ACIS Science & Calibration

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Overview:

- ACIS Calibration: A partial partial summary
- Calibration Assets & Challenges
- Science Highlights

Caveats

- Following are personal opinions & not necessarily very well-informed.
- All calibration results discussed here are the work of others at CXC, MIT, PSU & elsewhere.

Partial Partial Summary of Current ACIS Calibration Status

- Source location accuracy (0.6”, on-axis, 90%,radial) & image reconstruction accuracy (essentially perfect) are excellent(CXC).
- Broadband photometric accuracy (Snowden):
  - Probably better than 5%, 2-7 keV
  - Probably better than 10%, 0.5-2 keV (early mission!)
- Energy scale knowledge (Edgar, Schulz et al.):
  - S3: 1% or better E> 0.7 keV
  - FI: ~0.5% E> 0.5 keV

Some ACIS Calibration Challenges

- Tracking time-dependent A_{eff} at E < ~ 1 keV
- Energy-scale non-linearities at E < 1 keV (mainly CTI-related) in both BI and FI devices
- Producing & maintaining time-dependent energy-scale calibration
- Validating models for CTI-induced changes in spectral redistribution
- CC mode (cf Sanwal)
- Calibration at -110C
- Physical modeling of background

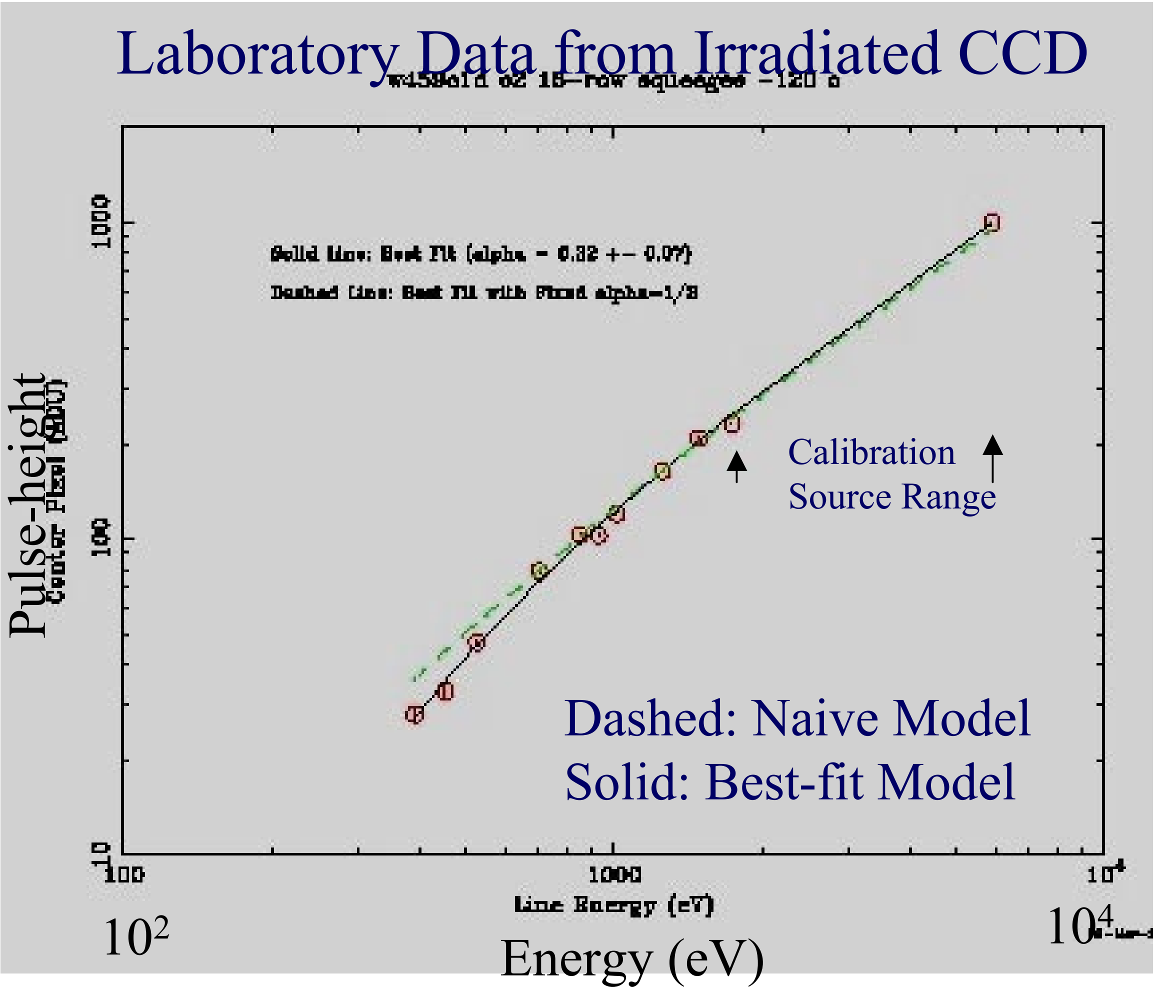
Chandra & ACIS Calibration Assets

- Onboard calibration source:
  - track/interpolate contamination
  - track energy scale at E>1.5 keV
  - sample redistribution at E>1.5keV
- Well-calibrated onboard gratings:
  - determine energy-dependence of contamination
  - extend energy scale to E< 1.5 keV (modulo CTI)
  - sample redistribution at E < 1.5 keV
- Multiple, relatively stable focal plane detectors:
  - cross-checks on contamination
  - ACIS response variations are slow
- Tenacious calibration/operations team

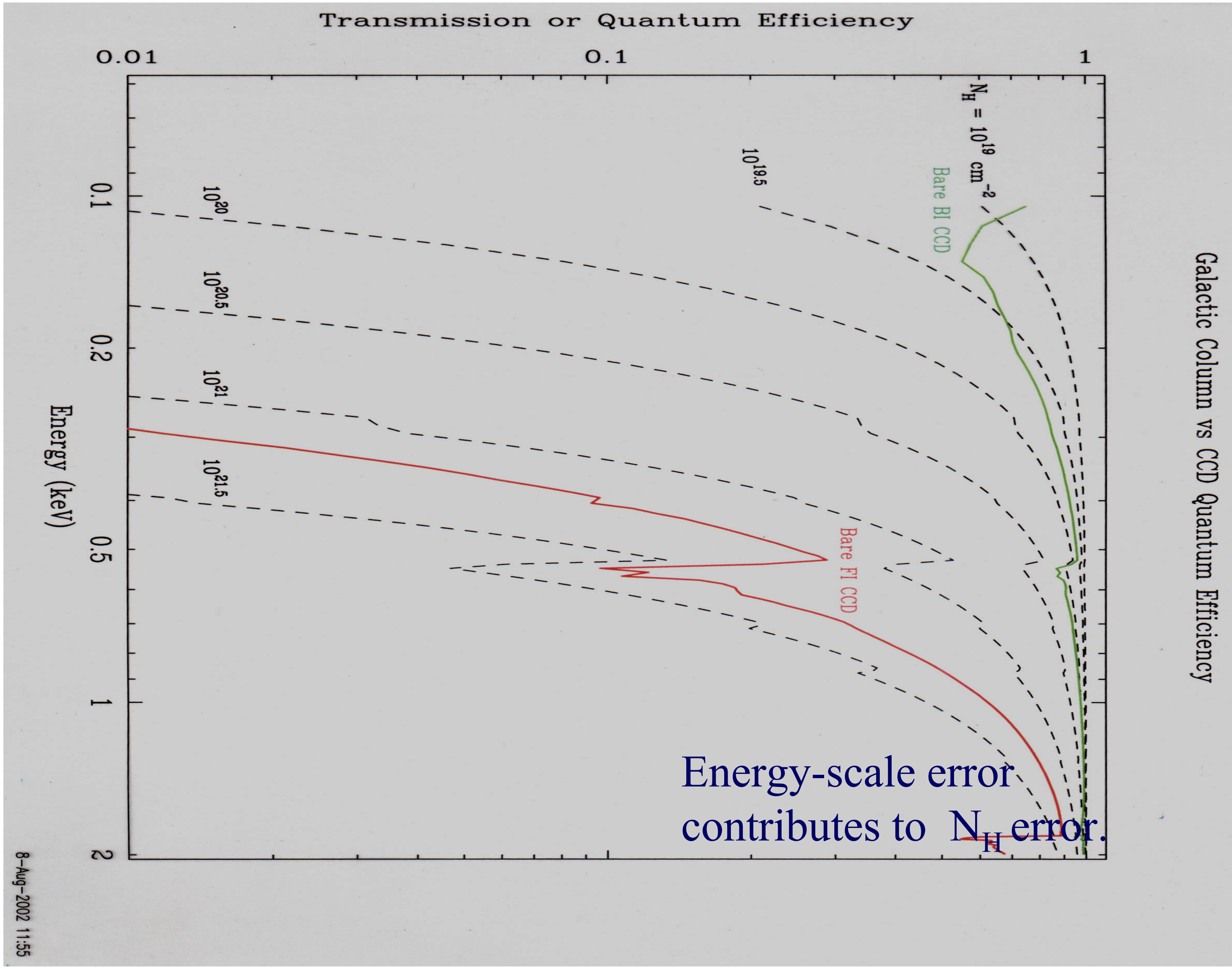
Chandra & ACIS Calibration Limitations

- There is no flux standard accessible from space.
- Onboard calibration source:
  - no lines below 0.7 keV (fluorescence yield)
- CTI
  - makes energy scale non-linear at low energies
  - makes energy scale depend (mildly) on background rate
  - makes detector response more sensitive to temperature
  - complicates use of gratings for energy scale determination
  - is not described with sufficient accuracy by a physical model

CTI-induced Non-linear Energy Scale is a Calibration Challenge



- Shape of energy scale must be calibrated on orbit: ground tests don't reproduce flight data to 1% level
- Calibration source useful only at E>1.5 keV
- Errors are largest at lowest energies.


Galactic Column vs CCD Quantum Efficiency
Transmission or Quantum Efficiency
0.01
0.1
1
Energy (keV)
0.1
0.2
0.5
1
2
N_H = 10^19 cm^-2
10^19.5
10^20
10^20.5
10^21
10^21.5
Bare BI CCD
Bare FI CCD
8-Aug-2002 11:55
Energy-scale error contributes to N_H error.

Chandra Deep Field North Survey

CHANDRA DEEP FIELD NORTH SURVEY. V. 2819

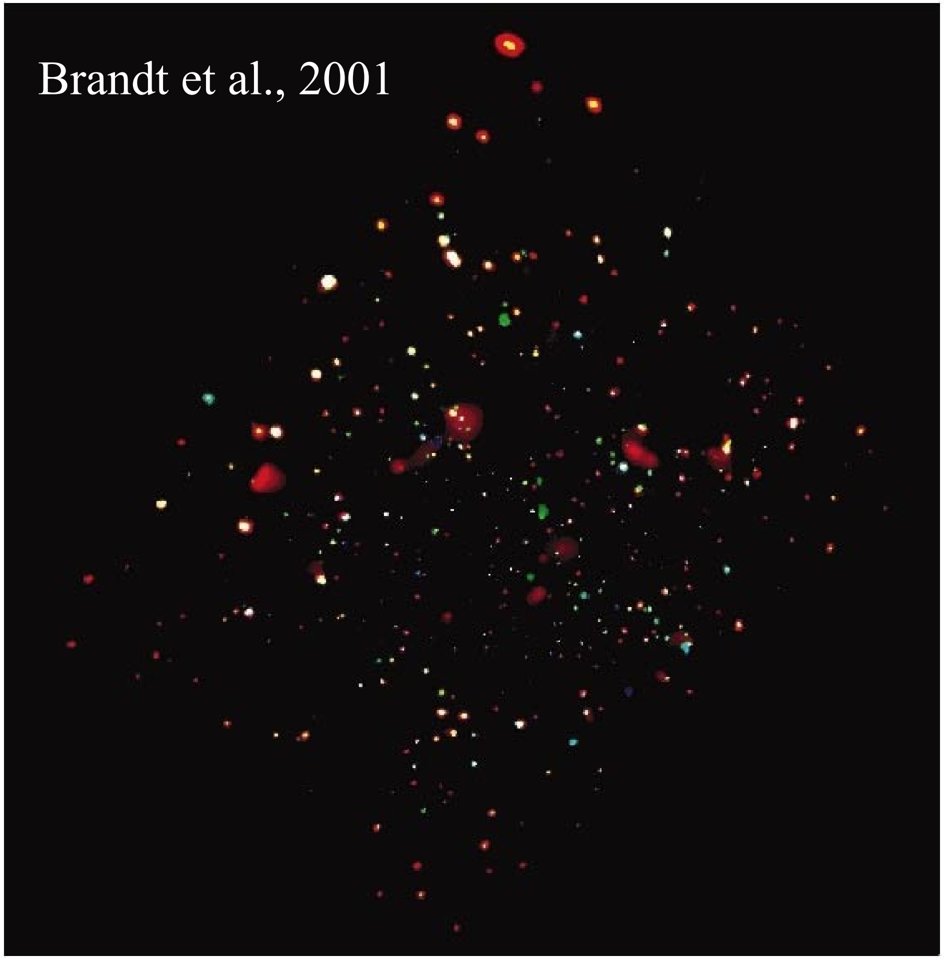


FIG. 5.—*Chandra* "true-color" image of the CDF-N. This image has been constructed from the soft-band (*red*), hard-band (*green*), and ultrahard-band (*blue*) images shown in Fig. 4. Two of the red diffuse patches are CXOHDFN J123620.0 + 621554 and J123756.0 + 621506 (see § 3.3).

- 100x deeper than prior surveys.
- 2 Msec (23 days) total exposure over 2 years.
- ~90% of diffuse X-ray background resolved.
- Stacking analysis reveals X-ray properties of LBG at z=3 & normal galaxies at z>0.4

Stacking X-ray Images of Lyman Break Galaxies

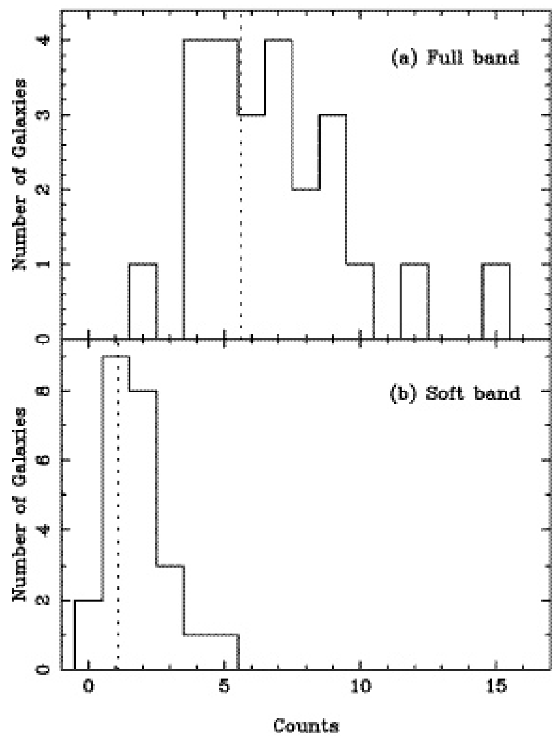


FIG. 2.—Histograms showing the number of (*a*) full-band counts and (*b*) soft-band counts obtained in the 30 pixel aperture for each of the galaxies used in the stacking analyses. The average number of counts expected from background is 5.6 for the full band and 1.1 for the soft band; these values are shown as the vertical dotted lines.

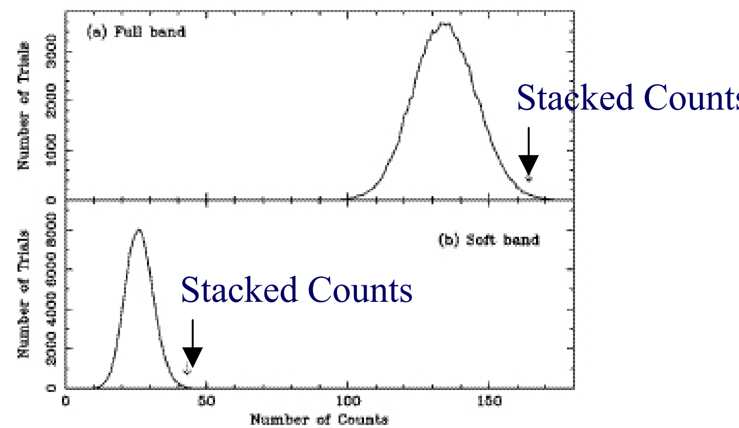


FIG. 4.—Results from Monte Carlo testing of the Lyman break galaxy stacking analyses for the (*a*) full band and (*b*) soft band. Each panel shows the results from 100,000 stacking trials plotted as the number of trials yielding a given number of counts. The resulting distributions are very nearly Gaussian. The arrow in each panel indicates the number of counts actually observed when the Lyman break galaxies are stacked.

$L_{X,LBG} \sim 3.2 \times 10^{41}$ erg s^{-1} @ z=3

(like nearby luminous starbursts)

Brandt et al., 2001

Chandra's View of the Galactic Center

Baganoff , Muno et al., 2002

- 650 ksec exposure
- Rapid X-ray flaring from within 10x r_s of SgrA*
- Complex diffuse emission
- 2300 new X-ray sources detected, several hundred new spectra.

Summary

•ACIS calibration is best above 1 keV.

•Significant problems (energy scale and detection efficiency) exist at lower energies, and are worst at lowest energies.

•*Chandra* has an unprecedented on-orbit calibration capability.

• ACIS calibration will continue to improve.