The Concept for a Wide Field Imaging X-ray Astronomy Mission:
The Chemical Evolution of the Universe

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We can always do better with more $$. The issue is what can we do for a reasonable "price point" that will capture the imagination of the the community at large and will lead to major scientific advances. =>

About 1 degree FOV with TES-like energy resolution with compromises:
[don't push the energy resolution down to 2 eV at 6 keV and] be willing to reduce the FOV and or number of pixels (or modify the size of pixels) fit within cost constraints

The concept and the theme given the previous slide

- Wide field as possible given graze angle constraints = 1 deg ,3000 cm^2
- Energy Range about 0.2-3 keV, high end graze angle, low end ISM
- Angular resolution 10", allows resolution of clusters at minimum size
- And is just possible with optics over FOV
- Energy solution of the TES (~5 eV at 6 keV) class to enable redshifts, temp, and element abundances
- Science Theme: the Chemical evolution of the Universe

The concept and the theme given the previous slides, cont.

- ❖ Deep high galactic latitude surveys, clusters and AGNs, cosmology and first black holes

- ❖ Nearby galaxies, clusters, and the ISM

- ❖ Moderate redshift studies including possibly finding filaments and mergers

- ❖ Planets not so much, but certainly the Moon and element mapping via X-ray is intriguing

- ❖ Won't do WHIM

The next few slides address specific questions posed by the panel

Does a mirror design for 10” over large FOV now exist, with ROSAT style mirrors?

No firm design exists from my group. The study done by HDOS (Goodrich soon to be United Technologies) showed that at least half a degree FOV was possible. There are a combination of techniques that can be used for filling out a 1 degree FOV with 10" angular resolution, such as (if possible) a segmented detector array as per XMM-newton and displacing flat detector from the optimal on axis focus. TRL 3-6 mostly design issue

Does a mirror design for 10” over large FOV now exist, with ROSAT style mirrors part 2?

ROSAT “style” mirrors are too heavy and the wall too thick, however what was really meant in my write up was mirrors tuned to the below about 2.5-3.0 keV range so as to accommodate a 3 m focal length with significant (1,000 cm^2 -3,000 cm^{-2} per module)

Are 500x500 readouts for the calorimeter feasible?

The answer is a qualified "yes" with TESs, depending on time and money more than anything. For one example see the recent paper by Kent Irwin et al

http://arxiv.org/abs/1110.1608

Are 500x500 readouts for the calorimeter feasible? part 2
More from Kent Irwin

(1) First, four "buttable" arrays is no problem at all, even with conventional multiplexing techniques, since you can take the leads out of the two exposed sides. This is, for example, what is done in SCUBA-2, which has 1,280 pixels on 4 different chips, which are "butted" together to make a 5,000 pixel array (actually, two 5,000-pixel arrays at different wavelengths.)

Are 500x500 readouts for the calorimeter feasible? Part 3
More from Kent Irwin

(2) The second comment is that fab is now progressing to arrays on 150 mm wafers, so you can cover an awful lot of area on one array. So it isn't clear to me when you would need to "butt" more than four wafers together, unless you are making something incredibly big.

(3) Lastly, with the new microwave readout techniques, you can definitely conceive of "daisy chaining" the mux from wafer to wafer on microwave lines, with simple bump bonds. Then you could definitely put more than four wafers together.

Are 500x500 readouts for the calorimeter feasible? From Dan McCammon

If you're talking further out, magnetic penetration depth thermometers look promising, but little work so far.

Overall TRL level of device, 1-3, depending on assumptions

Cost of Mission ??? Based on XMM $1-$2 Billion depending

Following Slides address science

The first supermassive black holes, obscured growth of supermassive black holes (SMBHs), Cosmic feedback from supermassive black holes.

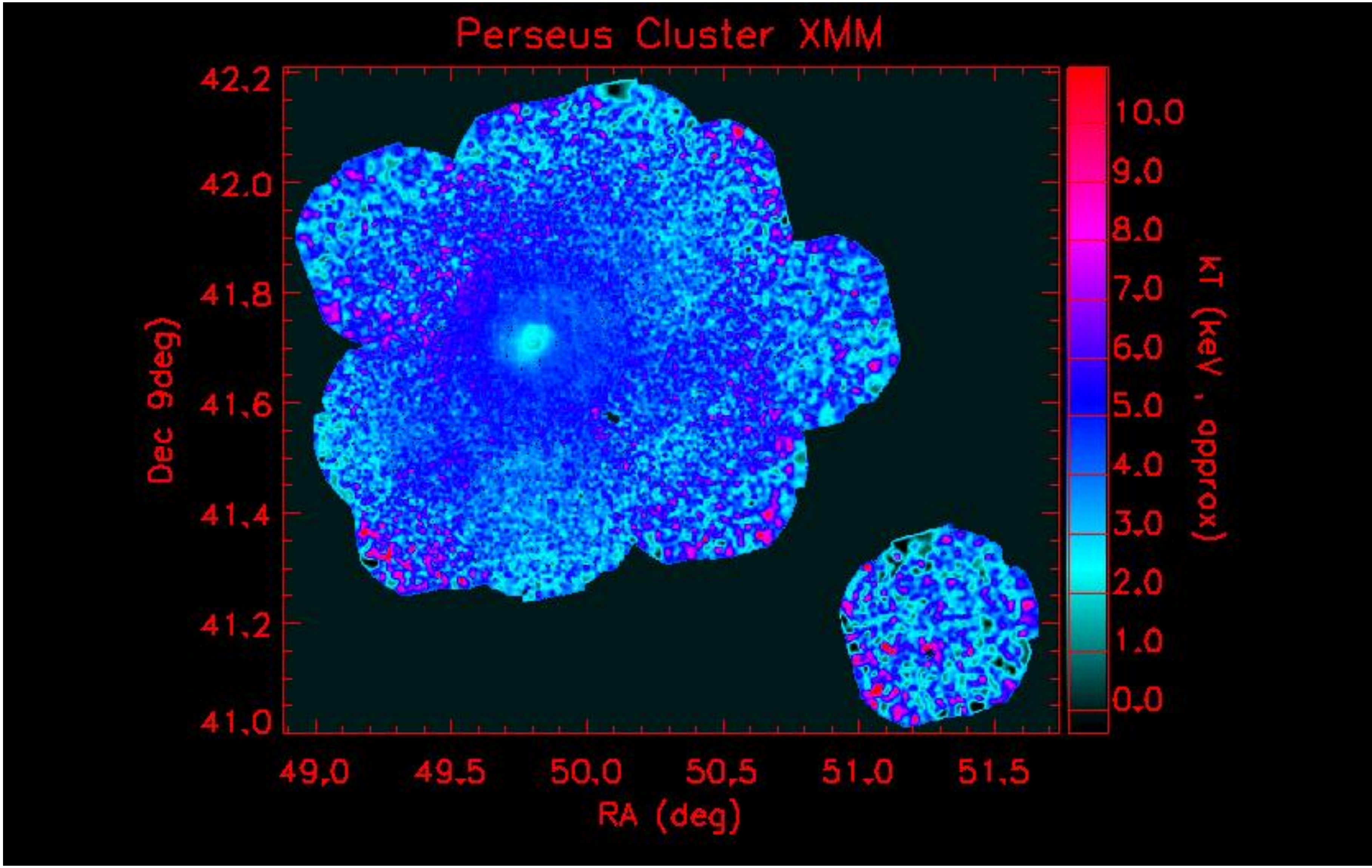
Redshifted iron line, 6.7 keV/(1+10) = 0.6 keV ✓

Large FOV deep surveys (i.e. 60 sq degrees) can find rare events and even find tidal flare events of beamed first light X-ray after glows from SMBH formation.   Plus find tidal flares in low (0.1-0.3) redshift systems to connect with theories of SMBH formation

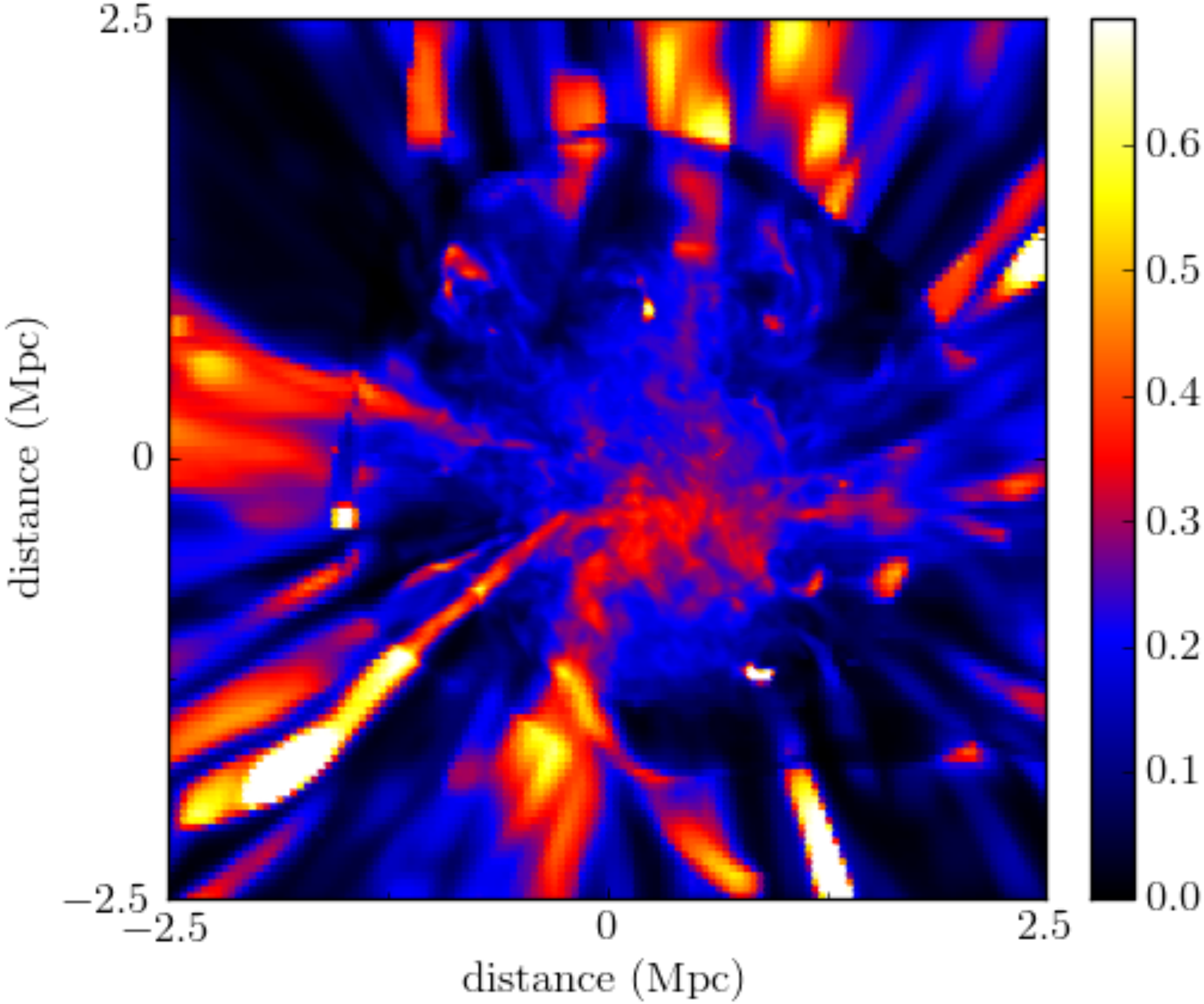
Large scale structure and the creation of chemical elements: The hot diffuse components of the Universe, Missing baryons and the Warm-Hot Intergalactic Medium, Cluster physics, evolution and cosmology, Chemical evolution through cosmic time.

Spectra and images follow, This the bread ‘n butter of the experiment✓ [except the missing baryons]

With TES-type resolution: imagine what we'll find in object such as this

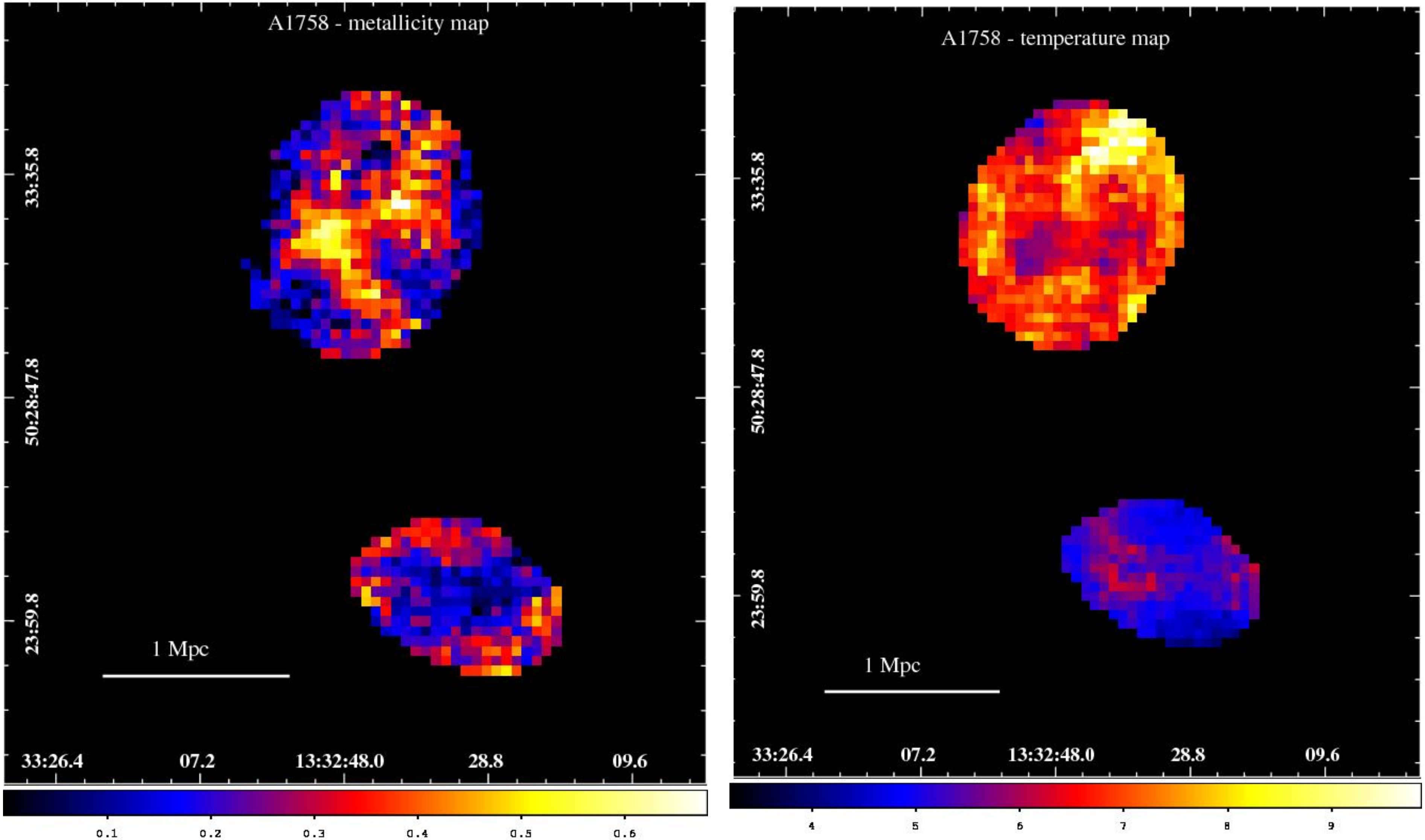


Simulation of what Perseus look like in metals



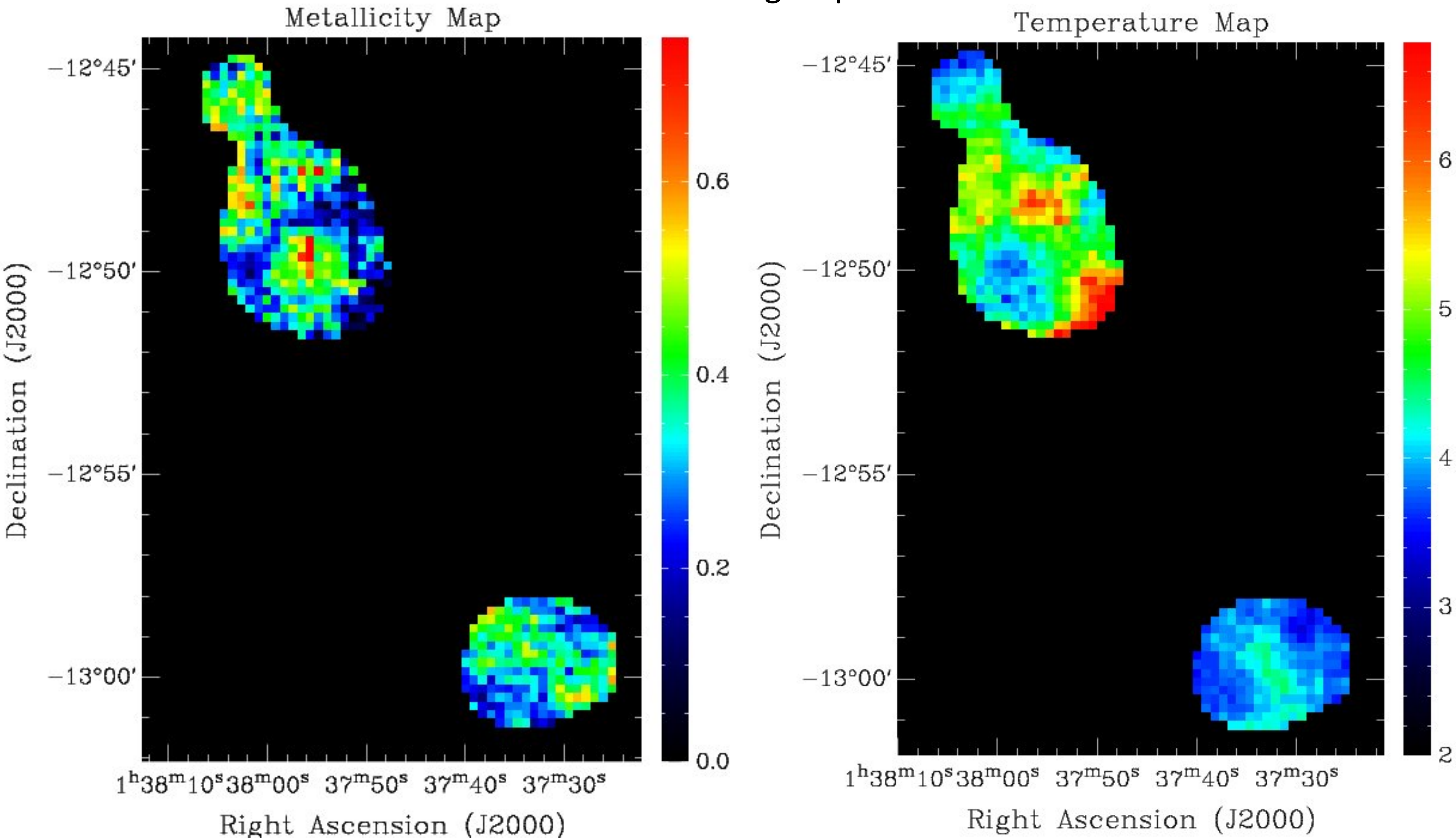
Provided by Marcus Haider via Craig Sarazin

A more distant cluster



From Florence Durret

More distant cluster group



Abell 222-223

From Florence Durret

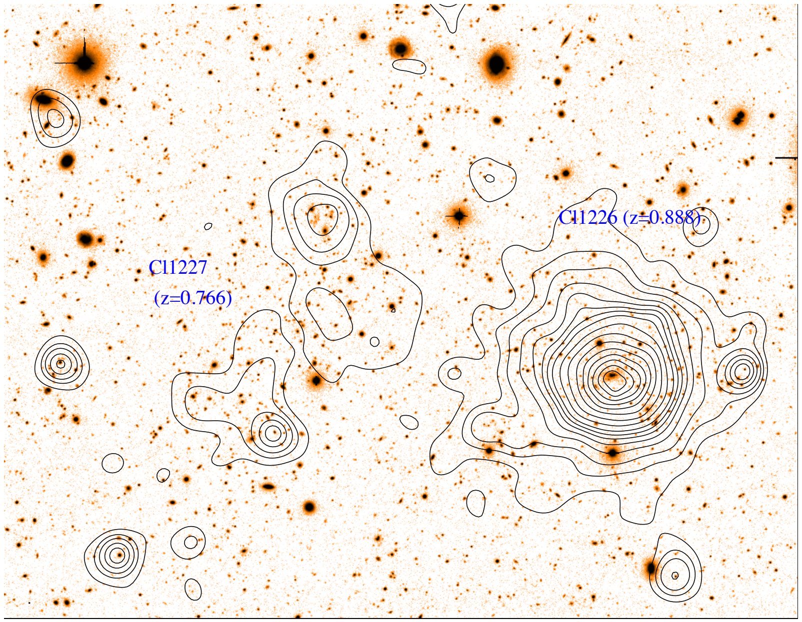
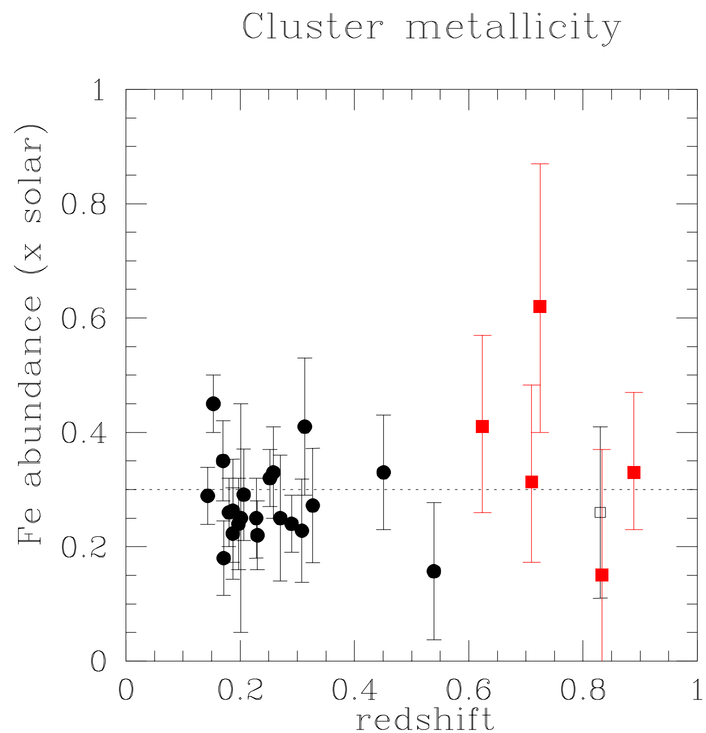


Fig. 1.6. *XMM* contours of ClJ1227.3+3333 (z=0.766), which is adjacent to ClJ1226.9+3332 on the sky, although at a different redshift. The contours are linearly spaced and the underlying image is in the R band, from Subaru.

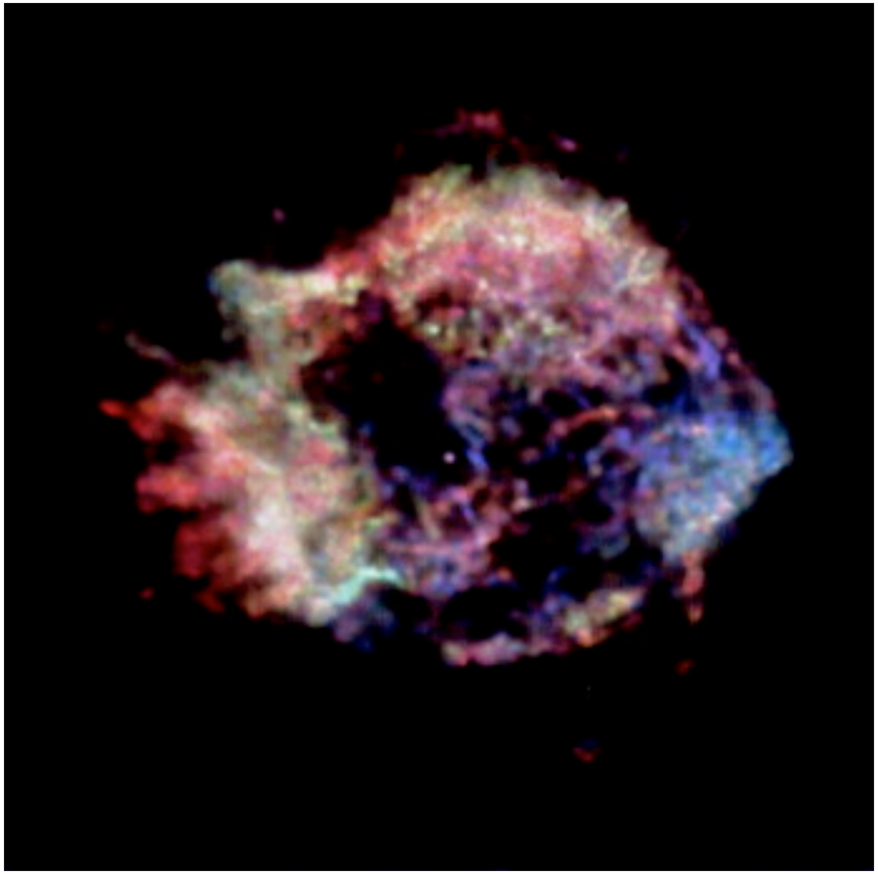


Tracking cluster metals versus redshift

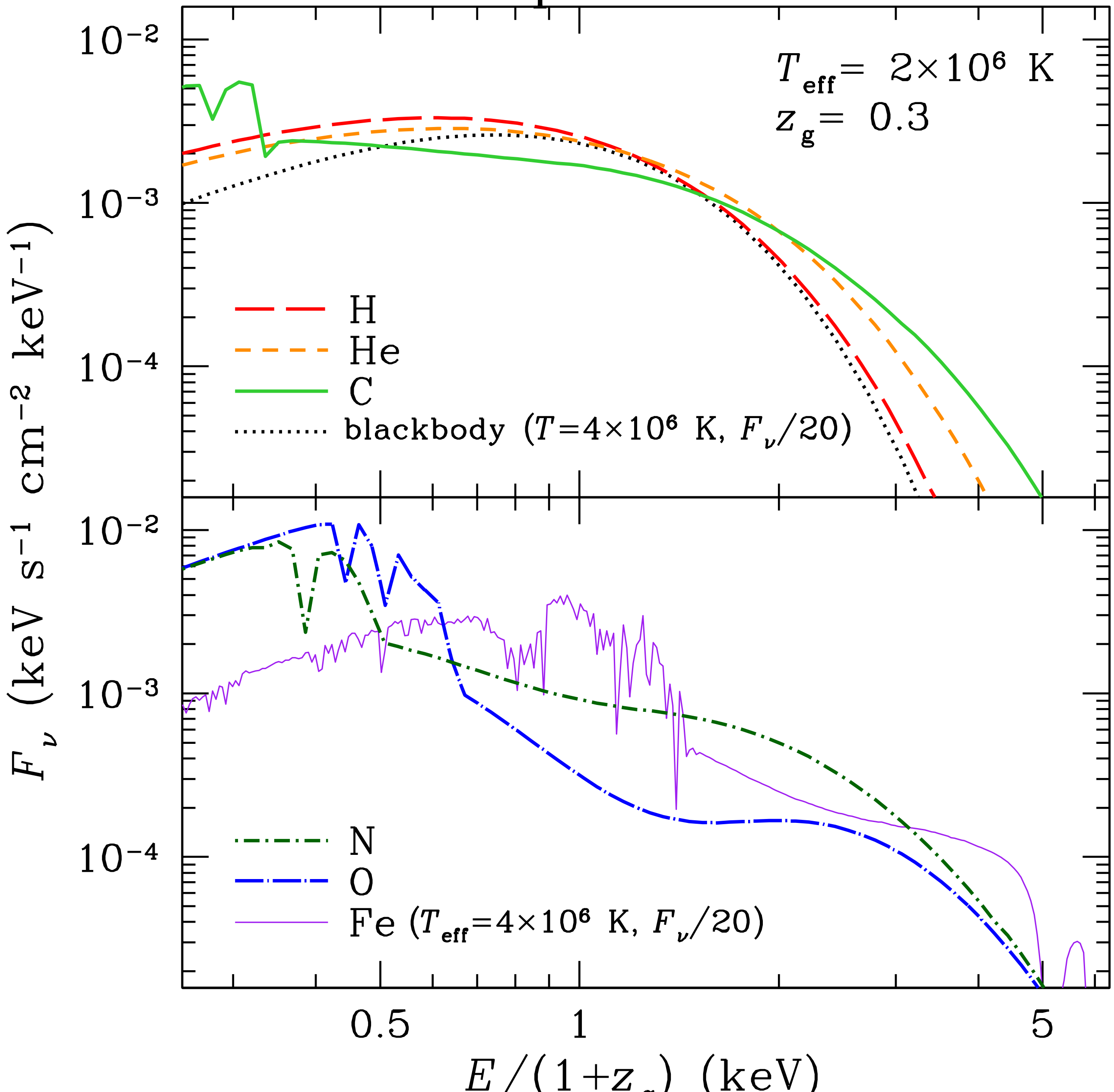
Approved for public release, distribution unlimited

Matter under extreme conditions: Strong gravity and accretion physics, Neutron star equation of state, Probing Quantum Chromodynamics through the neutron star equation of state.

Cas A; getting high resolution spectrum of central source, with redshift of lines is a possibility

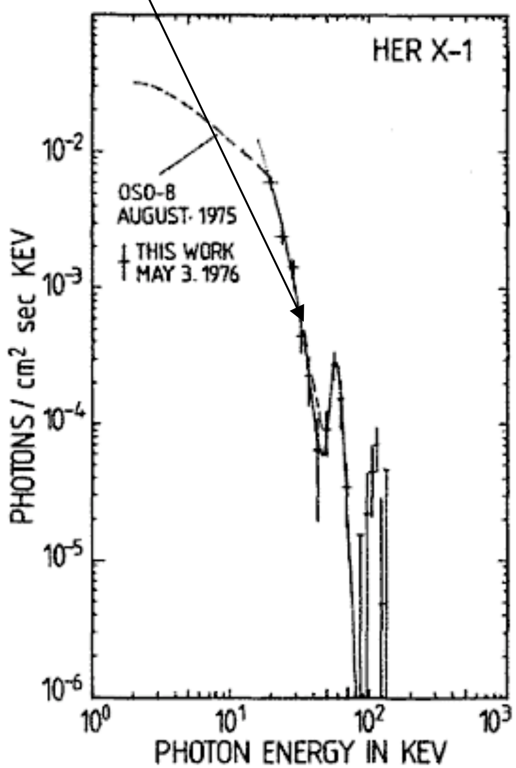


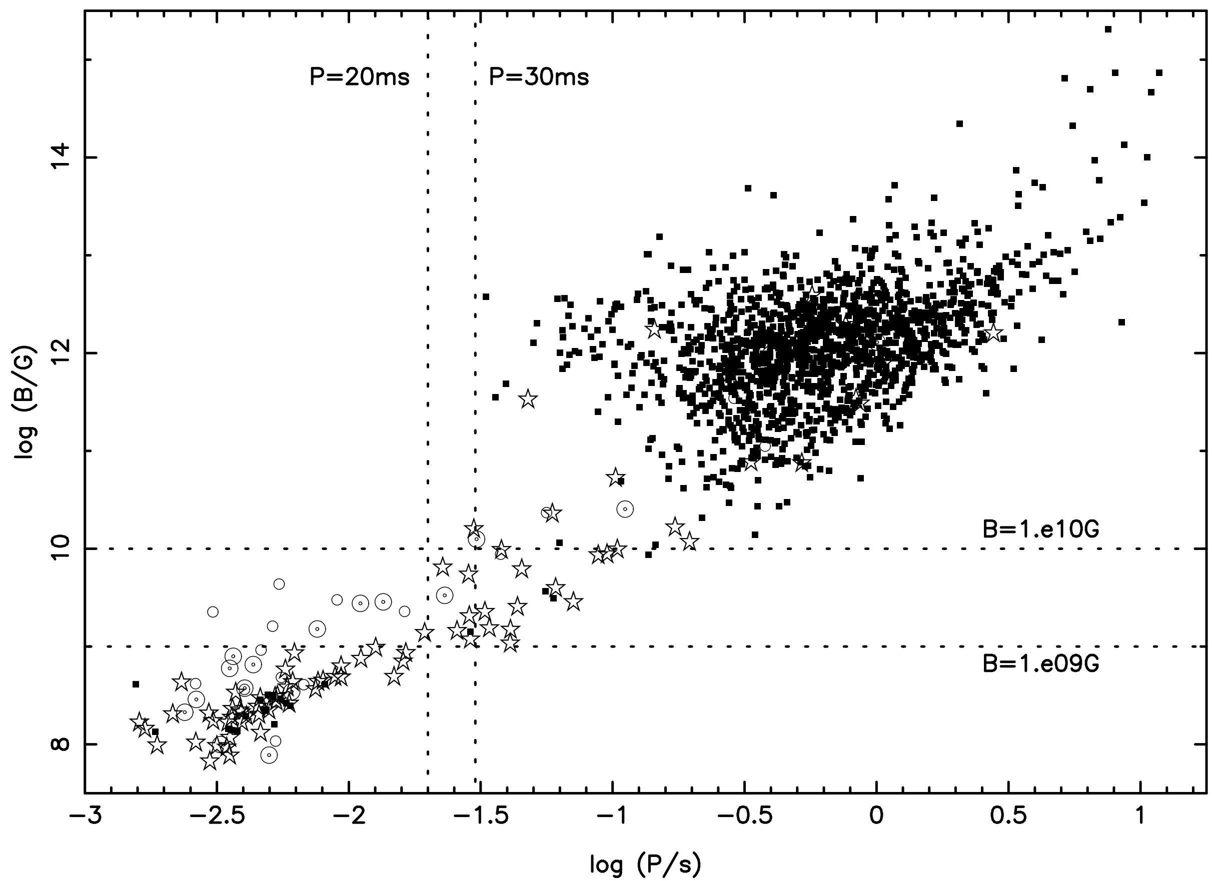
Cas Model Spectra



The feature caused by a 10^{12} Gauss field

10^{10} G field perfect for 0.3 keV observations

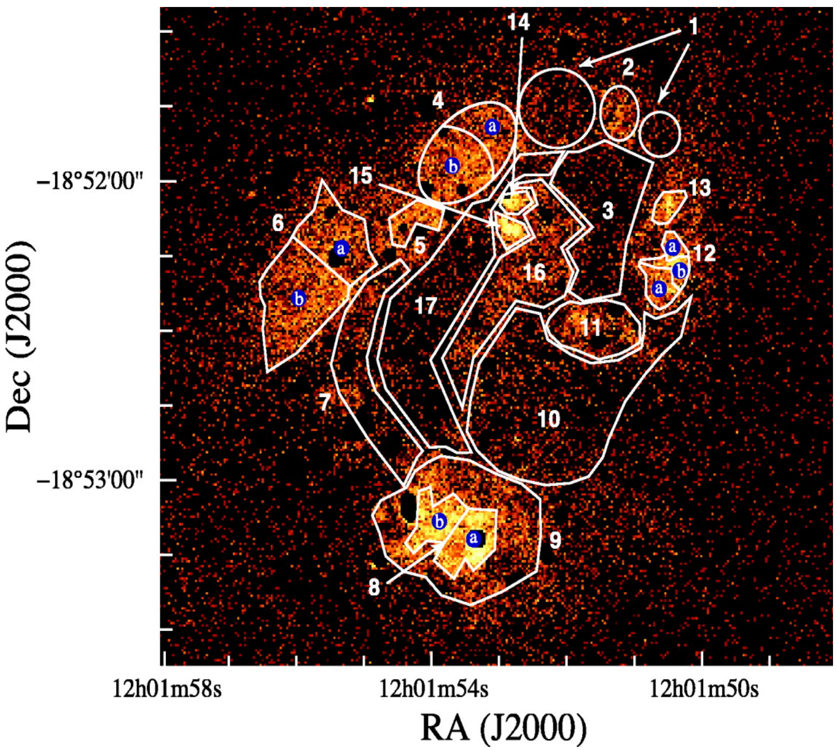


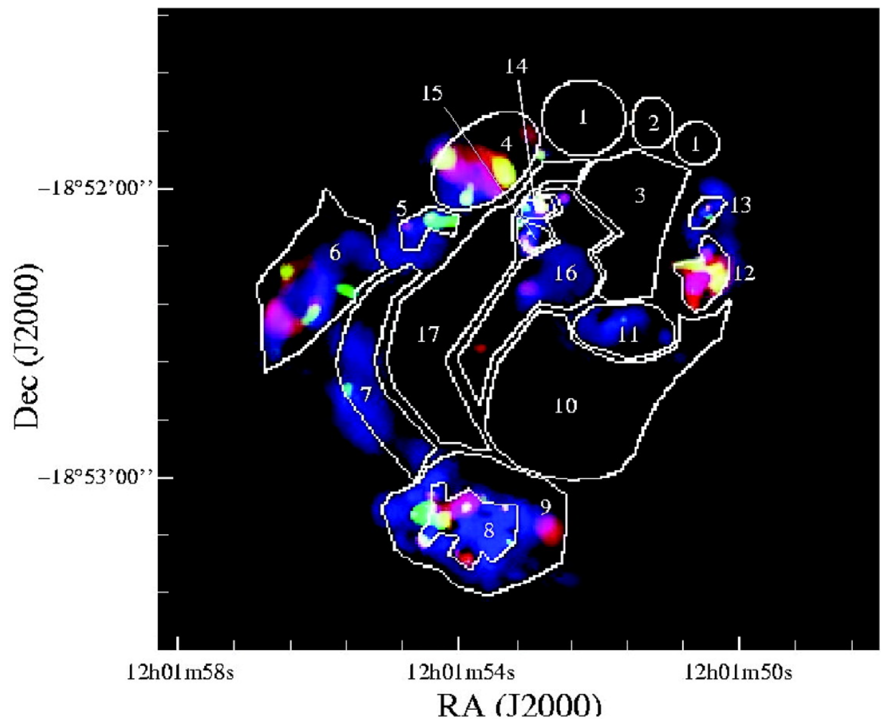


Life cycles of matter and energy in the Universe: Supernova remnants: formation of the elements, shock heating and particle acceleration, Characterizing the Inter-stellar Medium in the Galaxy, The Galactic Center and its surroundings, Stars and planets.
See next set of slides

Diffuse X-rays in the Antennae Galaxies

Interacting Galaxies with intense star formation





Baldi et al. 2006

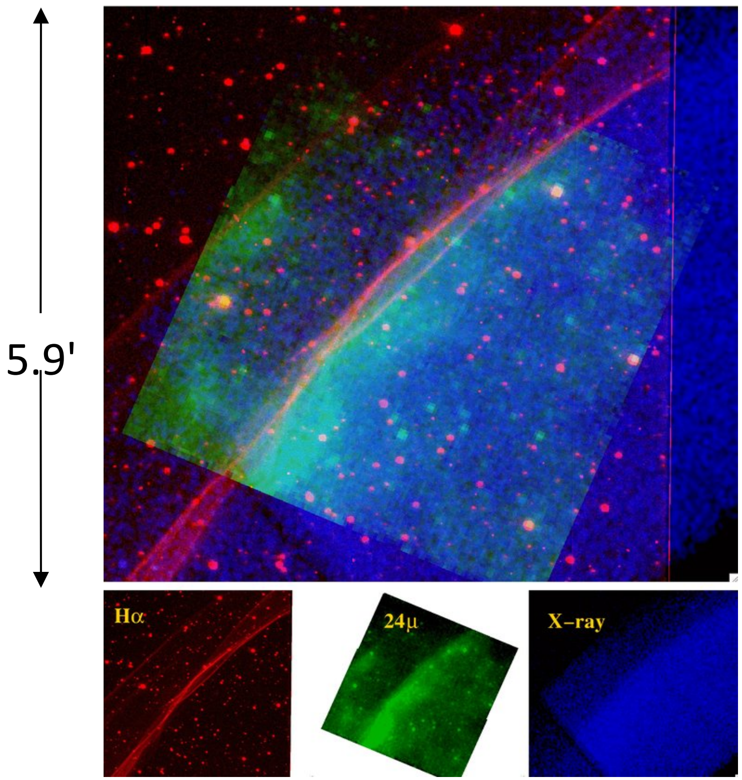
Red = Fe
Green = Mg
Blue = Si

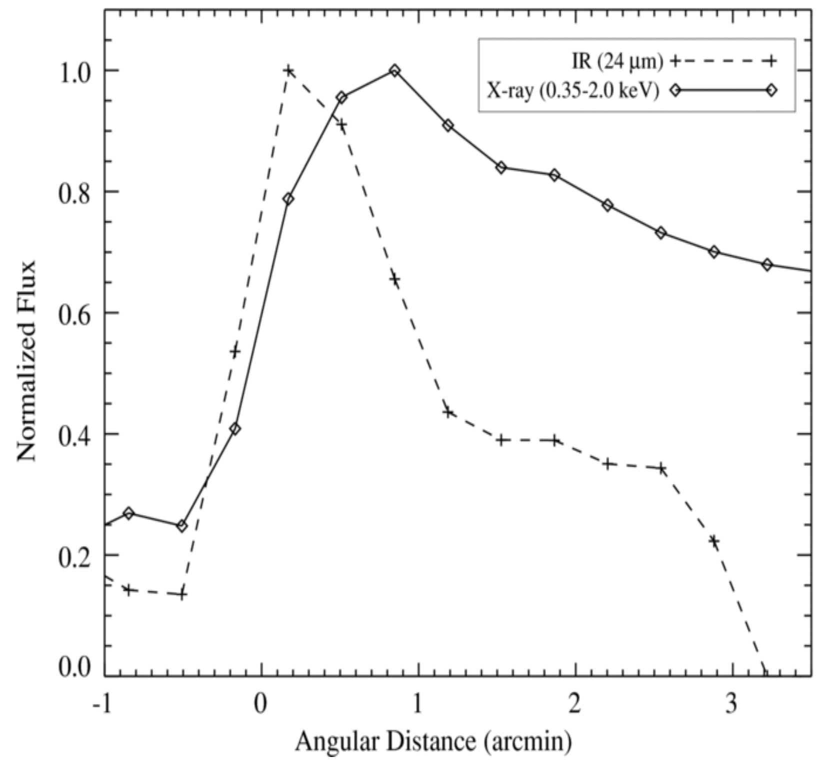
From John Raymond

Dust Destruction in SNR Shocks

Cygnus Loop: Spitzer + Chandra

Dust destroyed and C, Si, Fe added to gas over 1' scale

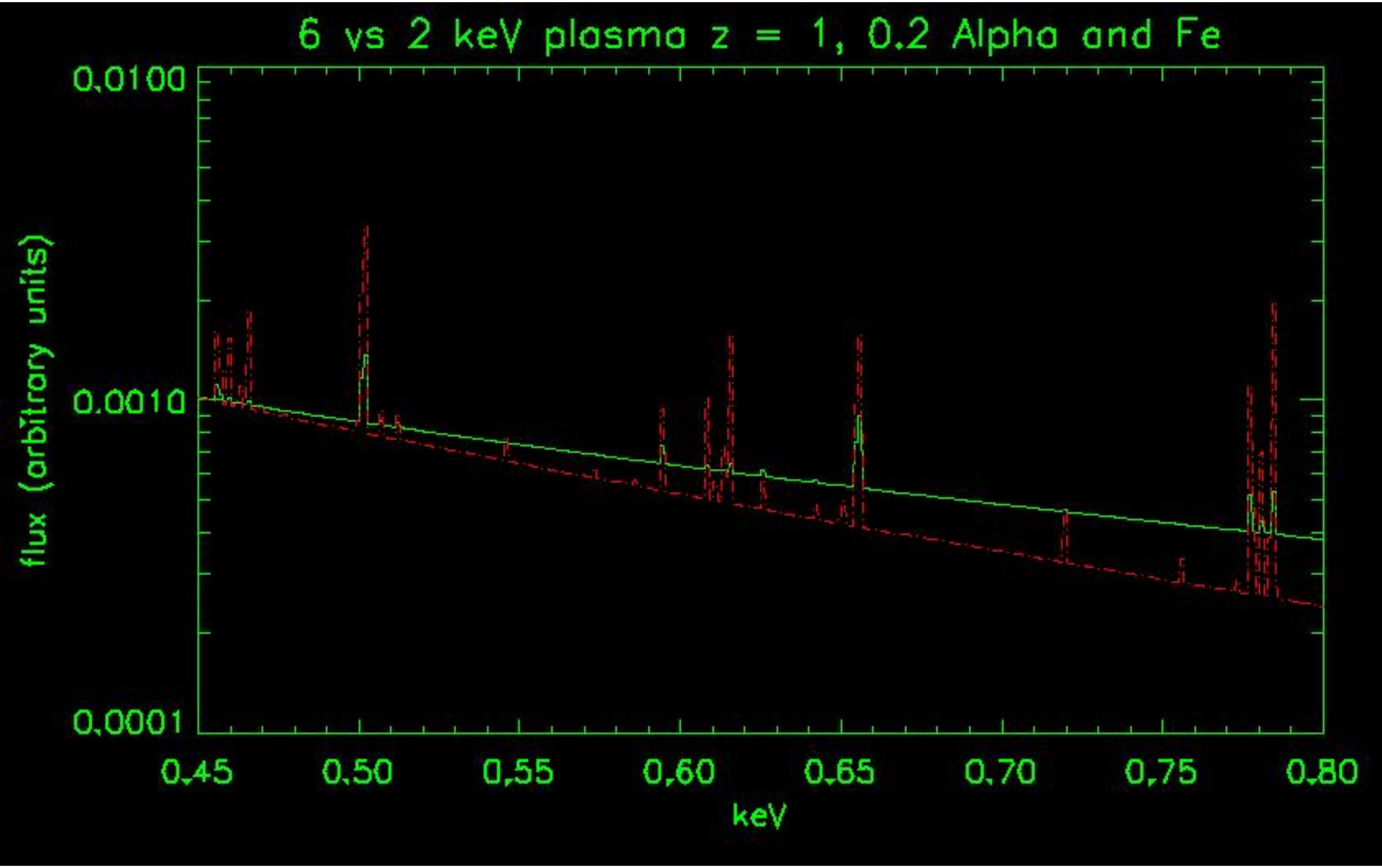


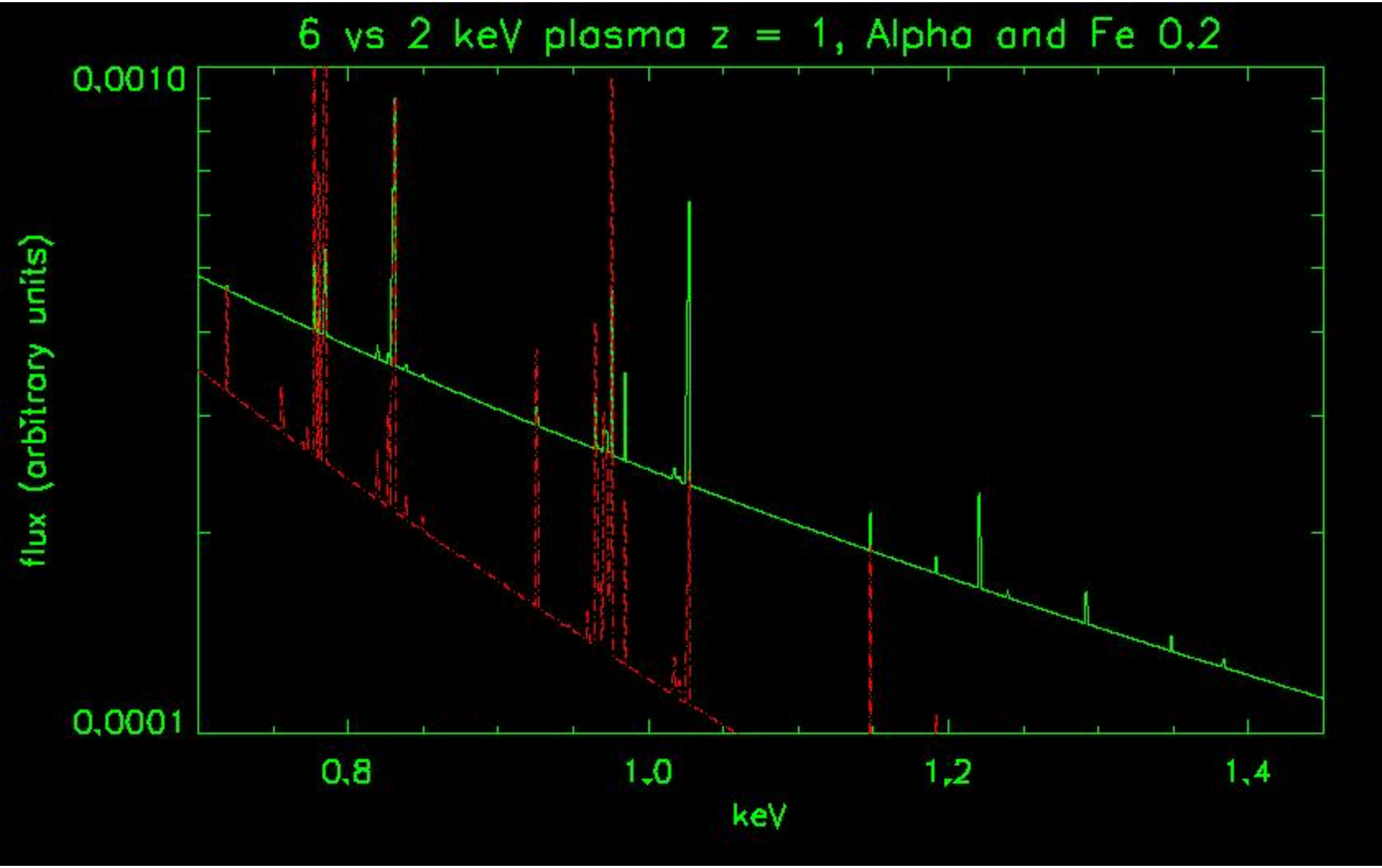


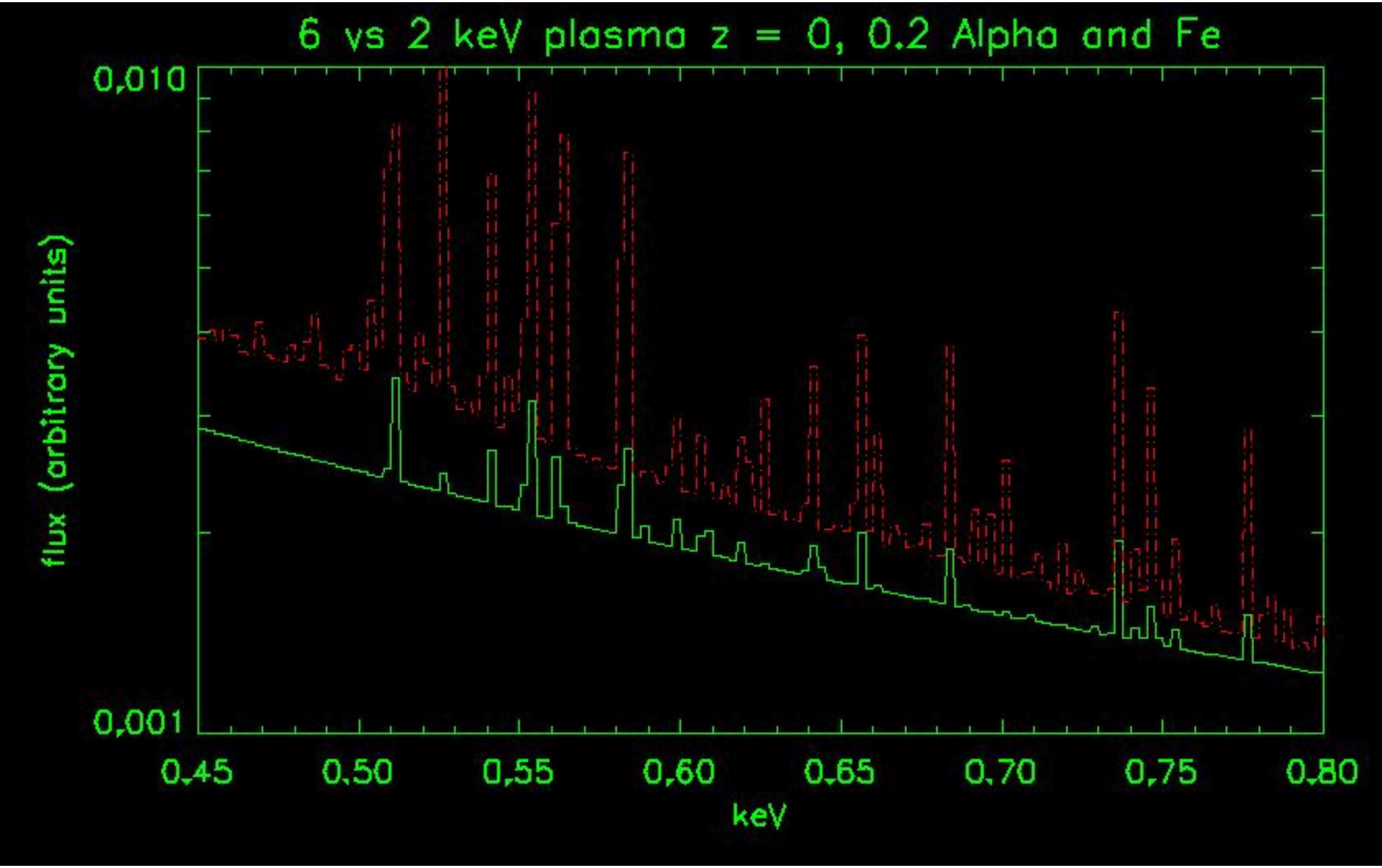
Sankrit et al. 2010

From John Raymond

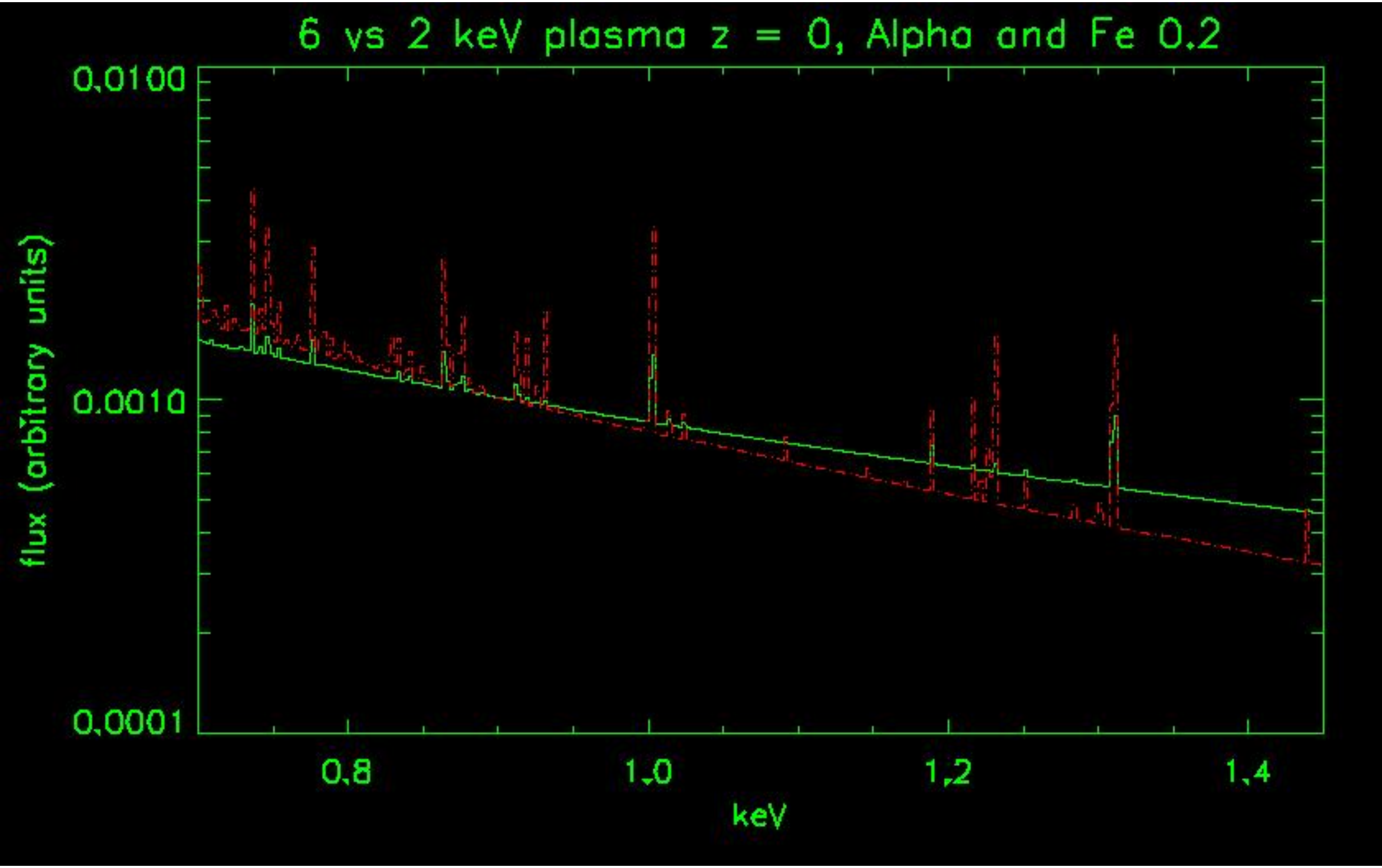
Next set of slides shows 5 eV resolution is good enough and can determine temperature without going to 6-7 keV


6 vs 2 keV plasma z = 1, 0.2 Alpha and Fe
0.0100
0.0010
0.0001
flux (arbitrary units)
0.45
0.50
0.55
0.60
0.65
0.70
0.75
0.80
keV


6 vs 2 keV plasma z = 1, Alpha and Fe 0.2
0.0010
0.0001
flux (arbitrary units)
0.8
1.0
1.2
1.4
keV



6 vs 2 keV plasma z = 0, 0.2 Alpha and Fe
0.010
0.001
flux (arbitrary units)
0.45
0.50
0.55
0.60
0.65
0.70
0.75
0.80
keV


6 vs 2 keV plasma z = 0, Alpha and Fe 0.2
0.0100
0.0010
0.0001
flux (arbitrary units)
0.8
1.0
1.2
1.4
keV

Thanks for input from: Florence Durret (images), Kent Irwin (low temperature devices), Dan McCammon (low temperature devices), and Craig Sarazin (image plus general comments), John Raymond (images)