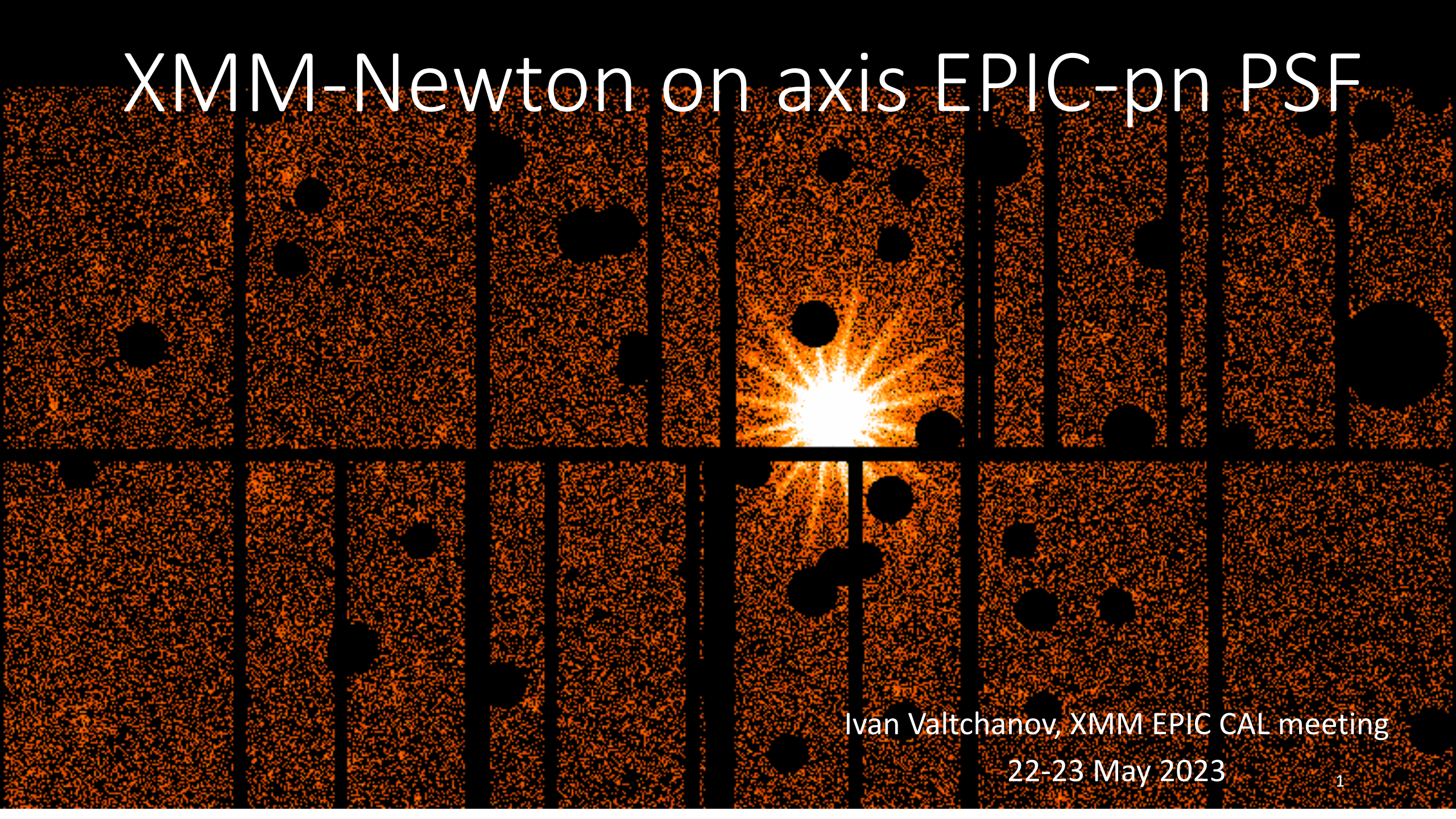
XMM-Newton on axis EPIC-pn PSF



Ivan Valtchanov, XMM EPIC CAL meeting

22-23 May 2023

Background information

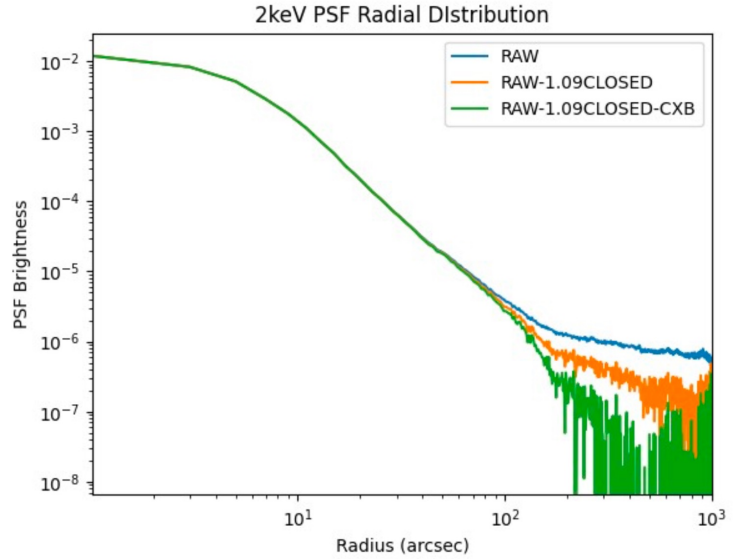


Figure 3: Radial Brightness of PSF at 2keV

- TN by David Lumb (Dec 2022)
- PN in LW mode
- Sample of 16 AGNs on axis
- Compare with CCF

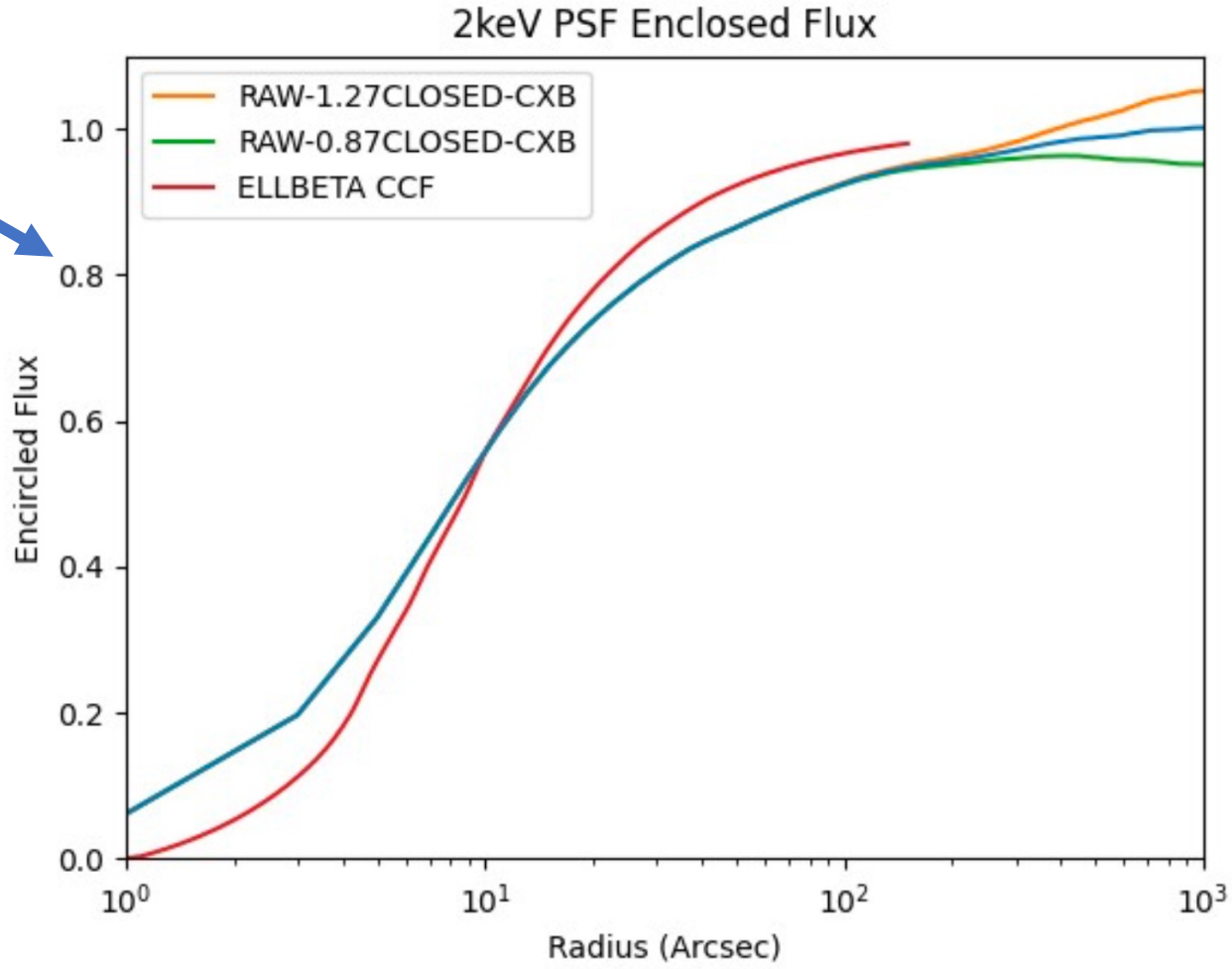


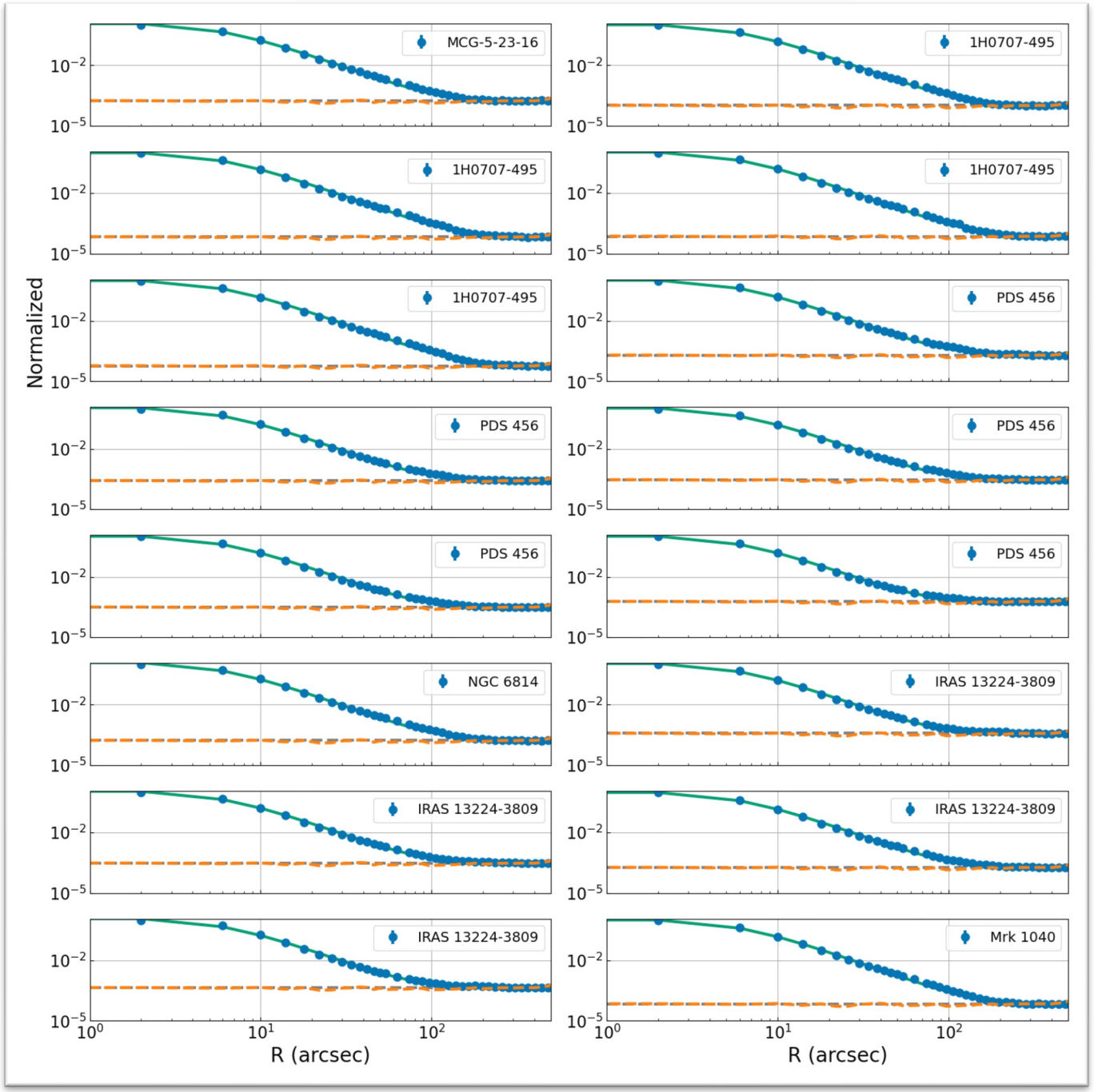
Figure 4: 2keV Enclosed Flux

Workflow

- Using a list of 16 AGNs from Lumb report, all in PN Large Window mode
- Process the OBS_IDs in a homogenuous way
  - Calibrated event lists from PPS via NXSA
  - Clean for periods of high background using the PPS derived thresholds
  - Filter events for PATTERN in [0:4] && FLAG == 0 && GTI && PI > 150
  - Generate images in [400,1400] eV and in [1500,2500] eV in detector coordinates with 2”/pixel:
    in counts and count-rates (using the exposure maps)
  - Detect and mask sources (using ewavelet) excluding the central region (not to mask the actual source)
    ➔ creating “cheese” mask
- Using the count-rate image in DETXY and the “cheese mask”: build radial profile with linear + log grid
  - Centroid of source is used as origin (center-of-mass for centroid)
  - Linear scale out to 20 pixels (40”) and then in log space out to 10’
- Same processing on “blank” sky PN LW observations (for background)

Method

- We have 16 AGN radial profiles + a background profile on the same radial grid
- We fit simultaneously all 16 profiles,
  keeping the core radius ($\mathbf{r_c}$) and slope ($\boldsymbol{\beta}$) to be the same for each source.
  - Model is **Moffat1d()** aka King-profile, beta-profile or ELLBETA in SAS.
  - The amplitude and the background are kept free and *different* for each dataset.
  - Initial $\mathbf{r_c}$ and $\boldsymbol{\beta}$**:**
    - **Test1:** allowed to vary within ~10% of the ELLBETA CCF parameters.
    - **Test2:** keep them free with initial values those from ELLBETA CCF
  - Least-square minimization of `(data-model)/data_error`



Radial profiles in log-log space

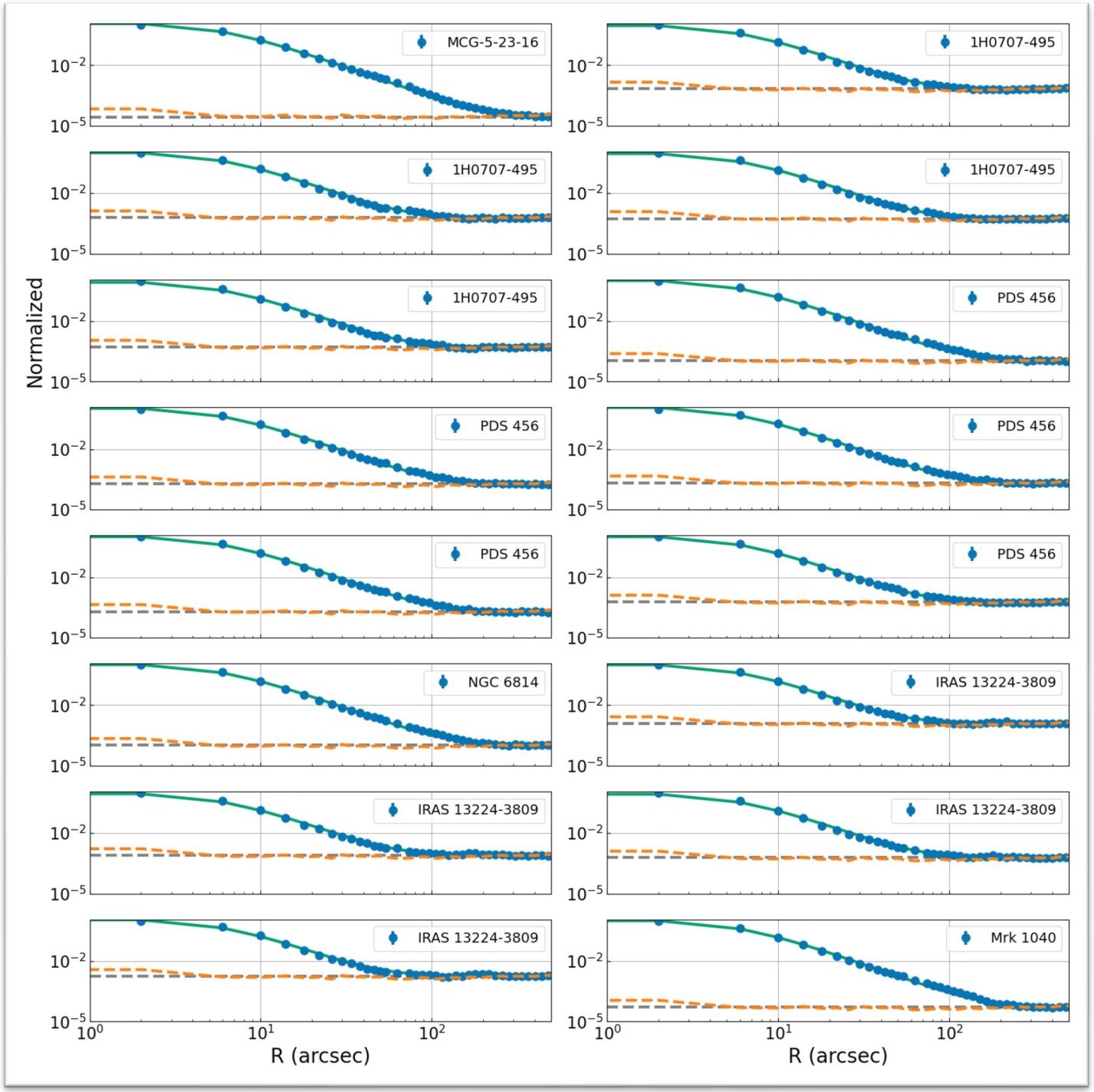
[400,1400] eV

Data as blue dots + error bars (small)

Best **simultaneous** fit: in green

Normalized background: orange dashed

Best-fit background: grey



Radial profiles in log-log space

[1500,2500] eV

Data as blue dots + error bars (small)

Best **simultaneous** fit: in green

Normalized background: orange dashed

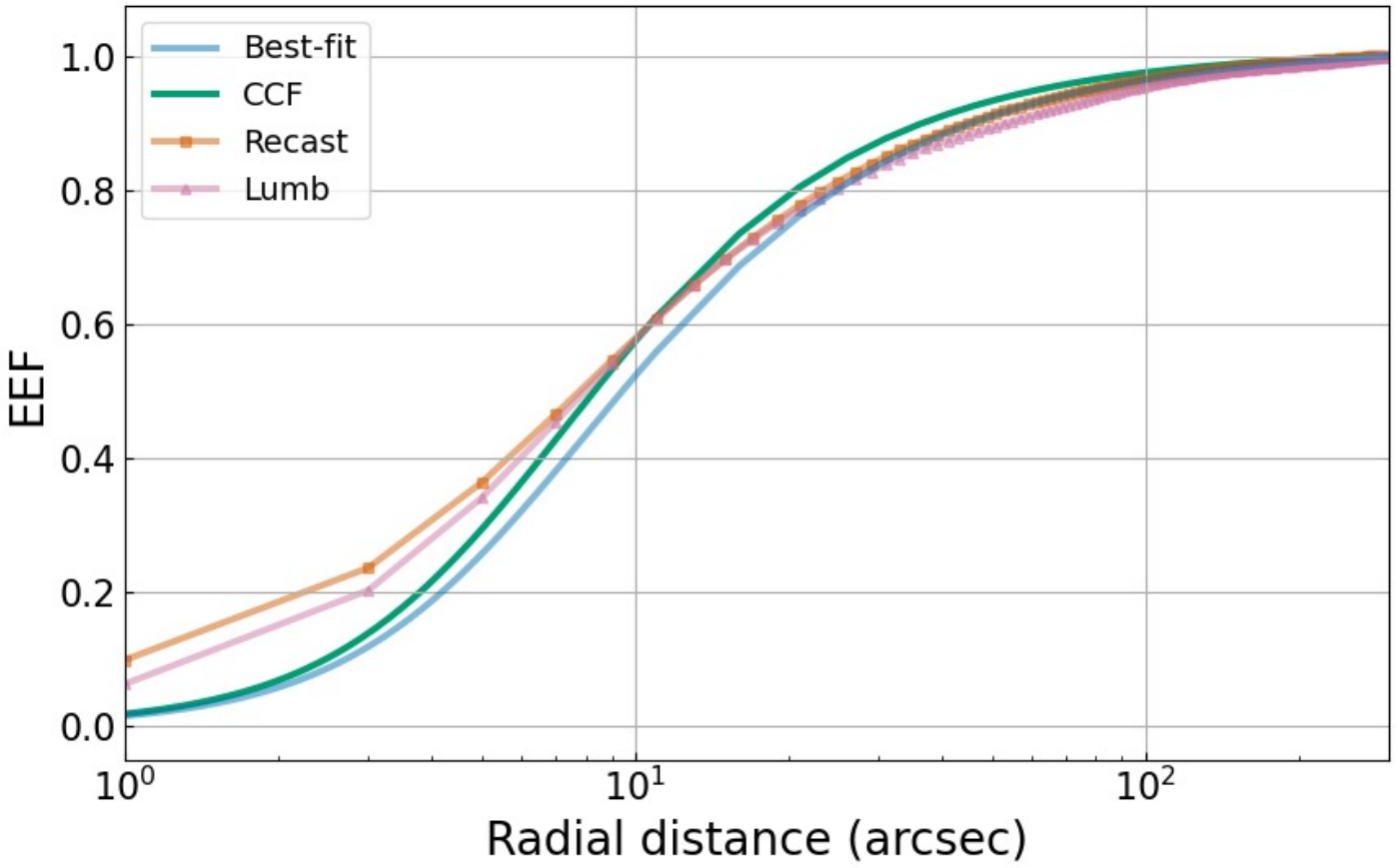
Best-fit background: grey

Best fit Parameters

- Input ELLBETA parameters from XRT3_XPSF_0018.CCF
  - Energy = 1500 eV, θ=0, **r_c=5.61”, β =1.59**
  - **Best-fit results:**

	R_{core} (“)	β
Case [0.4,1.4] keV	5.77 ± 0.04	1.52 ± 0.01
Case [1.5,2.5] keV	5.77 ± 0.04	1.51 ± 0.01

Encircled Energy Fraction



At 1 keV [0.4,1.4] keV band

Calculated analytically with the CCF or best-fit parameters

+ David Lumb derived EEF

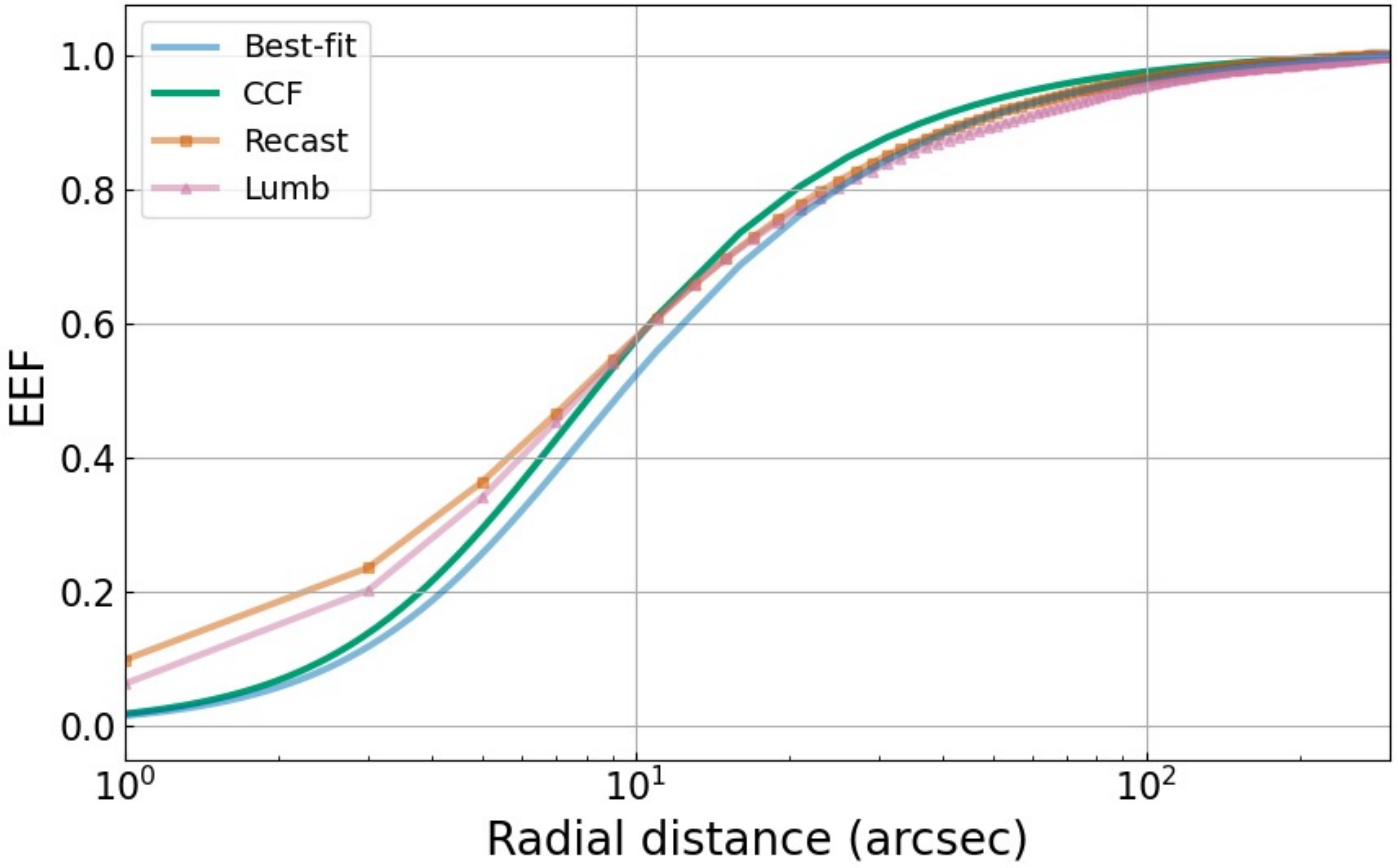
All normalized with EEF(300”) = 1

Example:
For R=31” ➔

EEF(CCF) = 0.88

EEF(this work) = 0.84

Encircled Energy Fraction



WARNING!

Deriving the EEF from the empirical radial profile (i.e. recast) is affected by pixelisation!

The EEF is overestimated out to R~20”

Results

- Simultanouse fit for radial profiles of 16 point-like sources in PN Large Window mode:
  - Only **r_c and β** are kept the same for each of the 16 profiles, amplitude and flat background are free
  - The derived PSF parameters are consistent for [0.4,1.4] and [1.5,2.5] keV
  - The derived PSF parameters are slightly off from the CCF ELLBETA parameters
    - The derived r_c is 0.17" larger than the value in the CCF
    - The derived β is 0.07 smaller than the value in the CCF

➔The EEF curve with the best-fit r_c and β is different from ELLBETA-derived EEF and from David Lumb-derived EEF (recast from radial profile)

➔EEF(31") = 0.88 in CCF , 0.84 with this method.

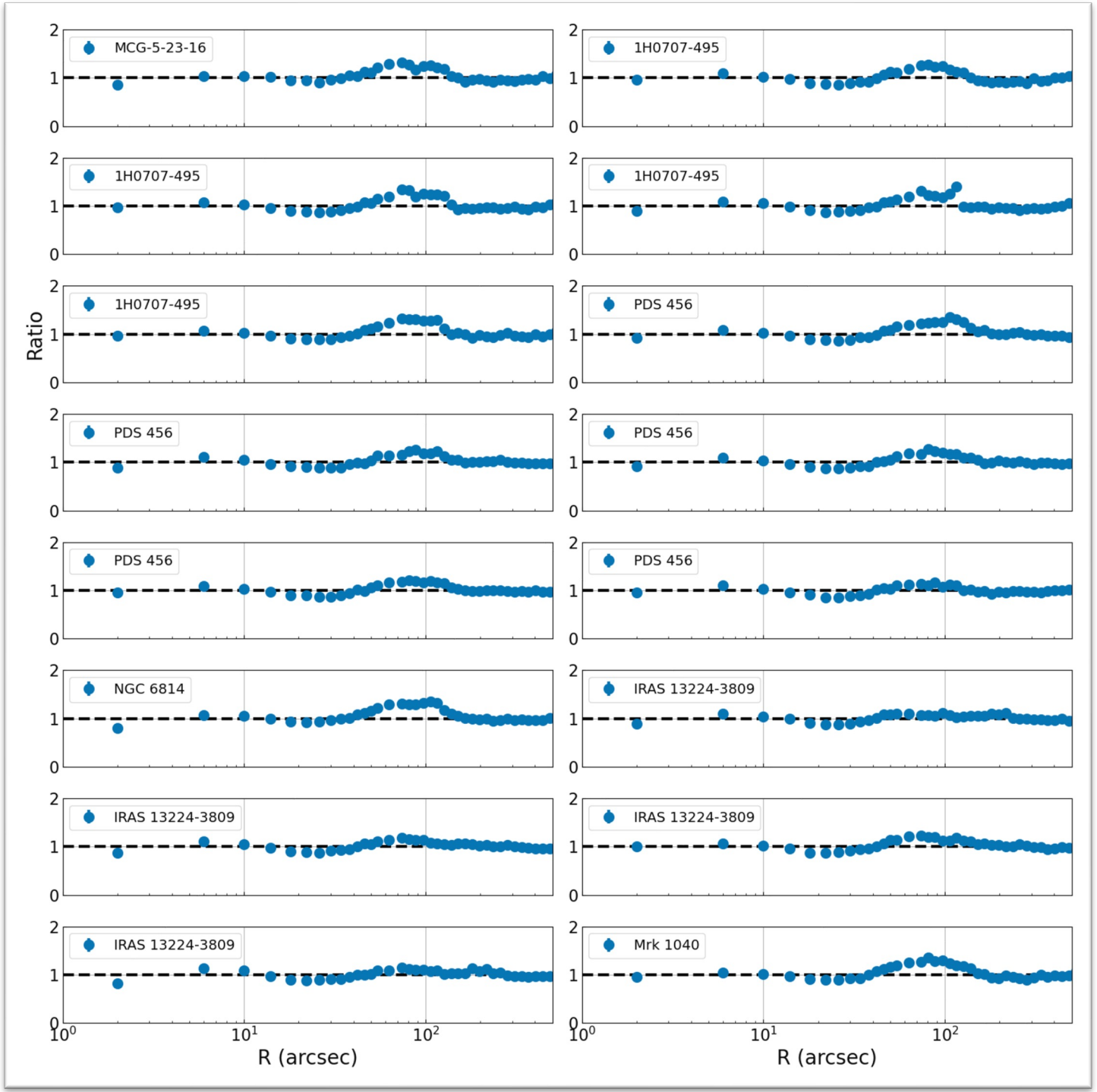
➔EEF(61") = 0.95 in CCF, 0.93 with this method.

Future work

- Apply the same method for higher energies
- Increase the sample with more PN LW observations of on-axis point-like sources (if necessary)
- Proceed with off-axis observations?
- Do MOS PSF with the same idea?

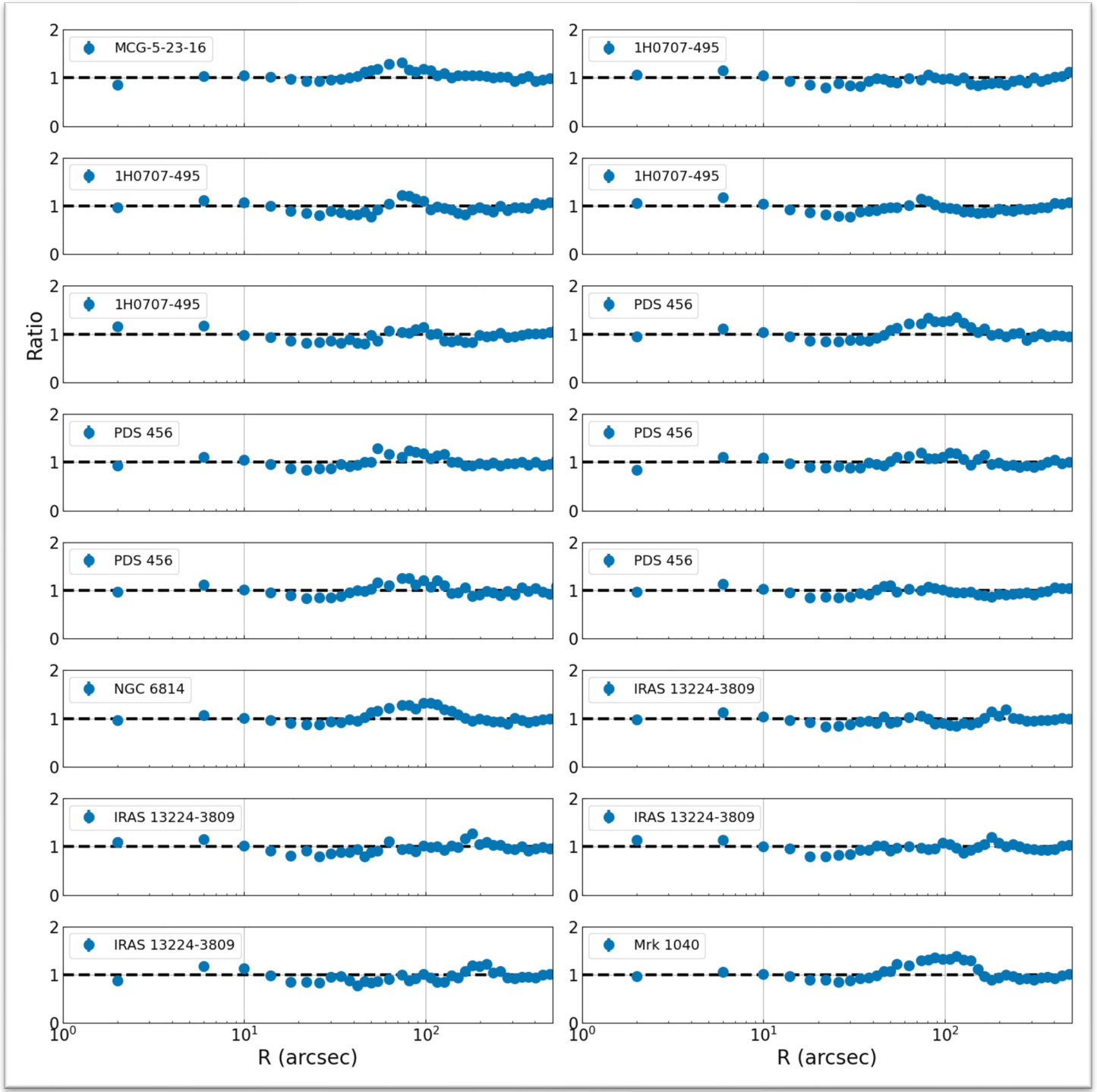
The end

How good is the simultaneous fit?



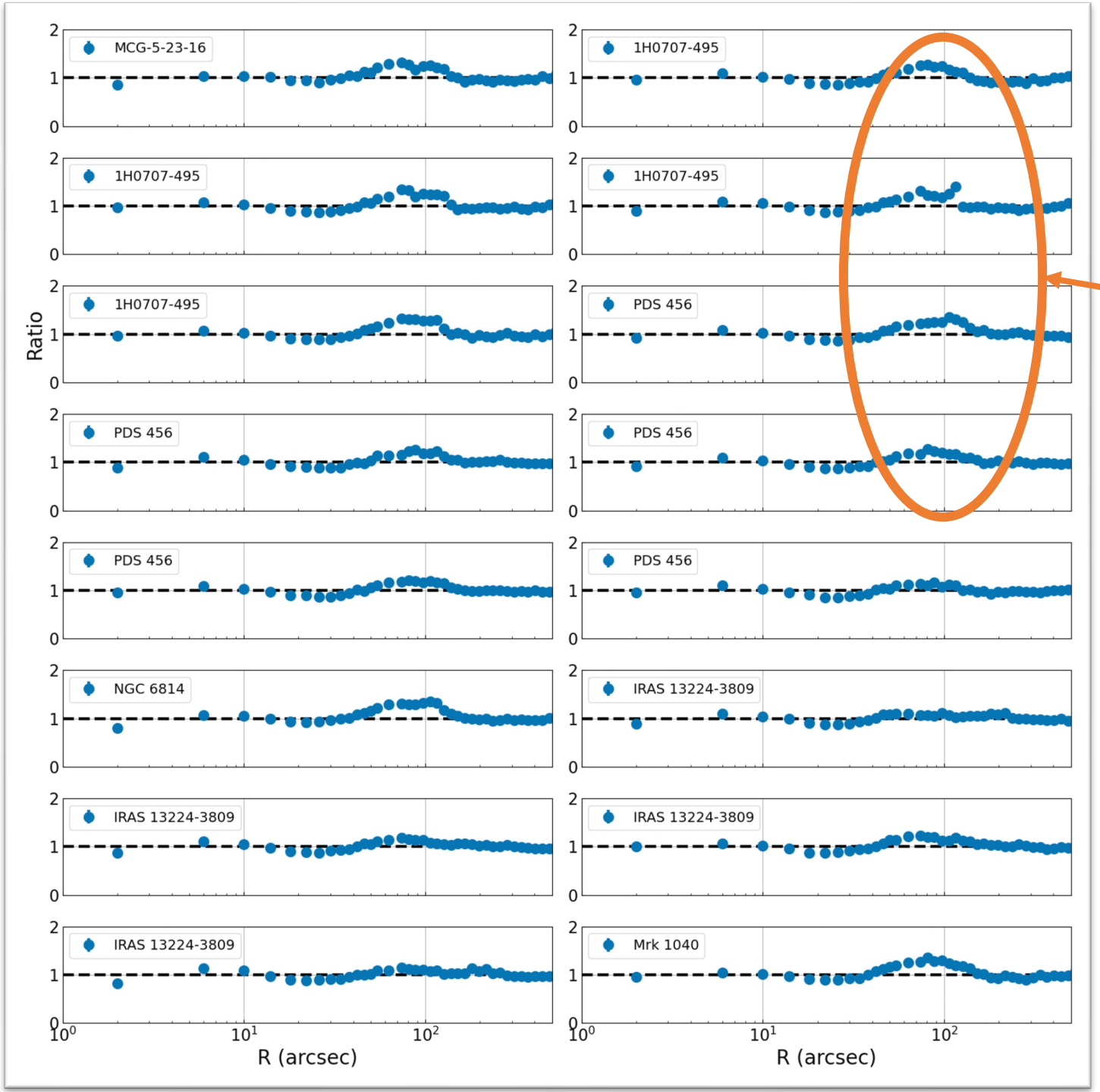
Data/Model in log-lin space

[400,1400] eV case



Data/Model in log-lin space

[1500,2500] eV case

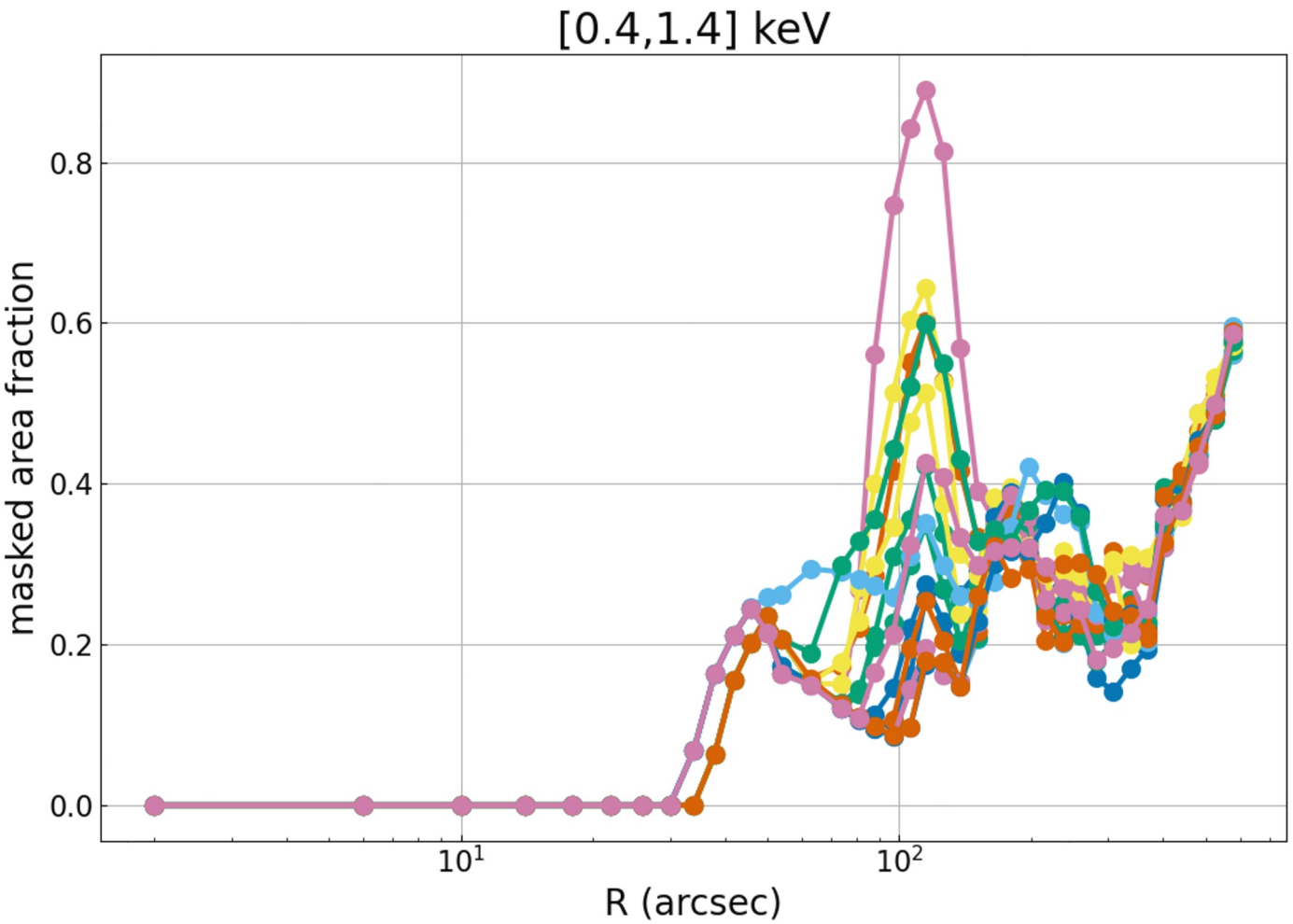


Data/Model in log-lin space

[400,1400] eV case

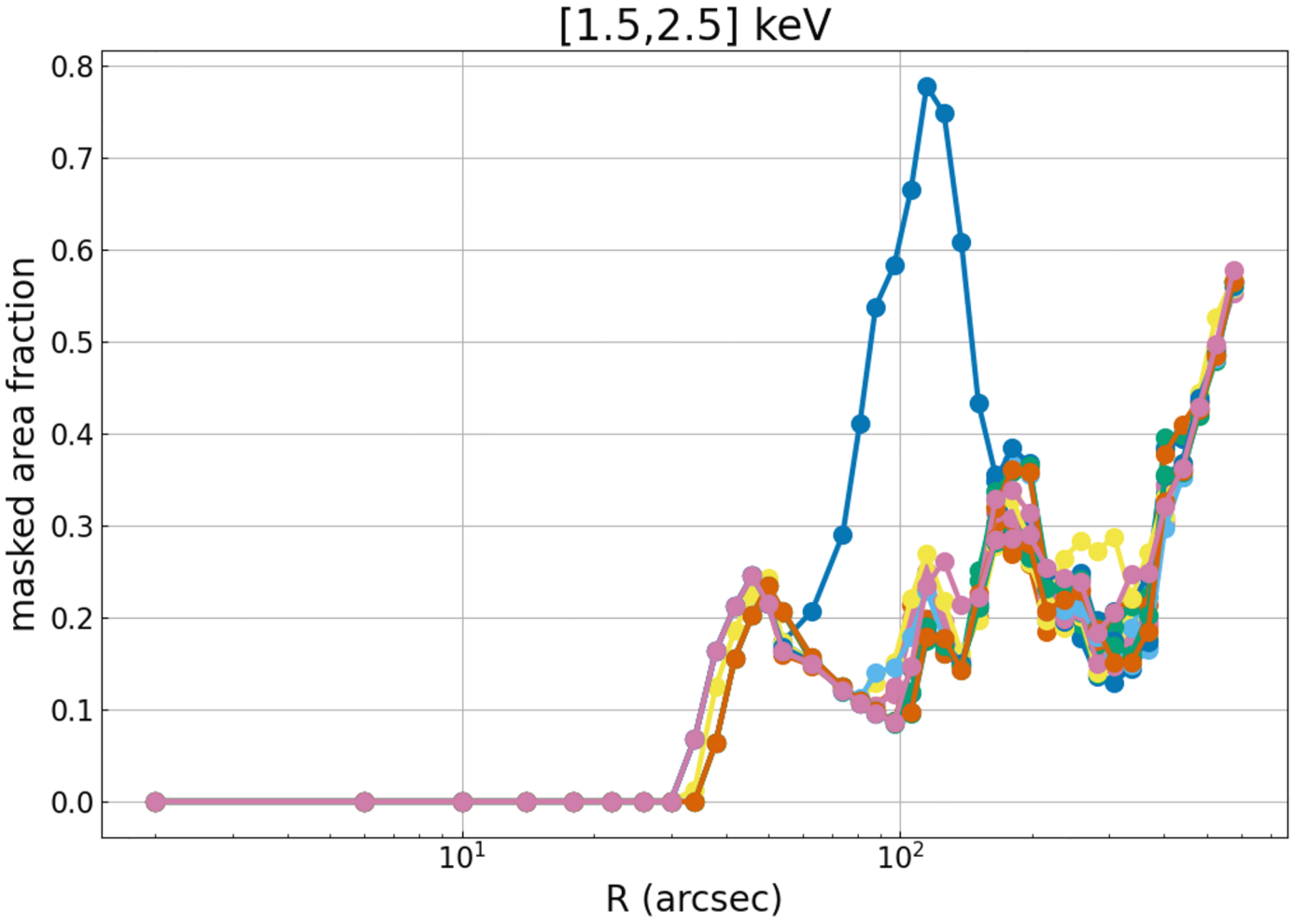
Characteristic bump at ~100”?

Fraction of masked area

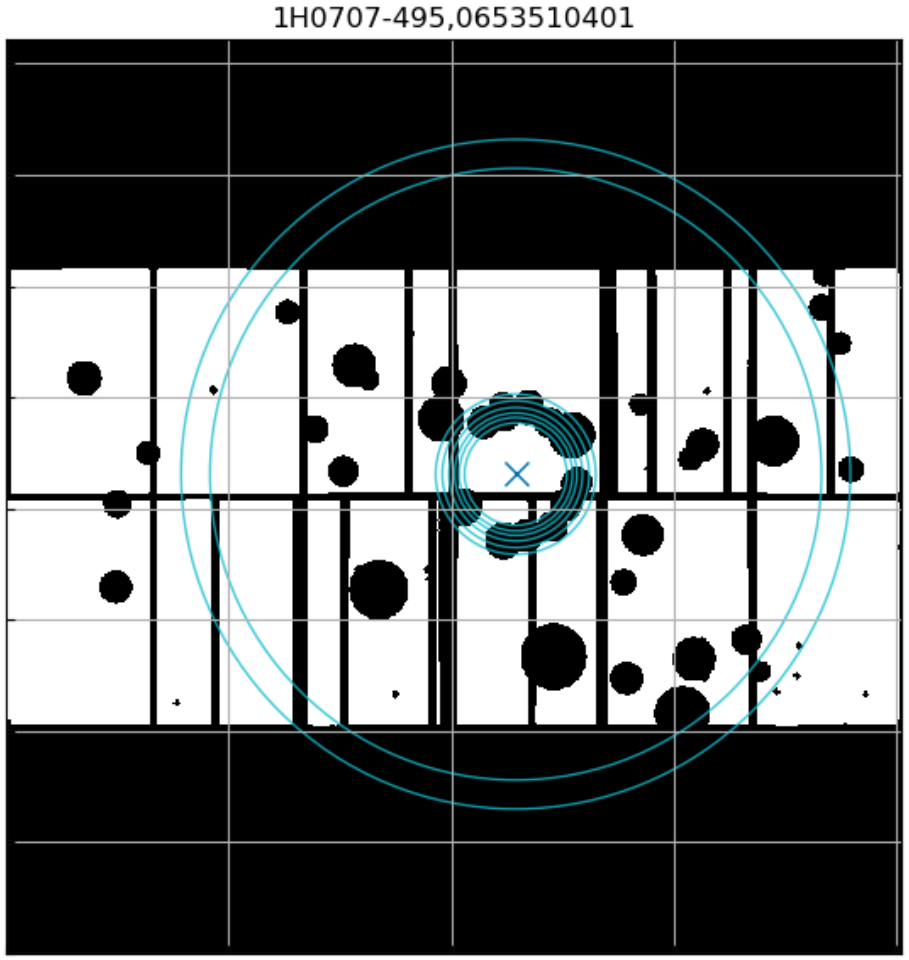


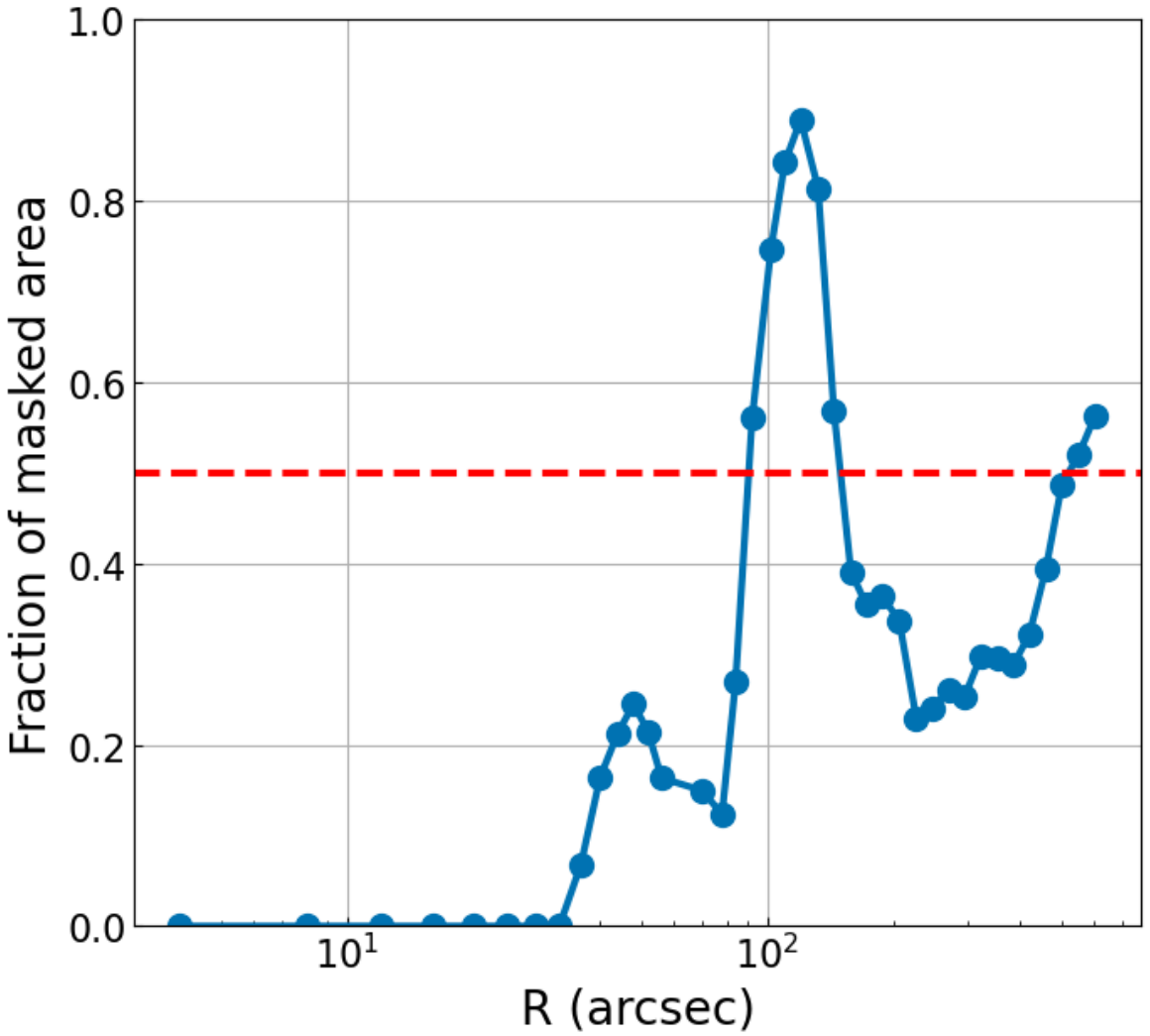
0 ➔ no masked area within radial region
0.5 ➔ half of the area is masked

Fraction of masked area

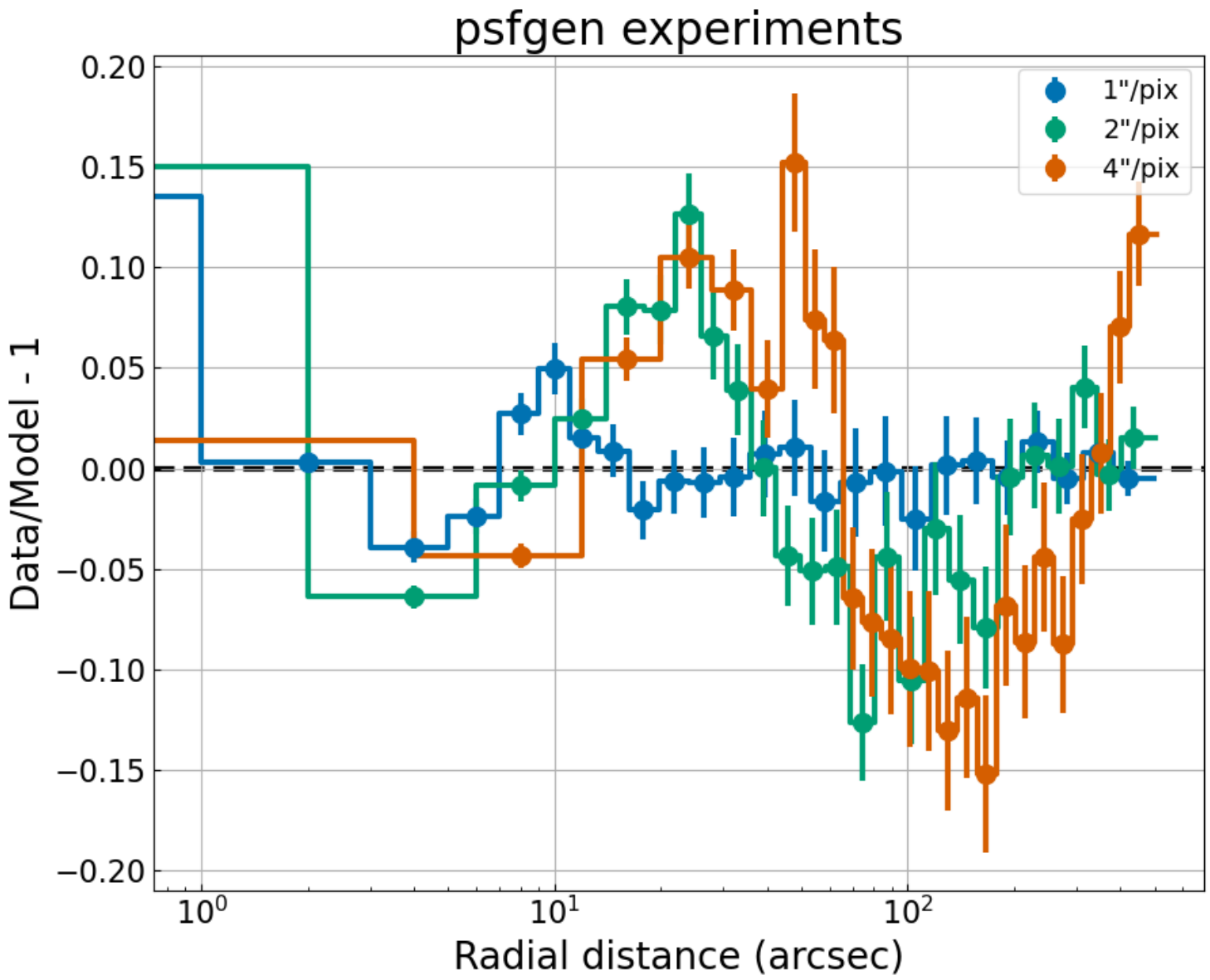


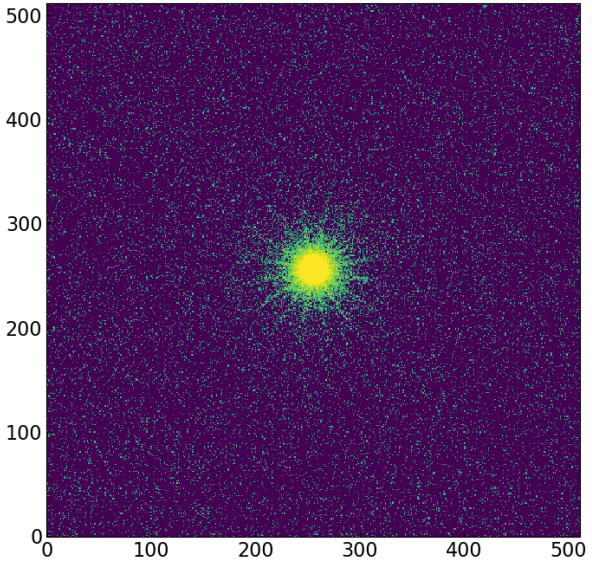
0 ➔ no masked area within radial region
0.5 ➔ half of the area is masked





Extreme case: spurious sources masked in the wings of the central source





Synthetic PSF image
No gaps or masked areas