

THE EPIC SIMULATOR AND PILE-UP MODELLING

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- 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?



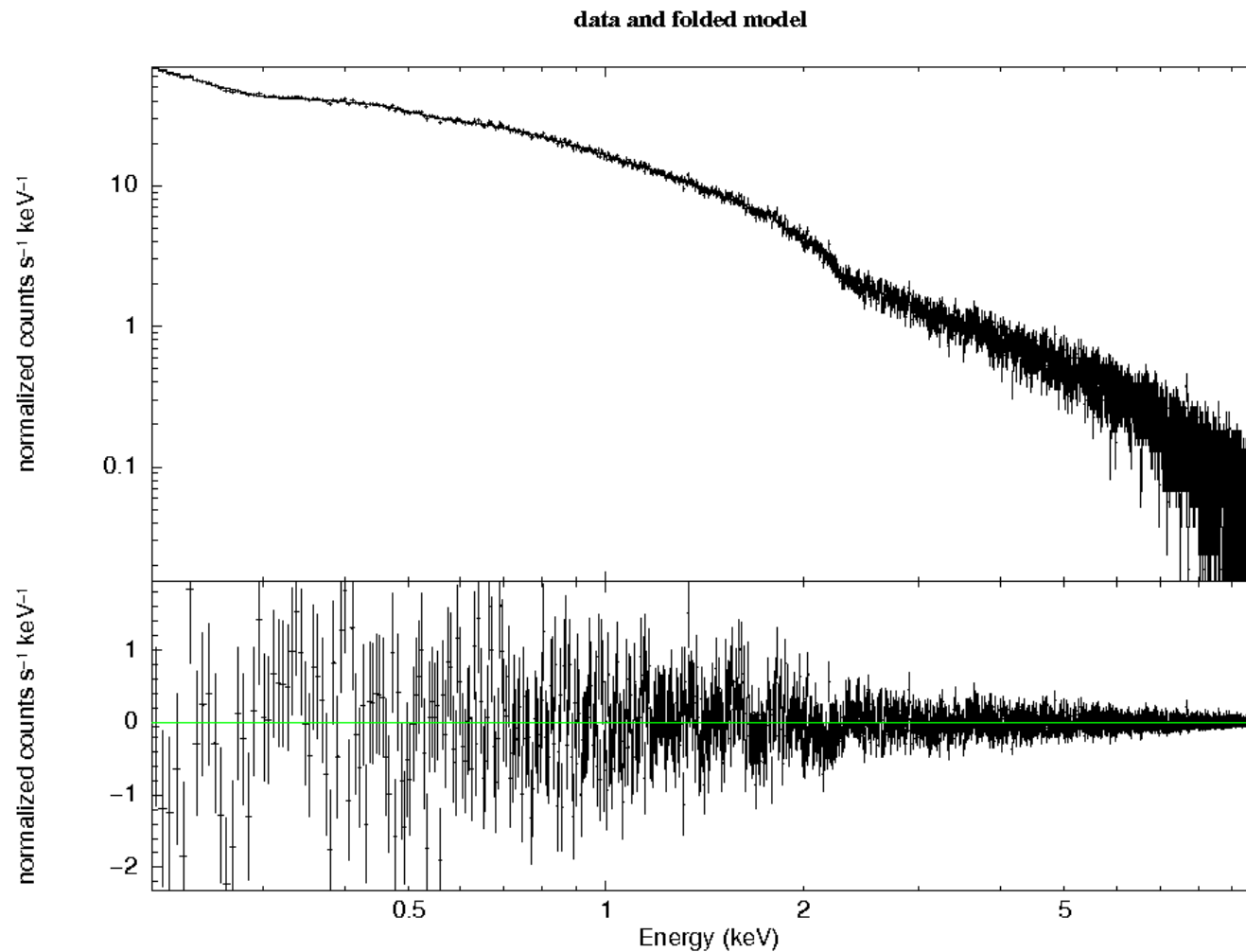
- New tool developed in IDL by Richard Saxton, Pedro Rodriguez, Prashin Jethwa
- Realistically simulate EPIC observations
- What does it do?
 - Input:
 - 1) instrument
 - 2) number of counts per frame
 - 3) number of frames in observation
 - 4) spectral model
 - 5) calibration files
 - Simulate (details 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 $\sim 2\text{keV}$
- ... consequence of ARF/RMF interpolation differences between XSPEC and simulator?

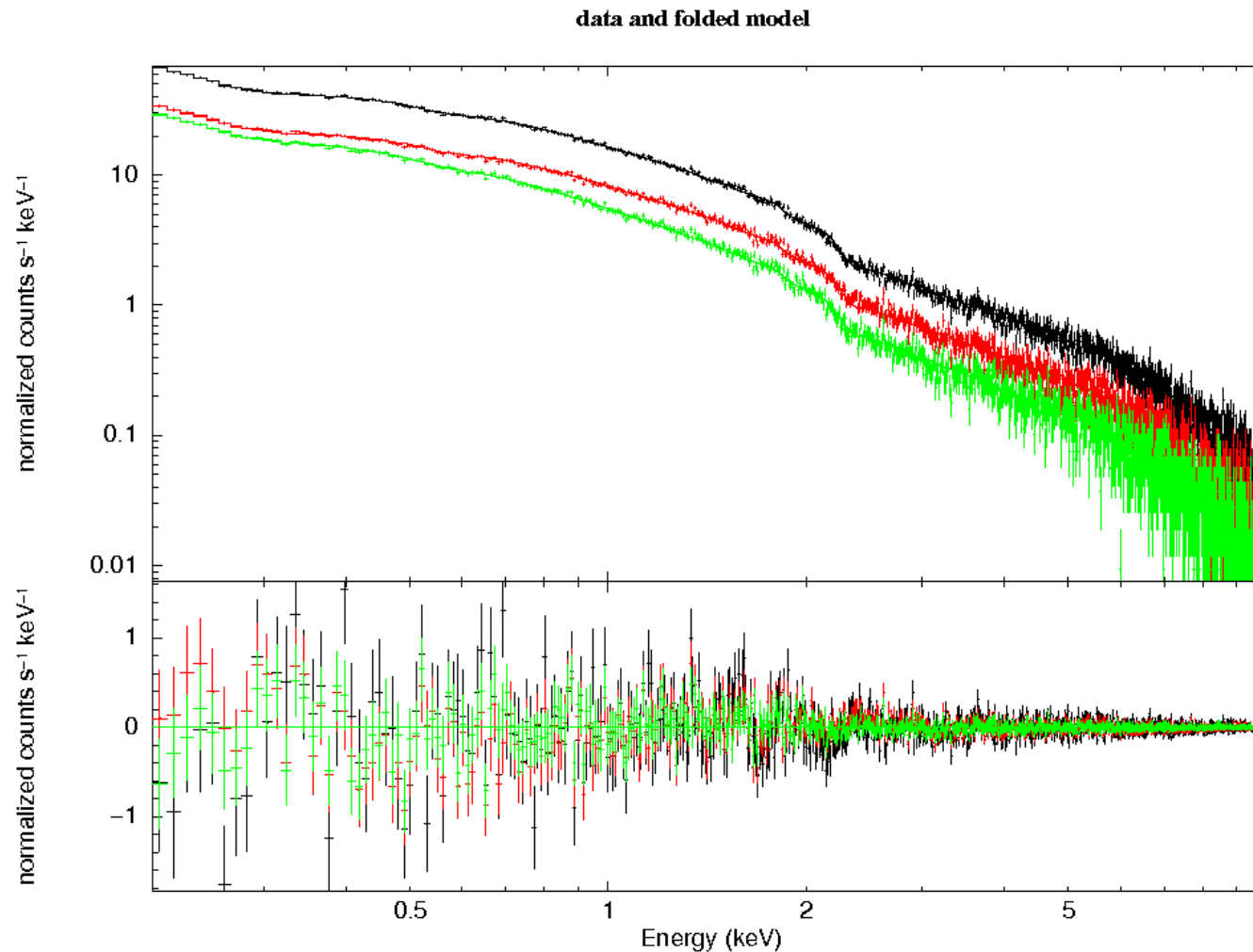
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THE EPIC SIMULATOR: how does it work?



- 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

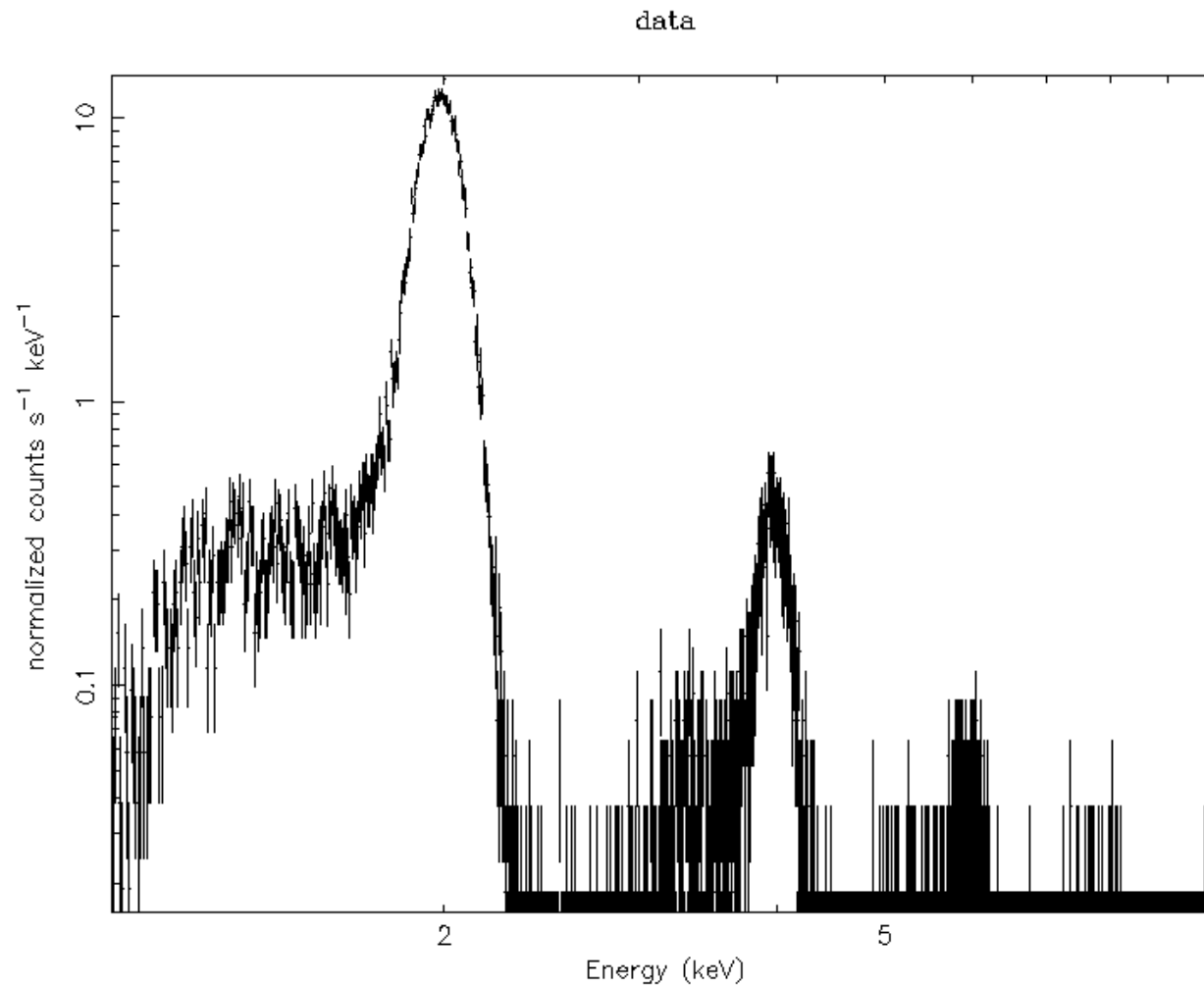
➤ **Black:**
Input
 $\Gamma = 1.997$
Flux = $3.5e-11$

➤ **Red:**
Output singles+doubles
 $\Gamma = 1.985$
Flux = $1.9e-11$

➤ **Green:**
Output singles
 $\Gamma = 1.992$
Flux = $1.7e-11$

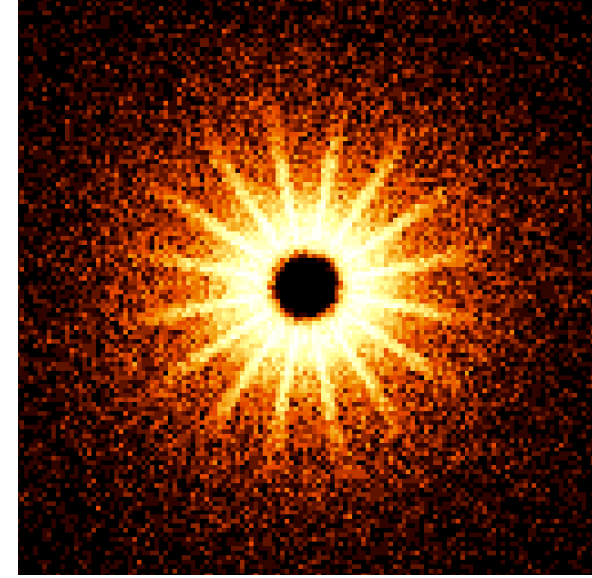
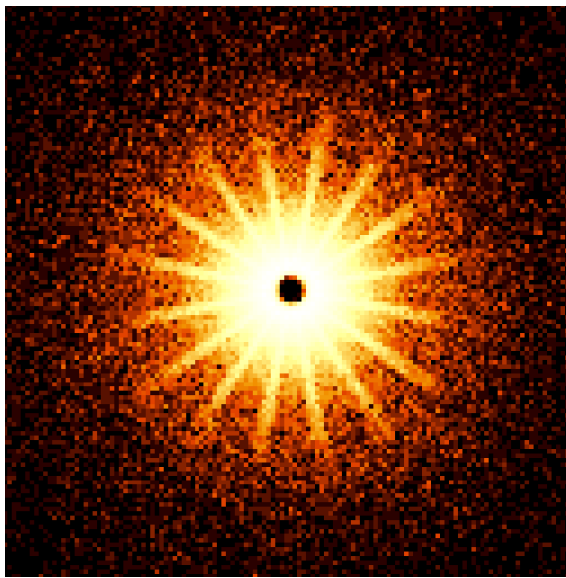
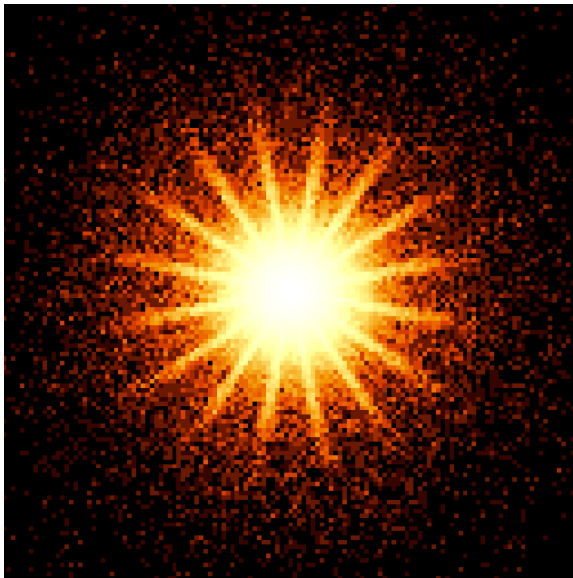
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THE EPIC SIMULATOR: piled-up Gaussian



- 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.

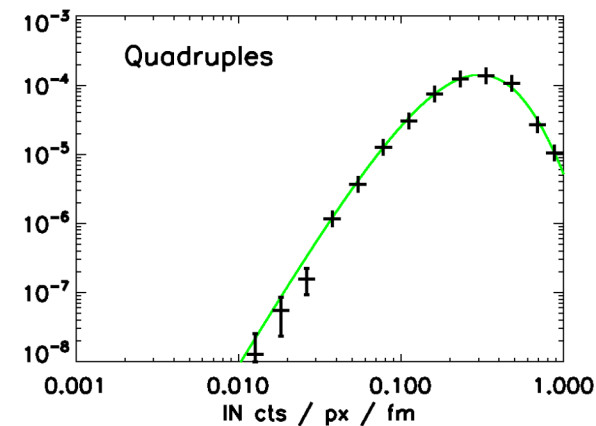
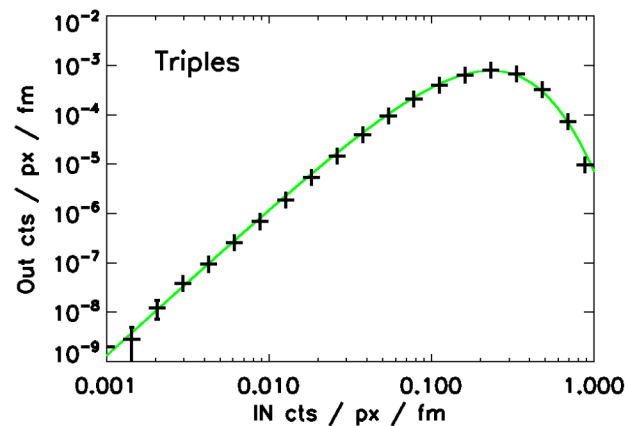
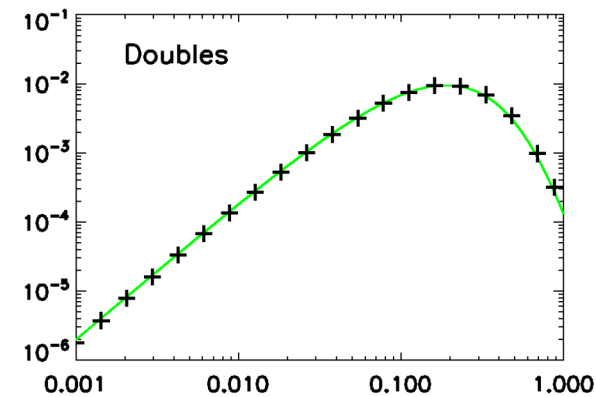
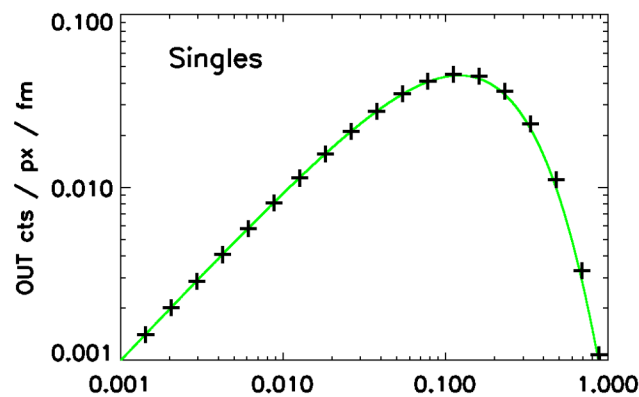
Left: 1 count / frame, Centre: 100 counts / frame, Right: 1000 counts / frame

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

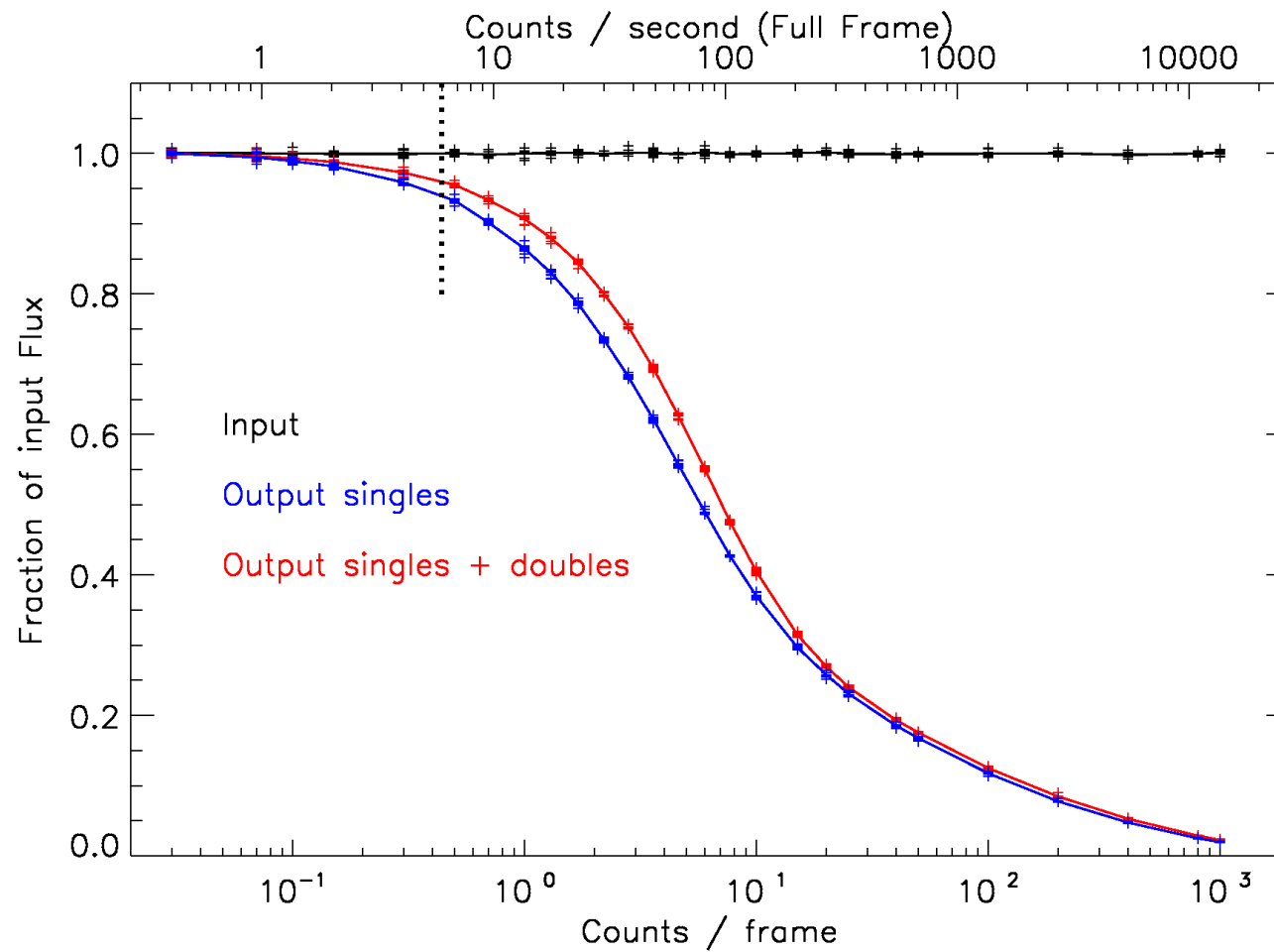
THE EPIC SIMULATOR: validation



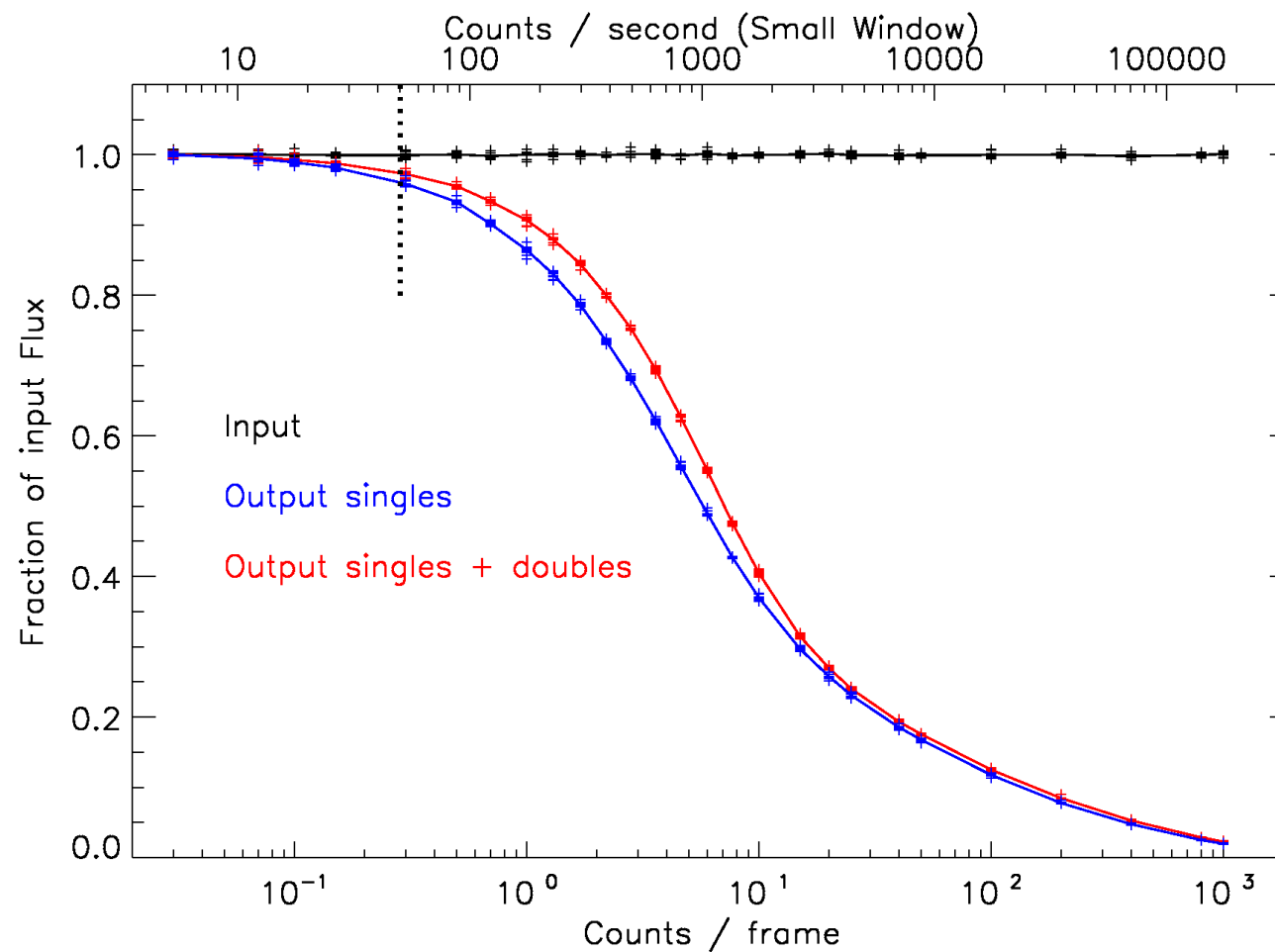
- Self-consistent: for low count rates the output spectrum = input spectrum
- Comparison against theoretical work (J. Ballet 1999)



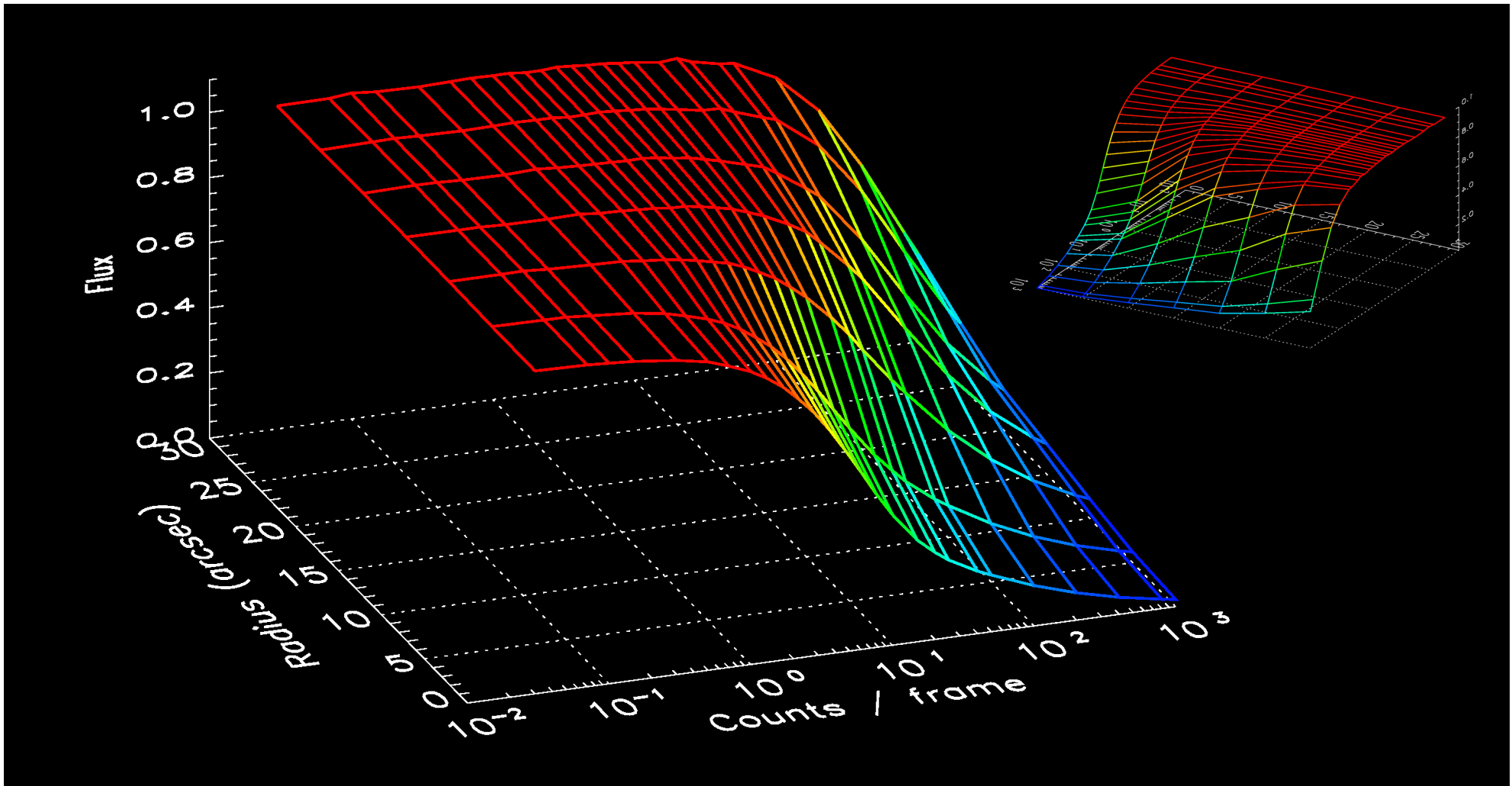
PILE-UP MODELLING: flux loss in PN full frame



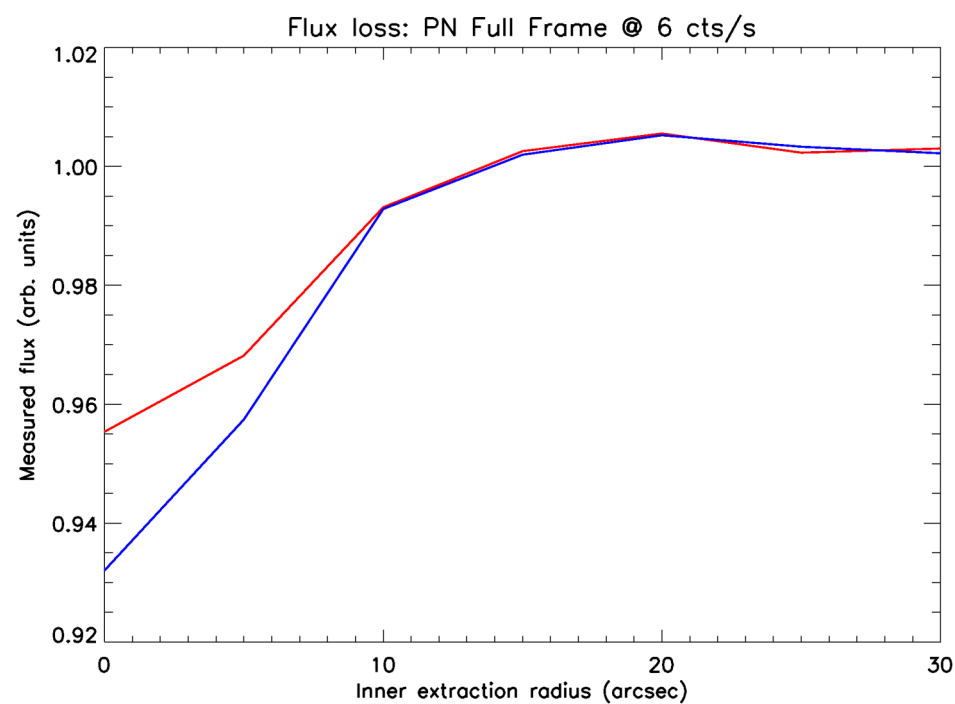
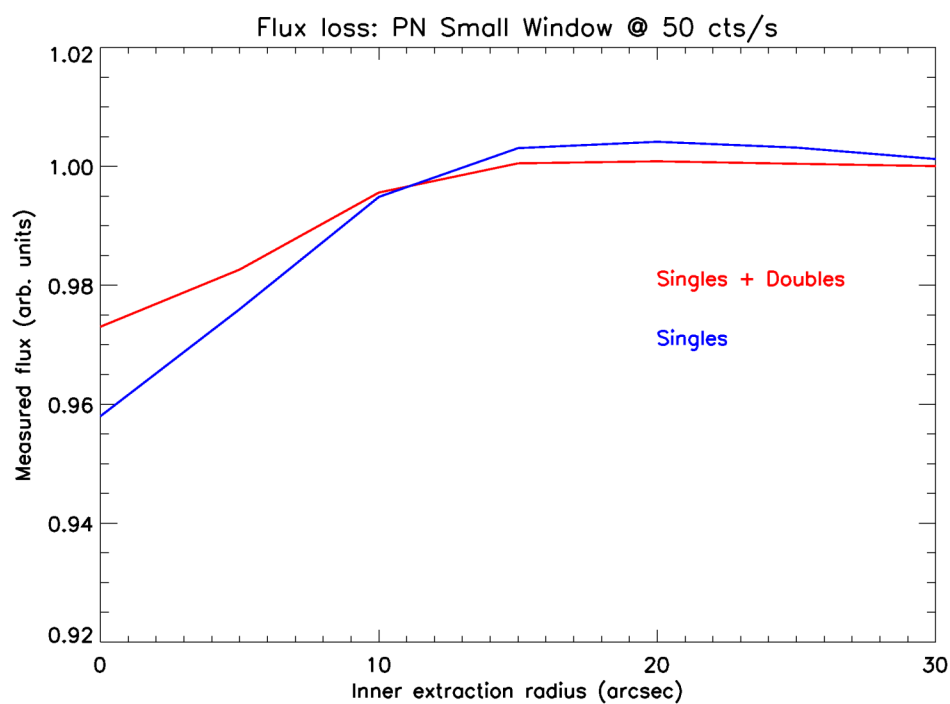
PILE-UP MODELLING: flux loss in PN small window



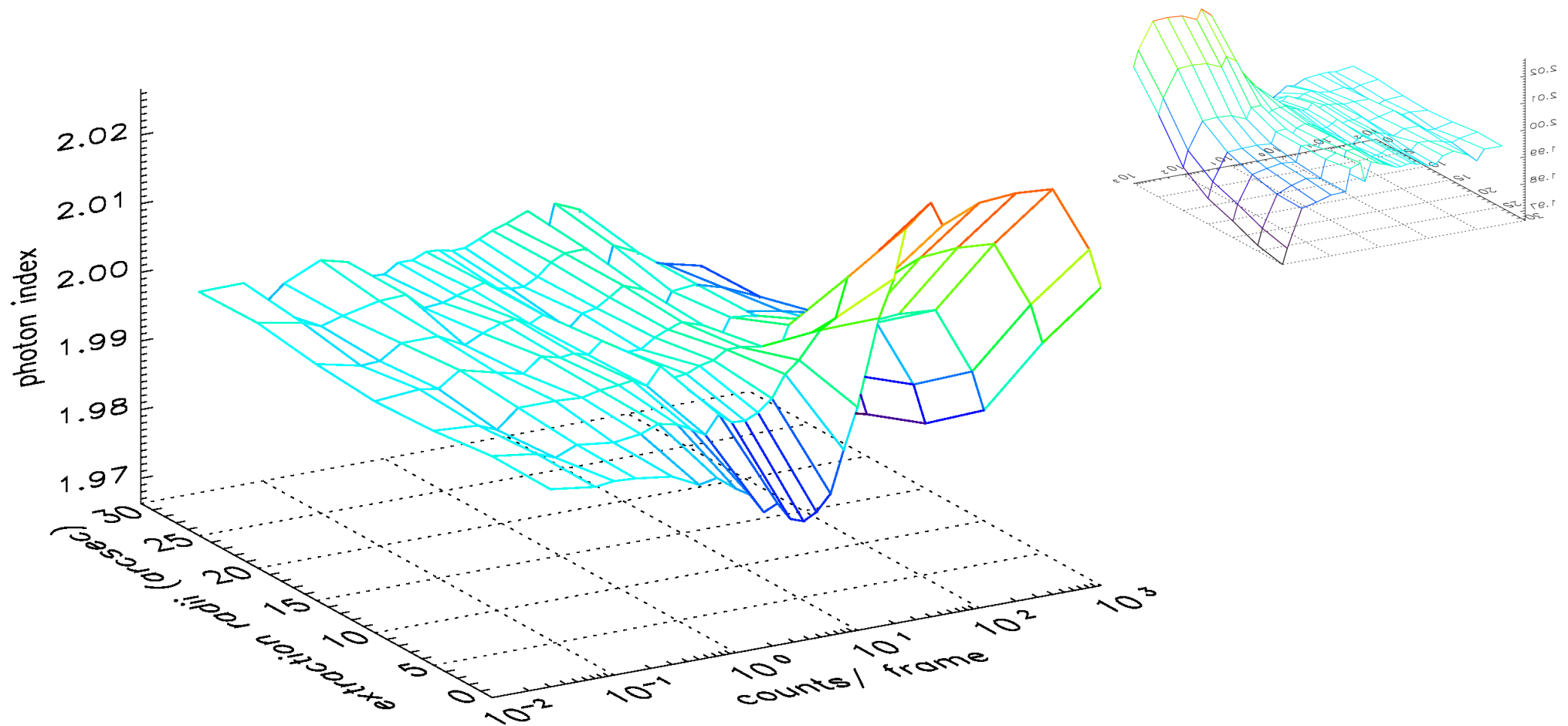
PILE-UP MODELLING: flux loss



PILE-UP MODELLING: flux measurement with excised core



PILE-UP MODELLING: spectral distortions



- 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