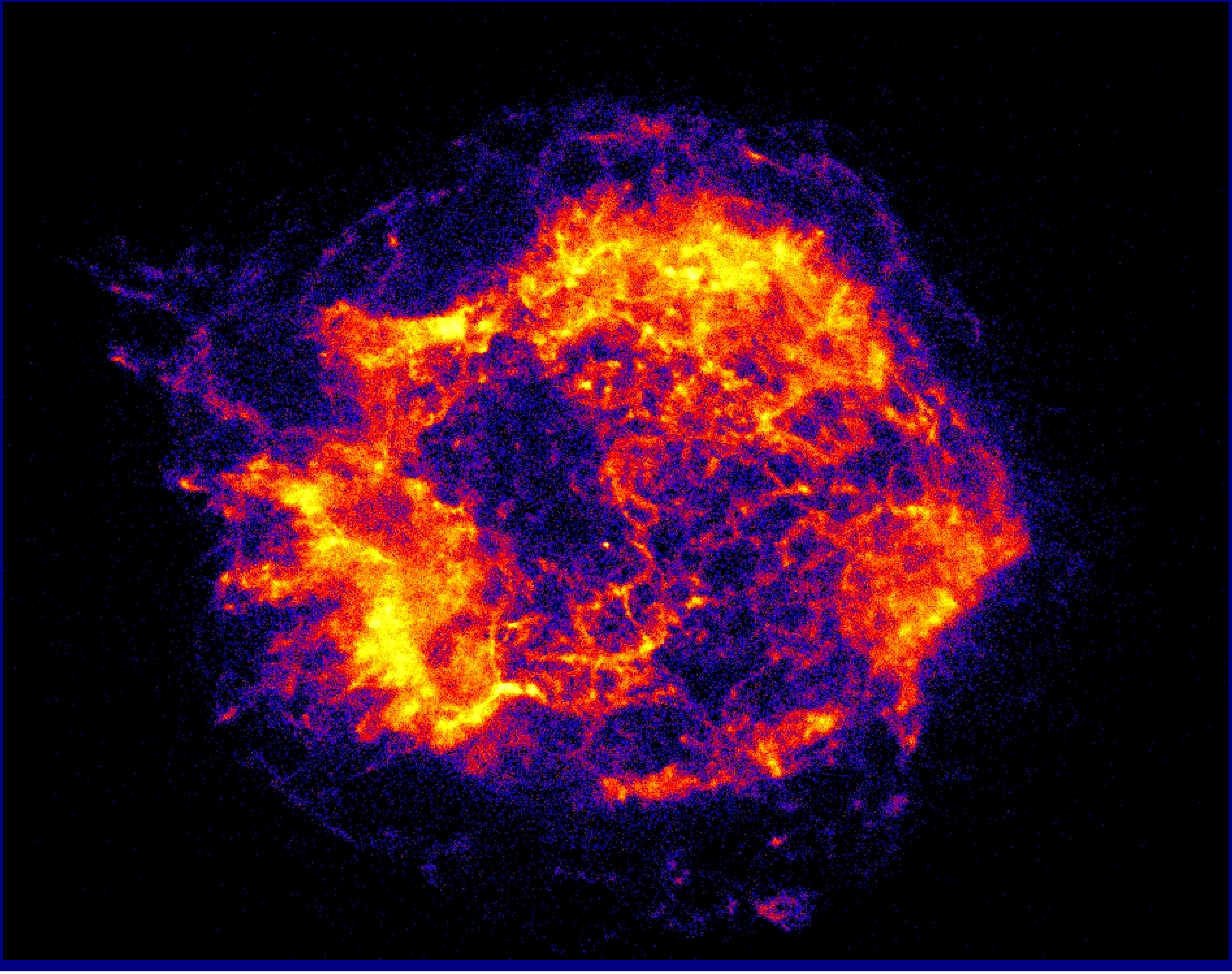
ACIS Gain Calibration with Cas A

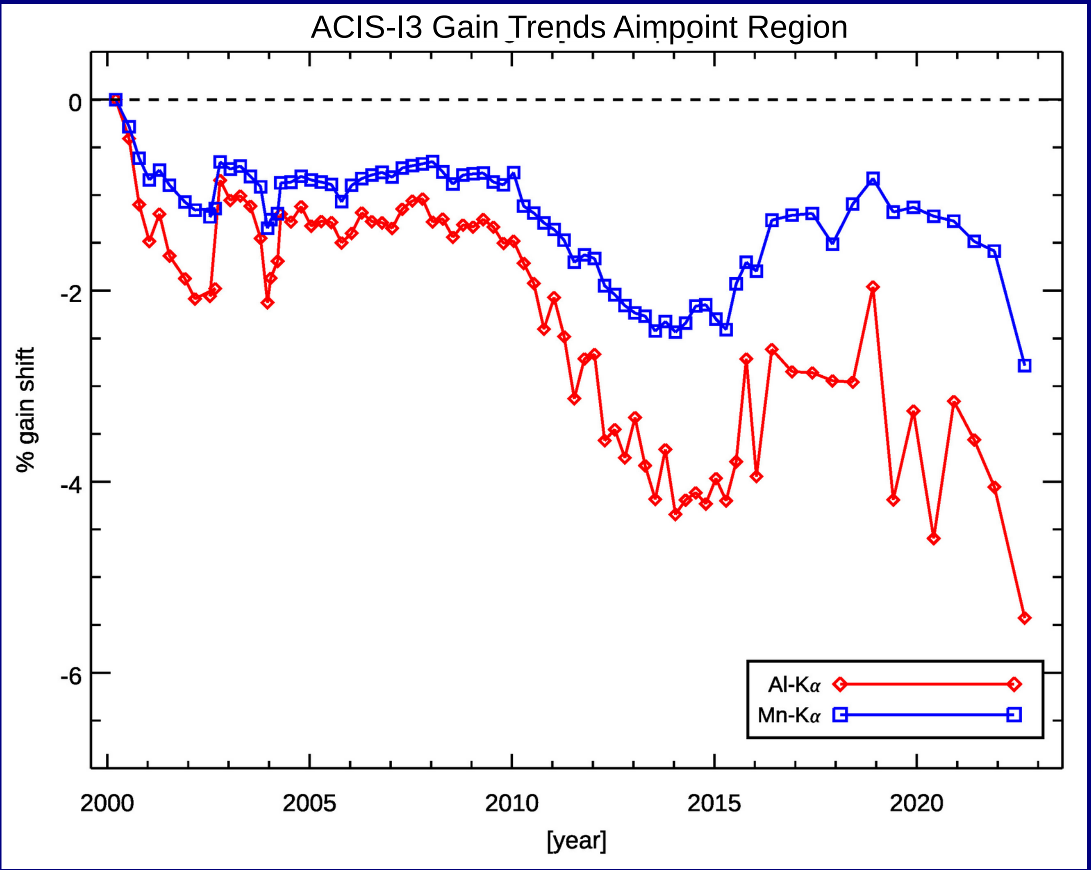
Nick Durham, Akos Bogdan, Hans Moritz Günther

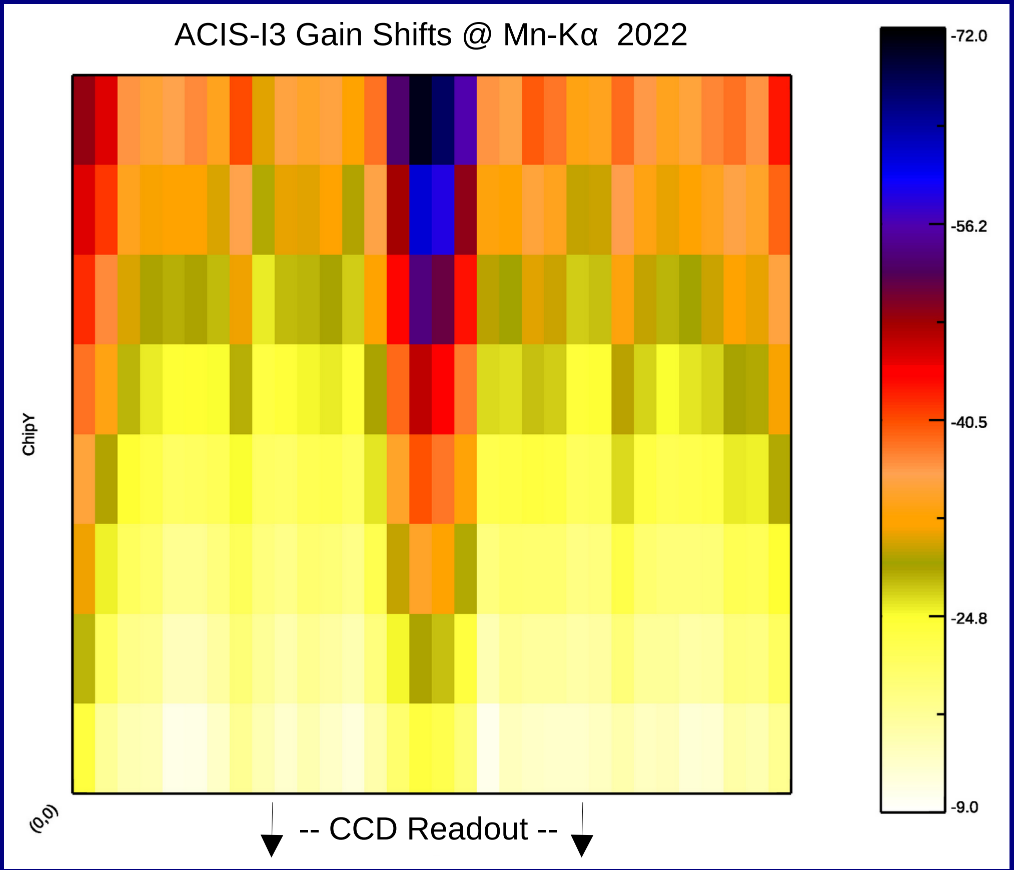
- Time-Dependent Gain Changes
- Motivation
- AP Source Data, Method, Application



ACIS TGain Correction

- Time-dependence due to changes in CTI
- Time-dependent corrections historically derived from ECS bright Al-Kα, Ti-Kα, and Mn-Kα line positions produced by ^{55}Fe source which fully illuminates both ACIS-I and ACIS-S
- Line positions measured in 32x128 pixel tiles for each chip, at cold focal plane temperatures, on regular intervals* and released via dated CALDB file
- TGain corrections defined as shifts from Jan 2000 measured line positions





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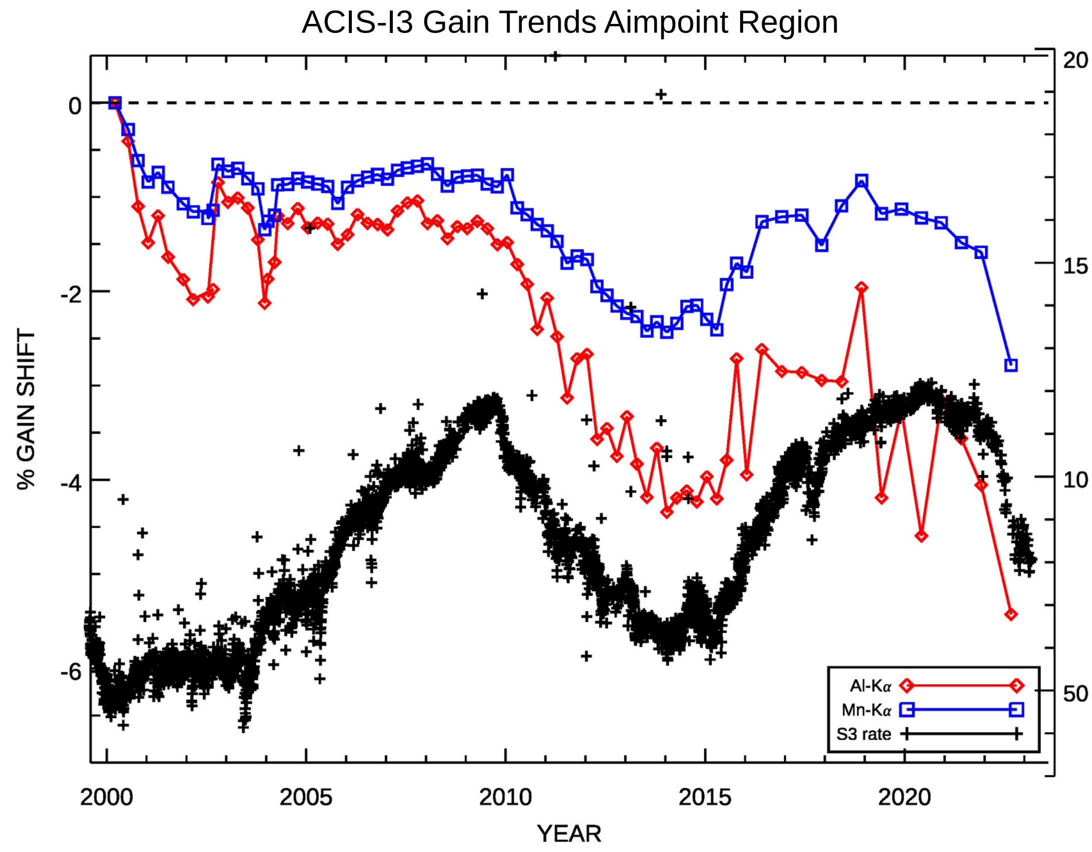
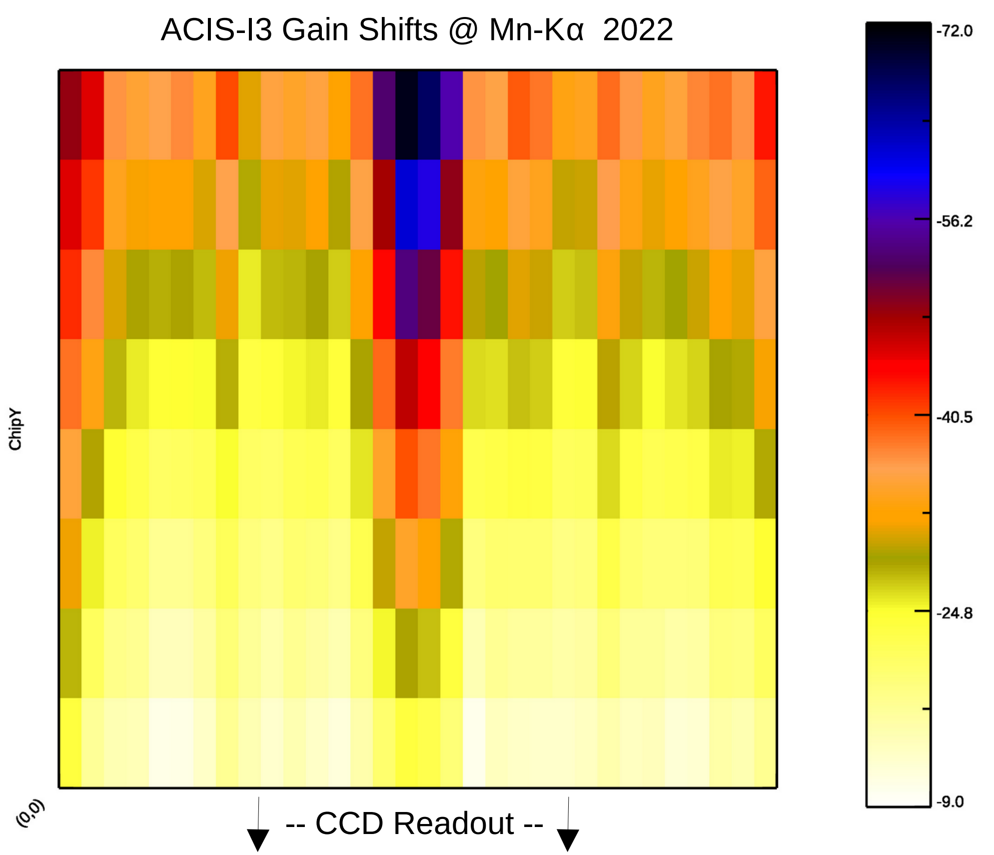
FI CTI largely driven by solar activity

High-energy particle backround reduced by solar wind

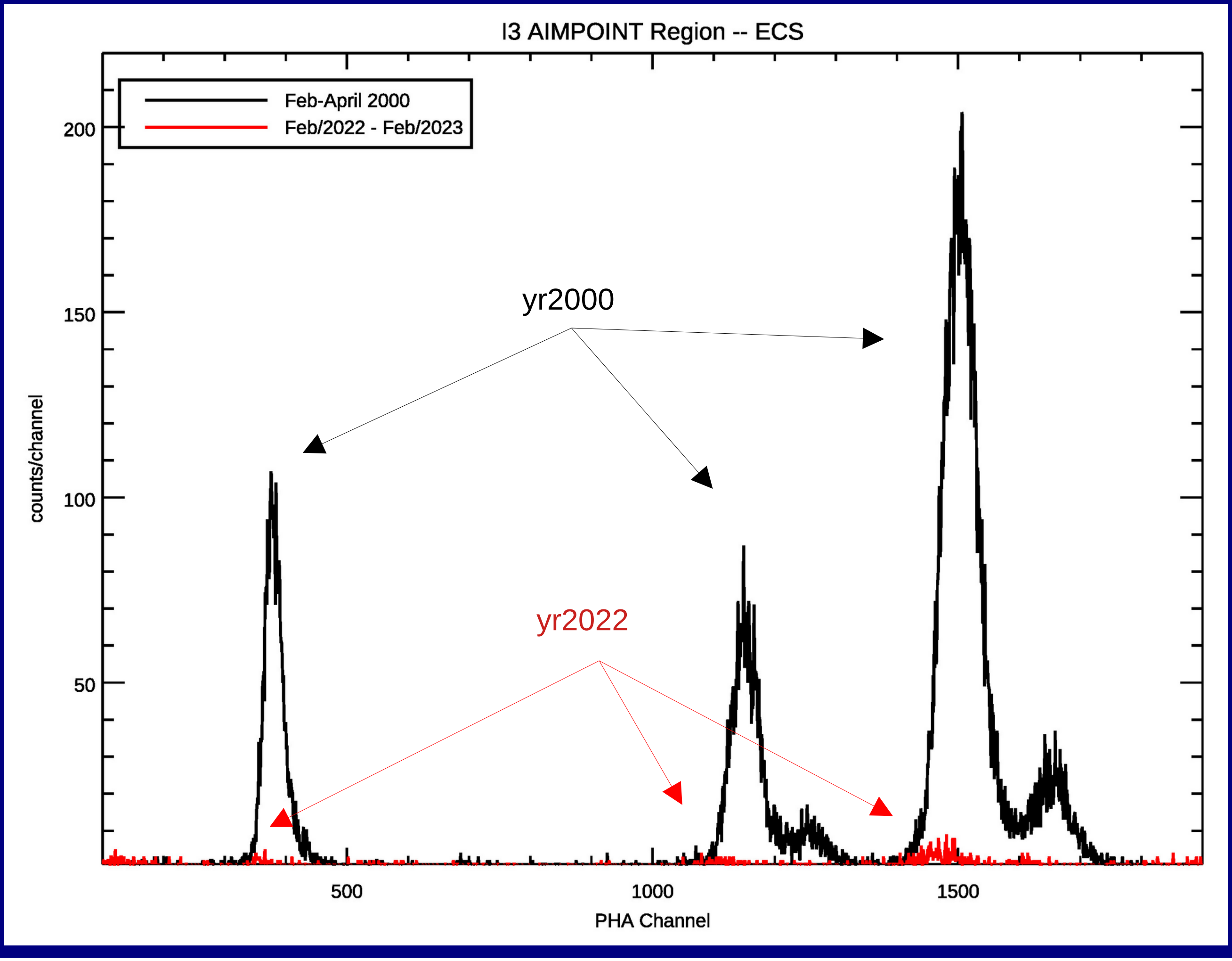
High-energy background provides sacrificial charge to CTI traps, reducing loss of event pulse height





TGain with ECS

- ^{55}Fe decay with 2.7 year ½ life
- Chandra has been flying for 23 years!
- 2023 very few counts in ECS despite efforts to to improve statistics:
  - Binning up in time from 3 → 6 → 12-months of cumulated exposure
  - Binning up spatially from 32x128 pixel tiles → 32x256
  - Relaxing focal plane temperature constraints from -120º : -119ºC → -120º : -117ºC

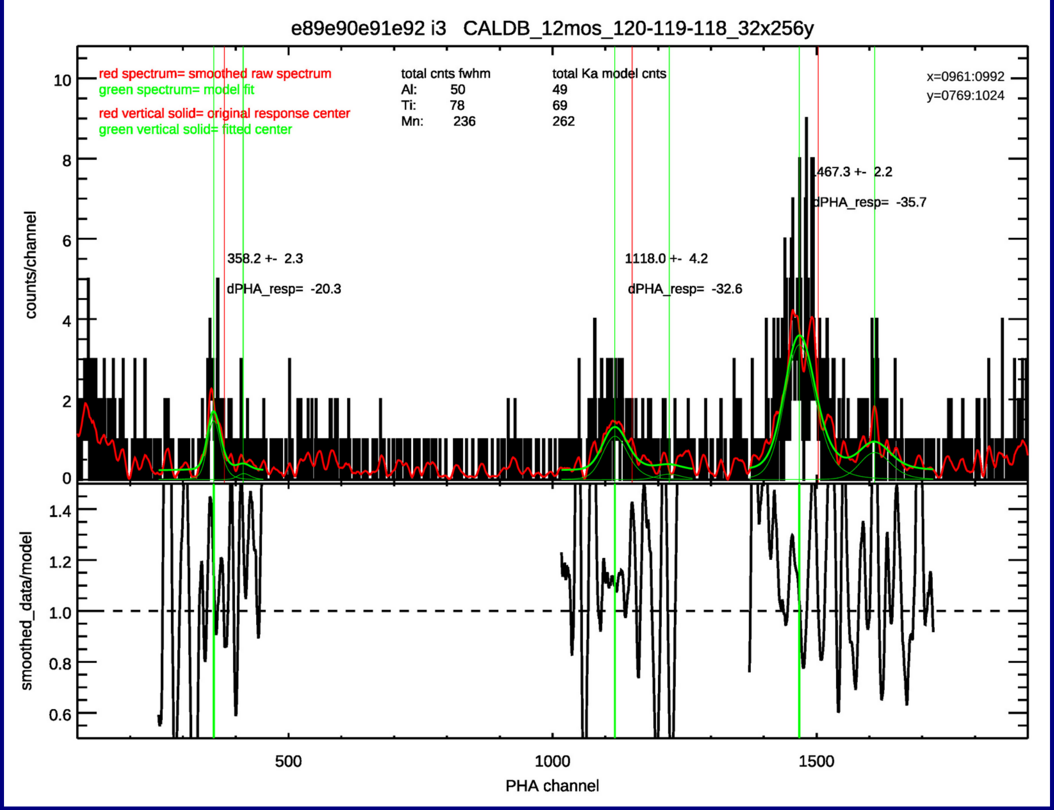


TGain with ECS

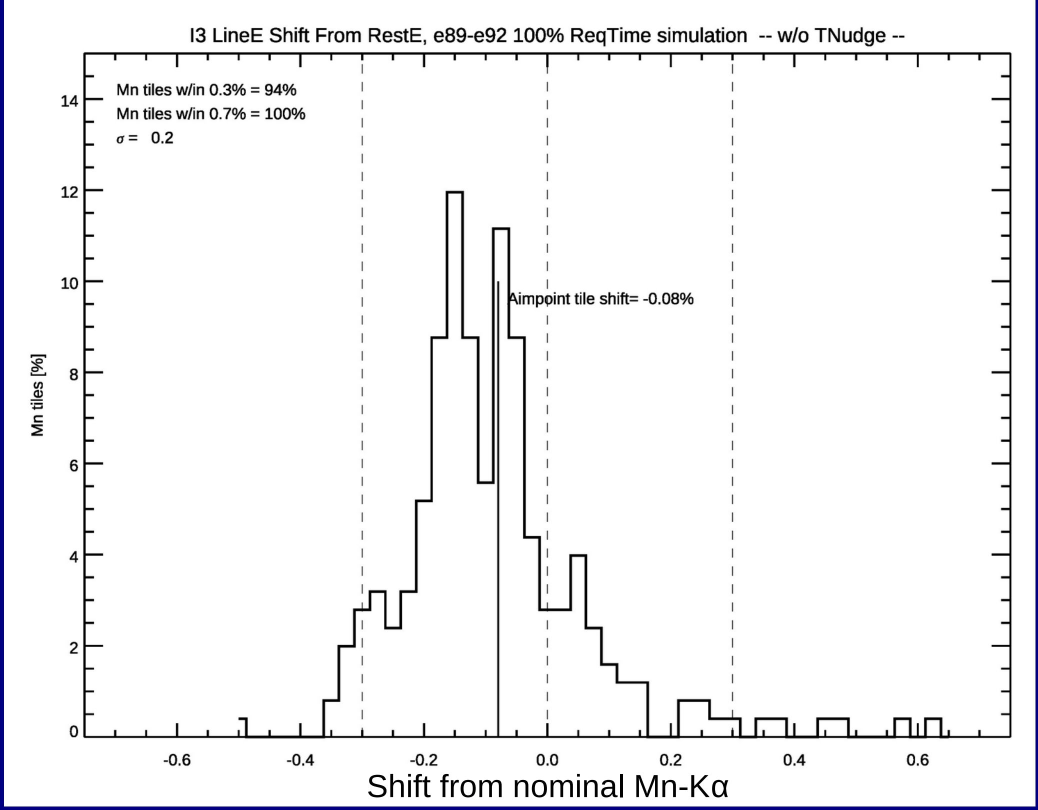
- ACIS Gain Calibrated Spec
  - >66% of pixels within +/- 0.3% of nominal LineE
  - 2023+ relaxed to +/- 0.6%

- Al-Kα and Ti-Kα S/N precludes further usefulness
- Mn-Kα also nearing end-of-life

ECS “bright” lines @ I3 Aimpoint
from 2022 TGain CalFile release



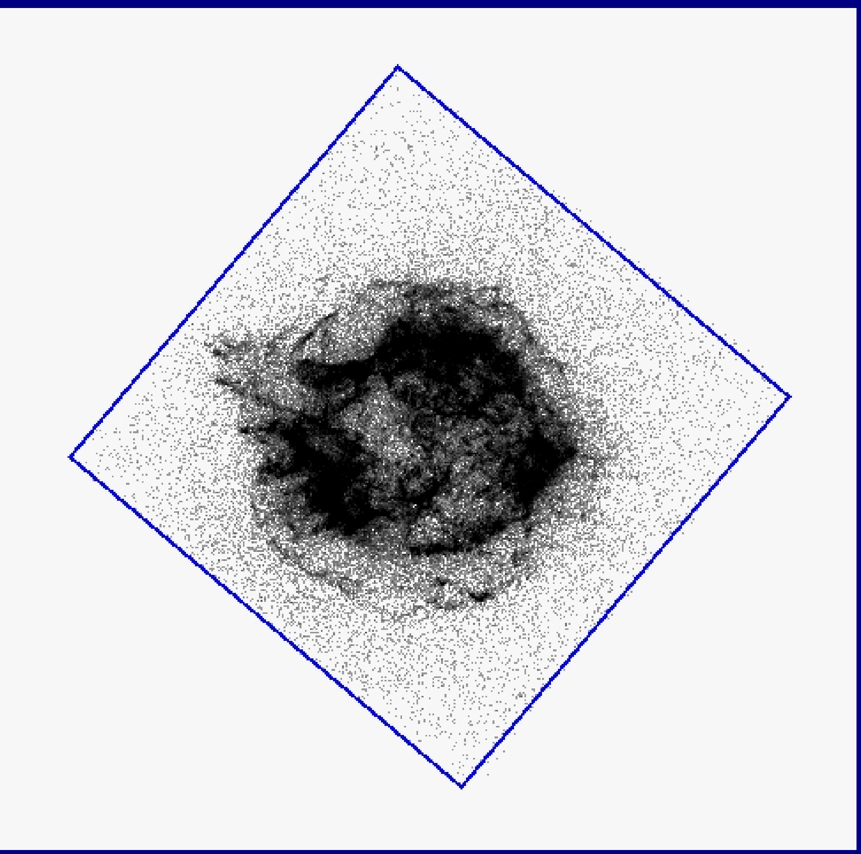
Simulation depicting 2022 ACIS-I3 gain accuracy @ Mn-Kα

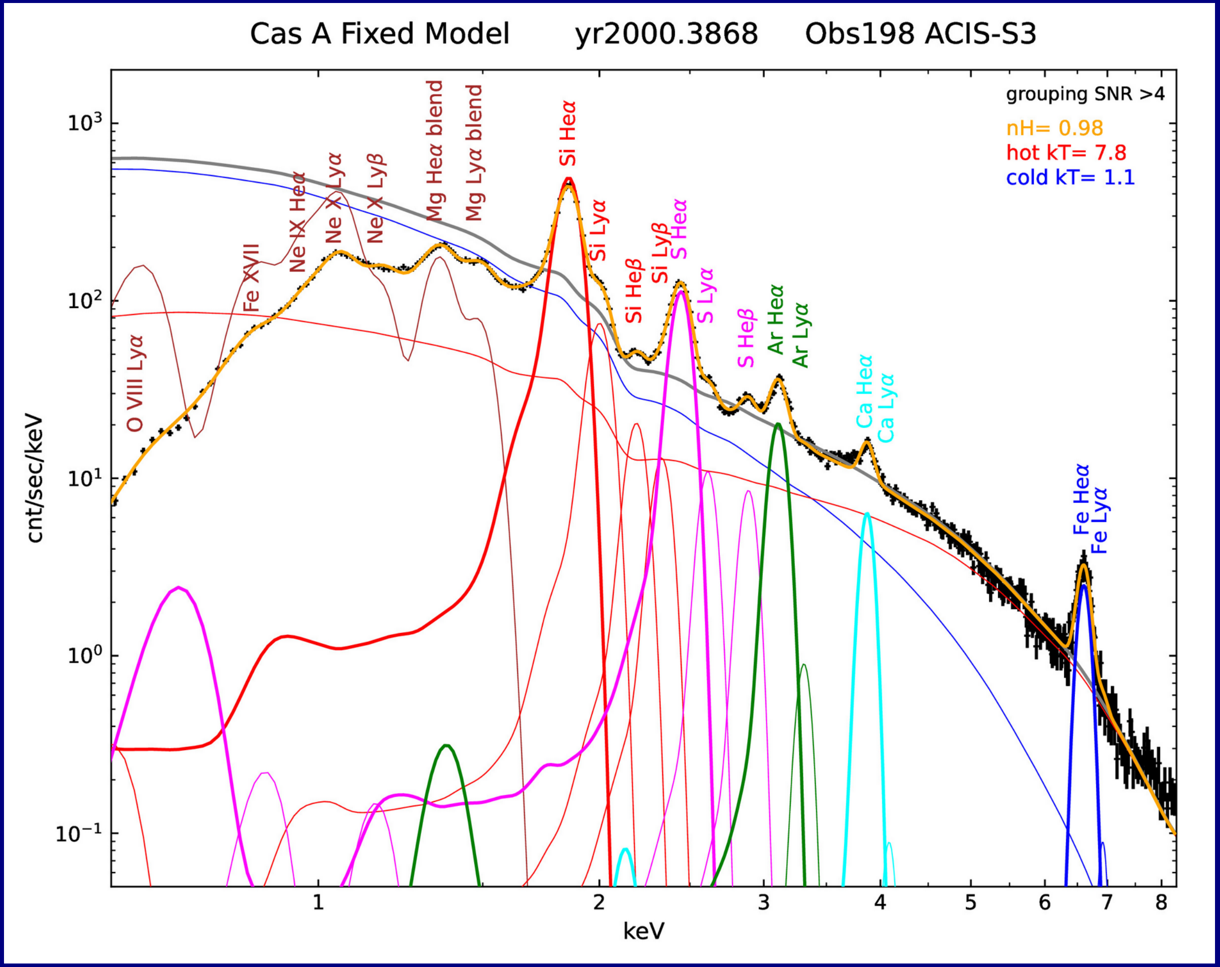


Search for Astrophysical Calibration Source

- 👍 Extended
- 👍 Bright
- 👍 Strong line emission

- 👎 Complicated spectrum
- 👎 Si velocities -4,000 to +6,000 km/sec (-13eV to + 20eV)
- 👎 Evolving spatially





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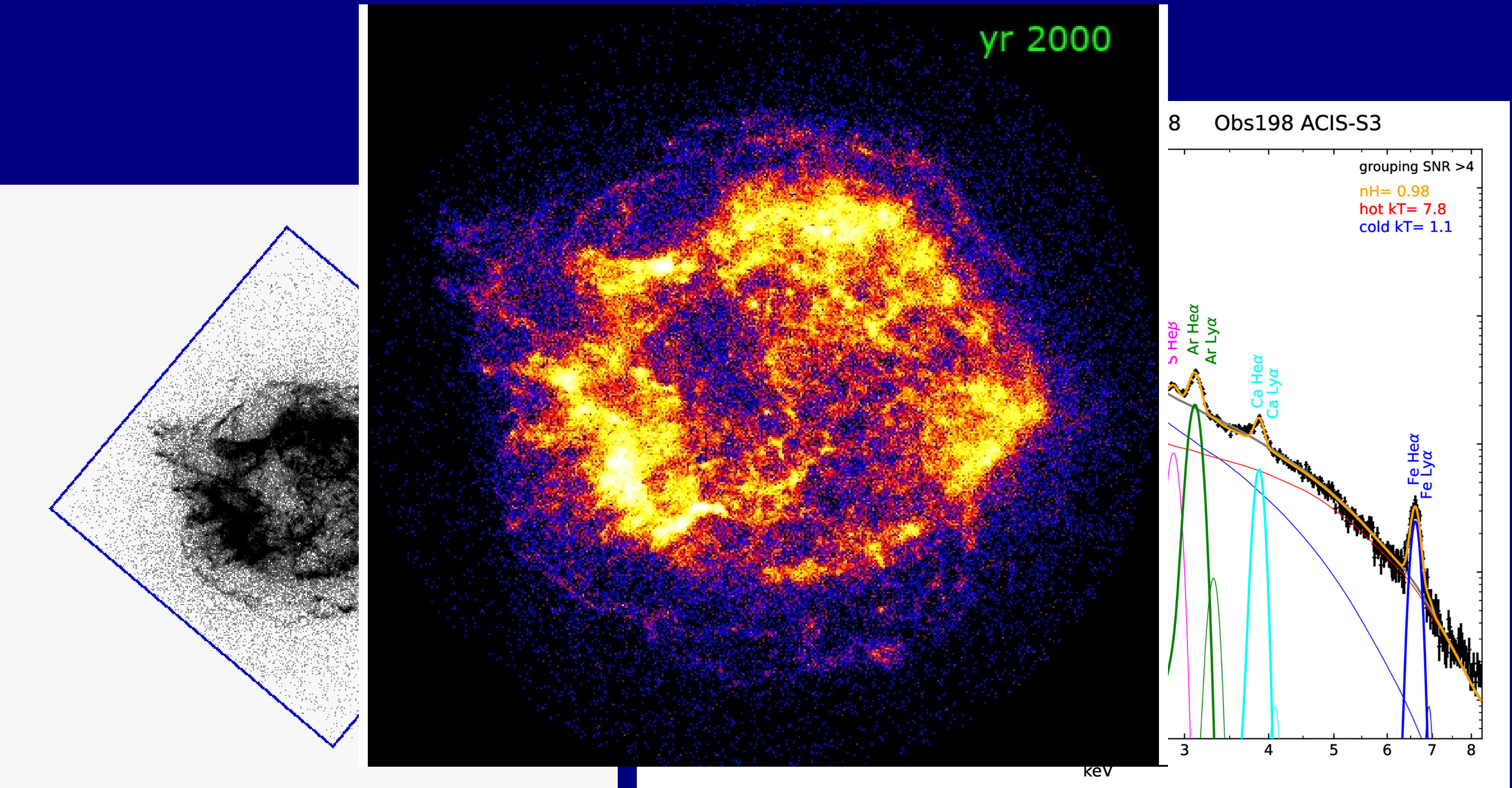

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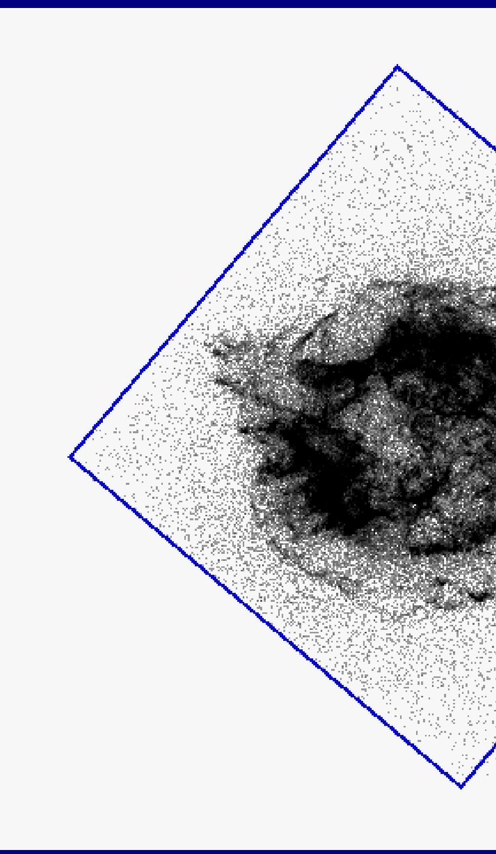
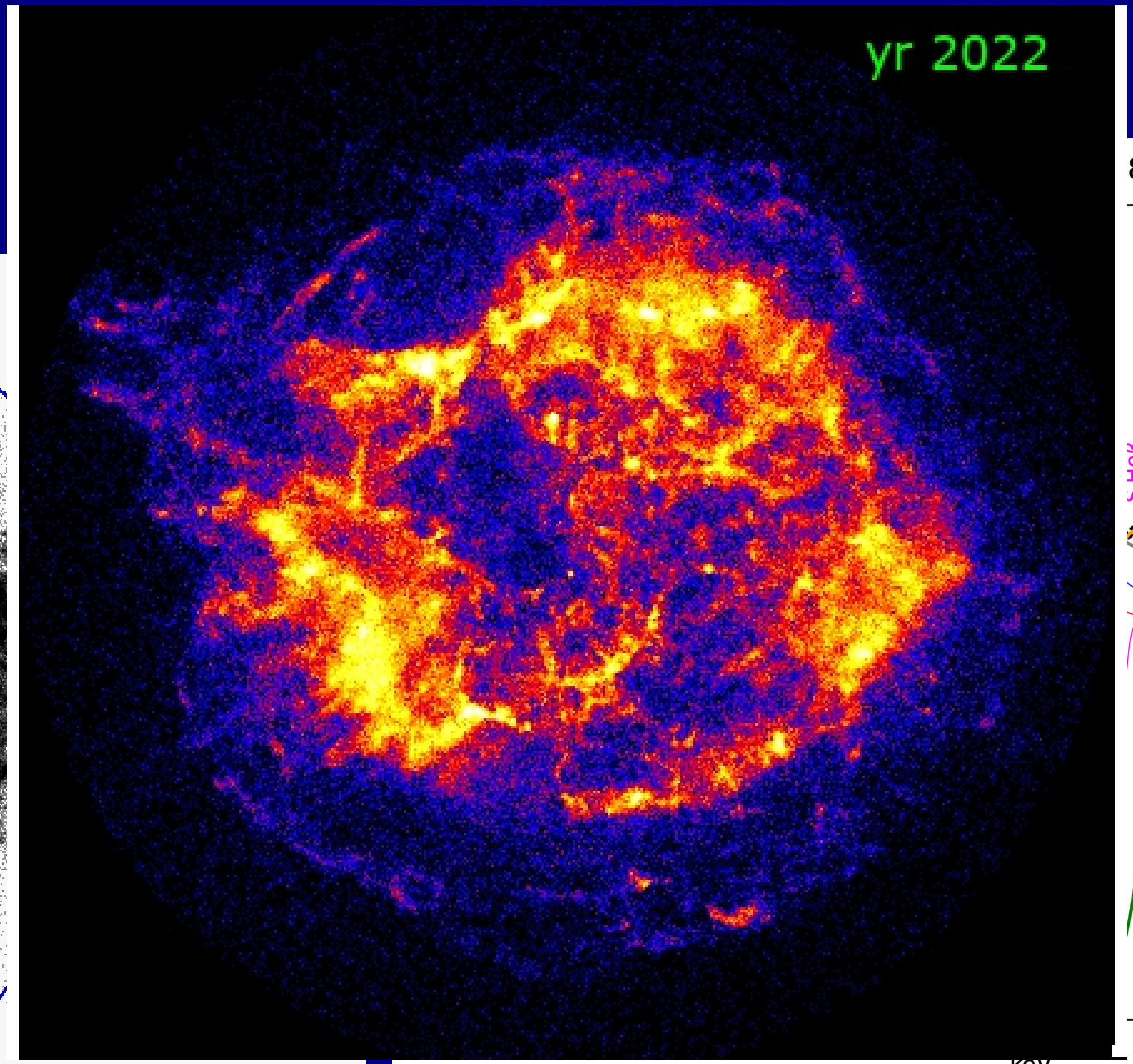
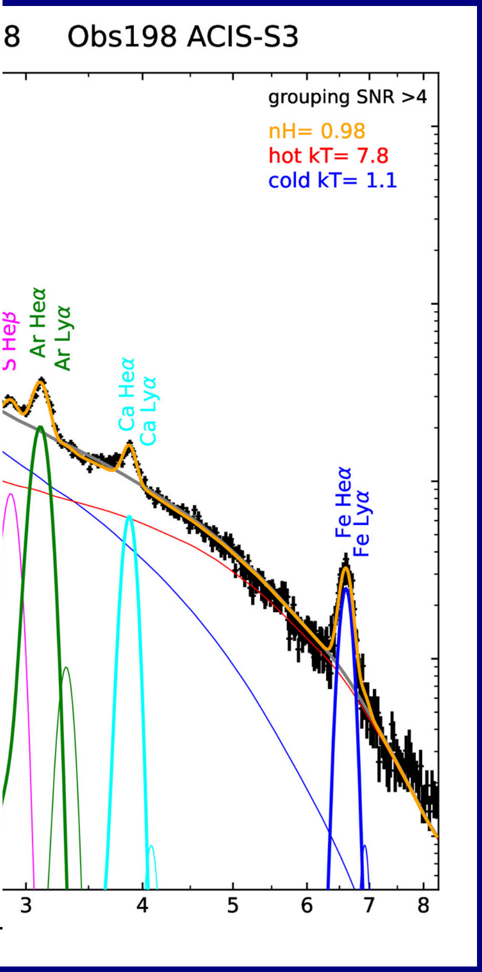
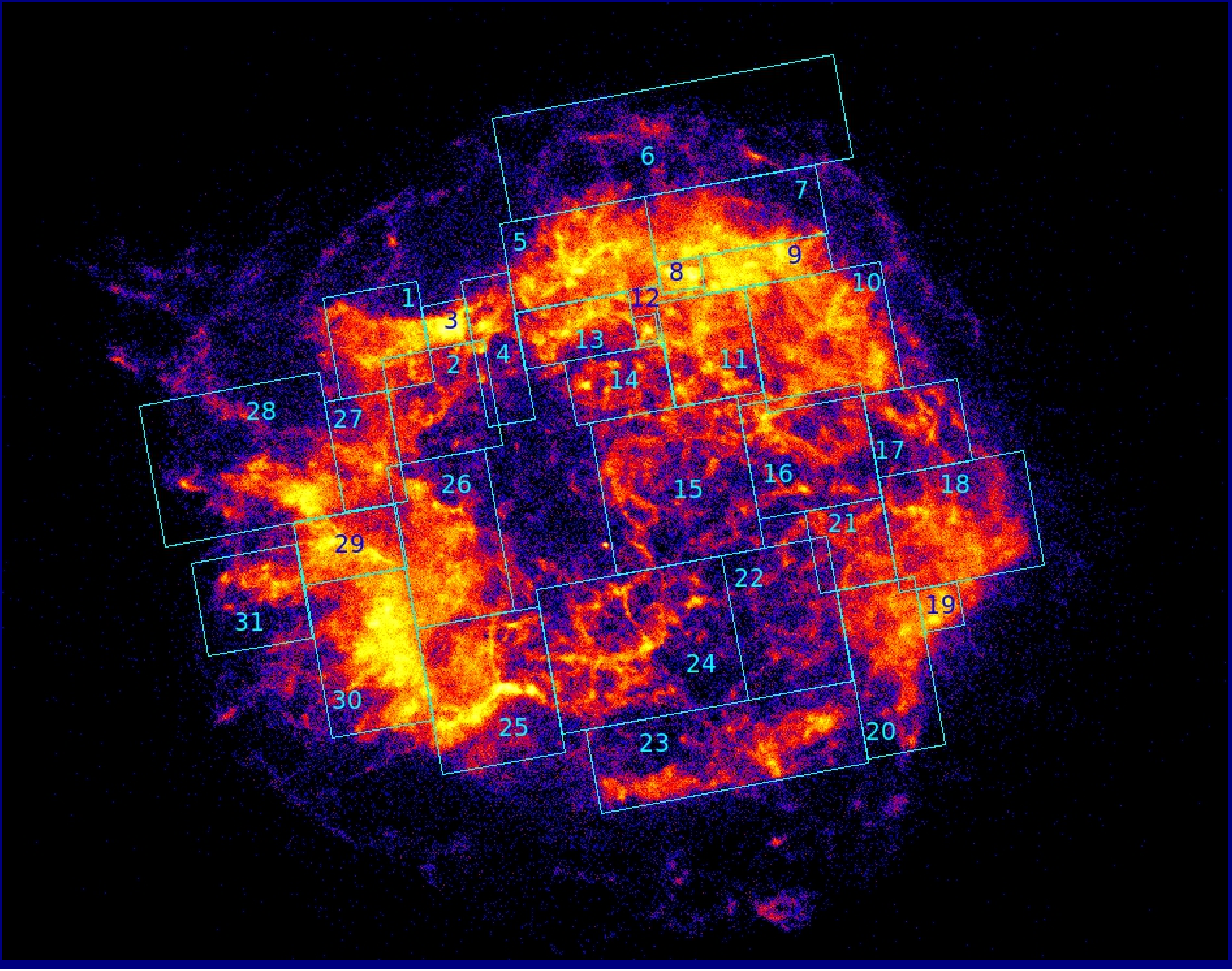






Velocity Corrections



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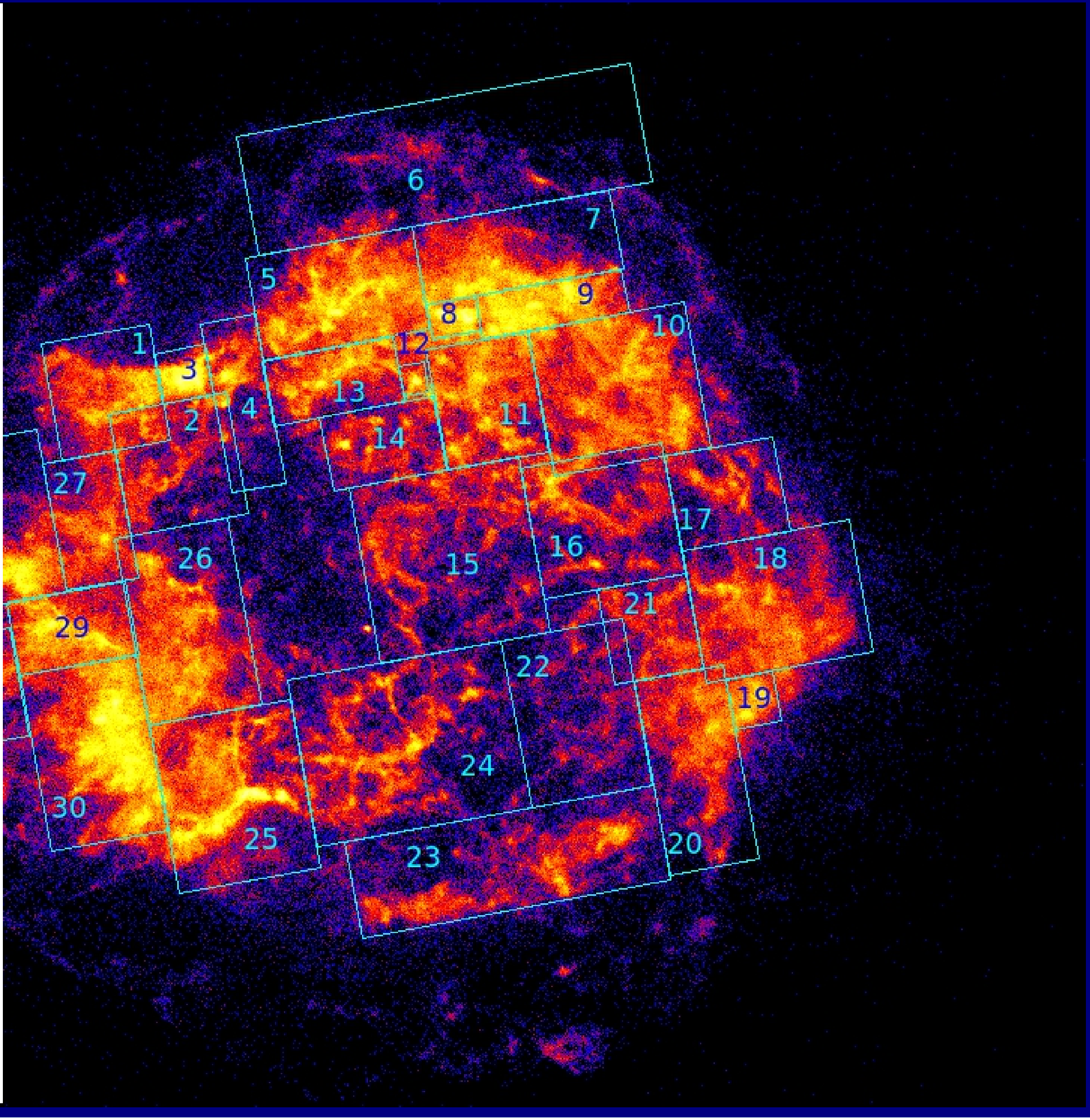

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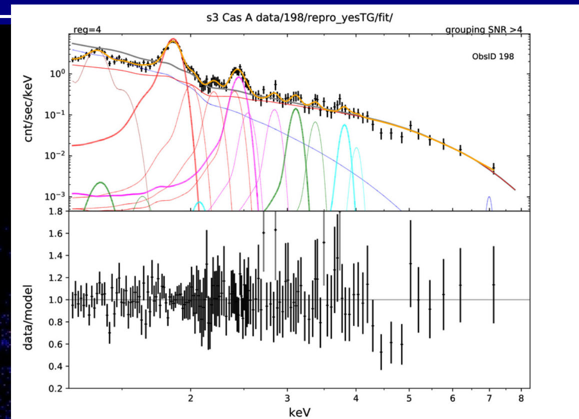

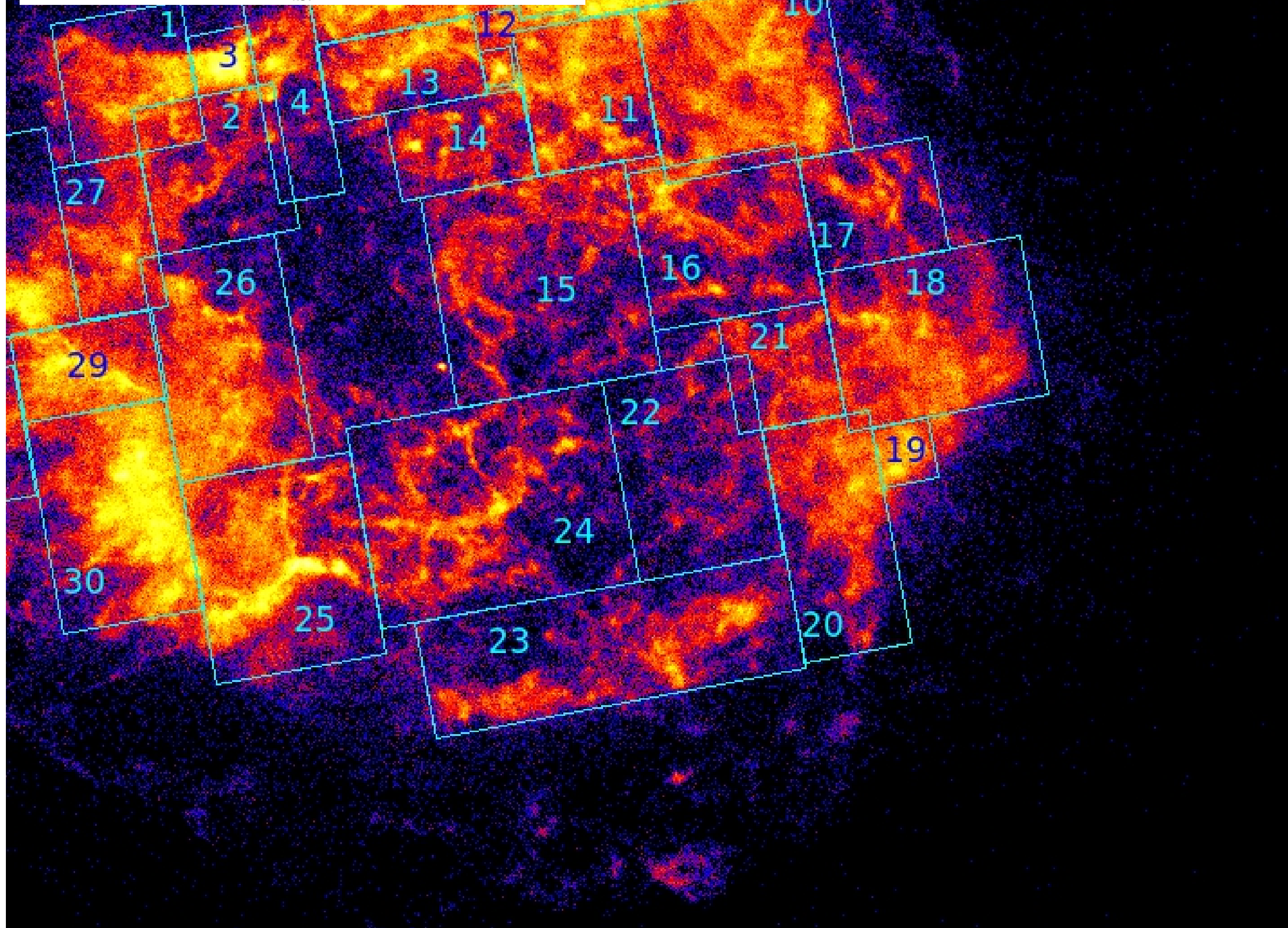

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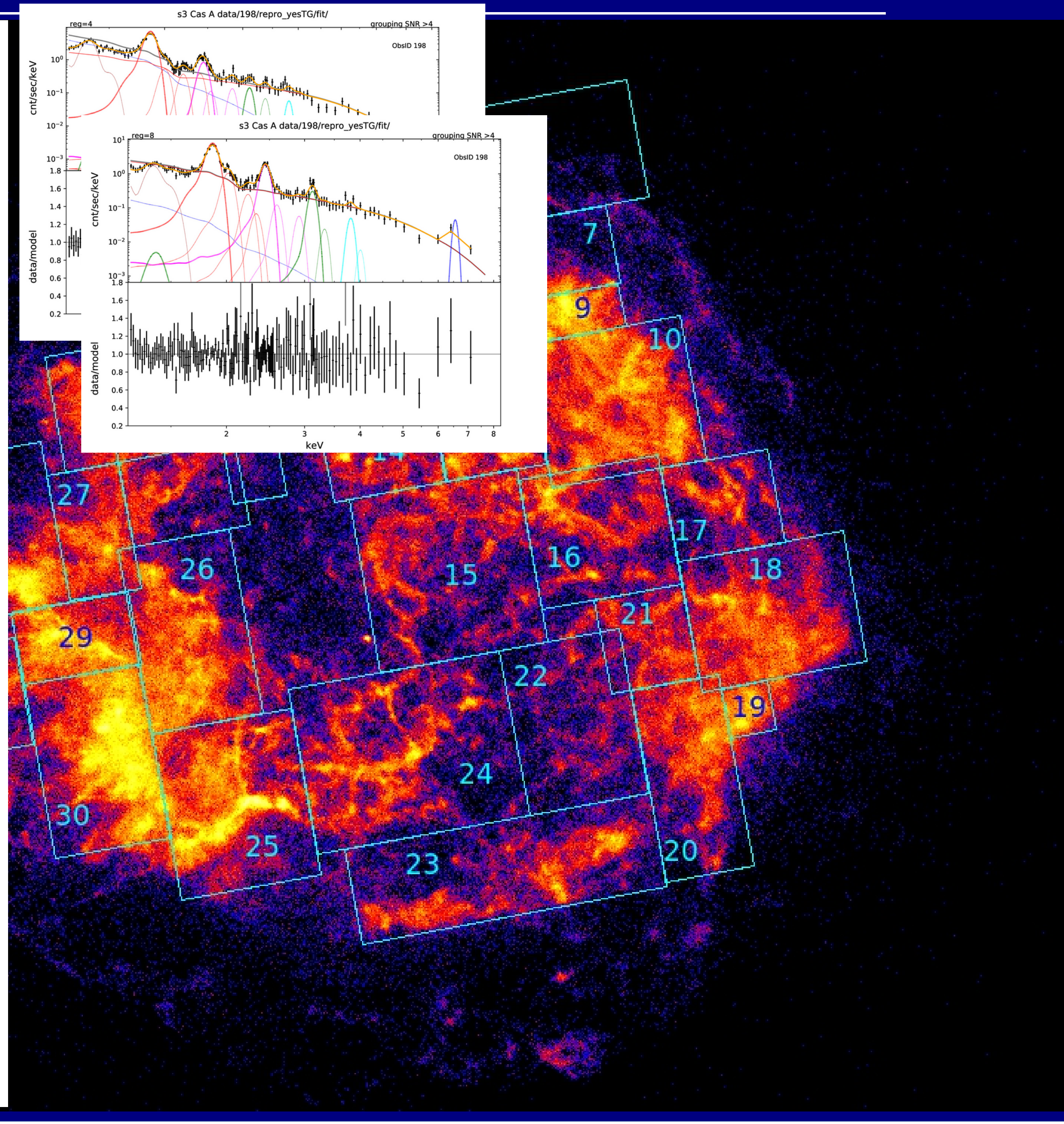

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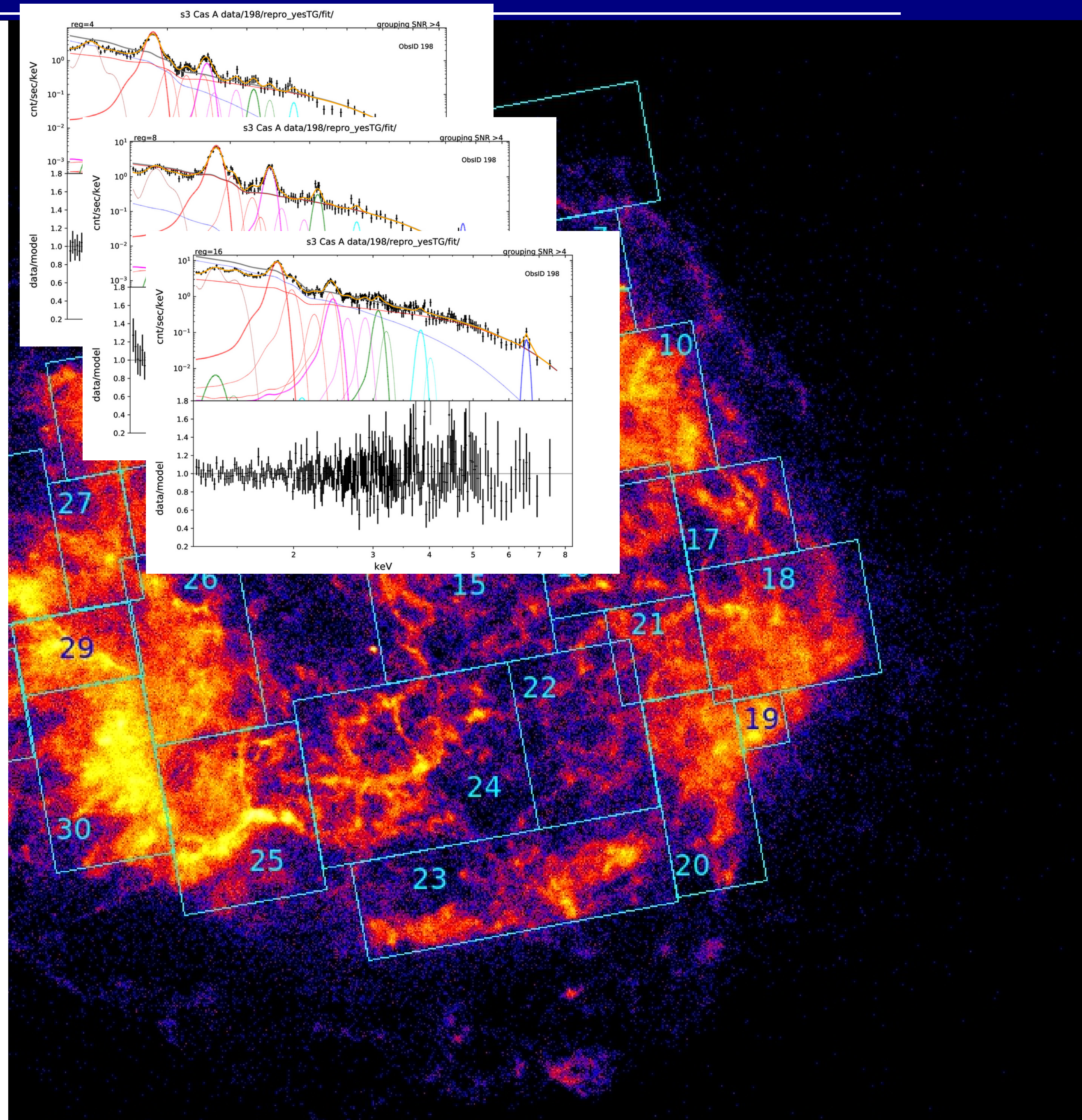

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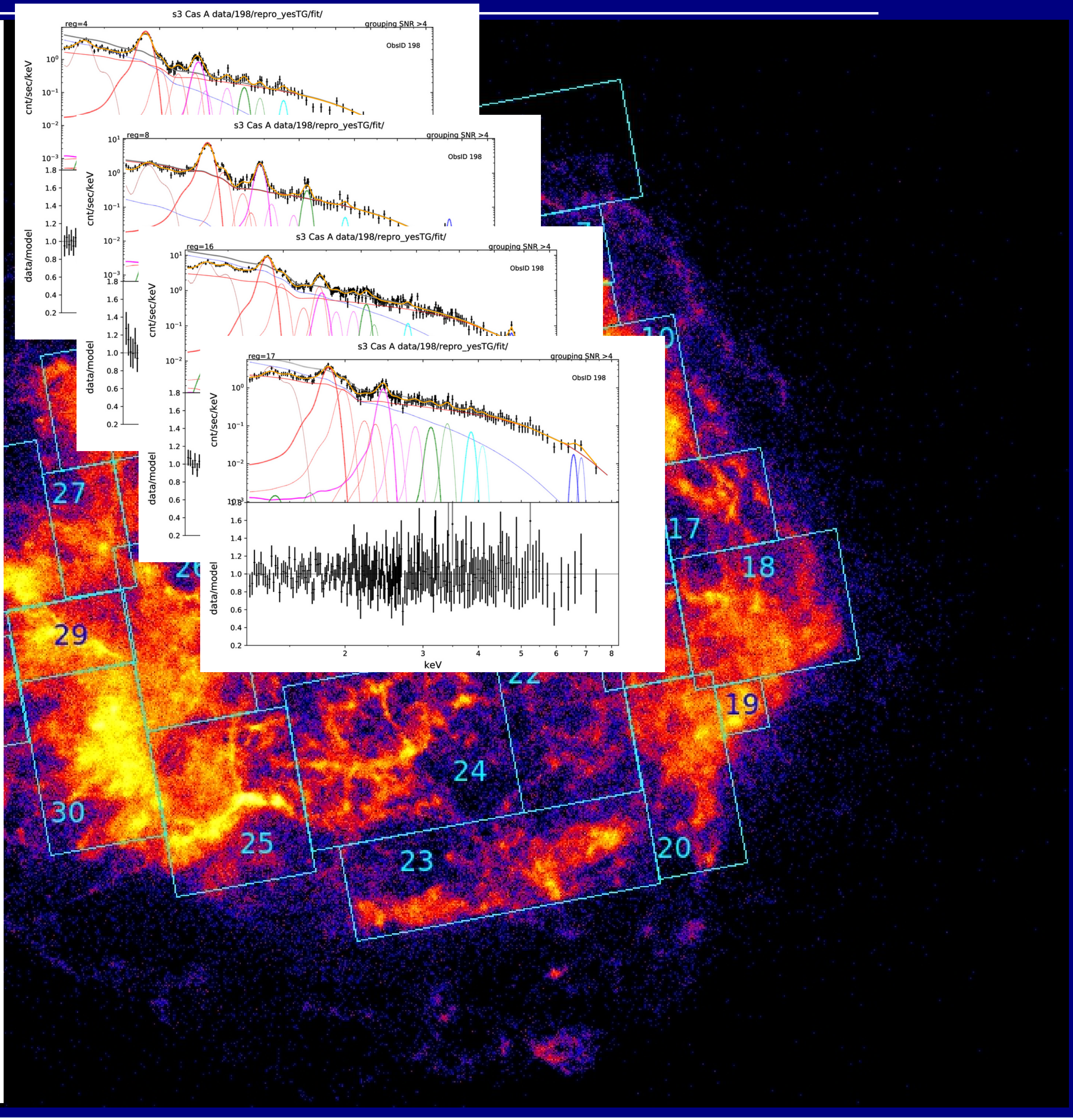

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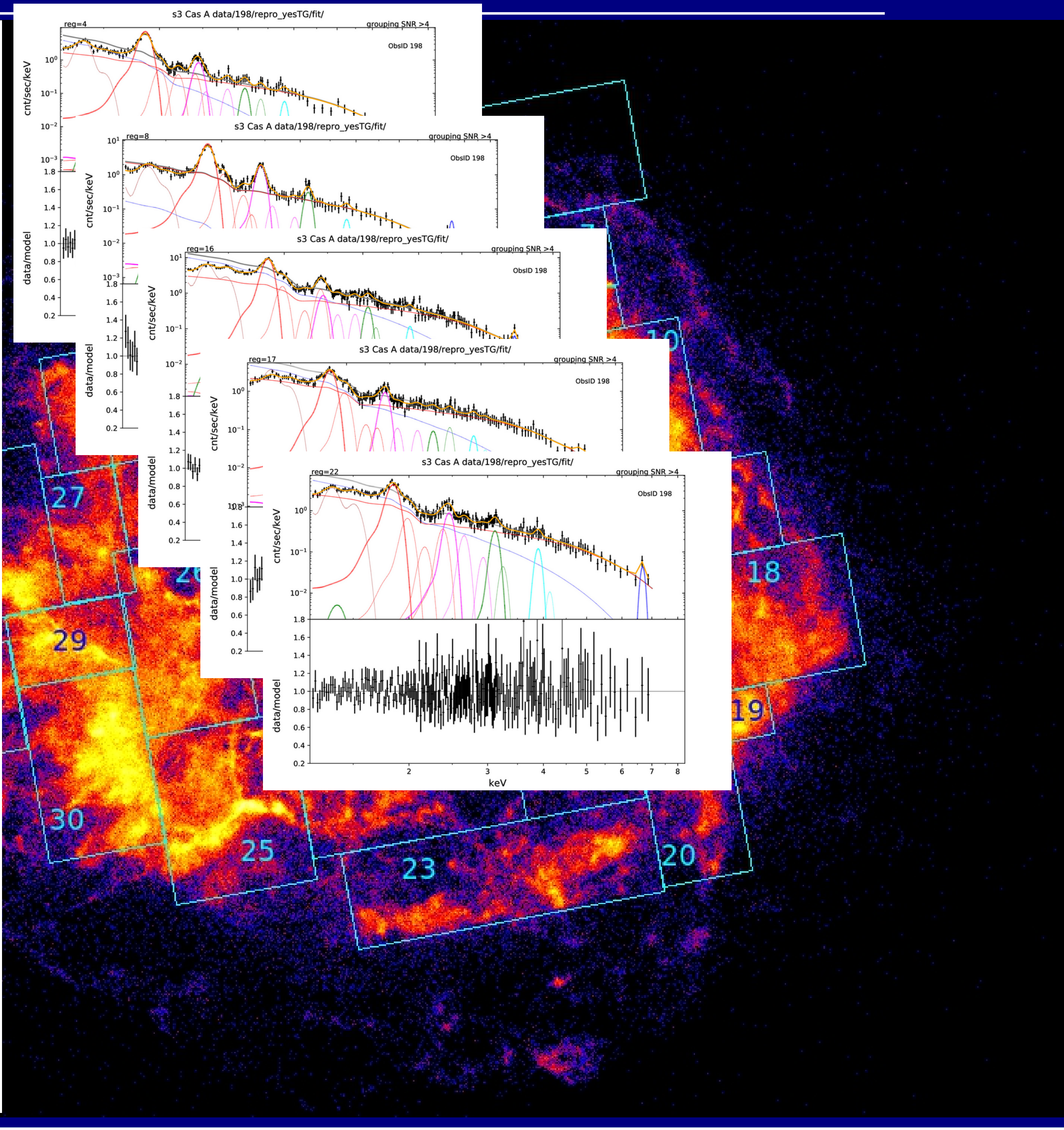

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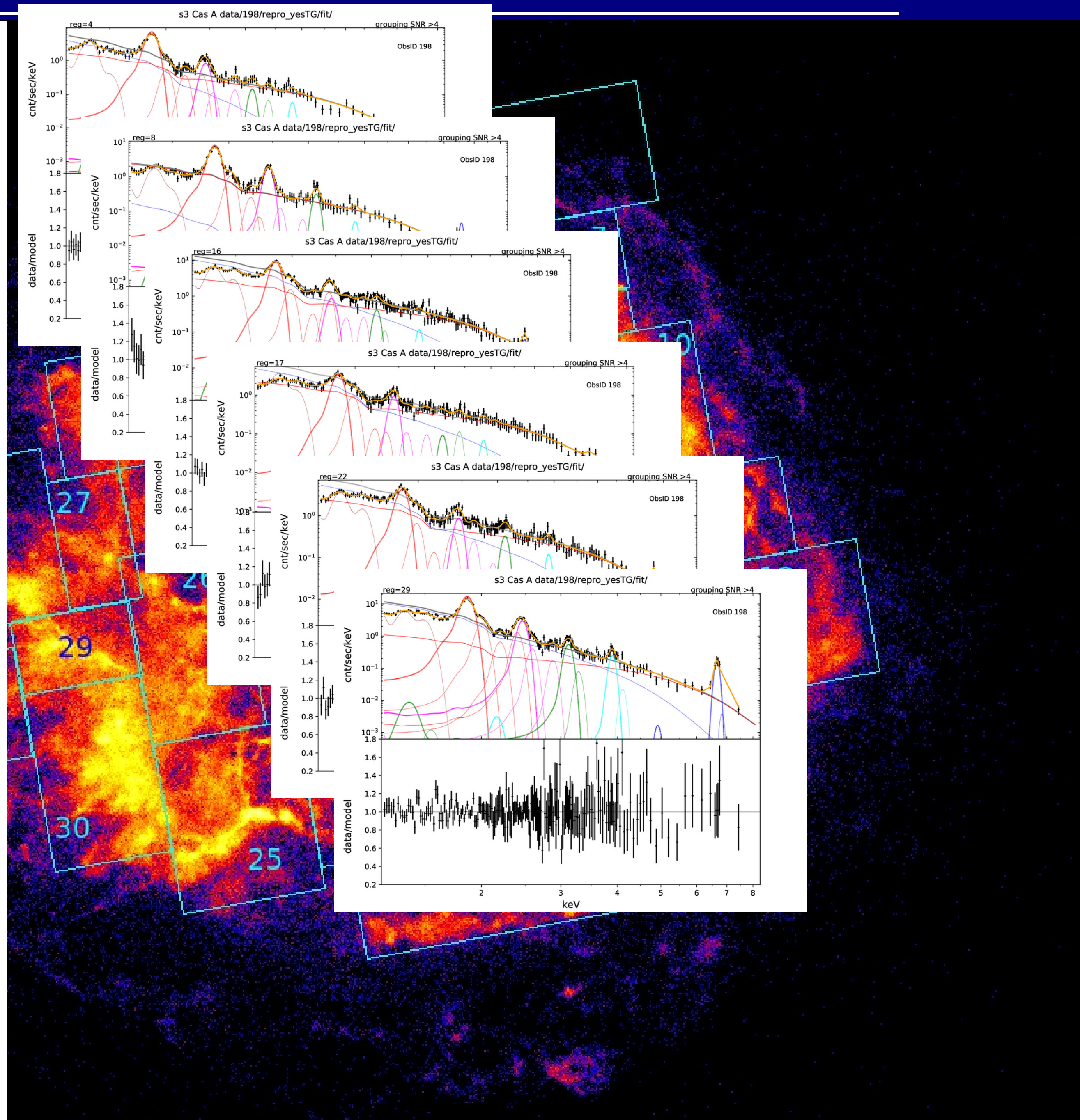
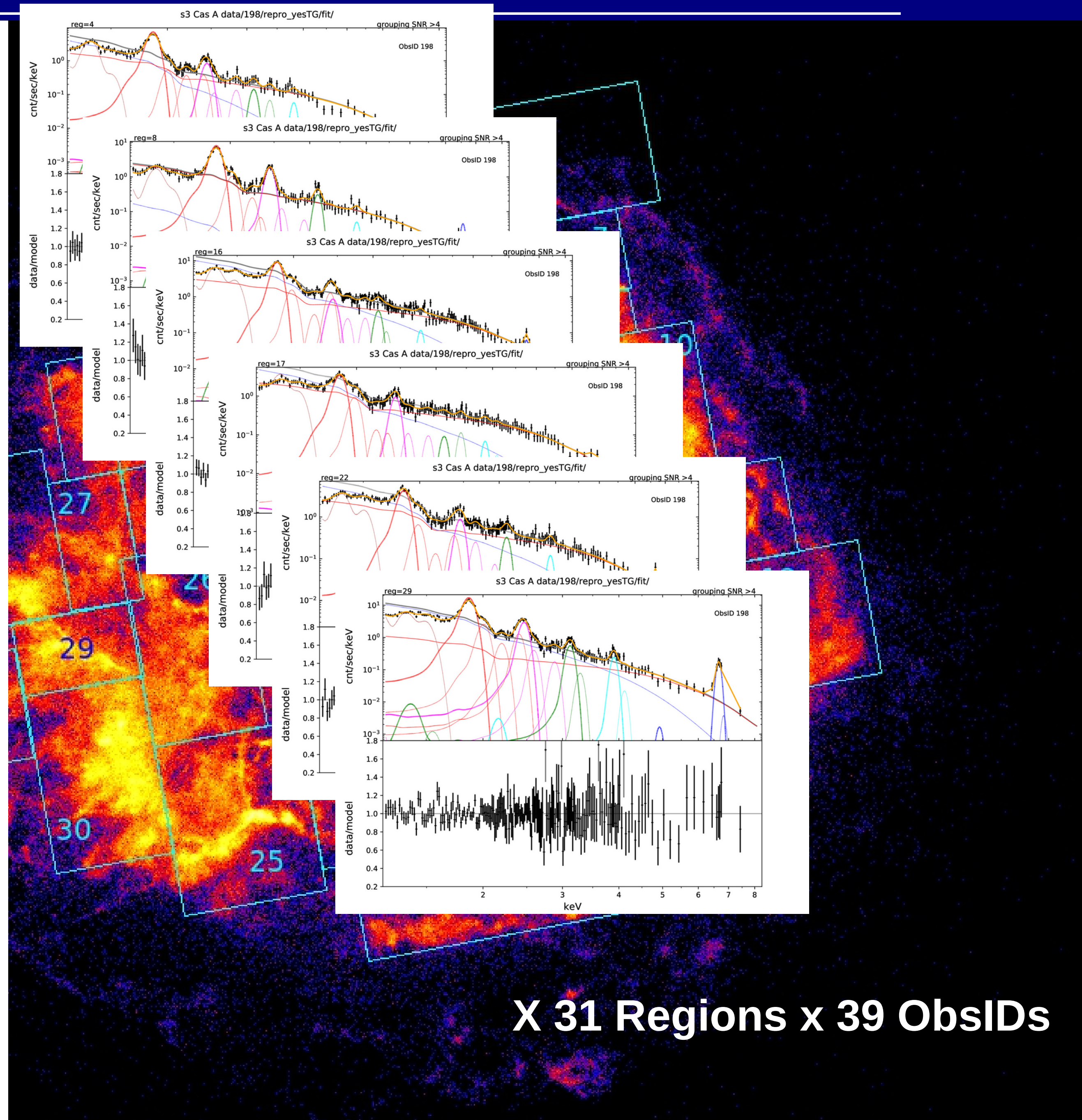
*3704	S3	10/19/2003	1.1 ksec
*5162	I3	3/15/2004	1.4 ksec
*5163	S3	3/15/2004	1.1 ksec
*5155	I3	11/01/2004	1.6 ksec
*5156	S3	10/29/2004	1.1 ksec
*6067	I3	4/13/2005	1.7 ksec
*6068	S3	4/12/2005	1.2 ksec
*6081	I3	10/23/2005	1.7 ksec
*6082	S3	10/23/2005	1.2 ksec
*6737	I3	3/22/2006	1.7 ksec
*6738	S3	3/22/2006	1.2 ksec
*6745	S3	10/15/2006	1.2 ksec
*6744	I3	10/15/2006	1.7 ksec
*8369	S3	3/10/2007	1.3 ksec
*8368	I3	3/10/2007	1.7 ksec
*9699	S3	3/24/2008	1.2 ksec
*9698	I3	3/24/2008	1.7 ksec
*10642	I3	5/10/2009	1.8 ksec
*10643	S3	5/10/2009	1.3 ksec

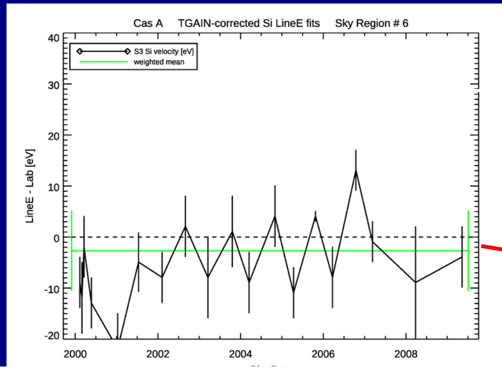


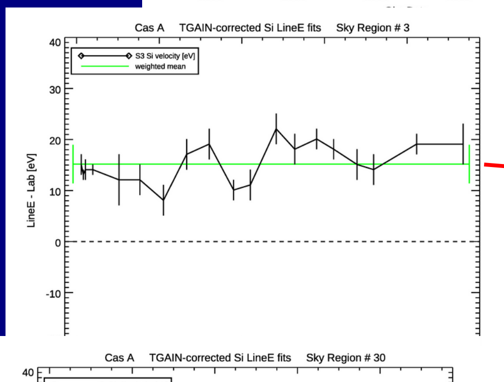
Velocity Corrections

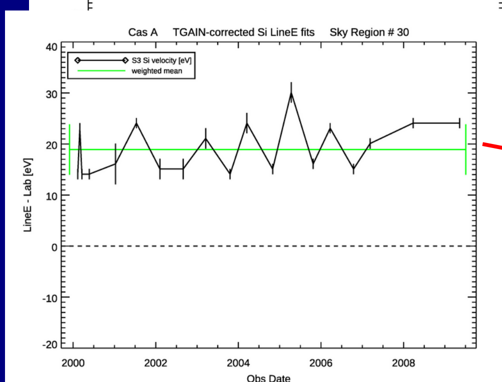
*226	I3	2/28/2000	2.7 ksec
*233	I3	2/28/2000	1.3 ksec
*234	I3	2/28/2000	1.3 ksec
*235	I3	2/28/2000	1.3 ksec
*230	S3	2/28/2000	2.0 ksec
*236	S3	2/28/2000	1.0 ksec
*237	S3	2/28/2000	1.0 ksec
*194	I3	5/19/2000	3.4 ksec
*198	S3	5/21/2000	2.5 ksec
*1547	S3	1/09/2001	1.0 ksec
*1545	I3	1/15/2001	1.5 ksec
*1548	S3	7/13/2001	1.0 ksec
*1546	I3	7/13/2001	1.4 ksec
*2870	S3	2/06/2002	1.0 ksec
*2869	I3	2/6/2002	1.4 ksec
*2877	S3	8/30/2002	1.0 ksec
*2876	I3	8/31/2002	1.4 ksec
*3696	I3	3/17/2003	1.7 ksec
*3697	S3	3/17/2003	1.1 ksec
*3703	I3	10/19/2003	1.5 ksec
*3704	S3	10/19/2003	1.1 ksec
*5162	I3	3/15/2004	1.4 ksec
*5163	S3	3/15/2004	1.1 ksec
*5155	I3	11/01/2004	1.6 ksec
*5156	S3	10/29/2004	1.1 ksec
*6067	I3	4/13/2005	1.7 ksec
*6068	S3	4/12/2005	1.2 ksec
*6081	I3	10/23/2005	1.7 ksec
*6082	S3	10/23/2005	1.2 ksec
*6737	I3	3/22/2006	1.7 ksec
*6738	S3	3/22/2006	1.2 ksec
*6745	S3	10/15/2006	1.2 ksec
*6744	I3	10/15/2006	1.7 ksec
*8369	S3	3/10/2007	1.3 ksec
*8368	I3	3/10/2007	1.7 ksec
*9699	S3	3/24/2008	1.2 ksec
*9698	I3	3/24/2008	1.7 ksec
*10642	I3	5/10/2009	1.8 ksec
*10643	S3	5/10/2009	1.3 ksec

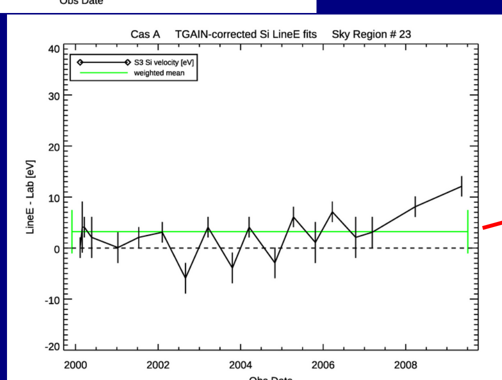


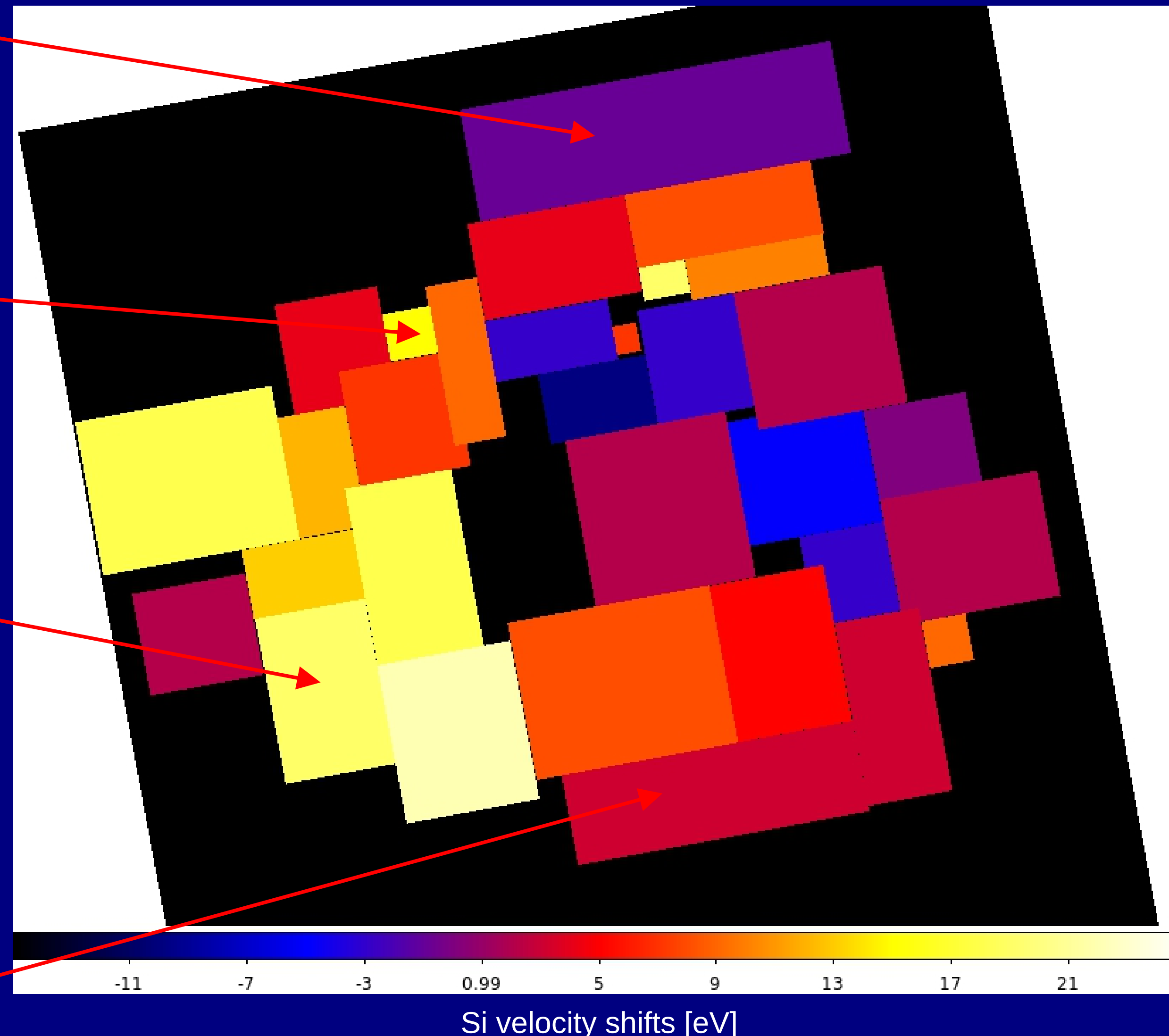
Velocity Corrections





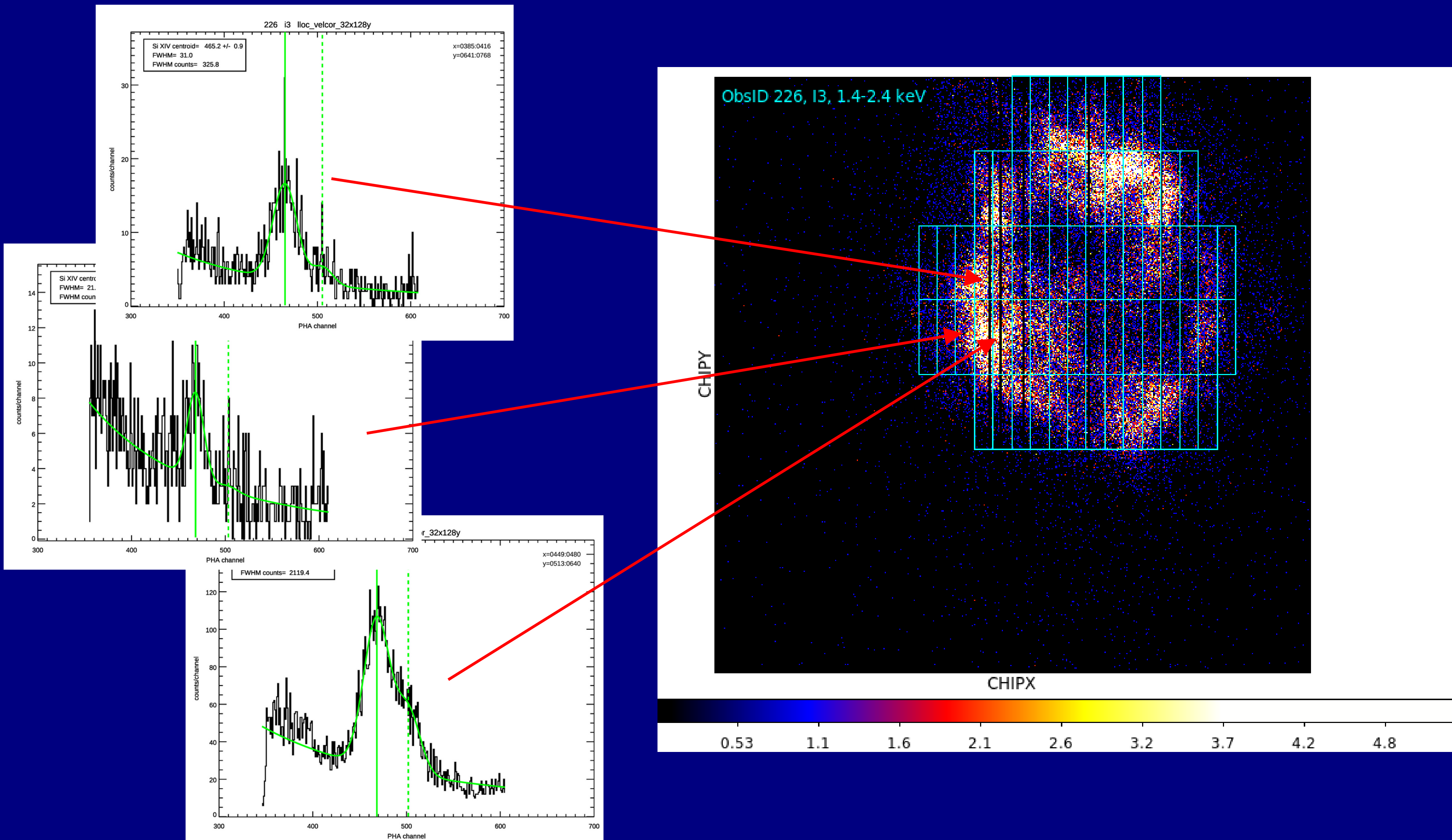






Cas A 32x128 pixel fits

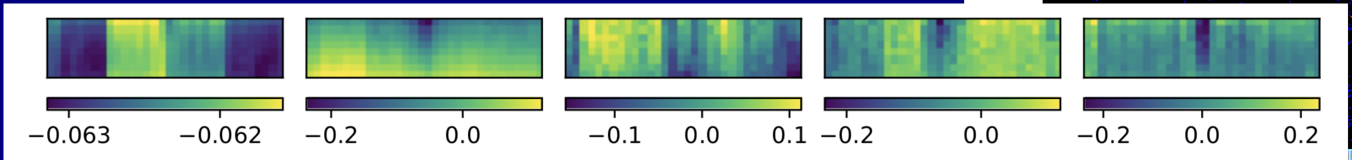
- Reprocess each ObsID without TGain corrections
- Shift PHA of each event by Si velocity corresponding to SkyXY position
- Fit Si positions in chipXY tiles for each ObsID using simple model:
  - powlaw + Si He-like gaussian + Si H-like gaussian



Filling in the Illumination Gaps

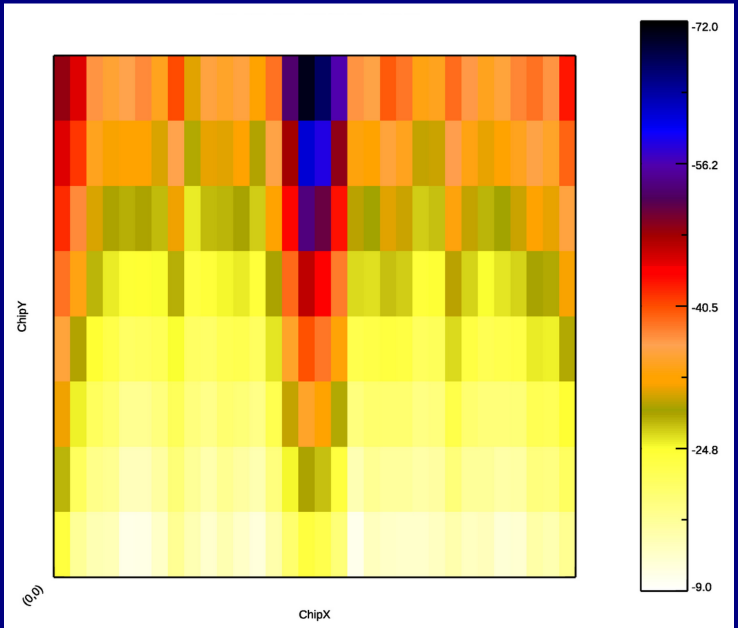
- Use Principle Component Analysis [PCA] to scale TGain spatial structure using Si positions where Cas A is bright enough to measure
- Prep:
  - Convert TGain pattern from each epoch to 256x1 array (32x128 regions)
  - PCA accurately describes spatial pattern with 5 components (base vectors)
  - 1st components describes largest variations – ex. node boundaries
  - Remaining components describe decreasingly important modifications to recreate the structure
- Spatial structure for any given TGain epoch can be recreated with only a few uniquely scaled PCA components

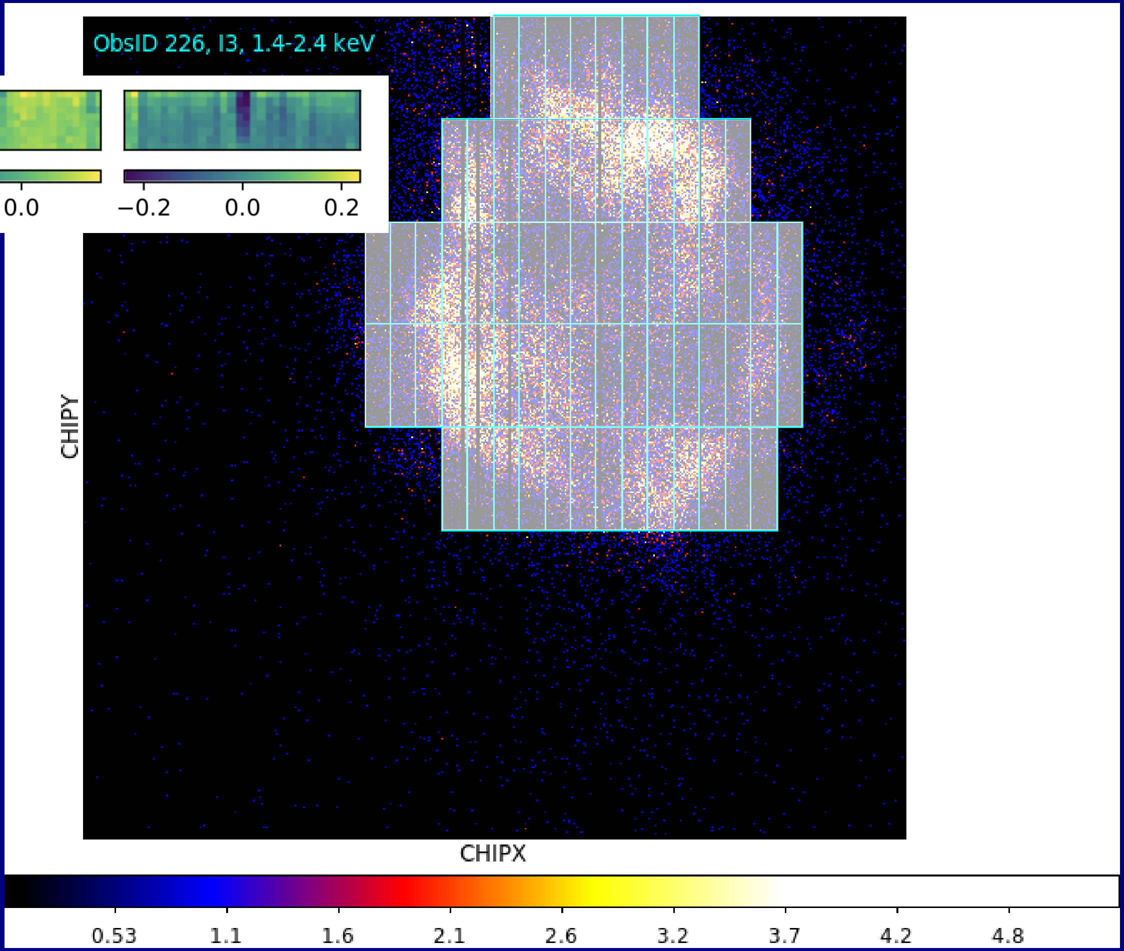
5x Most Significant PCA Components



x epoch2022 scaling factors

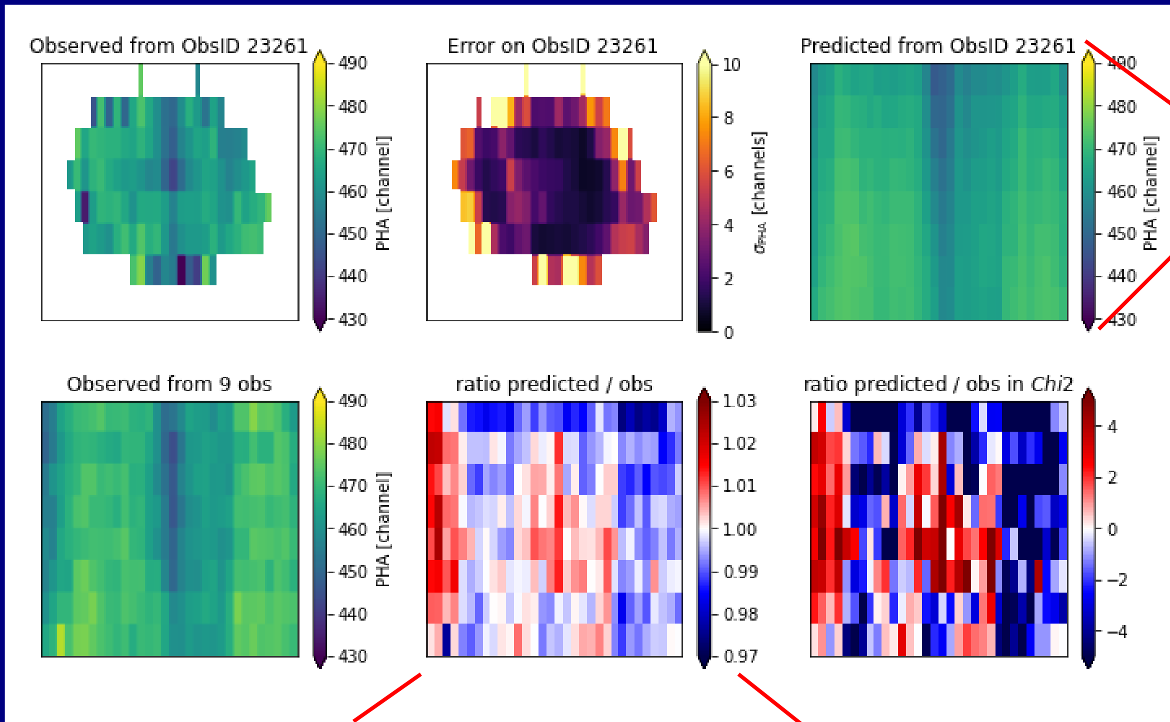
= recreation of epoch2022 spatial gain structure





Filling in the Illumination Gaps

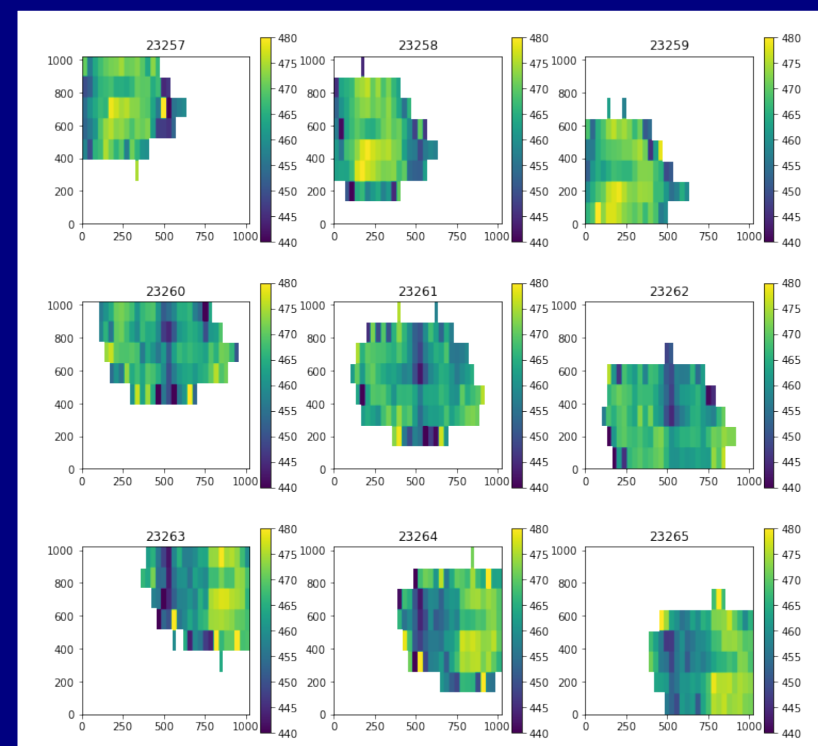
- Scaling factors calculated from tiles with available measurements
  - ☝ number of tiles measurements return ☝ accuracy filling the missing unmeasured chip tiles

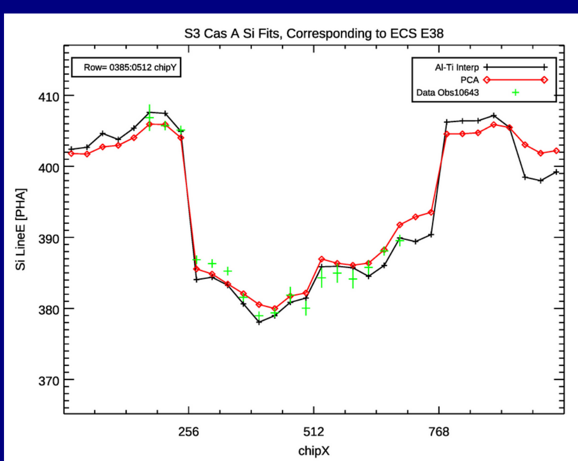


Spatial map of Si created with 1x pointing of Cas A to scale PCA components

Residuals in spatial structure using only 1x 2ksec Cas A pointing

Measured Si positions for 9x offset pointings of Cas A





Si position interpolated from ECS Al & Ti positions compared to PCA prediction

Chip location:
Y= 385:512
X= 1:1024

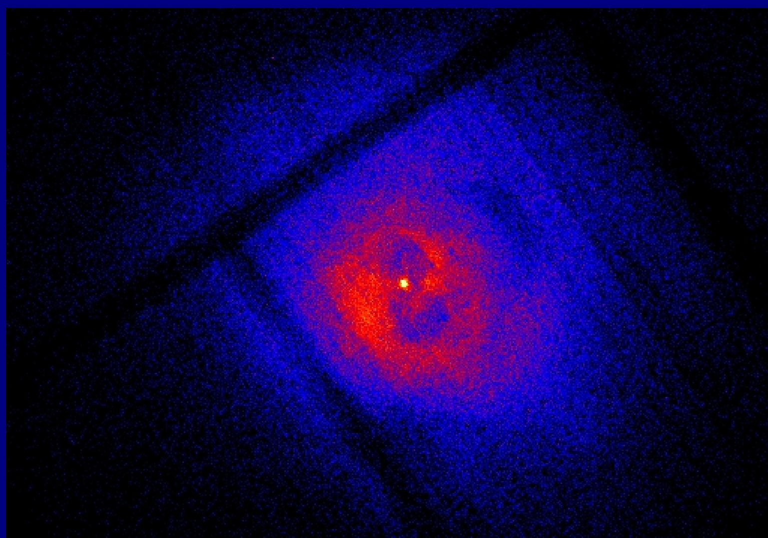
ACIS TGain Observing Plan 2023+

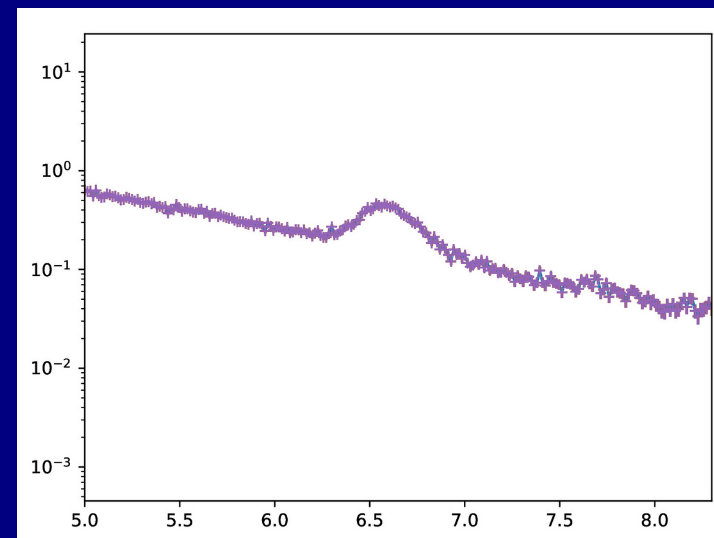
Low-Energy Si

2 ksec Cas A Observations once per year x10 (each ACIS CCD)

High-Energy:

Proposed Fe measurements of Perseus





More information on PCA as applied to ACIS Gain:

Principal component analysis of the Chandra ACIS gain

Hans Moritz Günther[a], Ákos Bogdán[b], and Nick Durham [b]

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