On the scientific impact of the uncertainties in the *Athena* mirror effective area

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AREA CALIBRATION-REQUIREMENTS IN *ATHENA* - I

R-SCIOBJ-112 Cluster bulk motions and turbulence	Athena shall measure how gravitational energy is dissipated into bulk motions and gas turbulence in the galaxy cluster population, by achieving a 5σ detection of these quantities in a sample of 10 massive clusters.	Kinetic energy dissipated from gravitational assembly in 10 galaxy clusters in the nearby Universe.

R-SCIOBJ-242 AGN spin census	Athena shall determine the SMBH spin distribution in the local Universe as a probe of the growth process (mergers versus accretion, chaotic versus standard accretion).	Spin distribution of 25 nearby SMBH.

2a-080 Absolute temperature/metallicity calibration uncertainty

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Fractional temperature uncertainty at a reference temperature			
Requirement	**4 (TBC)**	**%**	Reference temperature of 5 keV at redshift z=0.5, abundance Z=0.3 solar (assuming also a reference spectral model, e.g. APEC with Anders & Grevesse (1989) abundances)	111, 112, 121, 122, 134, 232

2a-081 Absolute flux calibration uncertainty

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Maximum on-axis absolute calibration error (rms) in the 0.5-10 keV energy range			
Requirement	**12 (TBC)**	**%**	At BoL	111, 121, 221,

2a-082 Relative flux calibration uncertainty as function of energy

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Maximum on-axis relative calibration error (rms) in the 0.5-10 keV energy range			
Requirement	**5 (TBC)**	**%**	At BoL	121, 132, 134,

AREA CALIBRATION-REQUIREMENTS IN *ATHENA* - II

Requirement	Total value	Mirror allocation
Absolute effective area (0.5-10 keV)	10%	6%
Relative effective area (0.5-10 keV)	4%	2%
Fine structure effective area	3%	1%

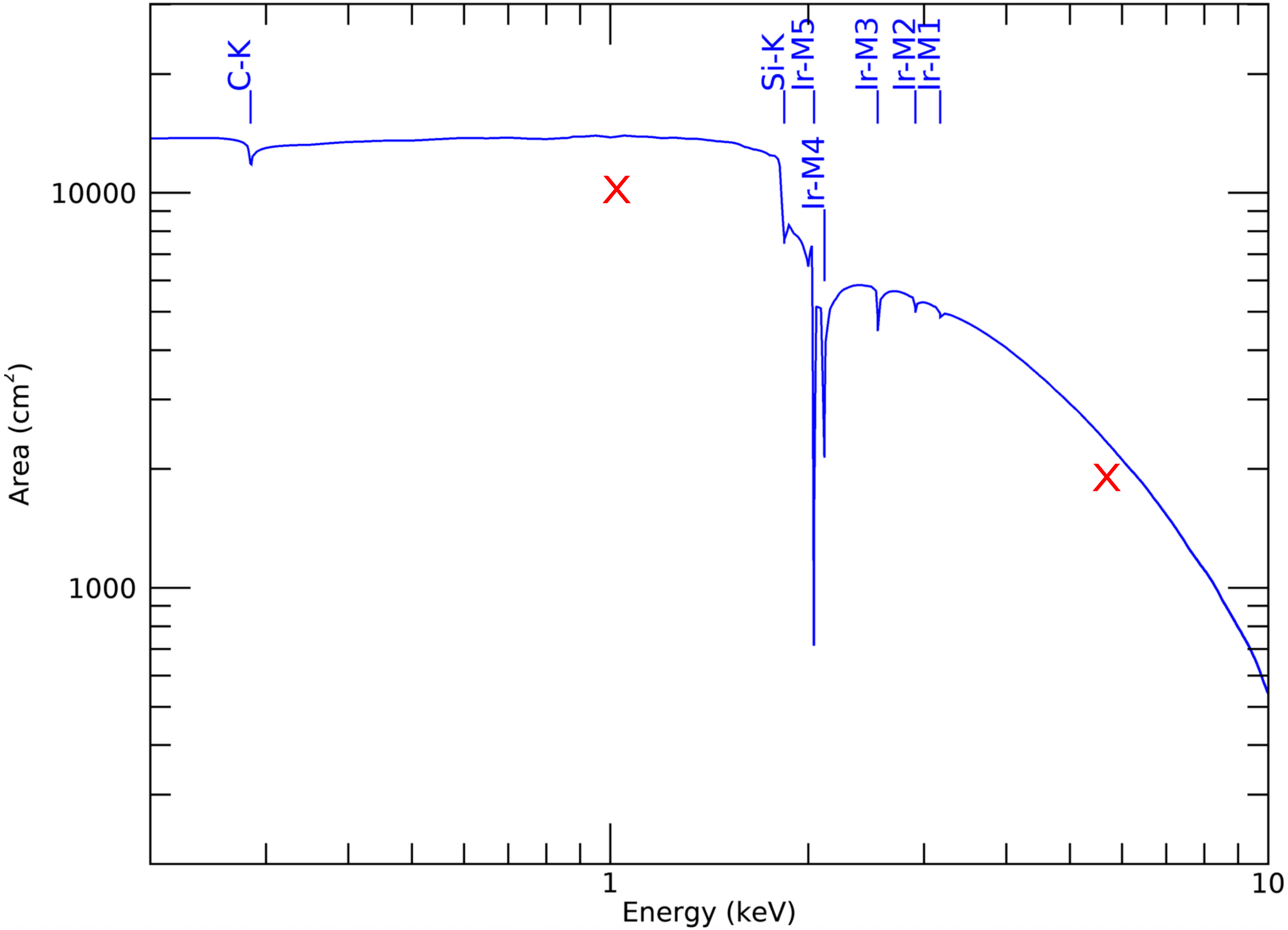
Do the mirror area calibration requirements enable the parent science objectives?

What is the science impact of their (possible) relaxation?

Note: the requirements were slightly relaxed after the paper was published

ATHENA EFFECTIVE AREA

- "15 rows" configuration ("13 rows" in NewAthena)
- Ir+SiC coating (Pt+C+Cr in NewAthena)
- Other minor changes in the configuration of the individual mirror modules during the reformulation
- NewAthena area (X):
  - ~10^4 cm^2 @1 keV
  - ~$2x10^3$ cm^2 @6 keV



PERTURBATION FUNCTION

Monte-Carlo method: create a large number of stochastically perturbed mirror ARFs according to:

$$A^*(E) = A(E) \times [1 + P(E)]$$

$$P(E) = P_a + P_r(E) + \Sigma_i P_f^i(E)$$

P_a → absolute

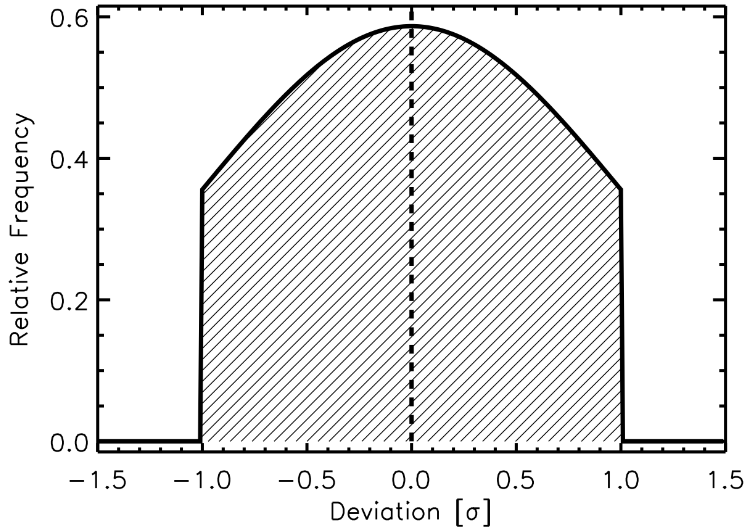
$P_r(E)$ → relative

$\Sigma_i P_f^i(E)$ → fine structure

Each *P* is extracted from a Gaussian truncated distrubution "á la Drake"

THE "Á LA DRAKE" METHOD

Drake at al., 2006, SPIE, 6270, 40

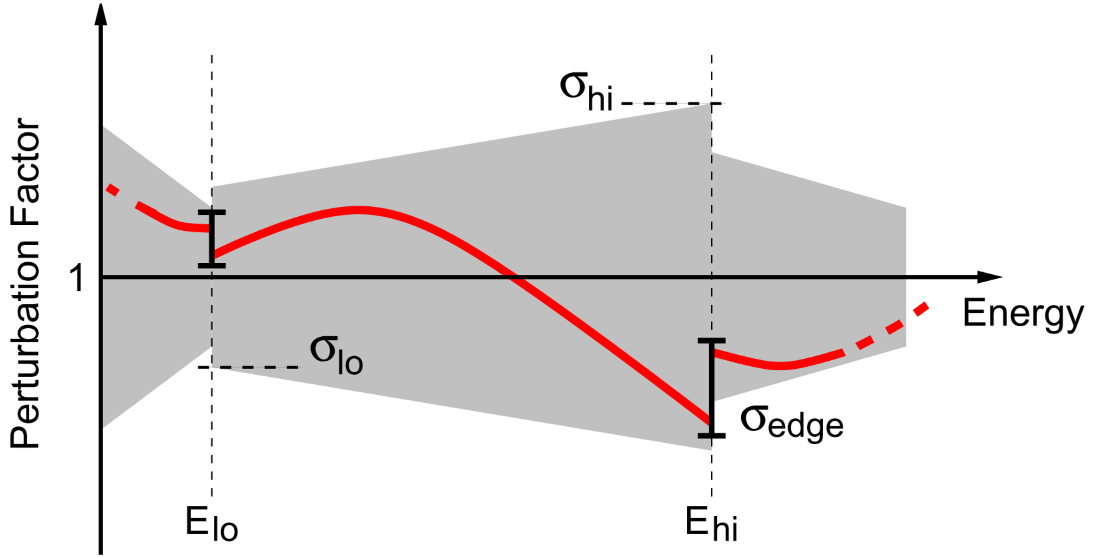


- For each effective area, we extract a value of the perturbation function from a Gaussian 1-σ truncated distribution with mean 0 and standard deviation equal to the requirement

- P_r values are extracted at three energies (0.2, 1.8, 10 keV) and a cubic spline interpolation applied

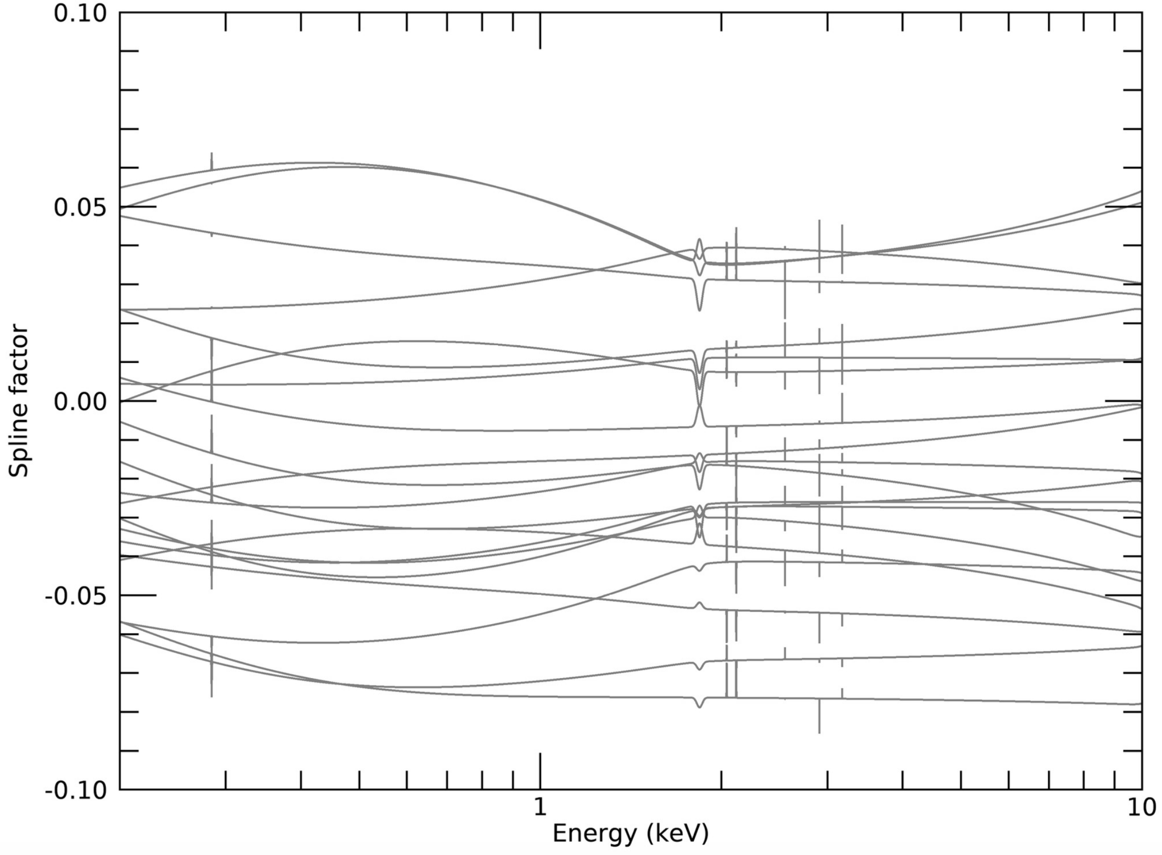
- **Important caveat**: this is a *phenomenological and agnostic procedure*. No assumption is made on the origin of the calibration uncertainties

- [→ This work cannot help to inform the detailed mirror design. More will come before NewAthena Adoption]

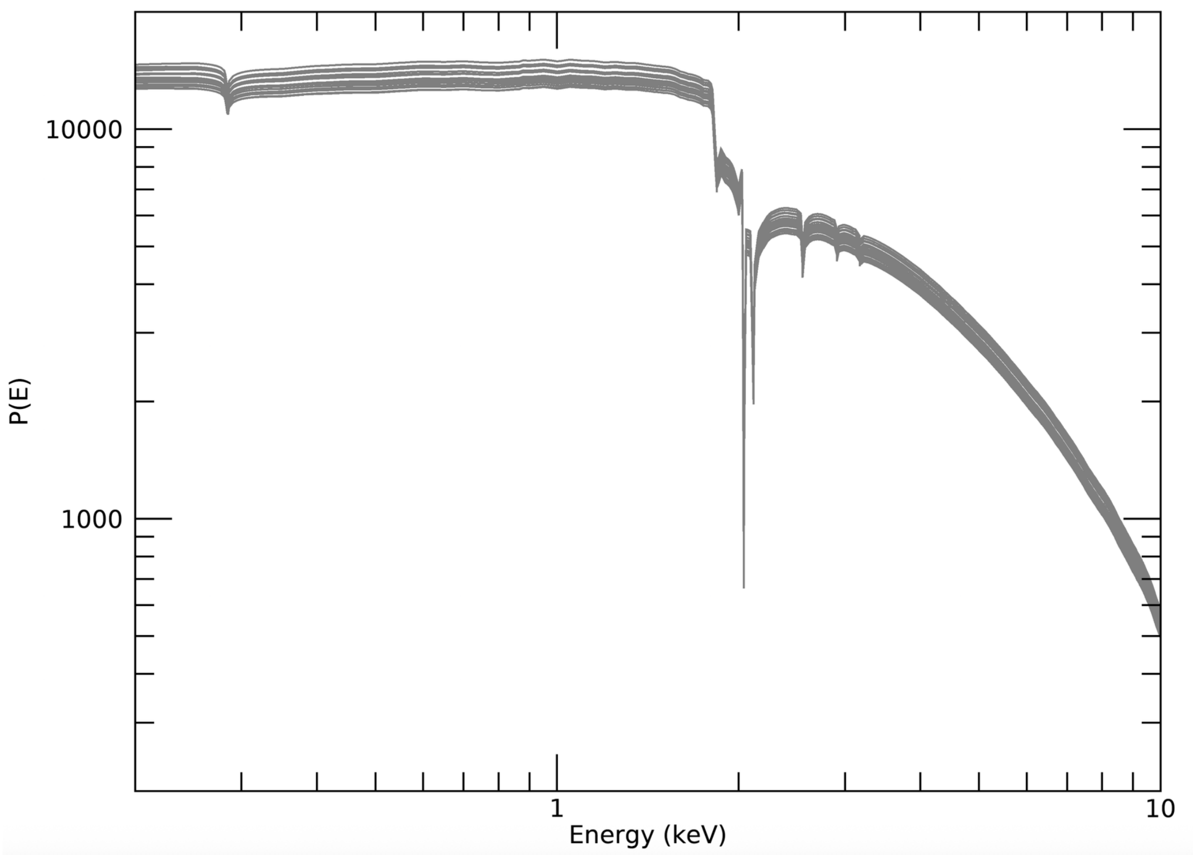


EXAMPLES

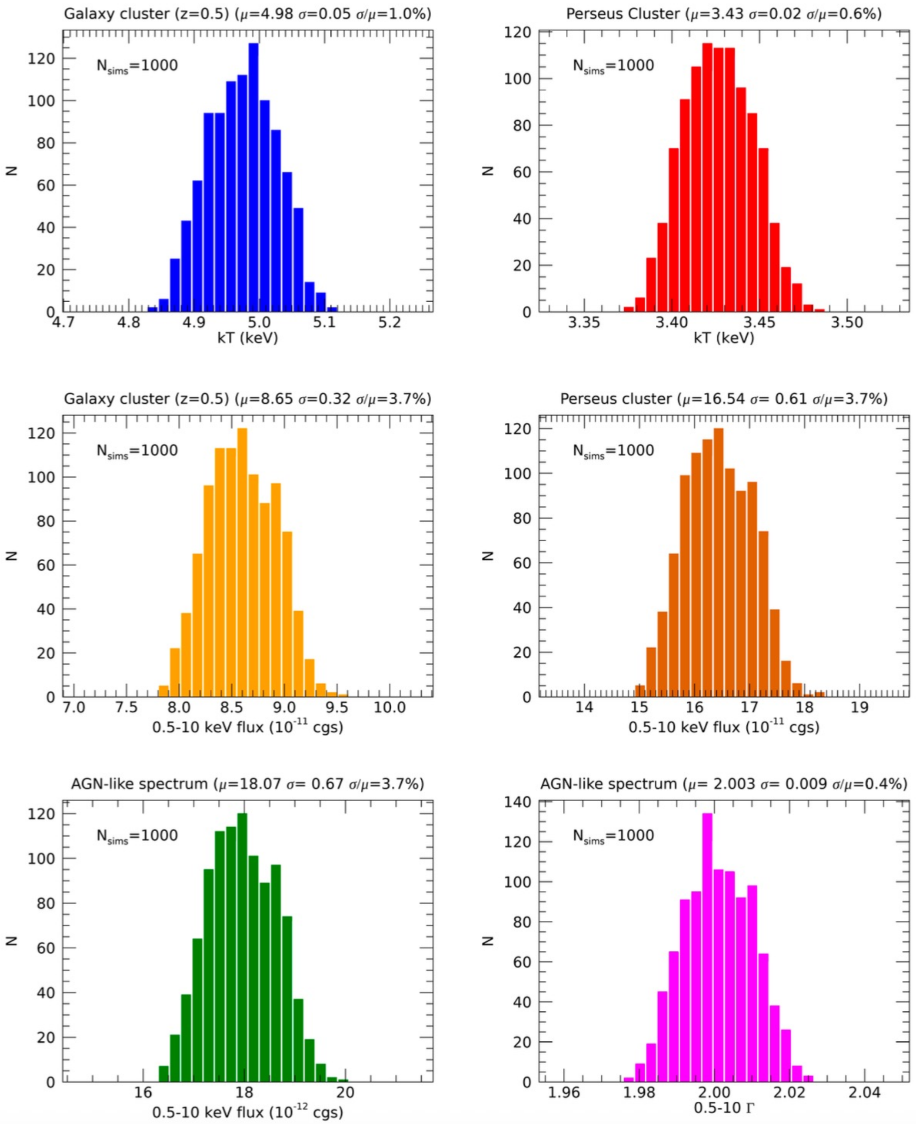
Perturbation functions



Perturbed ARFs

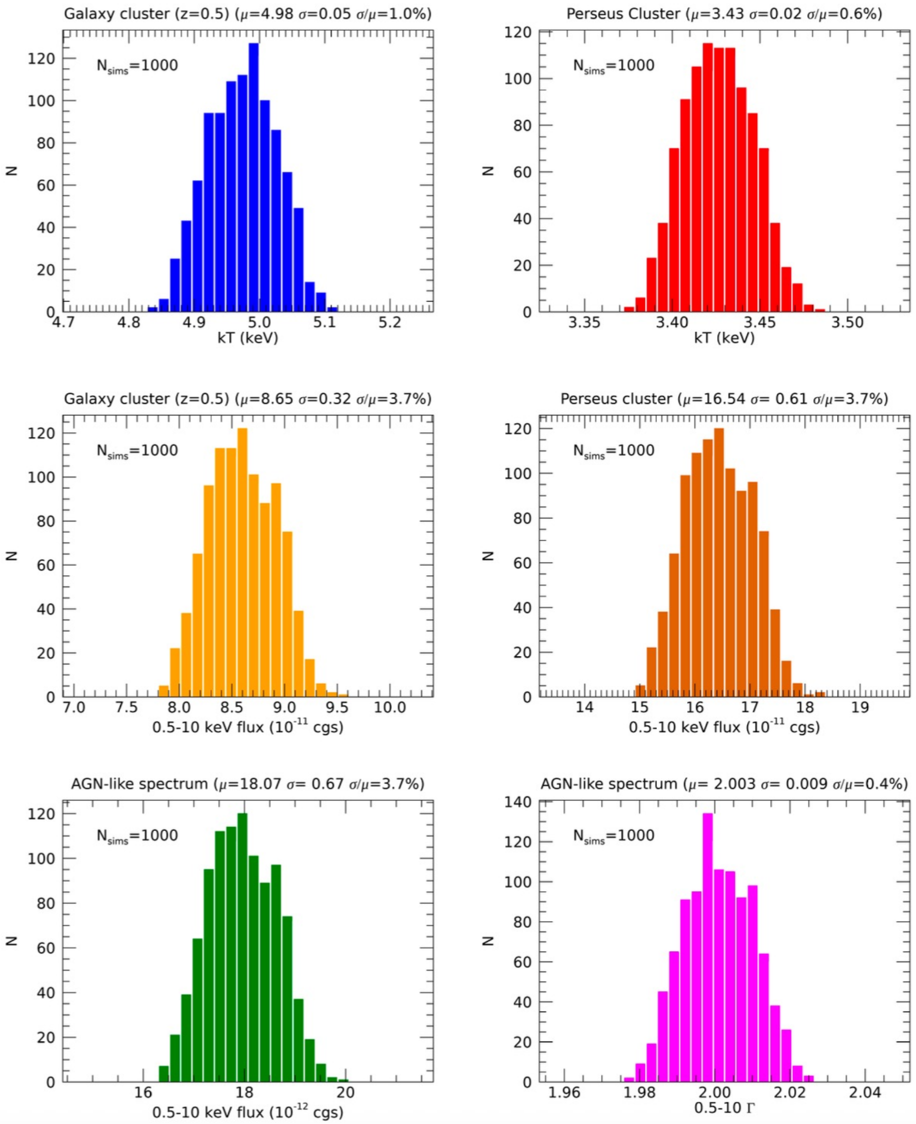


RESULTS: GALAXY CLUSTERS AND AGN SPECTRAL SHAPE



- Use the perturbed ARFs to simulate driving science objectives
- Calculate distributions of critical observables
- Compare to science requirements (critical observable accuracies)

RESULTS: GALAXY CLUSTERS AND AGN SPECTRAL SHAPE



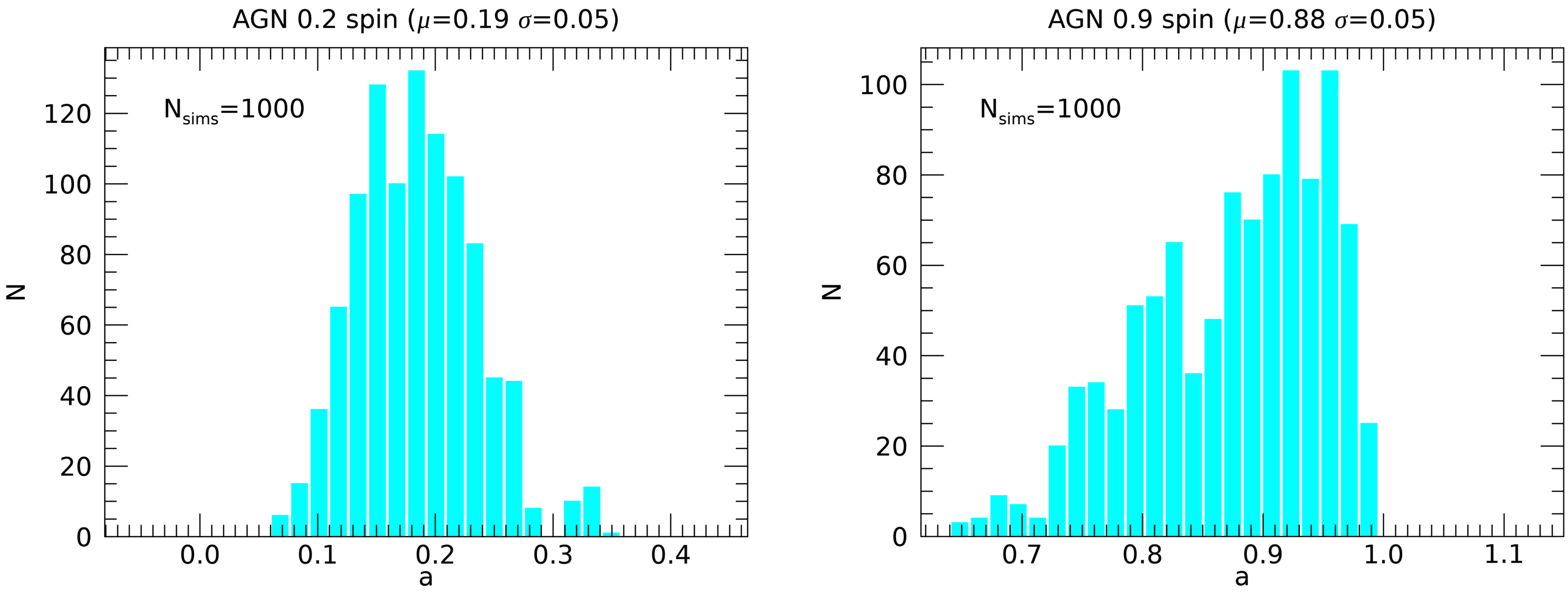
- Use the perturbed ARFs to simulate driving science objectives
- Calculate distributions of critical observables
- Compare to science requirements (critical observable accuracies)

Table 3 Standard deviations for the distribution of the critical observables.

Critical observable	σ	Verification criterion
σ_{kT}/kT (high-redshift cluster)	1.0%	$\leq 2\%$
σ_{kT}/kT (Perseus cluster)	0.6%	$\leq 2\%$
σ_F/F (high-redshift clusters)	3.7%	$\leq 6\%$
σ_F/F (Perseus cluster)	3.7%	$\leq 6\%$
σ_F/F (AGN)	3.7%	$\leq 6\%$
σ_Γ (AGN)	0.009	≤ 0.008

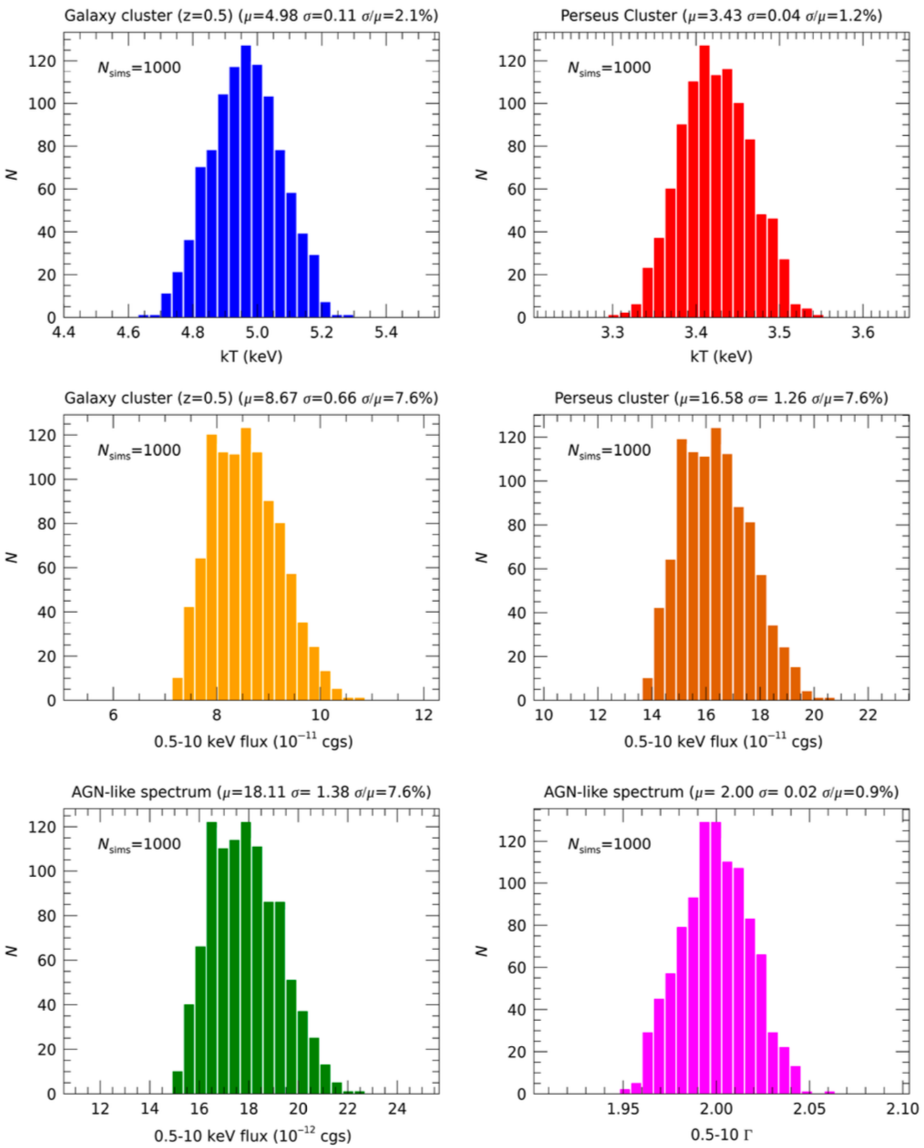
RESULTS: BLACK HOLE SPIN

A more complex and realistic science case: determination of black hole spins in AGN



Typical systematic error is (~0.05), lower than the requested accuracy (~0.1)

WHAT IF WE OFFSHOOT THE CALIBRATION REQUIREMENTS?



The accuracy of (these) astrophysical observables scales ~linearly with the effective area calibration requirements

Critical observable	σ
σ_{kT}/kT (high-redshift cluster)	2.1%
σ_{kT}/kT (Perseus cluster)	1.2%
σ_F/F (high-redshift clusters)	7.6%
σ_F/F (Perseus cluster)	7.6%
σ_F/F (AGN)	7.6%
σ_Γ (AGN)	0.020

Violation!

CONCLUSION

We must define a calibration plan fulfilling the stringent Athena effective area calibration requirements!

ADDITIONAL MATERIAL

HOW TO DETERMINE THE FINE STRUCTURE CORRECTIONS

- The P_f energies and widths are determined by fitting "peaks" in the effective area derivative
- They correspond to the strongest absorption edges