In [4]:
```
import PALpulsarInit
import bayesutils as bu
import os, sys, glob
import numpy as np
import h5py as h5
import matplotlib.pyplot as plt
```

Getting Data into the HDF5 File Format

In [9]:
```
# run the help function for PALpulsarInit
!python PALpulsarInit.py -h
```

```
Usage: PALpulsarInit.py [options]

Options:
  -h, --help            show this help message and exit
  --parDir=PARDIR       Full path to par files (required)
  --timDir=TIMDIR       Full path to tim files (required)
  --noiseDir=NOISEDIR   Full path to noise files
  --outFile=OUTFILE     Full path to output filename (required)
  --distFile=DISTFILE   Full path to pulsar distance file
  --DMOFF=DMOFF         Turn on DMMODEL fitting
```

In [6]:
```
# first lets just get the actual data into the file
!python PALpulsarInit.py --parDir './mdc_data/partim/open1/' --timDir './mdc_data/partim/open1/'
```

```
WARNING [TIM1]: Please place MODE flags in the parameter file
WARNING: duplicated warnings have been supressed.
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=251469438580184544.000000
good=36028797018963968.000000
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=251469439262882464.000000
good=36028797018963968.000000
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=251469439263602336.000000
good=36028797018963968.000000
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=251469439263200448.000000
good=36028797018963968.000000
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=251469439263027584.000000
good=36028797018963968.000000
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=251469439263120992.000000
good=36028797018963968.000000
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=251469439263195232.000000
good=36028797018963968.000000
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=251469439262550016.000000
```

```
good=36028797018963968.000000
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=25146943926319612 8.000000
good=36028797018963968.000000
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=25146943926273379 2.000000
good=36028797018963968.000000
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=25146943926311769 6.000000
good=36028797018963968.000000
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=25146943926284217 6.000000
good=36028797018963968.000000
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=25146943926281244 8.000000
good=36028797018963968.000000
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=25146943926319728 0.000000
good=36028797018963968.000000
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=25146943926288041 6.000000
good=36028797018963968.000000
******
ERROR [TKfit.C:176] Warning: wmax very large. Precision issues likely to break fit
wmax=25146943926313427 2.000000
good=36028797018963968.000000
```

In [10]:
```
# now lets read in the file
pfile = h5.File('./mdc_data/open1_demo.hdf5')
```

In [13]:
```
# we can look at which pulsars are in the data file
pfile['Data']['Pulsars'].keys()
```

Out[13]:
```
[u'J0030+0451',
 u'J0218+4232',
 u'J0437-4715',
 u'J0613-0200',
 u'J0621+1002',
 u'J0711-6830',
 u'J0751+1807',
 u'J0900-3144',
 u'J1012+5307',
 u'J1022+1001',
 u'J1024-0719',
 u'J1045-4509',
 u'J1455-3330',
 u'J1600-3053',
 u'J1603-7202',
 u'J1640+2224',
 u'J1643-1224',
 u'J1713+0747',
 u'J1730-2304',
 u'J1732-5049',
 u'J1738+0333',
 u'J1741+1351',
 u'J1744-1134',
```

```
 u'J1751-2857',
 u'J1853+1303',
 u'J1857+0943',
 u'J1909-3744',
 u'J1910+1256',
 u'J1918-0642',
 u'J1939+2134',
 u'J1955+2908',
 u'J2019+2425',
 u'J2124-3358',
 u'J2129-5721',
 u'J2145-0750',
 u'J2317+1439']
```

In [14]:
```
# then we can see what dataets we have for each pulsar
pfile['Data']['Pulsars']['J2317+1439'].keys()
```

Out[14]:
```
[u'TOAs',
 u'bands',
 u'designmatrix',
 u'freqs',
 u'parFile',
 u'pname',
 u'residuals',
 u'timFile',
 u'tmp_errpost',
 u'tmp_errpre',
 u'tmp_name',
 u'tmp_valpost',
 u'tmp_valpre',
 u'toaErr']
```

In [15]:
```
# all of the code in PAL relies on this hdf5 file then being read into a python class

# define the pulsargroup
pulsargroup = pfile['Data']['Pulsars']

# fill in pulsar class
psr = [PALpulsarInit.pulsar(pulsargroup[key]) for key in pulsargroup]
```

```
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
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WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
```

```
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
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WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
```
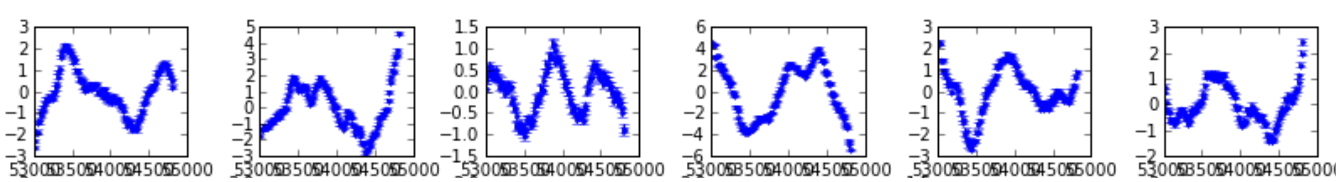
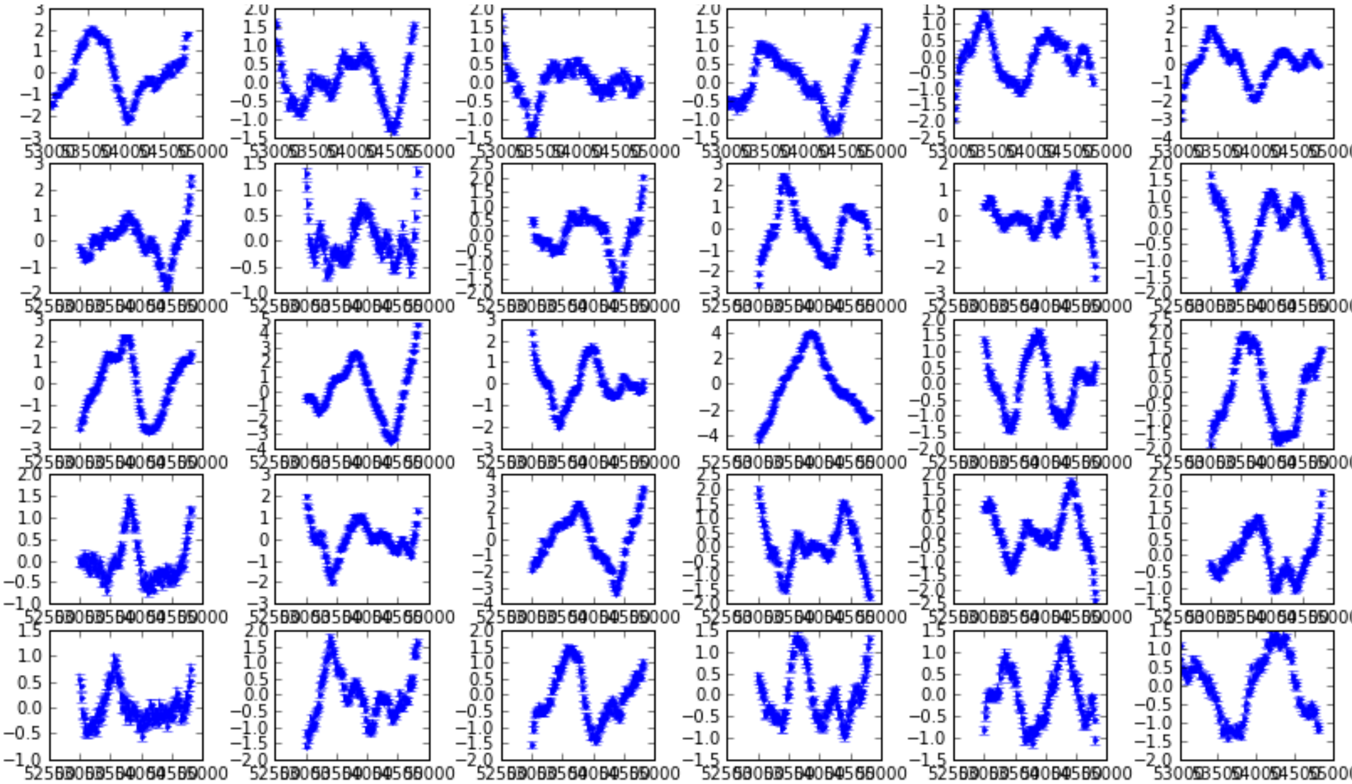

In [21]:

```
# this pulsar class works in a similar way but instead of using keys the datasets are just elemen
figure(figsize=(11.5, 8))
for ct, p in enumerate(psr):
    plt.subplot(6, 6, ct+1)
    plt.errorbar(p.toas/86400, p.res*1e6, p.err*1e6, fmt='.')

plt.tight_layout(h_pad=0.1, w_pad=0.1)
```





Running Noise Estimation

In [22]:
```
# at the moment I have a MultiNest and an MCMC implementation of the Hybrid Time-Frequency Methoc
!python testing/lentati_single_pulsar_noise.py -h
```

```
usage: lentati_single_pulsar_noise.py [-h] --h5File H5FILE [--outDir OUTDIR] --pulsar PNAME
                                      [--nmodes NMODES] [--powerlaw] [--fc] [--broken] [--
single]

Run Lentati style noise estimation

optional arguments:
  -h, --help         show this help message and exit
  --h5File H5FILE    Full path to hdf5 file containing PTA data
  --outDir OUTDIR    Full path to output directory (default = ./)
  --pulsar PNAME     name of pulsar to use
  --nmodes NMODES    number of fourier modes to use (default=10)
  --powerlaw         Use power law model (default = False)
  --fc               Use power law model with cross over frequency (default = False)
  --broken           Use power law with two spectral indices and a cross over frequency (default =
                     False)
  --single           Have one frequency and amplitude free to look for single frequency source
                     (default = False)
```

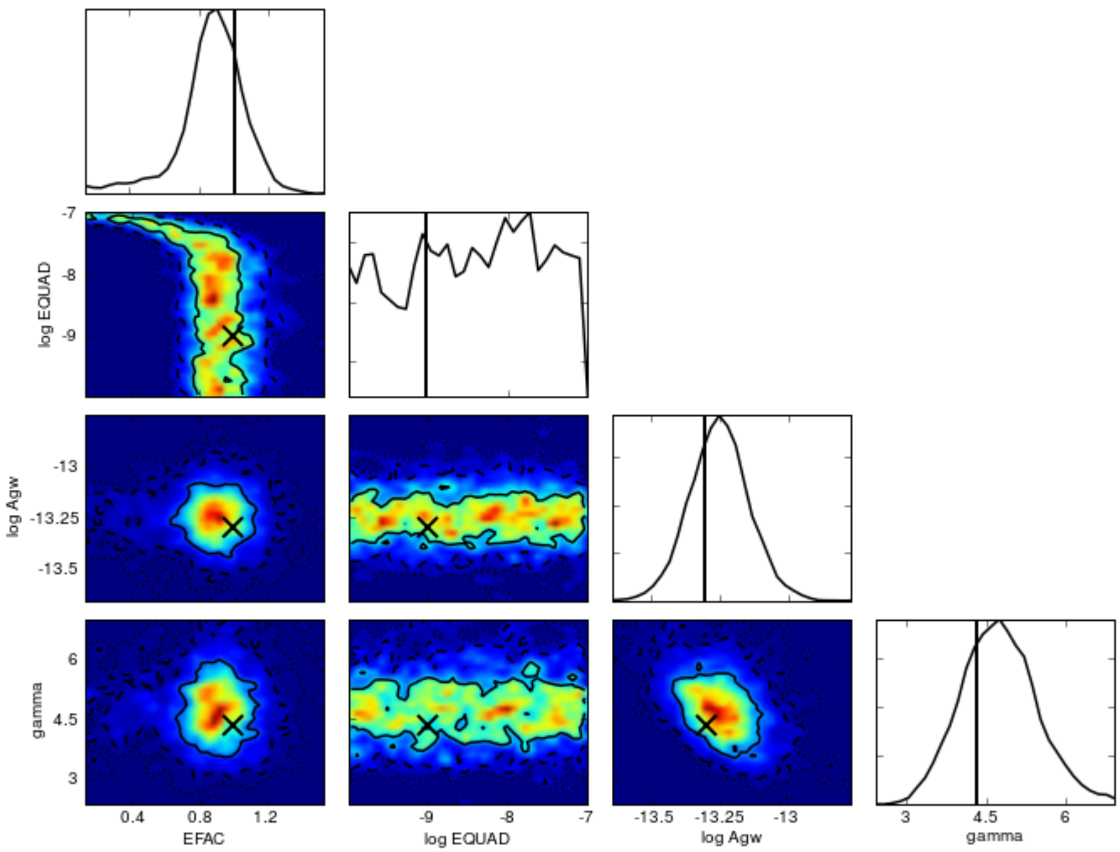
In [24]:
```
# run one of the MDC pulsars as an example
!python testing/lentati_single_pulsar_noise.py --h5File ./mdc_data/open1_demo.hdf5 --outDir demo_
```

```
Reading in HDF5 file
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
Parameterizing Power spectrum coefficients by a power law
 ****************************************************
 MultiNest v3.0
```

```
 Copyright Farhan Feroz & Mike Hobson
 Release Jun 2013

 no. of live points =  500
 dimensionality =    4
 running in constant efficiency mode
 *****************************************************
 Starting MultiNest
 generating live points
 live points generated, starting sampling
Acceptance Rate:                         0.994575
Replacements:                                 550
Total Samples:                                553
Nested Sampling ln(Z):                -440.906081
```

In [31]:

```
# now take a look at the results
d = np.loadtxt('demo_noise_results/powerlaw/J0030+0451/testpost_equal_weights.dat')

# since this is the open MDC we know the "true" values [efac, log equad, log Agw, gw power spectr
inj = [1.0, -9, np.log10(5e-14), 4.333]
label = ['EFAC', 'log EQUAD', 'log Agw', 'gamma']

# call the triplot function from bayesutils to take a look at the 1 and 2 dimensional marginalize
bu.triplot(d[:,:-1], inj=inj, labels=label)
```



In [32]:

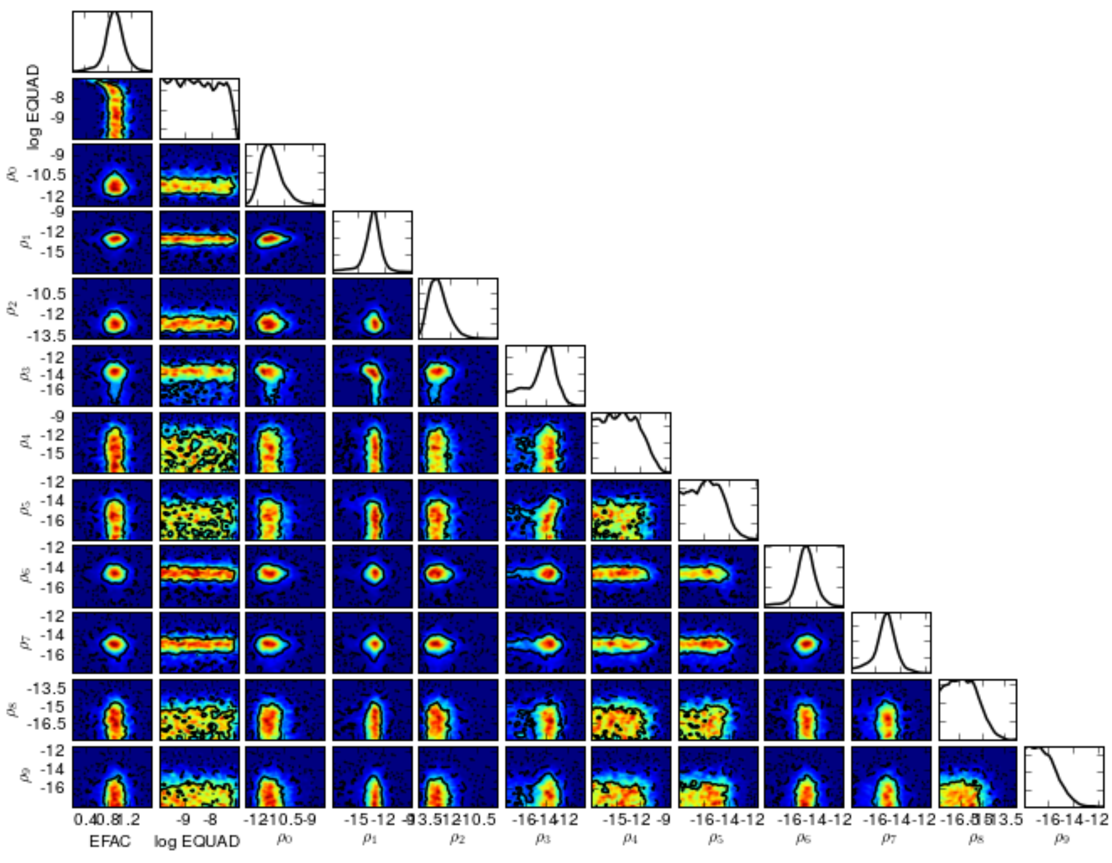
```
# we can also do this with the model-independent method
!python testing/lentati_single_pulsar_noise.py --h5File ./mdc_data/open1_demo.hdf5 --outDir demo_
```

```
Reading in HDF5 file
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
Parameterizing Power spectrum coefficients by 10 independent coefficients
```

```
 *****************************************************
 MultiNest v3.0
 Copyright Farhan Feroz & Mike Hobson
 Release Jun 2013

 no. of live points =  500
 dimensionality =   12
 running in constant efficiency mode
 *****************************************************
 Starting MultiNest
 generating live points
 live points generated, starting sampling
Acceptance Rate:                        0.994575
Replacements:                                550
Total Samples:                               553
Nested Sampling ln(Z):                1044.474952
```

In [37]:

```
# again we can make a triangle plot (it works for arbitrary size)
# now take a look at the results
d = np.loadtxt('demo_noise_results/independent/J0030+0451/testpost_equal_weights.dat')

# since this is the open MDC we know the "true" values
label = ['EFAC', 'log EQUAD']
for ii in range(d.shape[1]-3):
    label.append(r'$\rho_%s$'%(int(ii)))

bu.triplot(d[:,0:-1], labels=label)
```

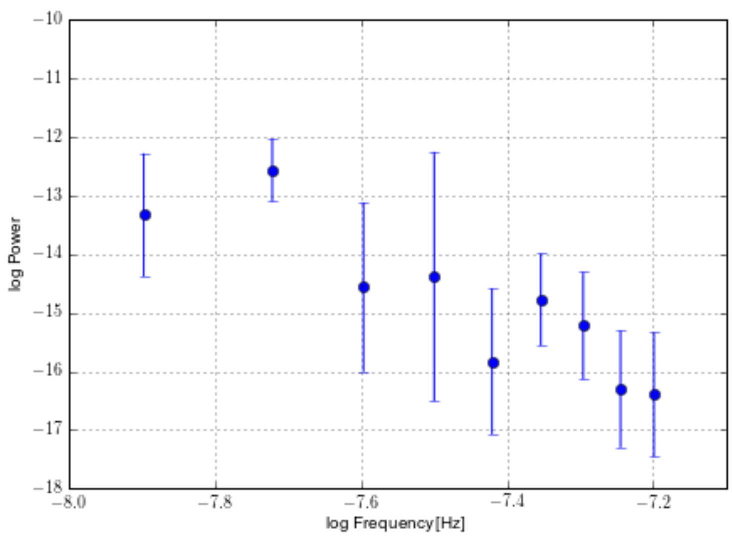


In [42]:

```
# we can also plot the power spectrum
nmodes = 10
T = 5 * 3.16e7     # 5 year data span
f = np.linspace(1/T, nmodes/T, nmodes)     # nyquist sampling
```

```
# log of power spectrum coefficients from output
lp = np.mean(d[:,2:-1], axis=0)
err = np.std(d[:,2:-1], axis=0)

# make plot
plt.figure(figsize=(7,5))
plt.errorbar(np.log10(f), lp, err, fmt='o')
plt.grid()
plt.xlim(-8.0, -7.1)
plt.xlabel('log Frequency [Hz]')
plt.ylabel('log Power')
```

Out[42]: <matplotlib.text.Text at 0x108f11ad0>



Getting Noise Values into HDF5 file

In [46]:
```
# at the moment I don't have any nice scripts to make out noise files
# after we have done noise estimation we need to make nosise par files
# for each pulsar. Currently PAL only supports the powerlaw format but
# this will be changed soon as I'm going to change the inner workings
# of PALpulsarInit.

# an example of a noise par file is
!cat ./mdc_data/open_mdc1_noise_files/J0030+0451.noise

# here the amplitude is in GW units gamma is the power spectral index, equad is in seconds and ef
```

```
Pname J0030+0451
Amp 5e-14
gam 4.33
equad 0
efac 1
```

In [48]:
```
# PALpulsarInit will recognize these keywords and store the noise values as well as the inverse c
# matrix term G (G^T C G)^-1 G^T for use in certain detection codes like the F-statistic

# for now we will need to delete our original hdf5 file in order to add the noise parameters
!rm ./mdc_data/open1_demo.hdf5

# run PALpulsarInit again
```

```
!python PALpulsarInit.py --parDir './mdc_data/partim/open1/' --timDir './mdc_data/partim/open1/'
```

```
J0030+0451.par J0030+0451.tim J0030+0451.noise
J0218+4232.par J0218+4232.tim J0218+4232.noise
J0437-4715.par J0437-4715.tim J0437-4715.noise
J0613-0200.par J0613-0200.tim J0613-0200.noise
J0621+1002.par J0621+1002.tim J0621+1002.noise
J0711-6830.par J0711-6830.tim J0711-6830.noise
J0751+1807.par J0751+1807.tim J0751+1807.noise
J0900-3144.par J0900-3144.tim J0900-3144.noise
J1012+5307.par J1012+5307.tim J1012+5307.noise
J1022+1001.par J1022+1001.tim J1022+1001.noise
J1024-0719.par J1024-0719.tim J1024-0719.noise
J1045-4509.par J1045-4509.tim J1045-4509.noise
J1455-3330.par J1455-3330.tim J1455-3330.noise
J1600-3053.par J1600-3053.tim J1600-3053.noise
J1603-7202.par J1603-7202.tim J1603-7202.noise
J1640+2224.par J1640+2224.tim J1640+2224.noise
J1643-1224.par J1643-1224.tim J1643-1224.noise
J1713+0747.par J1713+0747.tim J1713+0747.noise
J1730-2304.par J1730-2304.tim J1730-2304.noise
J1732-5049.par J1732-5049.tim J1732-5049.noise
```

Optimal Statistic and Cross Correlation Statistic

In [49]:

```
# run the help for the Optimal Statistic
!python PALOptimalStatistic.py -h
```

```
Usage: PALOptimalStatistic.py [options]

Run the Optimal-statistic stochastic BG code as                                 defined in
Chamberlin, Creighton, Demorest et al (2013)

Options:
  -h, --help            show this help message and exit
  --h5File=H5FILE       Full path to hdf5 file containing PTA data
  --outDir=OUTDIR       Full path to output directory (default = ./)
  --spectralIndex=GAM  Power spectral index of stochastic background (default = 4.3333 (SMBHBs))
```

In [50]:

```
# run it on open MDC 1
!python PALOptimalStatistic.py --h5File ./mdc_data/open1_demo.hdf5
```

```
Reading in HDF5 file
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
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WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
```

```
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
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WARNING: No distance error info, using sigma_d = 0.1 kpc
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WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
Computing Overlap Reduction Function Values
Running Optimal Statistic on 36 Pulsars
Results of Search

------------------------------------

A_gw^2 = 2.41138648053e-27
std. dev. = 1.82299549806e-28
SNR = 13.2276052415
SNR of 13.2276052415 is above threshold!
```

In [53]:
```
# if SNR < 3 then this function computes the upper limit based on the variance of the optimal sta

# get the value of the value of Agw
Agw = np.sqrt(2.41138648053e-27)
print Agw
```

```
4.91058701229e-14
```

In [54]:
```
# run the help for the cross correlation function basically the same as the Optimal Statistic
!python PALCrossCorrelationStatistic.py -h
```

```
Usage: PALCrossCorrelationStatistic.py [options]

Run the Cross Correlation statistic defined in
Demorest et al. (2012)

Options:
  -h, --help            show this help message and exit
  --h5File=H5FILE       Full path to hdf5 file containing PTA data
  --outDir=OUTDIR       Full path to output directory (default = ./)
  --spectralIndex=GAM   Power spectral index of stochastic background (default = 4.3333 (SMBHBs))
```

In [55]:
```
# run it
!python PALCrossCorrelationStatistic.py --h5File ./mdc_data/open1_demo.hdf5
```

```
Reading in HDF5 file
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
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WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
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WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
Computing Overlap Reduction Function Values
Running Cross correlation Statistic on 36 Pulsars
Results of Search

------------------------------------

A_gw^2 = 2.4113864814e-27
std. dev. = 1.82299549809e-28
Reduced Chi-squared = 0.933491011365
2-sigma upper limit based on chi-squared fit is A_gw < 5.20695934025e-14
```

In [57]:

```python
# get Agw
Agw = np.sqrt(2.4113864814e-27)    # same as Optimal Statistic!
print Agw
```

```
4.91058701318e-14
```

Simulating Data

In [59]:

```python
# run help for PALSimulation
!python PALSimulation.py -h
```

```
Usage: PALSimulation.py [options]

Simulate Fake Data (Under Construction)

Options:
```

```
  -h, --help            show this help message and exit
  --h5File=H5FILE       Full path to hdf5 file containing PTA data
  --outFile=OUTFILE     Full path to output filename
  --single              Add single source? (default = False)
  --nopterm             Dont include pulsar term in single source waveform? (default = False)
  --gwra=GWRA           GW Right Ascension (default = 1.0 radian)
  --gwdec=GWDEC         GW Declination (default = 0.5 radian)
  --gwinc=GWINC         GW inclination angle (default = 0.5 radian)
  --gwphase=GWPHASE     GW initial phase (default = 0.5 radian)
  --gwpolarization=GWPOLARIZATION
                        GW polarization angle (default = 0.5 radian)
  --gwchirpmass=GWCHIRPMASS
                        GW chirp mass (default = 5e8 Solar Masses)
  --gwmass1=GWMASS1     GW SMBMB mass 1 (default = None)
  --gwmass2=GWMASS2     GW SMBMB mass 2 (default = None)
  --gwdist=GWDIST       GW luminosity distance (default = 100 Mpc)
  --gwredshift=GWREDSHIFT
                        GW redshift of source (default = None)
  --gwfreq=GWFREQ       GW initial frequency (default = 1e-8 Hz)
  --snr=SNR             Single source SNR (default = None, use input GW distnace)
  --gwb                 Add stochastic background? (default = False)
  --gwbAmp=GWBAMP       GWB amplitude (default = 5e-15)
  --gwbIndex=GWBINDEX   GWB amplitude (default = 4.33)
  --noise               Add noise based on real data values? (default = False)
  --seed=SEED           Random number seed for noise realizations (default = 0, no seed)
  --DM                  Add DM based on real data values? (default = False)
  --tim=TIM             Output new tim files (default = None, dont output tim files)
```

In [63]:

```
# first lets simulate a single source with SNR=15 and just white noise for the pulsars in open1_c
!python PALSimulation.py --h5File './mdc_data/open1_demo.hdf5' --single --snr 15 --gwchirpmass 2e
```

```
Saving file to ./mdc_data/open1_demo_single.hdf5
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
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WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
```

In [66]:

```
# lets read the data into the pulsar class and take a look at the residuals
pfile = h5.File('./mdc_data/open1_demo_single.hdf5')

pulsargroup = pfile['Data']['Pulsars']

psr = [PALpulsarInit.pulsar(pulsargroup[key], addGmatrix=True, addNoise=True) for key in pulsargr
```

```
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
```

```
WARNING: No distance error info, using sigma_d = 0.1 kpc
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WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
```
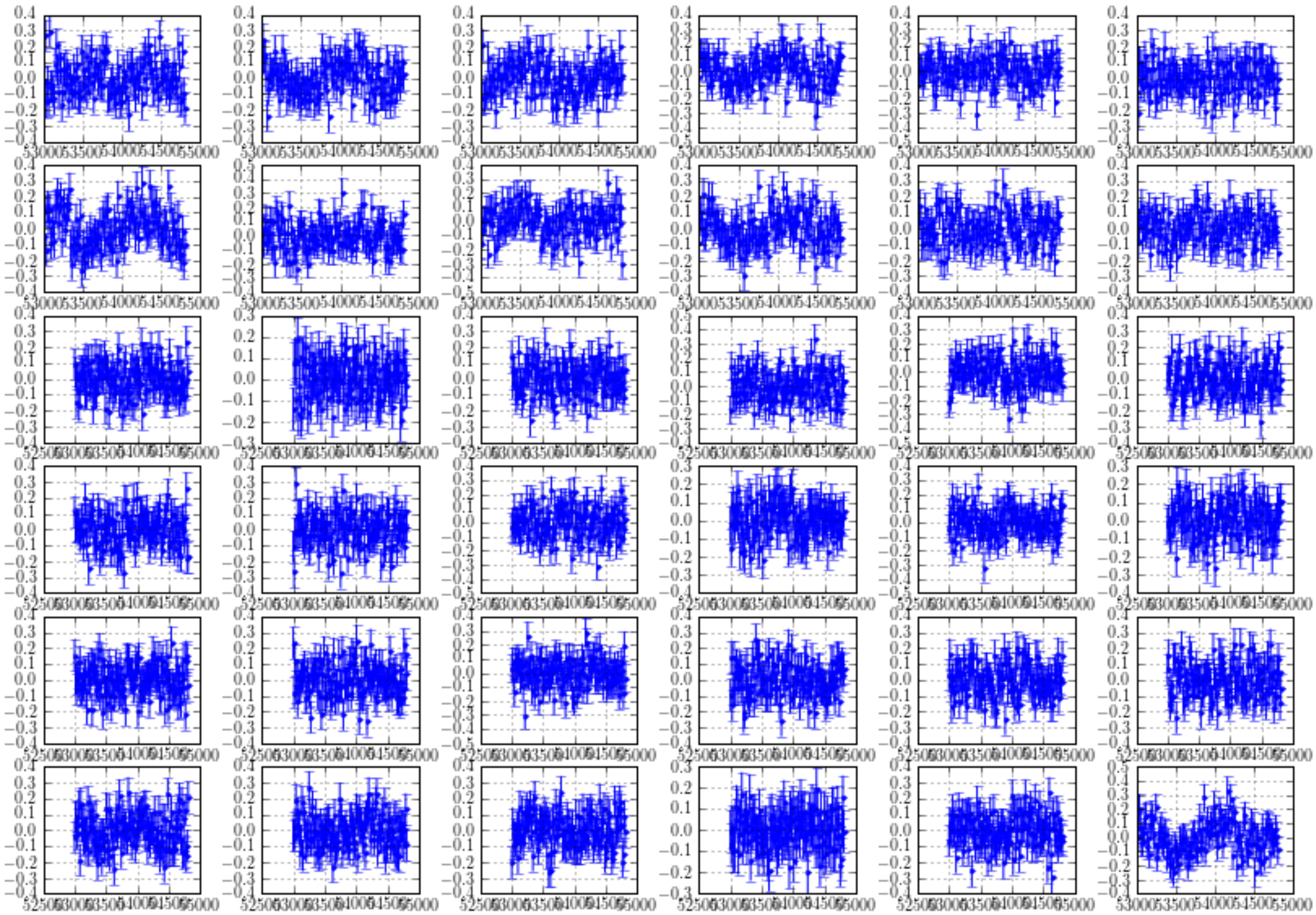

```
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
```

In [68]:
```
# plot it
figure(figsize=(11.5, 8))
for ct, p in enumerate(psr):
    plt.subplot(6, 6, ct+1)
    plt.errorbar(p.toas/86400, p.res*1e6, p.err*1e6, fmt='.')
    plt.grid()

plt.tight_layout(h_pad=0.1, w_pad=0.1)
```



In [70]:
```
# now lets simulate a stochastic background with Agw = 5e-15 with white noise
!python PALSimulation.py --h5File './mdc_data/open1_demo.hdf5' --outFile './mdc_data/open1_demo_g
```

```
Saving file to ./mdc_data/open1_demo_gwb.hdf5
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
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```

```
WARNING: No distance info, using d = 1 kpc
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WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
```

In [71]:

```
# again lets read in the data
# lets read the data into the pulsar class and take a look at the residuals
pfile = h5.File('./mdc_data/open1_demo_gwb.hdf5')

pulsargroup = pfile['Data']['Pulsars']

psr = [PALpulsarInit.pulsar(pulsargroup[key], addGmatrix=True, addNoise=True) for key in pulsargr
```

```
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
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WARNING: No distance info, using d = 1 kpc
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WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
```
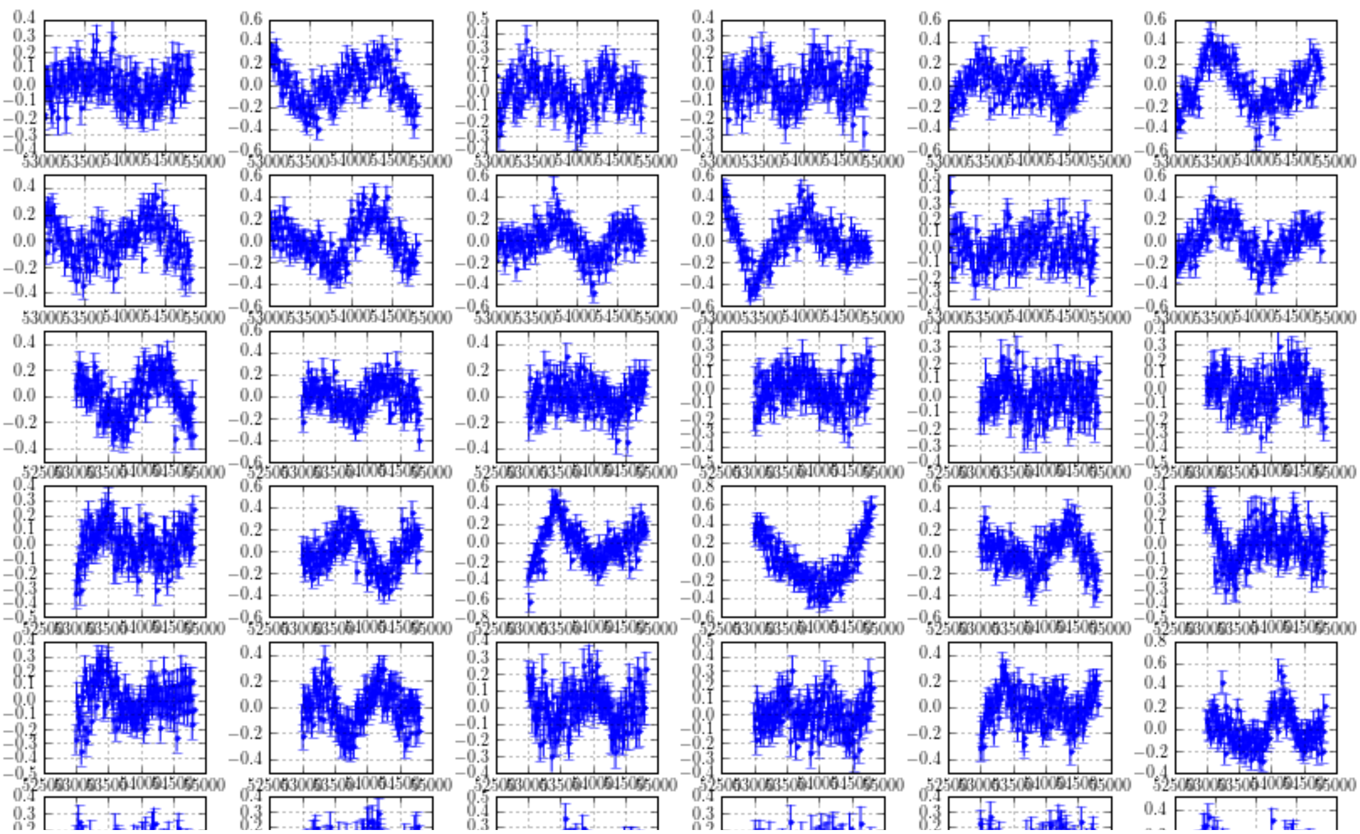
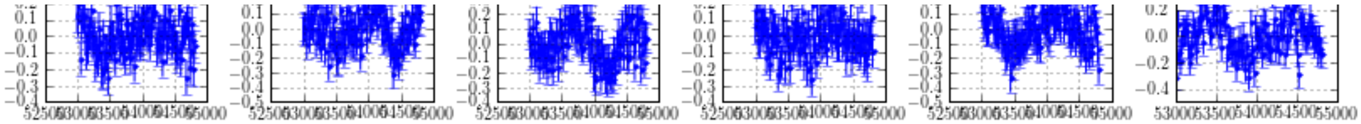

In [72]:

```
# and plot it

figure(figsize=(11.5, 8))
for ct, p in enumerate(psr):
    plt.subplot(6, 6, ct+1)
    plt.errorbar(p.toas/86400, p.res*1e6, p.err*1e6, fmt='.')
    plt.grid()

plt.tight_layout(h_pad=0.1, w_pad=0.1)
```





In [73]:
```
# finally for later lets simulate a single source and a stochastic background
!python PALSimulation.py --h5File './mdc_data/open1_demo.hdf5' --single --snr 15 --gwchirpmass 2e
```

```
Saving file to ./mdc_data/open1_demo_both.hdf5
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
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WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
```

In [74]:
```
# again lets read in the data
# lets read the data into the pulsar class and take a look at the residuals
pfile = h5.File('./mdc_data/open1_demo_both.hdf5')

pulsargroup = pfile['Data']['Pulsars']

psr = [PALpulsarInit.pulsar(pulsargroup[key], addGmatrix=True, addNoise=True) for key in pulsargr
```

```
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
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```

```
WARNING: No distance info, using d = 1 kpc
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WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
```
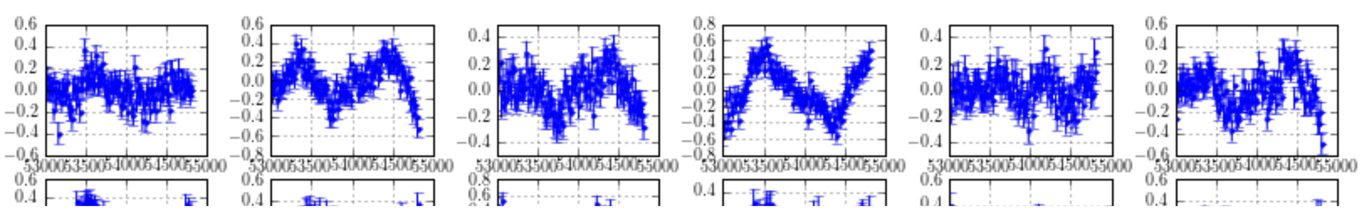
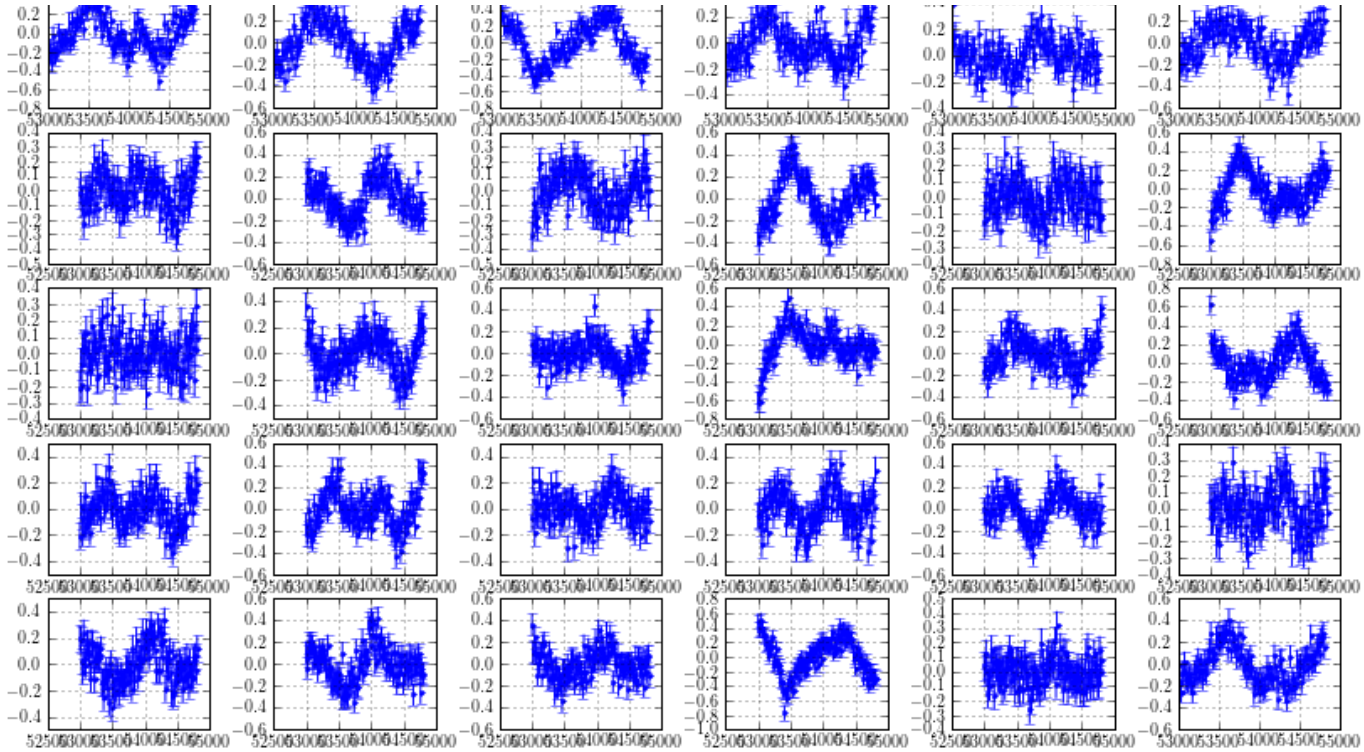

In [75]:

```
# and plot it

figure(figsize=(11.5, 8))
for ct, p in enumerate(psr):
    plt.subplot(6, 6, ct+1)
    plt.errorbar(p.toas/86400, p.res*1e6, p.err*1e6, fmt='.')
    plt.grid()

plt.tight_layout(h_pad=0.1, w_pad=0.1)
```





$\mathcal{F}_p$-Statistic

In [76]:
```
# run the help function
!python PALFstatistic.py -h
```

```
Usage: PALFstatistic.py [options]

Run F-statistic search as defined in Ellis, Siemens, Creighton (2012)

Options:
  -h, --help          show this help message and exit
  --h5File=H5FILE     Full path to hdf5 file containing PTA data
  --outDir=OUTDIR     Full path to output directory (default = ./)
  --runFpStat         Option to run Incoherent Fp Statistic (default = True)
  --runFeStat         Option to run Earth term Fe Statistic (default = False)
  --fhigh=FHIGH       Highest frequency to search (default = 5e-7 Hz)
  --nfreqs=NFREQS     Number of frequencies to search (default = 200)
  --logsample         Sample in log frequency (default = False)
  --best=BEST         Only use best pulsars based on weighted rms (default = 0, use all)
```

In [77]:
```
# we will run the Fp statistic on our simulated single source dataset
# normally we will have to do a noise estimation but we know that there
# is only white noise and PALSimulation used white noise by default
!python PALFstatistic.py --h5File ./mdc_data/open1_demo_single.hdf5 --logsample
```

```
Reading in HDF5 file
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
```

```
WARNING: No distance error info, using sigma_d = 0.1 kpc
WARNING: No distance info, using d = 1 kpc
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WARNING: No distance error info, using sigma_d = 0.1 kpc
Beginning Fp Search with 36 pulsars, with frequency range 3.20433591498e-09 -- 5e-07
Done Search. Computing False Alarm Probability
Writing results to file .//open1_demo_single.txt
```
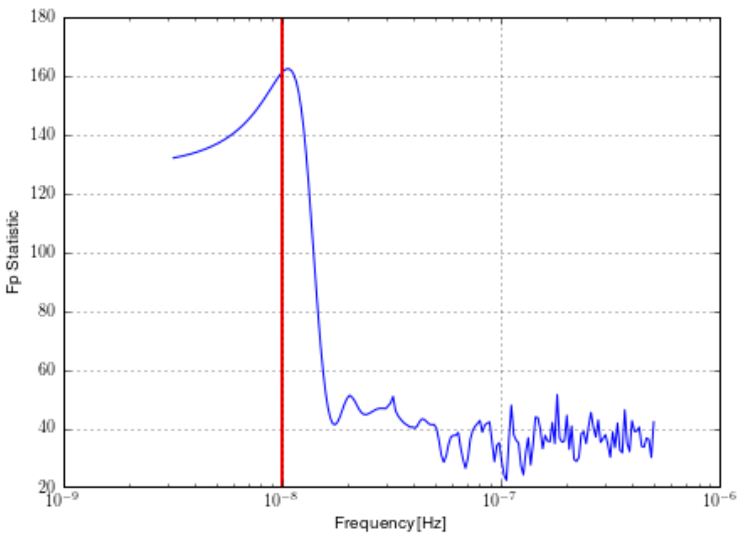

In [79]:
```
# read in the output file
d = np.loadtxt('open1_demo_single.txt')
```

In [87]:
```
# plot the Fp statistic vs frequency
plt.figure(figsize=(7,5))
plt.semilogx(d[:,0], d[:,1])
plt.grid()
plt.xlabel('Frequency [Hz]')
plt.ylabel('Fp Statistic')
plt.axvline(1e-8, lw=2, color='r')
```

Out[87]: <matplotlib.lines.Line2D at 0x1092abd10>



MCMC Single Source Search for Non-Evolving Sources

In [91]:
```
# run help function
!python testing/modelIndependent_time_domain_ss.py -h
```

```
usage: modelIndependent_time_domain_ss.py [-h] --h5File H5FILE [--outDir OUTDIR] [--best BEST]
                                          [--block BLOCK] [--scale SCALE] [--ntemps NTEMPS]
                                          [--nprocs NPROCS]

Run time domain single source MCMC

optional arguments:
  -h, --help         show this help message and exit
  --h5File H5FILE    Full path to hdf5 file containing PTA data
  --outDir OUTDIR    Full path to output directory (default = ./)
  --best BEST        Only use best pulsars based on weighted rms (default = 0, use all)
  --block BLOCK      How many parameters to update at each iteration (default = 0, use all)
  --scale SCALE      Scale factor on jump covariance matrix(default = 1, native scaling)
  --ntemps NTEMPS    Number of parallel temperature chains to run (default = 1)
  --nprocs NPROCS    Number of processors to use with parallel tempering (default = 1)
```

In [*]:
```
# run it
```

```
!python testing/modelIndependent time domain ss.py --h5File ./mdc data/open1 demo single.hdf5 --c
```

```
Reading in HDF5 file
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```

In [ ]: