The Athena X-ray observatory

ESA L-class mission

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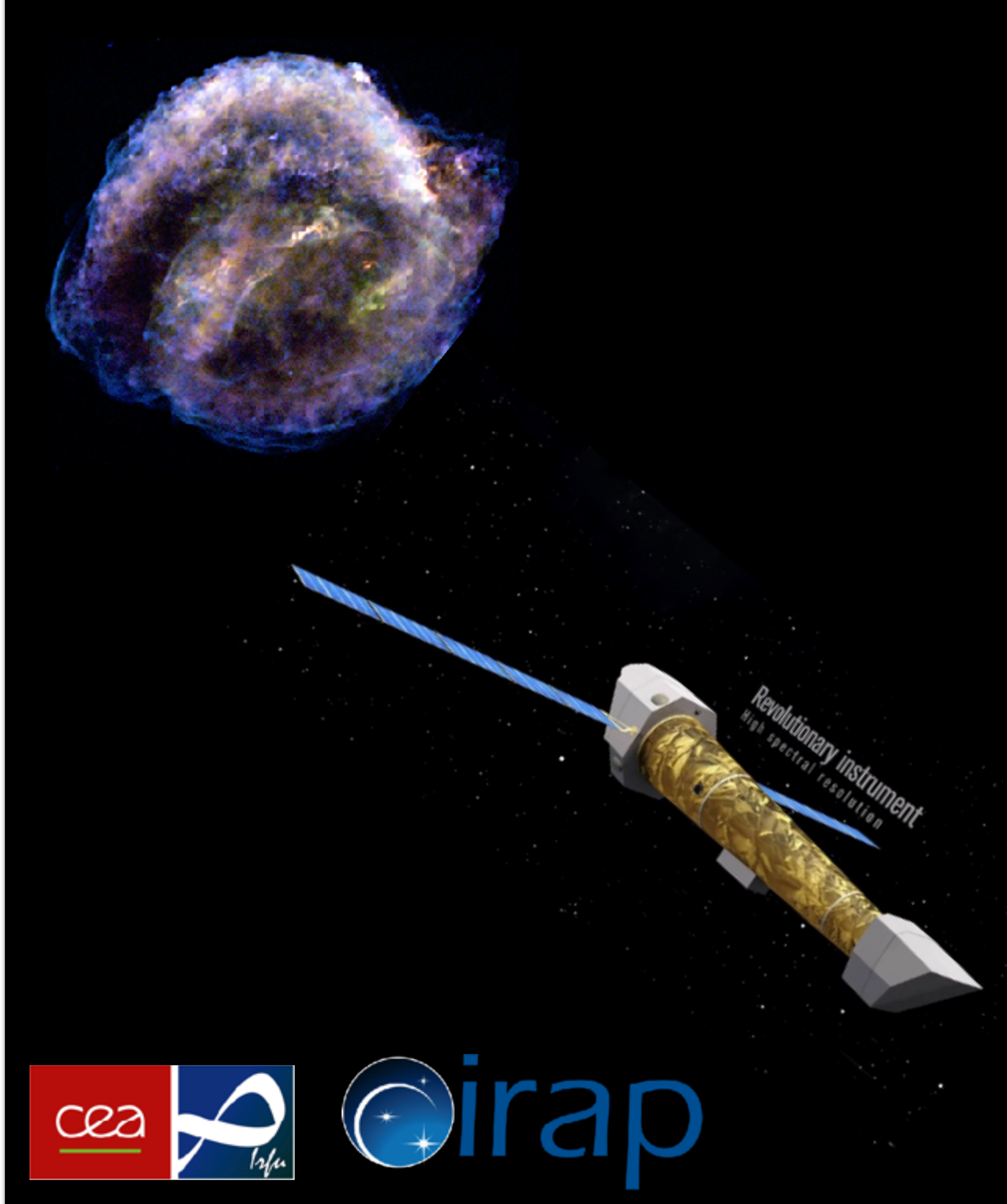
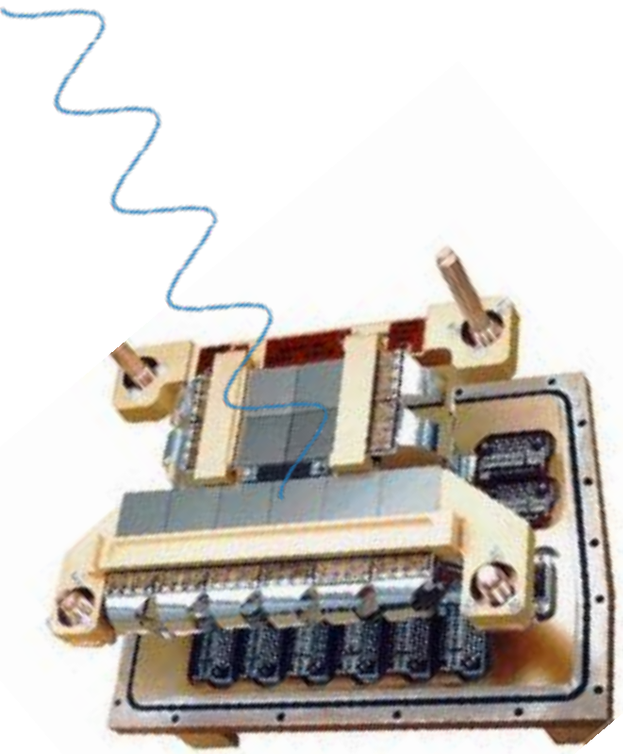
ASOV, 12 avril 2022



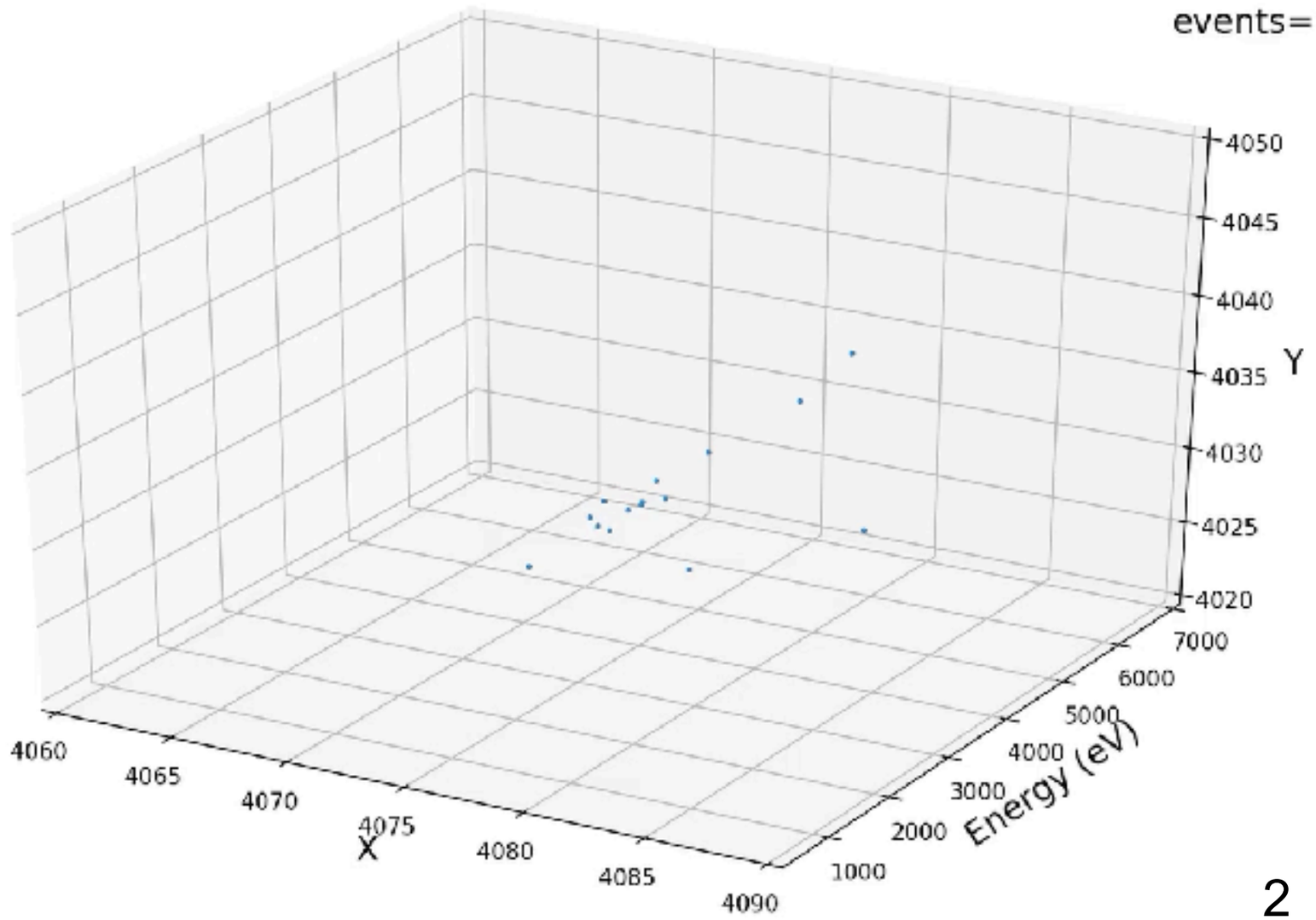
Spectro-imagers in high-energy

- X-ray spectro-imagers since Einstein (1978) and ROSAT (90)
- CCDs revolution with ASCA (93)

- Measure photon by photon:
  - X, Y, Energy, Time



Chandra ACIS



X-ray raw data to the user

Time of arrival | Detector coord. | Sky coord. | Energy | Event quality

Select All / Invert	TIME D s Modify	RAWX I PIXELS Modify	RAWY I PIXELS Modify	DETX I pixel Modify	DETY I pixel Modify	X J pixel Modify	Y J pixel Modify	PHA I CHAN Modify	PI I CHAN Modify	FLAG J Modify	PATTERN B Modify	CCDNR B Modify
1	1.813962421948E+08	302	6	32	-6481	24967	30815	571	1947	0	0	1
2	1.813962423123E+08	310	41	203	-5718	25105	30046	813	2754	0	0	1
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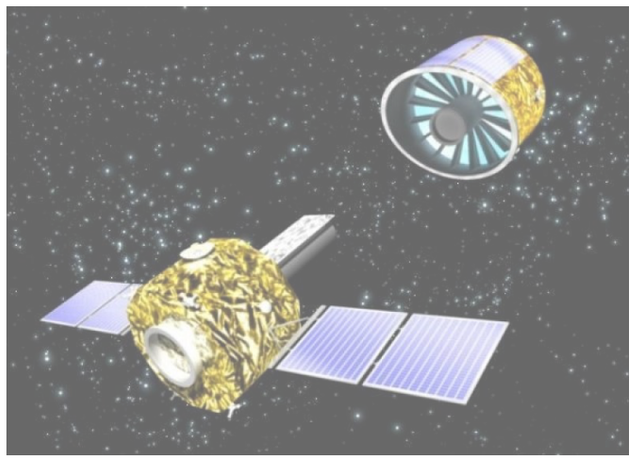
4	1.813962424250E+08	343	74	945	-4979	25814	29275	480	1637	0	1	1
5	1.813962421848E+08	353	83	1149	-4786	26009	29074	223	775	0	0	1
6	1.813962422734E+08	303	85	53	-4747	24913	29082	209	729	0	0	1
7	1.813962423884E+08	368	97	1483	-4472	26330	28746	1033	3505	0	0	1
0	1.813962423458E+08	205	108	-2098	-4234	22742	28662	522	1777	0	4	1
9	1.813962423223E+08	286	112	-313	-4141	24521	28493	382	1301	0	1	1
10	1.813962422956E+08	297	119	-84	-3997	24744	28339	834	2832	0	0	1
11	1.813962422278E+08	356	123	1226	-3902	26048	28187	565	1921	0	3	1
12	1.813962422742E+08	172	124	-2827	-3890	21999	28350	628	2134	0	0	1
13	1.813962422777E+08	322	147	475	-3386	25276	27704	423	1452	0	0	1
14	1.813962422007E+08	300	169	-12	-2897	24768	27237	999	3387	0	3	1
15	1.813962421460E+08	479	174	3937	-2792	28709	26961	269	922	0	0	1
16	1.813962422011E+08	247	175	-1168	-2758	23607	27148	1615	5482	0	0	1
17	1.813962421798E+08	121	176	-3943	-2748	20834	27258	428	1453	0	0	1
18	1.813962424293E+08	317	176	369	-2752	25142	27075	610	2074	0	0	1
19	1.813962423774E+08	99	177	-4435	-2709	20341	27240	597	2026	0	0	1
20	1.813962422672E+08	270	185	-682	-2542	24083	26911	399	1362	0	0	1

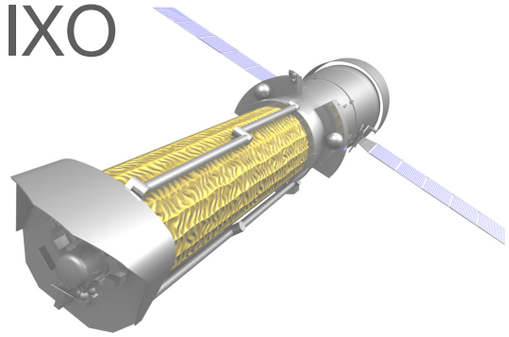
The long road for a successor

XMM-Newton 1999

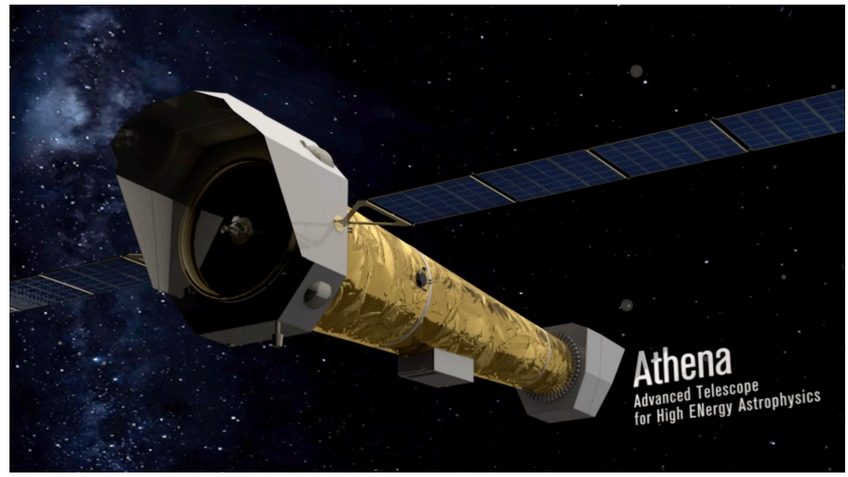
XEUS



IXO

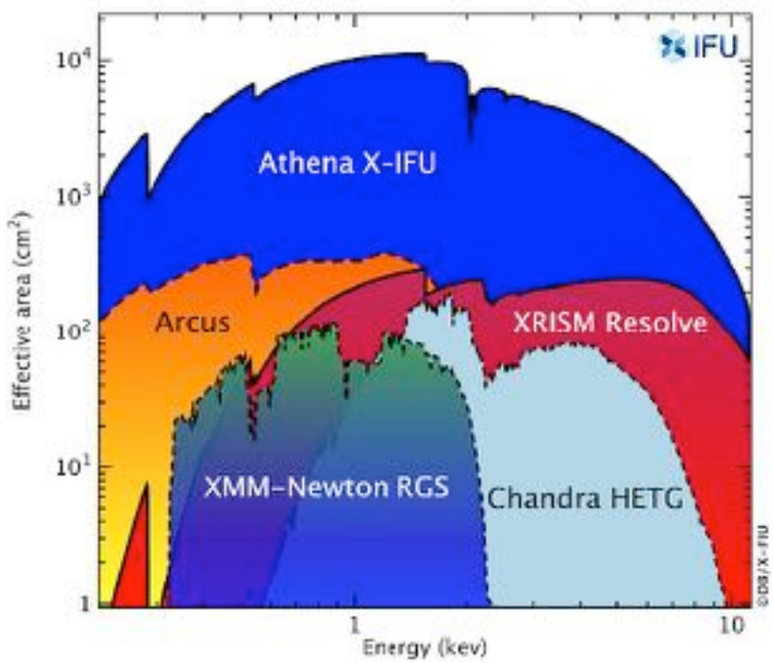


Athena 2034



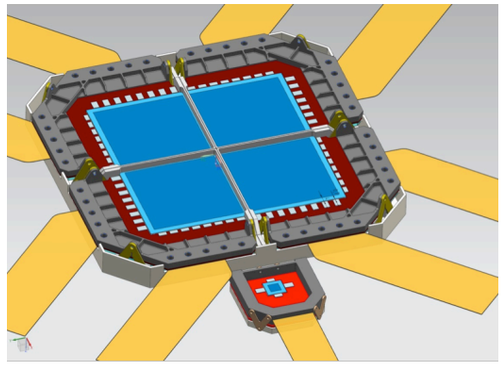
Selected in 2014
Mission adoption review in 2023

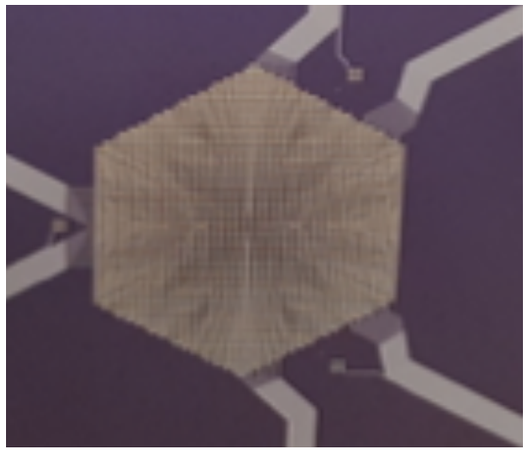
A much larger mirror
Two instruments



Advanced Telescope for High ENergy

- **L-class ESA mission (~1 B€). 10x collecting area and two instruments**
  - **A spectro-imager X-IFU : array of micro-calorimeters (PI D. Barret IRAP). 2.5 eV spectral resolution, 5' FoV.**
  - **A wide field imager WFI : 100 eV, 40' FoV (PI K. Nandra, MPE)**





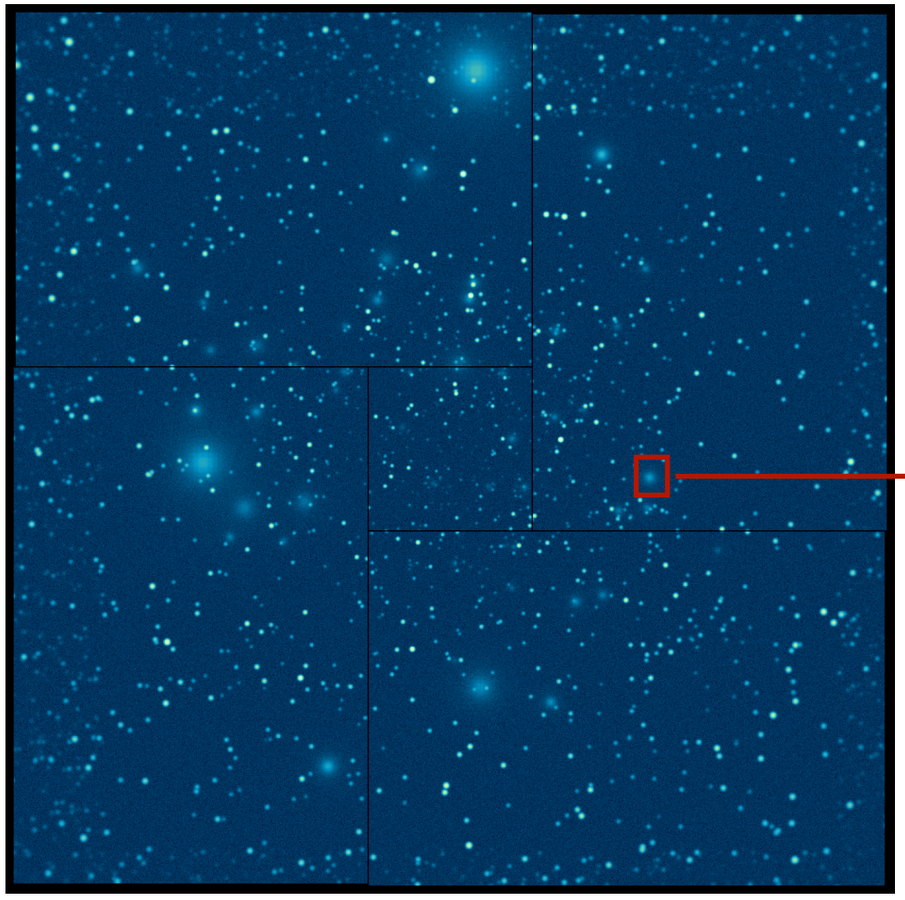
Cooled to 50 mK

https://youtu.be/_WvV6tLDNF8

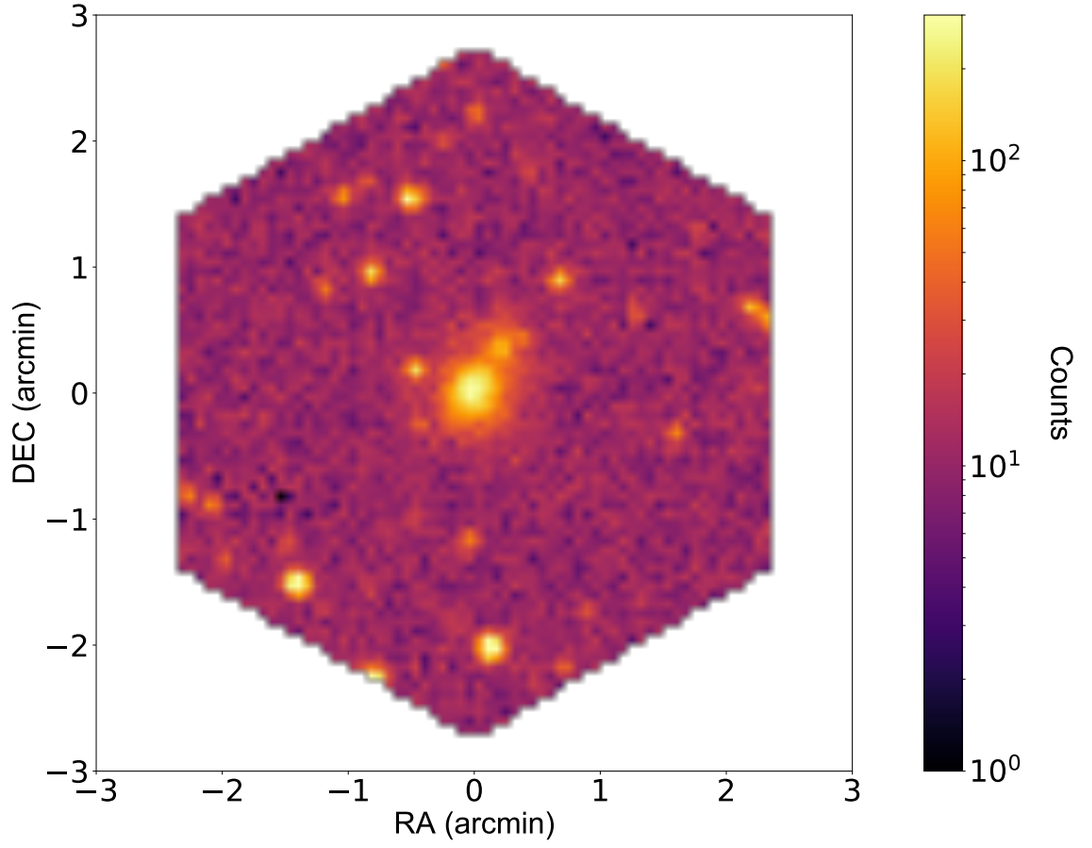
Complementary instruments

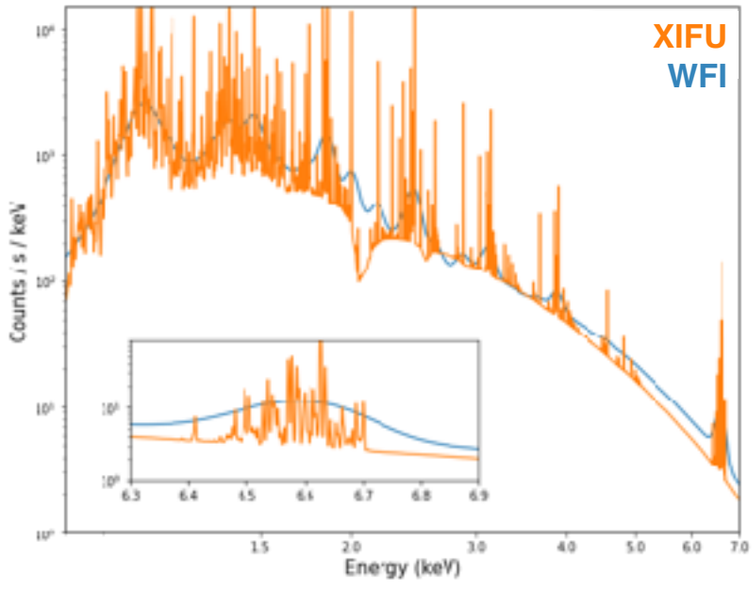
- **Small FoV, detailed spectral study**

Crédits: MPE team & E. Cucchetti (équipe X-IFU)



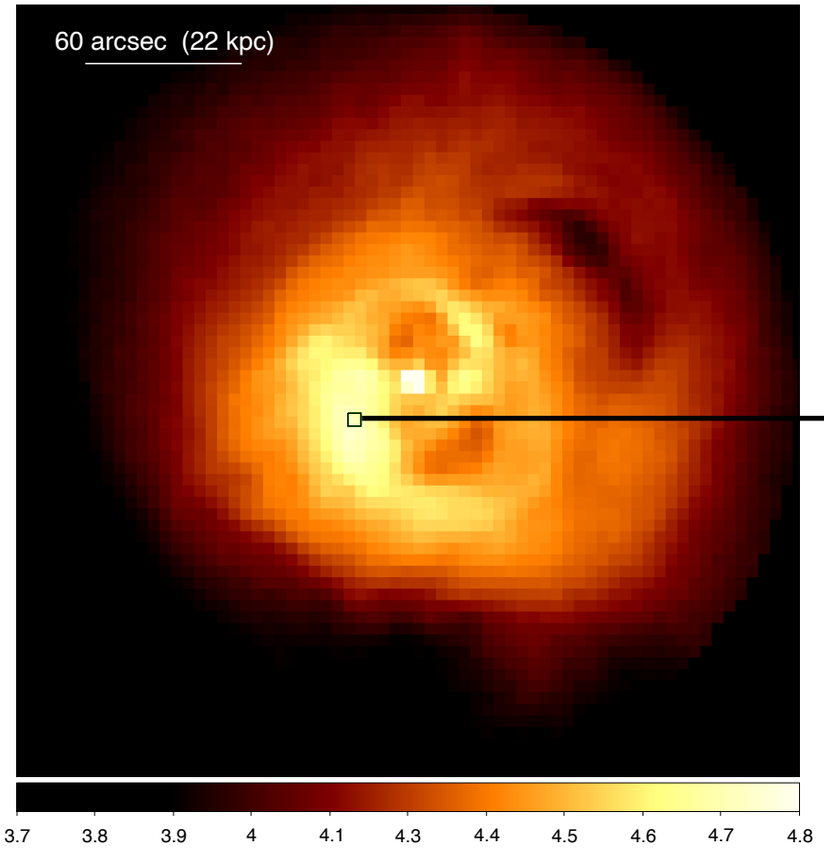
Follow-up of a cluster with X-IFU



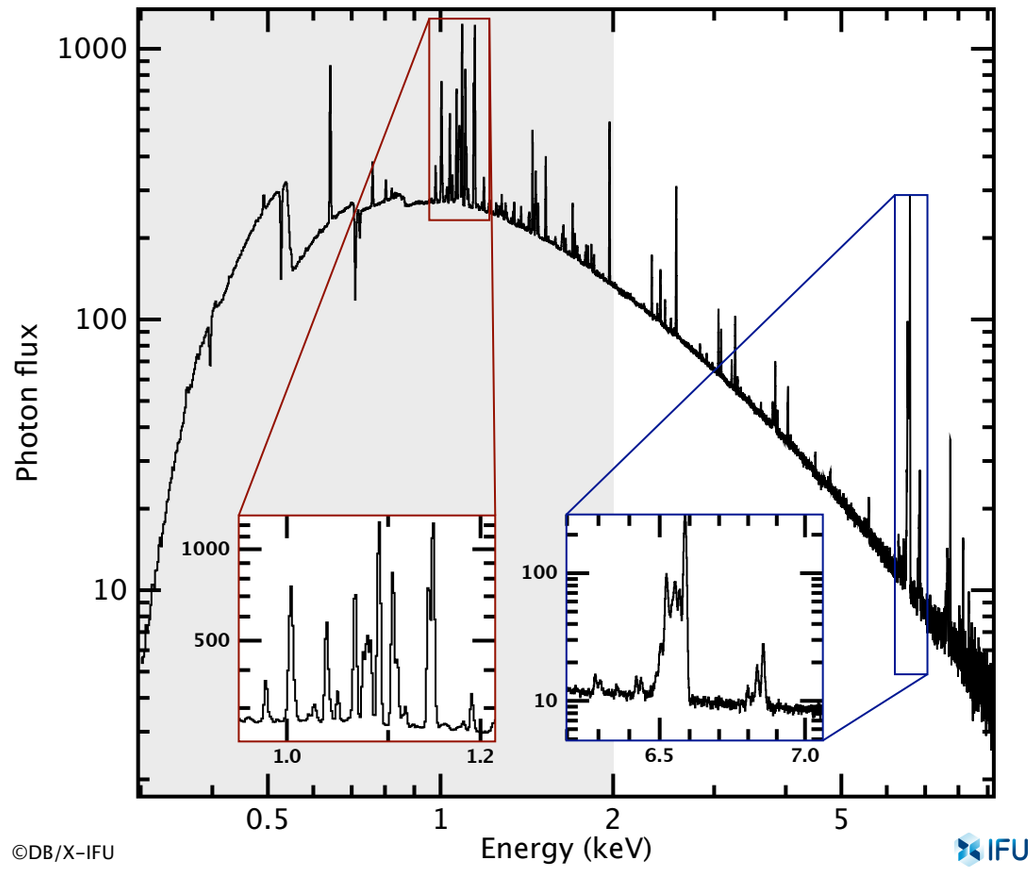


An X-ray Integral Field Unit

Crédits: J. Sanders, C. Pinto & équipe X-IFU

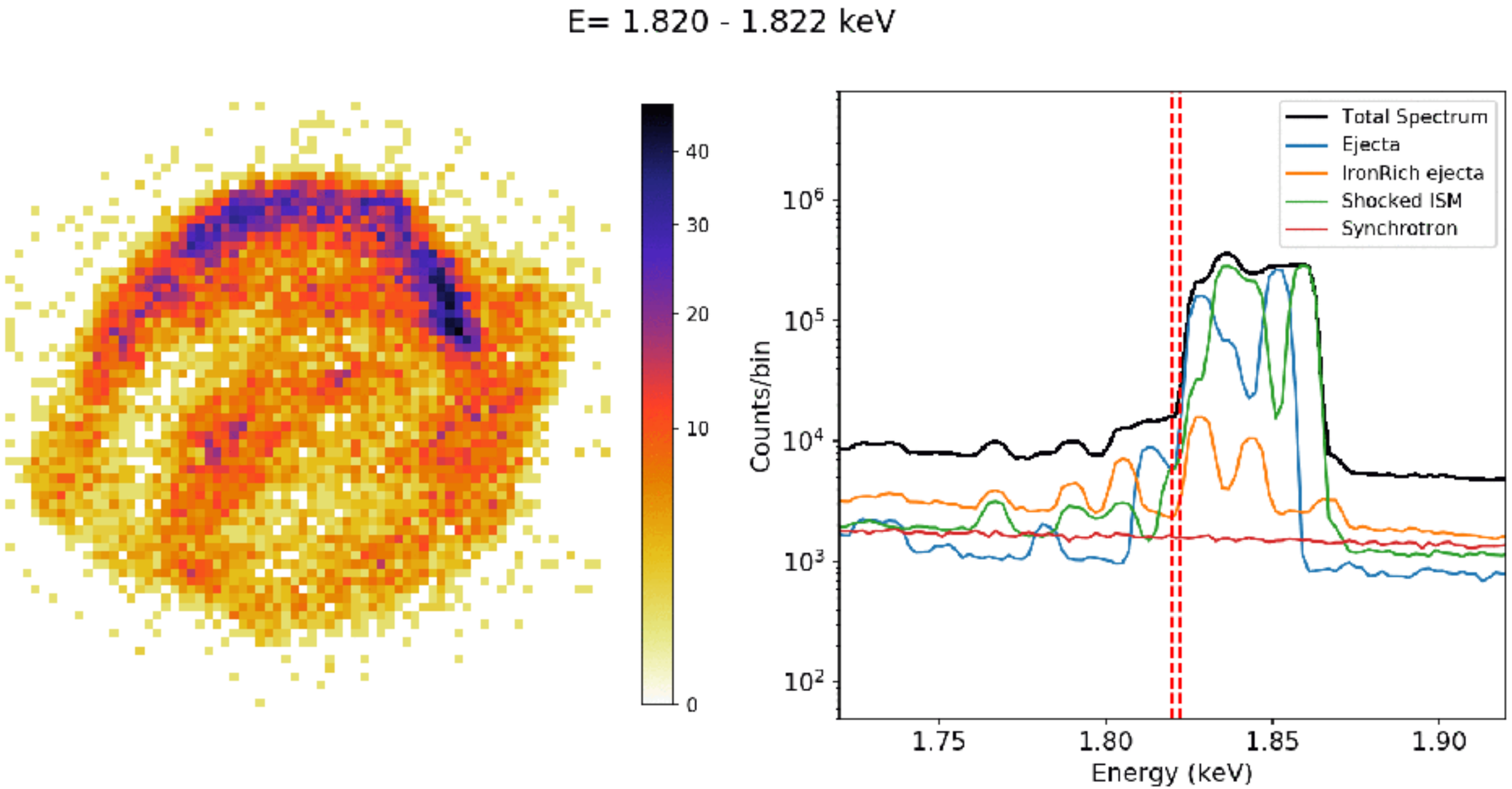


Amas Perseus vu par X-IFU (simulation basée sur Chandra)



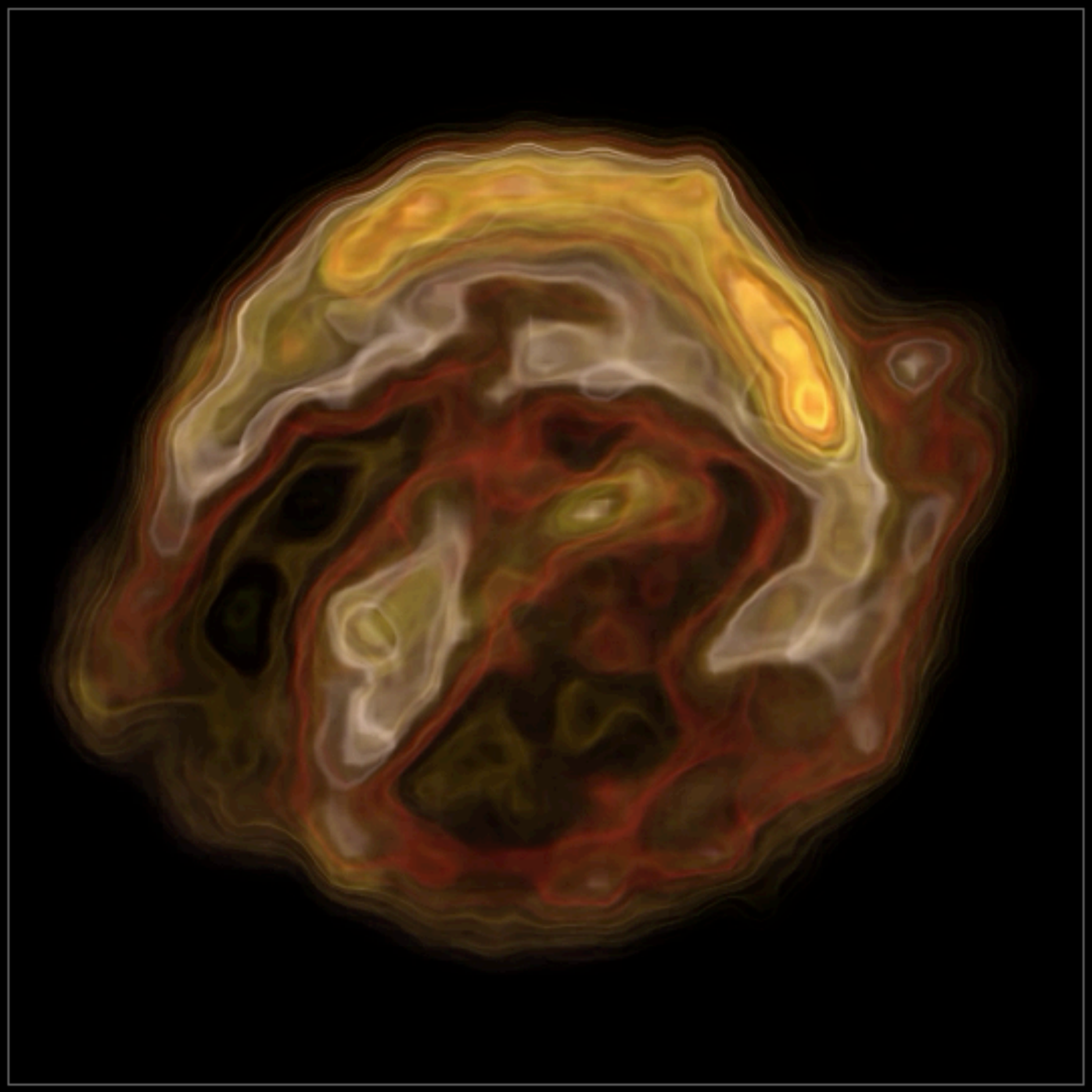
Spectre d'un pixel de l'image de Perseus (basé sur Hitomi)

What X-IFU data will look like

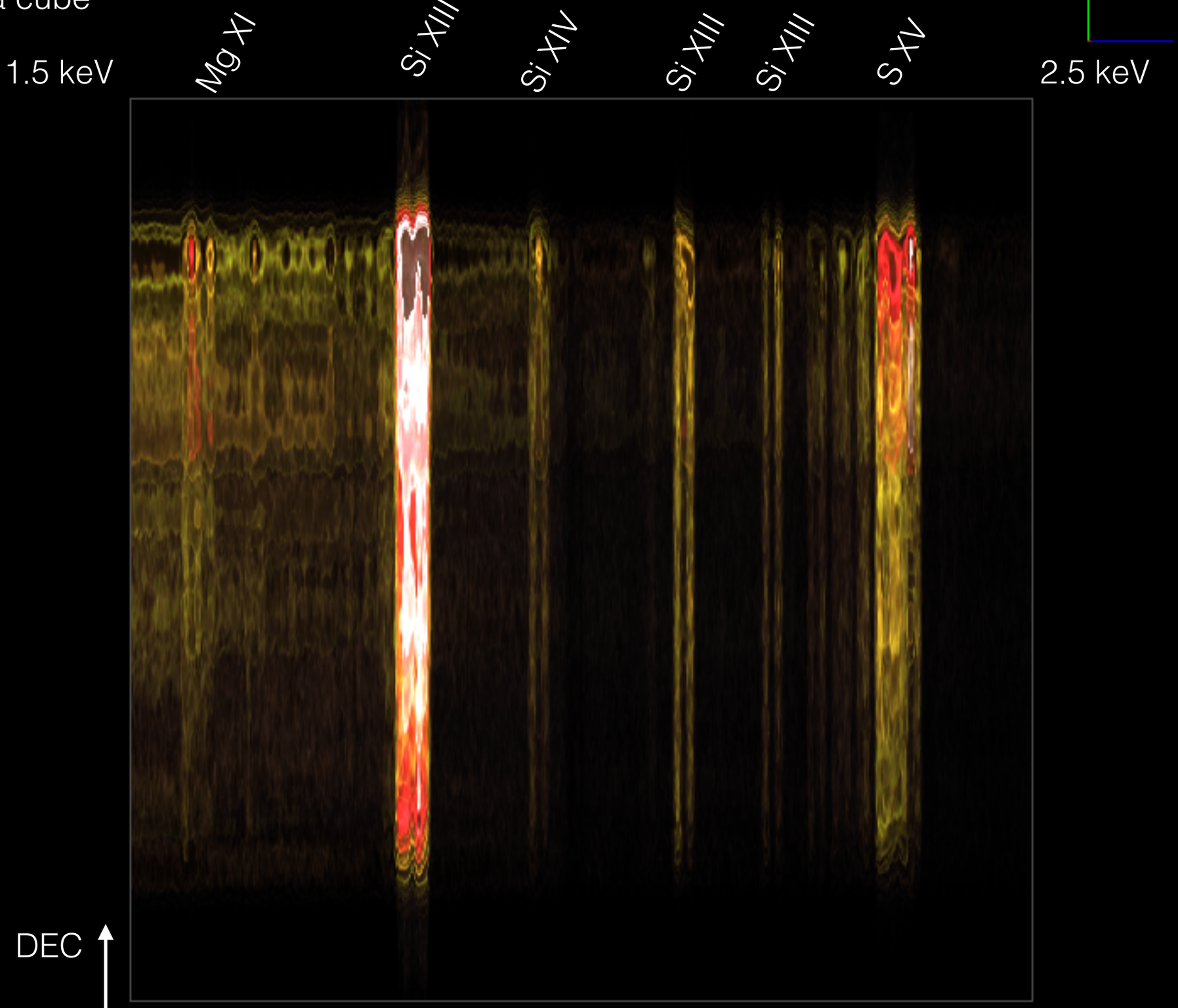


Kepler fits in X-IFU FoV
100 ks

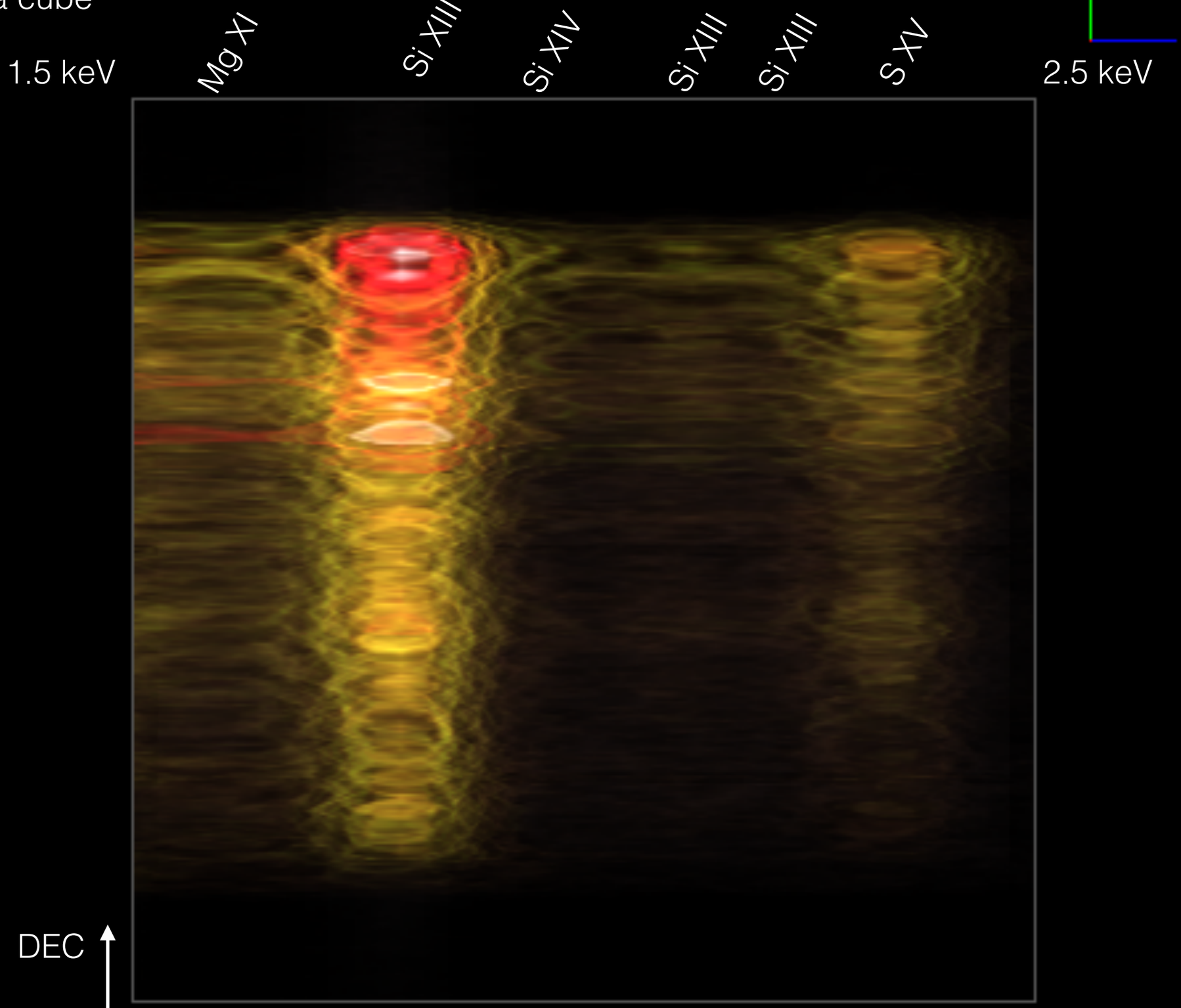
X-IFU Kepler SIXTE simulation
1.5-2.5 keV data cube



X-IFU Kepler SIXTE simulation
1.5-2.5 keV data cube



Chandra observations
1.5-2.5 keV data cube

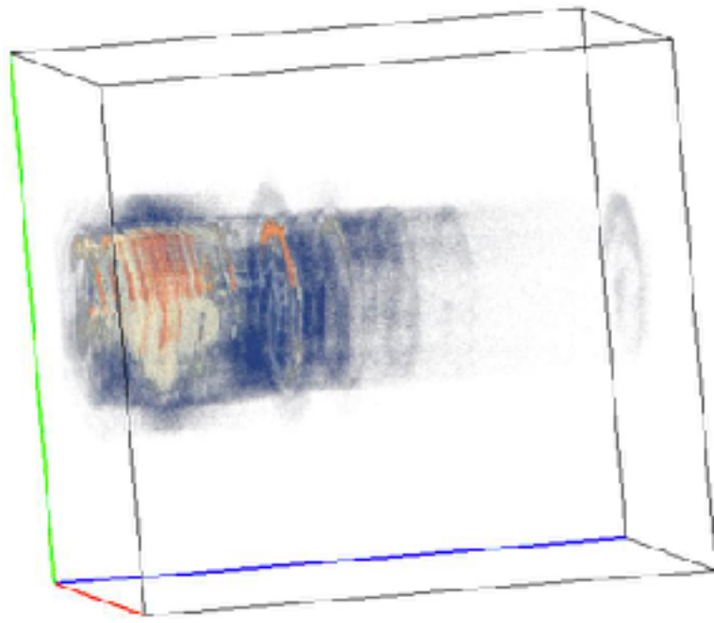


X-ray data are multi-dimensional by nature

- **Current philosophy in XMM pipeline is focused on 2D/1D:**
  - **Input data are 4-dimensional (X,Y,E,T) but**
  - **1) Generate images in energy bands**
  - **2) Search for point sources**
  - **3) Produce spectral and light curve results**

- **Thanks to the increase effective area + high-spectral resolution**
  - **Keep the 4-dimensional data structure to:**
  - **Detect source in (X,Y,E,T)**
  - **Search for transients**
  - **Generate multi-dimensional products (3D, 4D)**

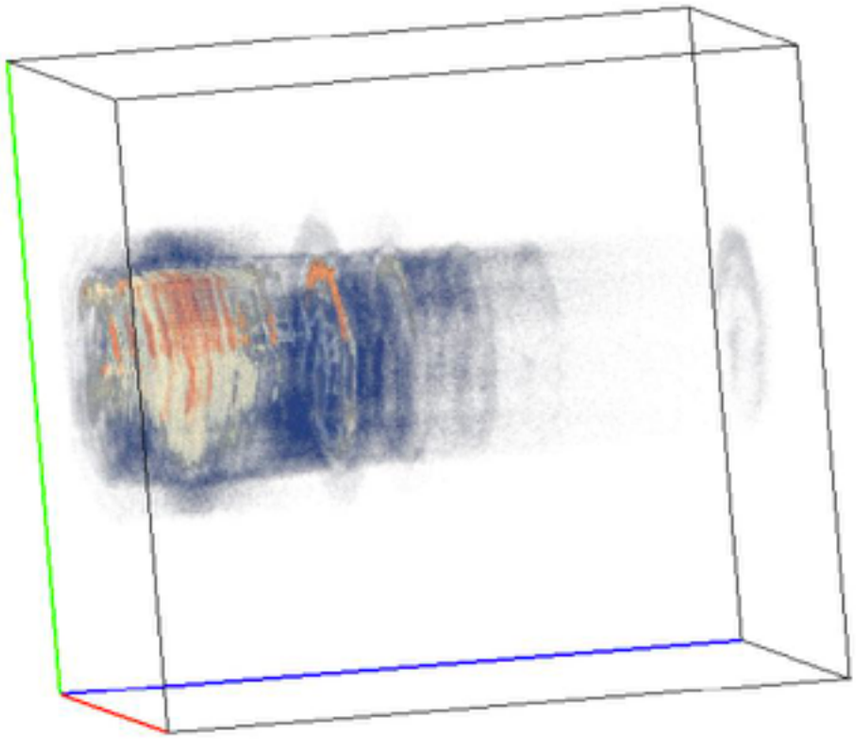
Kepler X-IFU simulation



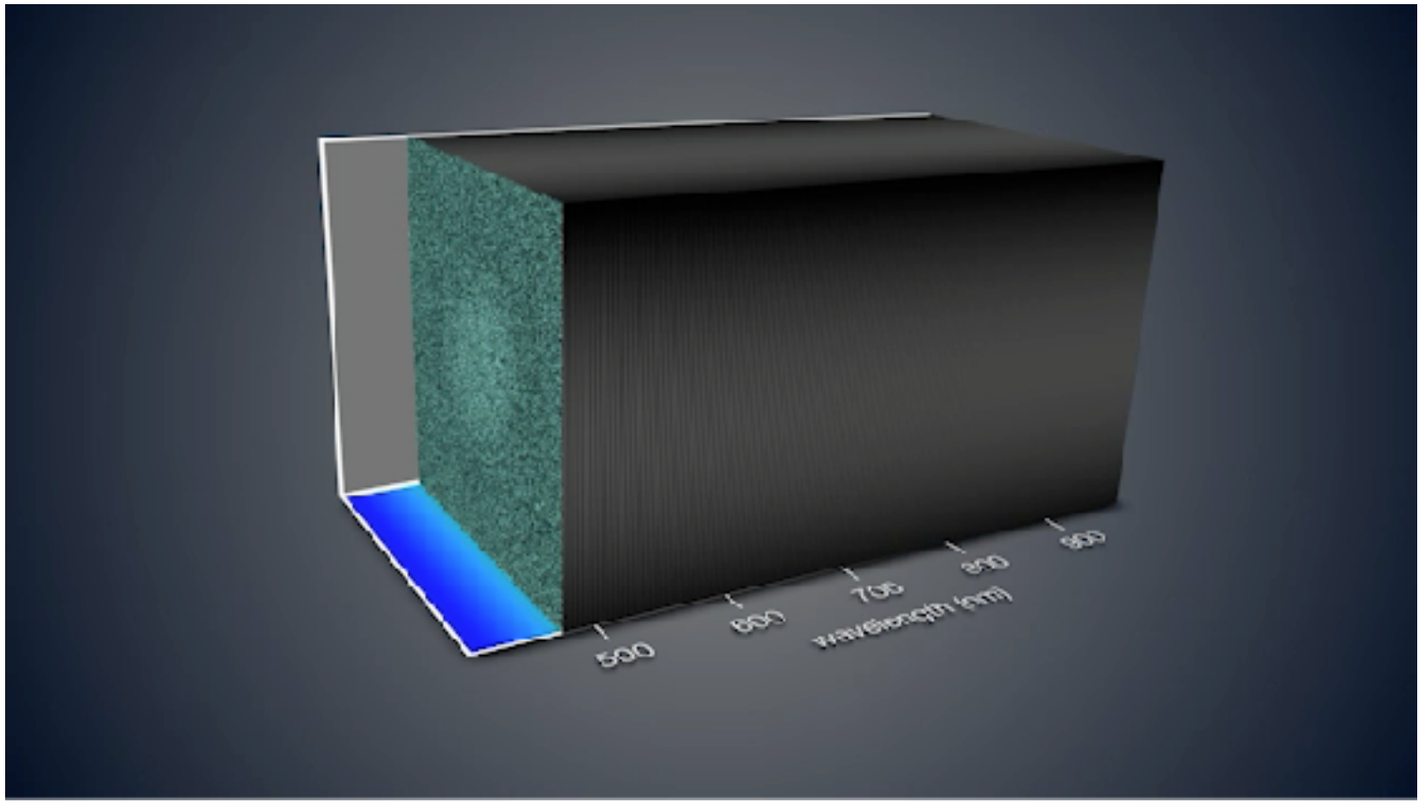
https://skfb.ly/6N8XX

Data visualization

- How to inspect and visualize 3(and 4)-dimensional objects



- Athena X-IFU simulation



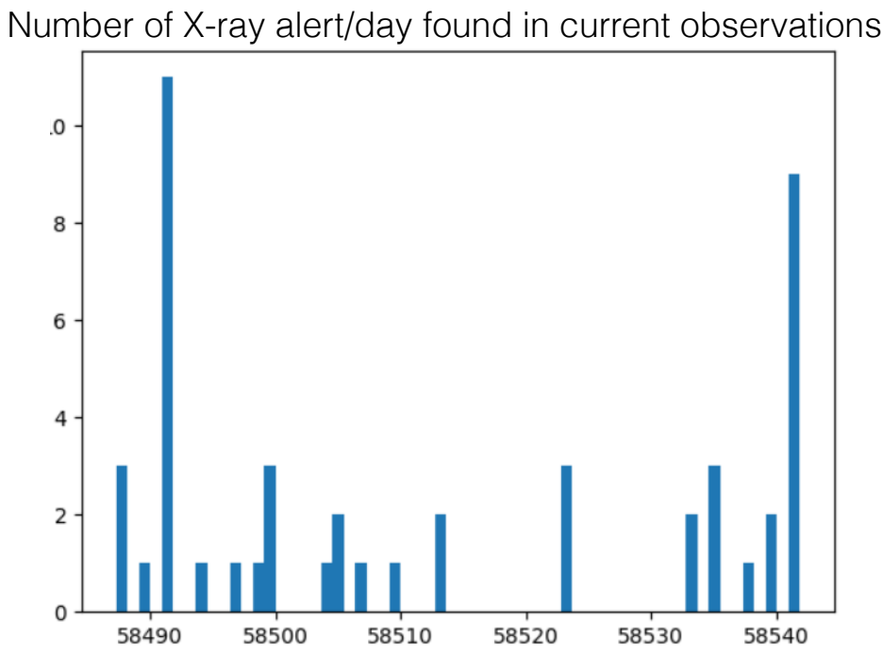
- MUSE data

Data products are similar to SKA, ALMA, MUSE

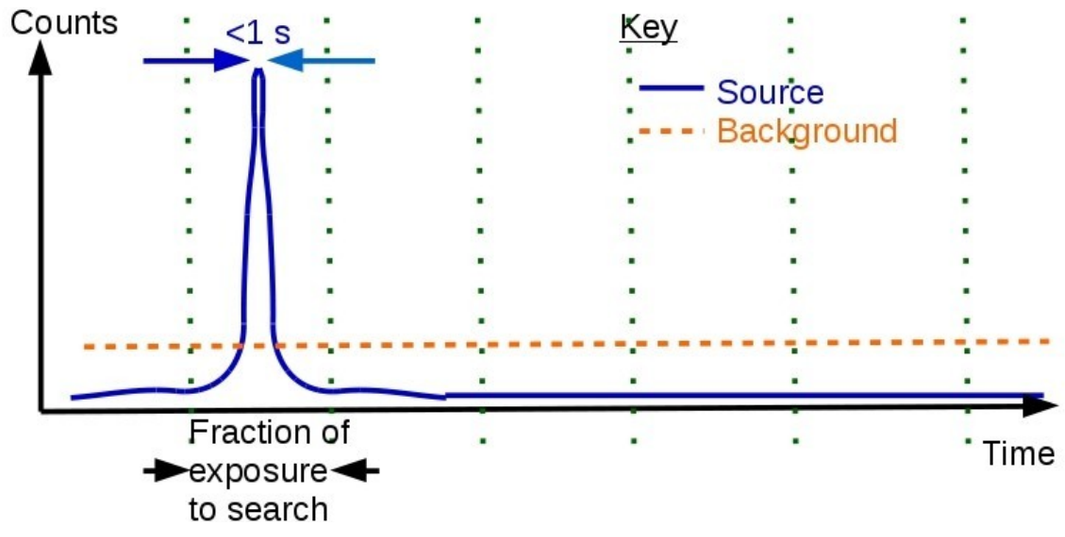
From XMM to Athena : ongoing EU project

Lessons learnt and future work

- **Transient alerts to the community in each XMM observation**
- **Leverages on 30 yrs of X-ray data**
- **Task to be inserted in XMM pipeline**



- **Search for short transients drown in bkg**
- **Looking at individual camera frame**



- **Ongoing work: detection with stacked catalogues, MWL association, src classification, etc**

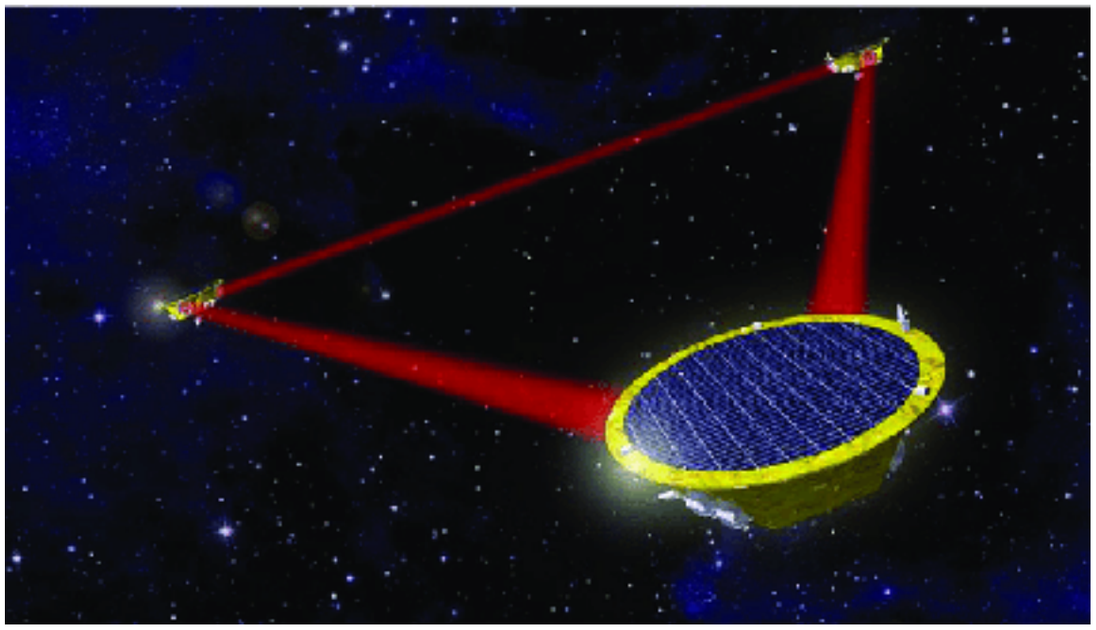
Current & future catalog and VO events

- **Alerts to the community of variable sources in near real time**
- **With it's large FoV and high effective area, a large number of transients events are expected from the WFI instrument.**

- **Catalogs & products accessible via VO (e.g. XCATDB+IRAP cat)**
  - **Point source catalogs (including spectra+light curves)**
  - **Source classification**
  - **Images in different energy bands**
  - **Images at different epochs**
  - **Stacked observations products (ongoing)**
  - **X-ray event list that can be filtered in Energy & time ? (Probably >Gb for one observation)**

Athena - LISA synergies

Both launched in mid-2030



A common science goal : formation & growth of first black holes
Massive BH coalescence at z=1-3

- **Multi-messenger & VO:**
  - **LISA will detect in advance the merger candidates**
  - **Athena can follow-up the before, during & after the merger**
    - **e.g. X-ray emission during the inspiral phase**
  - **For other transients, Athena can repoint in XX mn ??**

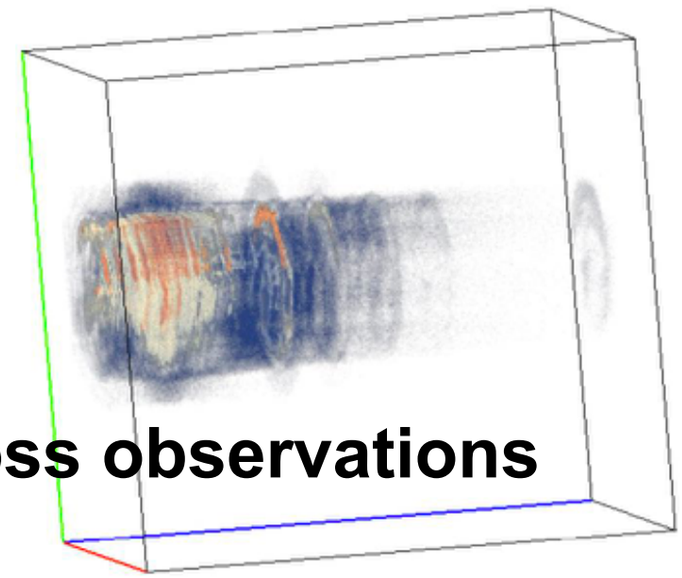
Conclusion

- **Athena is the next generation X-ray observatory with unprecedented sensitivity and spectral resolution (XIFU)**
- **XIFU + WFI will produce 4D products (X,Y,E,T) with high statistics**
  - **Change the way we detect & characterize sources**

- **Data visualization of data cubes (ALMA, SKA, MUSE ?)**

- **X transients machine : Wide Field Imager (WFI) + high effective area**
- **MM: Athena + LISA synergies for massive BH**

- **VO products:**
  - **Data cube with «slicing on demand»**
  - **Time slice or energy slice within an obs or across observations**



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