pyBLoCXS Demo

Jenny Posson-Brown, on behalf of Vinay Kashyap
CXC/SAO

pyBLoCXS: MCMC-based algorithm for Bayesian Low-Count X-ray Spectral analysis in Sherpa. In CIAO as of v4.4.

(Brian Refsdal, Aneta Siemiginowska, David van Dyk, Taeyoung Park, Shandong Min, Jin Xu)

Allows for inclusion of calibration uncertainties in parameter estimation.

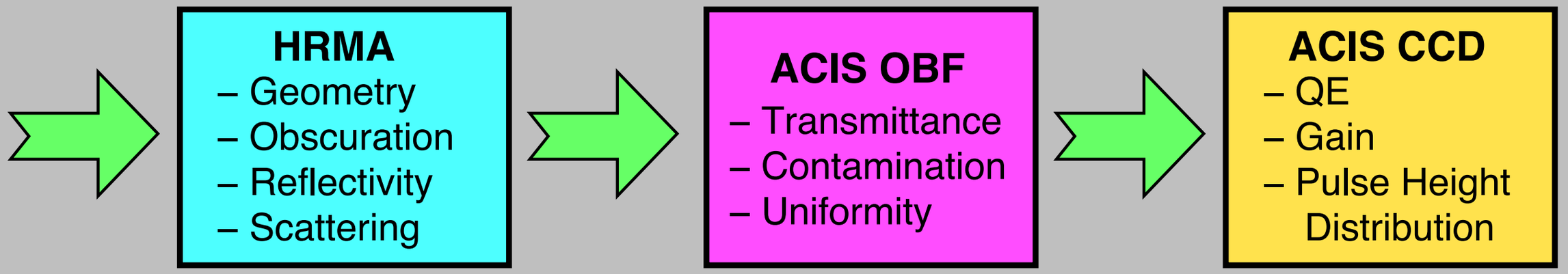
Step 1: Get MCCal script, which generates possible ARFs based on nominal ARF and calibration uncertainties (Jeremy Drake & Pete Ratzlaff)

http://hea-www.harvard.edu/~rpete/mccal/

(currently only for ACIS-S3, imaging, on-axis obs)

/proj/axaf/bin/perl mccal-1.0/arfmunge obs866_acis.arf obs866_00.arf

Main Uncertainties in Instrument Response: Chandra ACIS–S



random variations of input parameters

$\mu(.)$: multiplicative perturbative functions

$\Omega(\sigma)$: truncated Gaussian

– μ_H

– sample contam models

– vignetting $V(\theta)$ from

$\mu_V(E,\theta) = \Omega(\sigma_V)(1-V(\theta)) + \theta\ \Omega(\sigma_S)(1-R_{DW}/R)$

$\sigma_V, \sigma_S = 0.2$

– $\mu_{OBF}(E)$

– Contamination Layer

$\ln(\mu_{CL}(E)) = -\sum_X \Omega(\sigma_X)\tau_X$

$X \equiv C,O,F,Fl$

$\mu_{CL}(0.7\ keV) < 0.05$

– $\mu_{QE}(E)$

– 13% in CCD depletion depth and 20% in SiO_2 thickness

– $\Omega(\sigma_G)$, σ_G=1% @0.7 keV, 0.5% @1.5 keV, 0.2% @≥4 keV

Drake, et al., 2006, Proc. SPIE, 6270, 6270il

Step 2: Use n ARFs generated by MCCal to make ARF Error File (AREF).

IDL> .run samp2fits.pro

AREF FITS file has 2 extensions:

- SPECRESP : contains original response

- SIMCOMP: n rows, each w/ energy-dependent Δ response values

Step 3. Fit in Sherpa

Basic use (not including cal uncertainties):

– usual *Sherpa* set up

```
load_data("filename.pha")
ignore(":0.3,7.0:")
set_model(xsphabs.abs1*xspowerlaw.p1)
set_stat('cstat')
set_method('neldermead')
fit()
```

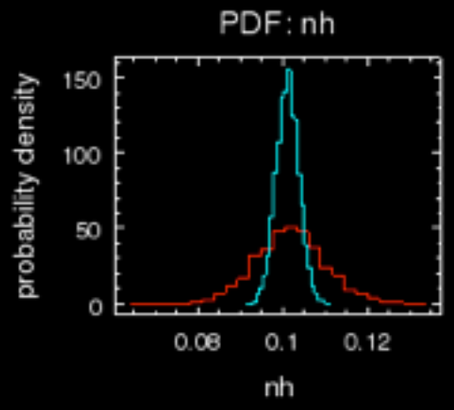
– this part calls the MCMC sampler

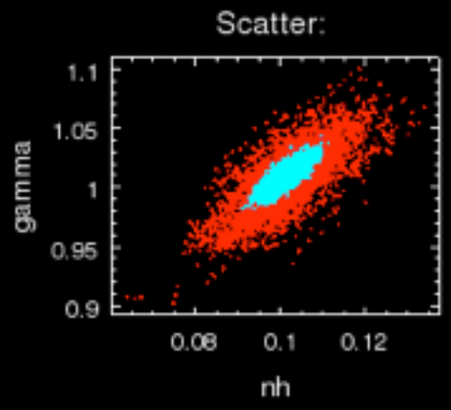
```
set_sampler("MetropolisMH") # also "MH"
stats, accept, params = get_draws(niter=1000)
bestfit = params[::,stats.argmin()].T
[params[i].std() for i in [0,1,2]]
```

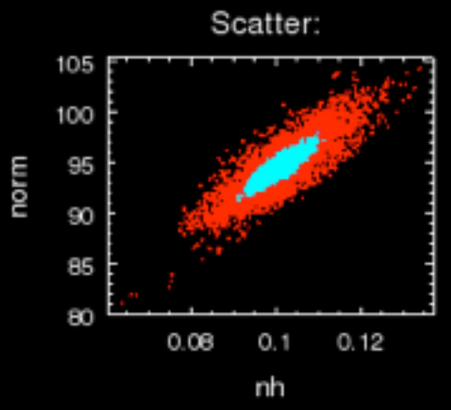
Including cal uncertainties, using ARF Error File:

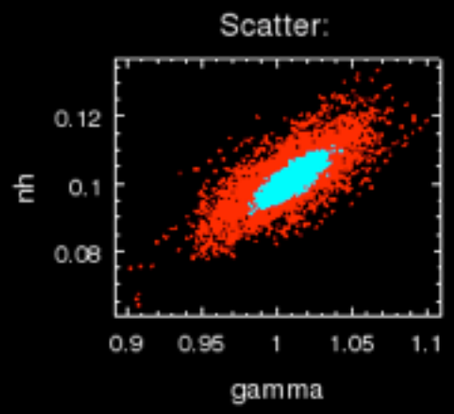
– set up as before, and then

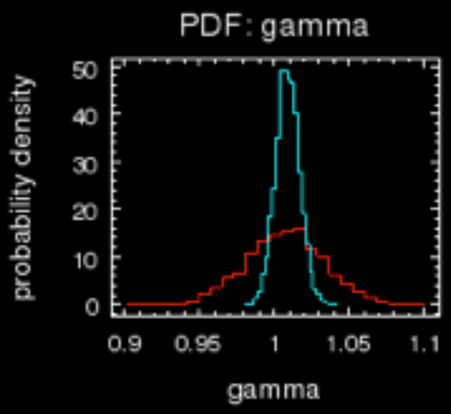
```
set_sampler("PragBayes")
set_sampler_opt('simarf',"aref_Cedge.fits")
set_sampler_opt('p_M',0.5)
stats_sim, accept_sim, params_sim = get_draws(niter=1e3)
bestfit_sim = params_sim[::,stats_sim.argmin()].T
[params_sim[i].std() for i in [0,1,2]]
```

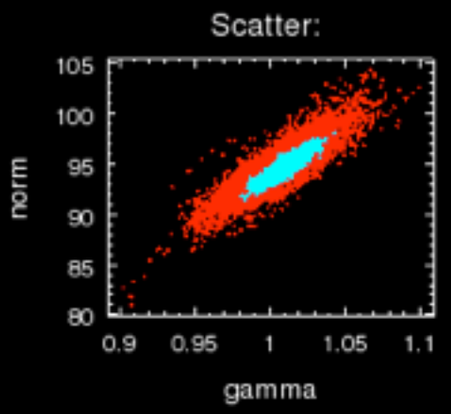

PDF: nh
probability density
150
100
50
0
0.08
0.1
0.12
nh

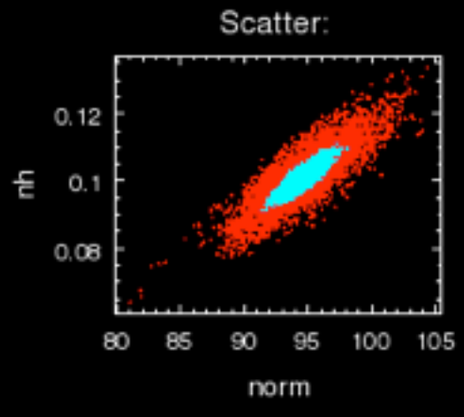

Scatter:
gamma
1.1
1.05
1
0.95
0.9
0.08
0.1
0.12
nh

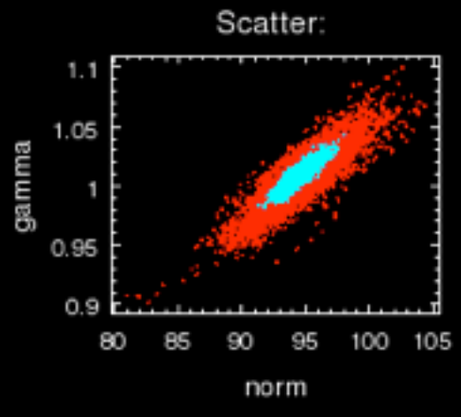

Scatter:
norm
105
100
95
90
85
80
0.08
0.1
0.12
nh

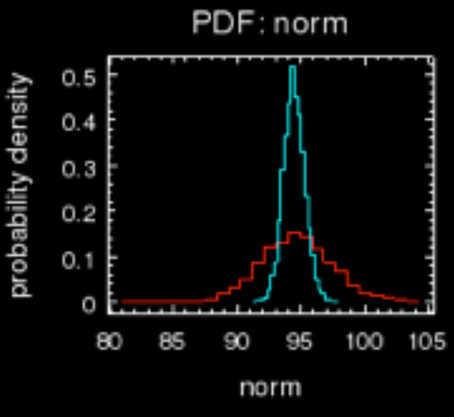

Scatter:
nh
0.12
0.1
0.08
0.9
0.95
1
1.05
1.1
gamma

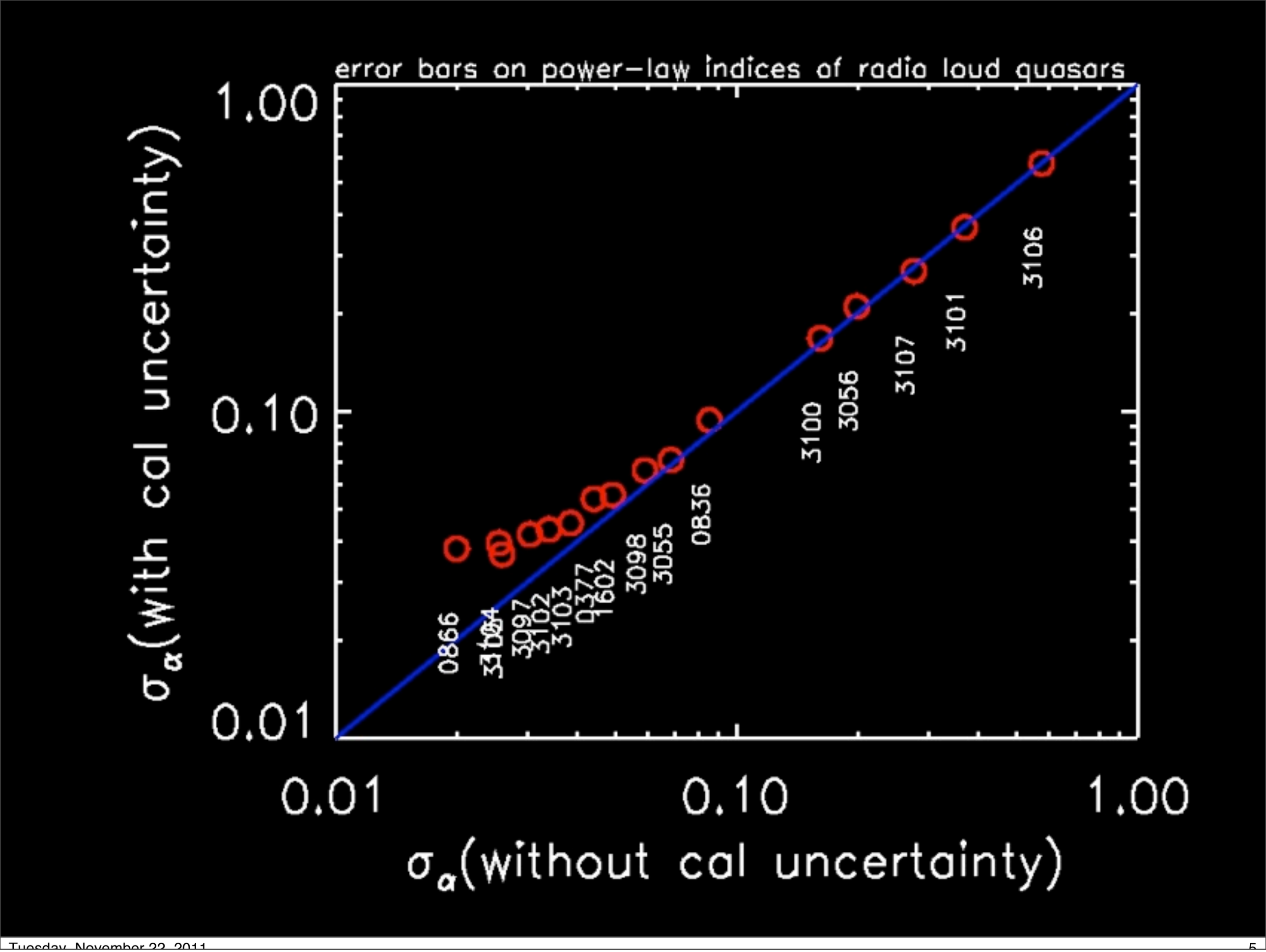

PDF: gamma
probability density
50
40
30
20
10
0
0.9
0.95
1
1.05
1.1
gamma


Scatter:
norm
105
100
95
90
85
80
0.9
0.95
1
1.05
1.1
gamma


Scatter:
nh
0.12
0.1
0.08
80
85
90
95
100
105
norm


Scatter:
gamma
1.1
1.05
1
0.95
0.9
80
85
90
95
100
105
norm


PDF: norm
probability density
0.5
0.4
0.3
0.2
0.1
0
80
85
90
95
100
105
norm


error bars on power-law indices of radio loud quasars
1.00
0.10
0.01
0.01
0.10
1.00
σα(with cal uncertainty)
σα(without cal uncertainty)
3100
3056
3107
3101
3106
0836
3098
3055
0377
1602
3097
3102
3103
0866

For more information:

"Bayesian Analysis in Sherpa" - Sherpa thread
http://cxc.cfa.harvard.edu/sherpa/threads/pyblocxs/index.html

"How to handle calibration uncertainties in high-energy Astrophysics"
http://cxc.harvard.edu/cda/SPIE/kashyap2008.pdf

Vinay - kashyap@head.cfa.harvard.edu