Exploratory analysis

April 5, 2022

[1]:
```
dataset_name = "hou"
```

[2]:
```
%reload_ext autoreload
%autoreload 2
```

[3]:
```
import datasets
import numpy as np
import pandas as pd
import seaborn as sn
import matplotlib.pyplot as plt
import matplotlib
matplotlib.rcParams['figure.figsize'] = (14, 12)


dataset_module = datasets.datasets_by_name_all[dataset_name]
x,y,metadata = dataset_module.load(dropna=True,verbose=True)
y = datasets.map_y_em(y,dataset_name)

# generate dataframe with both x and y
xy = pd.concat([x,y],axis=1)
xym = pd.concat([x,y,metadata],axis=1)
xym.describe()
```

```
Warning loading data from Hou2016_VPHAS-SDSS-IPHAS-2MASS.csv:
Dropped 27 rows with missing values.
Rows (original):   1034
Rows (after drop): 1007
```

[3]:

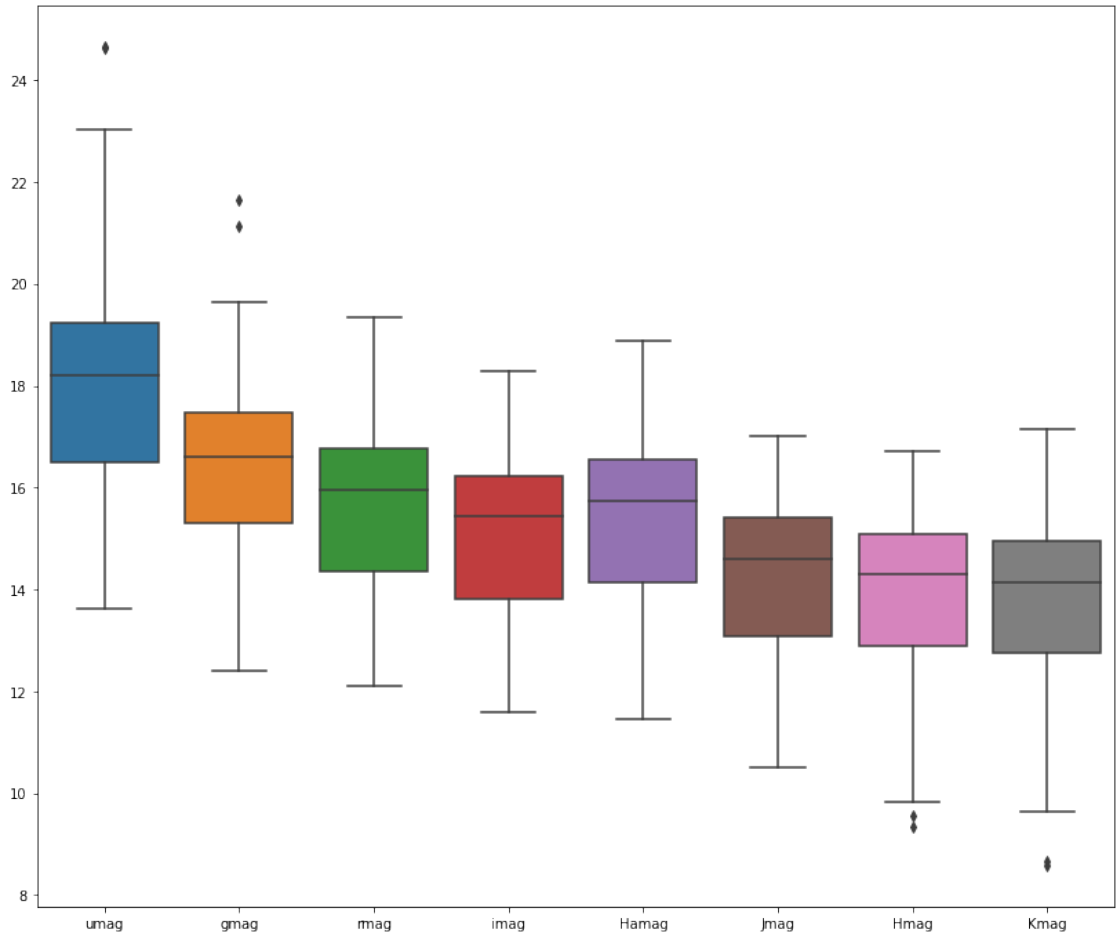
	umag	gmag	rmag	imag	Hamag	\
count	1007.000000	1007.000000	1007.000000	1007.000000	1007.000000	
mean	17.947877	16.366036	15.557746	15.048451	15.347805	
std	1.660195	1.368795	1.418495	1.370818	1.440670	
min	13.616000	12.398000	12.100000	11.590000	11.450000	
25%	16.505000	15.296000	14.365000	13.825000	14.125000	
50%	18.217000	16.618000	15.950000	15.430000	15.750000	
75%	19.226000	17.470500	16.755000	16.225000	16.560000	
max	24.651000	21.633000	19.330000	18.290000	18.890000	

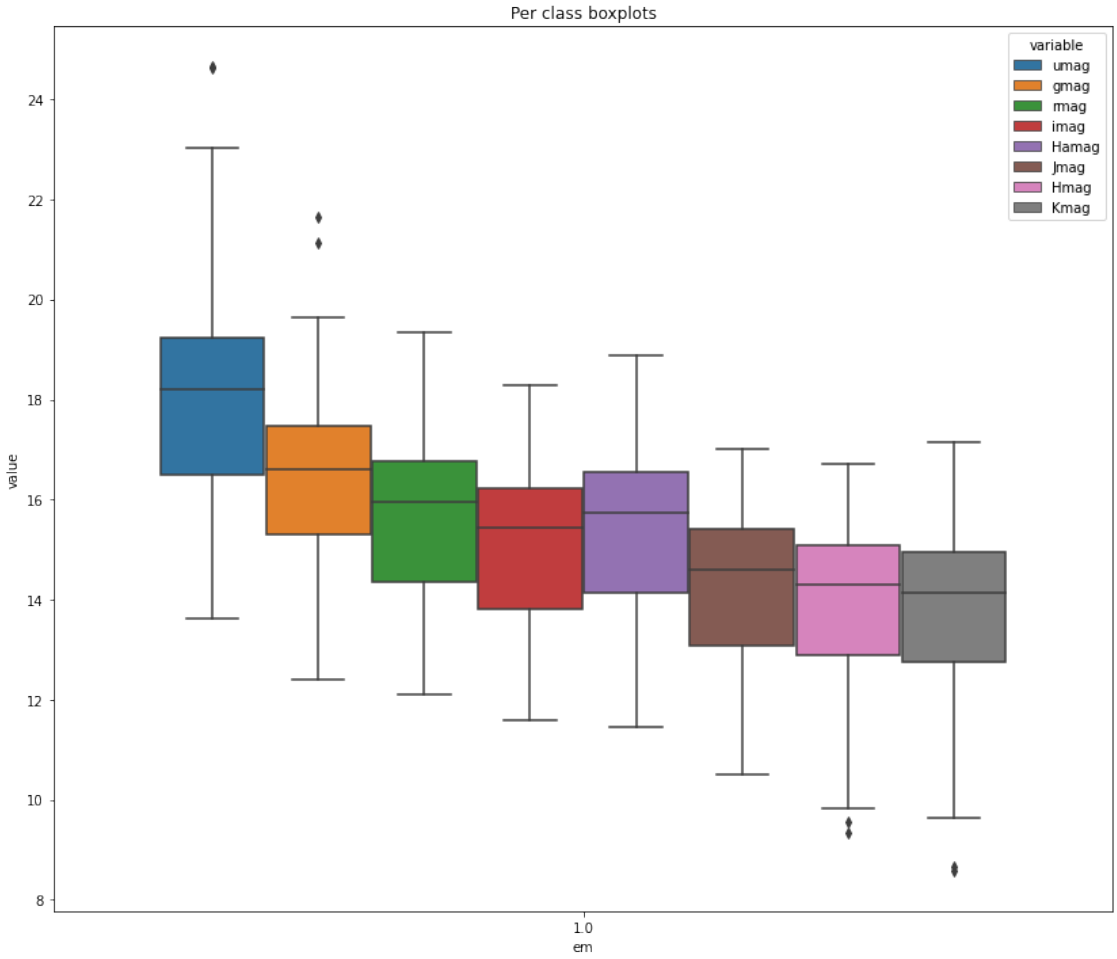
```
              Jmag         Hmag         Kmag      em      e_Kmag  …  \
count  1007.000000  1007.000000  1007.000000  1007.0  983.000000  …
mean     14.248893    13.983537    13.843248     1.0    0.067548  …
std       1.329480     1.331519     1.341729     0.0    0.046918  …
min      10.501000     9.331000     8.578000     1.0    0.017000  …
25%      13.083000    12.900500    12.767000     1.0    0.028000  …
50%      14.586000    14.294000    14.133000     1.0    0.052000  …
75%      15.405500    15.085000    14.954000     1.0    0.097000  …
max      17.013000    16.700000    17.150000     1.0    0.273000  …

                k      DEJ2000       h_err       e_rmag      e_Hamag  \
count  917.000000  1007.000000  910.000000  1007.000000  1007.000000
mean    13.724305    24.022729    0.051823     0.003088     0.005968
std      1.333291     9.064148    0.032369     0.004853     0.005799
min      8.578000     0.735073    0.019000     0.000000     0.000000
25%     12.628000    21.160213    0.027000     0.000000     0.000000
50%     13.963000    23.277021    0.040000     0.000000     0.010000
75%     14.848000    28.799729    0.068000     0.010000     0.010000
max     17.006000    54.285438    0.192000     0.040000     0.040000

            RAJ2000       k_err      e_Hmag       e_Jmag      w1_err
count  1007.000000  900.000000  998.000000  1003.000000  917.000000
mean     87.987971    0.062864    0.055280     0.037995    0.032071
std       8.727635    0.044079    0.034933     0.017376    0.010619
min      54.744007    0.017000    0.019000     0.018000    0.022000
25%      84.995892    0.027000    0.027000     0.024000    0.024000
50%      87.834310    0.046000    0.043500     0.032000    0.029000
75%      91.464080    0.089000    0.073750     0.048000    0.037000
max     104.905030    0.229000    0.270000     0.152000    0.132000

[8 rows x 25 columns]
```

1 Variable visualization

[4]:
```
sn.boxplot(data=x)

plt.figure()
xy_long = pd.melt(xy, id_vars='em')
sn.boxplot(x='em', y='value', hue='variable', data=xy_long)
plt.title("Per class boxplots")
```

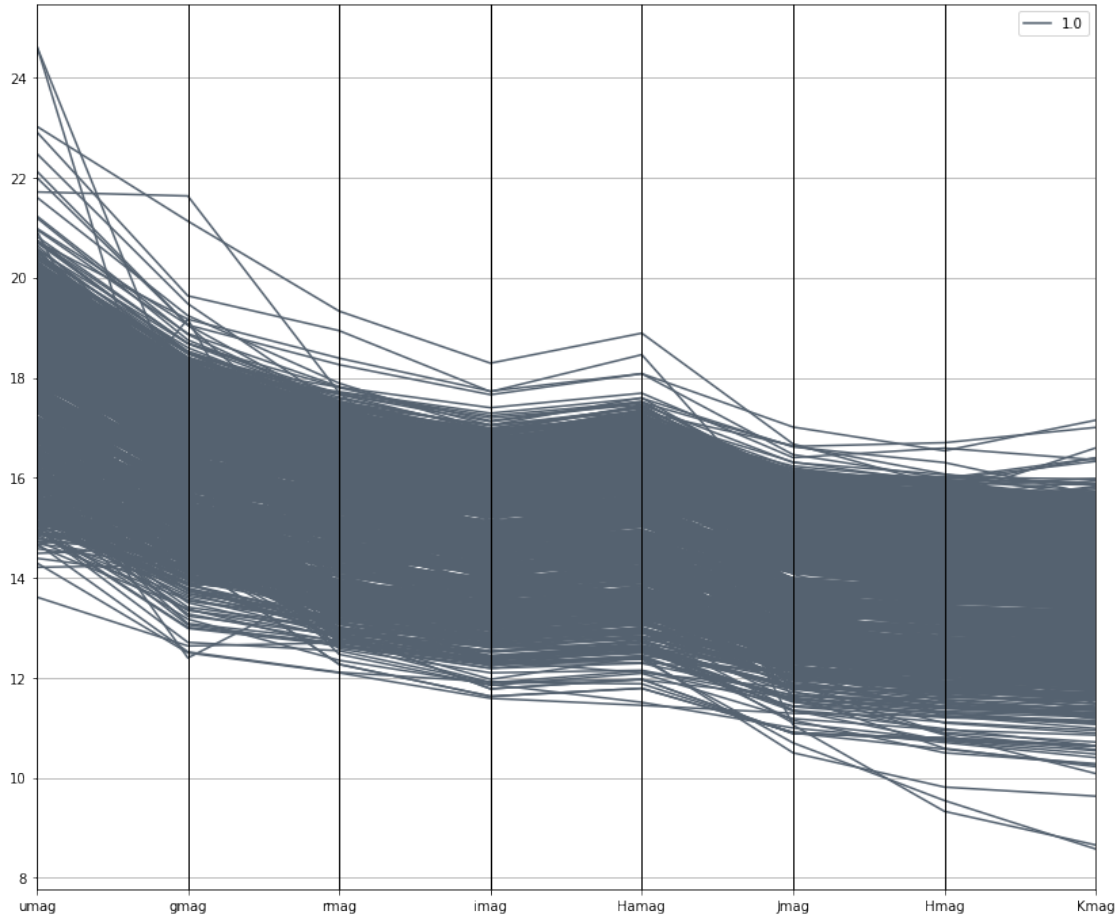
[4]:
```
Text(0.5, 1.0, 'Per class boxplots')
```


24
22
20
18
16
14
12
10
8
umag
gmag
rmag
imag
Hamag
Jmag
Hmag
Kmag

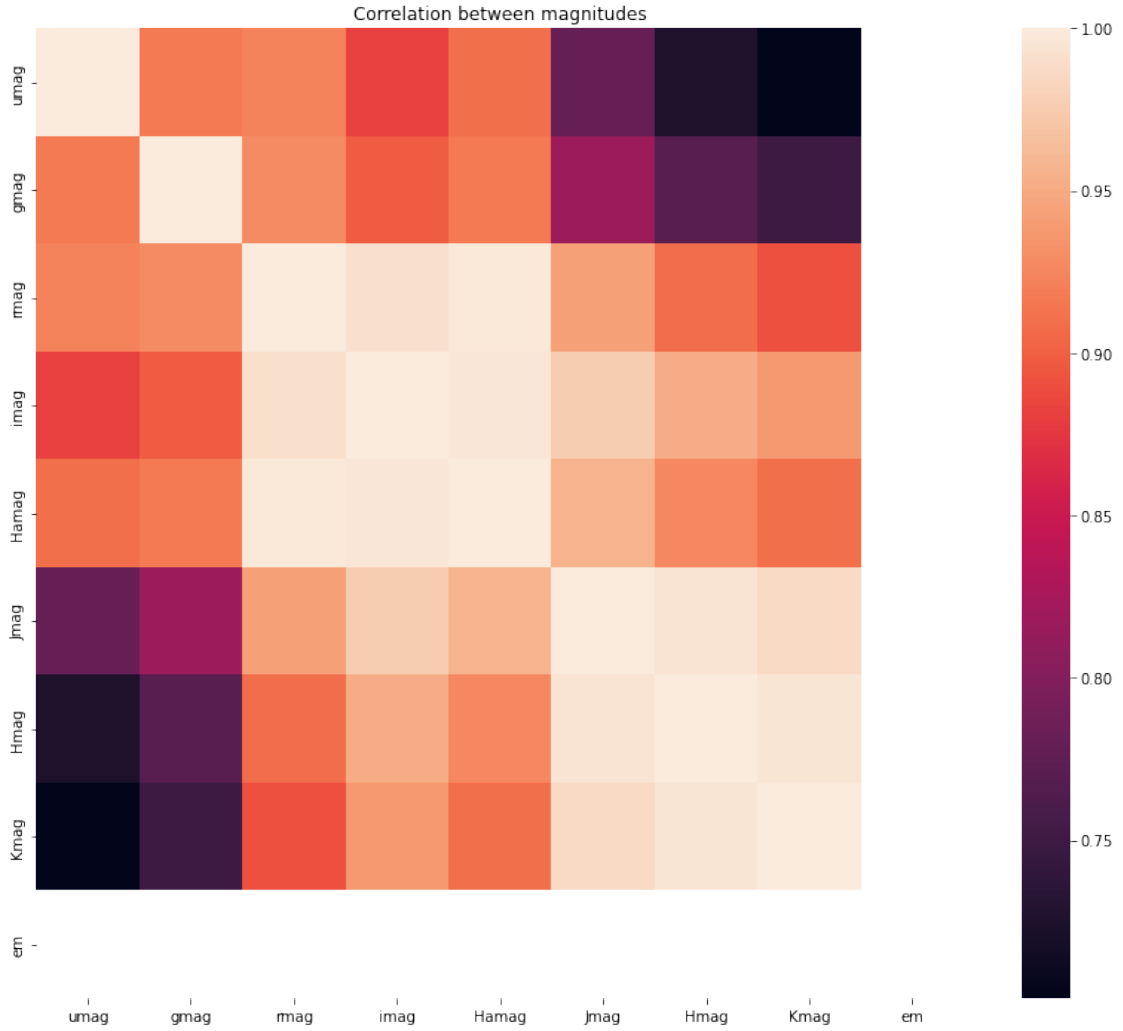


[5]:
```
pd.plotting.parallel_coordinates(xy,"em",color=('#556270','#C7F464'))
```

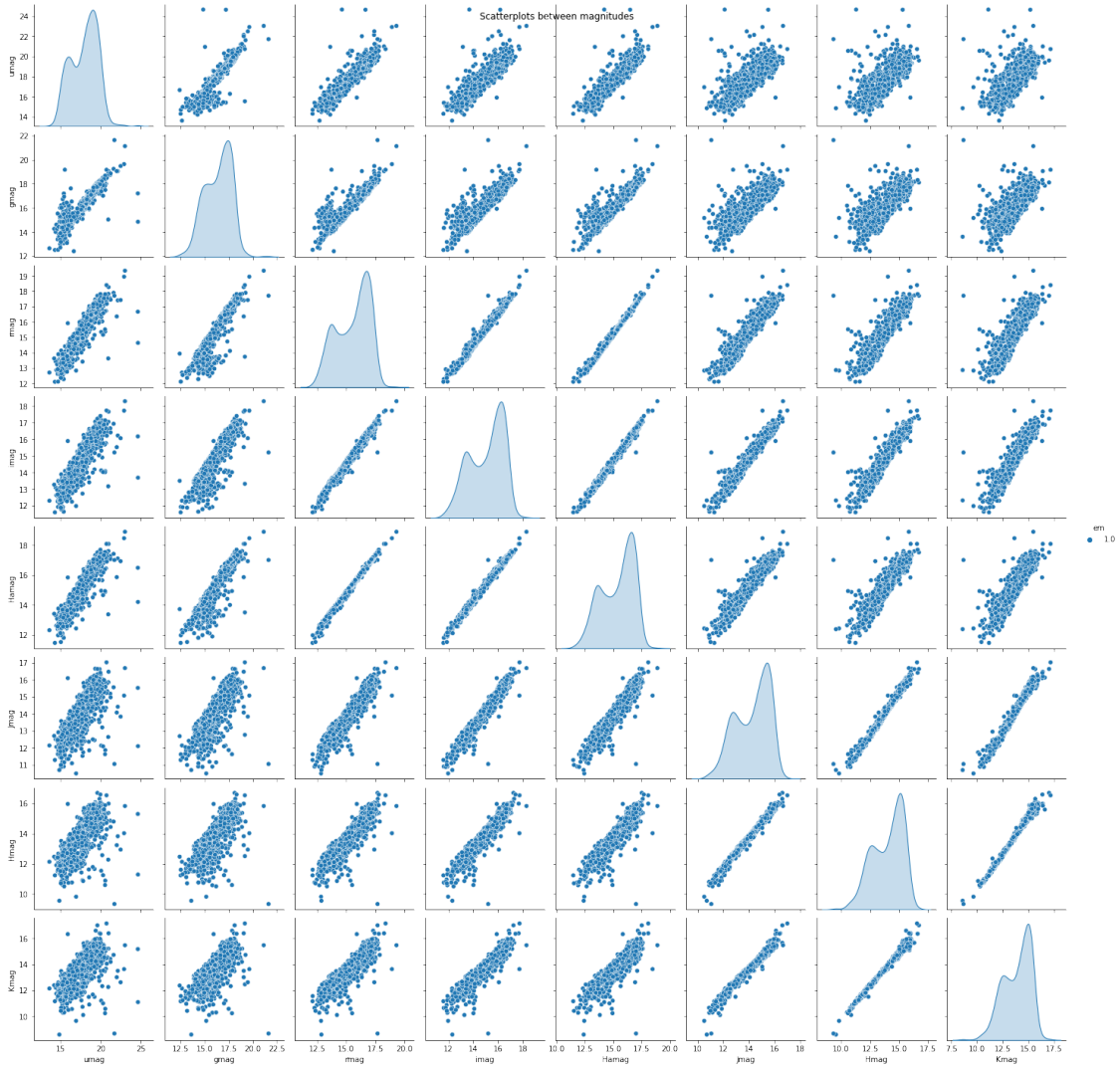
[5]: <AxesSubplot:>



[6]:
```
sn.heatmap(xy.corr().abs())
plt.title("Correlation between magnitudes")
plt.show()

sn.pairplot(xy,hue="em")
plt.suptitle("Scatterplots between magnitudes")
# axes=pd.plotting.scatter_matrix(x,c=y["em"],alpha=0.
 ↪9,grid=False,figsize=(14,12))
```



[6]: Text(0.5, 0.98, 'Scatterplots between magnitudes')



2 Outlier detection via confidence interval

[7]:
```
from scipy import stats
m = len(x.columns) # number of columns = number of hypothesis
confidence= 0.99
adjusted_confidence = 1- (1-confidence)/m  # bonferroni-adjusted confidence
max_zscore = stats.norm.ppf(adjusted_confidence)
print(f"Confidence  (desired): {confidence}")
print(f"Confidence (adjusted): {adjusted_confidence}")
print(f"Z-score    (adjusted): {max_zscore}")

indices = (np.abs(stats.zscore(x-x.mean())) > max_zscore).any(axis=1)
outliers_x = x[indices]
```

```
if dataset_name != "all_em":
    outliers_metadata = metadata[indices]
    outliers_x = pd.concat([outliers_x,outliers_metadata],axis=1)
outliers_x
```

```
Confidence  (desired): 0.99
Confidence (adjusted): 0.99875
Z-score    (adjusted): 3.023341439739154
```

[7]:

	umag	gmag	rmag	imag	Hamag	Jmag	Hmag	Kmag	e_Kmag	\
94	23.028	21.130	19.33	18.29	18.89	16.676	15.830	15.471	0.146	
132	24.635	17.203	16.66	16.17	16.48	15.515	15.300	15.175	0.118	
622	16.941	15.160	12.83	11.97	12.42	10.501	9.816	9.634	0.026	
629	24.651	14.845	14.63	13.68	14.19	12.102	11.286	11.082	0.044	
662	14.853	13.601	12.86	12.31	12.37	10.700	9.547	8.578	0.020	
683	21.713	21.633	17.70	15.20	17.00	11.054	9.331	8.658	0.023	

	e_imag	…	e_Hamag	RAJ2000	k_err	ID	e_Hmag	\
94	0.03	…	0.04	83.549950	0.146	J053411.98+290903.2	0.120	
132	0.01	…	0.01	81.378157	0.118	J052530.75+293821.3	0.105	
622	0.00	…	0.00	97.414520	0.026	J062939.48+005504.4	0.026	
629	0.00	…	0.00	88.095161	0.044	J055222.83+204152.3	0.030	
662	0.00	…	0.00	87.728220	0.020	J055054.77+201447.6	0.029	
683	0.00	…	0.01	100.284660	0.023	J064108.31+102408.1	0.024	

	e_Jmag	Halpha_type	Fe_type	w1_err	objtype_SIMBAD
94	0.112	II	NaN	0.047	NaN
132	0.061	II	NaN	0.042	NaN
622	0.024	VI	NaN	0.023	NaN
629	0.026	VI	NaN	0.062	NaN
662	0.021	V	NaN	0.031	NaN
683	0.022	II	NaN	0.023	NaN

[6 rows x 28 columns]

3 Outlier detection via IQR

[8]:
```
iqr_factor=1.5
q25,q75=x.quantile(0.25),x.quantile(0.75)
iqr=q75-q25
min_values = q25-iqr_factor*iqr
max_values = q75+iqr_factor*iqr
# ou
indices = (np.logical_or(x<min_values,x>max_values)).any(axis=1)
outliers_x = x[indices]
if dataset_name != "all_em":
```

```
    outliers_metadata = metadata[indices]
    outliers_x = pd.concat([outliers_x,outliers_metadata],axis=1)
outliers_x
```

[8]:

	umag	gmag	rmag	imag	Hamag	Jmag	Hmag	Kmag	e_Kmag	\
94	23.028	21.130	19.33	18.29	18.89	16.676	15.830	15.471	0.146	
132	24.635	17.203	16.66	16.17	16.48	15.515	15.300	15.175	0.118	
629	24.651	14.845	14.63	13.68	14.19	12.102	11.286	11.082	0.044	
662	14.853	13.601	12.86	12.31	12.37	10.700	9.547	8.578	0.020	
683	21.713	21.633	17.70	15.20	17.00	11.054	9.331	8.658	0.023	

	e_imag	…	e_Hamag	RAJ2000	k_err	ID	e_Hmag	\
94	0.03	…	0.04	83.549950	0.146	J053411.98+290903.2	0.120	
132	0.01	…	0.01	81.378157	0.118	J052530.75+293821.3	0.105	
629	0.00	…	0.00	88.095161	0.044	J055222.83+204152.3	0.030	
662	0.00	…	0.00	87.728220	0.020	J055054.77+201447.6	0.029	
683	0.00	…	0.01	100.284660	0.023	J064108.31+102408.1	0.024	

	e_Jmag	Halpha_type	Fe_type	w1_err	objtype_SIMBAD
94	0.112	II	NaN	0.047	NaN
132	0.061	II	NaN	0.042	NaN
629	0.026	VI	NaN	0.062	NaN
662	0.021	V	NaN	0.031	NaN
683	0.022	II	NaN	0.023	NaN

[5 rows x 28 columns]

4 Analysis of q-features (q_3) (all magnitudes)

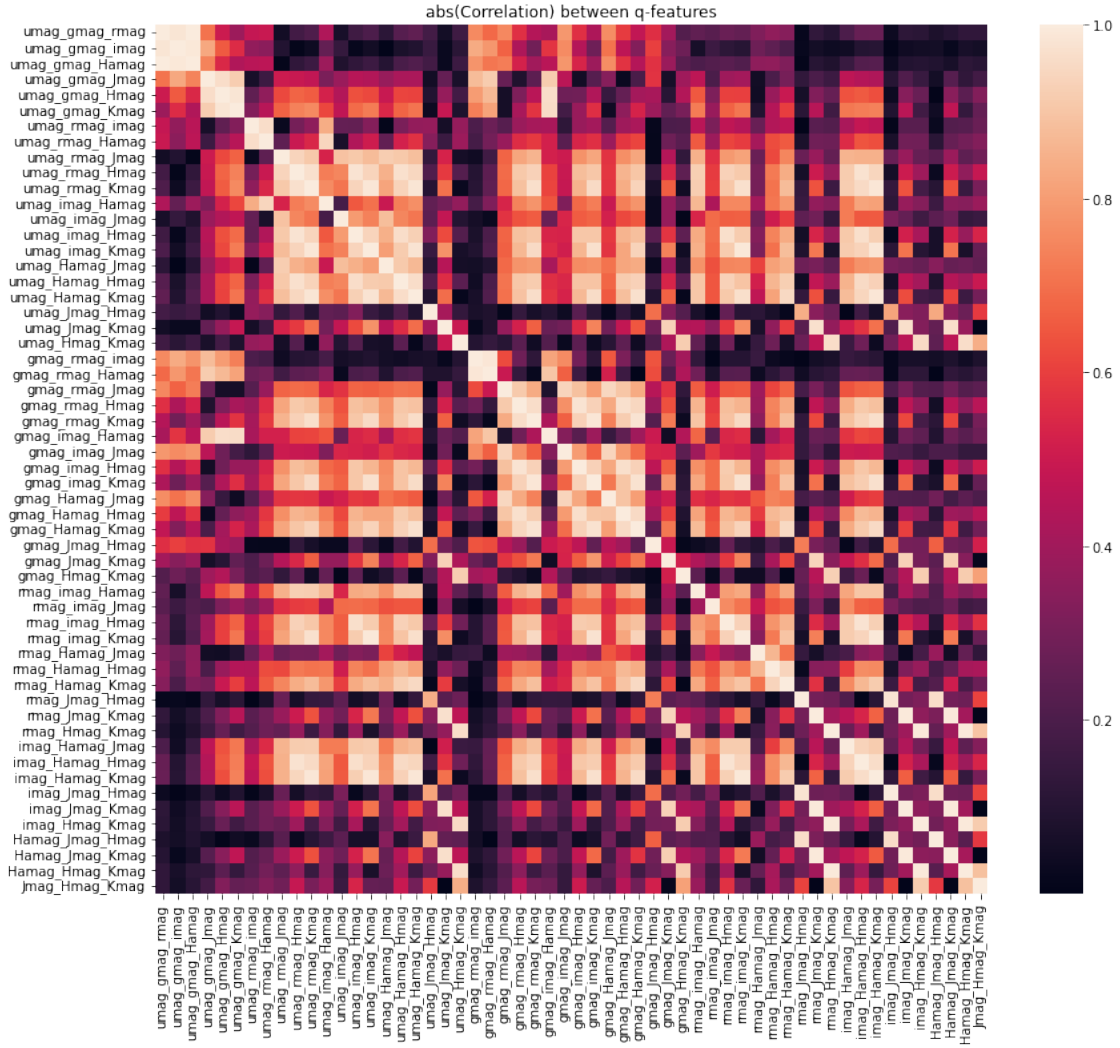
[9]:
```
x_np=x.to_numpy()
import qfeatures
coefficients = dataset_module.coefficients
systems = dataset_module.systems
coefficients_np = np.array([coefficients[k] for k in x.columns])
systems = [systems[k] for k in x.columns]
q=qfeatures.calculate(x_np,coefficients_np,x.columns,systems,combination_size=3)
m = q.magnitudes

q_df = pd.DataFrame(m, columns = q.column_names)
q_df.describe()
```

[9]:

	umag_gmag_rmag	umag_gmag_imag	umag_gmag_Hamag	umag_gmag_Jmag	\
count	1007.000000	1007.000000	1007.000000	1007.000000	
mean	1.200440	0.741977	1.063210	-1.623278	
std	0.823664	0.872624	0.843513	1.436653	
min	-6.198398	-7.366959	-6.524593	-15.935431	

```
25%          1.178662        0.741553         1.024215       -2.055917
50%          1.369199        0.963304         1.265187       -1.360764
75%          1.489747        1.051404         1.369208       -0.828021
max          9.704550        9.063398         9.472379        5.653403

       umag_gmag_Hmag  umag_gmag_Kmag  umag_rmag_imag  umag_rmag_Hamag  \
count     1007.000000     1007.000000     1007.000000      1007.000000
mean        -4.063644       -7.404559        1.770638         2.186077
std          2.257856        3.456072        0.516441         0.622566
min        -29.070391      -46.138137       -0.026327        -0.079757
25%         -4.958109       -8.856859        1.531942         1.868495
50%         -3.670370       -6.819732        1.732561         2.143327
75%         -2.723609       -5.253641        1.956249         2.447827
max          4.414391        4.119078        8.865444         9.593336

       umag_rmag_Jmag  umag_rmag_Hmag  …  imag_Hamag_Jmag  imag_Hamag_Hmag  \
count     1007.000000     1007.000000  …      1007.000000      1007.000000
mean        -1.391000       -4.728029  …         0.356941         0.975940
std          1.015766        2.267895  …         0.134663         0.385626
min        -15.186556      -33.829435  …        -0.094083        -0.067130
25%         -1.894056       -5.835587  …         0.273833         0.739326
50%         -1.311667       -4.451217  …         0.339347         0.922130
75%         -0.854889       -3.377304  …         0.421736         1.161500
max          4.667222        1.825435  …         1.751083         5.368848

       imag_Hamag_Kmag  imag_Jmag_Hmag  imag_Jmag_Kmag  imag_Hmag_Kmag  \
count      1007.000000     1007.000000     1007.000000     1007.000000
mean          1.814892        0.228467       -0.512821        0.491838
std           0.720126        0.231544        0.514158        0.610817
min          -0.639804       -0.871457       -5.255294       -2.465464
25%           1.356389        0.099630       -0.738353        0.206157
50%           1.719804        0.231152       -0.444235        0.462778
75%           2.188350        0.353446       -0.242647        0.749595
max           9.922418        1.406913        2.277294        5.374222

       Hamag_Jmag_Hmag  Hamag_Jmag_Kmag  Hamag_Hmag_Kmag  Jmag_Hmag_Kmag
count      1007.000000      1007.000000      1007.000000     1007.000000
mean          0.279772        -0.783490         0.594054        0.146156
std           0.341645         0.754679         0.813179        0.185327
min          -1.889261        -8.177190        -3.191216       -0.707641
25%           0.092609        -1.085876         0.228765        0.047830
50%           0.280348        -0.676980         0.558020        0.132556
75%           0.472978        -0.394304         0.937892        0.221882
max           1.874522         3.231967         7.073667        1.382222

[8 rows x 56 columns]
```

[10]:
```
sn.heatmap(q_df.corr().abs())
plt.title("abs(Correlation) between q-features")
plt.show()
```



5 Analysis of q-features (q_4) (calculated by system to avoid combinatory explosion)

[11]:
```
x_np=x.to_numpy()
import qfeatures
coefficients = dataset_module.coefficients
systems = dataset_module.systems
coefficients_np = np.array([coefficients[k] for k in x.columns])
systems = [systems[k] for k in x.columns]
```

```
q= qfeatures.calculate(x_np,coefficients_np,x.
 ↪columns,systems,combination_size=4,by_system=False)

m = q.magnitudes

q_df = pd.DataFrame(m, columns = q.column_names)
q_df.describe()
```

[11]:

	umag_gmag_rmag_imag	umag_gmag_rmag_Hamag	umag_gmag_rmag_Jmag	\
count	1007.000000	1007.000000	1007.000000	
mean	0.656622	0.235753	0.684577	
std	0.629001	0.950934	0.617204	
min	-4.461667	-5.723059	-4.476063	
25%	0.576500	-0.009324	0.621308	
50%	0.768667	0.491529	0.788937	
75%	0.883667	0.738000	0.898818	
max	8.080167	6.984824	8.072969	

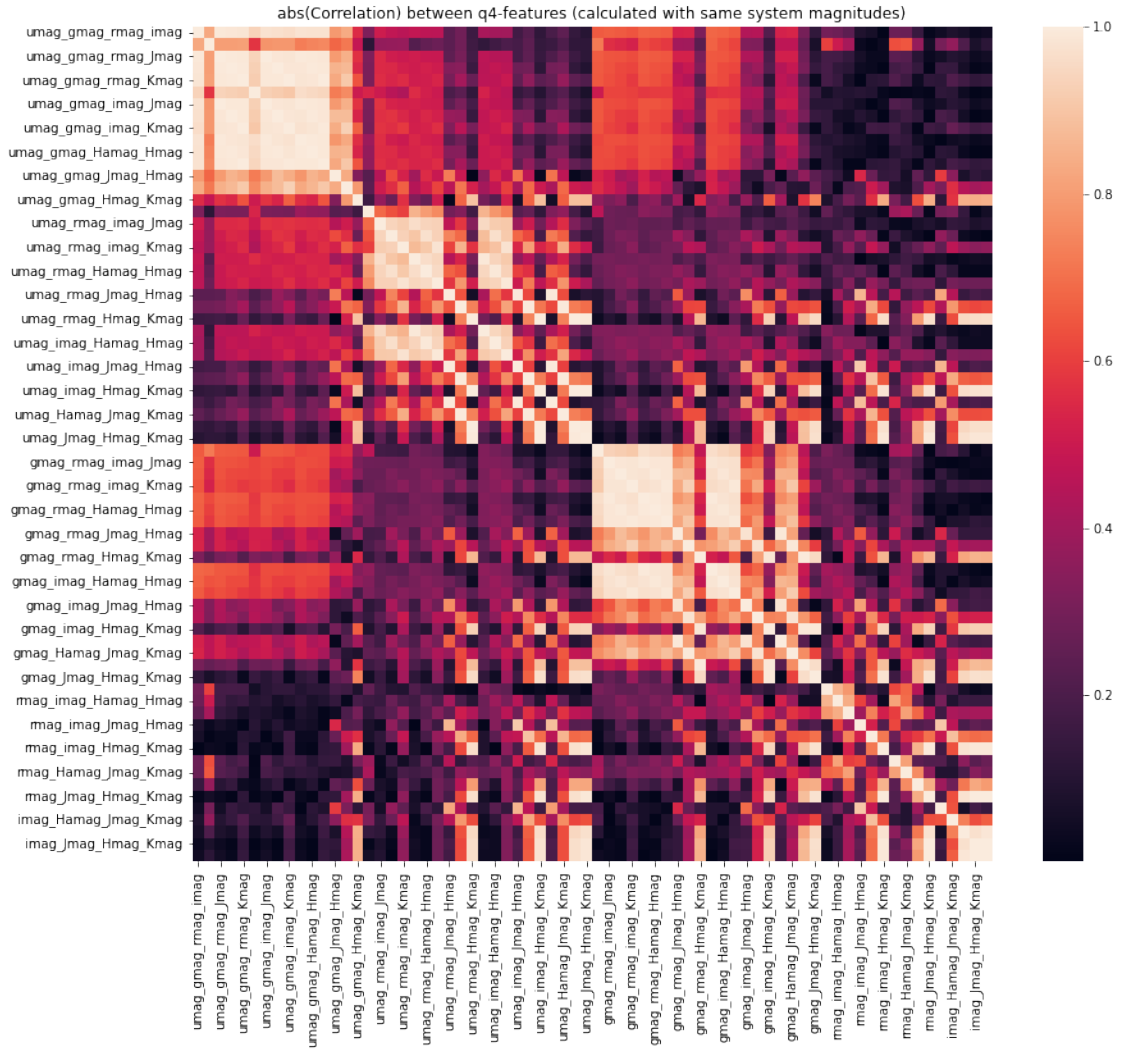
	umag_gmag_rmag_Hmag	umag_gmag_rmag_Kmag	umag_gmag_imag_Hamag	\
count	1007.000000	1007.000000	1007.000000	
mean	0.654334	0.649305	0.823012	
std	0.617284	0.621667	0.606004	
min	-4.850924	-4.838054	-4.482791	
25%	0.582541	0.578894	0.754326	
50%	0.761249	0.755592	0.875488	
75%	0.870968	0.866666	0.994628	
max	7.835751	7.876200	8.513209	

	umag_gmag_imag_Jmag	umag_gmag_imag_Hmag	umag_gmag_imag_Kmag	\
count	1007.000000	1007.000000	1007.000000	
mean	0.701520	0.653236	0.646178	
std	0.615750	0.618014	0.625663	
min	-4.484788	-5.037768	-4.998903	
25%	0.628702	0.584576	0.569703	
50%	0.794273	0.757464	0.746736	
75%	0.920096	0.870512	0.870546	
max	8.068606	7.718432	7.789034	

	umag_gmag_Hamag_Jmag	…	rmag_imag_Hmag_Kmag	rmag_Hamag_Jmag_Hmag	\
count	1007.000000	…	1007.000000	1007.000000	
mean	0.738310	…	-0.037285	0.036439	
std	0.603590	…	0.521563	0.110454	
min	-4.484183	…	-3.225325	-0.426577	
25%	0.686063	…	-0.233831	-0.015962	
50%	0.818486	…	-0.024156	0.022962	
75%	0.928926	…	0.158766	0.070250	
max	8.203239	…	4.357792	0.885077	

```
       rmag_Hamag_Jmag_Kmag  rmag_Hamag_Hmag_Kmag  rmag_Jmag_Hmag_Kmag  \
count           1007.000000           1007.000000          1007.000000
mean               0.043371              0.055076            -0.139585
std                0.103537              0.167450             1.366288
min               -0.447874             -0.793831            -7.844610
25%               -0.008116             -0.020065            -0.605331
50%                0.029300              0.055130            -0.100169
75%                0.072101              0.127045             0.353955
max                0.841449              1.267208            11.552649

       imag_Hamag_Jmag_Hmag  imag_Hamag_Jmag_Kmag  imag_Hamag_Hmag_Kmag  \
count           1007.000000           1007.000000          1007.000000
mean               0.139503              0.121967             0.092361
std                0.203930              0.187311             0.388465
min               -0.725654             -0.781280            -3.090584
25%                0.026096              0.031208            -0.055390
50%                0.108154              0.094179             0.077403
75%                0.217404              0.183490             0.234448
max                1.846885              2.144010             2.645649

       imag_Jmag_Hmag_Kmag  Hamag_Jmag_Hmag_Kmag
count          1007.000000           1007.000000
mean             -0.102300             -0.194661
std               0.848137              1.229256
min              -4.619286             -7.264935
25%              -0.394214             -0.599403
50%              -0.086571             -0.155636
75%               0.203929              0.240981
max               7.194857             10.285442

[8 rows x 70 columns]
```

[12]:
```
sn.heatmap(q_df.corr().abs())
_=plt.title("abs(Correlation) between q4-features (calculated with same system␣
 ↪magnitudes)")
```



[13]:
```
q_dfy=pd.concat([q_df,y],axis=1)
sn.pairplot(q_dfy,hue="em")
_=plt.suptitle("Scatter plots between q4-features (calculated with same system␣
 ↪magnitudes)")
```