psearch_py_nb

May 10, 2018

psearch_py_nb.ipynb (V0.5): Jupyter notebook for the Python module psearch_py.py

Kenneth Mighell (mighell at noao dot edu)
2018 May 10

```
In [1]: %matplotlib inline
        import matplotlib.pyplot as plt
```

```
In [2]: # import the psearch_py module (psearch_py.py, optional: psearch_pyc.so)
        # The Python/Cython/C code of the psearch_py module is available at
        #     https://github.com/AbhijitSaha/Psearch/tree/master/psearch_py
        import psearch_py
```

```
In [3]: # Show the documentation (docstring) of the psearch_py function of the module
        print psearch_py.psearch_py.__doc__
```

```
    NAME:
        psearch_py

    INPUTS:
        hjd: time (Heliocentric Julian Day) input data array
        mag: magnitude input data array (co-alligned with hjd)
        magerr: magnitude error input data array (co-alligned with hjd)
        filts: filter input data array (co-aligned with hjd) with
            integer identifier indicating passband
        filtnams =  string array containing character names corresponding to
            coded filts values.  E.g., if you have 5 bands labeled u,g,r,i,z
            with filts values 0,1,2,3,4 respectively, filtnams would be set by:
            filtnams = ['u', 'g', 'r', 'i', 'z']
        pmin: Minimum value of period to be tested.
            E.g., pmin = 0.2
```

```
        dphi: Maximum change in relative phase between first and last epoch to
            be permitted when stepping to next test period.
            E.g., dphi = 0.02

    OUTPUTS:
        ptest: 1-D array with N dimensions of periods for which the periodograms
            are computed.  It is the same for ALL bands/channels.
        psi_m: M x N array of the Psi periodogram, where M is the number of
            bands/channels in the input array filtnams
        thresh_m: M x N array containing threshold values of Psi at each period
            and band for assessing significance for psi_m

    ORIGINAL IDL DEFINITION:
        pro Psearch, hjd, mag, magerr, filts, filtnams, pmin, dphi, ptest, $
            psi_m, thresh_m
```

```
In [4]: # Show the references for this module
        psearch_py.reference()
```

```
Saha, A., & Vivas, A. K. 2017, Astronomical Journal, 154, 231;
    "A Hybrid Algorithm for Period Analysis from Multiband Data with
    Sparse and Irregular Sampling for Arbitrary Light-curve Shapes"
IDL CODE (Abhijit Saha):
    https://github.com/AbhijitSaha/Psearch
PYTHON/CYTHON/C CODE (Kenenth Mighell):
    https://github.com/AbhijitSaha/Psearch/psearch_py

MODULE:
    /private/tmp/Psearch-master/psearch_py/psearch_py.pyc
    [psearch_py (0.19.4)  mode: Python/Cython/C  (*** fast ***) ]
```

Please read the article of **Saha & Vivas (2017, AJ, 154, 231)** for details of the Psearch algorithm.

If you can not get the article, get and read the *preprint* at
https://arxiv.org/abs/1709.10156

The original IDL code is available at
https://github.com/AbhijitSaha/Psearch

The Python/Cython/C code is available at
https://github.com/AbhijitSaha/Psearch/tree/master/psearch_py

---

In [5]:
```
# Initialize the notebook environment
import numpy as np
import time as tm
import sys
import IPython

if (sys.version_info >= (3, 0)):
    sys.stdout.write("\n\n*** ERROR *** This module requires Python 2.X, " +
        "not Python 3.X\n\n")
    sys.exit(1)
```

In [6]:
```
# Get some data
# ugriz DECam observations of ab-type RR Lyrae star OGLE-BLG-RRLYR-11078
# P=0.5016240 days (Soszynski et al. 2014, Acta Astronomica, 64, 177)
ifile = 'B1392all.tab'
#============================
hjd_, mag_, magerr_, filts_ = np.loadtxt( ifile, unpack=True)[:4]
ok = (magerr_ > 0.0 ) & (magerr_ <= 0.2)
hjd0    = hjd_[ok]
mag0    = mag_[ok]
magerr0 = magerr_[ok]
filts0  = filts_[ok]
print len(mag0),' good data points found out of', len(mag_)
```

```
368  good data points found out of 373
```

In [7]:
```
# Select some fraction of the good data set
prob_cut = 1.000  # 100% --> all the data
#prob_cut = 0.5    #  50% --> half of the data
prob = np.random.rand( len(hjd0) )
idx = (prob <= prob_cut)
hjd    = hjd0[idx]
mag    = mag0[idx]
magerr = magerr0[idx]
filts  = filts0[idx]
print len(mag),' data points'
```

```
368  data points
```

In [8]:
```
# Set pmin, dphi, and filtnams
pmin = 0.20
dphi = 0.02
filtnams = ['u', 'g', 'r', 'i', 'z']
```

In [9]:
```
# And away we go!
time00 = tm.time()
periods, psi_m, thresh_m = \
    psearch_py.psearch_py( hjd, mag, magerr, filts, filtnams, pmin, dphi )
time01 = tm.time()
print '\n\n%8.3f seconds [walltime for psearch_py]\n' % (time01-time00)
```

```
psearch: BEGIN ======================================================

REFERENCE:

Saha, A., & Vivas, A. K. 2017, Astronomical Journal, 154, 231;
    "A Hybrid Algorithm for Period Analysis from Multiband Data with
    Sparse and Irregular Sampling for Arbitrary Light-curve Shapes"
IDL CODE (Abhijit Saha):
    https://github.com/AbhijitSaha/Psearch
PYTHON/CYTHON/C CODE (Kenenth Mighell):
    https://github.com/AbhijitSaha/Psearch/psearch_py

MODULE:
    /private/tmp/Psearch-master/psearch_py/psearch_py.pyc
    [psearch_py (0.19.4)  mode: Python/Cython/C  (*** fast ***) ]

psearch:  u  filter
periodpsi2: BEGIN
periodpsi2:  57  observations
periodpsi2: number of frequency samples =  173211
scargle: DONE     0.792 seconds
scargle: DONE     0.793 seconds
scargle: DONE     0.788 seconds
ctheta_slave: DONE     0.529 seconds
ctheta_slave: DONE     0.529 seconds
ctheta_slave: DONE     0.531 seconds
periodpsi2: END
TABLE: BEGIN
rank   -----Period [days]-----       Psi    index  Frequency  Thresh
 1     0.5012330 +-  0.0000036    203.18    69054   1.995080    4.63
 2     0.5012475 +-  0.0000036    181.99    69052   1.995023    4.27
 3     0.5016102 +-  0.0000036    177.32    69002   1.993580    4.07
 4     0.5020025 +-  0.0000036    165.71    68948   1.992022    2.28
 5     0.5016392 +-  0.0000036    165.16    68998   1.993465    3.11
 6     1.0108859 +-  0.0000147    150.45    34189   0.989231    3.23
```

```
 7     0.5008636 +-  0.0000036    144.50    69105   1.996552    4.96
 8     1.0093552 +-  0.0000147    143.58    34241   0.990732    4.30
 9     0.5019734 +-  0.0000036    133.21    68952   1.992138    2.28
10     0.5015811 +-  0.0000036    132.89    69006   1.993695    4.32
TABLE: END
psearch:  g  filter
periodpsi2: BEGIN
periodpsi2:  68  observations
periodpsi2: number of frequency samples =  173211
scargle: DONE     0.939 seconds
scargle: DONE     0.938 seconds
scargle: DONE     0.938 seconds
ctheta_slave: DONE     0.656 seconds
ctheta_slave: DONE     0.659 seconds
ctheta_slave: DONE     0.656 seconds
periodpsi2: END
TABLE: BEGIN
rank   -----Period [days]-----       Psi    index  Frequency  Thresh
 1     0.5016247 +-  0.0000036    834.53    69000   1.993522    1.20
 2     0.5020025 +-  0.0000036    599.93    68948   1.992022    1.22
 3     0.5012402 +-  0.0000036    518.81    69053   1.995051    1.56
 4     0.5023808 +-  0.0000036    373.32    68896   1.990522    1.52
 5     0.5024026 +-  0.0000036    295.81    68893   1.990435    1.68
 6     0.5008636 +-  0.0000036    261.72    69105   1.996552    2.34
 7     1.0047616 +-  0.0000146    257.38    34398   0.995261    4.47
 8     1.0093552 +-  0.0000147    243.13    34241   0.990732    1.45
 9     1.0078291 +-  0.0000147    230.33    34293   0.992232    2.83
10     1.0063076 +-  0.0000146    215.26    34345   0.993732    4.54
TABLE: END
psearch:  r  filter
periodpsi2: BEGIN
periodpsi2:  69  observations
periodpsi2: number of frequency samples =  173211
scargle: DONE     0.949 seconds
scargle: DONE     0.946 seconds
scargle: DONE     0.945 seconds
ctheta_slave: DONE     0.664 seconds
ctheta_slave: DONE     0.670 seconds
ctheta_slave: DONE     0.664 seconds
periodpsi2: END
TABLE: BEGIN
rank   -----Period [days]-----       Psi    index  Frequency  Thresh
 1     0.5016247 +-  0.0000036    834.08    69000   1.993522    4.52
 2     0.5012475 +-  0.0000036    766.45    69052   1.995023    3.55
 3     0.5020025 +-  0.0000036    453.85    68948   1.992022    5.33
 4     0.5008636 +-  0.0000036    429.24    69105   1.996552    3.19
 5     0.5020170 +-  0.0000036    414.18    68946   1.991964    5.50
 6     0.5023808 +-  0.0000036    268.97    68896   1.990522    6.44
```

```
 7     0.5024026 +-  0.0000036    247.39    68893   1.990435    6.80
 8     0.5012257 +-  0.0000036    192.32    69055   1.995109    3.07
 9     1.0047616 +-  0.0000146    183.17    34398   0.995261    1.39
10     1.0032494 +-  0.0000145    181.23    34450   0.996761    1.26
TABLE: END
psearch:  i  filter
periodpsi2: BEGIN
periodpsi2:  94  observations
periodpsi2: number of frequency samples =  173211
scargle: DONE     1.287 seconds
scargle: DONE     1.285 seconds
scargle: DONE     1.285 seconds
ctheta_slave: DONE     0.926 seconds
ctheta_slave: DONE     0.927 seconds
ctheta_slave: DONE     0.924 seconds
periodpsi2: END
TABLE: BEGIN
rank   -----Period [days]-----       Psi    index  Frequency  Thresh
 1     0.5016247 +-  0.0000036    972.54    69000   1.993522   13.06
 2     0.5020170 +-  0.0000036    648.29    68946   1.991964   13.47
 3     0.5012402 +-  0.0000036    551.07    69053   1.995051   13.35
 4     0.5008564 +-  0.0000036    348.90    69106   1.996580    9.46
 5     0.5024026 +-  0.0000036    291.71    68893   1.990435   12.32
 6     0.3339042 +-  0.0000016    256.80   103709   2.994871   10.75
 7     0.3338978 +-  0.0000016    207.73   103711   2.994928   13.07
 8     0.3337274 +-  0.0000016    207.40   103764   2.996457   10.19
 9     1.0032494 +-  0.0000145    204.03    34450   0.996761    9.67
10     0.5015594 +-  0.0000036    197.32    69009   1.993782    9.51
TABLE: END
psearch:  z  filter
periodpsi2: BEGIN
periodpsi2:  80  observations
periodpsi2: number of frequency samples =  173211
scargle: DONE     1.106 seconds
scargle: DONE     1.104 seconds
scargle: DONE     1.107 seconds
ctheta_slave: DONE     0.774 seconds
ctheta_slave: DONE     0.774 seconds
ctheta_slave: DONE     0.778 seconds
periodpsi2: END
TABLE: BEGIN
rank   -----Period [days]-----       Psi    index  Frequency  Thresh
 1     0.5016247 +-  0.0000036    598.15    69000   1.993522    6.48
 2     0.5020170 +-  0.0000036    470.46    68946   1.991964    5.60
 3     0.5012402 +-  0.0000036    464.76    69053   1.995051    7.49
 4     0.5024026 +-  0.0000036    272.20    68893   1.990435    5.11
 5     0.5008564 +-  0.0000036    219.98    69106   1.996580    8.72
 6     0.3339042 +-  0.0000016    181.06   103709   2.994871    4.97
```

```
 7     0.5027962 +-  0.0000036    133.10    68839   1.988878    6.38
 8     0.3337339 +-  0.0000016    121.28   103762   2.996400    4.48
 9     0.5015521 +-  0.0000036     99.58    69010   1.993811    4.67
10     0.3337210 +-  0.0000016     99.46   103766   2.996515    5.19
TABLE: END

========== ALL FILTERS ==========

TABLE: BEGIN
rank   -----Period [days]-----       Psi    index  Frequency  Thresh
 1     0.5016247 +-  0.0000036   3411.90    69000   1.993522   28.86
 2     0.5012402 +-  0.0000036   2324.19    69053   1.995051   29.96
 3     0.5020170 +-  0.0000036   2149.13    68946   1.991964   27.98
 4     0.5024026 +-  0.0000036   1204.91    68893   1.990435   26.84
 5     0.5008636 +-  0.0000036   1173.50    69105   1.996552   30.15
 6     0.3339042 +-  0.0000016    836.99   103709   2.994871   28.00
 7     1.0032494 +-  0.0000145    709.01    34450   0.996761   24.84
 8     1.0093552 +-  0.0000147    669.49    34241   0.990732   27.00
 9     1.0047907 +-  0.0000146    663.95    34397   0.995232   28.47
10     1.0108859 +-  0.0000147    597.45    34189   0.989231   25.23
TABLE: END

Reference:

Saha, A., & Vivas, A. K. 2017, Astronomical Journal, 154, 231;
    "A Hybrid Algorithm for Period Analysis from Multiband Data with
    Sparse and Irregular Sampling for Arbitrary Light-curve Shapes"
IDL CODE (Abhijit Saha):
    https://github.com/AbhijitSaha/Psearch
PYTHON/CYTHON/C CODE (Kenenth Mighell):
    https://github.com/AbhijitSaha/Psearch/psearch_py

MODULE:
    /private/tmp/Psearch-master/psearch_py/psearch_py.pyc
    [psearch_py (0.19.4)  mode: Python/Cython/C  (*** fast ***) ]

psearch: END ==========================================================


  27.209 seconds [walltime for psearch_py]
```

In [10]:
```
# Show the top 10 peaks of the combined Psi distribution
psearch_py.table_psi_kjm_py( xx=periods, yy=psi_m.sum(0), ee=thresh_m.sum(0), n=10 )
```

```
TABLE: BEGIN
```

```
rank    -----Period [days]-----        Psi     index  Frequency  Thresh
 1     0.5016247 +-  0.0000036   3411.90     69000   1.993522   28.86
 2     0.5012402 +-  0.0000036   2324.19     69053   1.995051   29.96
 3     0.5020170 +-  0.0000036   2149.13     68946   1.991964   27.98
 4     0.5024026 +-  0.0000036   1204.91     68893   1.990435   26.84
 5     0.5008636 +-  0.0000036   1173.50     69105   1.996552   30.15
 6     0.3339042 +-  0.0000016    836.99    103709   2.994871   28.00
 7     1.0032494 +-  0.0000145    709.01     34450   0.996761   24.84
 8     1.0093552 +-  0.0000147    669.49     34241   0.990732   27.00
 9     1.0047907 +-  0.0000146    663.95     34397   0.995232   28.47
10     1.0108859 +-  0.0000147    597.45     34189   0.989231   25.23
TABLE: END
```

The rank=1 result in the above table gives the best period estimate:

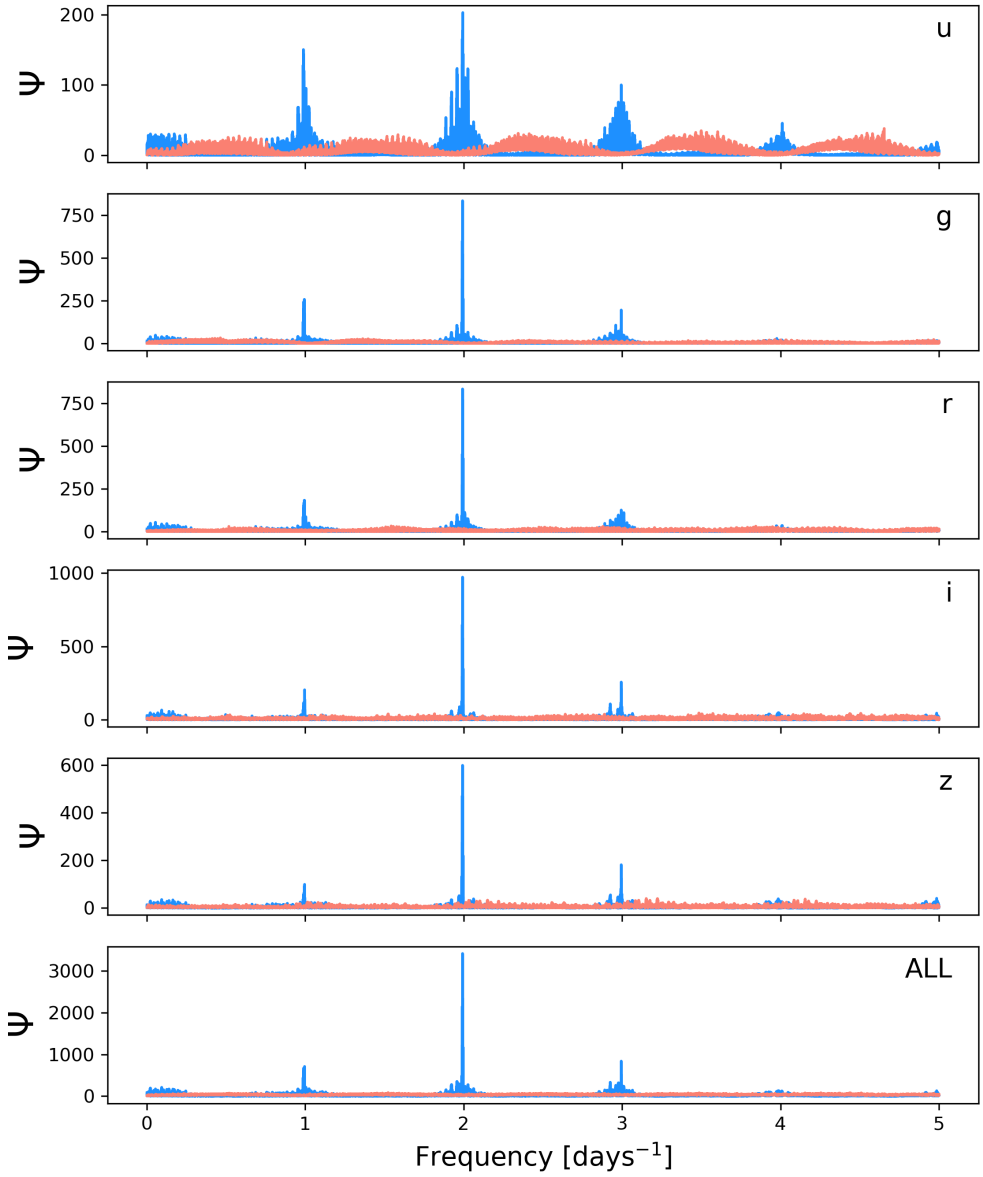
Period = 0.5016247 +- 0.0000036 days

which is a frequency of 1.993522.

```
In [11]: # Plot Psi vs. Frequency for all filters
         tag = ifile+'     '+'%7.2f%%' % (prob_cut*100.0)
         plot1 = 'psearch_fig_psi.png'
         psearch_py.fig_psi_kjm_py( 1/periods, psi_m, thresh_m, filtnams, tag=tag,
             plotfile=plot1 )
         IPython.display.Image(filename=plot1,width=600)

psearch_fig_psi.png  <--- plotfile written  :-)


Out[11]:
```




```
In [12]: # Period of the strongest peak of the combined Psi distribution
         idx = np.argmax(psi_m.sum(0))
```

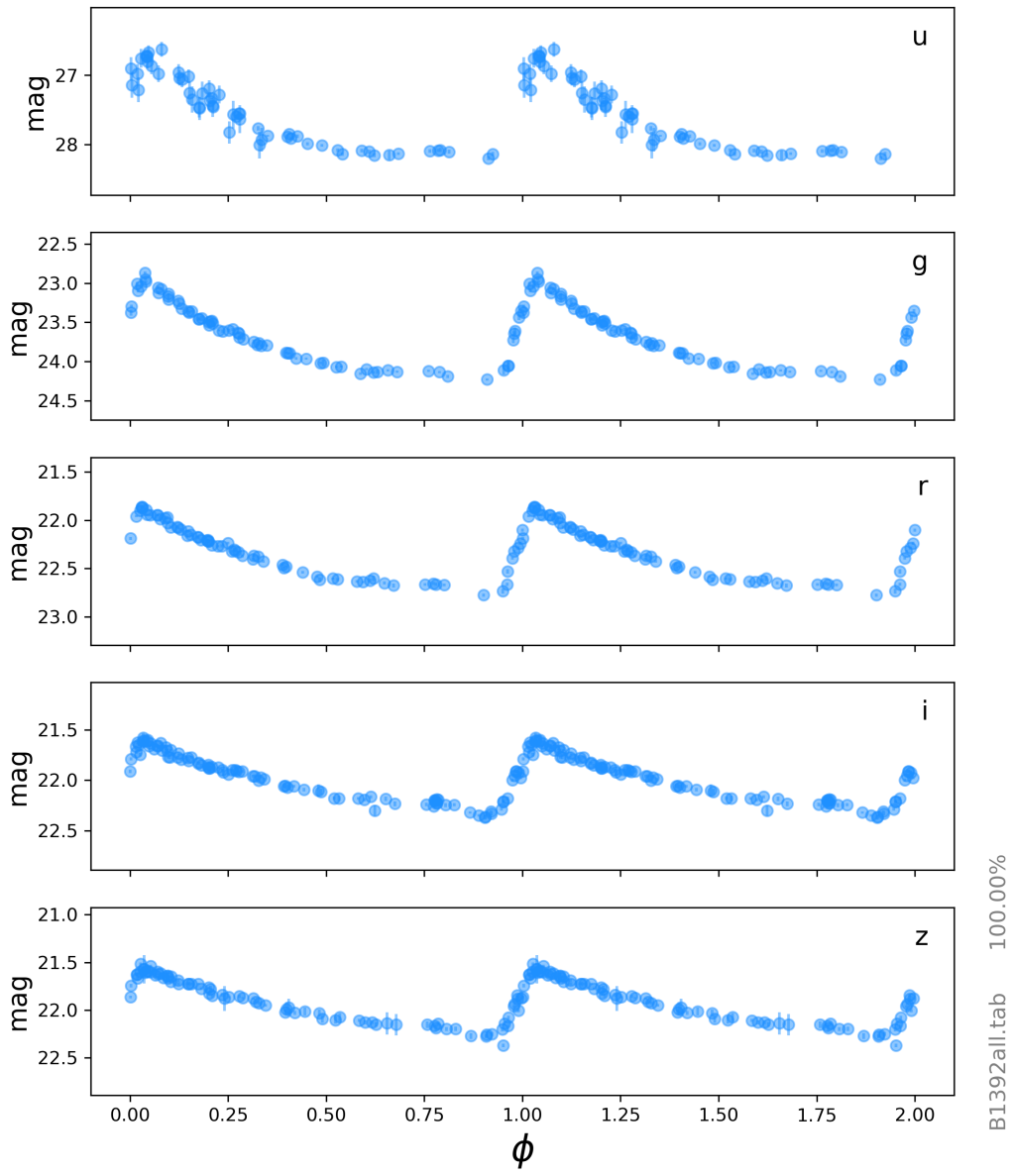
```
        p_peak = periods[idx]
        print '\nPeriod: %9.6f' % p_peak
```

```
Period:  0.501625
```

In [13]:
```
        # Plot phased light curves for all filters
        plot2 = 'psearch_fig_phi.png'
        psearch_py.fig_phi_kjm_py( hjd, mag, magerr, filts, filtnams, period=p_peak,
            tag=tag, plotfile=plot2 )
        IPython.display.Image(filename=plot2,width=600)
```

```
psearch_fig_phi.png  <--- plotfile written  :-)
```

Out[13]:

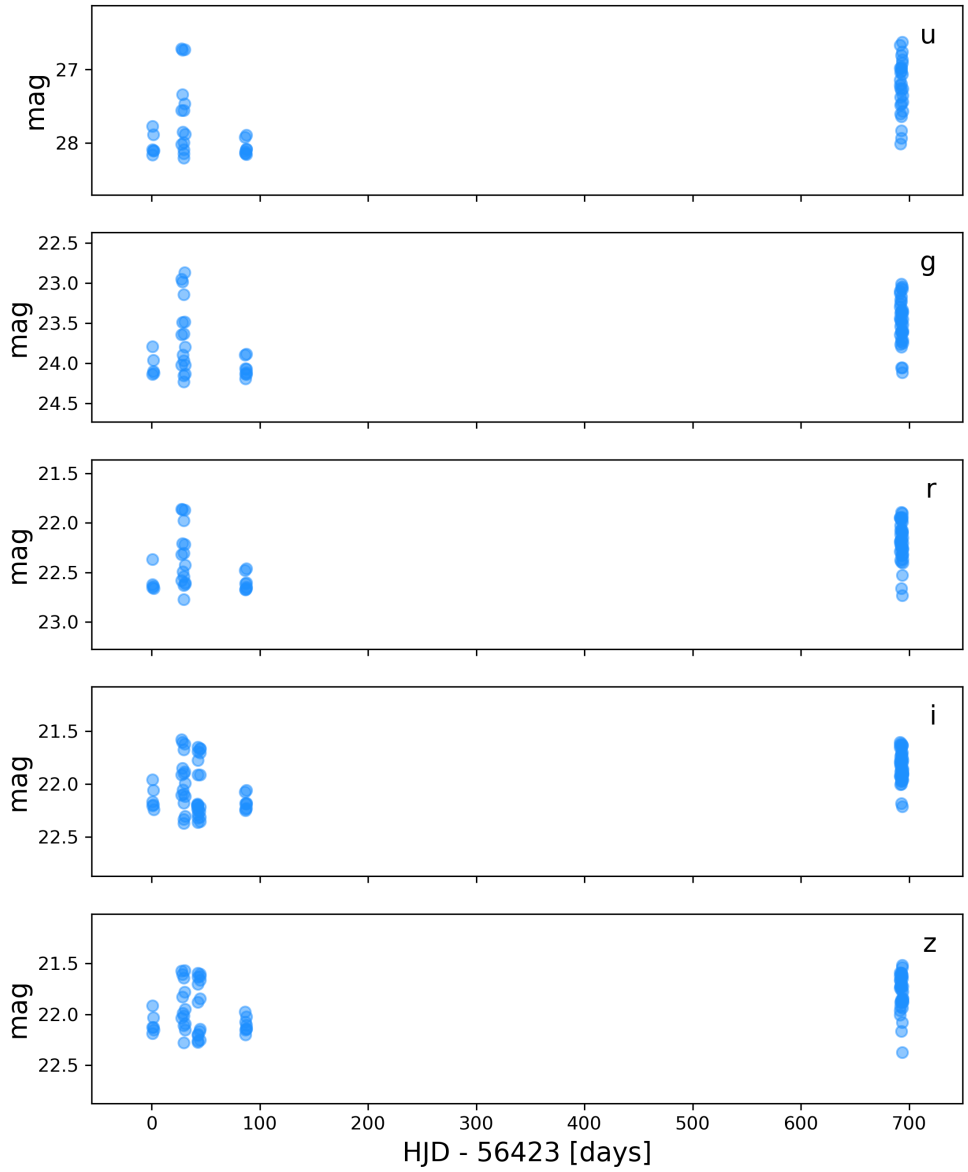


In [14]:
```
# Plot HJD vs. magnitude for all filters
plot3 = 'psearch_fig_obs.png'
```

```
        psearch_py.fig_obs_kjm_py( hjd, mag, filts, filtnams, tag=tag, plotfile=plot3)
        IPython.display.Image(filename=plot3,width=600)
```

```
psearch_fig_obs.png  <--- plotfile written  :-)
```

Out[14]:




```
In [15]: print "That's all folks!\n\n:-)"
```

```
That's all folks!

:-)
```