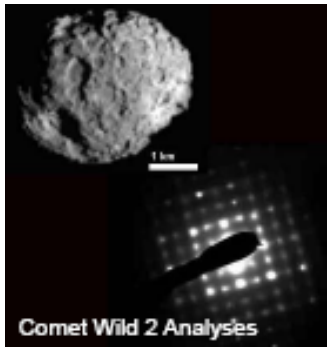
The Fine Detail of Comet Wild 2: TEM and Synchrotron Characterisation



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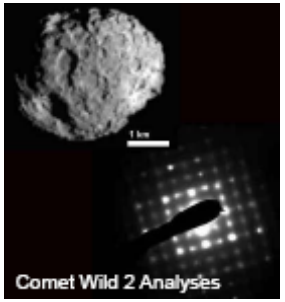


Oxide Minerals in Wild 2

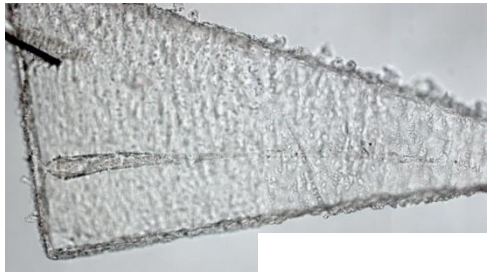
- Sample return from short period Comet Wild2, 2006-
- Identify and characterise oxide minerals in Wild2
  - How common are they in the samples?
  - Capture related oxidation?
  - High temperature e.g. Fe-Cr-V-Ti oxides?
  - Other origins - low temperature hydrothermal, space weathering?
  - *Compare this short period comet to chondrites, Interplanetary Dust Particles (IDPs)*

Samples: Tracks 41, 121, 134

- Track 41 type B 'turnip'

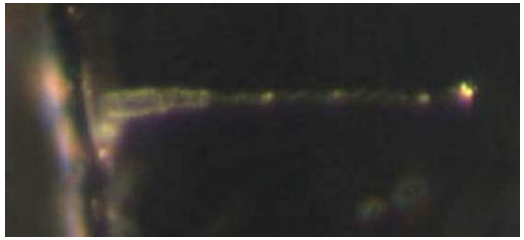
Track length 4 mm, slice 0.8 mm from entrance

- Track 134 type A 'carrot'
  - No previous analyses



Track length 0.4 mm

- Track 121 type A 'carrot'
  - ferric oxide (Hematite) – microRaman Foster et al. LPSC XXXIX,
  Mg-silicates Bridges et al. LPSC XXXIX

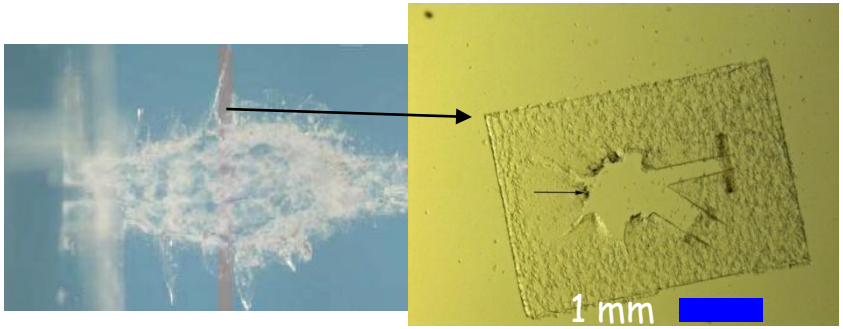


Track length 0.9 mm

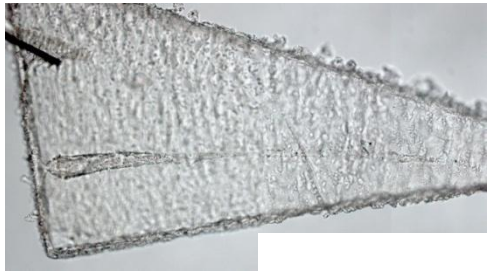
Samples: Tracks 41, 121, 134

- Track 41

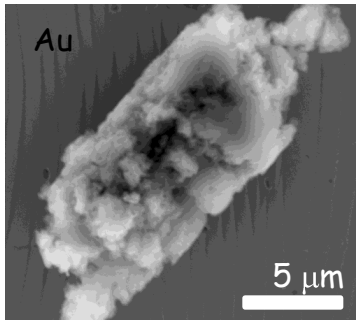
  Grossemy et al. 2008 predict near entrance samples will show some oxidation

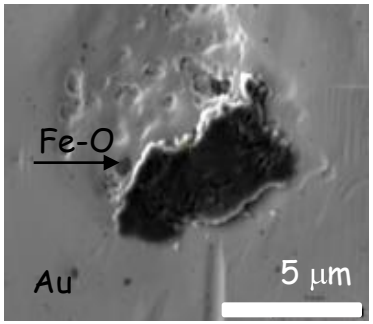


- Track 134
  - No previous analyses



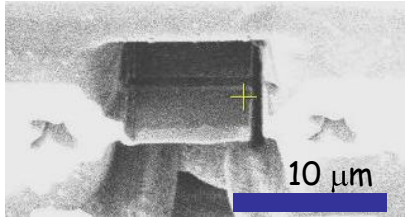
- Track 121
  - Terminal area slices on Au mounts

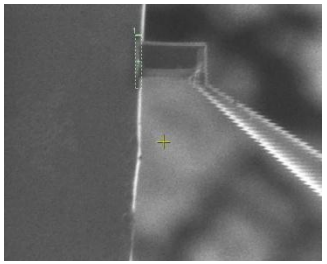




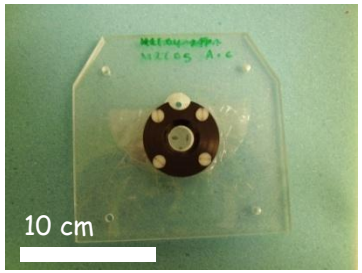
Techniques 1: FIB-SEM, TEM

- FIB-SEM extraction of Fe oxide from track 121 material on Au mounts
  - Quanta 200 3D, Omniprobe, 100 nm wafers on Cu grid (Changela & Bridges, LPSC XXXX; Bridges et al. MAPS 2009)
- TEM Jeol 2100
  - LaB_6, 200 kV
  - Selected Area Diffraction, STEM, EDS
  - Microtome sections (NASA-JSC), FIB-SEM sections (U. Leicester)





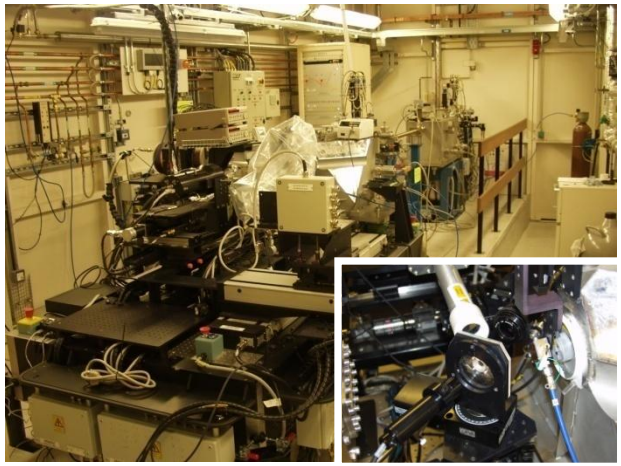
Techniques 2: Synchrotron



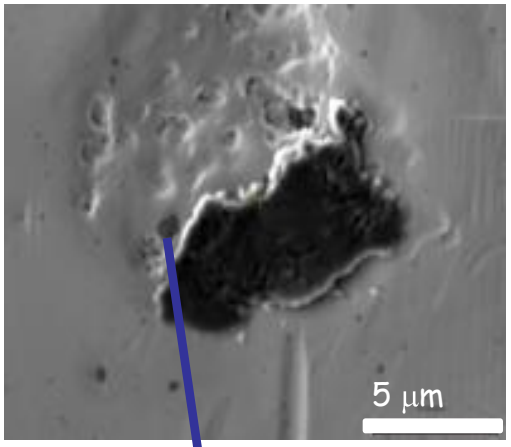
Sample mount

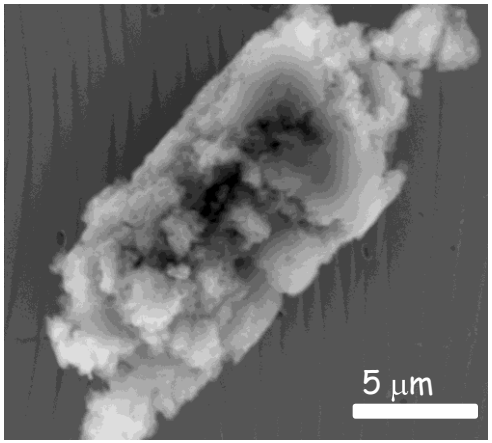
- Diamond Light Source, UK
- 3 GeV, 200 mA
  - Beamline I18, nine element Ge detector (detect Ca upwards), monochromated, 13 keV range, $\Delta E/E$ 10^{-4} – 10^{-5}
- Fe Kα XANES (& EXAFS)
  - Energy steps 0.2-0.4 eV, 6962-7500 eV
  - Mineral standards Fe, hematite, magnetite, goethite, pyrrhotite, olivine
- XRS
  - 4 μm step size, 500s spot analyses
  - 250 μm x 250 μm maps

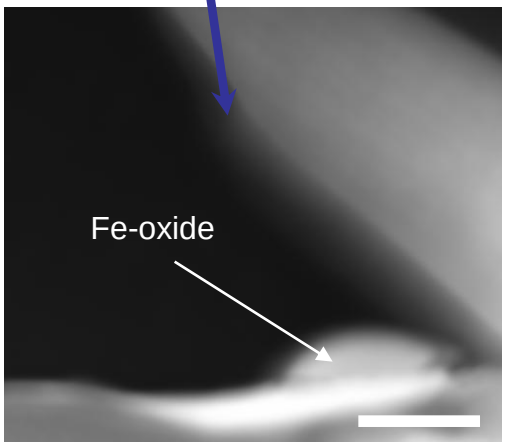
Beamline I18



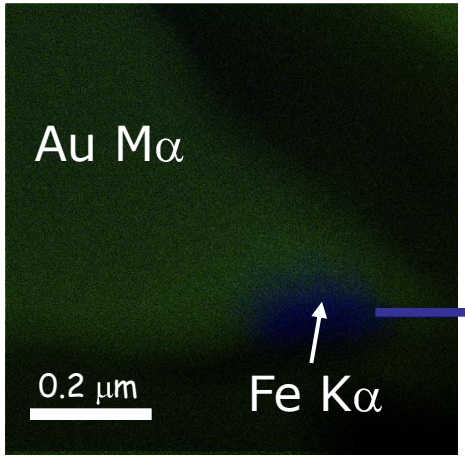
Track 121 Terminal Area TEM



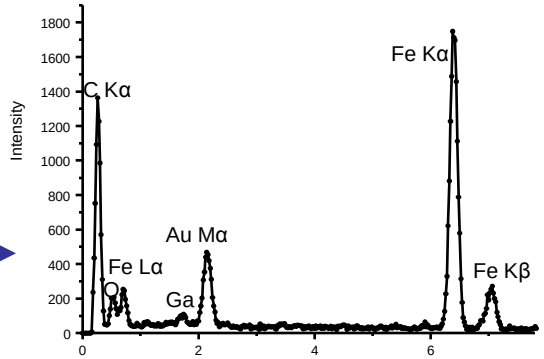




STEM image



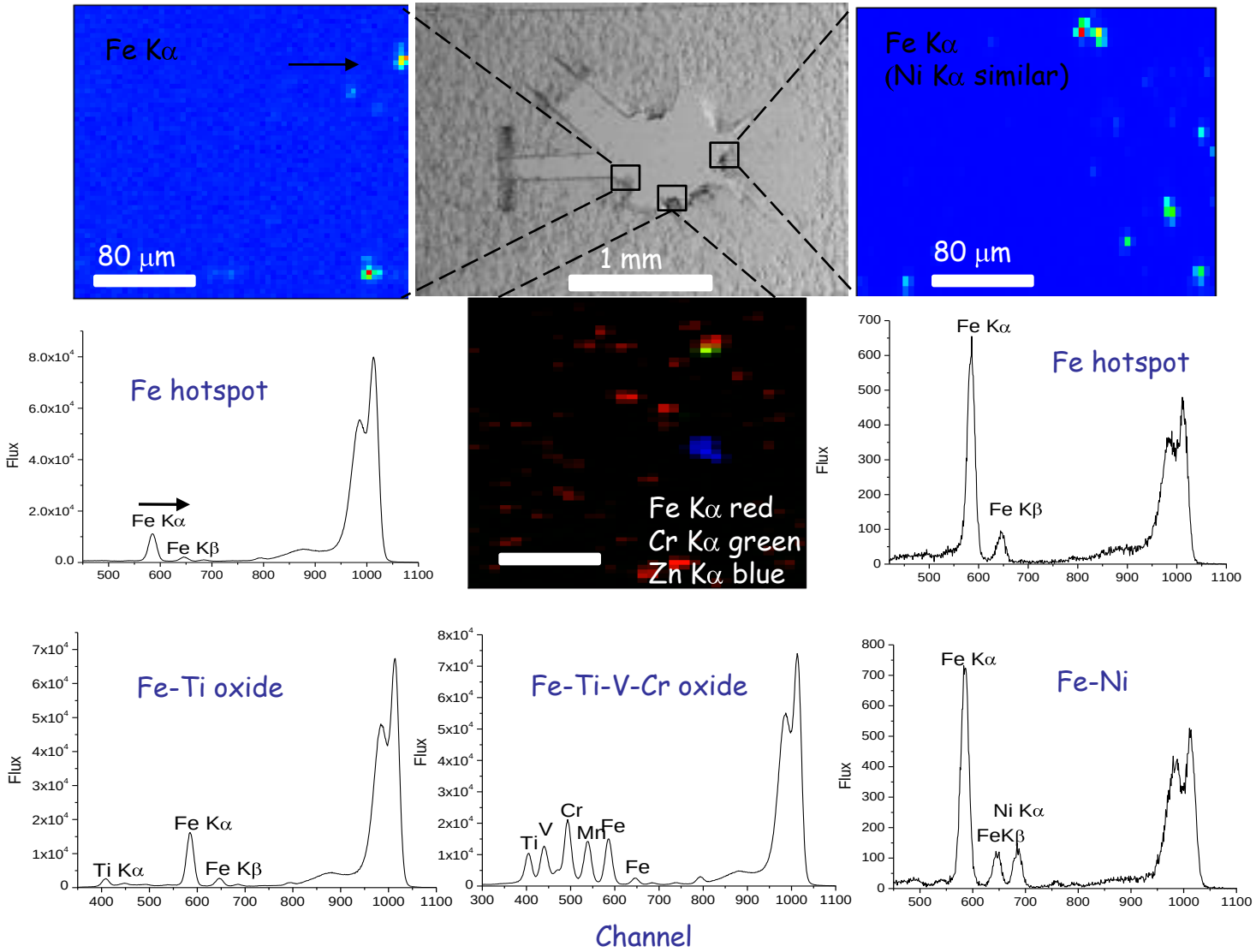
EDS Mapping



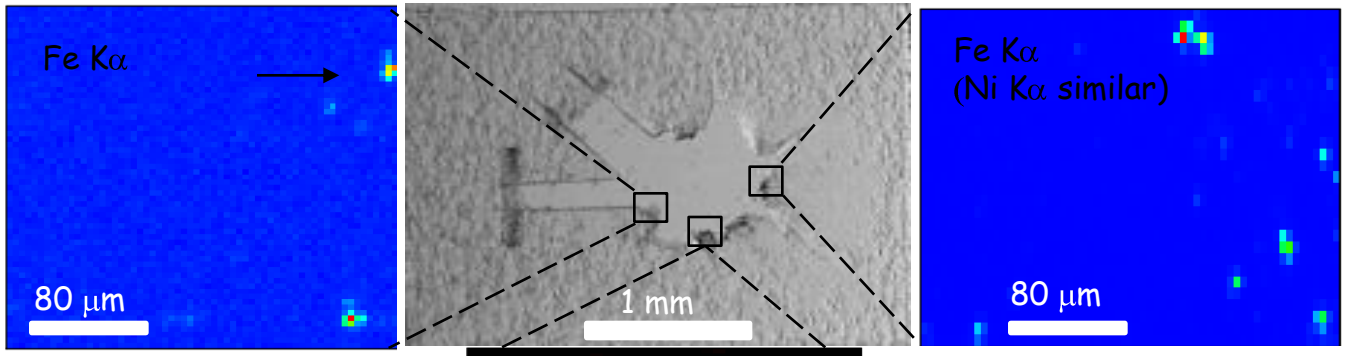
Energy KeV

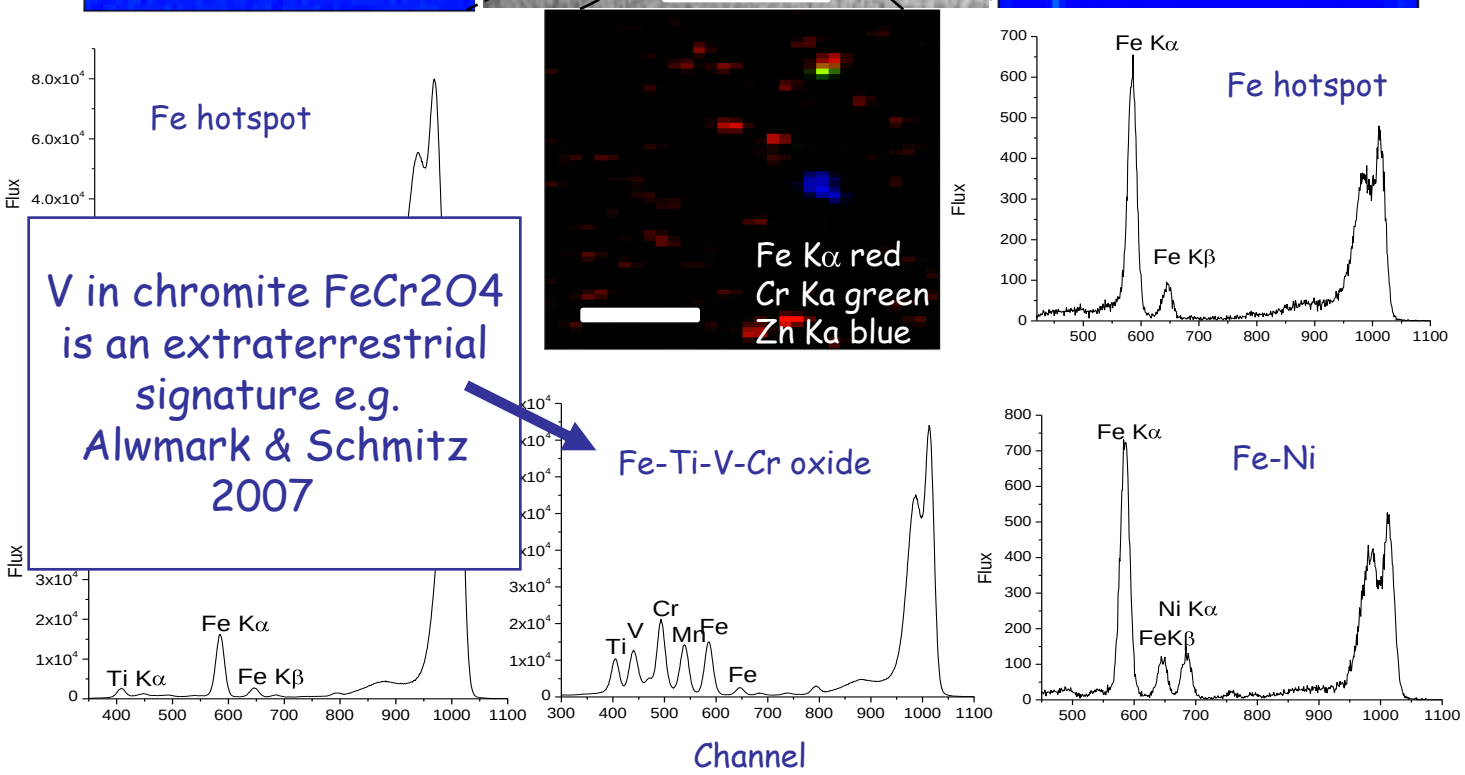
•No electron diffraction - amorphous

Track 41 slice XRS maps and spectra



Track 41 slice XRS maps and spectra

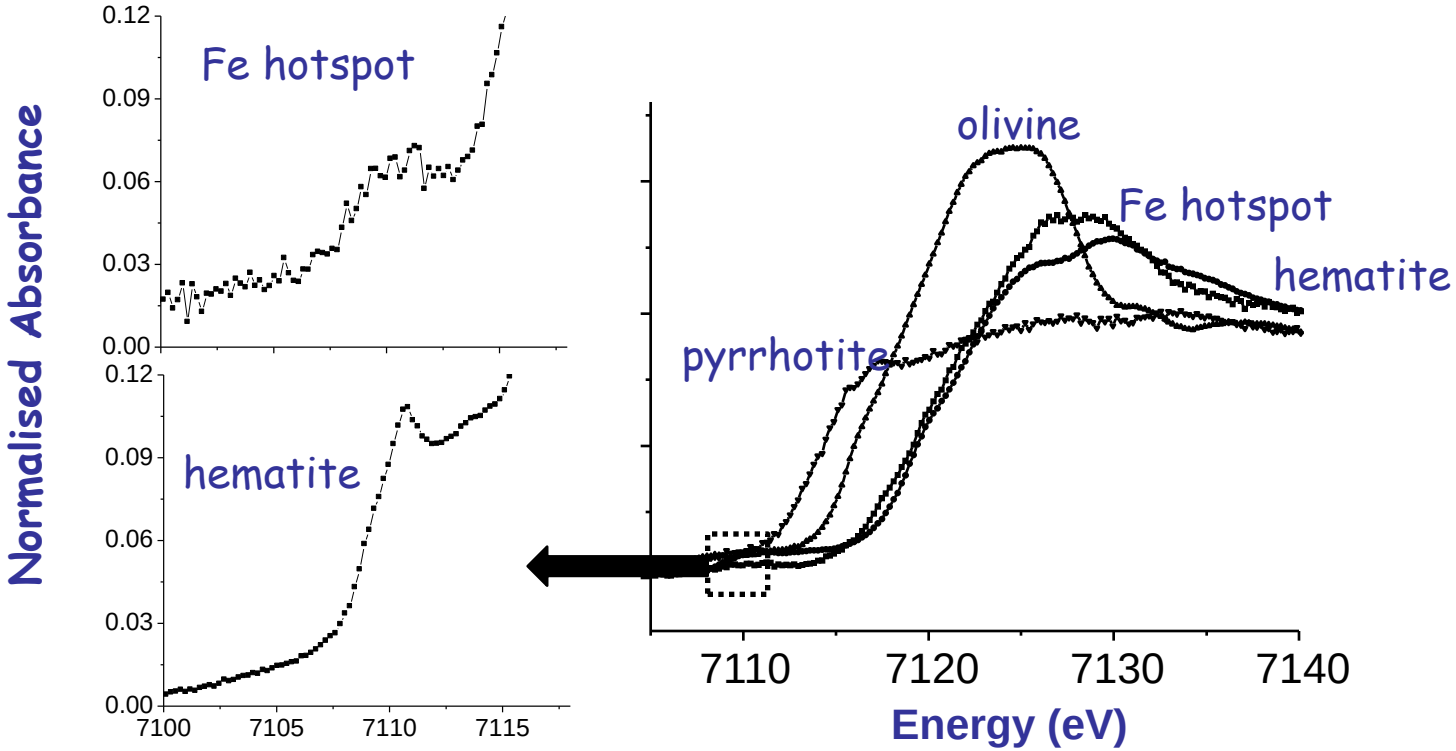




V in chromite FeCr2O4 is an extraterrestrial signature e.g. Alwmark & Schmitz 2007

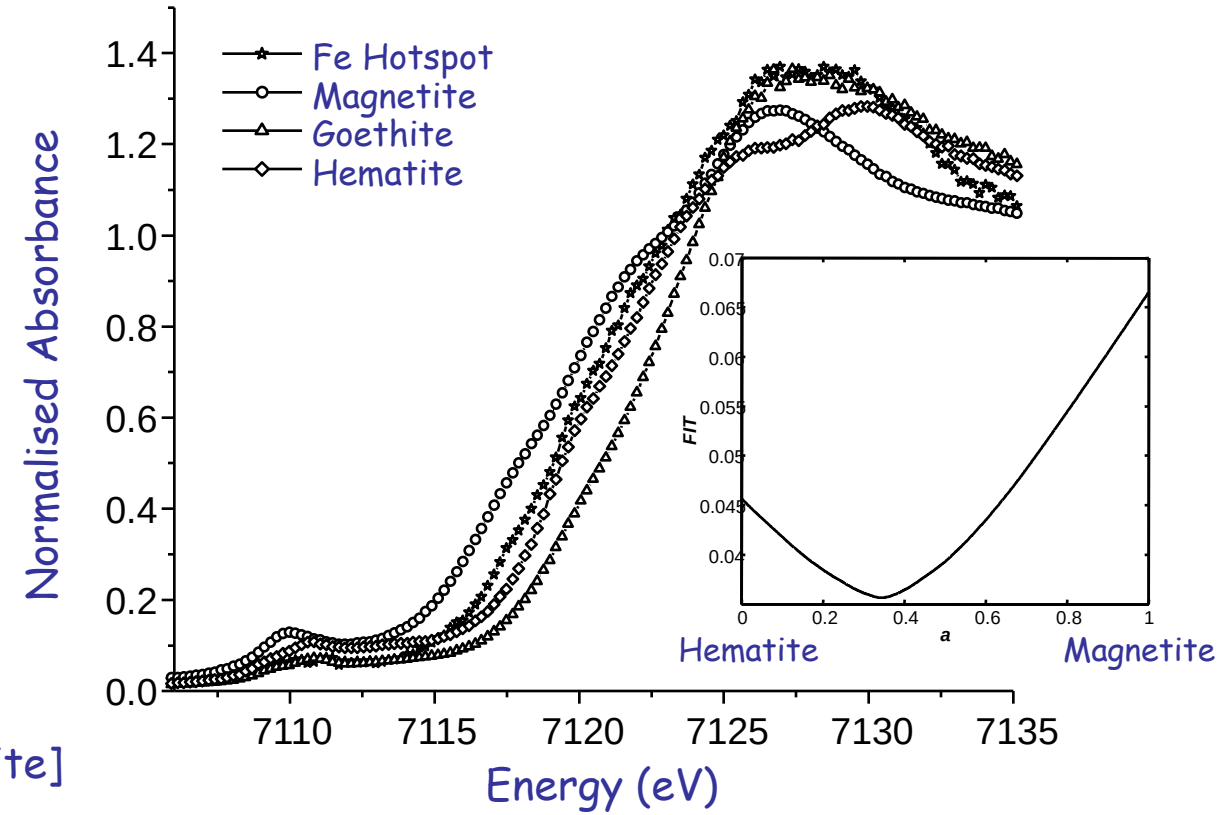
Track 41 slice Fe-XANES

- Pre edge feature 7111 eV shows presence of Fe^{3+}



Track 41 slice Fe-XANES

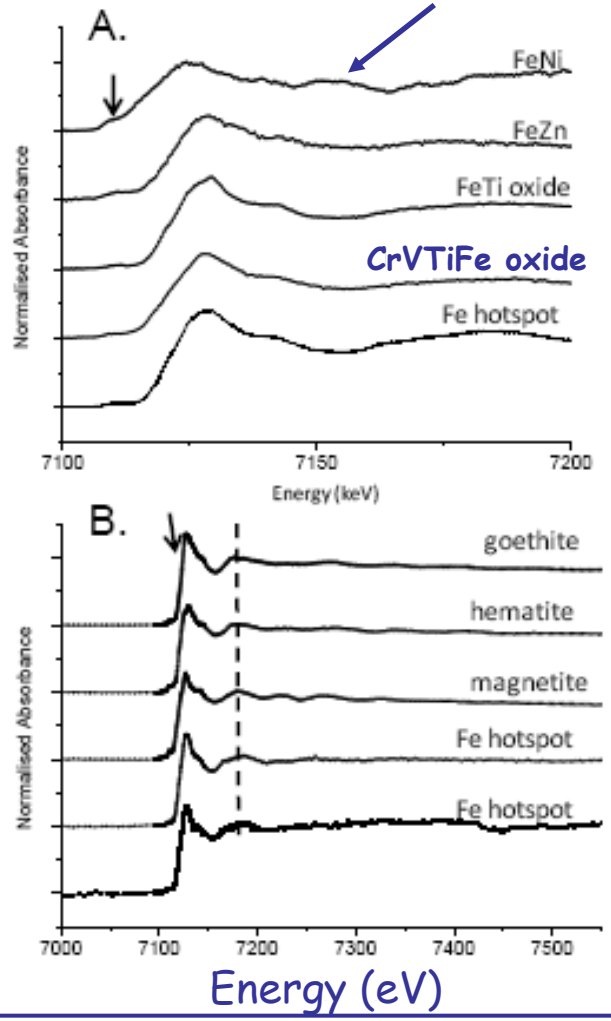
- Best fit magnetite 38%, hematite 62%



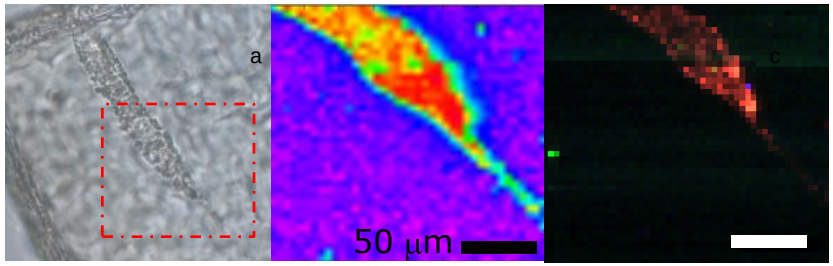
Fit: Fe –[(1-a)magnetite +a.hematite]

Track 41 Fe-XANES

- FeNi has an absorbance feature at 7160 eV Characteristic of metal (Pingitore et al. 2002)
- Absorbance features A, 7110-7112 eV and dashed line show presence of Fe^{3+}
- FeNi has been partially oxidised



Track 134 - XRS



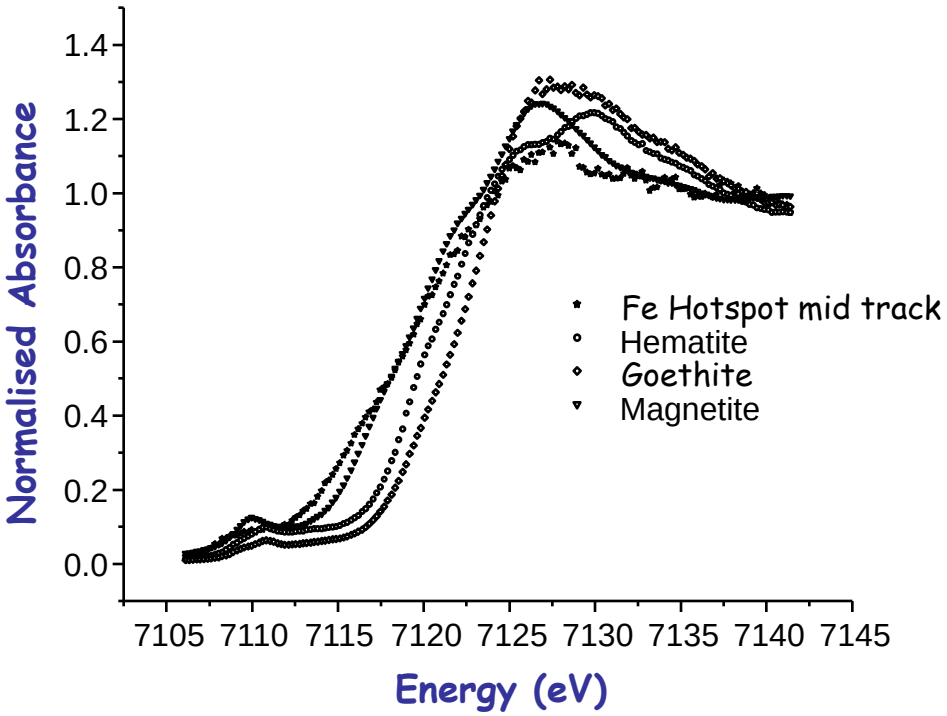
Fe Kα

4 μm pixels

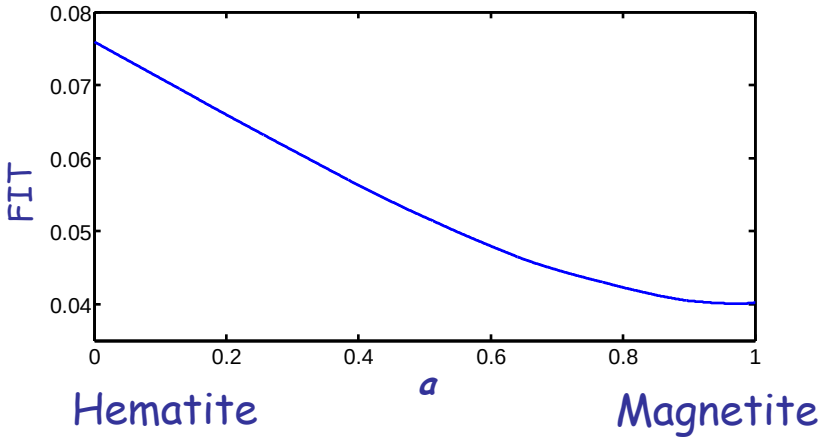
Red (Fe Kα)
Green (Ni Kα)
Blue (Ca Kα)

- Fe-Ni grains mid track
- Fe hotspots concentrated towards terminal end
- Terminal Grain Fe-S

Track 134 – mid track Fe oxide

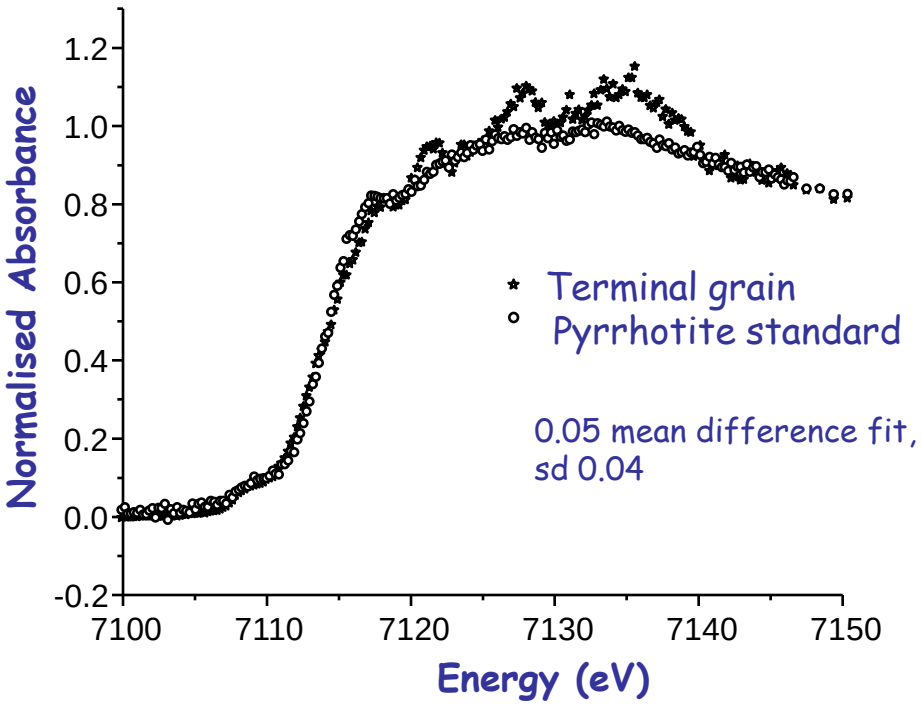


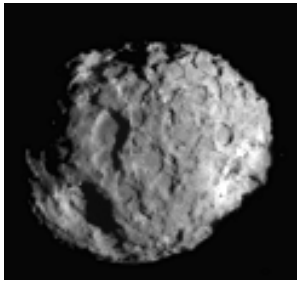
- Best fit to standards:
95% magnetite, 5% hematite



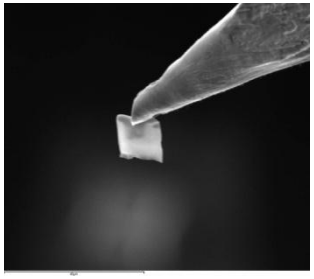
Track 134 Terminal Grain

- Fe XANES
- Close fit to pyrrhotite standard over XANES, Fe K near edge region





Conclusions



- XANES, TEM shows that Fe-bearing oxides are common in Comet Wild2 samples (e.g. in each of tracks 41, 121, 134) and have a variety of origins
  - FeNi metal partially oxidised (Fe3+) during capture e.g. track 41 slice (near entrance) shown by Fe-XANES near edge structure
  - Hematite-magnetite grains vary in proportion between the 2 minerals 5-68%
  - Wild2 has an intermixed variety of oxidation states e.g. chromite, magnetite and FeNi metal, pyrrhotite (FeS) co-exist in same samples reminiscent of chondrites (Bridges et al. 2009, MAPS)
    - Next stage compare directly to chondrite groups…