Allocating, Finding, and Correcting Systematic Errors
Instrumental Effective Areas

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Definitions 1

- **Statistical Errors (precision)**
  - Dominated by random processes
  - Estimator bias

- **Sample Errors**
  - Physical outliers (e.g., getting WDs in QSO sample)
  - Bad measurements: cosmic rays, dead pixels

- **Systematic Errors (accuracy)**
  - Errors in system modeling (calibration)
  - Allocate (allow for), find (discover), correct (fix)
  - Cockroaches: hunt down and exterminate
Definitions 2

Absolute Errors (0th moment)
- Affect physical values: flux, energy, location, etc.
- Allocate via modeling (inc. simulation)
- Correct for zero point bias: background, noise...
- Find, correct via external ref. (e.g. cross-cal)

Relative Errors (high order moments)
- Affect differences and ratios
  - Effective area: spectral slopes, line ratios
  - Energy scale: orbital velocities, cluster dispersion
- Alternative definition: relative is only a percentage
Role of Physical Models

- With physical model:
  - Positivity generally ensured
  - Extrapolation beyond data is more reliable
  - Sharp features can be modeled (e.g. edges)
  - No longer a systematic error....

- Correcting errors without physical model:
  - Keep it simple (Bayesian....)
  - Generally want basis functions (nondegenerate)
  - Powerlaw or Chebyshev polynomials used most
  - Fourier decomposition is intuitive
TREATMENT OF SYSTEMATIC ERRORS

- Not random, not Gaussian, not symmetric!
- Cannot “add in quadrature” with random errors
  - Exception: if system has uncorrectable excess noise
- Answers are biased: repeating doesn’t reduce error
- Often merely estimated — not precise!

Relative vs. Absolute
- Can eliminate one without fixing other
  - e.g. distortion correction v. mispointing telescope
  - e.g. flux of source with power law spectrum
- Relative error depends on $E, \lambda, t, x, \alpha, \ldots$
HETGS Effective Area

- **Simulation**
  - Model grating bars, facets, structure **physical**
  - Model implemented in *marx*

- **Ground Calibration**
  - Found model errors --> corrected efficiencies **physical**

- **Internal Flight Calibration**
  - MEG v. HEG --> corrected eff’s **non-physical**
  - Check +1 against -1 --> fix ACIS BI QE **physical**

- **Cross-calibration (with XMM)**
  - No problems yet.... **non-physical**
General Suggestions

- Fix systematic errors physically if possible
- Fix systematic errors by any means
- Assign possible systematic errors
  - give a range of validity
  - give correlation of systematic errors
- Develop experience database
  - systematic errors are everyone’s problems
  - communicate between users and correctors
  - keep public logs of issues, fixes