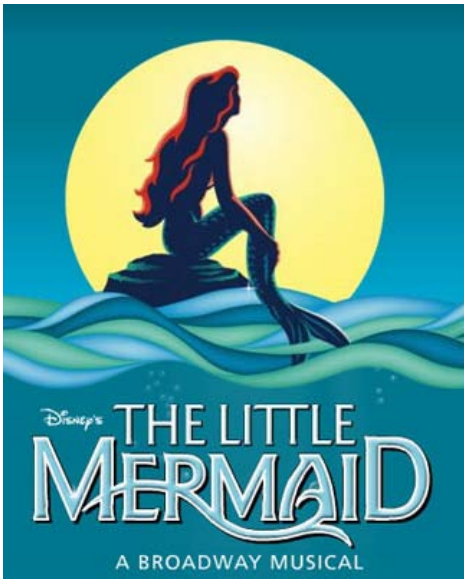
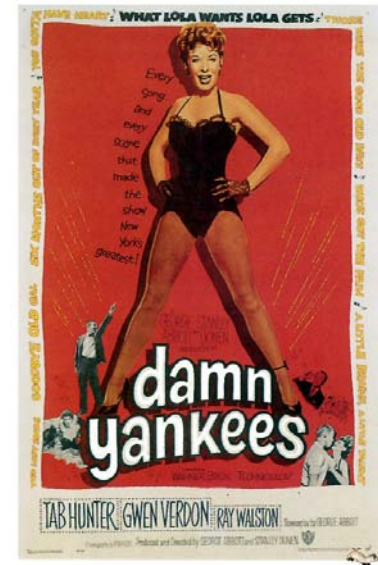
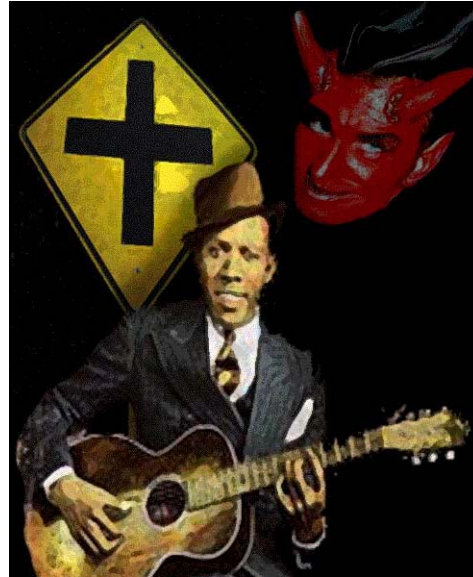


# Bruker ARTAX $\mu$ XRF spectrometer



# Famous Faustian Bargains



# diagram of instrument

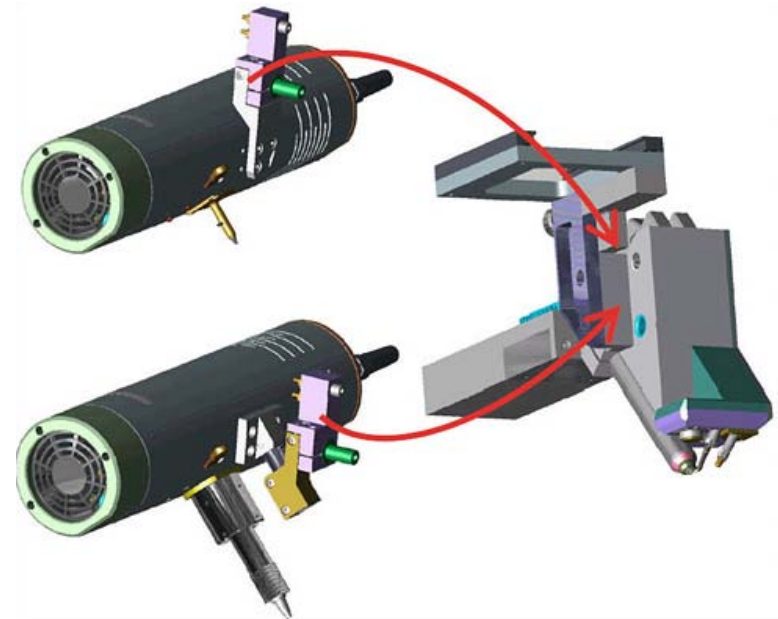
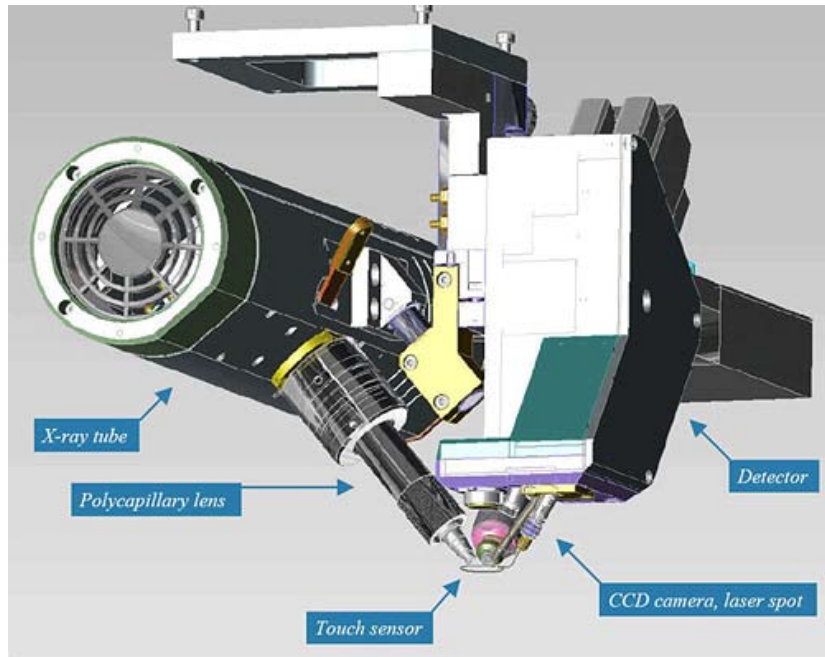


illustration of changing tubes

# Tubes and spot sizes



Cr 650  $\mu\text{m}$  spot  
(w/collimator)

Mo 65  $\mu\text{m}$  spot  
(w/polycapillary lens)

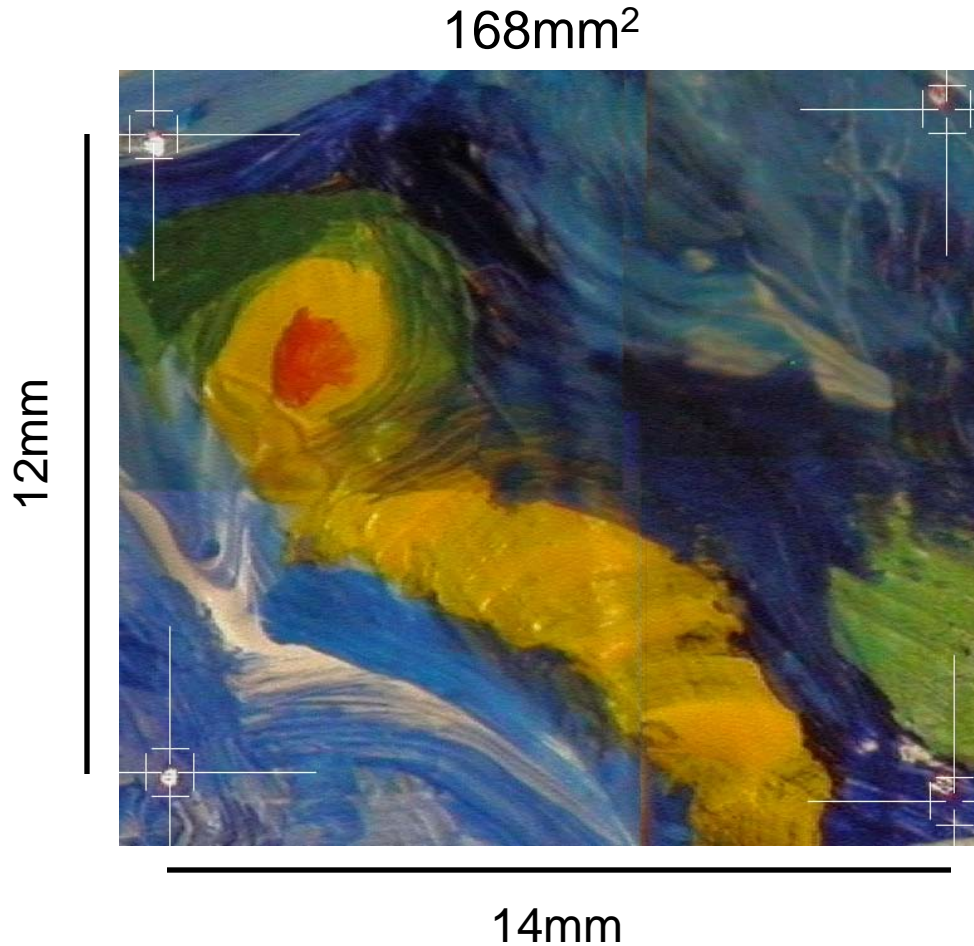
W 650  $\mu\text{m}$  spot  
(w/collimator)



collimators and polycapillary lens can all be removed for a 2mm spot

all tubes can be run up to 50kV & 1000 $\mu\text{A}$   
minimum operating voltage = 12kV

# test area mapping with the W tube (650 $\mu\text{m}$ spot)



0.5mm step size → 2 hour scan  
**reality: 3 hours 13 minutes**

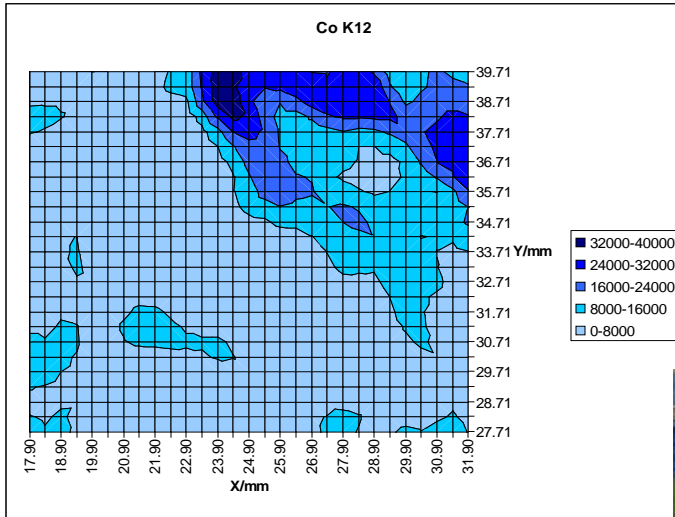
1.0mm step size → 32.3 minutes  
**reality: 57 minutes**

1.5mm step size → 15 minutes  
**reality: 27 minutes**

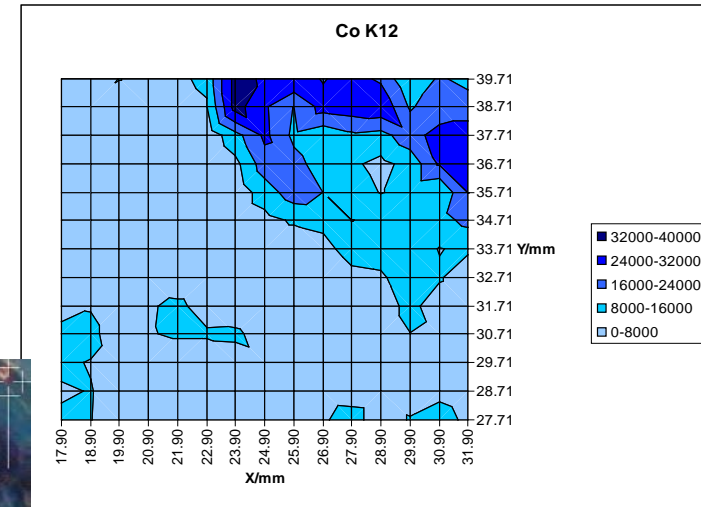
2.0mm step size → 9.2 minutes  
**reality: 18 minutes**

all maps run with 10 second scans

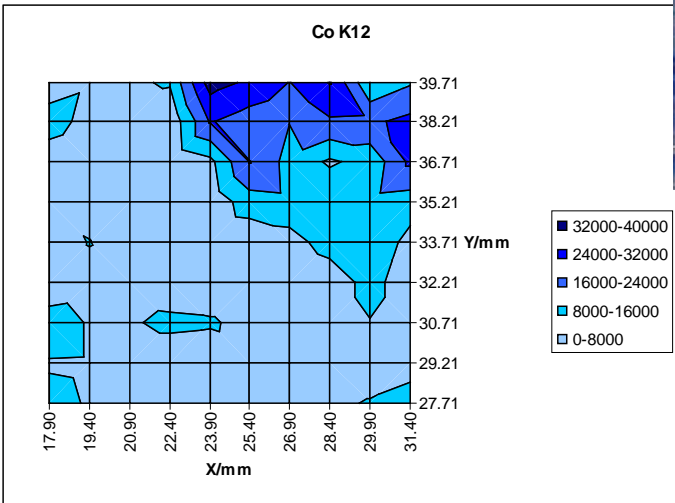
# Co



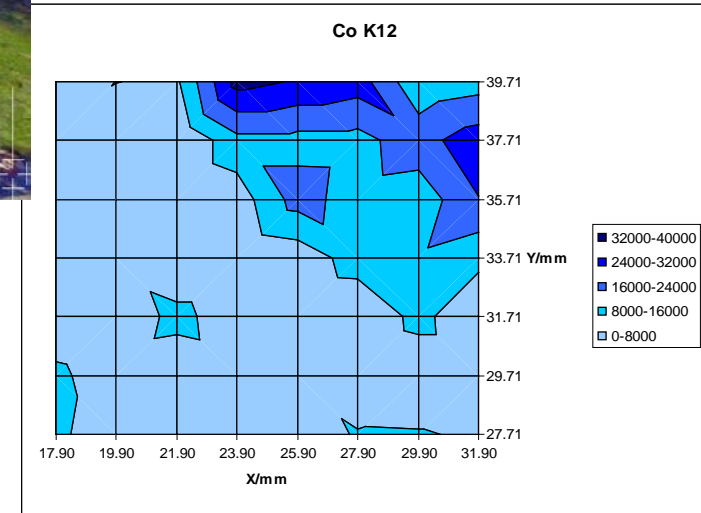
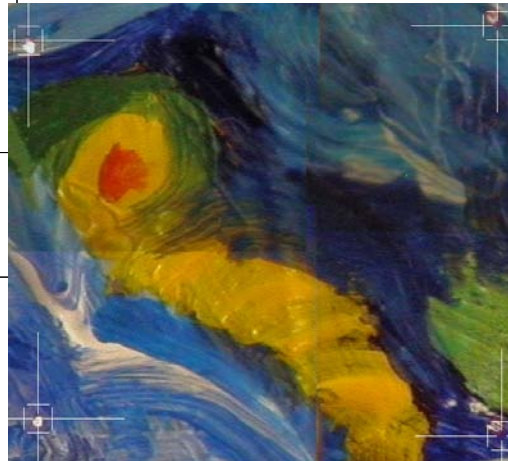
0.5 mm step size



1.0 mm step size



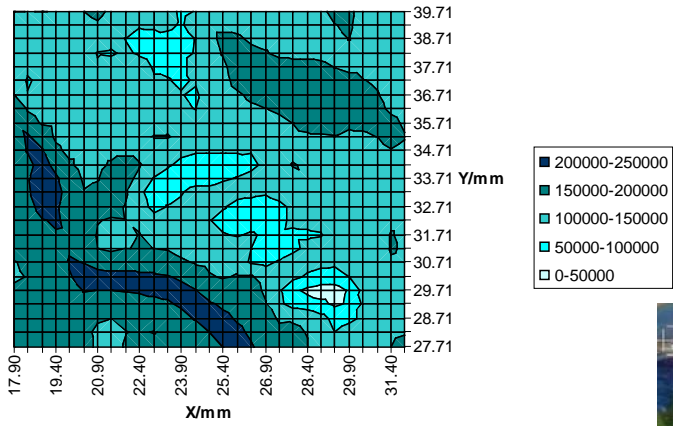
1.5 mm step size



2.0 mm step size

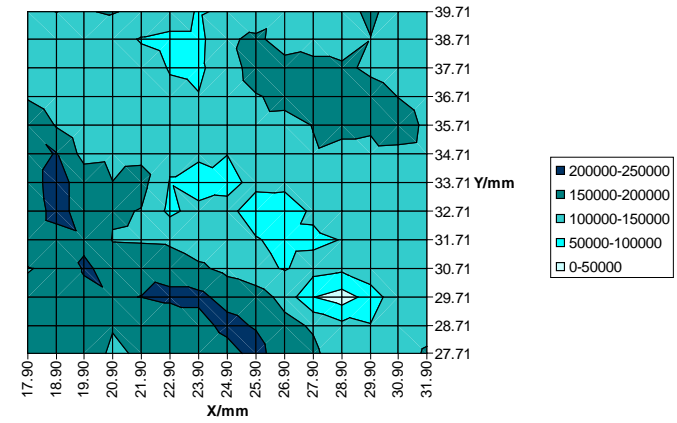
# Zn

Zn K12



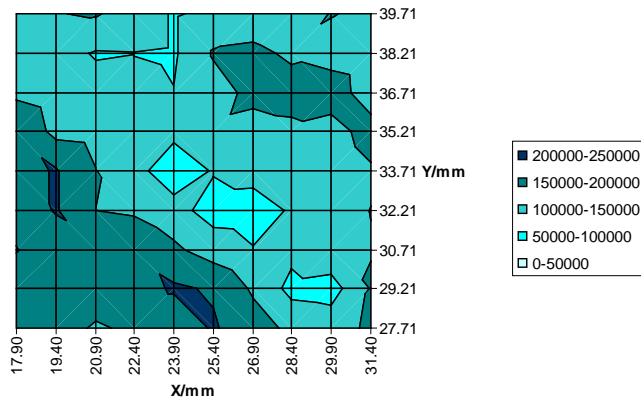
0.5 mm step size

Zn K12



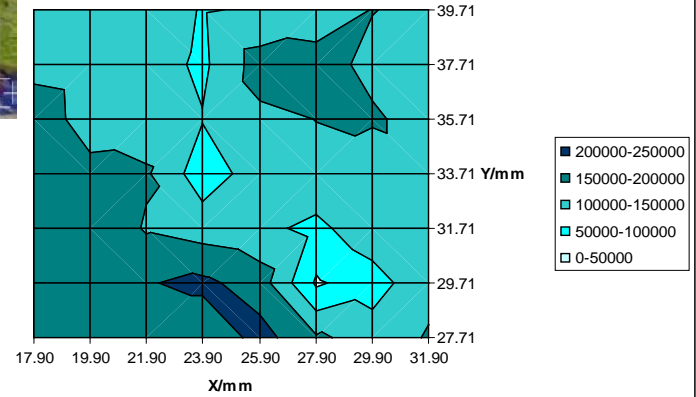
1.0 mm step size

Zn K12

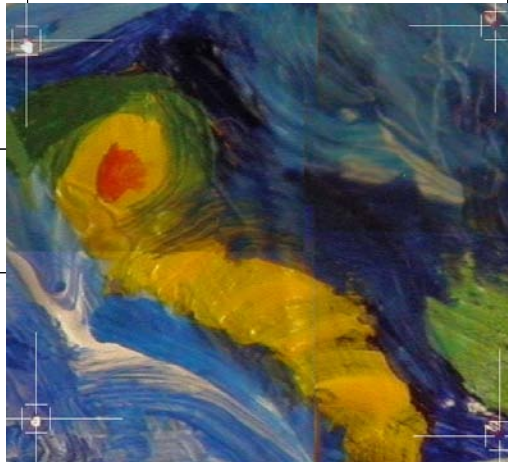


1.5 mm step size

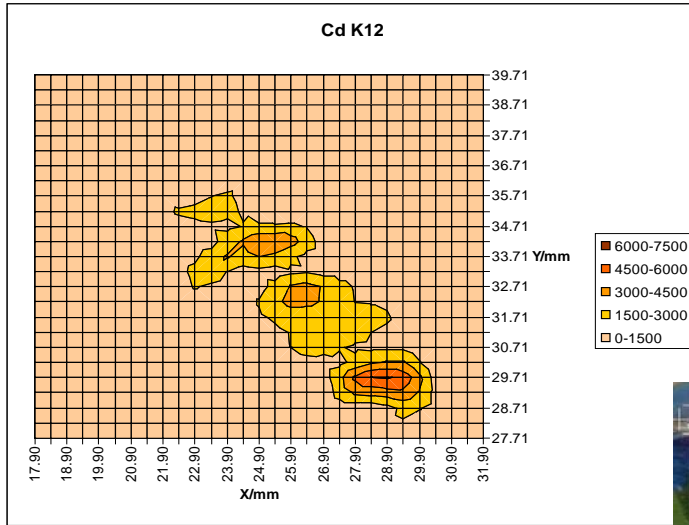
Zn K12



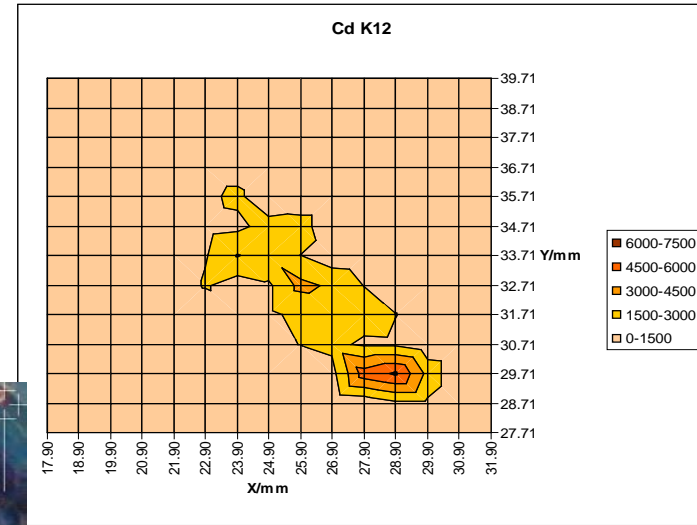
2.0 mm step size



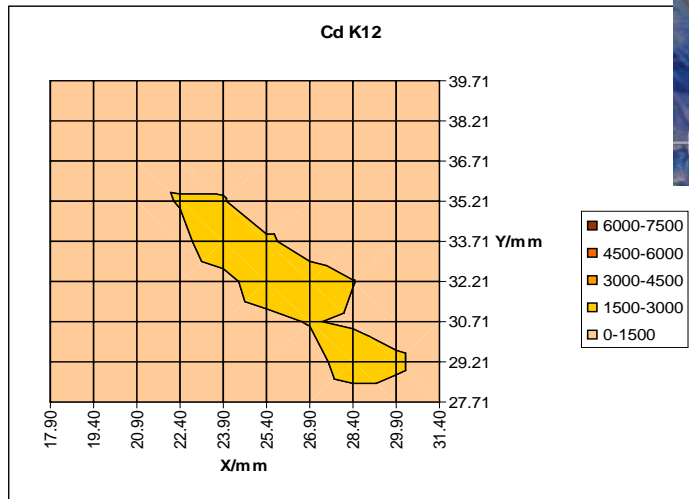
# Cd K



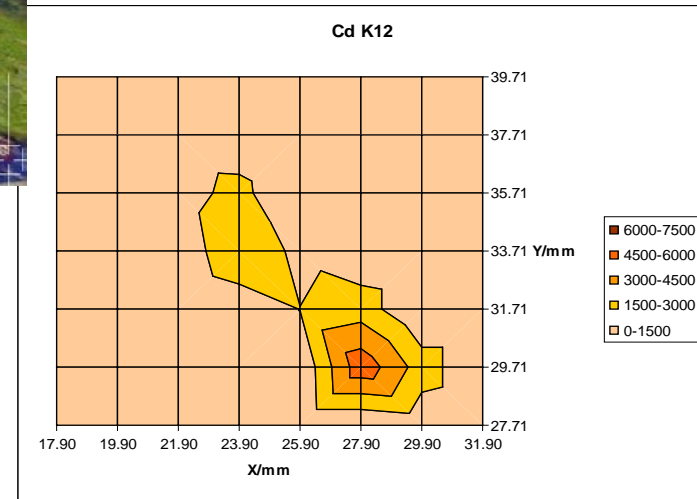
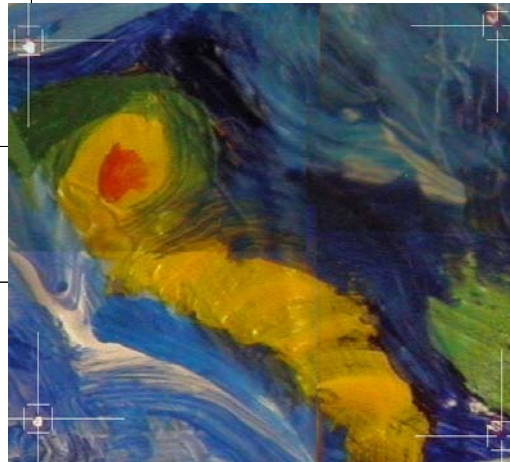
0.5 mm step size



1.0 mm step size



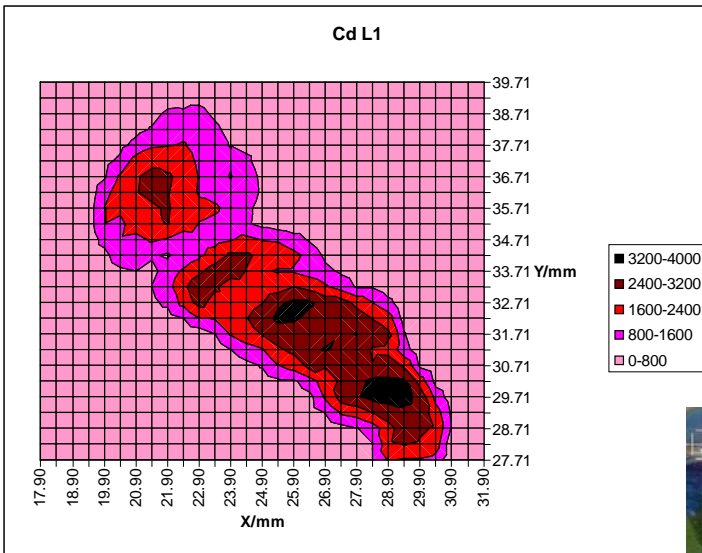
1.5 mm step size



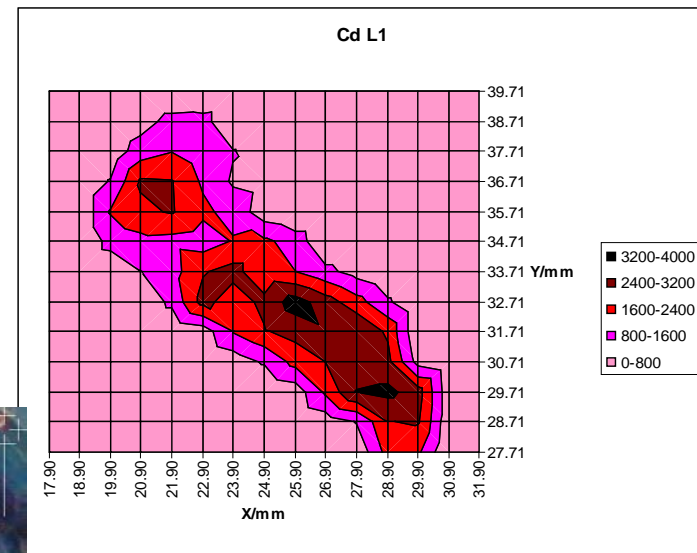
2.0 mm step size



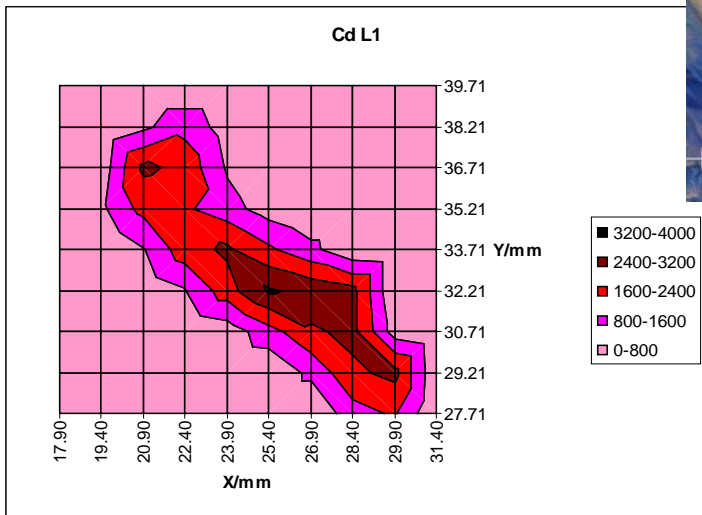
# Cd L



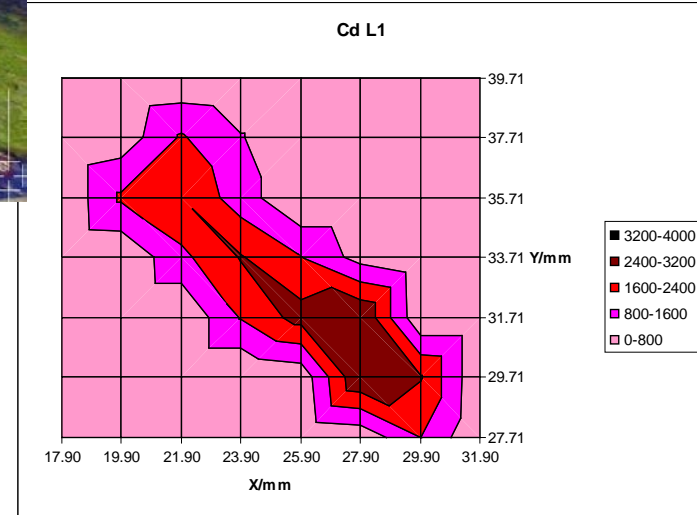
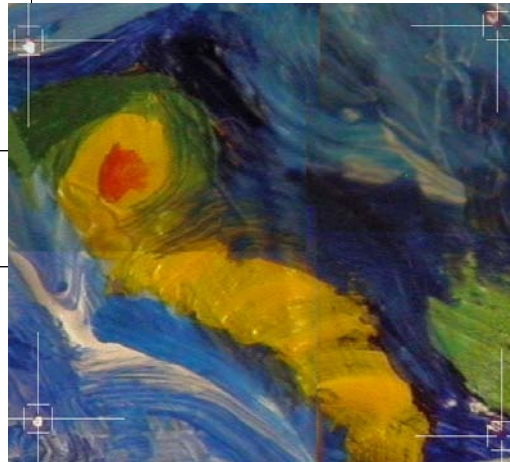
0.5 mm step size



1.0 mm step size



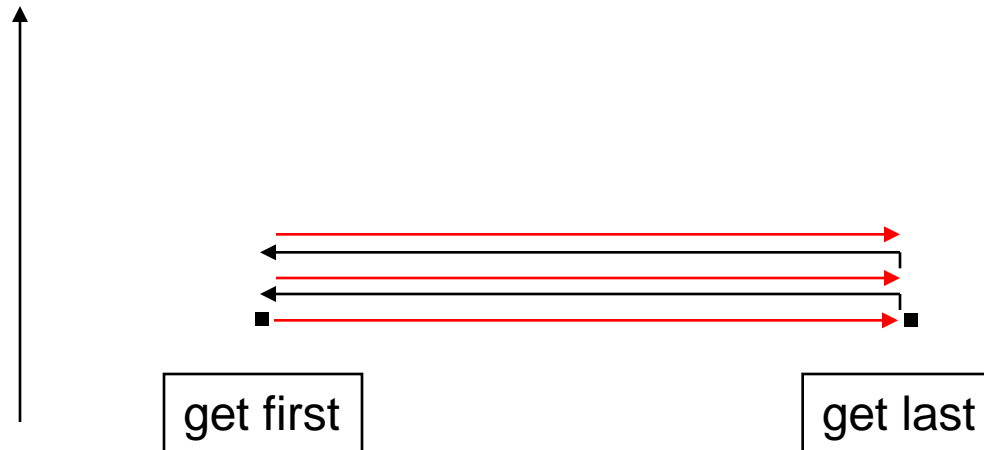
1.5 mm step size



2.0 mm step size

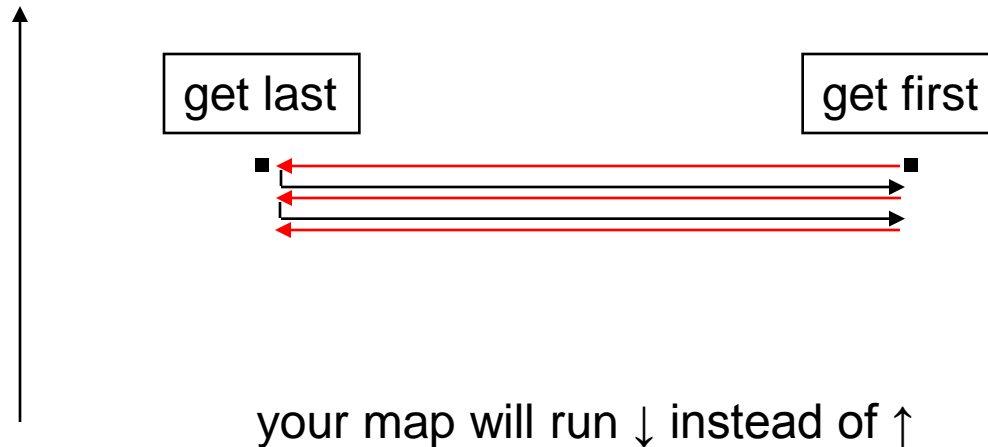
# logistics of area mapping

1. choose starting and ending spots in the x-direction
2. choose total distance to be scanned in y-direction
3. start scan (acquisition shown in red, other movement in black)

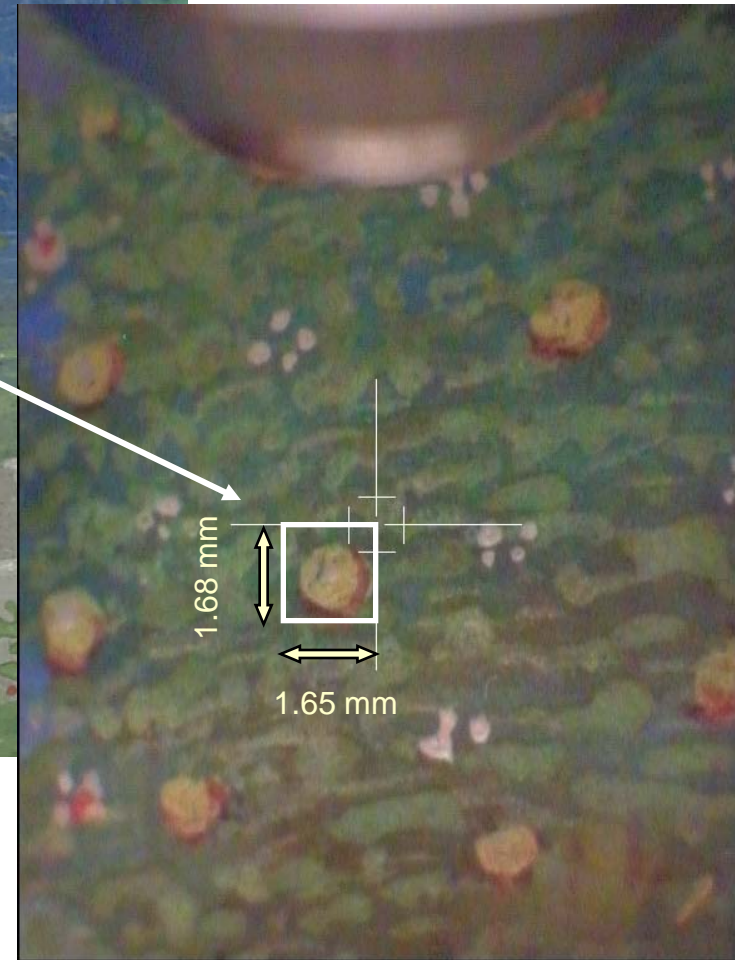
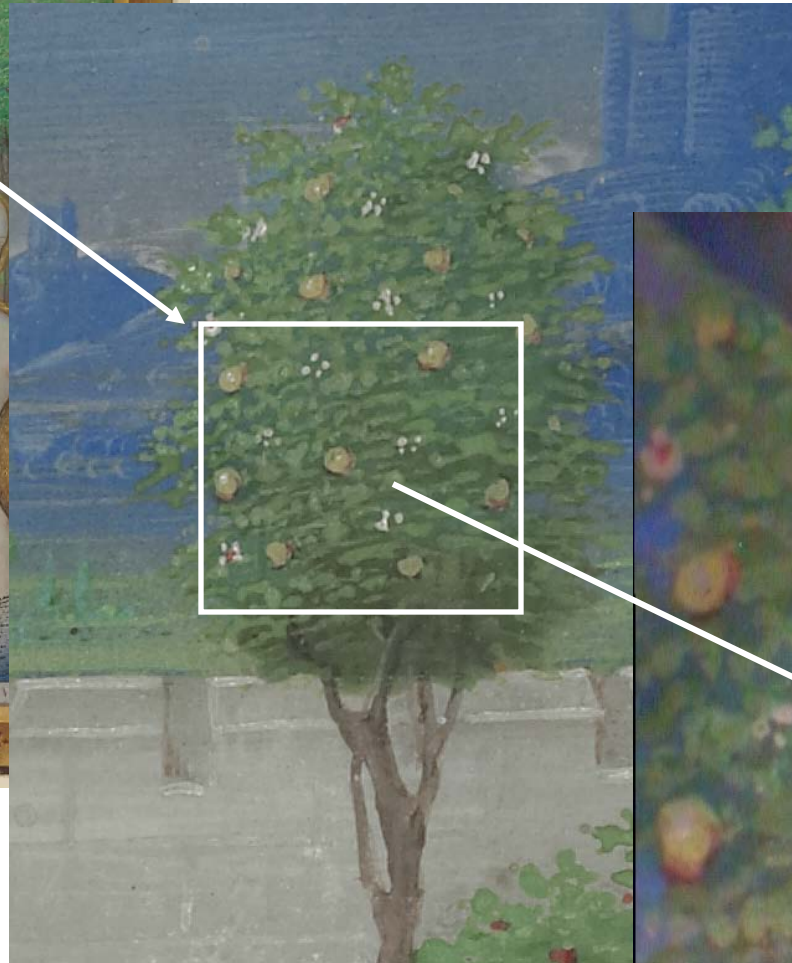
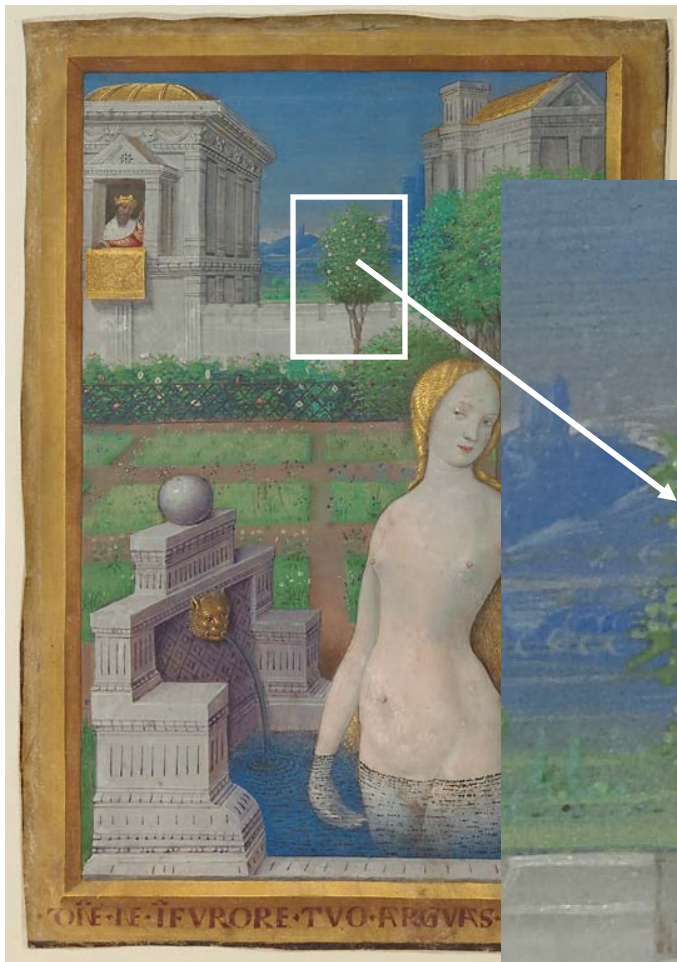


# more logistics of area mapping

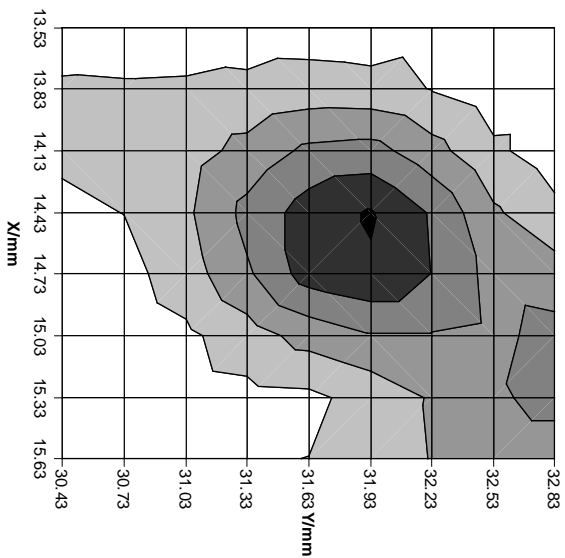
1. if you choose “get first” to the right of “get last”...
2. then choose total distance to be scanned in y-direction
3. and start your scan (acquisition shown in red, other movement in black)



Jean Bourdichon, *Bathsheba Bathing*,  
Hours of Louis XII, 1498-99,  
JPGM Ms 79 (2003.105)

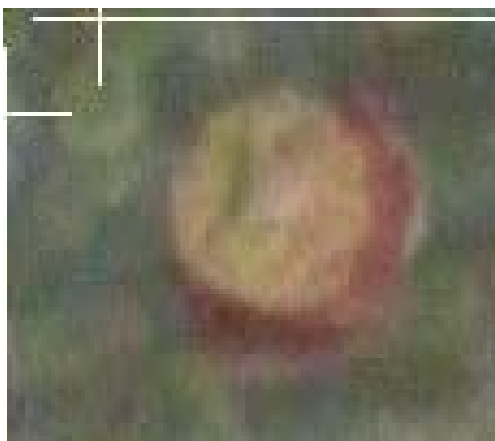
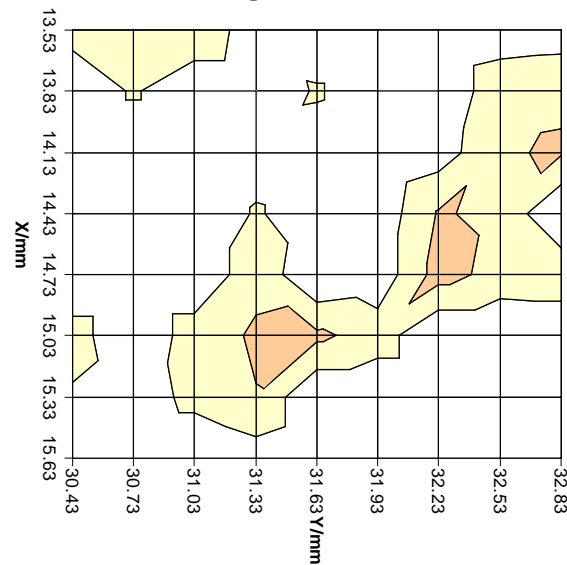


# Pb L $\alpha$

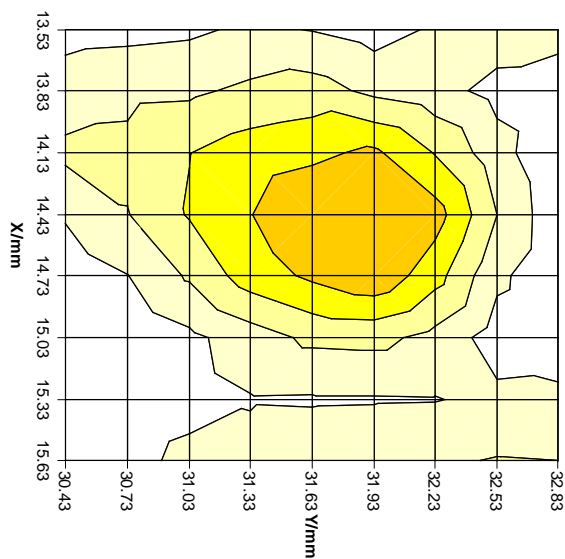


Scan area: 2.40 x 2.10 mm  
Step size: 0.3 mm  
Beam spot size: 650  $\mu$ m  
# spectra: 72, 30 sec. acq.  
W tube, 40kV, 600  $\mu$ A  
Time: 36 min (live time)

# Hg L $\alpha$

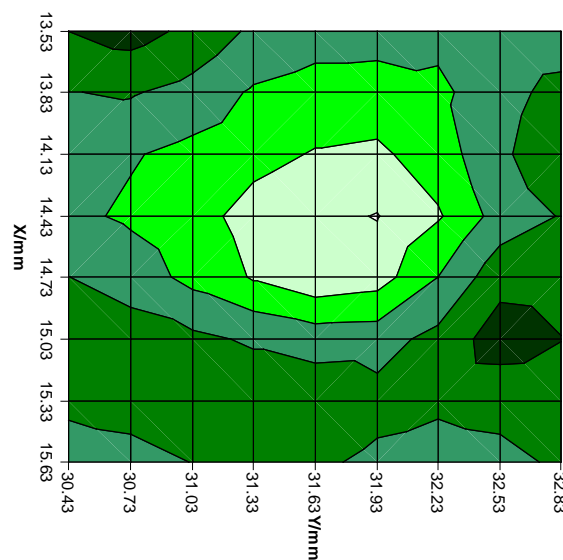


# Sn L $\alpha$

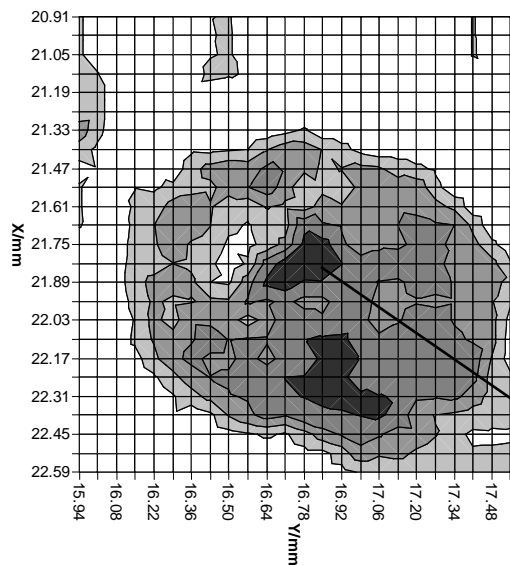


W tube  
0.65 mm spot

# Cu K $\alpha$

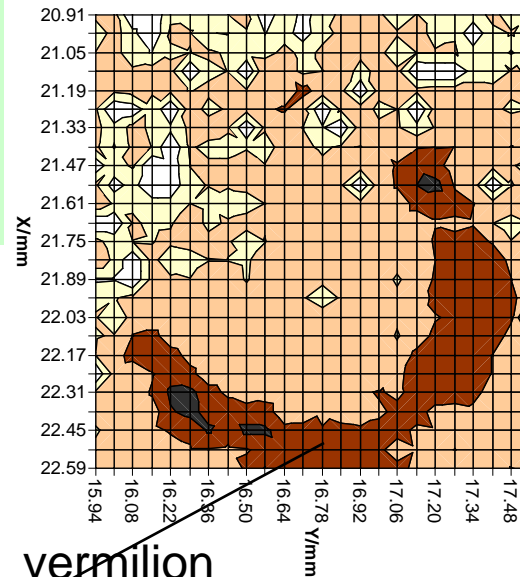


# Pb L $\alpha$

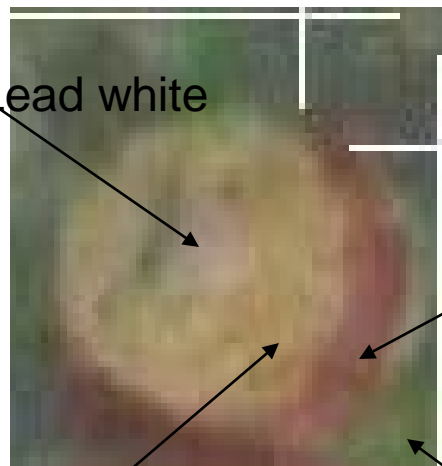
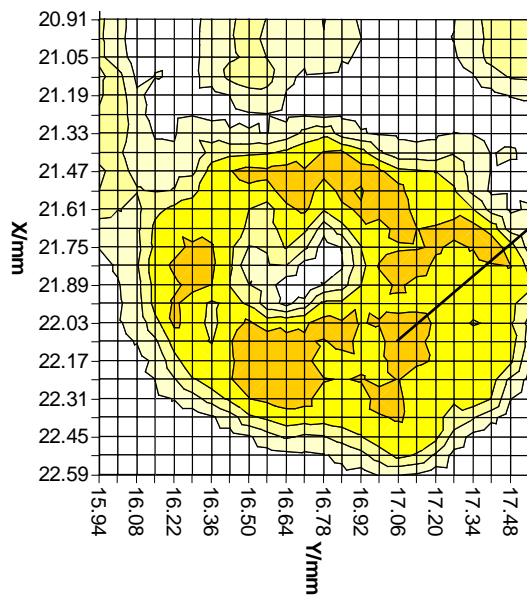


Scan area: 1.68 x 1.65 mm  
Step size: 0.07 mm  
Beam spot size: 65  $\mu$ m  
# spectra: 600, 20 sec. acq.  
Mo tube, 40kV, 600  $\mu$ A  
Time: 3 hr 20 min (live time)

# Hg L $\alpha$



# Sn L $\alpha$



Lead white

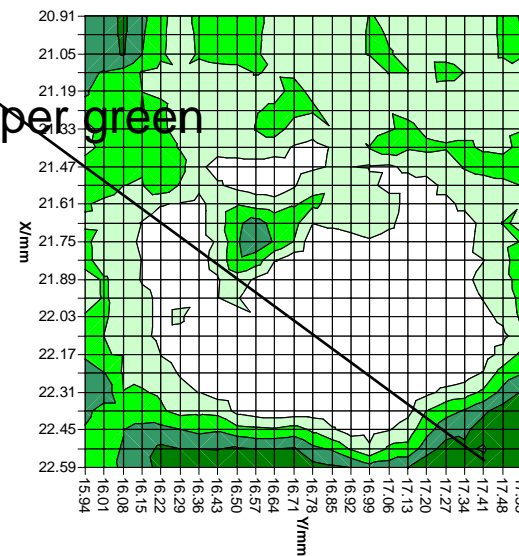
vermilion

Lead tin yellow

Copper green

Mo tube  
0.065 mm spot

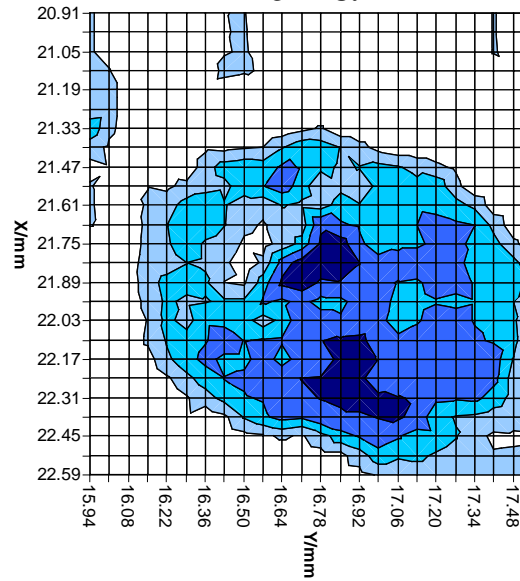
# Cu K $\alpha$



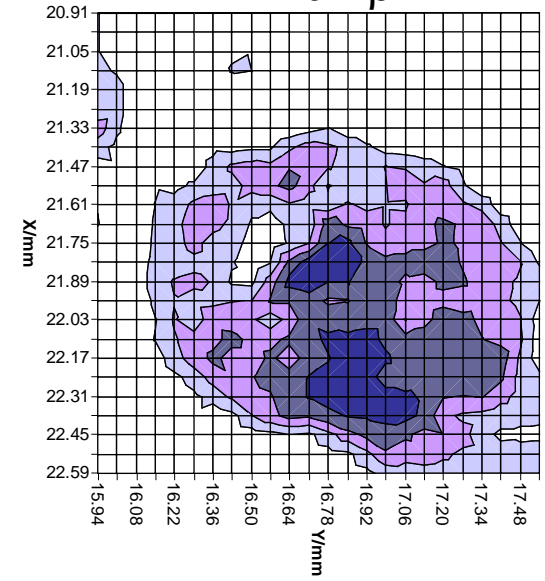
# Looking at maps of individual ROIs



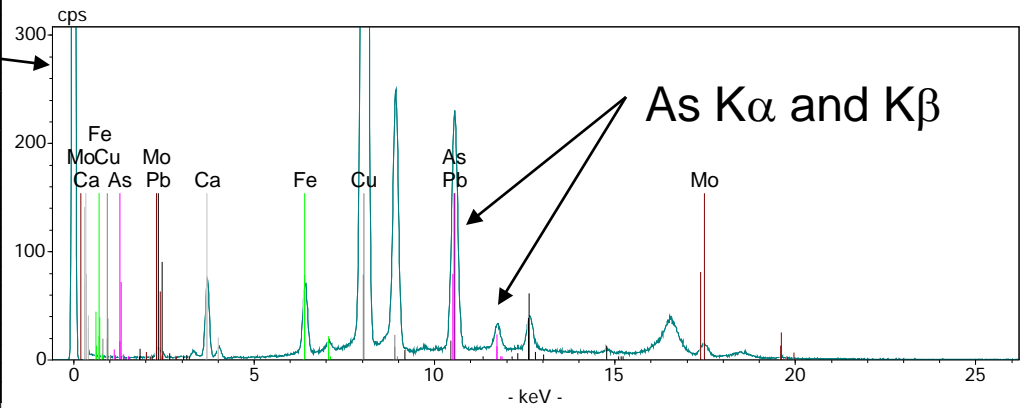
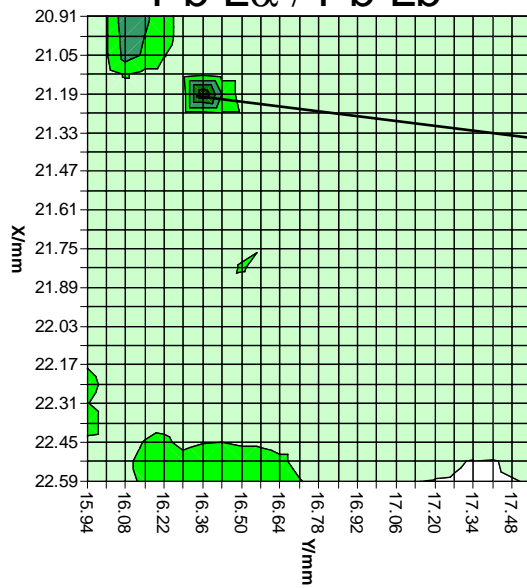
### Pb L $\alpha$



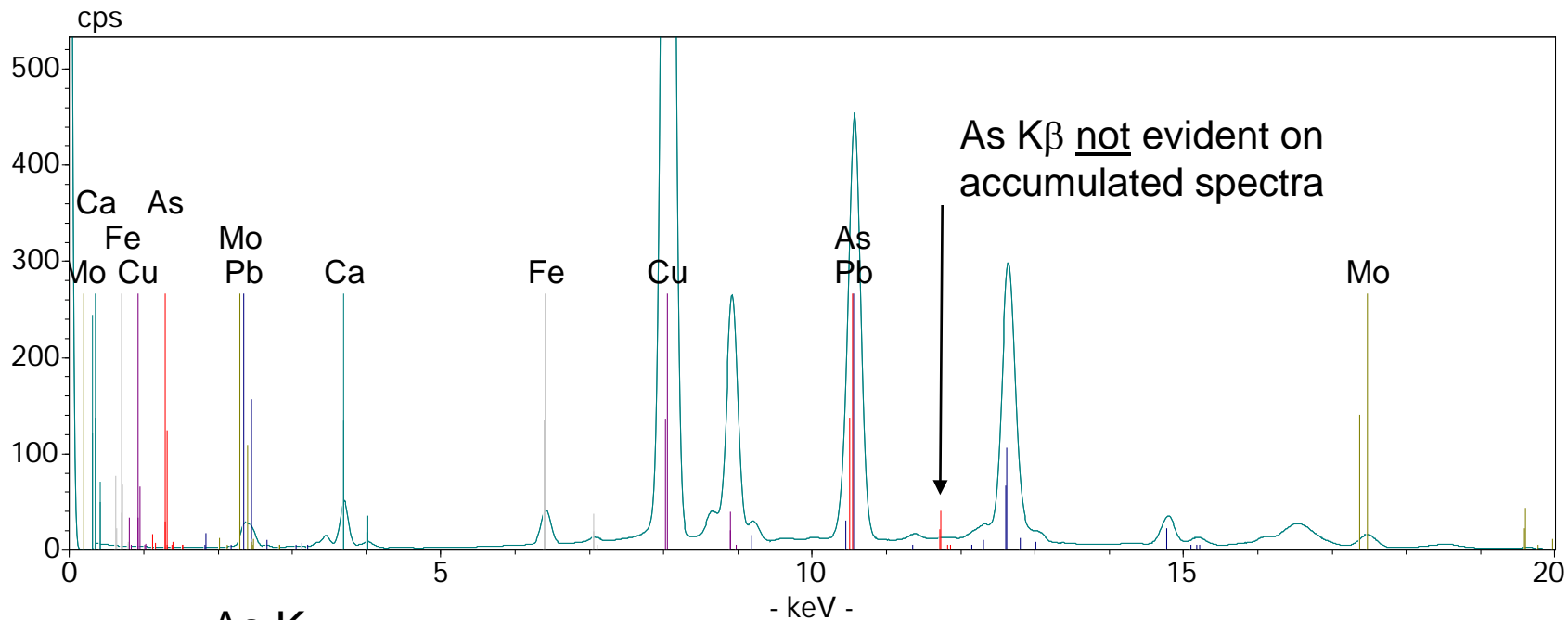
### Pb L $\beta$



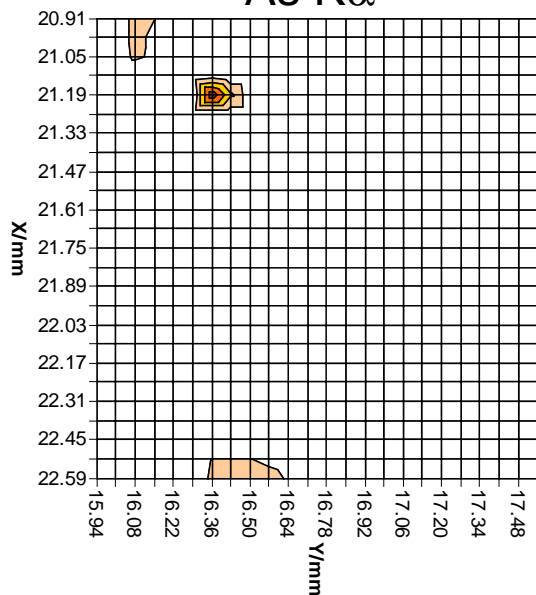
### Pb L $\alpha$ / Pb L $\beta$



Spectrum from high L $\alpha$ /L $\beta$  area shows As!



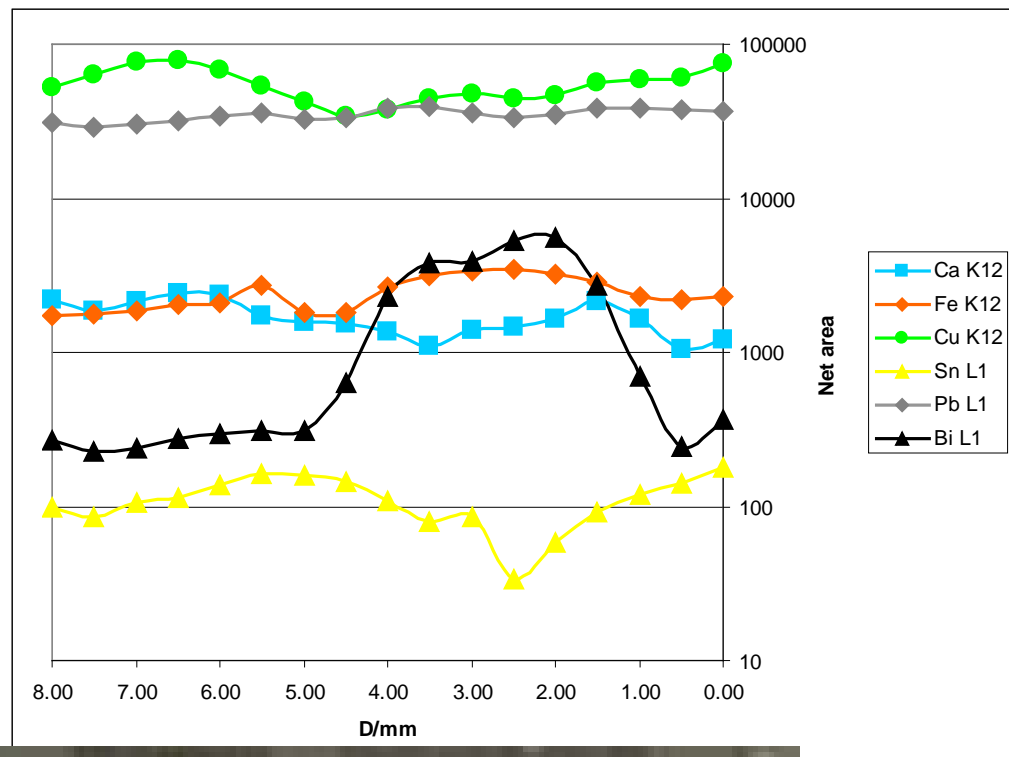
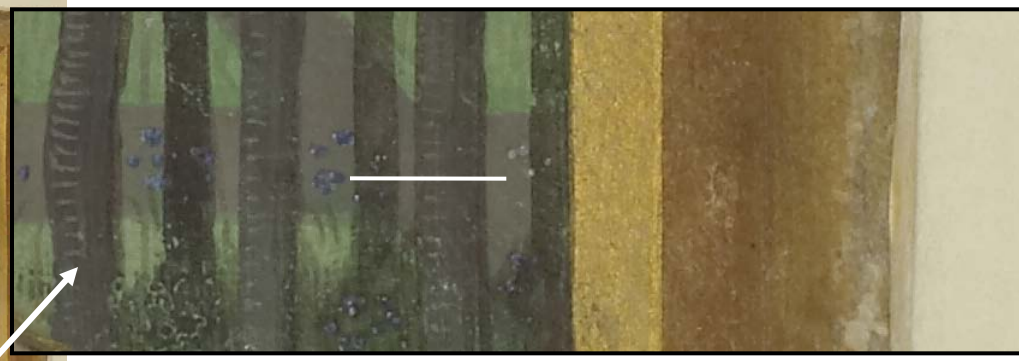
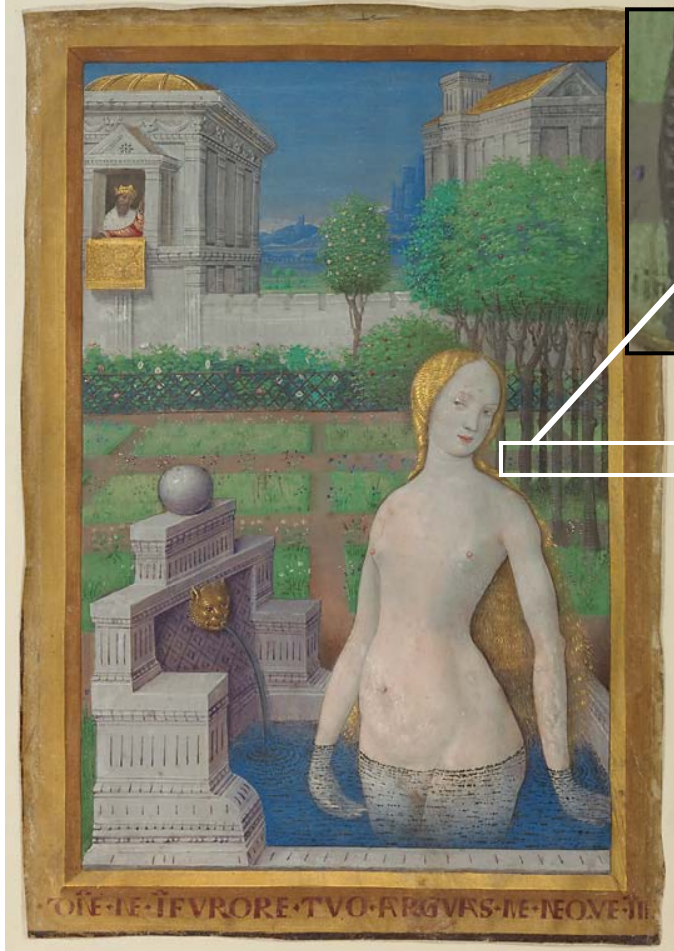
As K $\alpha$



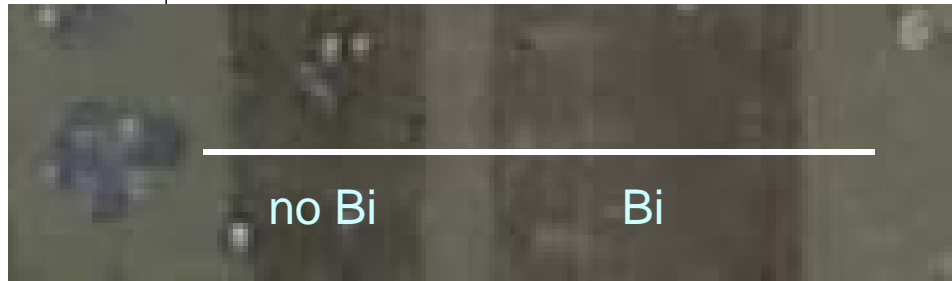
As map  
generated by  
manually  
selecting As for  
deconvolution

- Would be helpful to be able to select ROIs for mapping
- Information may be gleaned by looking at  $L\alpha/L\beta$  ratios
- Best check is looking at the raw data





Line scan: 8 mm  
 Step size: 0.5 mm  
 Beam spot size: 0.65mm  
 # spectra: 17, 30 sec. acq.  
 W tube, 40kV, 600  $\mu$ A  
 Time: 8.5 min (live time)



# The *Laudario* of Sant'Agnese

2005.26; Ascention of Christ



Pacino di Bonaguida

2006.13.v; Martyrdom of St. Lawrence



Pacino di Bonaguida

2003.106; Pentecost



Master of the Dominican Effigies

Pacino di Bonaguida, et al.  
Italian  
about 1340

# Analysis of flesh tones

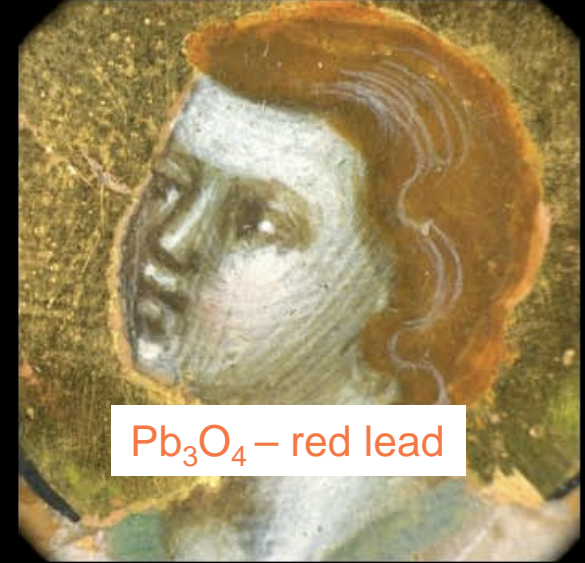


HgS – vermilion

2005.26; Pacino di Bonaguida



2006.13.v; Pacino di Bonaguida



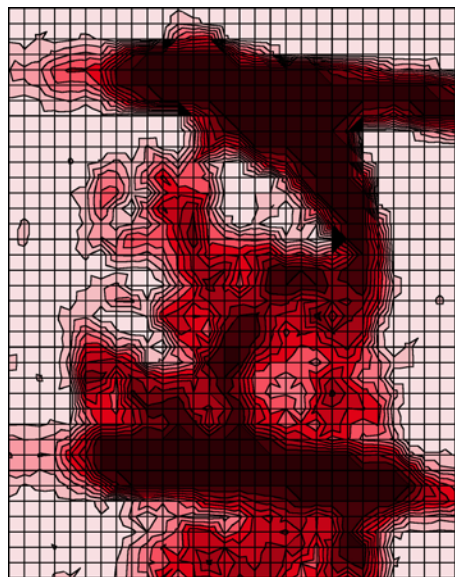
Pb<sub>3</sub>O<sub>4</sub> – red lead

2003.106; Master of the Dominican Effigies



- W-tube
- 650 μm x-ray spot size
- 40 kV, 600 μA, no filters
- area maps
  - 0.35 mm step size
  - 10 sec scans
  - > 1000 scans per map

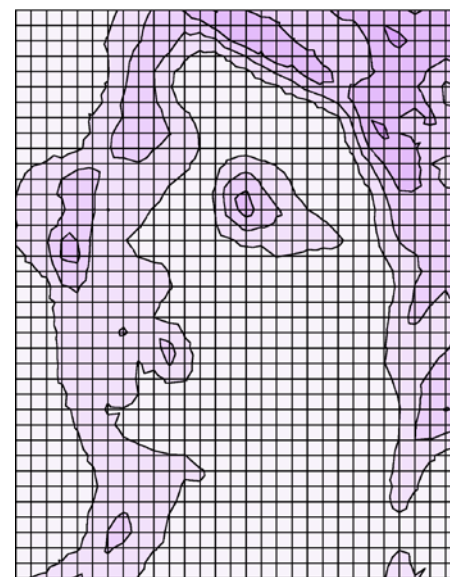
# Imaging of 2006.13 (*Martyrdom of St. Lawrence*)



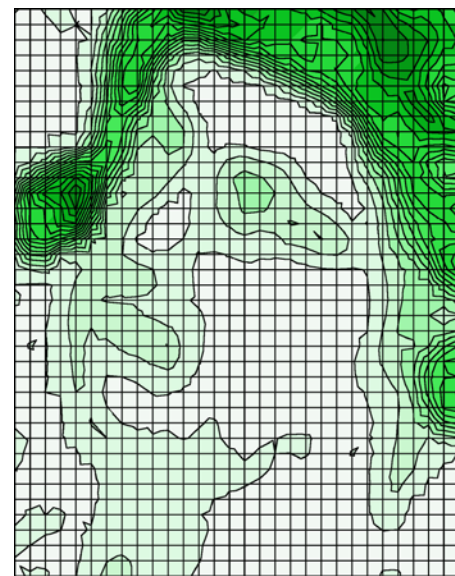
Hg L



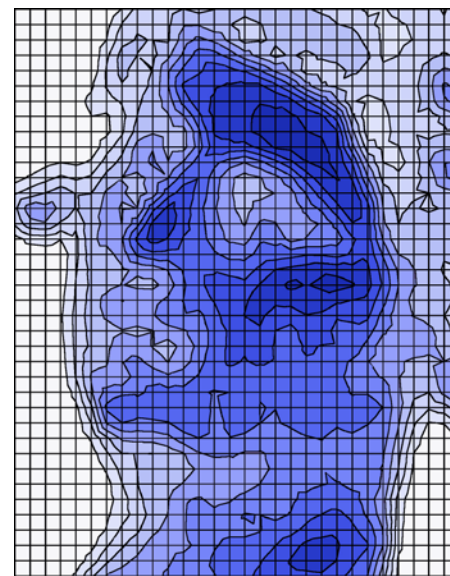
2006.13.v; Pacino di Bonaguida



Ca K

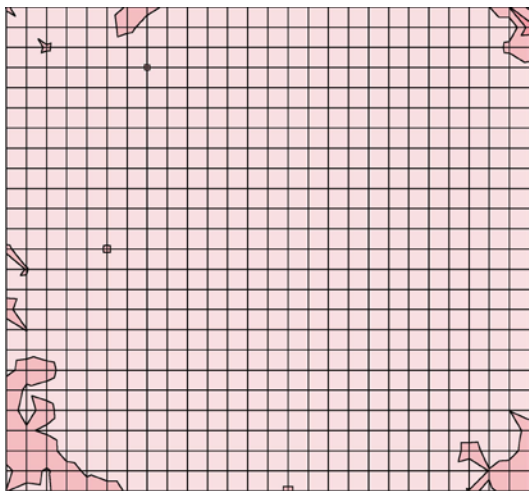


Fe K

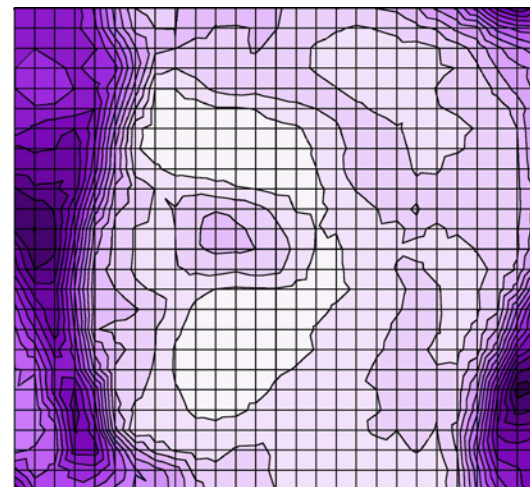


Pb L

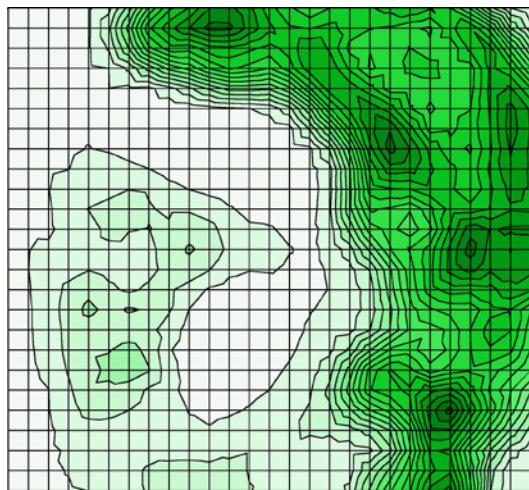
# Imaging of 2006.106 (*Pentecost*)



Hg L

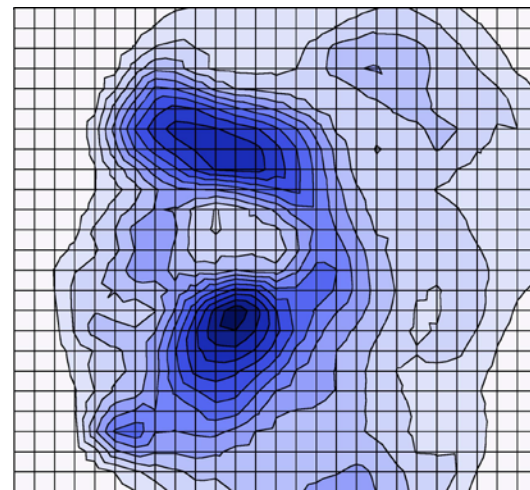
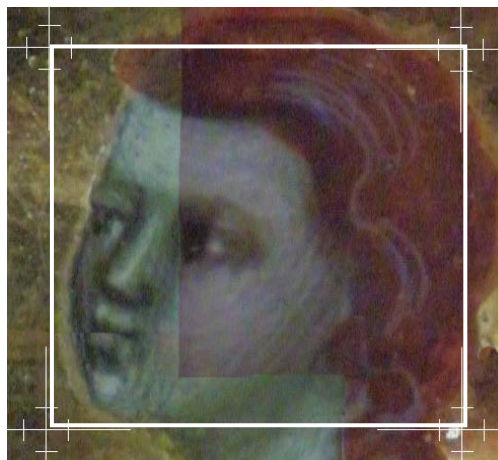


Ca K



Fe K

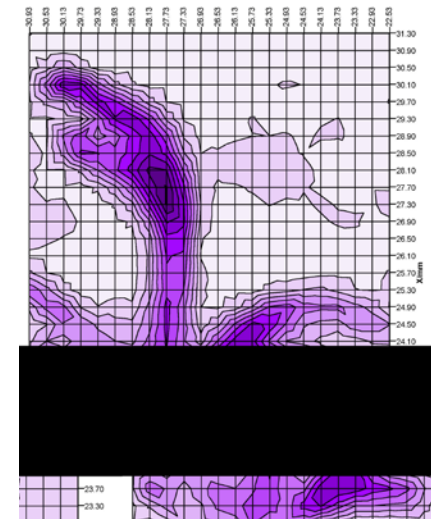
2003.106; Master of the Dominican Effigies



Pb L

# Imaging of 2005.26 (*The Ascension of Christ*)

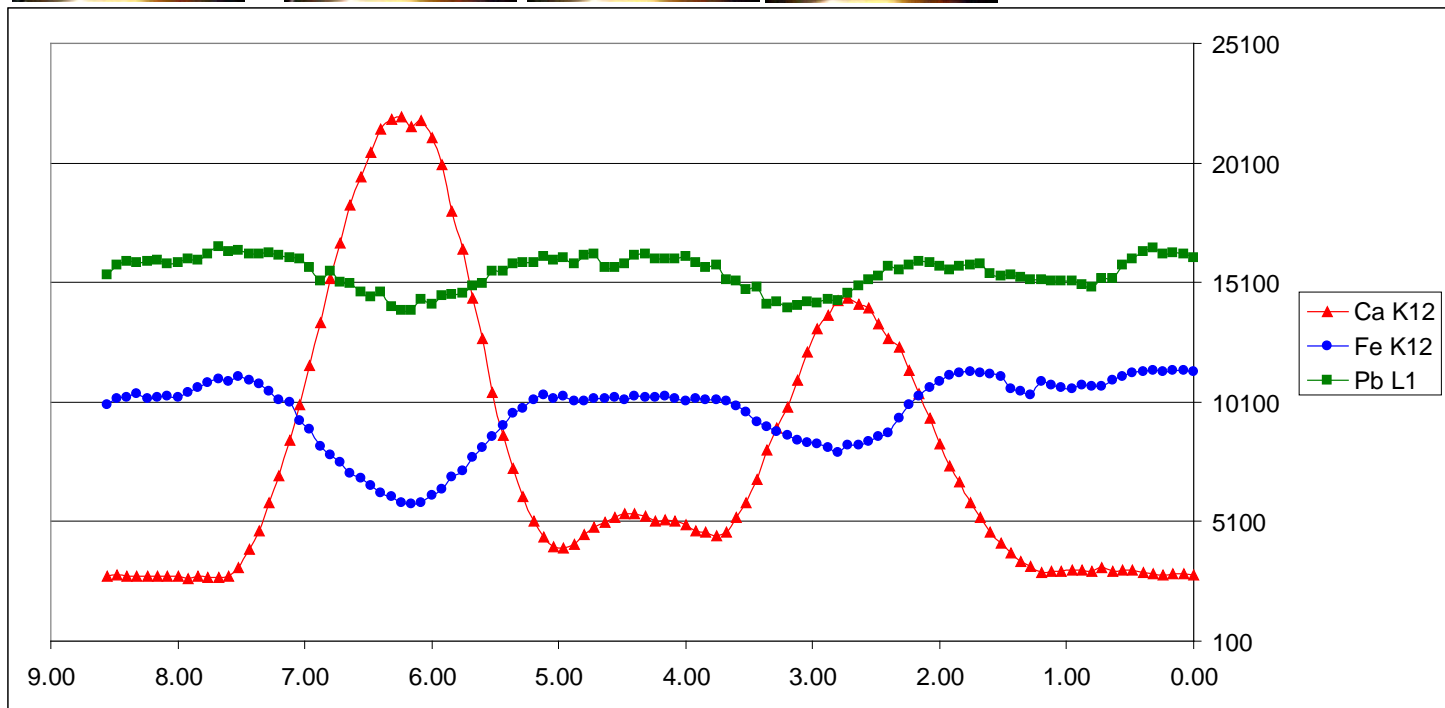
Pacino di Bonaguida



Ca K  
map

Ca substrate from faded organic lake

- Line scan to compare to area plot of little plant



# Pacino's Chiarito Tabernacle

In the gallery....



In the laboratory....



Pacino di Bonaguida  
Chiarito Tabernacle  
Italian, about 1340s  
Gilded gesso and tempera on panel  
38 1/4 x 11 5/16 in.  
JPGM 85.PB.311



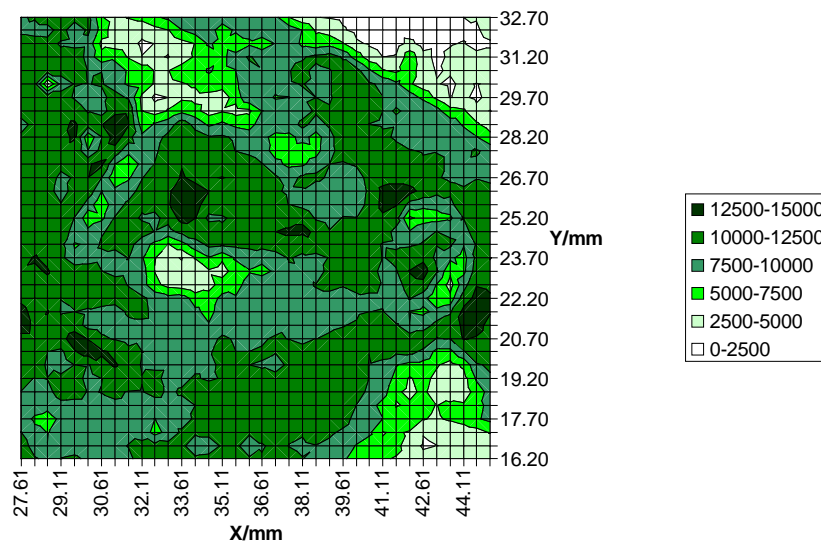
Pacino's

Chiarito Tabernacle  
JPGM 85.PB.311

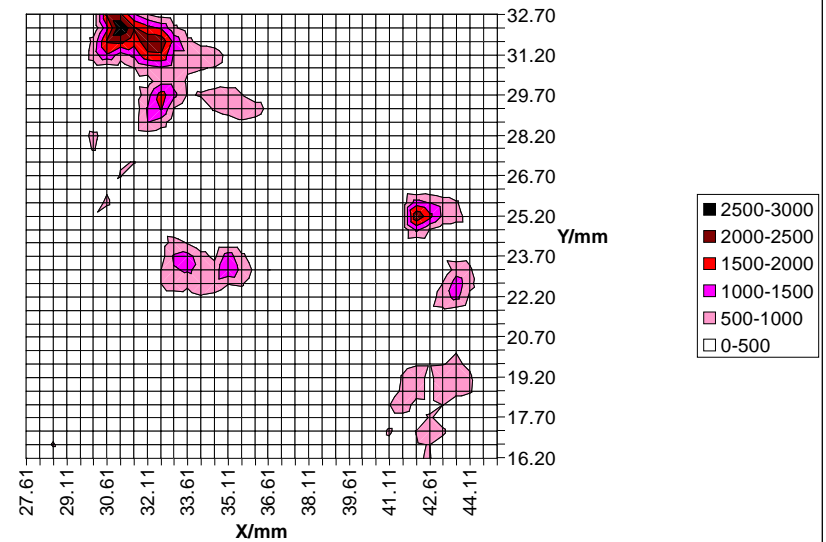


Map of Chiarito's face

Fe K12



Hg L1

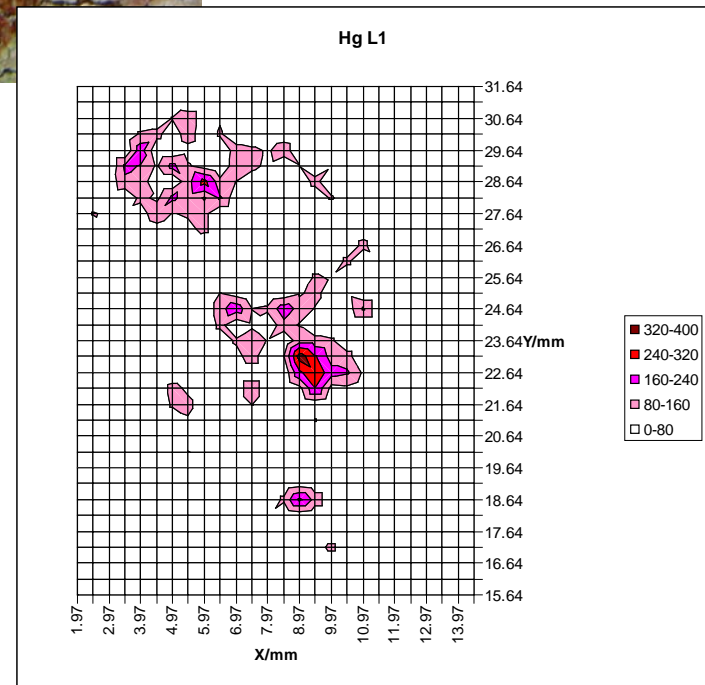
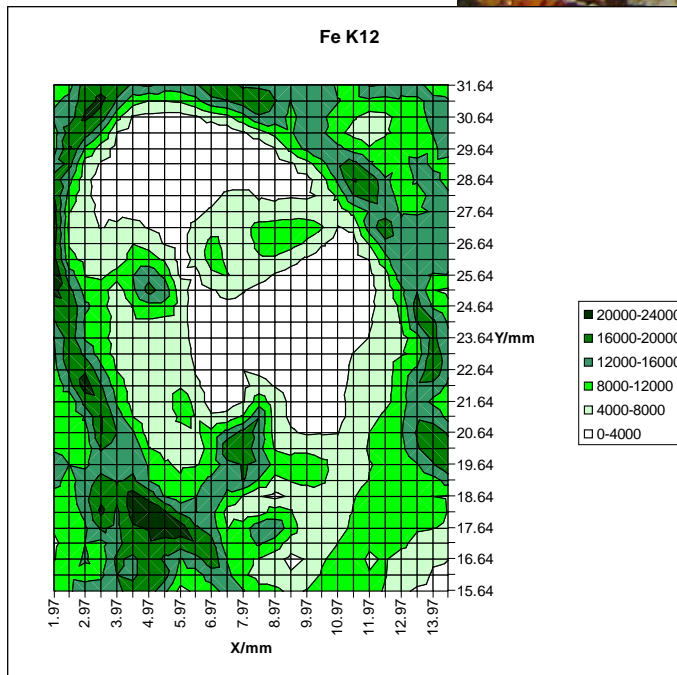


Pacino's

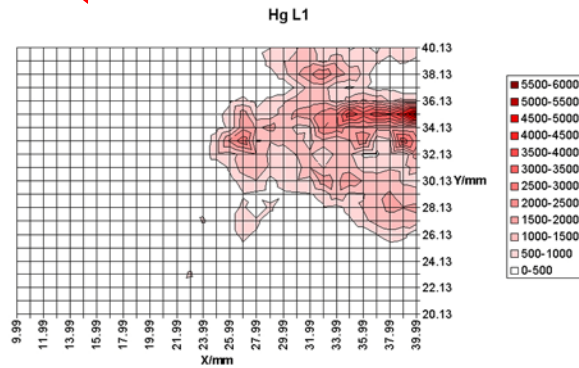
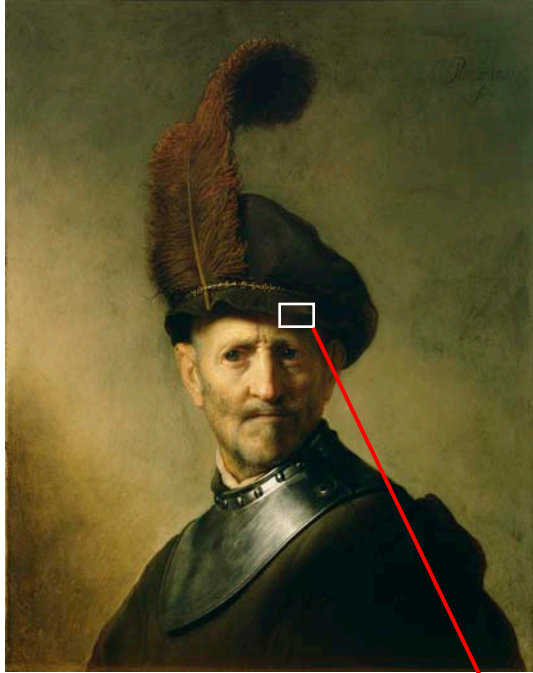
Chiarito Tabernacle  
JPGM 85.PB.311



Map of Jesus's face



# Rembrandt's *Old Man in Military Costume* (78.PB.246)





**JPGM Accession #:** 2008.41.2

**Artist/Maker:** P. Cipriani

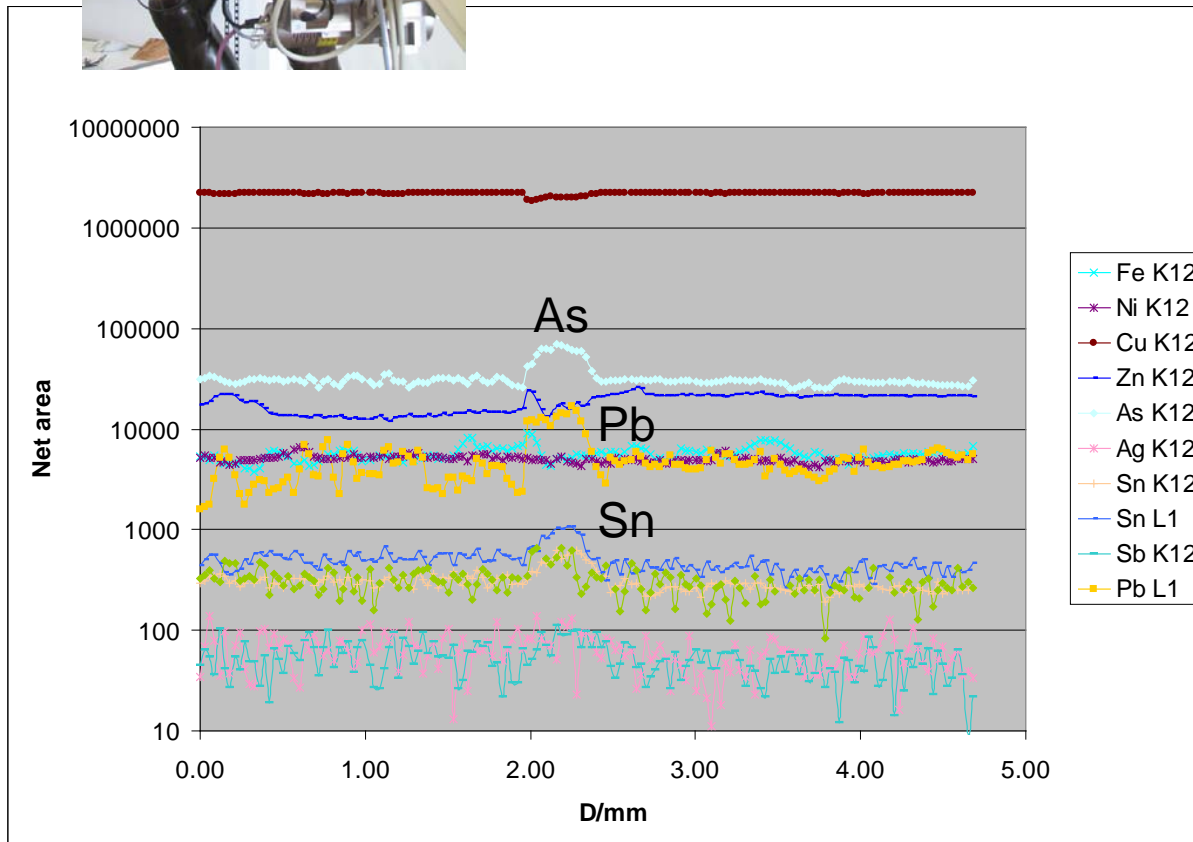
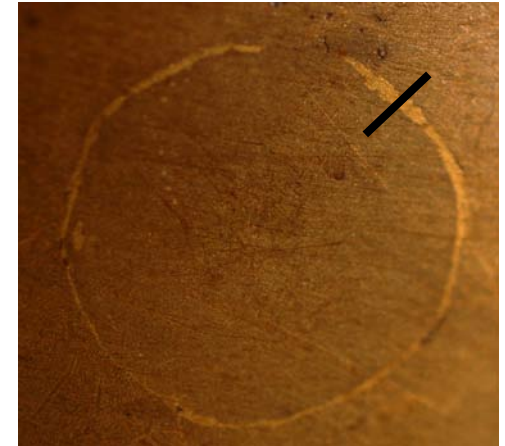
**Title:** Dancing Faun

**Execution Date:** 18th century

**Dimensions:** H: 143.5 cm



Line scans show increase in Pb, As and Sn across the solder line.



Parameters:  
Mo tube, 50kV/200  $\mu$ A  
No vacuum, No filter  
45 sec scans,  
0.03 mm/step  
158 spectra  
total distance 4.68 mm



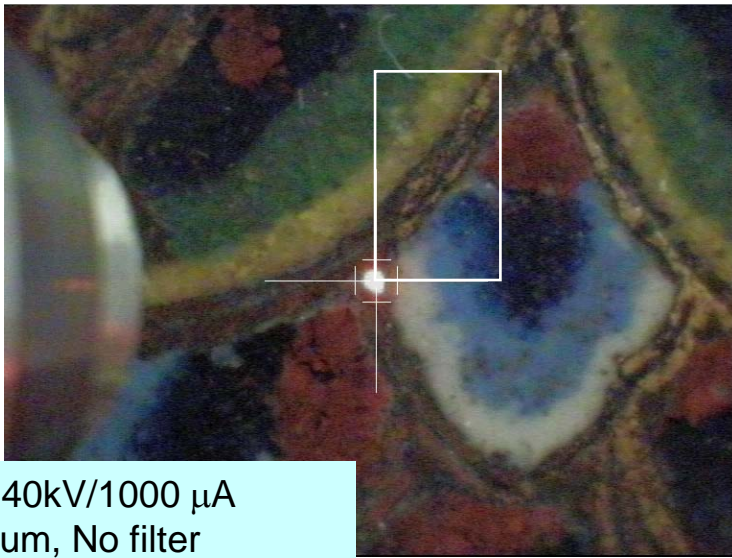
## Christ in Majesty

Limoges School  
French, about 1188

Copper (half relief), engraved, gilt,  
champlevé enamel, colored glass

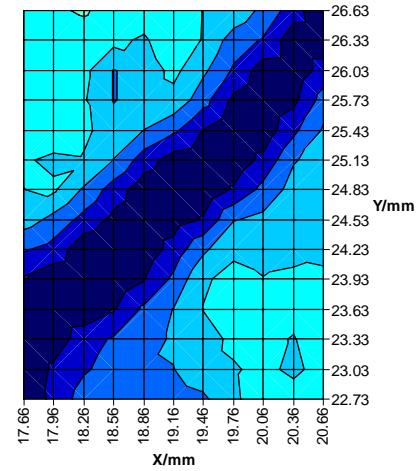
H: 17 7/8 in.

JPGM 2007.6

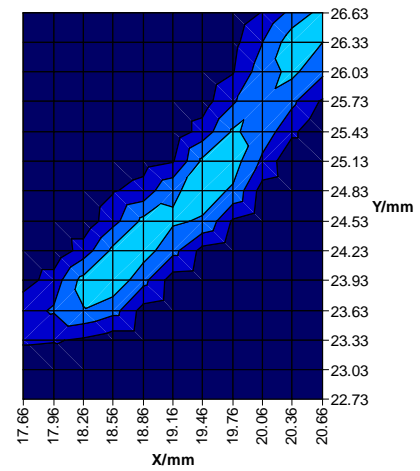


W tube, 40kV/1000  $\mu$ A  
No vacuum, No filter  
60 sec scans,  
0.3 mm/step  
154 spectra  
Area mapped: 3.0 x 4.0 mm

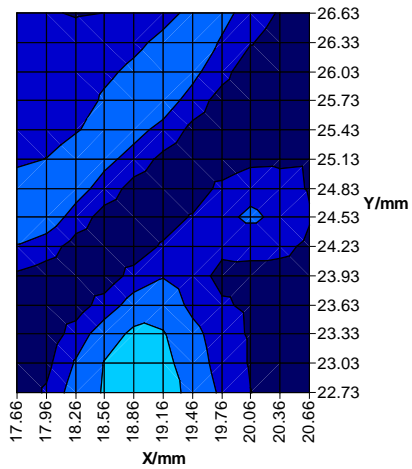
Si



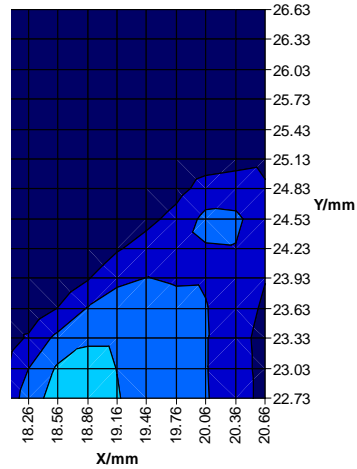
Au



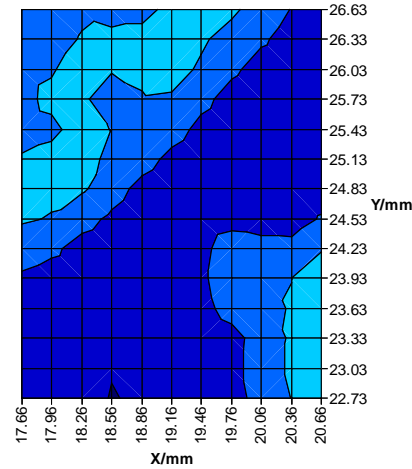
Pb



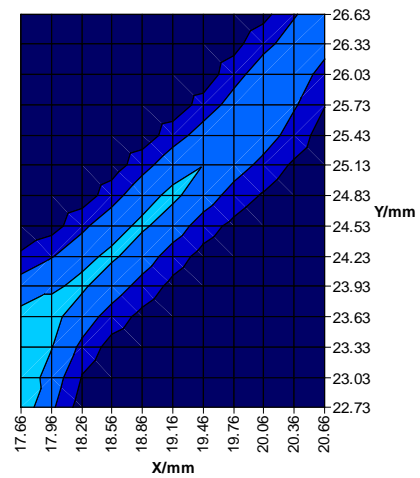
Sn



Sb



Cu



# Quantitative analysis of low Z materials

Polycapillary  
(65  $\mu\text{m}$  spot)



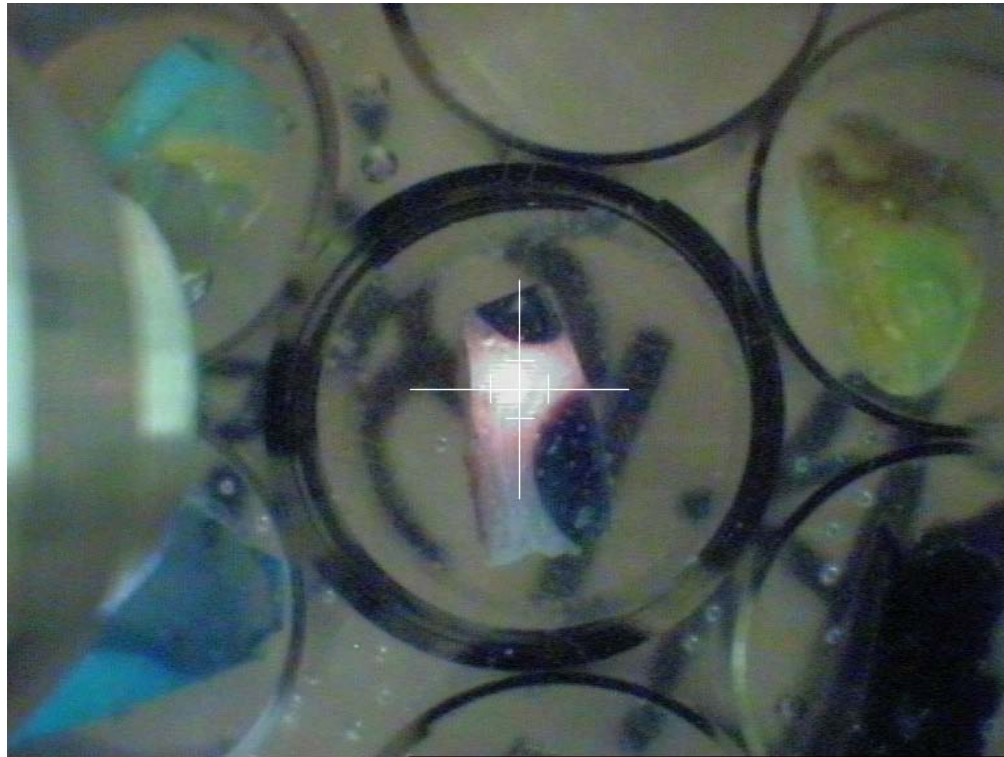
He purge  
streams from  
both X-ray tube  
and detector

Hellenistic glass object from Black sea region

No reasonable regions available for sampling



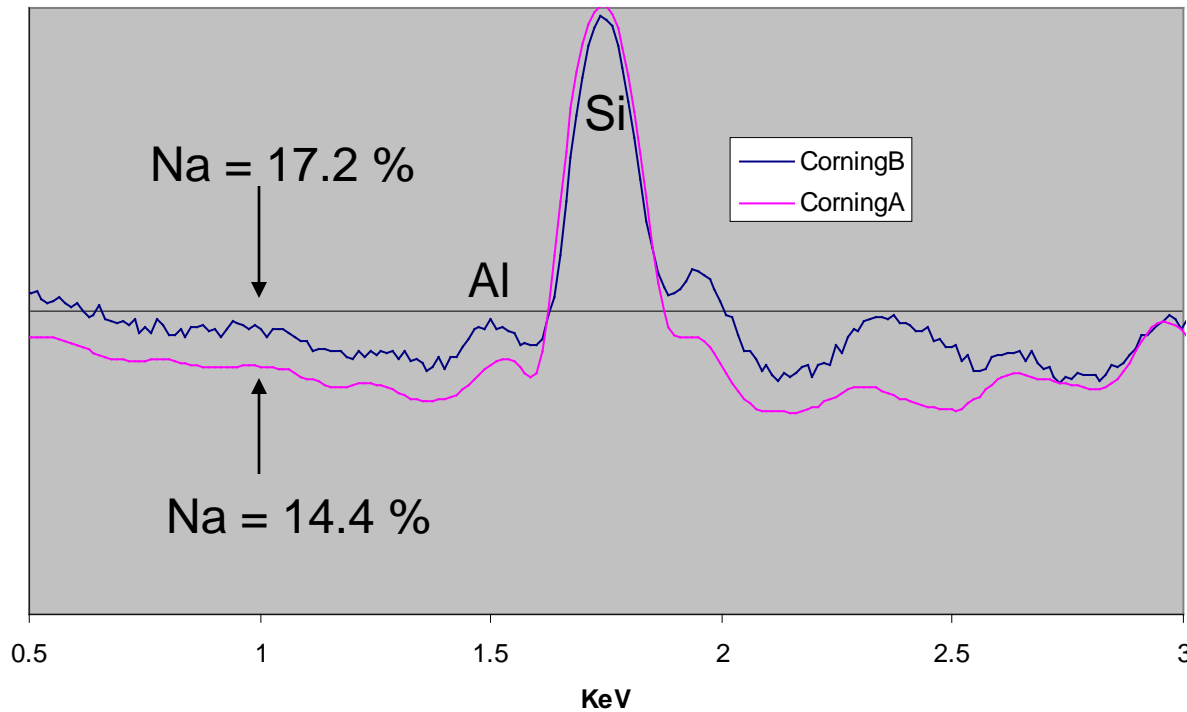
Can a reasonable analysis of glass be achieved by polycapillary XRF with He purge?



Test case: mounted and polished glass samples from Pinchnvari (black sea) already run by SEM/WDS.

Identical matrix to intact vessels that can't be sampled

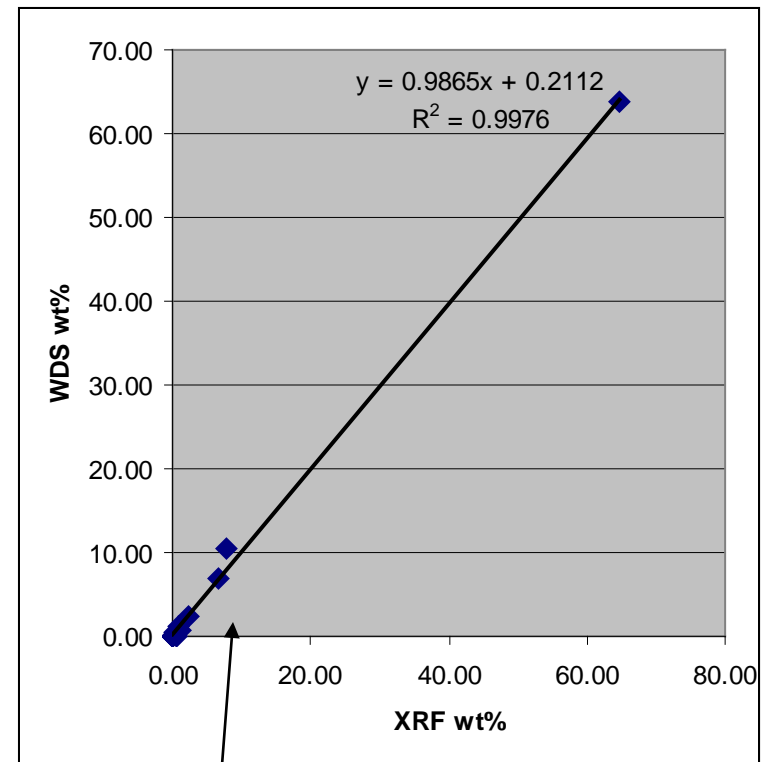
# Problem: Even with He purge poor response for low Z



Can't "see" major elements below Al

Poor correspondence  
in Na and Mg

	Pic16b XRF	WDS
Na <sub>2</sub> O	1.86	12.44
MgO	0.01	0.44
Al <sub>2</sub> O <sub>3</sub>	2.45	2.27
SiO <sub>2</sub>	64.69	63.73
K <sub>2</sub> O	0.36	0.51
CaO	6.76	6.92
TiO <sub>2</sub>	0.06	0.06
MnO	0.02	0.03
Fe <sub>2</sub> O <sub>3</sub>	1.14	0.79
CoO	0.01	0.00
CuO	0.02	0.03
SnO <sub>2</sub>	0.60	0.02
Sb <sub>2</sub> O <sub>3</sub>	0.77	1.10
PbO	7.69	10.50



Above Mg, good linear response  
between XRF wt% and WDS wt%  
values!

Quantification based on empirical calibration curve

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