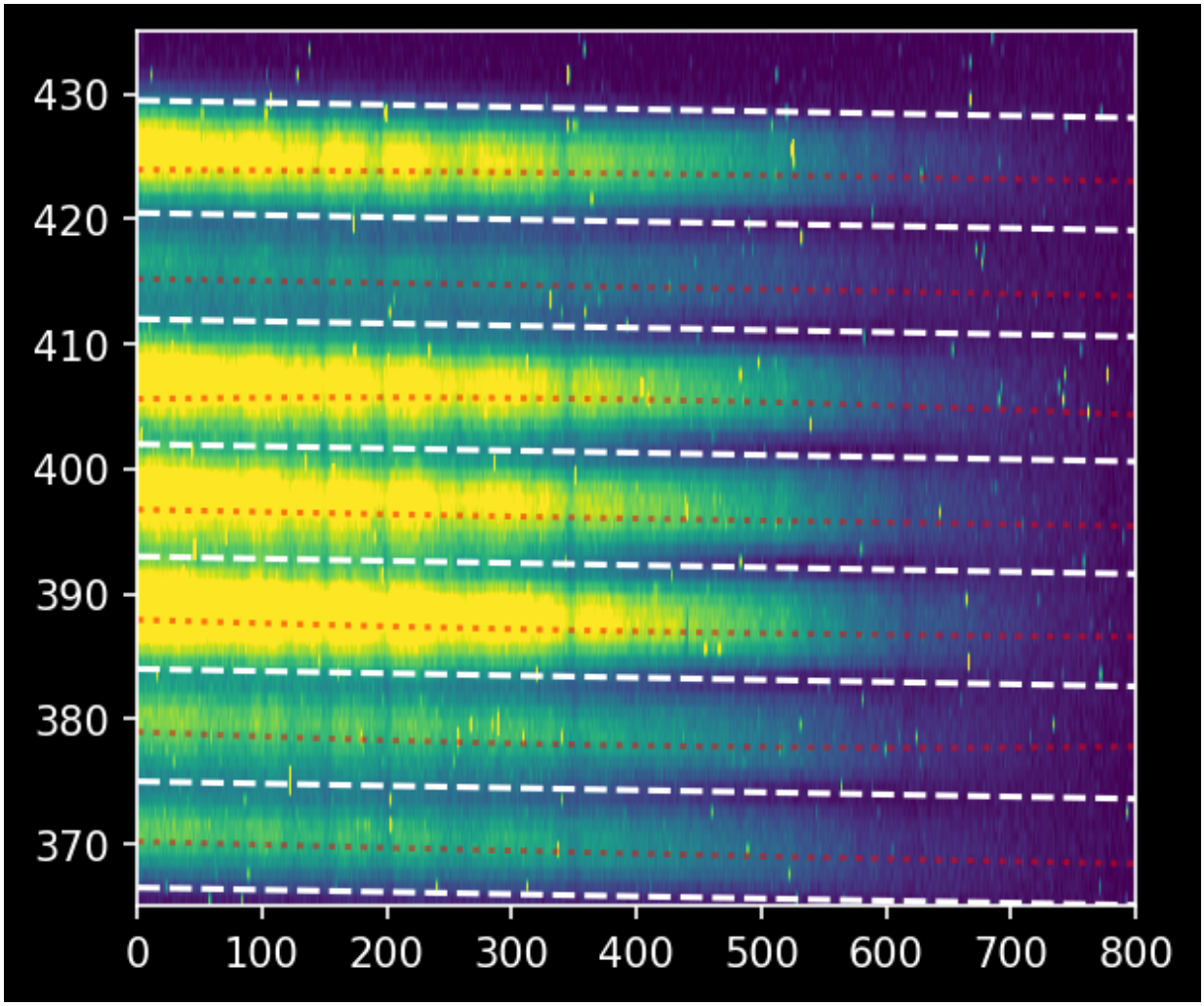
In [19]:
```
# We fit a 2rd-order polynomial
polymodel = Polynomial1D(degree=2)
linfitter = LinearLSQFitter()
fitted_polymodels = {index: linfitter(polymodel, xvals[:xend], weighted_yaxis_val
                     for index, weighted_yaxis_values in traces.items()}
```

In [20]:
```
fitted_polymodels
```

Out[20]:
```
{0: <Polynomial1D(2, c0=370.18767438, c1=-0.00258129, c2=0.00000046)>,
 1: <Polynomial1D(2, c0=378.97155598, c1=-0.00406682, c2=0.00000325)>,
 2: <Polynomial1D(2, c0=387.93470384, c1=-0.00293566, c2=0.00000156)>,
 3: <Polynomial1D(2, c0=396.75953049, c1=-0.00196855, c2=0.00000041)>,
 4: <Polynomial1D(2, c0=405.60972145, c1=0.00136373, c2=-0.0000037)>,
 5: <Polynomial1D(2, c0=415.22937824, c1=-0.00160604, c2=-0.00000013)>,
 6: <Polynomial1D(2, c0=423.96529981, c1=-0.00042539, c2=-0.00000094)>}
```

In [21]:
```
pl.imshow(flat_array[ystart:yend, :xend],
          extent=[0,xend,ystart,yend],
          vmin=0, vmax=700,
         )
pl.plot([0,xend], ystart + intertrace_cuts + np.array([0,xend])[:,None] * slope,
pl.gca().set_aspect(10)
for tracefit in fitted_polymodels.values():
    pl.plot(xvals[:xend], tracefit(xvals[:xend]), 'r:', alpha=0.5)
pl.axis((0,xend,ystart,yend))
```

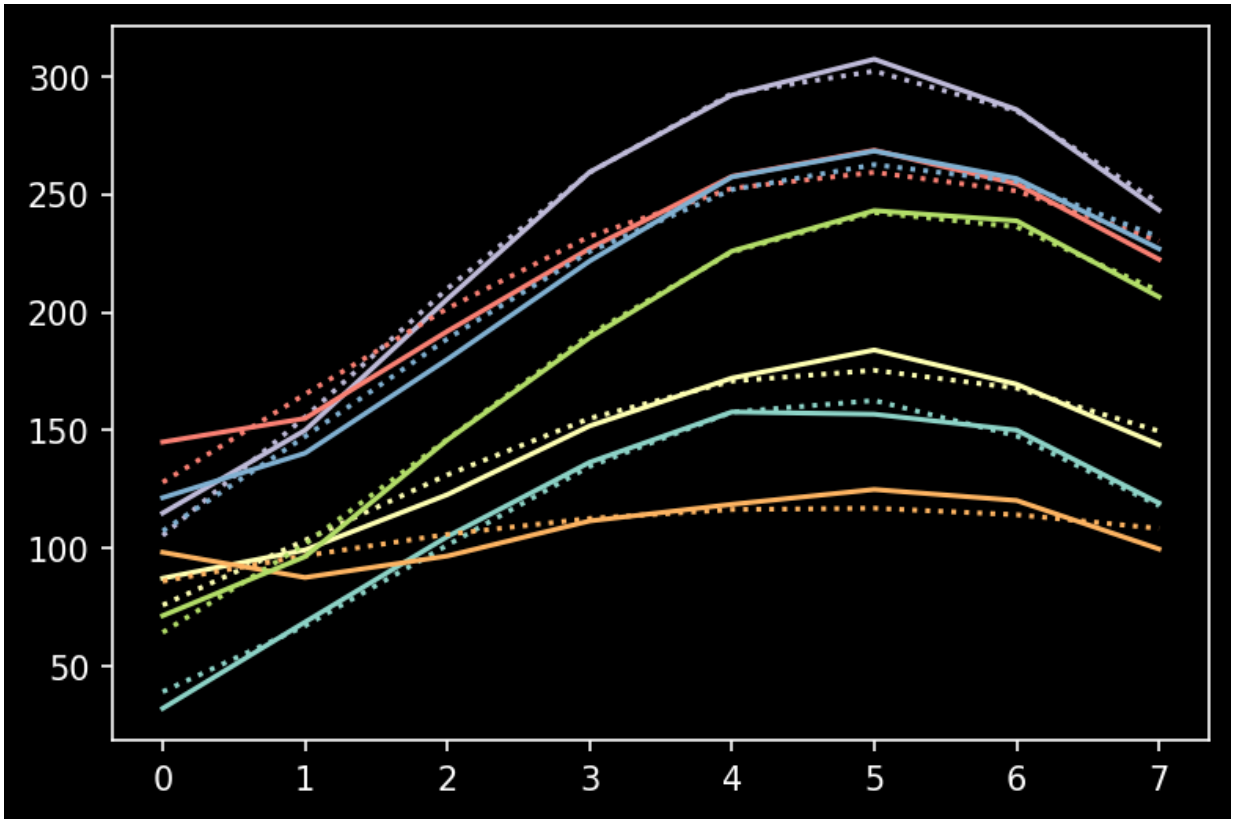
Out[21]: (0.0, 800.0, 365.0, 435.0)



obtain trace profile

In [22]:
```
from astropy.modeling.models import Gaussian1D
from astropy.modeling.fitting import LevMarLSQFitter
lmfitter = LevMarLSQFitter()
guess = Gaussian1D(amplitude=160, mean=0, stddev=5)
```

In [23]:
```
npixels_to_cut_trace = 4

for trace_index, polymodel_trace in fitted_polymodels.items():
    trace_center = polymodel_trace(xvals)

    cutout_trace = np.array([flat_array[int(yval)-npixels_to_cut_trace:int(yval)+
                         for yval, ii in zip(trace_center, xvals)]).T

    trace_profile = cutout_trace.mean(axis=1)
    trace_profile_xaxis = np.arange(len(trace_profile))
    fitted_trace_profile = lmfitter(model=guess, x=trace_profile_xaxis, y=trace_p
    model_trace_profile = fitted_trace_profile(trace_profile_xaxis)

    line, = pl.plot(trace_profile, label=trace_index)
    pl.plot(trace_profile_xaxis, model_trace_profile, color=line.get_color(), lin
```

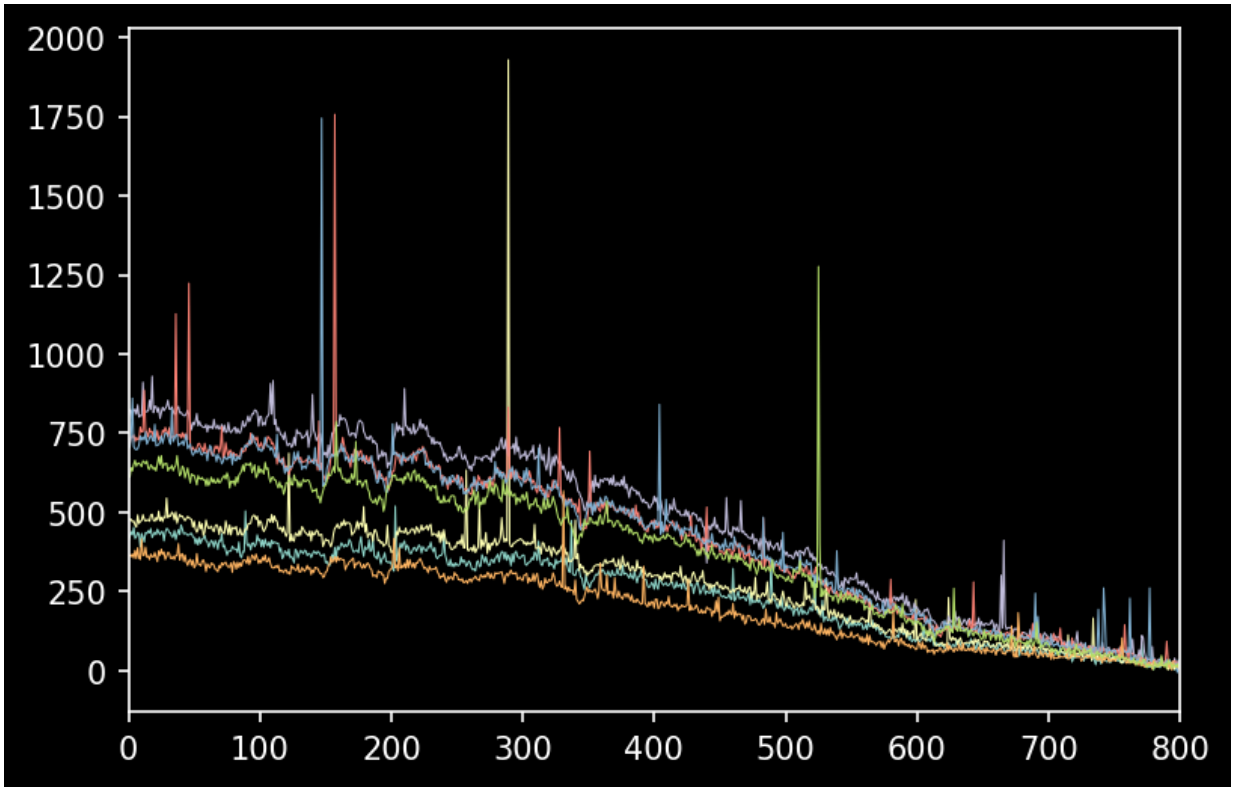


extract traced spectra

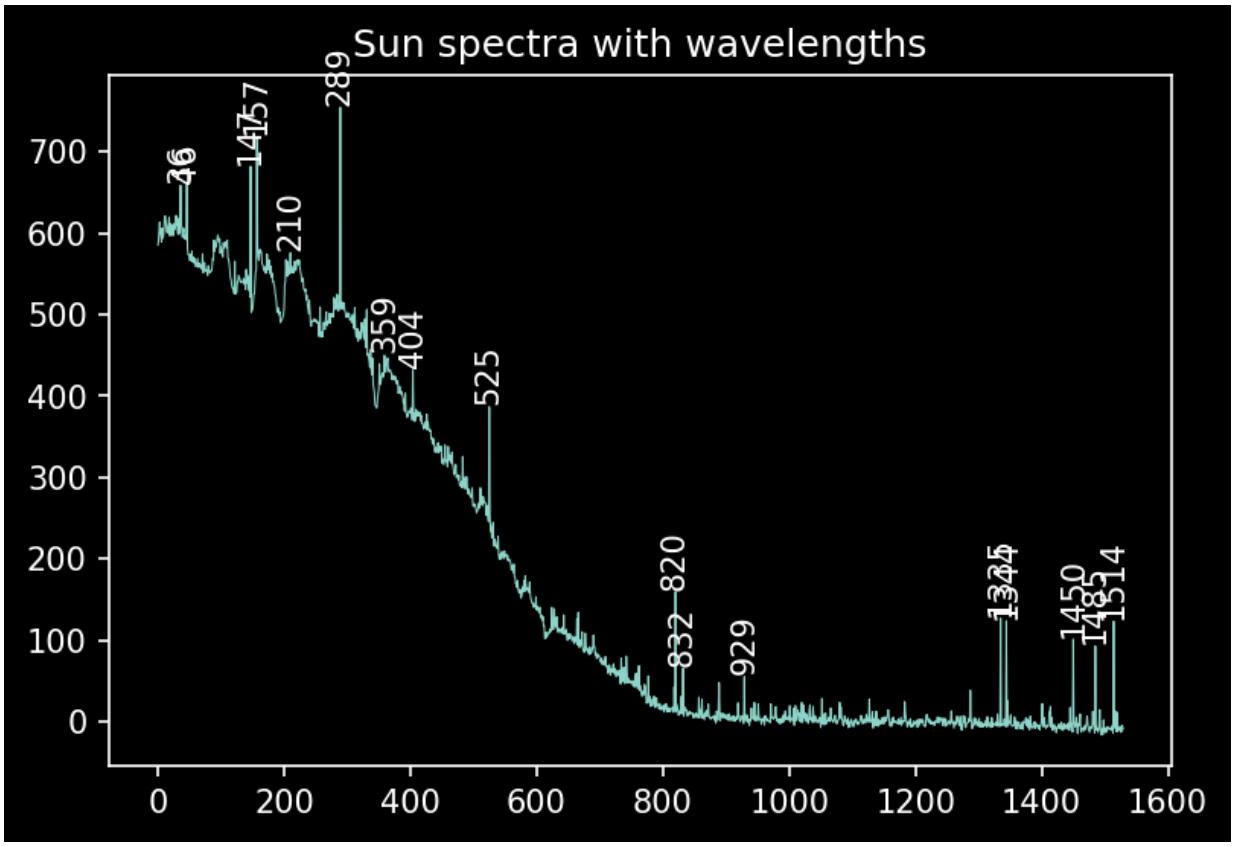
In [24]:
```
spectra = {}
for trace_index, polymodel_trace in fitted_polymodels.items():
    trace_center = polymodel_trace(xvals)

    cutout_trace = np.array([flat_array[int(yval)-npixels_to_cut_trace:int(yval)+
                        for yval, ii in zip(trace_center, xvals)]).T

    trace_profile = cutout_trace.mean(axis=1)
    trace_profile_xaxis = np.arange(len(trace_profile))
    fitted_trace_profile = lmfitter(model=guess, x=trace_profile_xaxis, y=trace_p
    model_trace_profile = fitted_trace_profile(trace_profile_xaxis)

    trace_avg_spectrum = np.array([np.average(
            flat_array[int(yval)-npixels_to_cut:int(yval)+npixels_to_cut, ii],
            weights=trace_profile)
                                   for yval, ii in zip(trace_center, xvals)])
    spectra[trace_index] = trace_avg_spectrum
```

In [25]:
```
for index in spectra:
    pl.plot(spectra[index], linewidth=0.5)
pl.xlim(0,800)
```

Out[25]: (0.0, 800.0)



In [28]:
```
import scipy.signal

mean_he = np.nanmean([spectra[ind] for ind in spectra], axis = 0)
pl.plot(mean_he, linewidth = 0.5)
pl.title("Sun spectra with wavelengths")

peaks,_ = scipy.signal.find_peaks(mean_he, prominence = 50)

for peak in peaks:
    pl.text(peak,
            min([mean_he[peak] + 10, 2000]), peak,
            rotation = 90, horizontalalignment = 'center',)
```



In [29]:
```
peaks
```

Out[29]:
```
array([  36,   46,  147,  157,  210,  289,  359,  404,  525,  820,  832,
        929, 1335, 1344, 1450, 1485, 1514], dtype=int64)
```

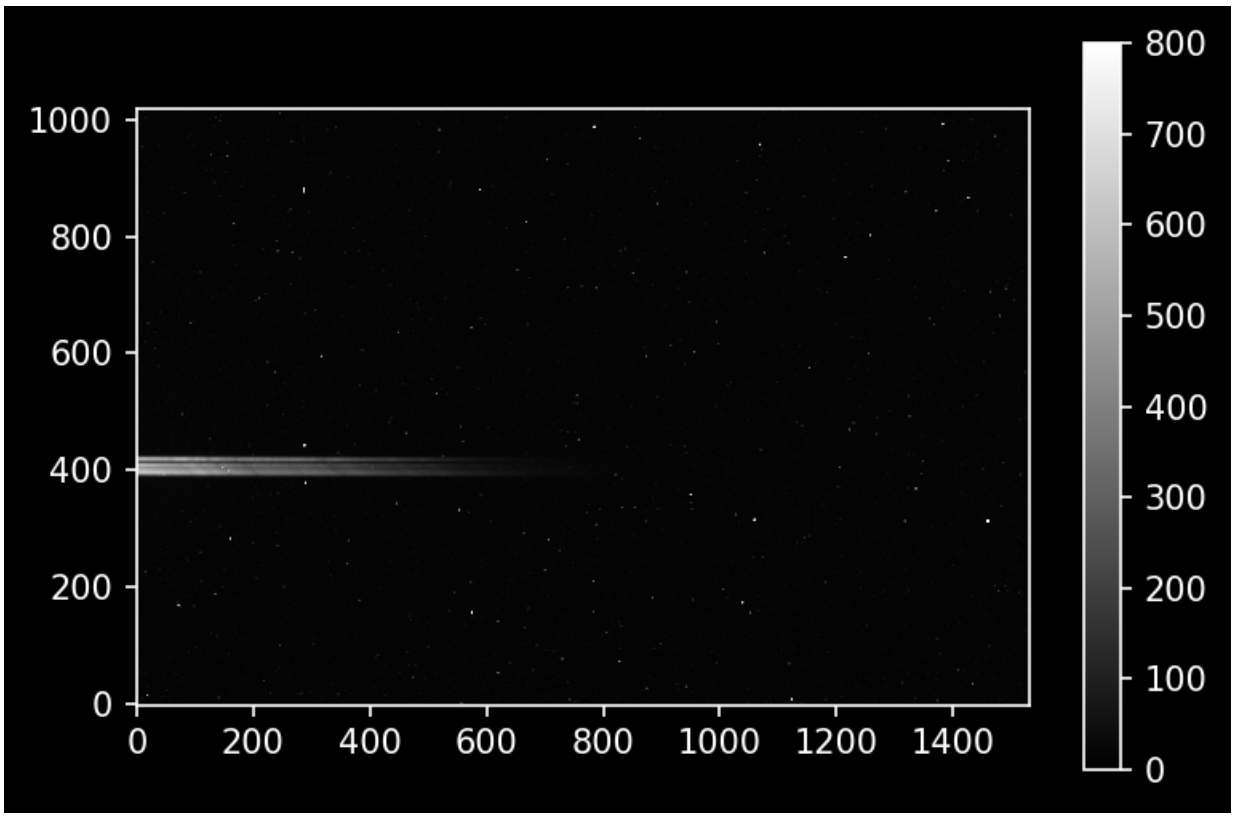
Alb a 30s

In [26]:
```
alb_a_30s_image_data
```

Out[26]:
```
array([[ 2.40000000e+00,  2.10000000e+01,  7.33333333e-01, ...,
         4.29866667e+02,  2.00000000e-01,  2.57333333e+01],
       [-1.33333333e+01,  1.40000000e+01,  1.28000000e+01, ...,
         2.32000000e+01,  1.36666667e+01,  3.38666667e+01],
       [ 2.02000000e+01,  2.86000000e+01,  1.01333333e+01, ...,
         1.40666667e+01,  1.28000000e+01,  1.52666667e+01],
       ...,
       [ 9.80000000e+00,  1.01333333e+01,  2.56666667e+01, ...,
         2.01333333e+01,  3.18666667e+01,  3.10666667e+01],
       [ 1.60666667e+01,  2.24666667e+01,  1.75333333e+01, ...,
         9.20000000e+00,  1.23333333e+01,  9.33333333e+00],
       [ 2.65333333e+01,  1.54666667e+01,  1.98666667e+01, ...,
         1.60000000e+01,  2.85333333e+01,  8.86666667e+00]])
```

In [27]:
```
%matplotlib inline
import pylab as pl
pl.rcParams['image.origin'] = 'lower'
pl.rcParams['figure.dpi'] = 150
pl.matplotlib.style.use('dark_background') # Optional!
pl.imshow(alb_a_30s_image_data, cmap='gray', vmax=0, vmin=800)
pl.colorbar()
```

Out[27]:
```
<matplotlib.colorbar.Colorbar at 0x2cbbd24ad00>
```



In [28]:
```
alb_a_array = np.array(alb_a_30s_image_data)
alb_a_array = alb_a_array - np.median(alb_a_30s_image_data)
```

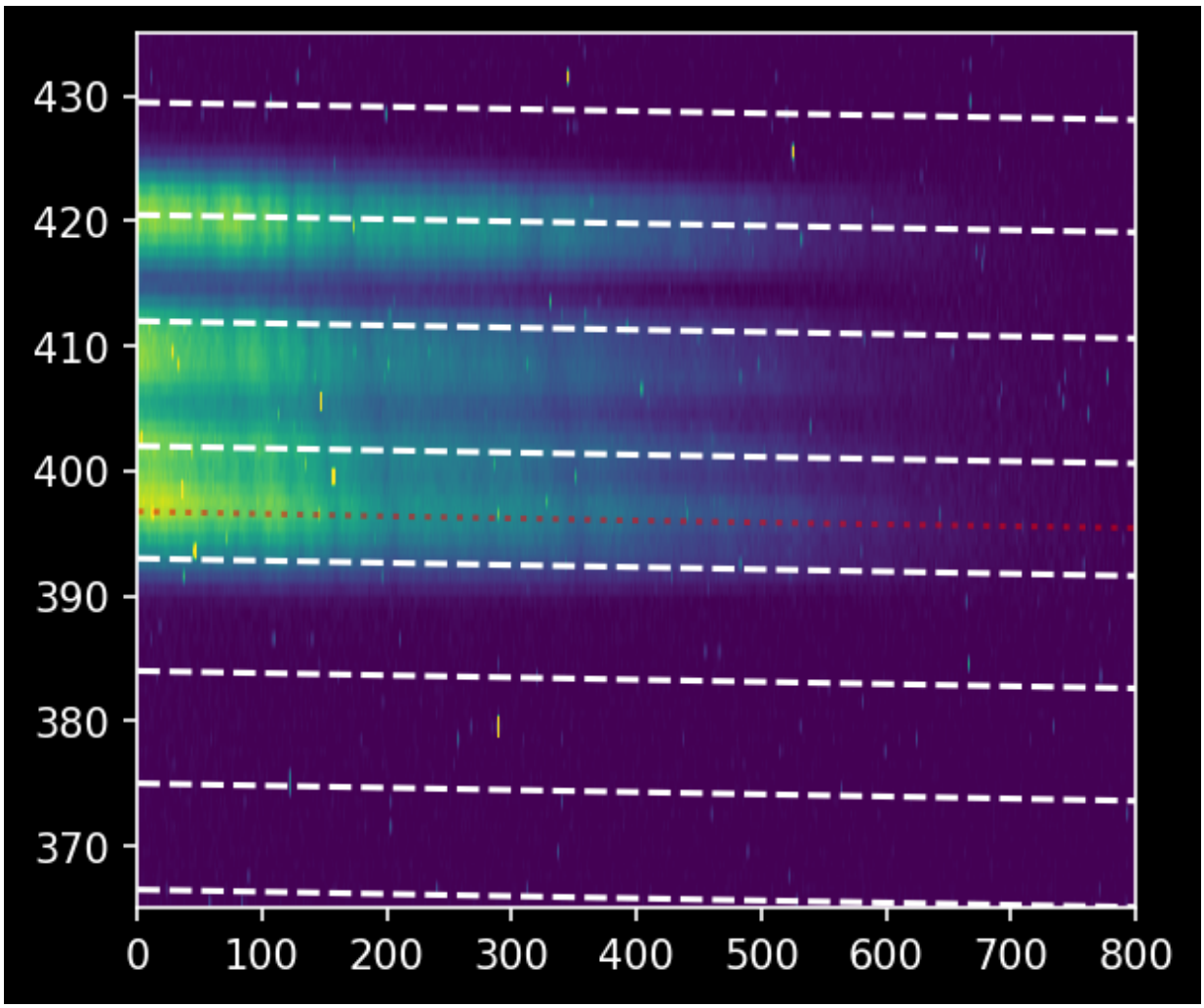
In [29]:
```
traces = {key: traces[key] for key in [3]}
```

In [30]:
```
# We fit a 2rd-order polynomial
polymodel = Polynomial1D(degree=2)
linfitter = LinearLSQFitter()
fitted_polymodels = {index: linfitter(polymodel, xvals[:xend], weighted_yaxis_val
                     for index, weighted_yaxis_values in traces.items()}
```

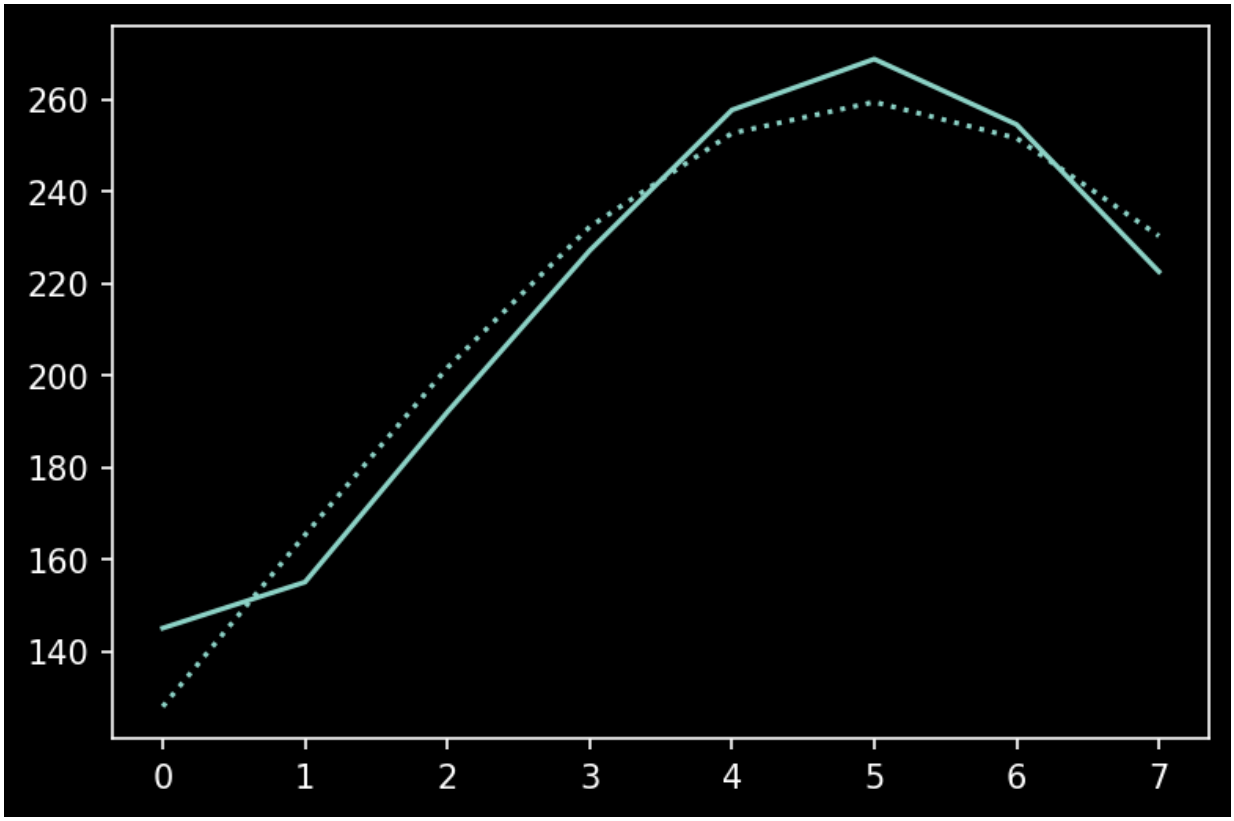
In [31]:
```
lmfitter = LevMarLSQFitter()
guess = Gaussian1D(amplitude=160, mean=0, stddev=5)
```

In [32]:
```
pl.imshow(alb_a_array[ystart:yend, :xend],
          extent=[0,xend,ystart,yend],
          vmin=0, vmax=700,
         )
pl.plot([0,xend], ystart + intertrace_cuts + np.array([0,xend])[:,None] * slope,
pl.gca().set_aspect(10)

for tracefit in fitted_polymodels.values():
    pl.plot(xvals[:xend], tracefit(xvals[:xend]), 'r:', alpha=0.5)
pl.axis((0,xend,ystart,yend))
```

Out[32]: (0.0, 800.0, 365.0, 435.0)



In [33]:
```
npixels_to_cut_trace = 4

for trace_index, polymodel_trace in fitted_polymodels.items():
    trace_center = polymodel_trace(xvals)

    cutout_trace = np.array([flat_array[int(yval)-npixels_to_cut_trace:int(yval)+
                         for yval, ii in zip(trace_center, xvals)]).T

    trace_profile = cutout_trace.mean(axis=1)
    trace_profile_xaxis = np.arange(len(trace_profile))
    fitted_trace_profile = lmfitter(model=guess, x=trace_profile_xaxis, y=trace_p
    model_trace_profile = fitted_trace_profile(trace_profile_xaxis)

    line, = pl.plot(trace_profile, label=trace_index)
    pl.plot(trace_profile_xaxis, model_trace_profile, color=line.get_color(), lin
```



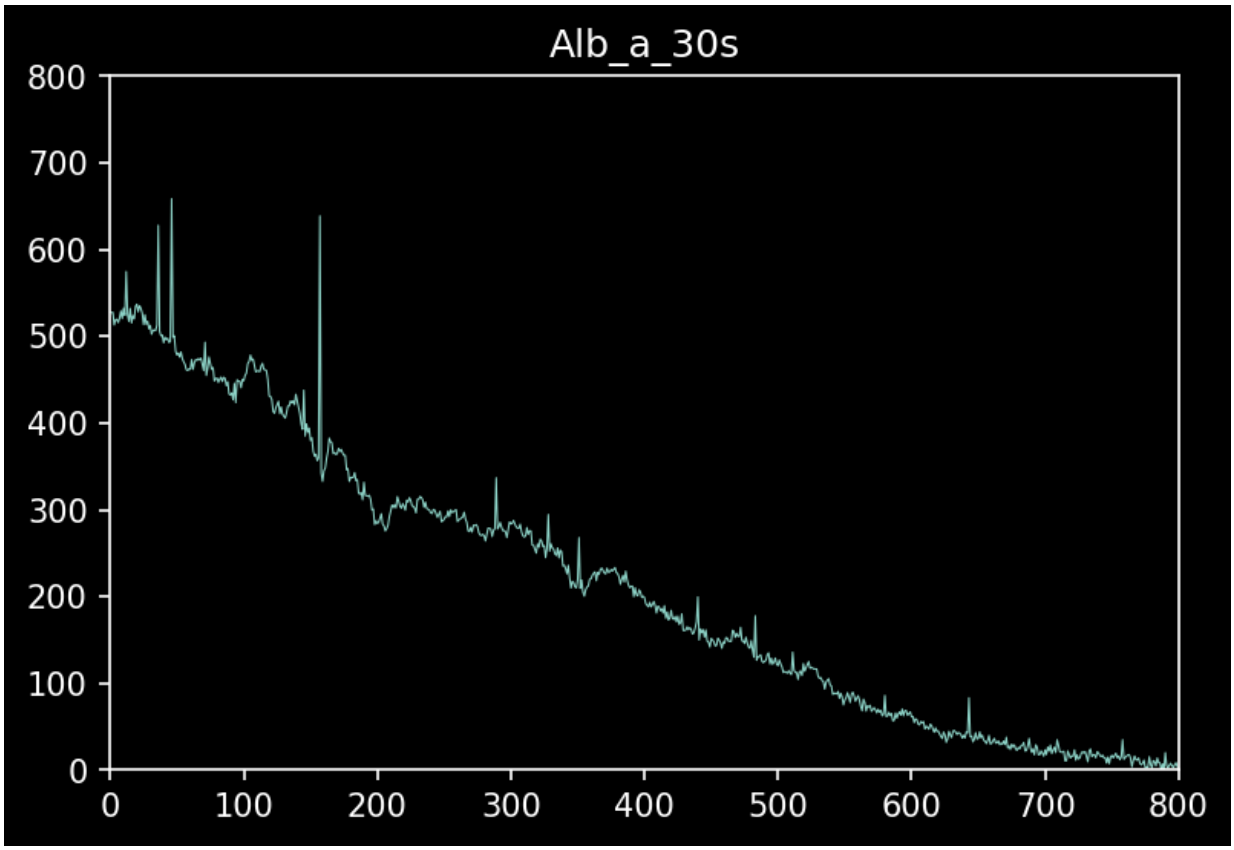
In [34]:
```
fitted_polymodels.values()
```

Out[34]:
```
dict_values([<Polynomial1D(2, c0=396.75953049, c1=-0.00196855, c2=0.00000041)
>])
```

In [35]:
```
spectra = {}

for trace_index, polymodel_trace in fitted_polymodels.items():
    trace_center = polymodel_trace(xvals)

    cutout_trace = np.array([alb_a_array[int(yval)-npixels_to_cut_trace:int(yval)
                        for yval, ii in zip(trace_center, xvals)]).T

    trace_profile = cutout_trace.mean(axis=1)
    trace_profile_xaxis = np.arange(len(trace_profile))
    fitted_trace_profile = lmfitter(model=guess, x=trace_profile_xaxis, y=trace_p
    model_trace_profile = fitted_trace_profile(trace_profile_xaxis)

    trace_avg_spectrum = np.array([np.average(
            alb_a_array[int(yval)-npixels_to_cut:int(yval)+npixels_to_cut, ii],
            weights=trace_profile)
                                for yval, ii in zip(trace_center, xvals)])
    spectra[trace_index] = trace_avg_spectrum
```

In [36]:
```
for index in spectra:
    pl.plot(spectra[index], linewidth=0.5)
    pl.ylim(0,800)
    pl.title("Alb_a_30s")
pl.xlim(0,800)
```

Out[36]: (0.0, 800.0)



In [ ]:

Retrieve the wavelength solution from helium

In [37]:
```
from astropy.modeling.models import Linear1D
wlmodel = Linear1D(slope=-1.00238884, intercept=-2.90420708)
```

In [38]:
```
from astropy import units as u
from astropy.visualization import quantity_support
quantity_support()
```

Out[38]:
```
<astropy.visualization.units.quantity_support.<locals>.MplQuantityConverter at
0x2cbc17839d0>
```

In [45]:
```
wavelengths = wlmodel(xvals) * u.nm
wavelengths
```

Out[45]:
$$[-2.9042071,\ -3.9065959,\ -4.9089848,\ \ldots,\ -1533.552,\ -1534.5544,\ -1535.556$$

In [ ]: