Planning and implementing XRISM in-flight calibration

Eric Miller (MIT) for the XRISM Team

In-flight calibration plan for XRISM

XRISM X-Ray Imaging and Spectroscopy Mission

- In-Flight Calibration Planning team charter (tl;dr version)
  - Develop a comprehensive and executable XRISM in-flight calibration plan.
  - Identify the XRISM in-flight calibration requirements.
  - Specify targets and exposures needed to fulfill these requirements, and the priority for performing the calibration observations.
  - “Open” activity; science team members are encouraged to participate.

XRISM IFCP Team….

Chair	Eric Miller *
Co-chair	Makoto Sawada *
Resolve Instrument Team	Megan Eckart Caroline Kilbourne Maurice Leutenegger Scott Porter Masahiro Tsujimoto Cor de Vries Takashi Okajima Takayuki Hayashi Keisuke Tamura Rozenn Boissay-Malaquin
Xtend Instrument Team	Hironori Matsumoto Koji Mori Hiroshi Nakajima Takaaki Tanaka
Science Operations Team	Yukikatsu Terada Mike Loewenstein Tahir Yaqoob Masayoshi Nobukawa Tomokage Yoneyama
Science Management Office	Makoto Tashiro Richard Kelley Rob Petre Matteo Guainazzi * Brian Williams Hiroya Yamaguchi
Science Team	Marc Audard Ehud Behar Laura Brenneman Lia Corrales Renata Cumbee Teruaki Enoto Liyi Gu Edmund Hodges-Kluck Yoshitomo Maeda Maxim Markevitch * Paul Plucinsky Katja Pottschmidt Minami Sakama Takumi Shioiri Aurora Simionescu *

* IFCP sub-group lead.

….has become the Cal-IP Team

XRISM X-Ray Imaging and Spectroscopy Mission

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Ehud Behar
Rozenn Boissay-Malaquin
Laura Brenneman
Lia Corrales
Renata Cumbee
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Hiro Takahashi
Mai Takeo
Tsubasa Tamba
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Takaaki Tanaka
Makoto Tashiro
Yukikatsu Terada
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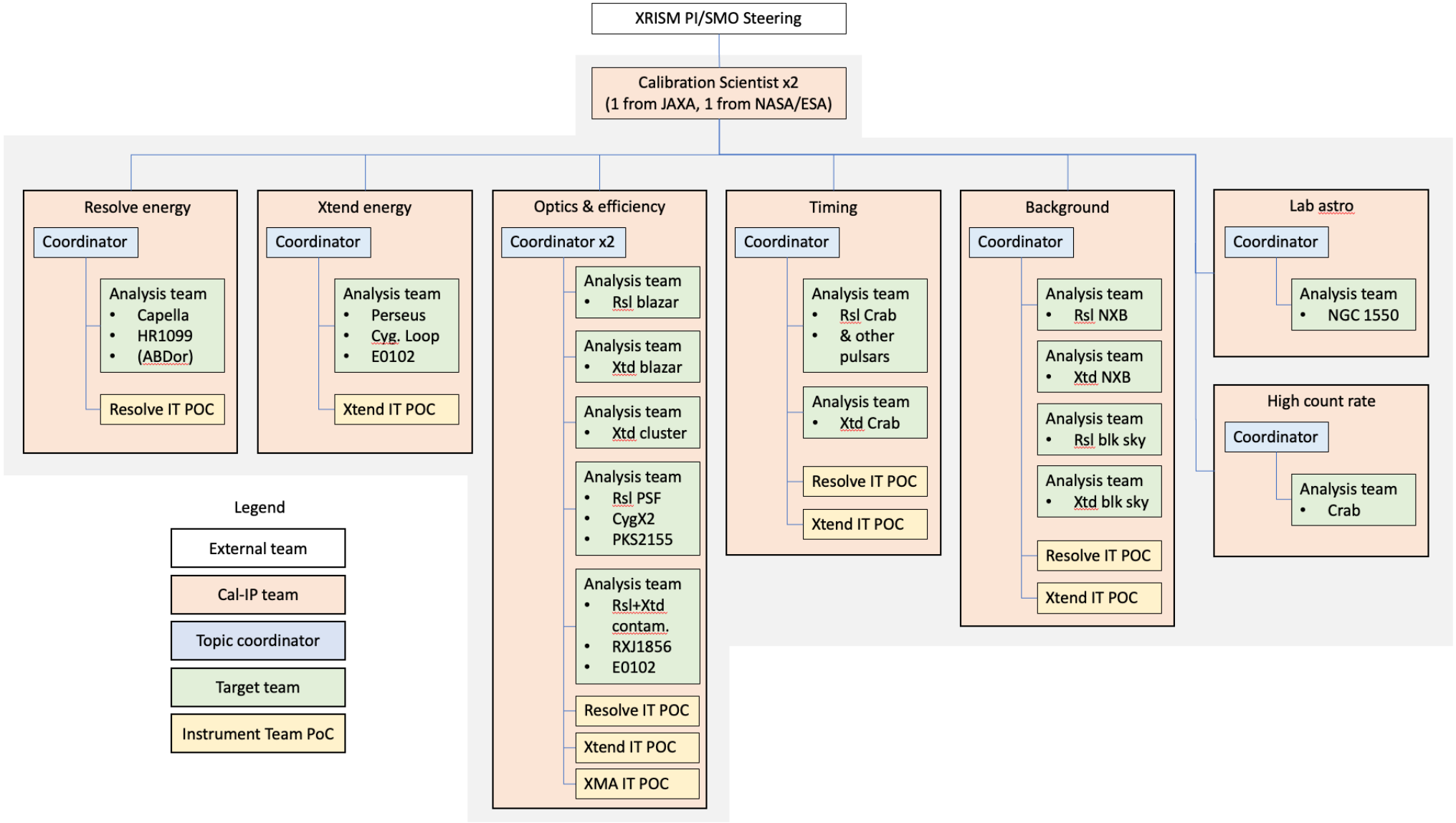
Aysegul Tumer
Hiroyuki Uchida
Yuusuke Uchida

Brian Williams
Hiroya Yamaguchi
Shigeo Yamauchi
Tahir Yaqoob
Tomokage Yoneyama

Calibration Scientists (Cal-IP leads)
Cal Team coordinators
Analysis Team leads
IT points of contact

74 total members

Cal-IP structure



Resolve Gate Valve contingency plan

XRISM X-Ray Imaging and Spectroscopy Mission

- In November 2023, the team began to plan changes to calibration targets if the Resolve Gate Valve remained closed (*GVC* operation).

Thanks to the Cal-IP team for your hard work!

- Calibration targets changed due to GVC:
  - Capella on-axis and raster scan (Resolve energy): too soft
  - 3C 273 w/ Be filter (Resolve Aeff): unnecessary
  - PKS 2155 → **Cyg X-2** (Resolve PSF): too faint
  - AB Dor → **HR 1099** on-axis HiRes and MidRes (Resolve energy): source flux
  - RXJ 1856 (Resolve and Xtend contamination): too soft, E0102 can be used
  - NGC 1550 (lab astro): too soft
- Calibration targets changed for other reasons:
  - Abell 478 → **Abell 2029** (Xtend optical axis and off-axis Aeff): visibility
  - 3C 273 w/ ND filter (Resolve Aeff): unnecessary and requires coordination
  - 1ES0033+595 → **G21.5-0.9** (Xtend Aeff): stable source, no coordination

XRISM calibration implementation team

XRISM X-Ray Imaging and Spectroscopy Mission

- Monday March 4 at TUS for 3+ hours, 35 people in person, more on Zoom

XRISM in-flight calibration presentations

XRISM X-Ray Imaging and Spectroscopy Mission

- Effective area
  - E. Miller, T. Hayashi — CoObs WG (Tue PM)
- PSF and optical axis
  - T. Hayashi — General Session 2 (Wed PM)
- Pointing accuracy
  - Y. Kanemaru — General Session 2 (Wed PM)
- Resolve energy
  - E. Miller — HighRes WG (Tue AM), this session
  - P. Plucinsky — Thermal SNR WG (Wed AM)
- Xtend energy
  - H. Suzuki, T. Yoneyama — this session!
- Timing
  - Y. Terada — this session!
  - M. Shidatsu — Timing WG (Wed PM)

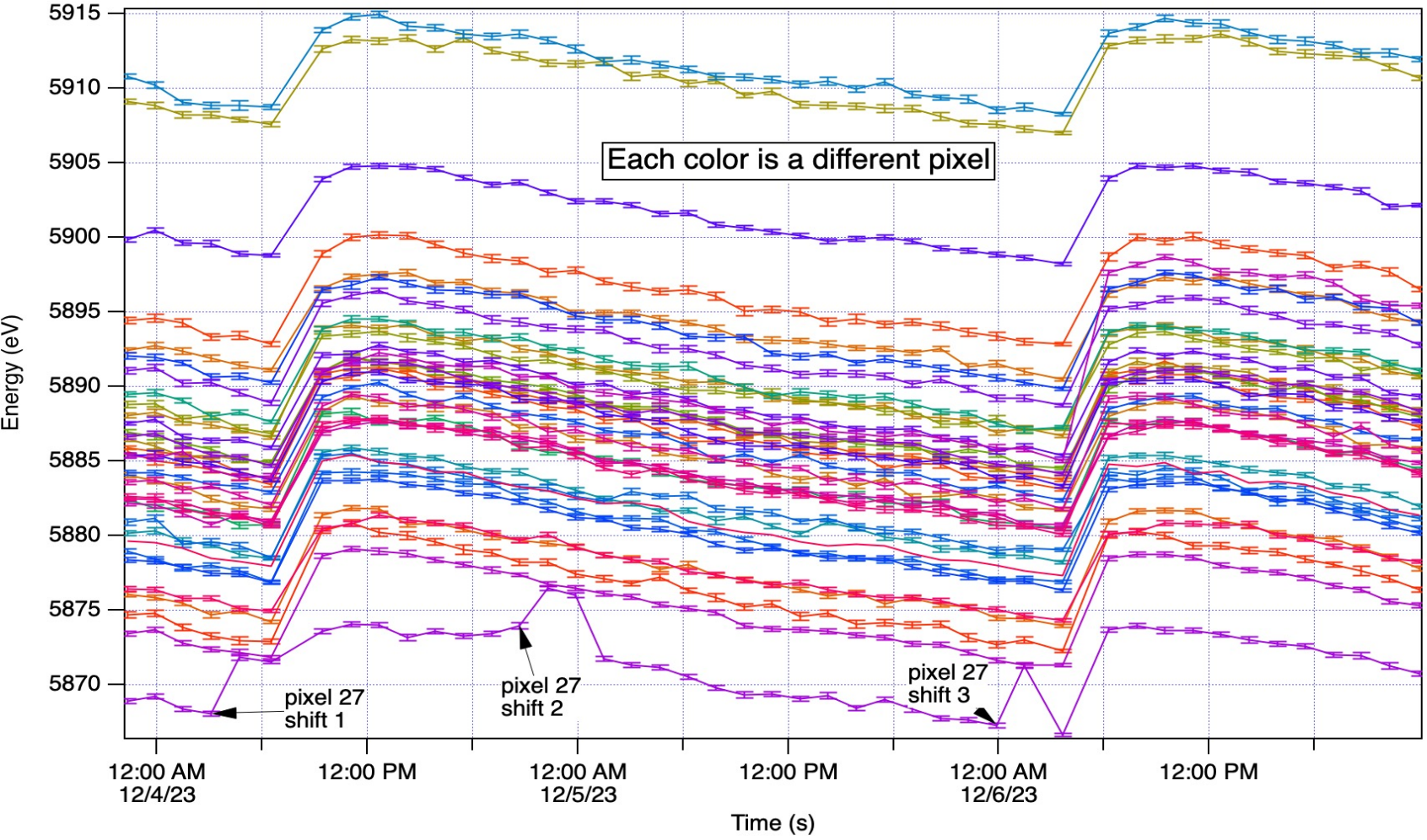
Resolve (soft) energy calibration

Resolve Energy group

Material from Scott Porter, Mike Loewenstein, Matteo Guainazzi, Resolve IT, et al.

MXS not option with closed gate valve

With the Gate Valve closed, each modulated x-ray source only illuminates half the array, and the rate across the illuminated half is highly non-uniform → gain tracking using the FW ^{55}Fe source during eclipse

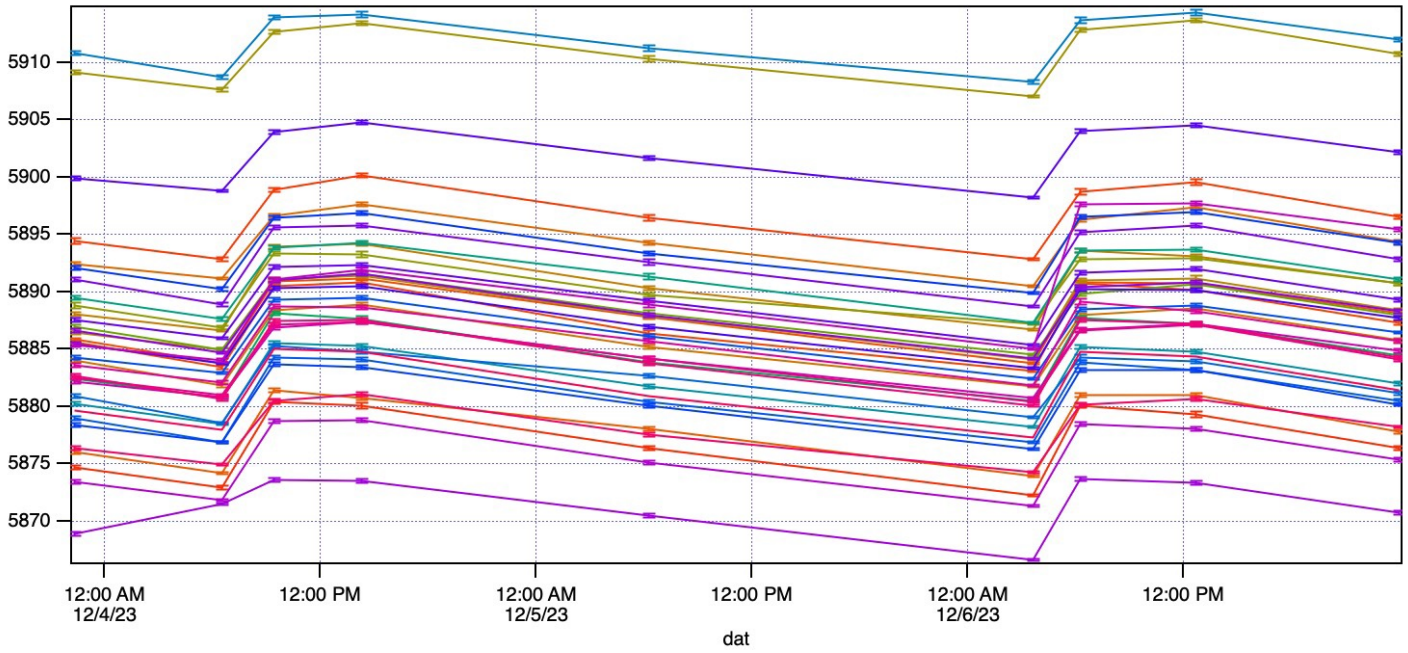


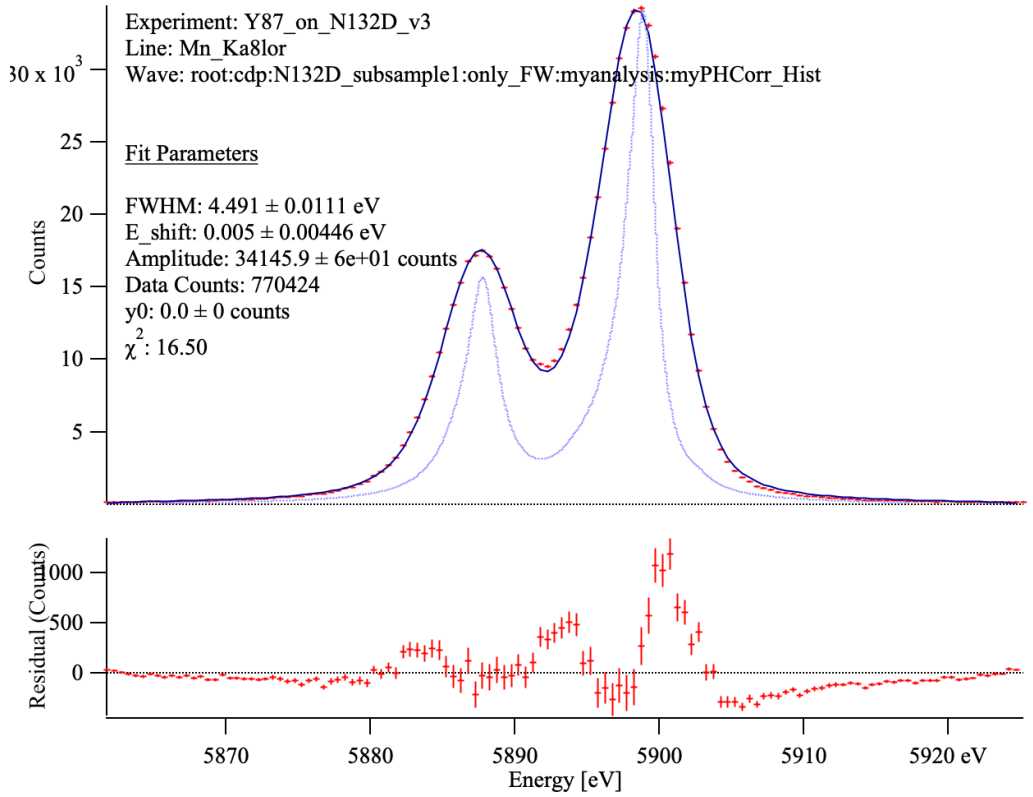
Trial gain tracking during observation of the N132D (every eclipse).

But we don't want to rotate the FW so often, so we determined the minimum set of fiducials needed to avoid LSF broadening.

Fiducial set for each ADR cycle

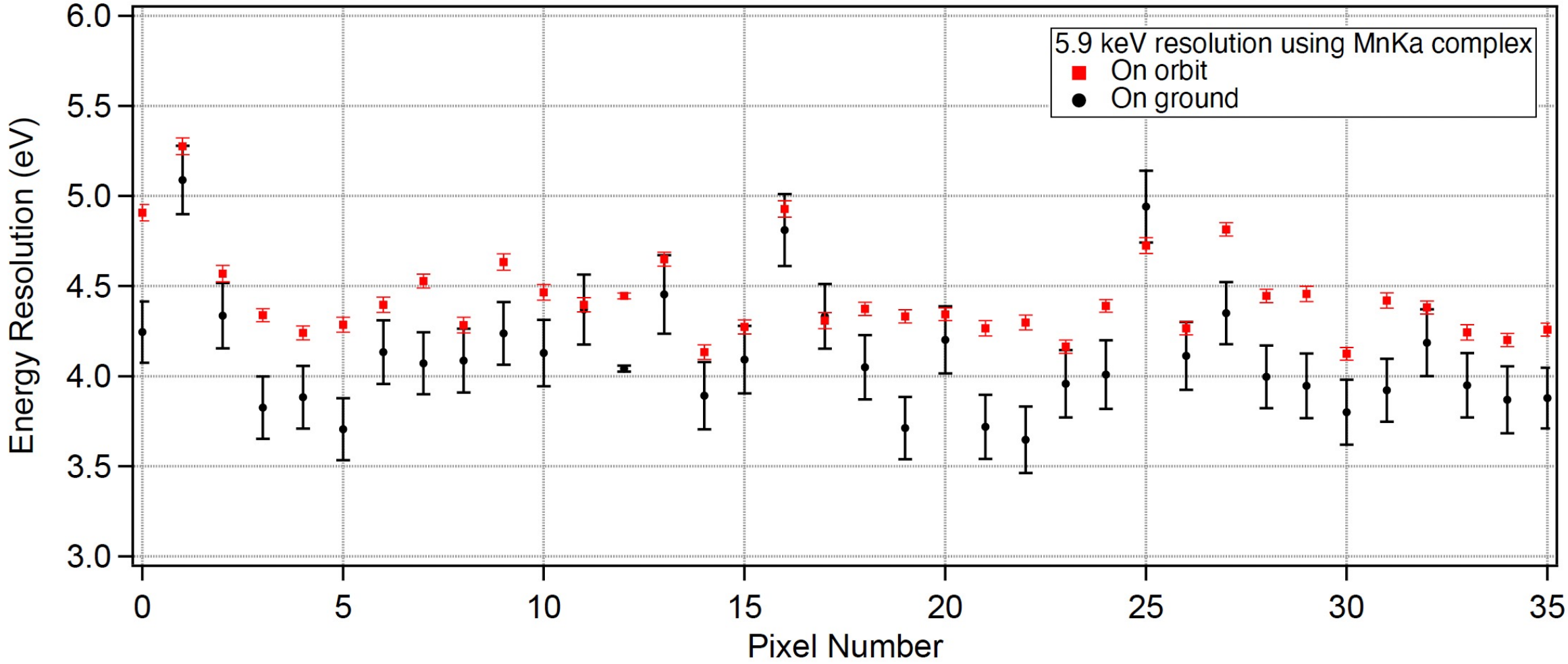
High-cadence gain fiducials revealed the minimum set needed to characterize the ADR cycles with negligible LSF broadening (except from pixel 27, which experiences gain steps not yet correlated with any telemetered parameter).





4.49 eV FWHM, 0.005 eV gain error @ 6 keV

Resolution of each pixel

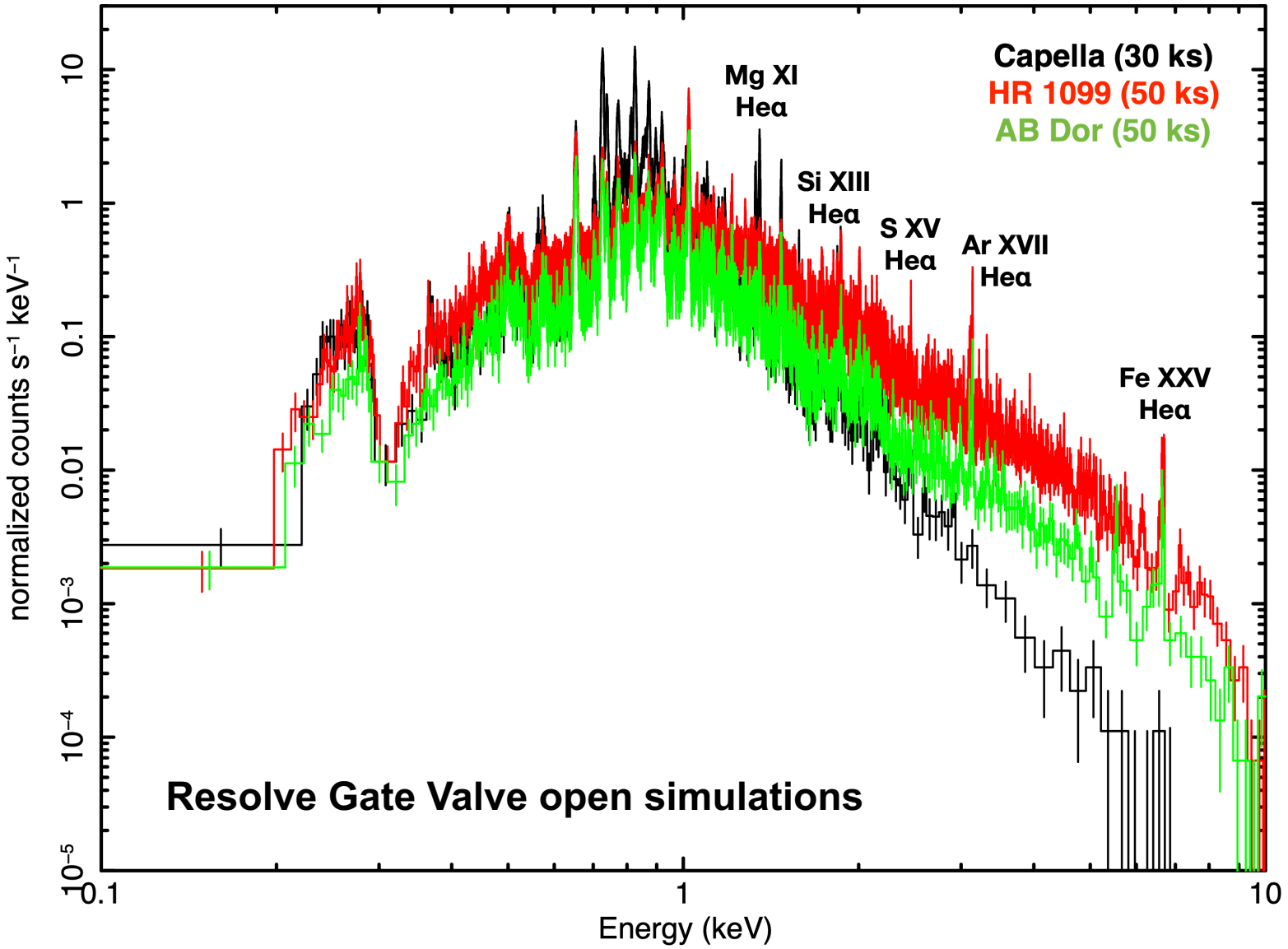


- Averaged over orbital position
- In-flight calibration data will provide similar information at several energies.

Resolve energy calibration

- Resolve gain and LSF calibration above 5 keV can be done with Fe55 and MXS direct.
- Below 5 keV requires celestial sources with narrow lines of known energies.
- GVO plan was:
  - Use Capella for ≤ 1 keV (aimpoint pixels)
  - Use HR 1099 or AB Dor for 2–3 keV (aimpoint pixels)
  - Use Capella for pixel and temperature dependence

Energy scale calibration @ 2 keV:
Req't: ≤ 2 eV for each pixel
Goal: ≤ 1 eV for each pixel



Resolve energy calibration

- Resolve gain and LSF calibration above 5 keV can be done with Fe55 and MXS direct.
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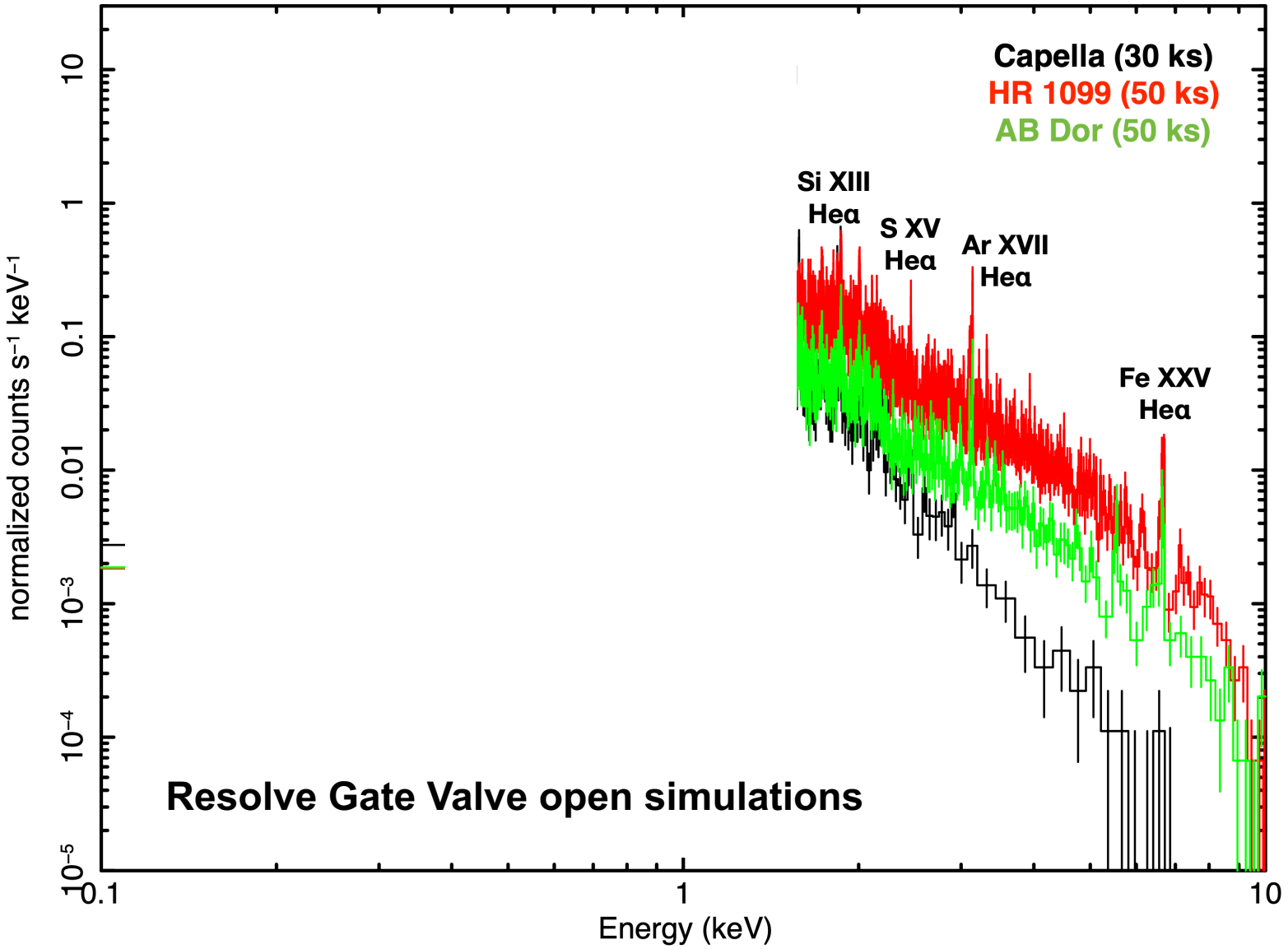
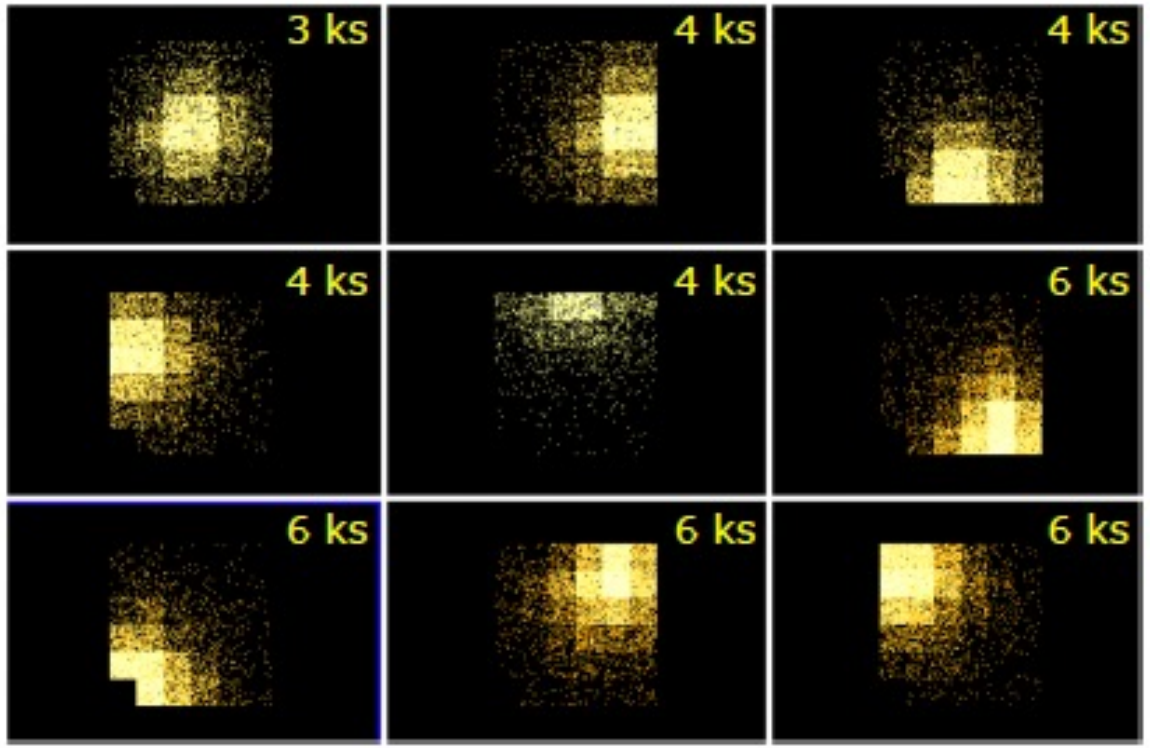
- GVC plan is:
  - ~~Use Capella for ≤ 1 keV (aimpoint pixels)~~
  - Use HR 1099 ~~or AB Dor~~ for 2–3 keV (aimpoint pixels)
  - Use ~~Capella~~ ??? for pixel and temperature dependence

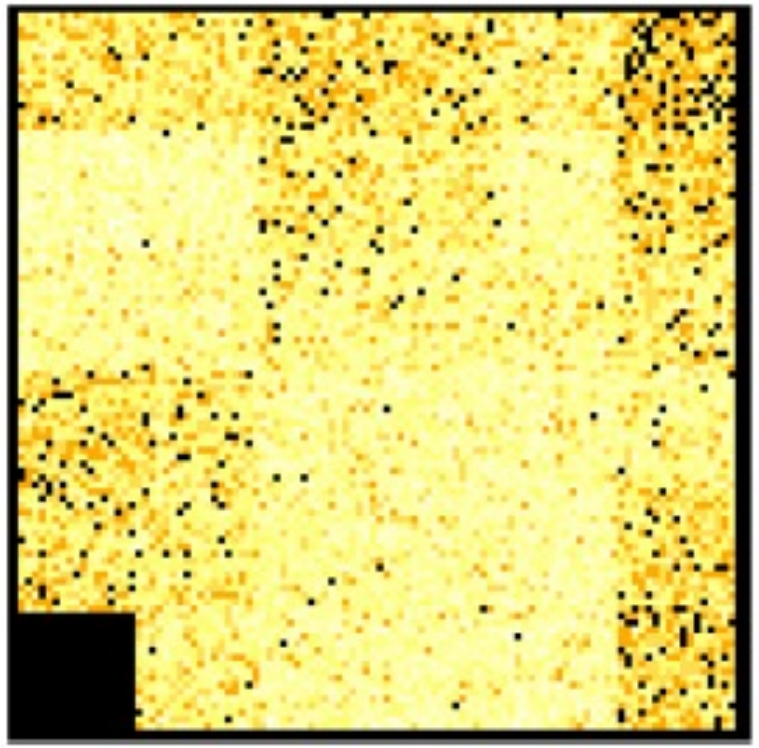
Energy scale calibration @ 2 keV:
Req't: ≤ 2 eV for each pixel
Goal: ≤ 0.2 eV for each pixel



Strategy with Gate Valve Open

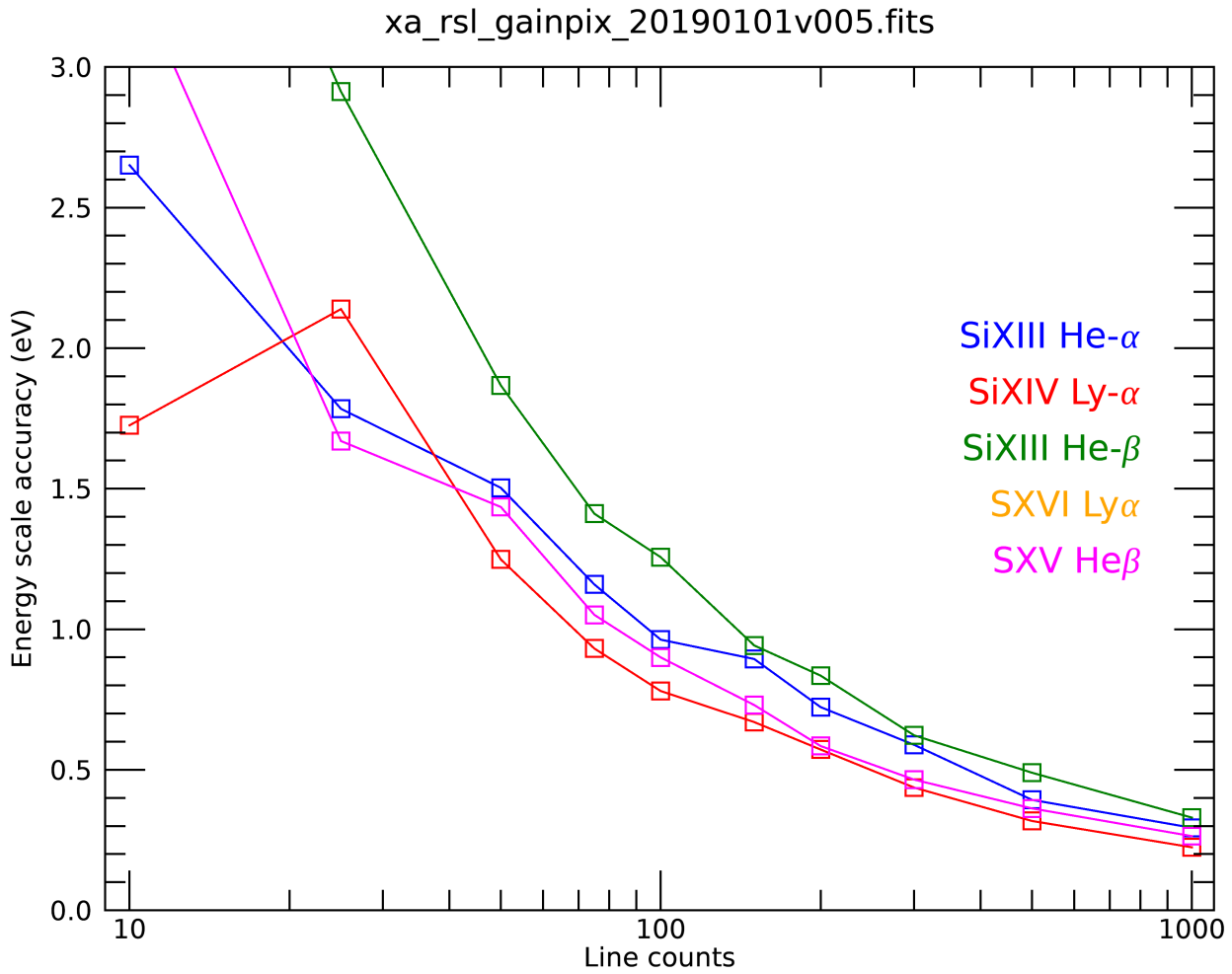
Strategy: “raster” with Capella: 43 ks x 6 (3 temperature, 2 modes)





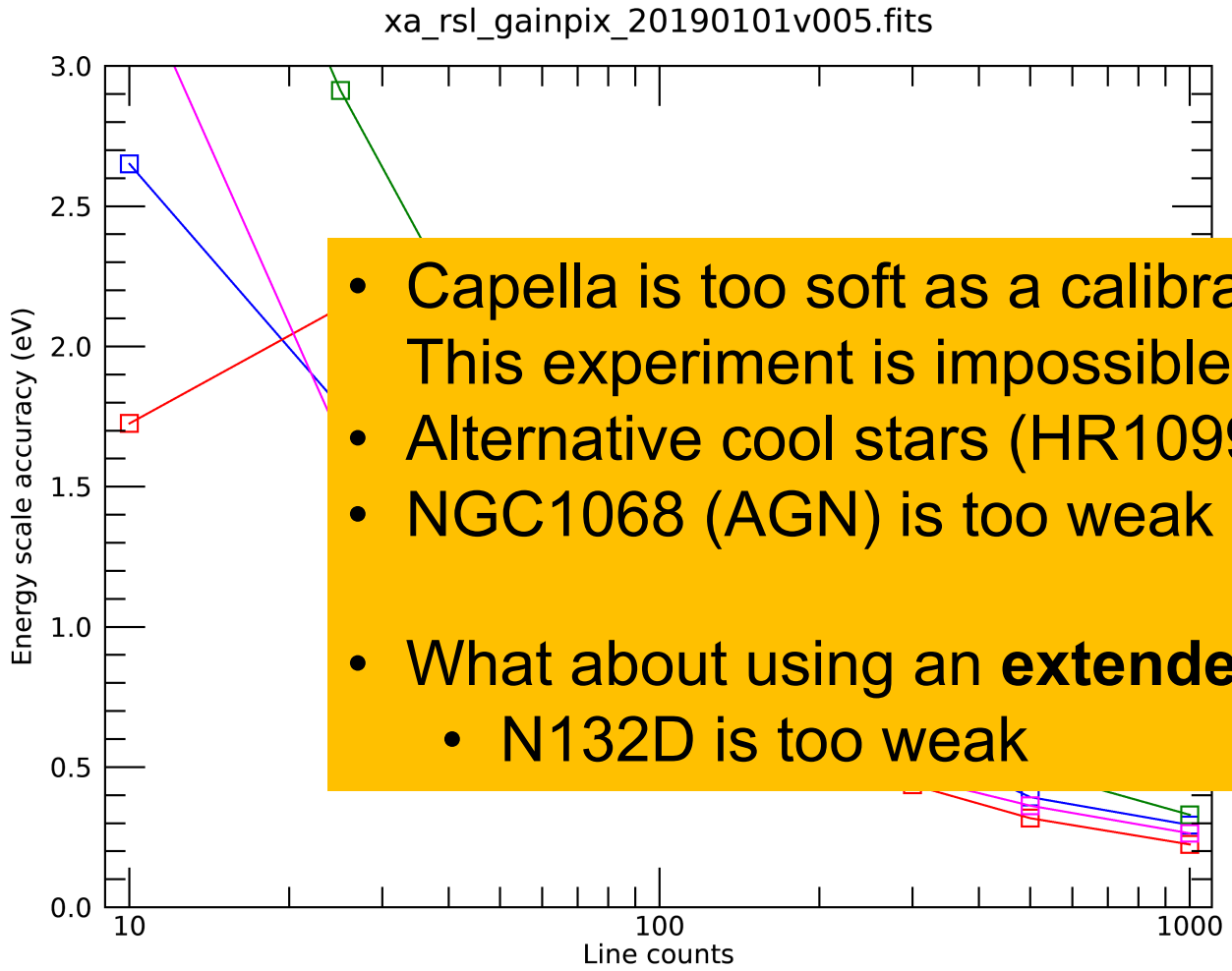
Accurate determination of the energy scale in the central pixel through a 30 ks observation

Accuracy in the gain reconstruction



- Let's assume:
  - a source spectrum with five soft X-ray transitions (labelled)
  - ^{55}Fe source delivering 10^4 counts
- ≥**70** (**200**) counts per line are needed to achieve a statistical error on the gain at their energies ≤**2.0** (≤**1.0**) eV
- Remember: these are counts **per pixel**

Accuracy in the gain reconstruction



- Let's assume:
  - a source spectrum with five soft X-ray transitions

...vering 10^4

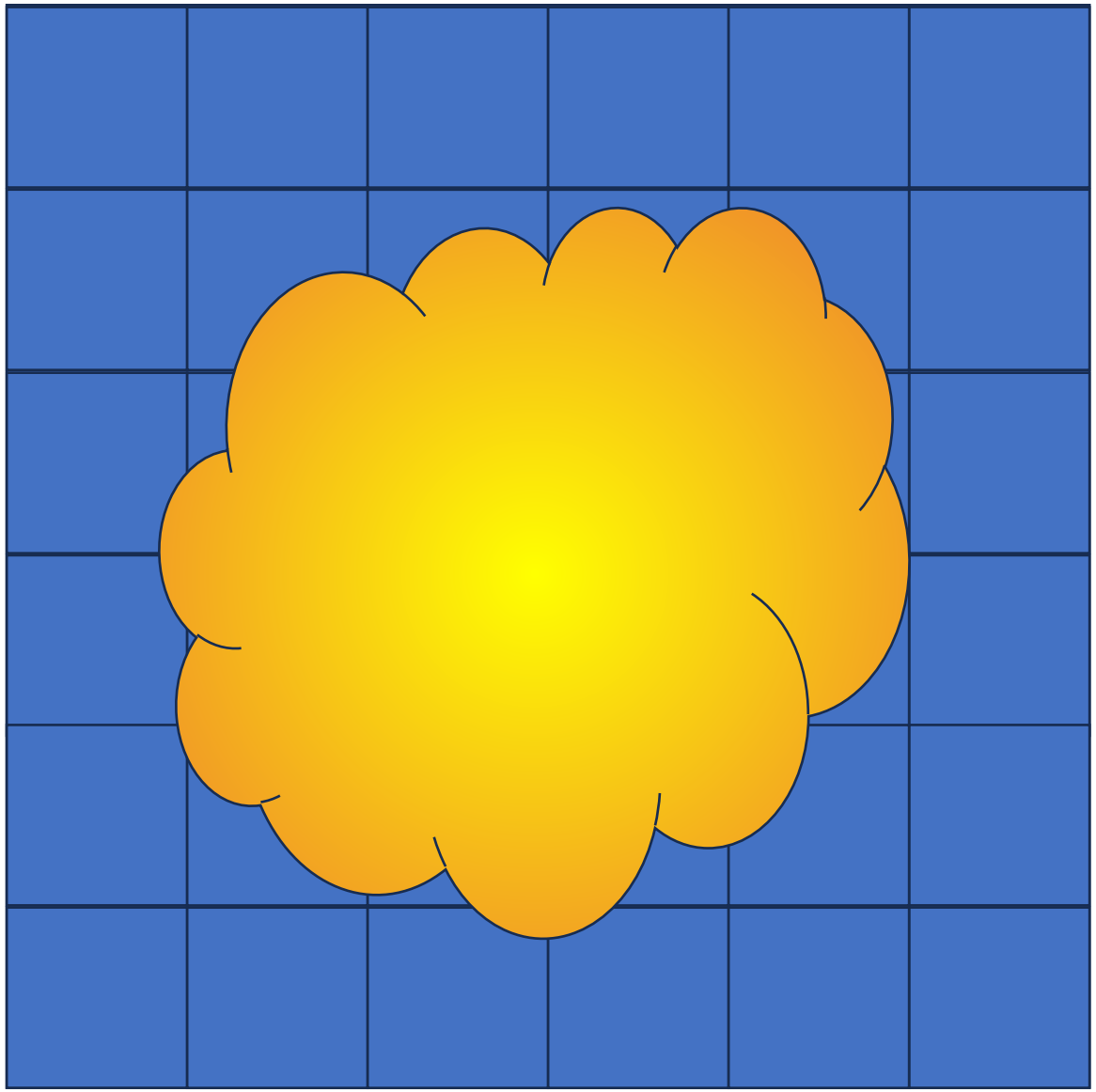
...per line are
...statistical
...their energies

- Capella is too soft as a calibration target with GVC. This experiment is impossible
- Alternative cool stars (HR1099, ABDor) are too weak
- NGC1068 (AGN) is too weak

- What about using an **extended source** instead?
  - N132D is too weak

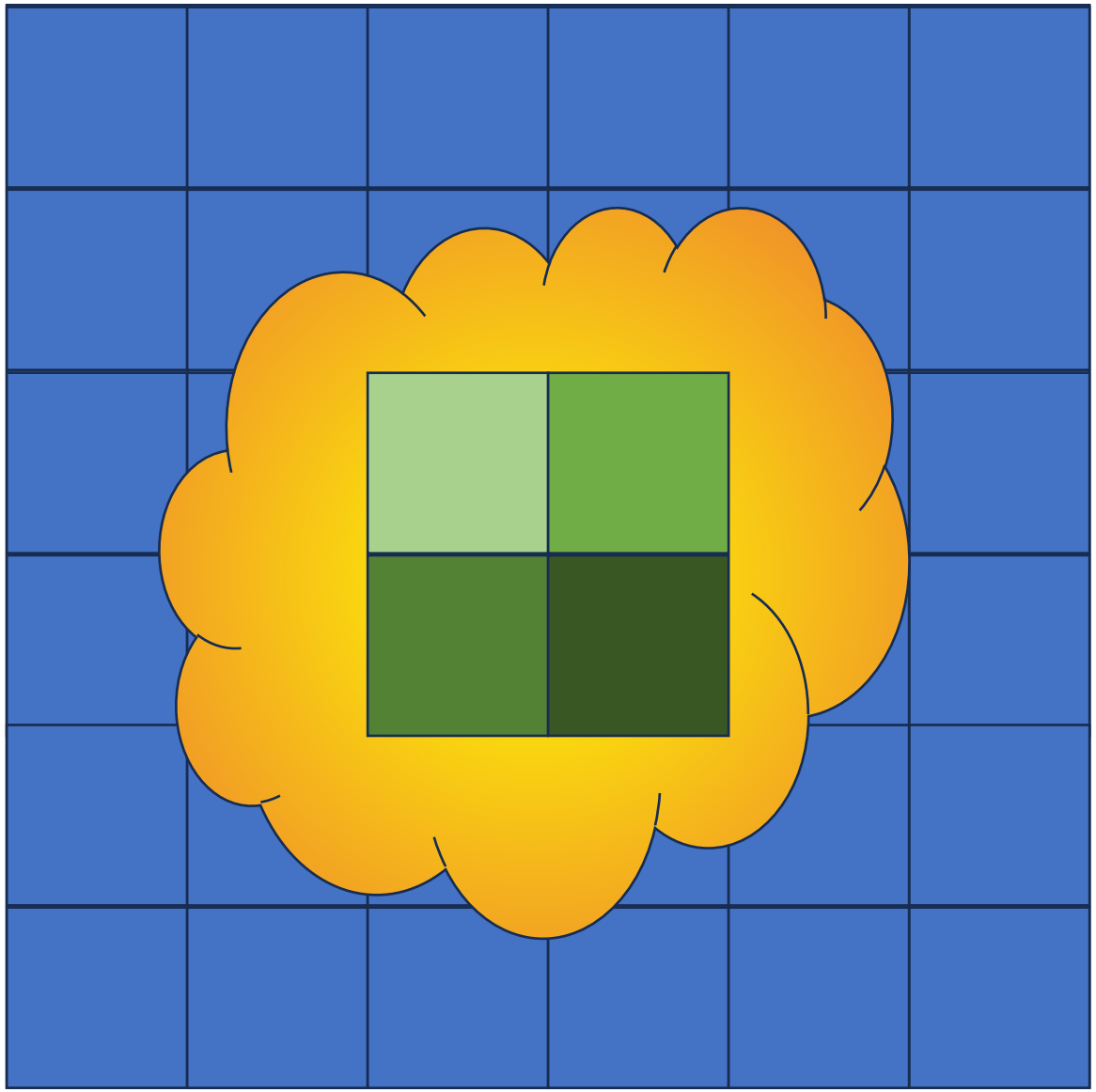
- Remember: these are counts **per pixel**

A bootstrap strategy



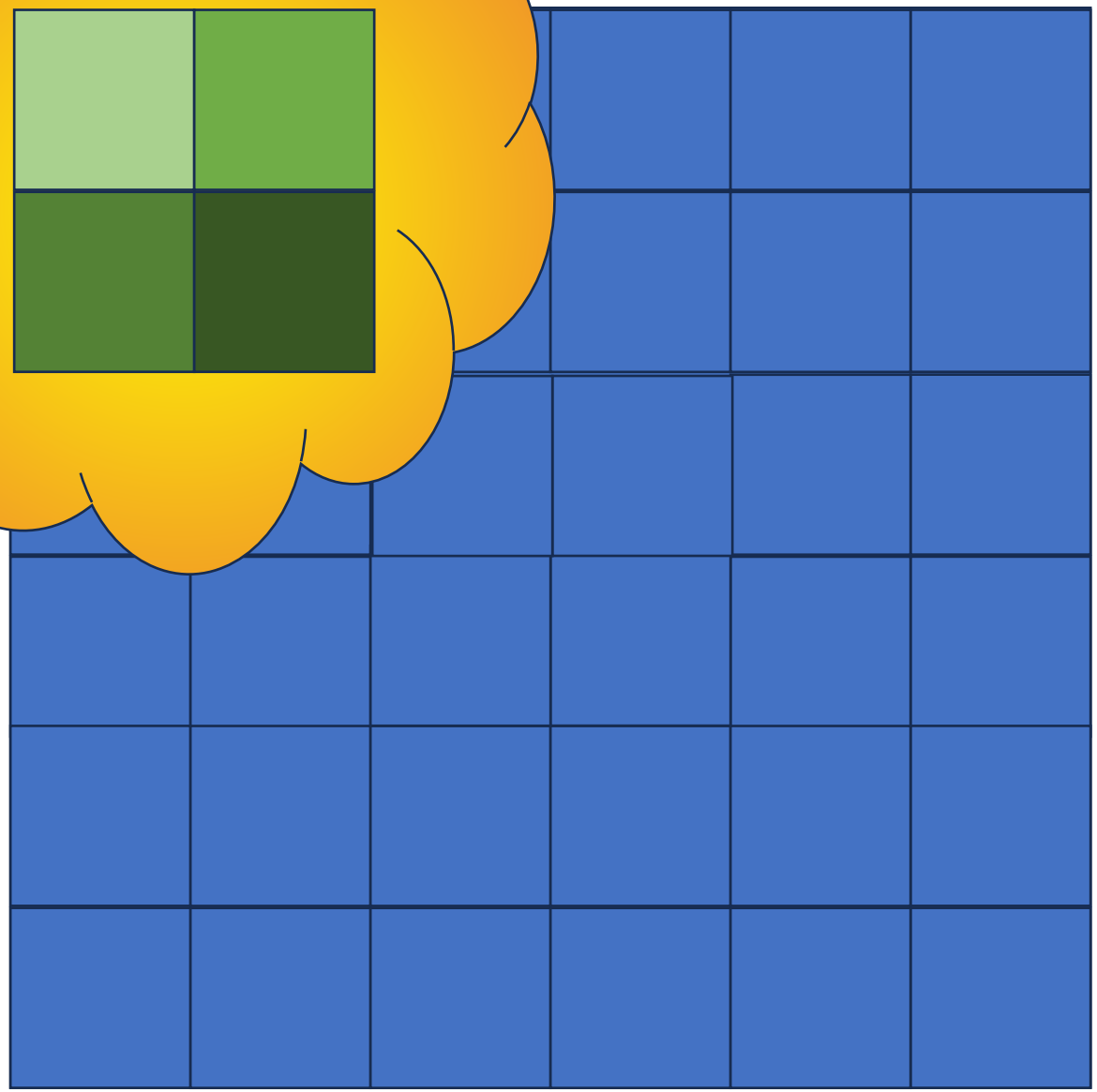
- Observe a bright extended source with unknown velocity structure.

A bootstrap strategy



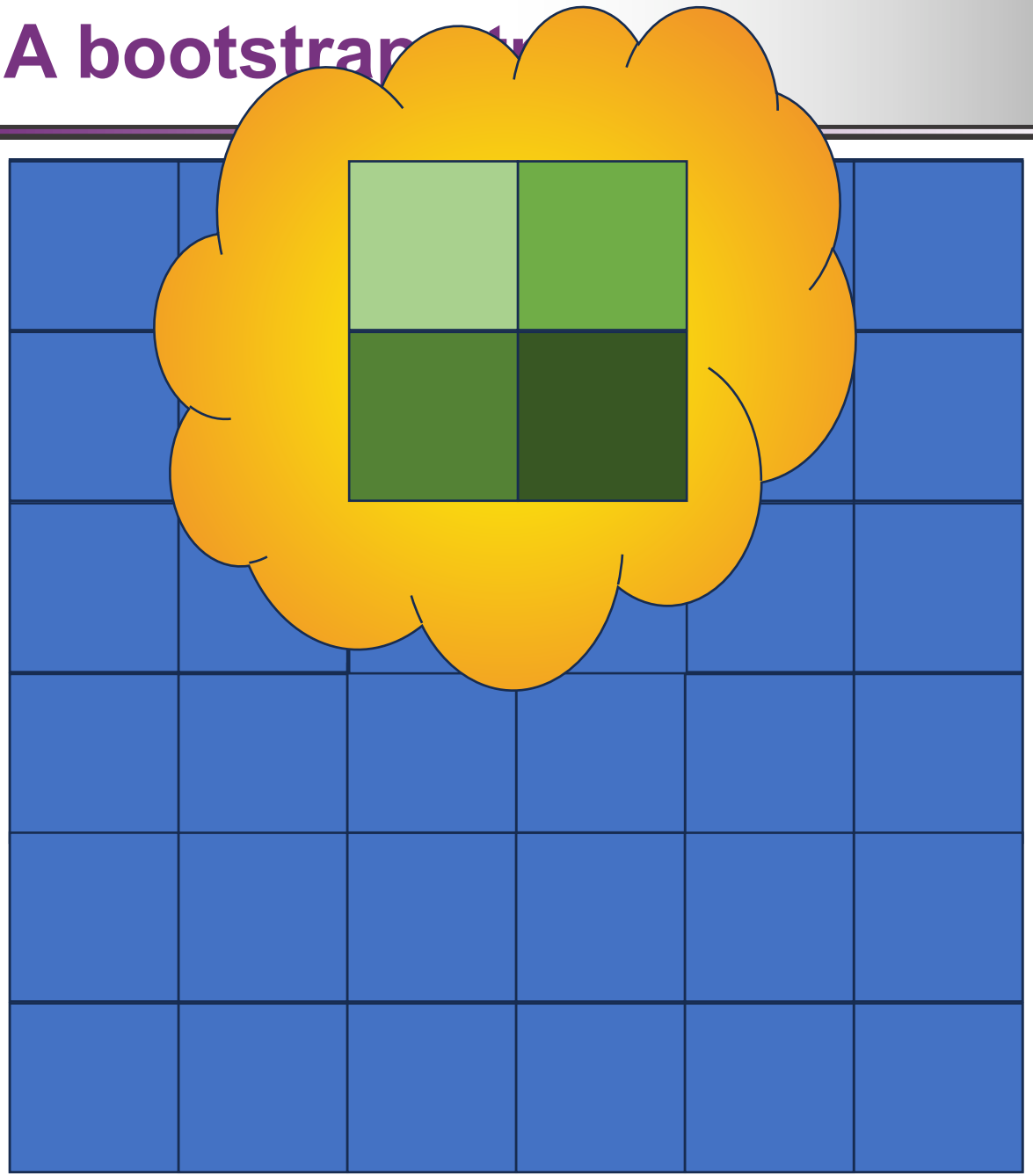
- Observe a bright extended source with unknown velocity structure.
- Four on-axis pixels are calibrated from HR 1099, so we *know* the velocities.

A [illegible] strategy



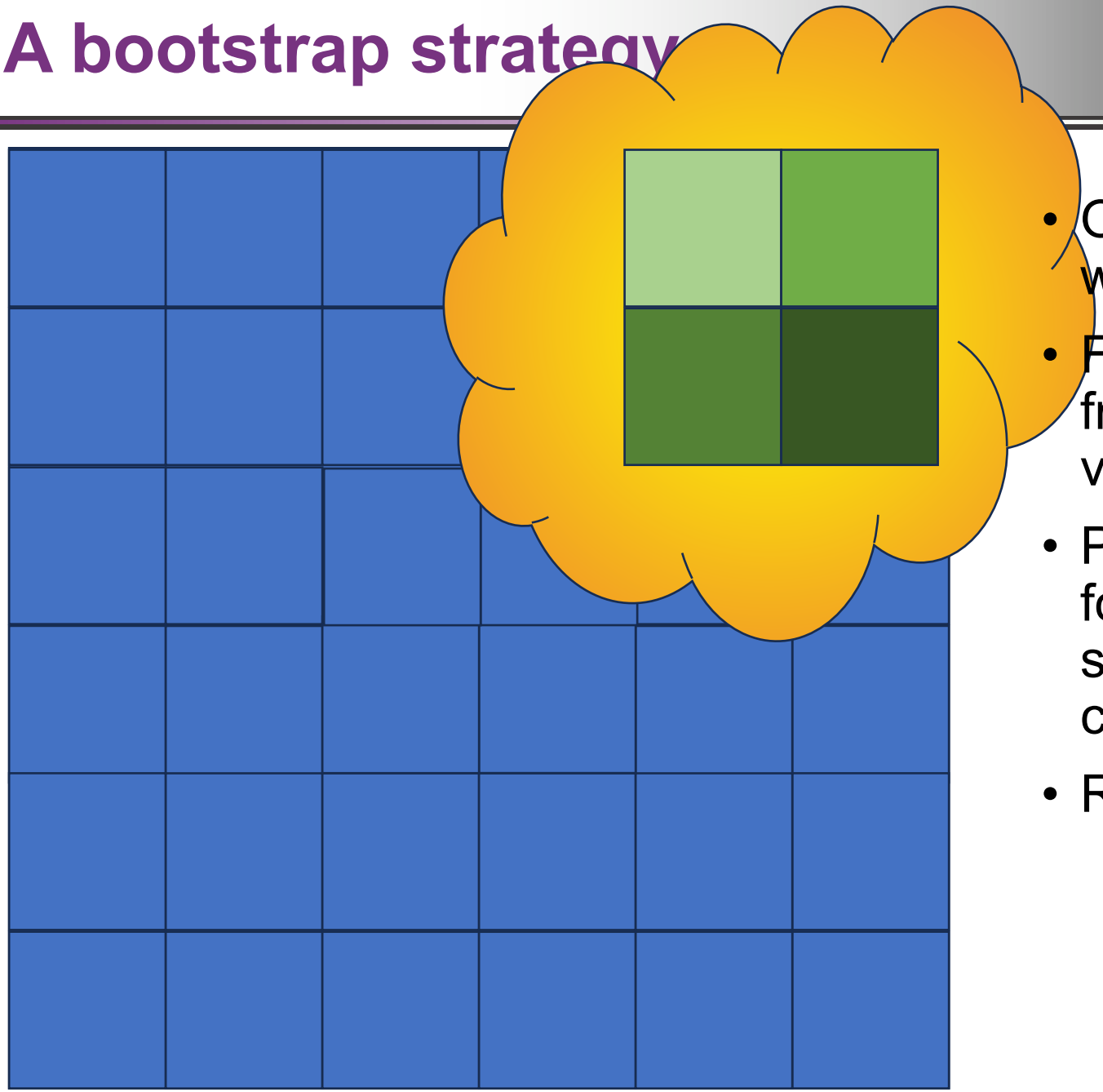
- Observe a bright extended source with unknown velocity structure.
- Four on-axis pixels are calibrated from HR 1099, so we *know* the velocities.
- Place the source at each vertex of four pixels. We know the velocity structure in each pixel and can calibrate.

A bootstrap[illegible]



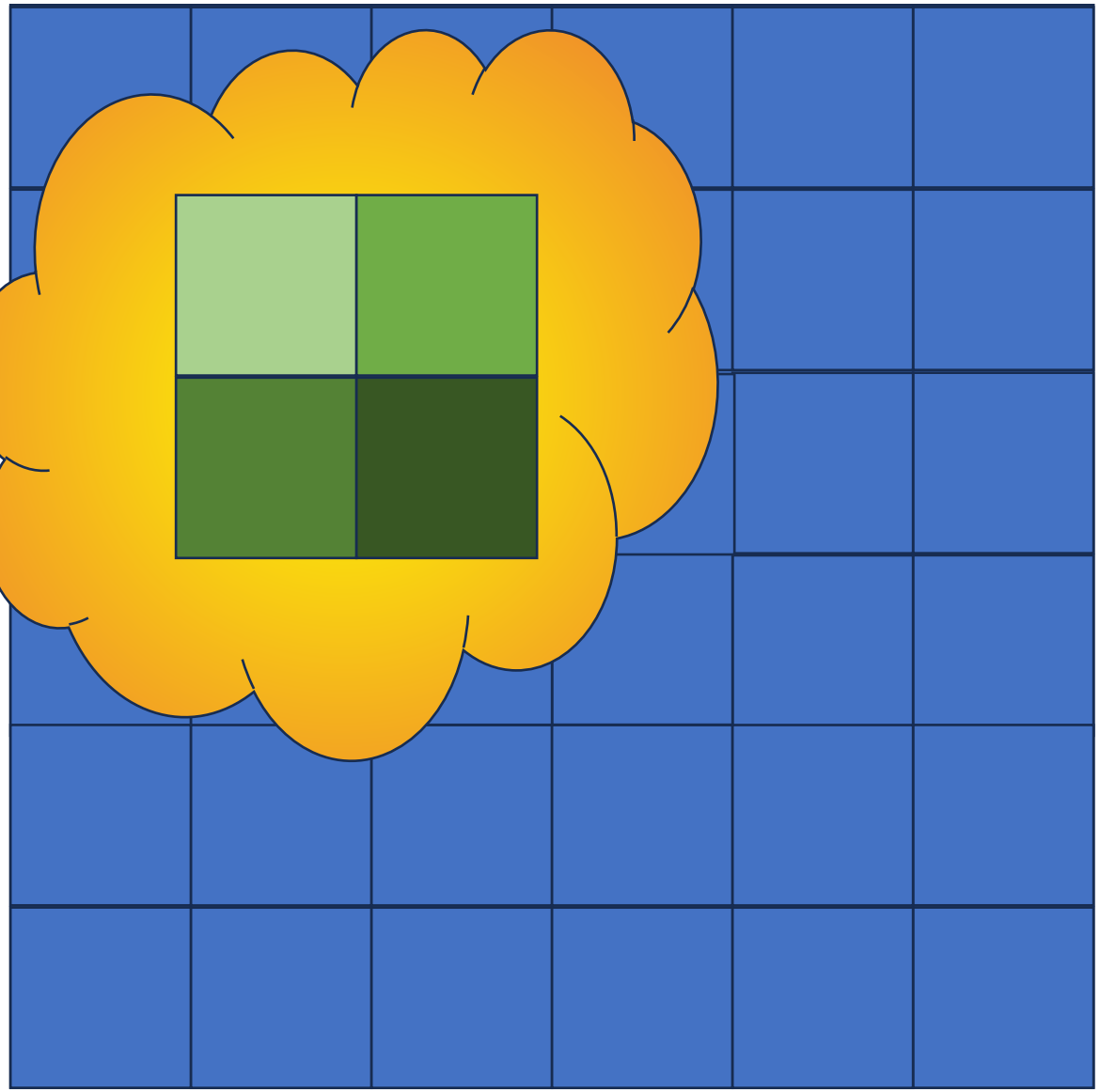
- Observe a bright extended source with unknown velocity structure.
- Four on-axis pixels are calibrated from HR 1099, so we *know* the velocities.
- Place the source at each vertex of four pixels. We know the velocity structure in each pixel and can calibrate.
- Repeat.

A bootstrap strategy



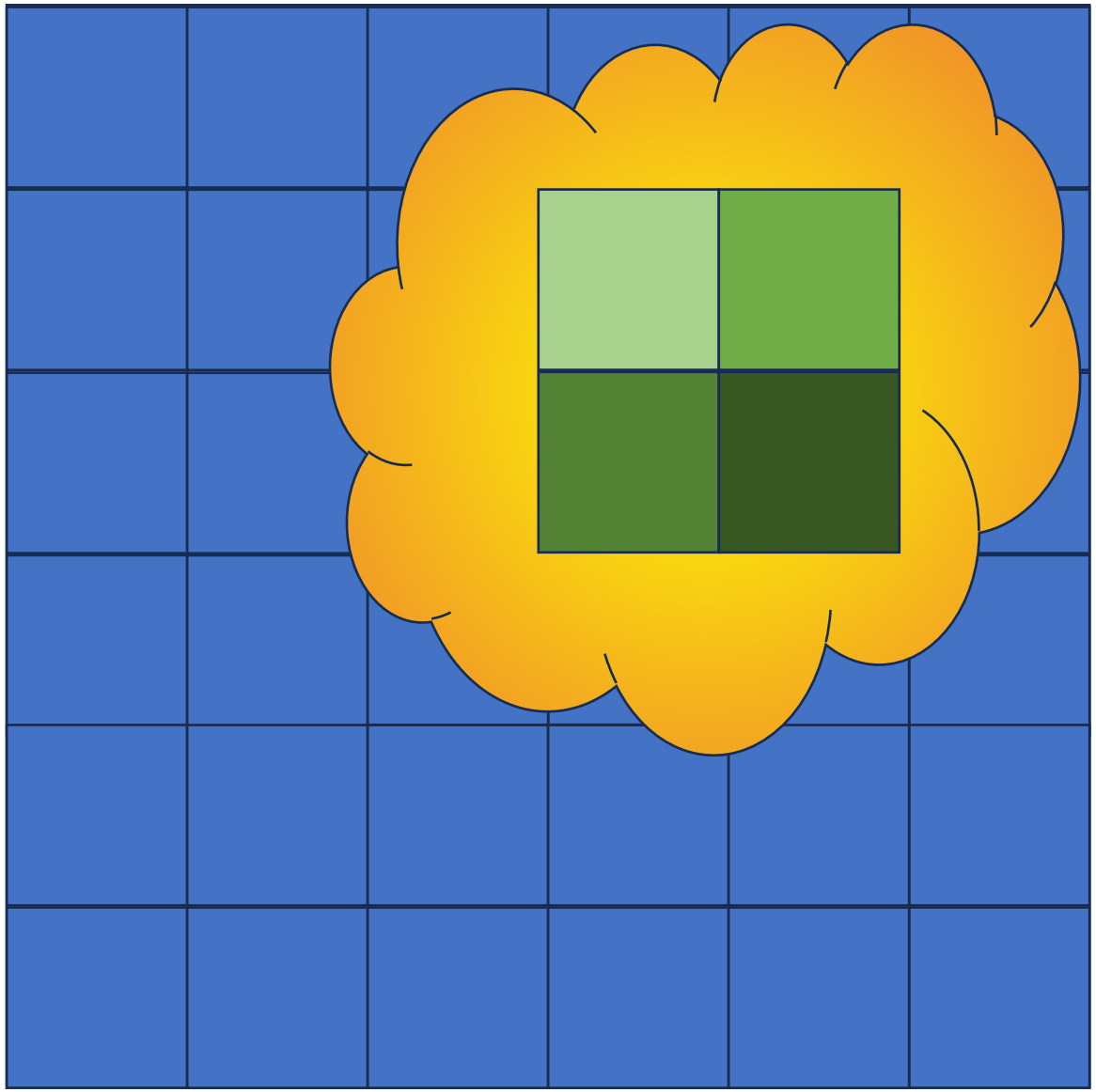
- Observe a bright extended source with unknown velocity structure.
- Four on-axis pixels are calibrated from HR 1099, so we *know* the velocities.
- Place the source at each vertex of four pixels. We know the velocity structure in each pixel and can calibrate.
- Repeat. Nine times total

A bootstrap strategy



- Observe a bright extended source with unknown velocity structure.
- Four on-axis pixels are calibrated from HR 1099, so we *know* the velocities.
- Place the source at each vertex of four pixels. We know the velocity structure in each pixel and can calibrate.
- Maybe this is too expensive, so only do inner five quadrants to start.

A bootstrap strategy



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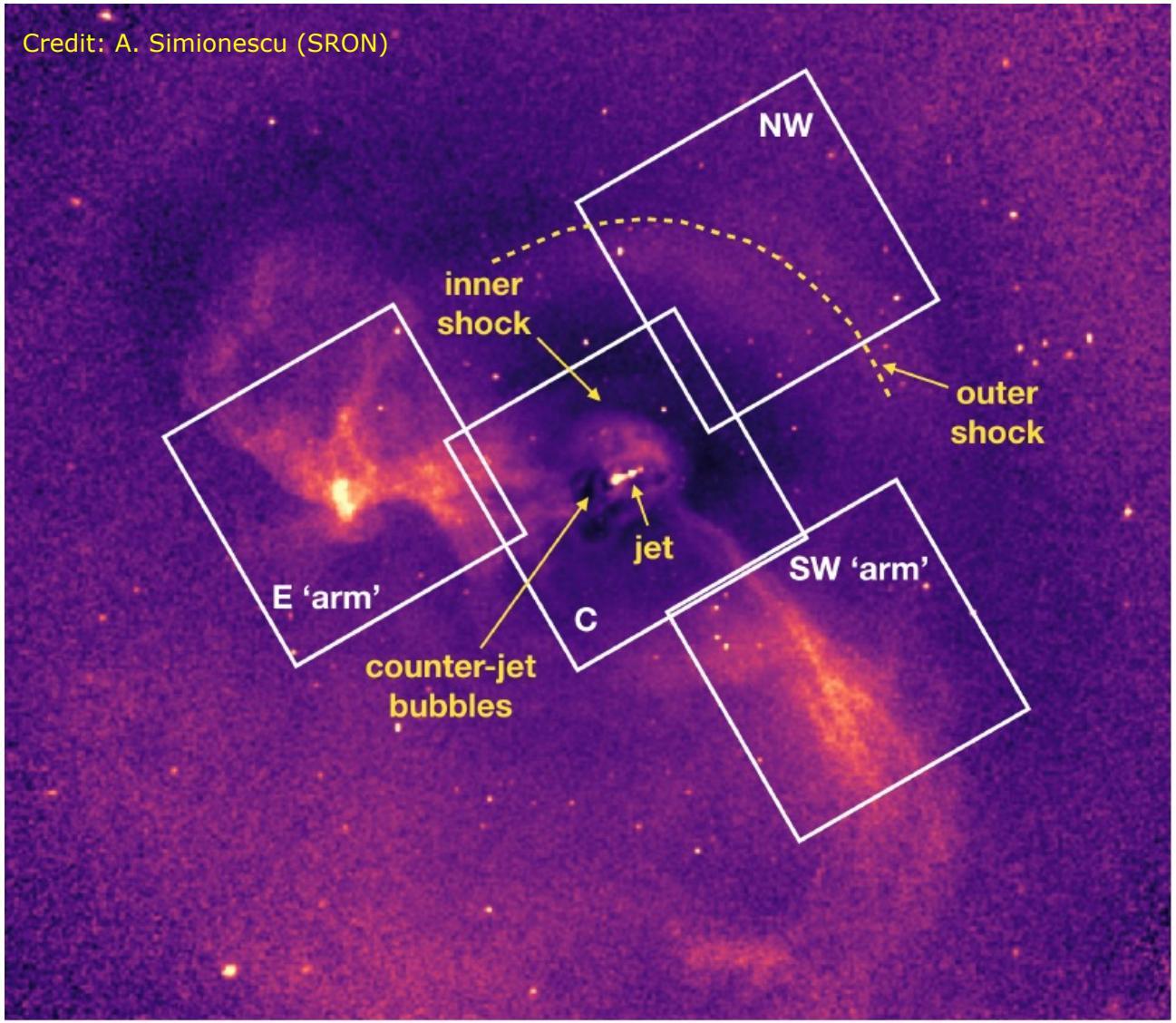
On-going work: searching for better alternatives



- XRB: CenX-3, Vela X-1 **Ruled out**
- AGN: Circinus Galaxy (to be observed on-axis in the week of January 29) **Ruled out**
- **Ruled out: M87, Centaurus, Puppis A**
  Possible sources:
  Cas A (?)
  Tycho (??)
  Cyg X-3 (???)
  other ideas?
  HR 1099 might be used for inner square

  Si K fluorescence, escape lines from all of the Fe55 FW data
  Iterative approach (inner pixels first)

Summary

- Cal-IP team has updated the IFCP to account for GVC operations and calibration.
- Targets have been observed, with some preliminary results presented here at IACHEC.
- Cal-IP is working with Resolve and Xtend ITs teams to ensure a successful calibration campaign!