THE EPIC SIMULATOR AND PILE-UP MODELLING

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OUTLINE

- Introduction to the EPIC simulator
  - What is it?
  - How does it work?
  - Validation
- Pile-up modelling
  - Flux losses
  - Spectral distortions
- Pile-up mitigation
  - Correcting spectral distortions

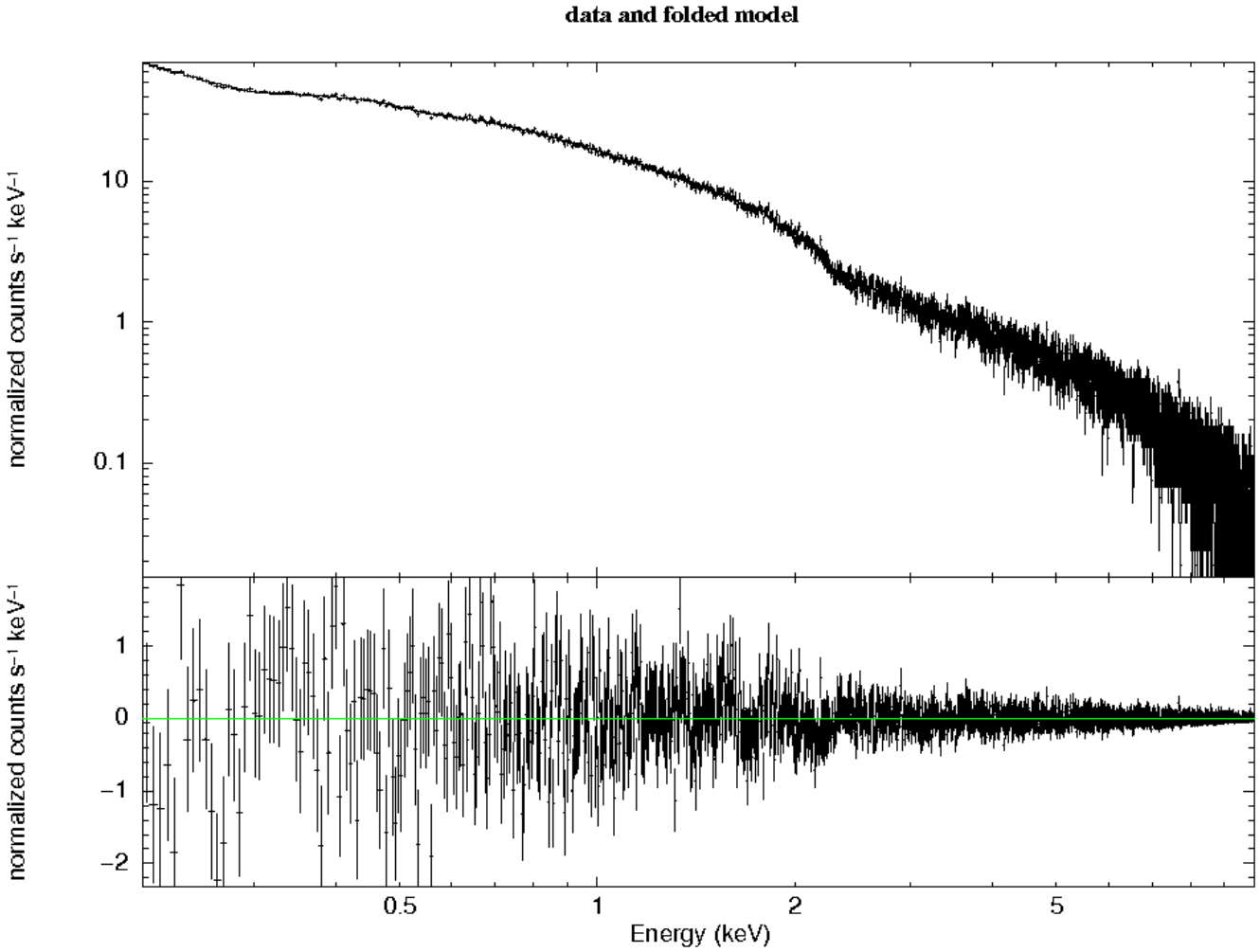
THE EPIC SIMULATOR: what is it?

- New tool developed in IDL by Richard Saxton, Pedro Rodriguez, Prashin Jethwa
- Realistically simulate EPIC observations
- What does it do?
  - Input: 1) instrument
    2) number of counts per frame
    3) number of frames in observation
    4) spectral model
    5) calibration files
  - Simulate (details on next slide…)
  - Output: 1) event list
    2) spectral files (PI vs. counts) and ARFs

THE EPIC SIMULATOR: how does it work?

- For a given (counts / frame), generate Poisson distributed photon numbers / frame
- For a given spectral model and ARF, assign energy to each photon
- For a photon of given energy, assign:
  1) position (PSF)
  2) PI channel (RMF)
  3) pattern (pattern fraction calibration)

THE EPIC SIMULATOR: un-piled-up spectrum

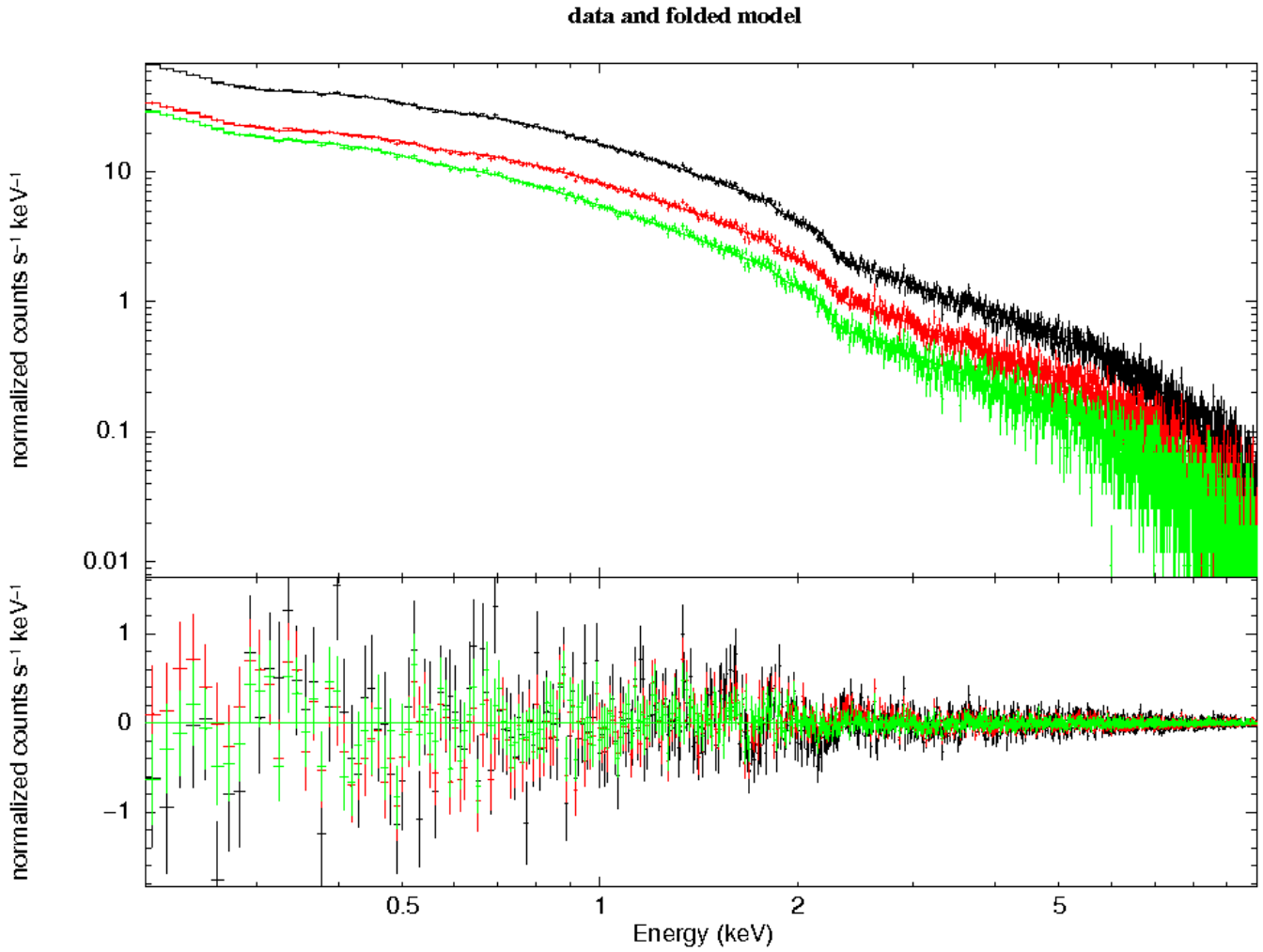


- Simulated input spectrum
- $\Gamma = 2$ power-law
- Residuals ~ 2keV
- … consequence of ARF/RMF interpolation differences between XSPEC and simulator?

THE EPIC SIMULATOR: how does it work?

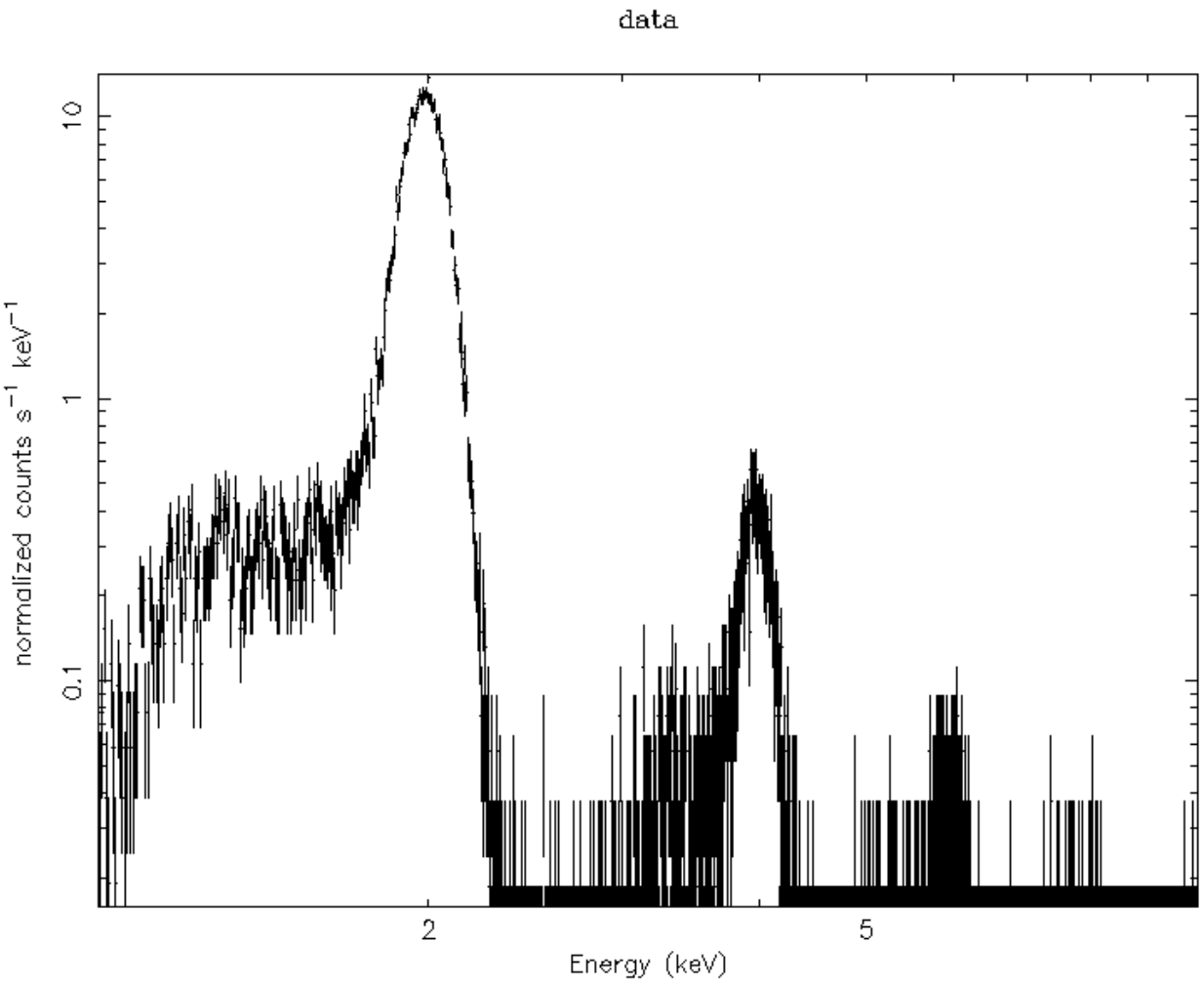
- For a given (counts / frame) , generate Poisson distributed photon numbers / frame
- For a given spectrum and ARF, assign energy to each photon
- For a photon of given energy, assign
  1) position (PSF)
  2) PI channel (RMF)
  3) position (pattern fraction calibration)
- Combine events within a single frame and identify resultant events
  - Sum energies
  - Merge patterns
  - Remove bad patterns
- Produce output spectrum and ARF for a given event pattern and extraction region

THE EPIC SIMULATOR: piled up spectra



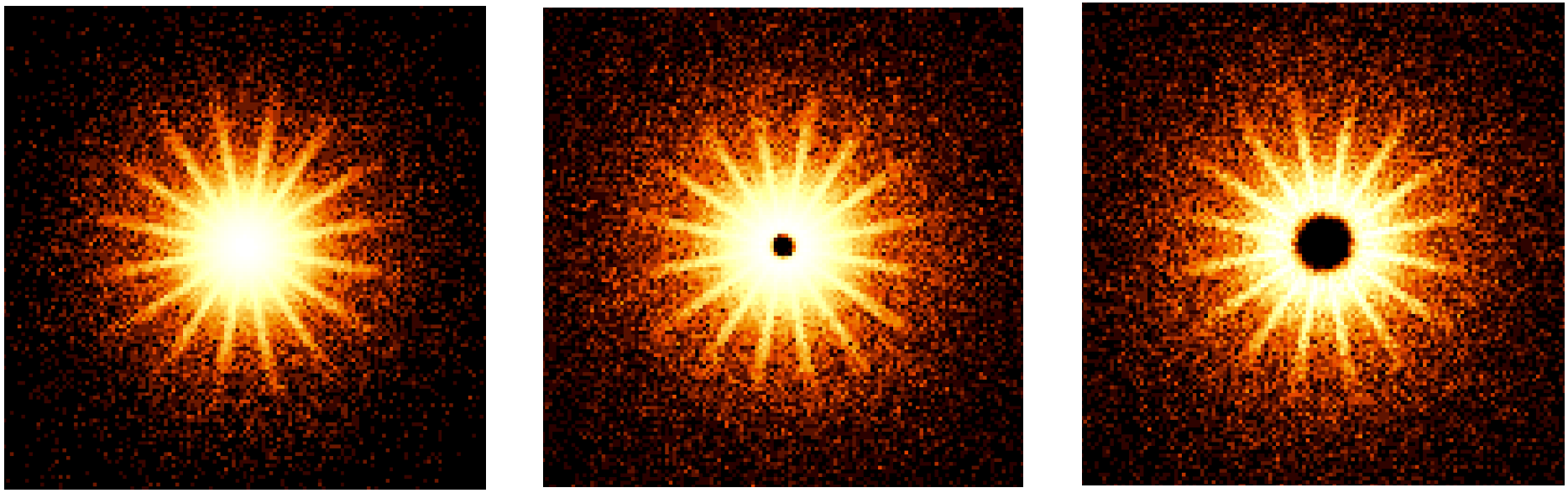
- Spectra are fit with pattern-appropriate ARF
- Black:
  Input
  Γ = 1.997
  Flux = 3.5e-11
- Red:
  Output singles+doubles
  Γ = 1.985
  Flux = 1.9e-11
- Green:
  Output singles
  Γ = 1.992
  Flux = 1.7e-11

THE EPIC SIMULATOR: piled-up Gaussian



- Input:
  Gaussian at 2keV
- Output:
  Gaussians at 2keV, 4keV, 6keV, 8keV, 10keV…

THE EPIC SIMULATOR: piled-up images

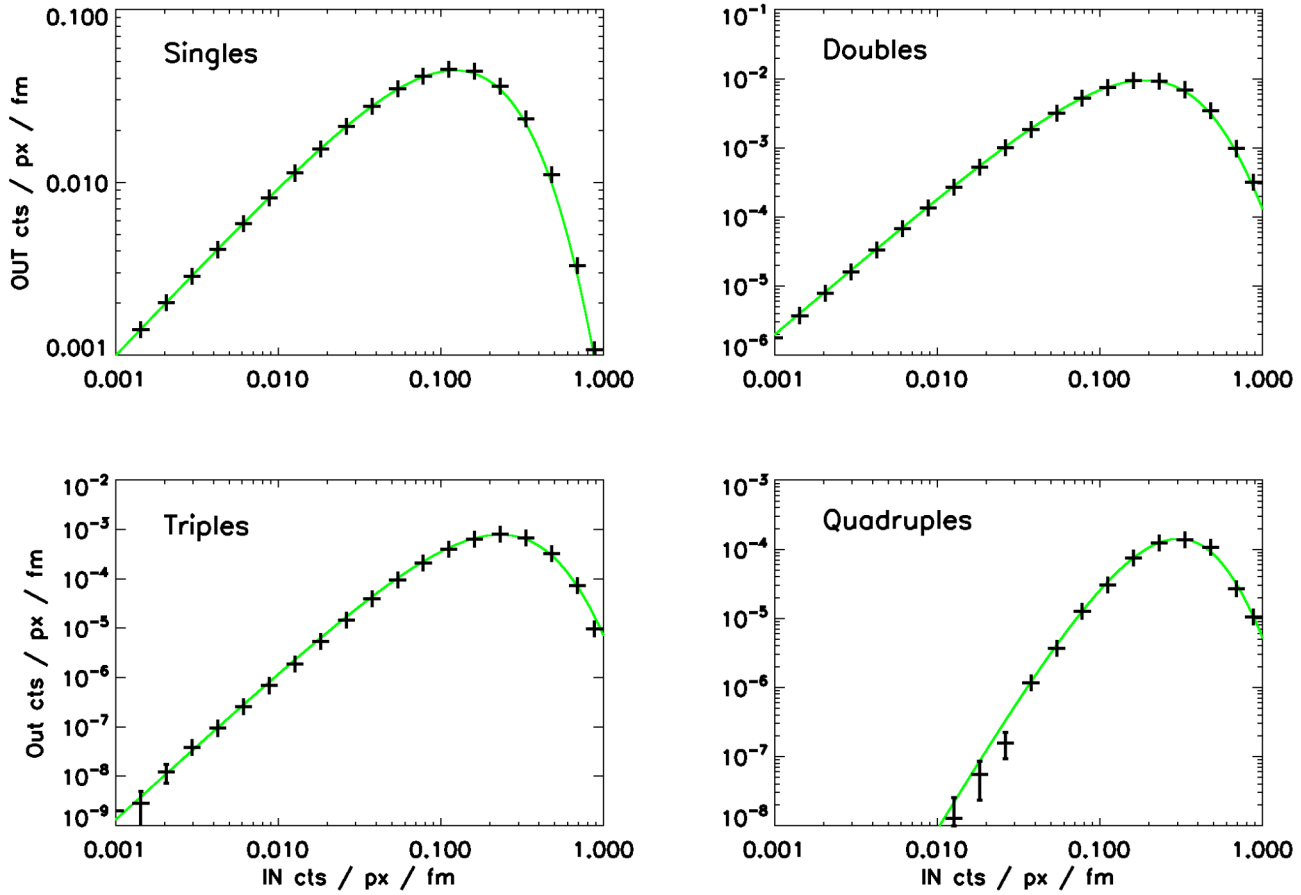


Core suppression as a consequence of pile-up.
Left: 1 count / frame, *Centre:* 100 counts / frame, *Right:* 1000 counts / frame

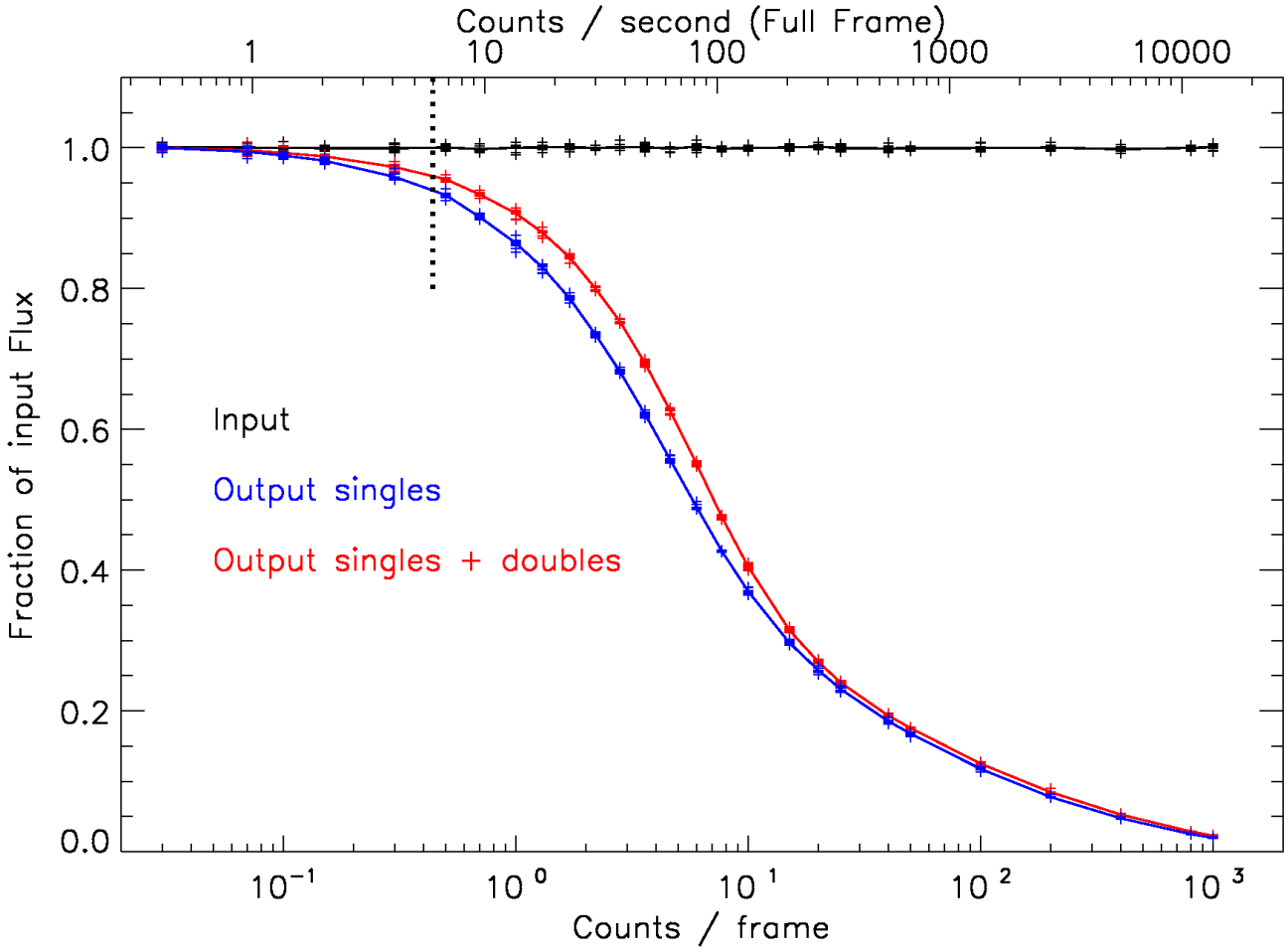
- Uses *ell-beta PSF*
- Extract spatial information
  - images
  - spectra from different extraction regions

THE EPIC SIMULATOR: validation

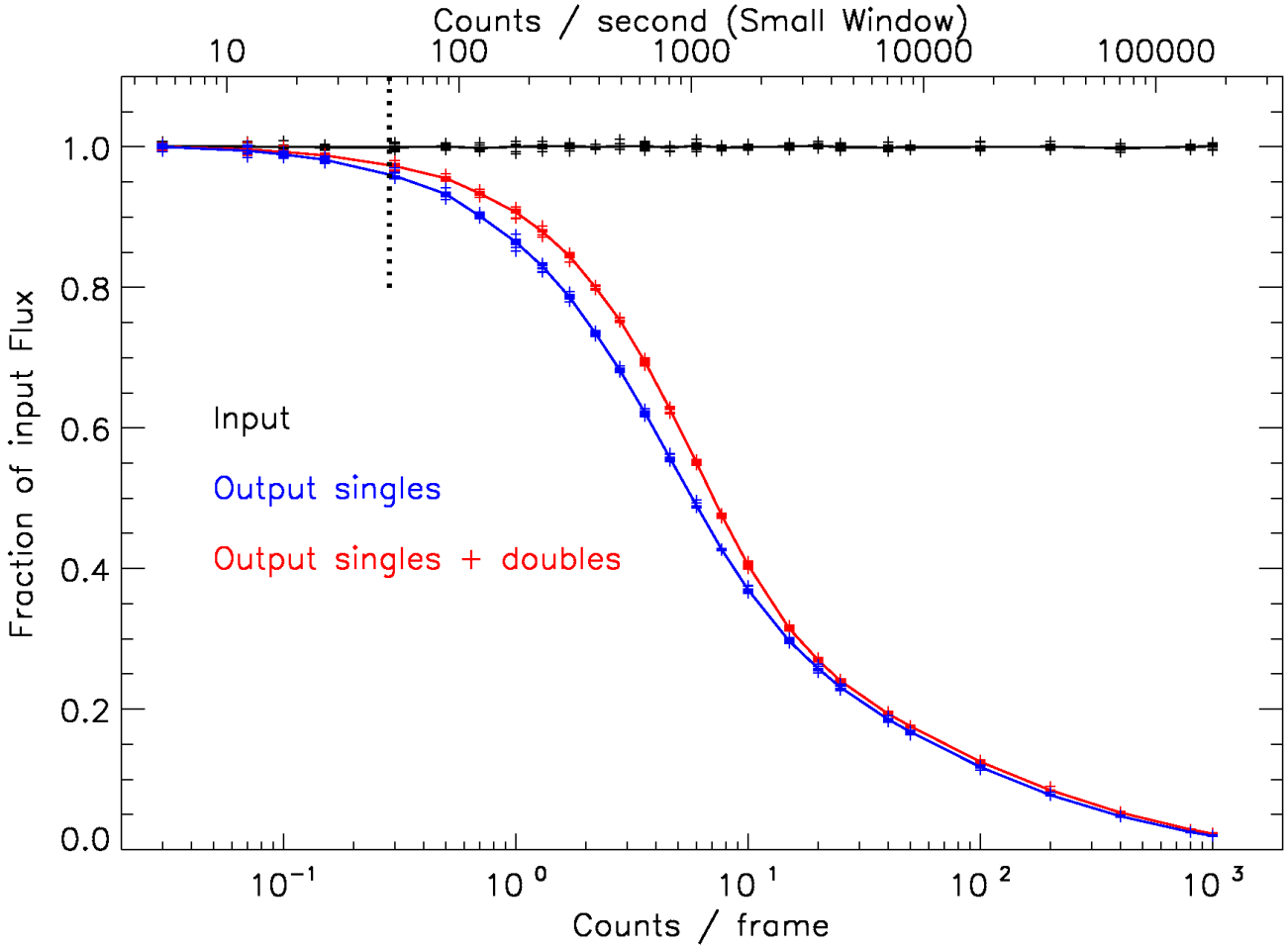
- Self-consistent: for low count rates the output spectrum = input spectrum
- Comparison against theoretical work (J. Ballet 1999)



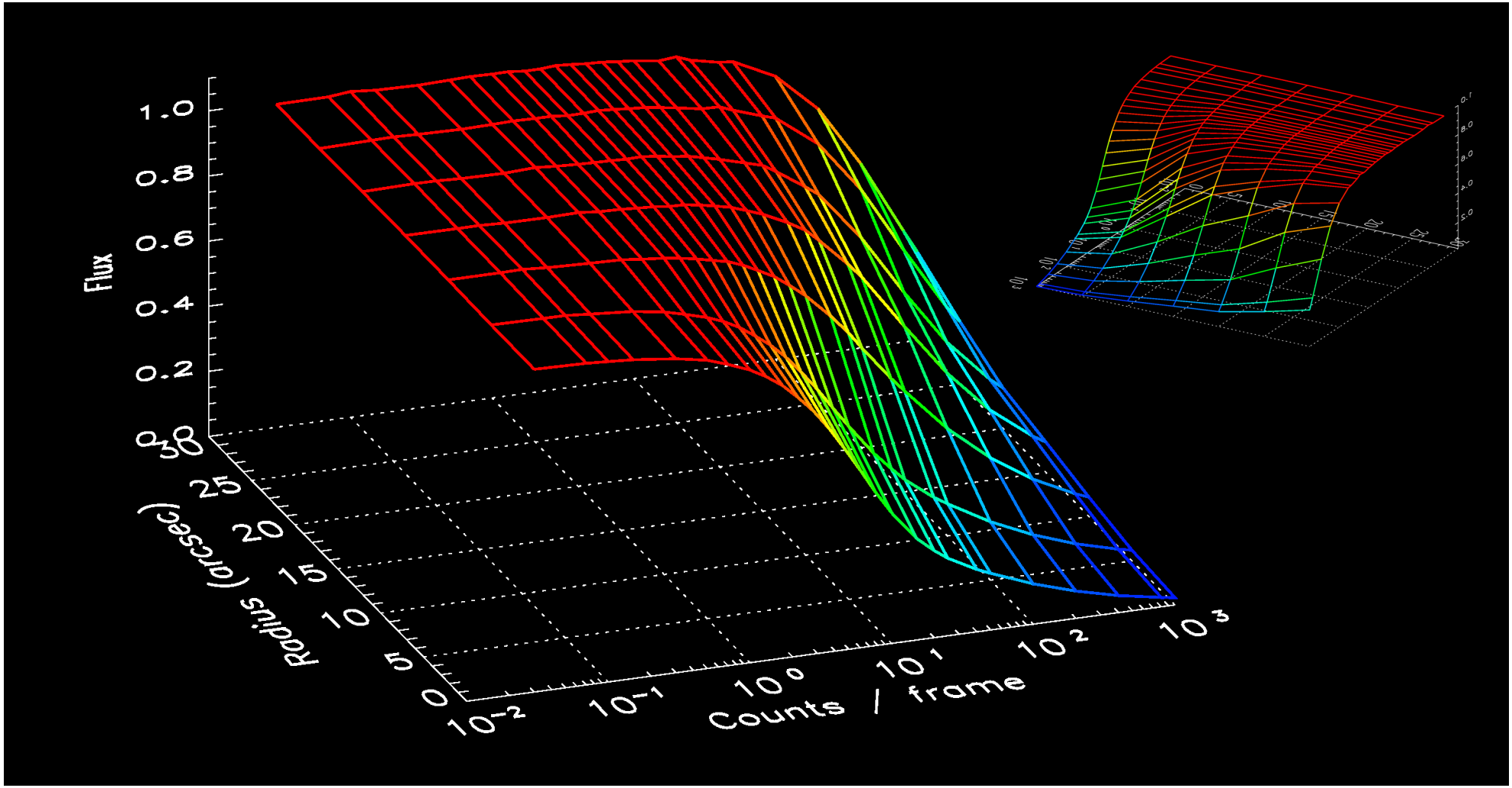
PILE-UP MODELLING: flux loss in PN full frame



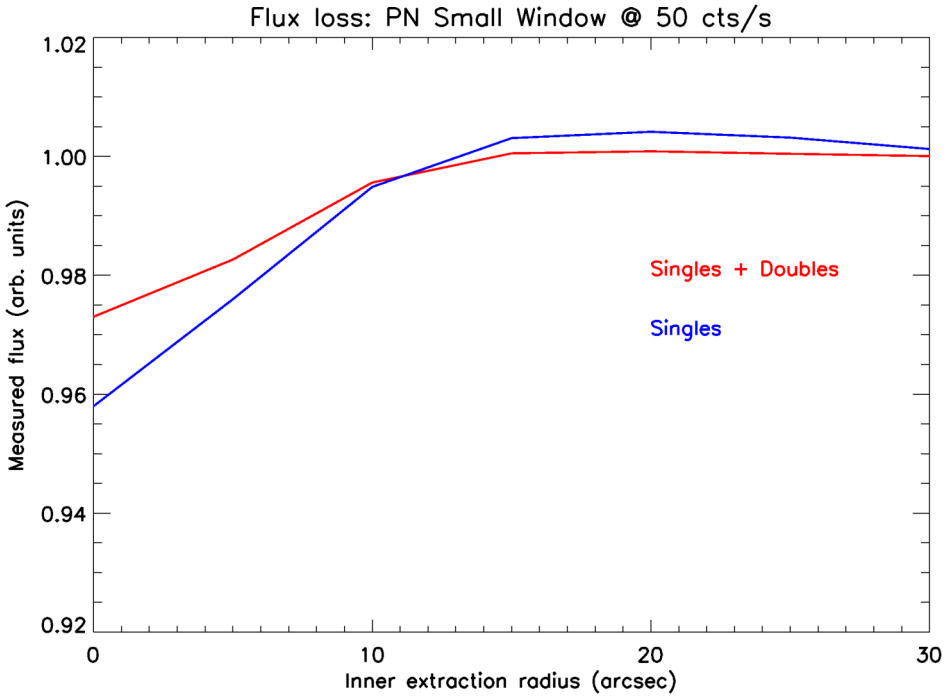
PILE-UP MODELLING: flux loss in PN small window

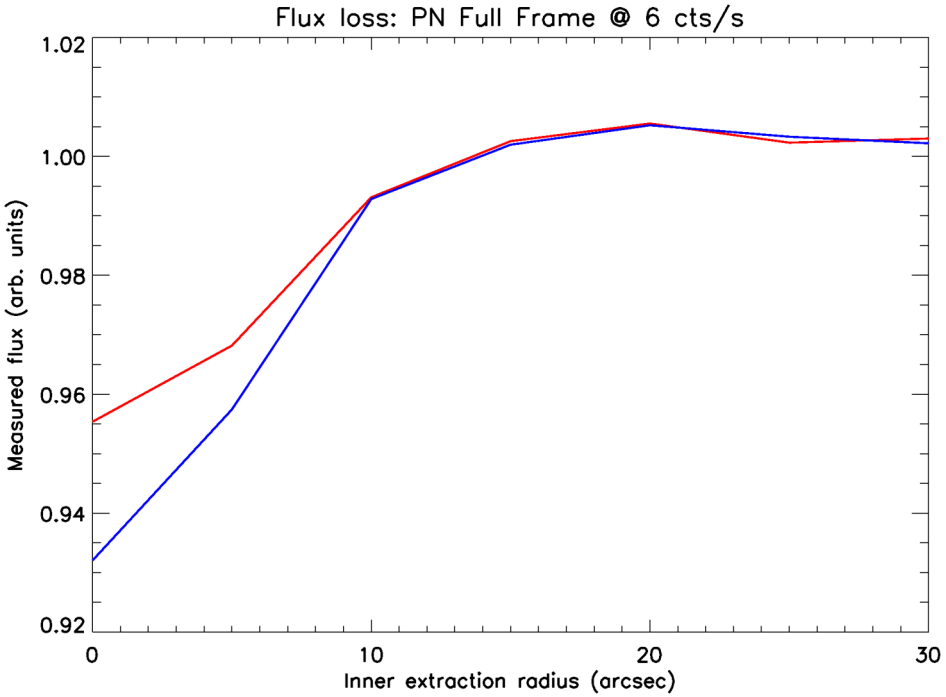


PILE-UP MODELLING: flux loss

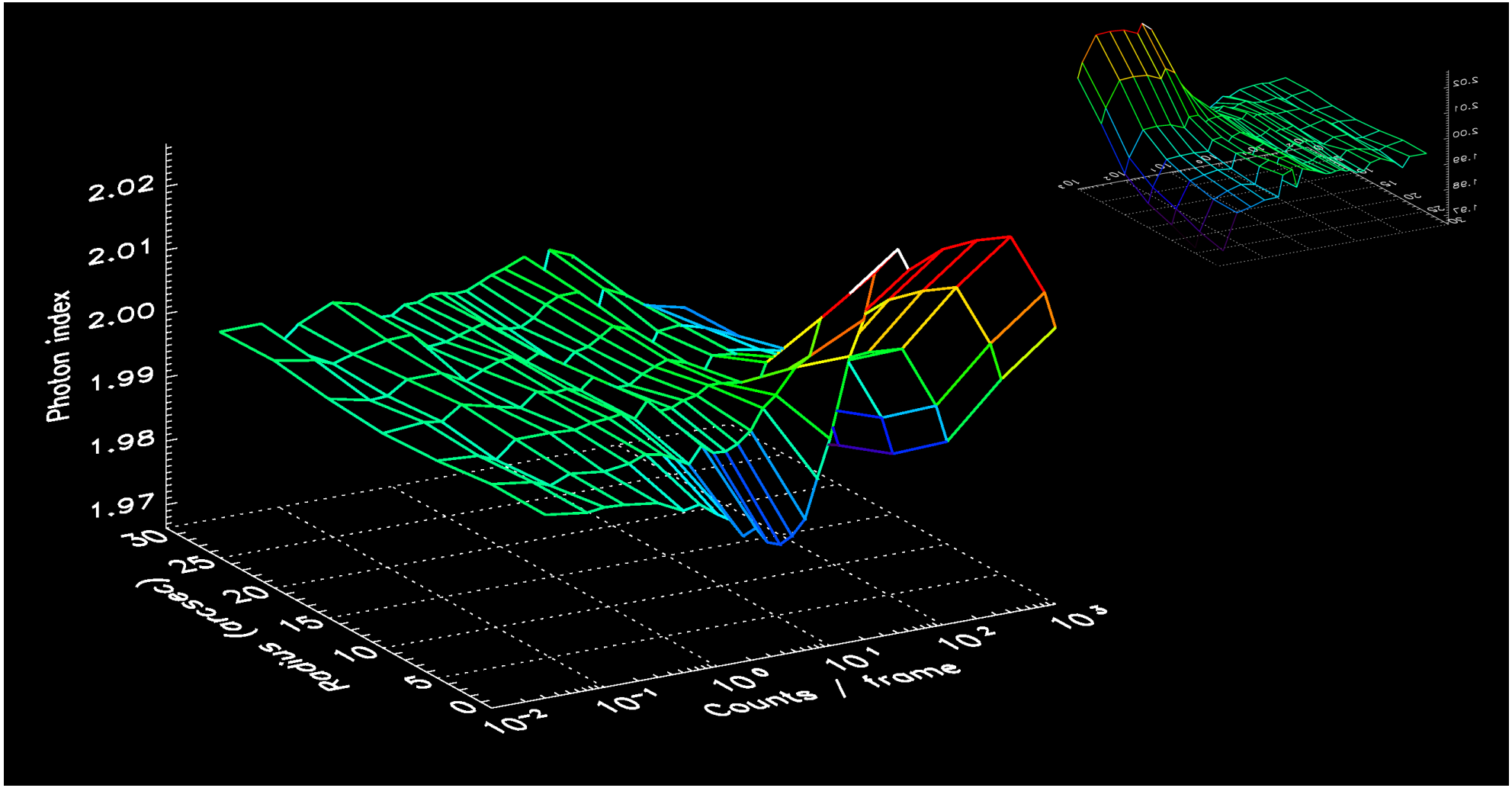


PILE-UP MODELLING: flux measurement with excised core





PILE-UP MODELLING: spectral distortions



PILE-UP MITIGATION

- Provides a control to test any pile-up correction method

- Can also be used in a new pile-up correction procedure (Andy Pollock):
  - Piled-up spectrum = FUNCTION (Original spectrum , pile-up parameters)
  - Use the simulator to generate a grid of pile-up parameters
    - Instrument dependent
    - Count rate dependent
    - Weakly spectrum dependent?
  - Incorporate these into XSPEC pile-up model

- Other correction procedures under consideration:
  - J. Ballet 1999, 2000, 2003
    - based on his theoretical pile up equations
    - alter response matrix to consider pile-up in fitting process
  - Idea proposed by Norbert Schartel
    - based on nuclear physics
    - as described in *Radiation Detection and Measurement*, G.F. Knoll