The properties of silicates in the interstellar medium

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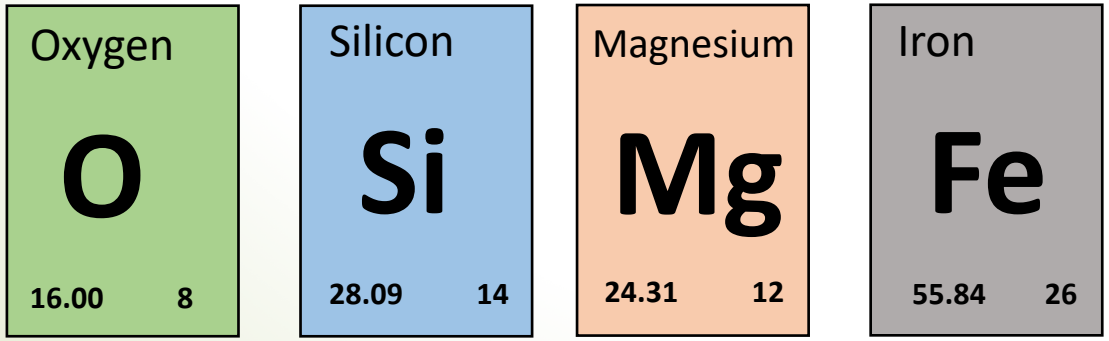
SRON
Netherlands Institute for Space Research www.sron.nl

ASIAA

Sterrewacht Leiden

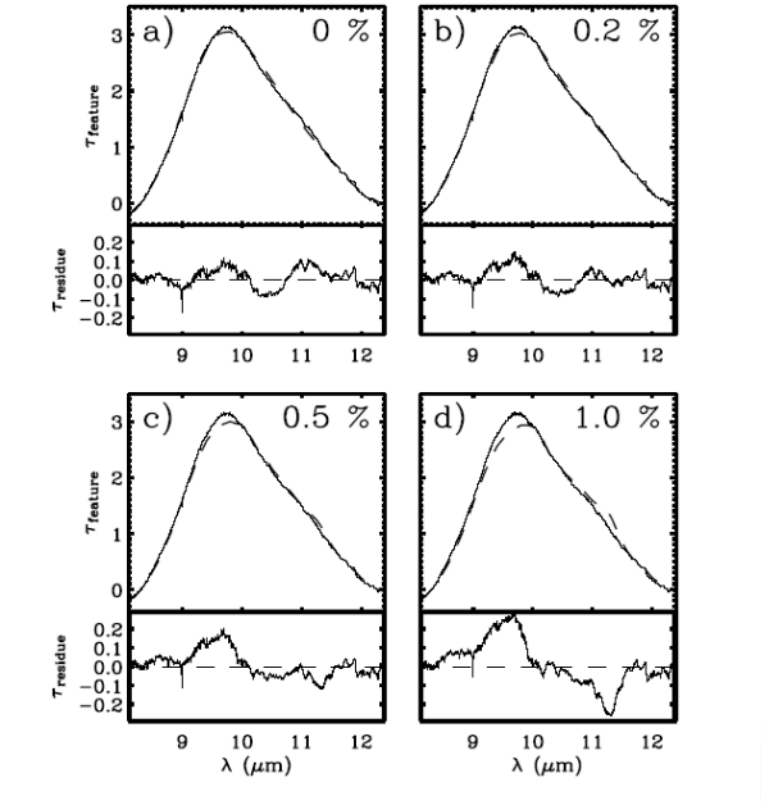
What we think we know about silicates in the ISM …

Main composition: Si, O, Mg and Fe
olivine and/or pyroxene silicates with smaller quantities of silicon oxides and SiC
Exact composition is still uncertain!

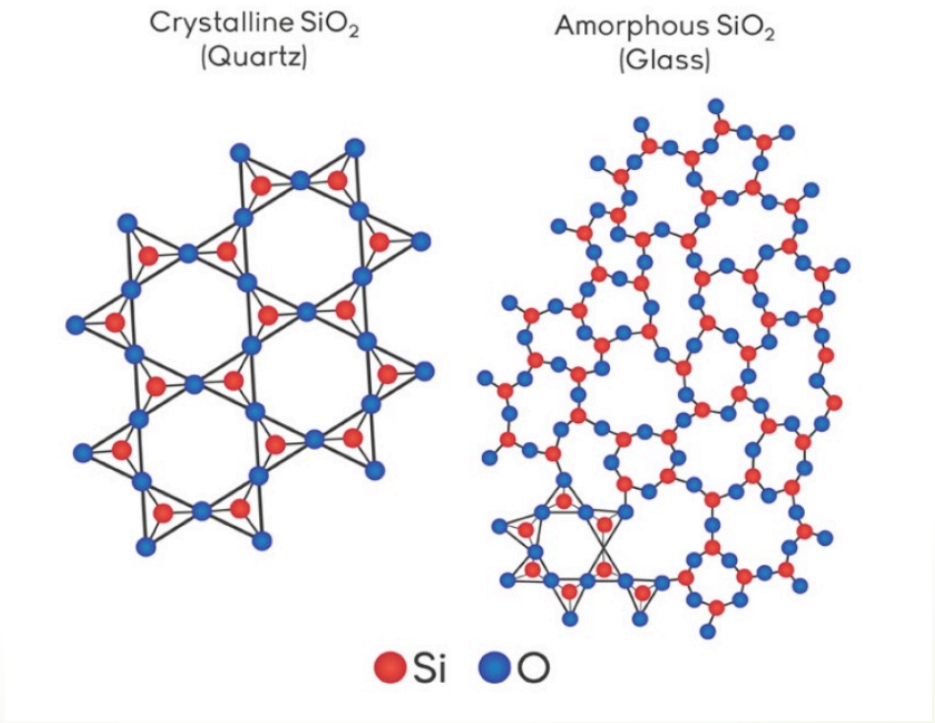


What we think we know about silicates in the ISM …

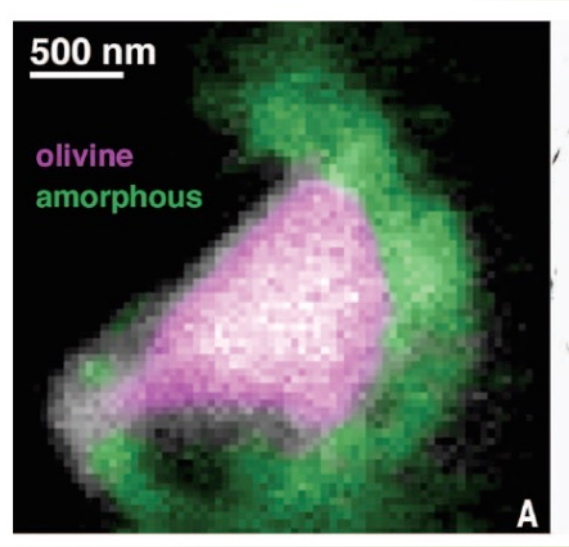
- Silicate dust in the Galaxy is mainly amorphous
  Formation process uncertain, contradiction with X-rays



Kemper et al. 2004



NDT Resource Center, Center for NDE, Ioawa State University

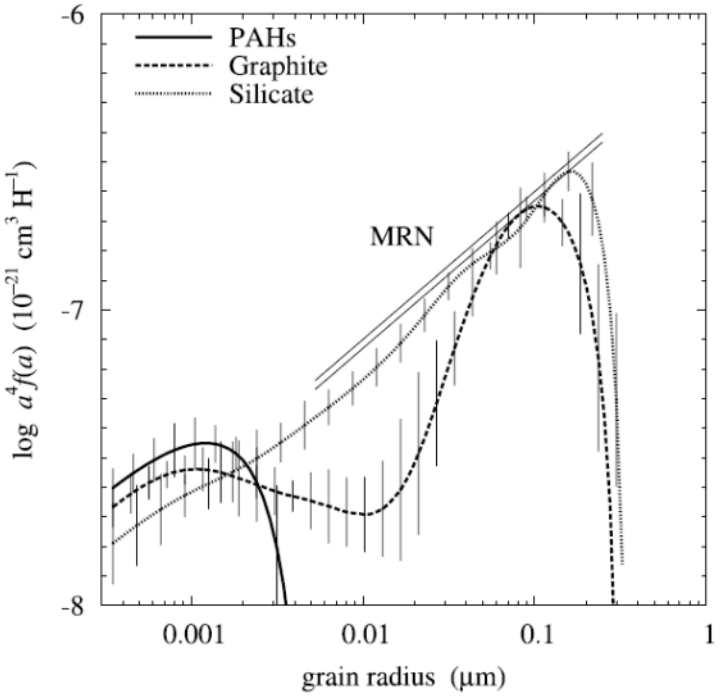


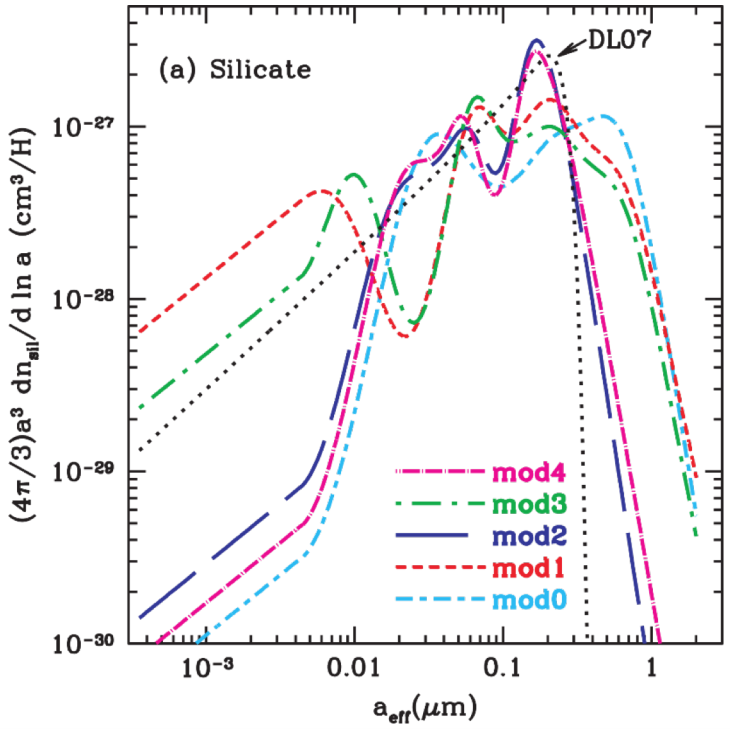
Westphal et al. 2014

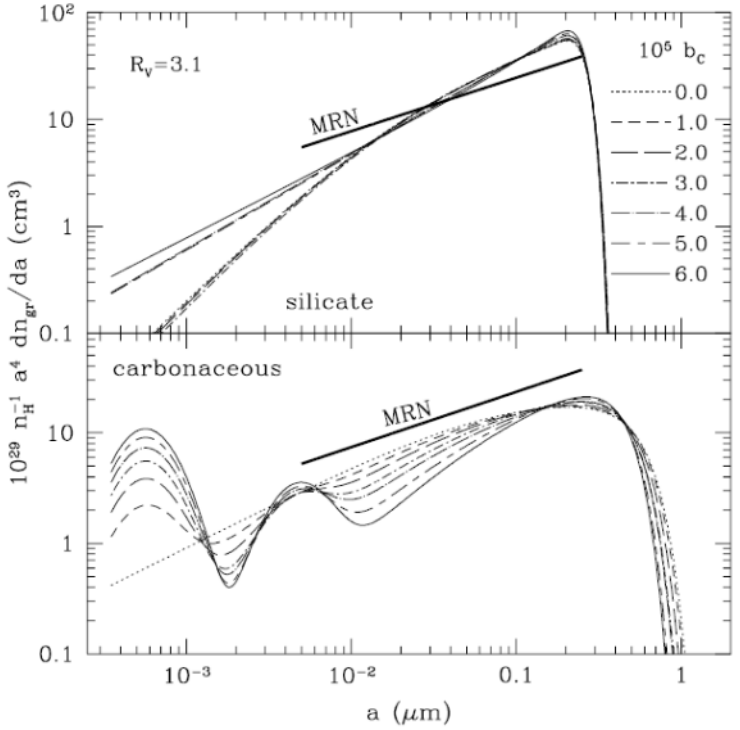
What we think we know about silicates in the ISM …

The sizes of the dust particles range from small molecular size to micron size dust

Many different size distribution models







Zubko et al. 2004, Mathis 1977 et al.

Draine & Fraisse 2009

Weingartner & Draine 2001

New perspectives on interstellar silicates from the X-rays and the infrared

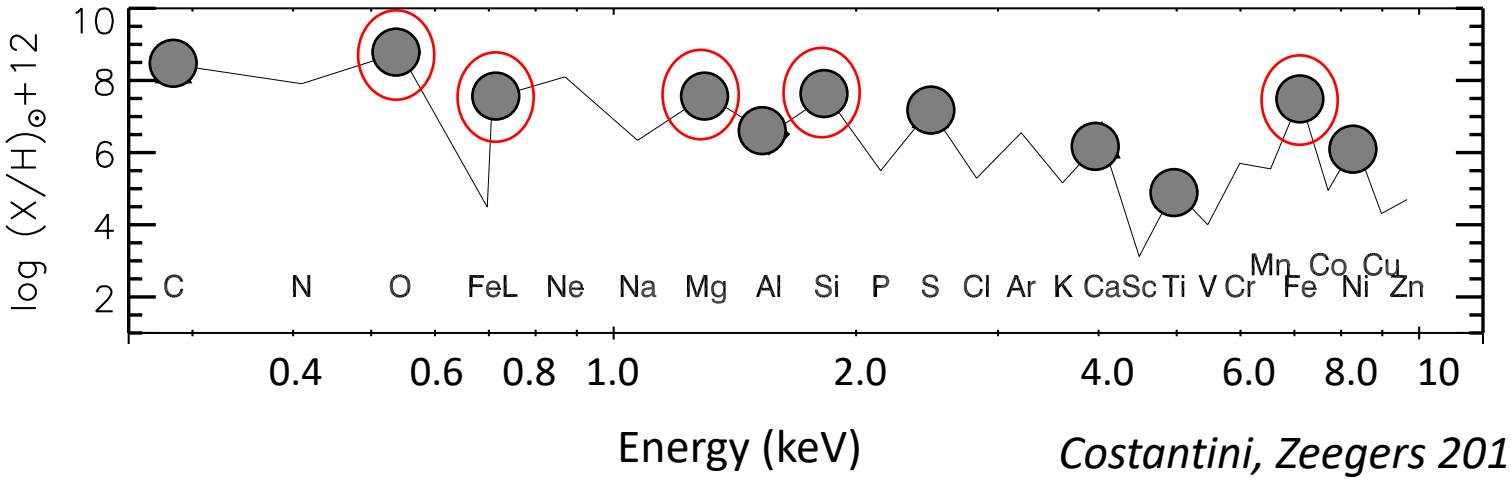
From the X-rays

- Composition of dust from X-ray spectroscopy
- New perspective on crystallinity
- Particle size distributions

From the infrared

- Properties of small grains in the ISM

What can we study in the X-rays?

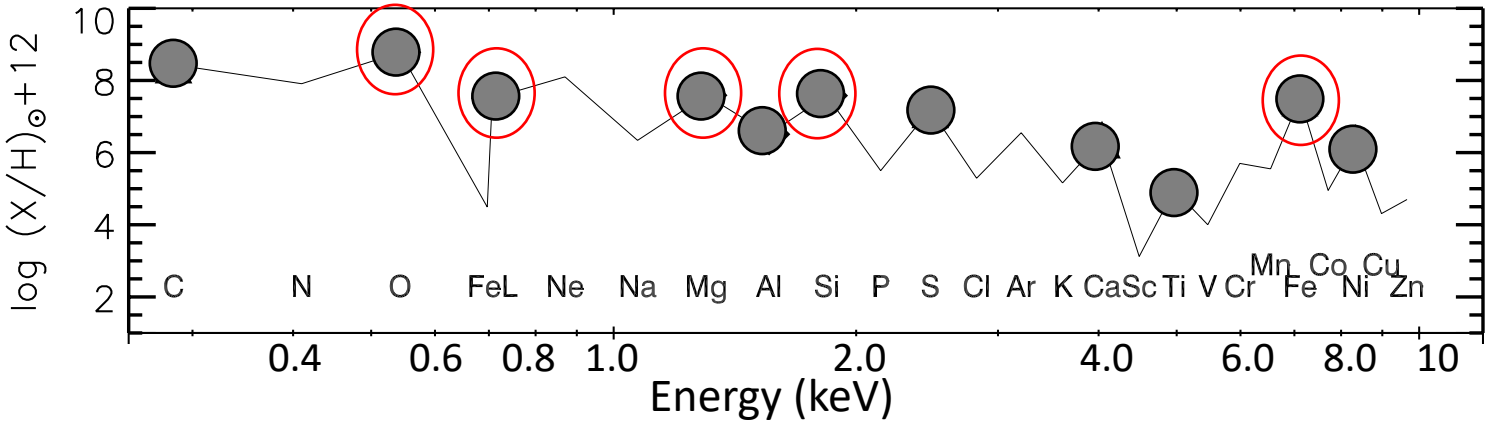


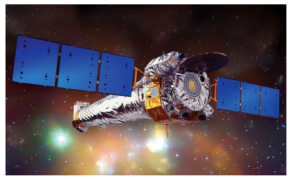
Costantini, Zeegers 2019

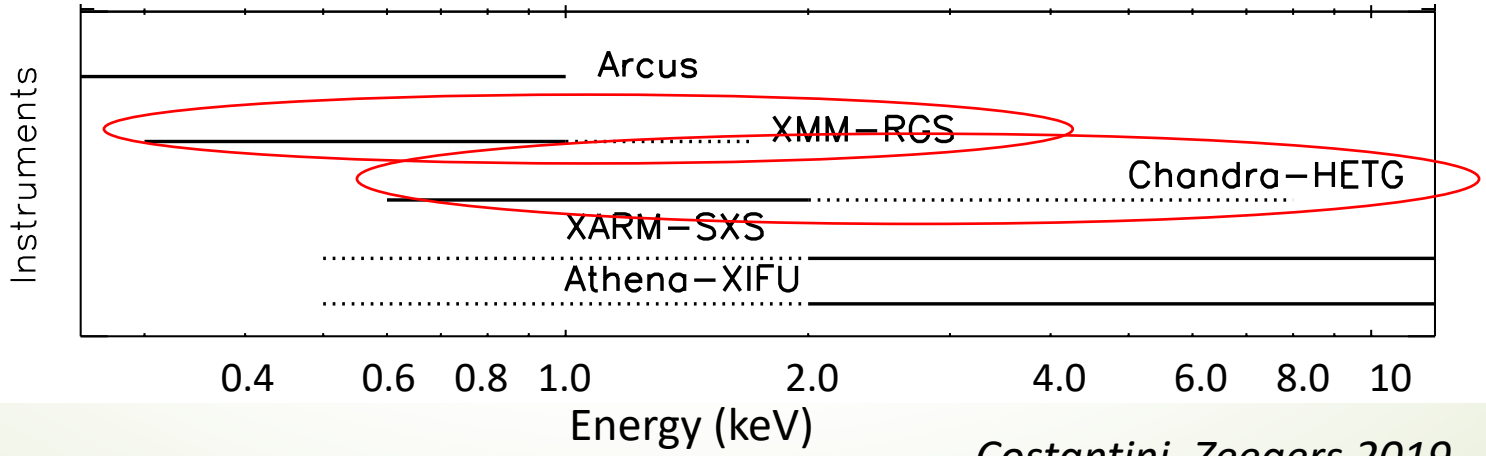
Observe absorption features in the soft X-rays of O, Mg, Si and Fe

Perfect for **Silicates!**

What can we study in the X-rays







Costantini, Zeegers 2019

Observing dust in the X-rays

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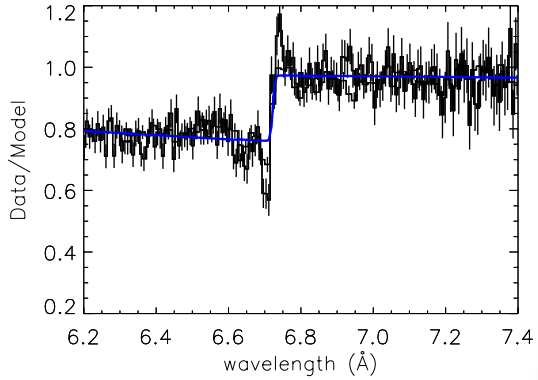
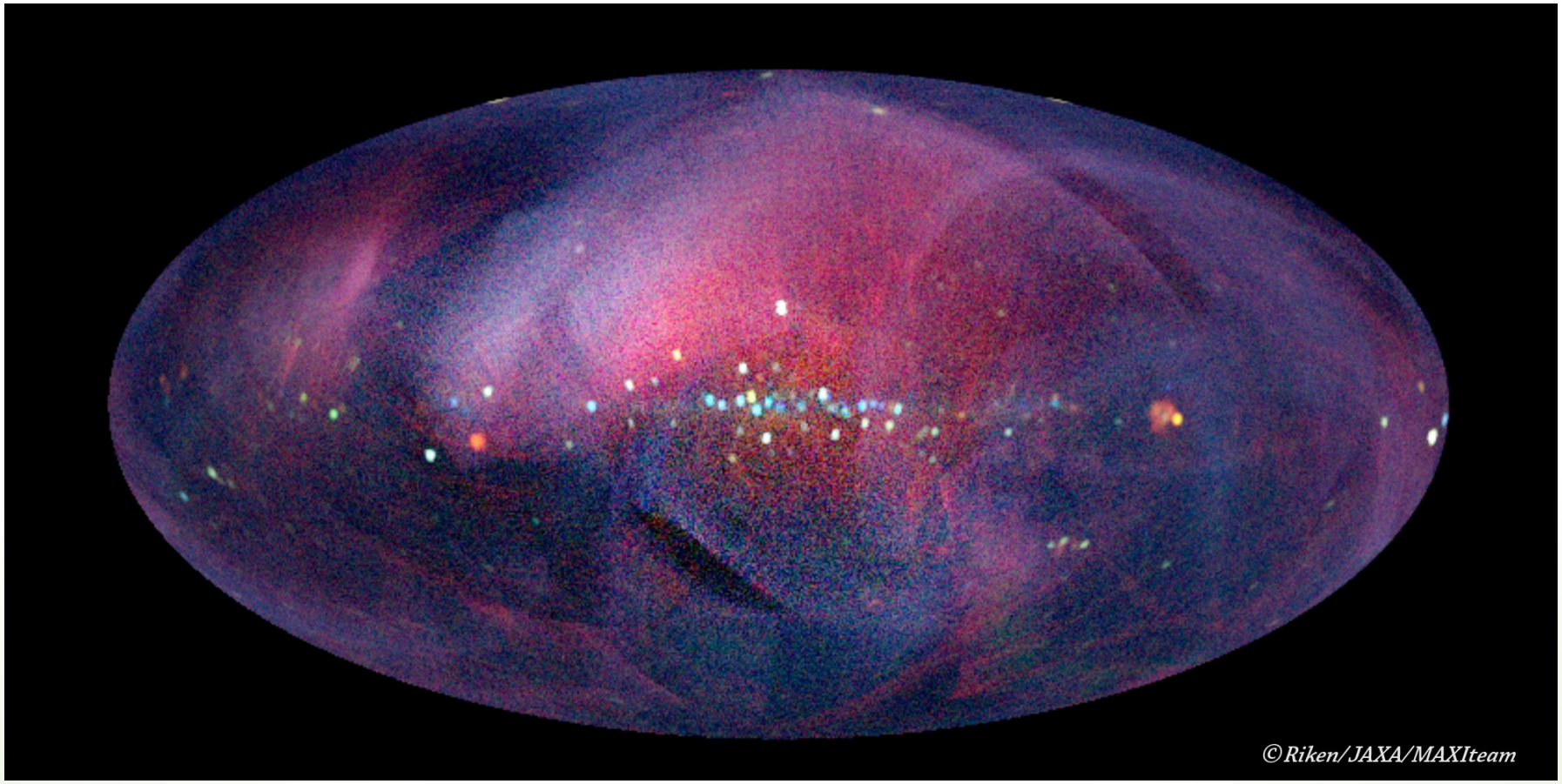


e.g. Lee 05,09 Costantini 12, Pinto 10,13, Corrales 16, Zeegers 17

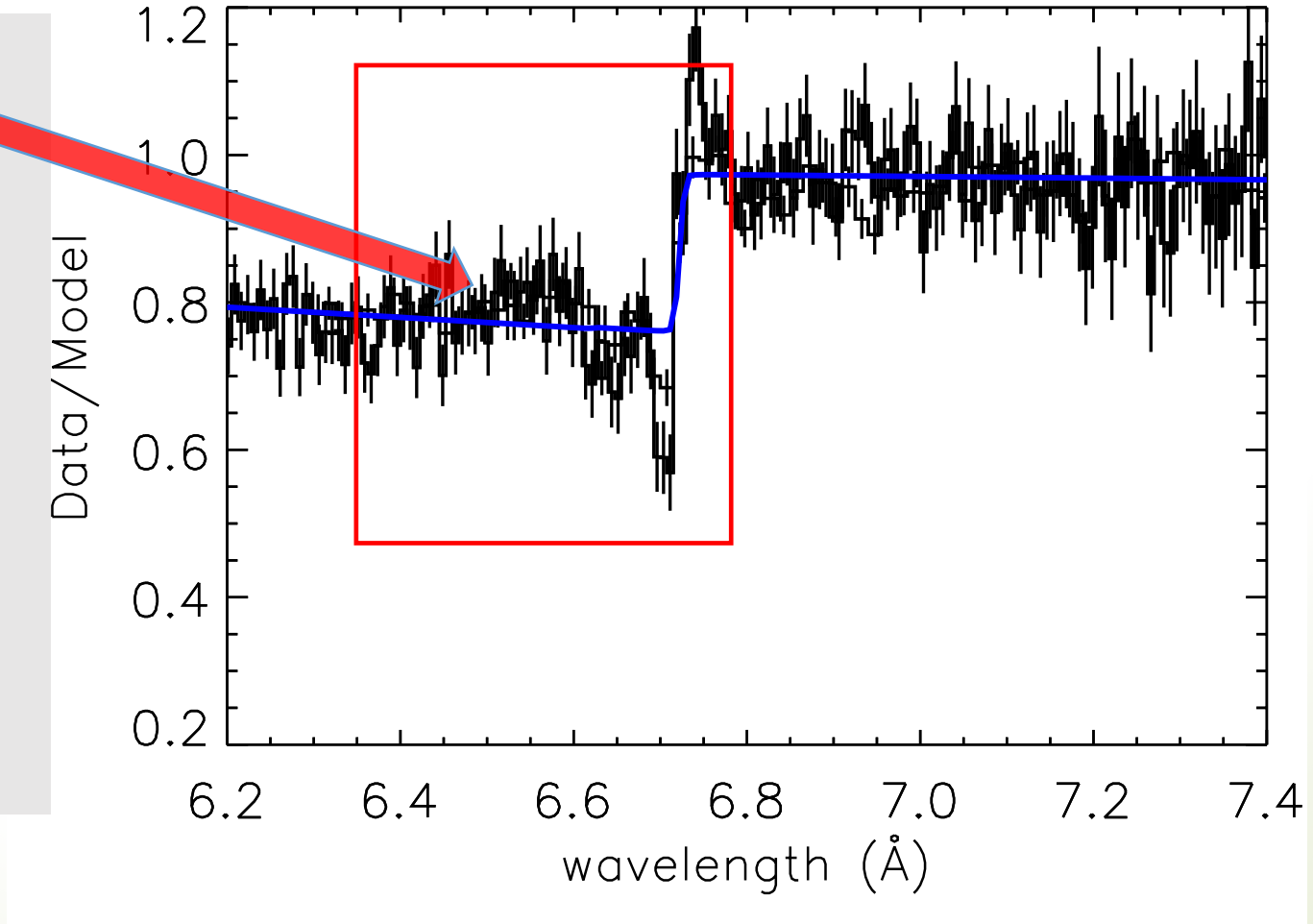
Sightlines towards the Galactic Plane



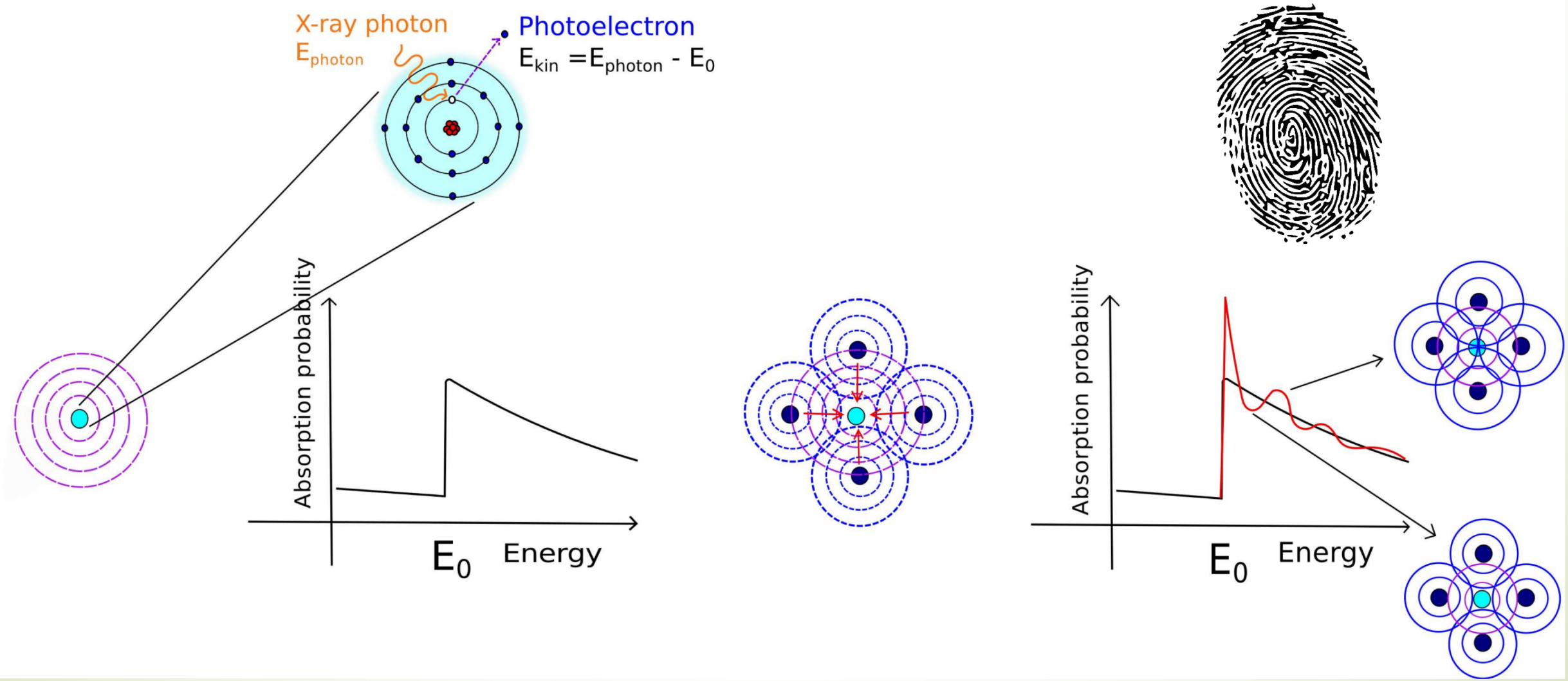
We can probe different lines of sight along the Galactic Plane

Observing dust in the X-rays

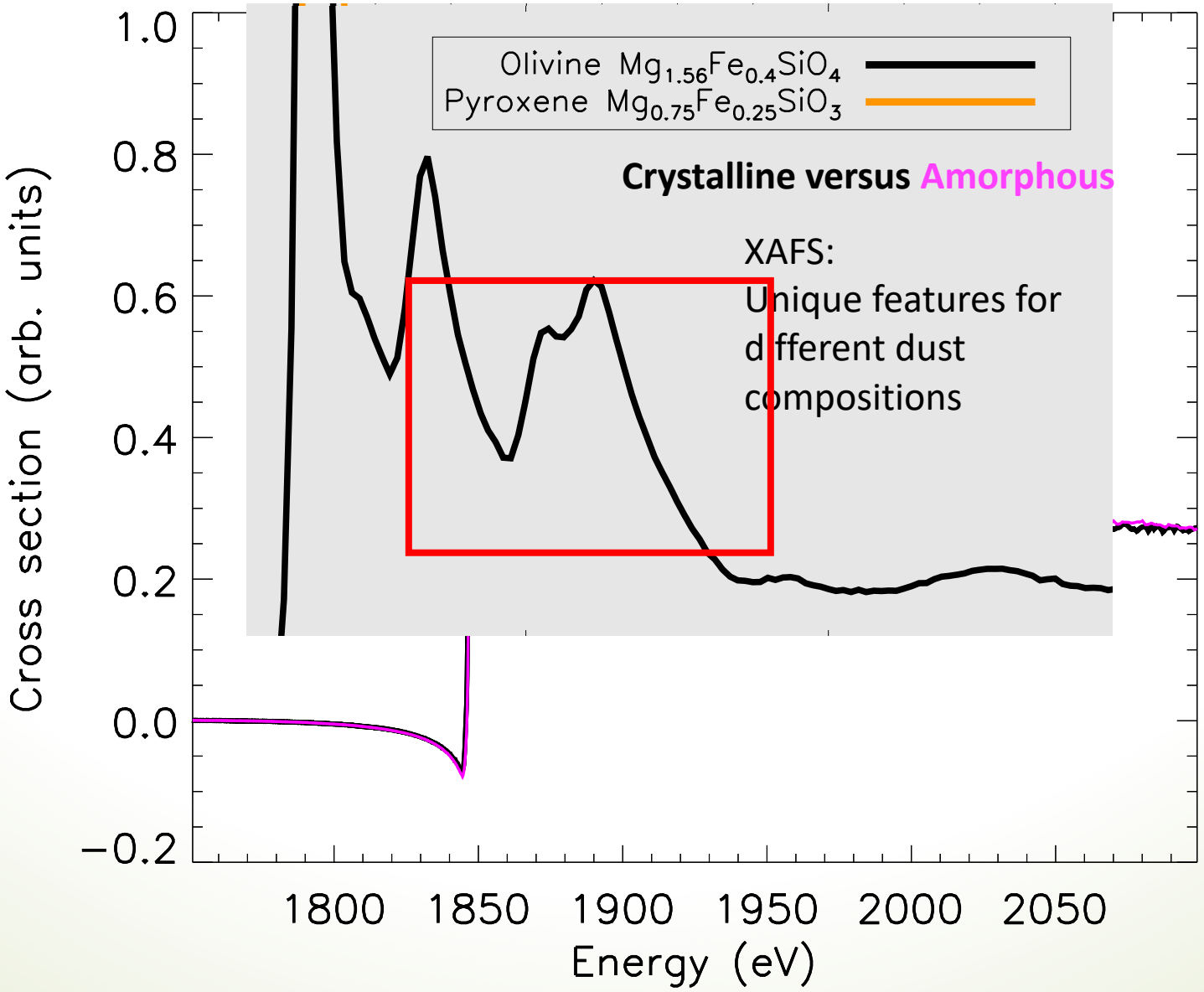
XAFS provide a unique fingerprint of Interstellar Dust



XAFS: X-ray absorption fine structure

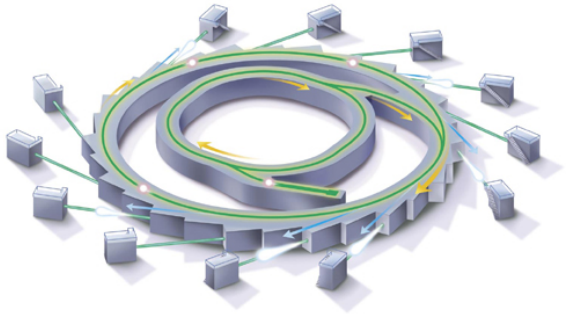


What can we learn from X-ray edges?



Laboratory dust campaign

Dust samples → Synchrotron measurements → Data analysis → Fitting Spectra



Natural or synthetized:
Olivines
Pyroxenes
Quartz types
(courtesy of H. Mutschke)

X-ray dust campaign

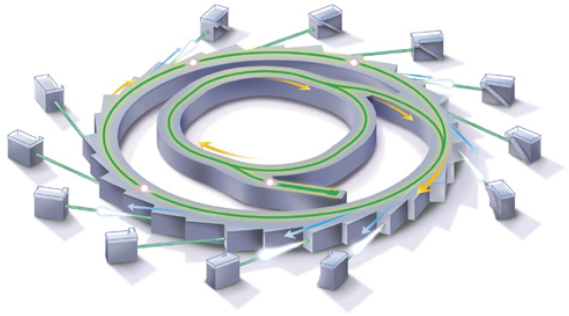
DUBBLE
Fe K at 7.11 keV

LUCIA
Mg K at 1.3 keV
Si K at 1.84 keV

Cadiz (TITAN)
O K at 0.543 keV
Fe L at 0.7 keV

Laboratory dust campaign

Dust samples → Synchrotron measurements → Data analysis → Fitting Spectra



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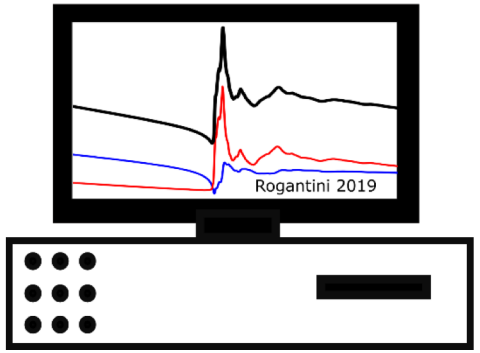


Conversion from lab absorption spectra to extinction models

Extinction curve

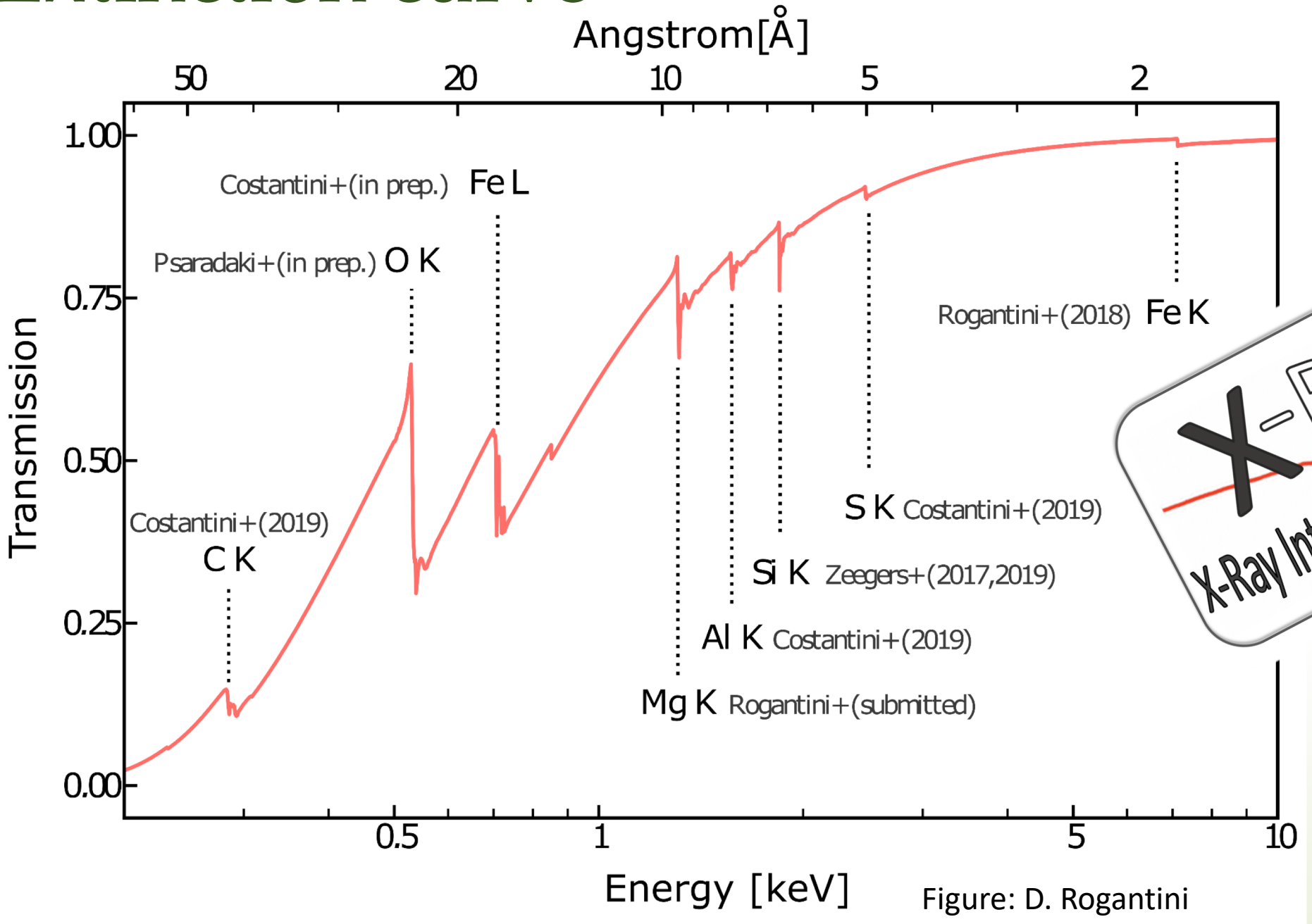
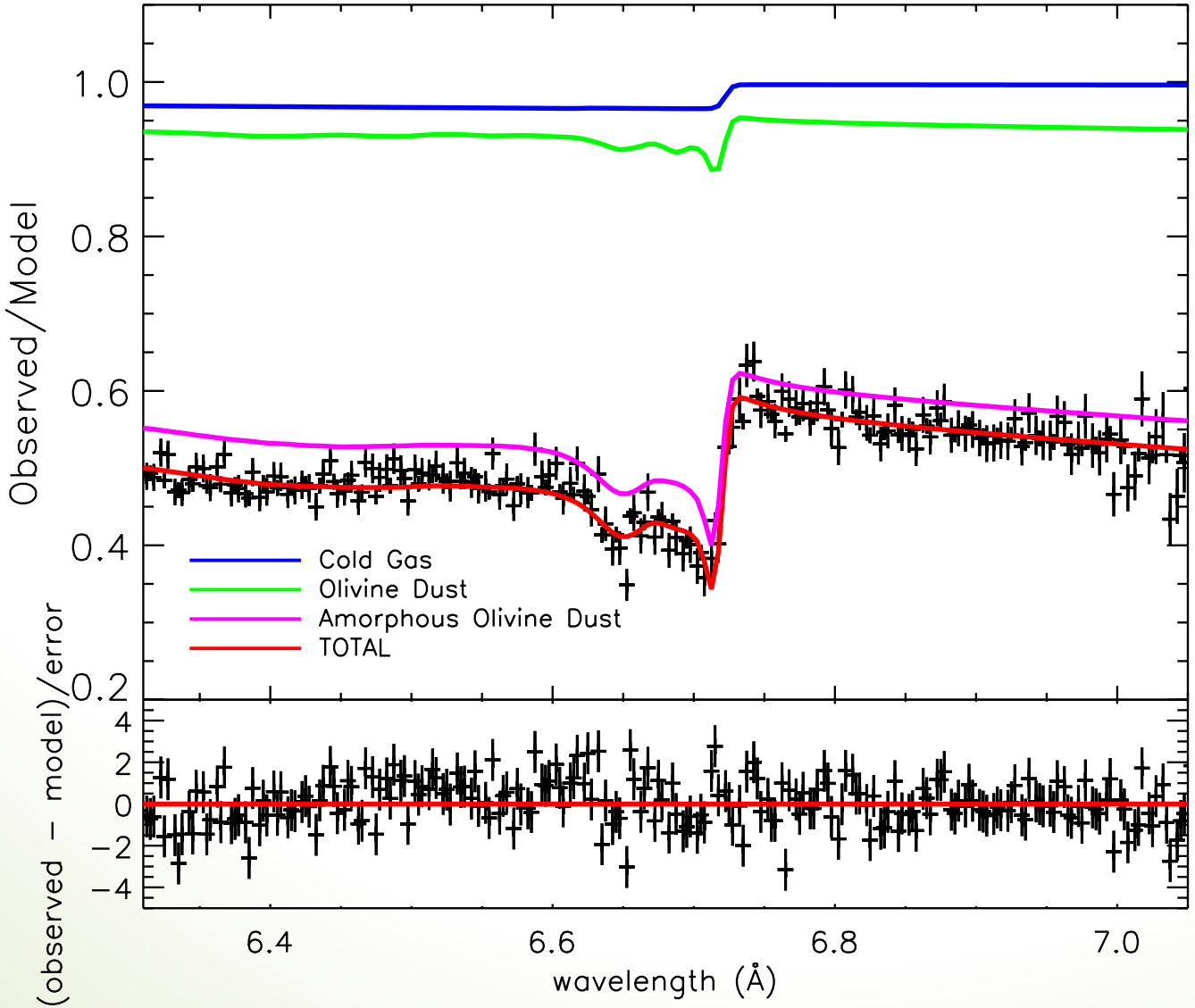


Figure: D. Rogantini

Analyzing the Si K-edge with:
9 Sources (Chandra)
14 dust samples

GX 5-1



Best fit:

Mix of amorphous Olivine

($[Mg_{0.5}Fe_{0.5}]_2SiO_4$)

and

Crystalline Olivine

($Mg_{1.56}Fe_{0.4}Si_{0.91}O_4$)

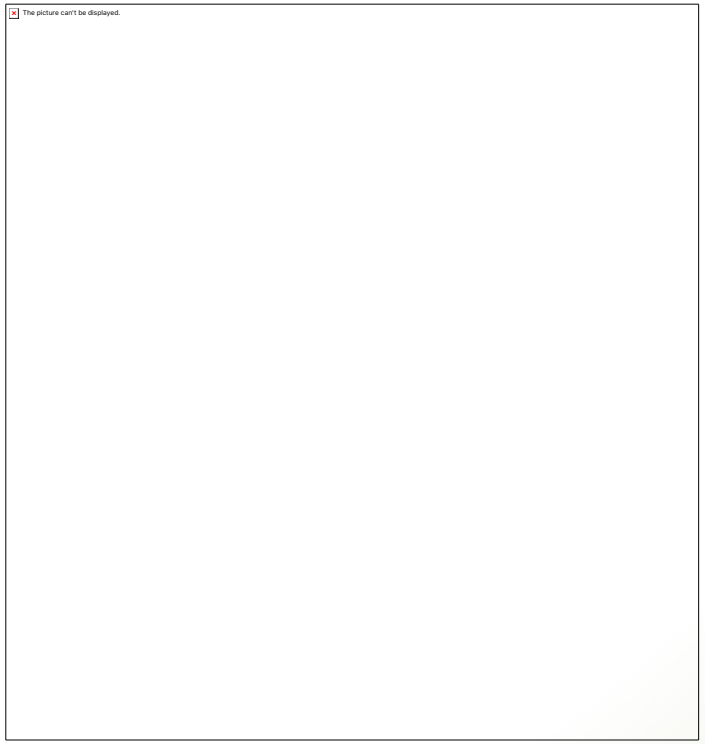
(*Zeegers et al.2017, Zeegers et al. 2019*)

Results Si K-edge
using X-ray spectroscopy

- Olivine dust preferred over pyroxene

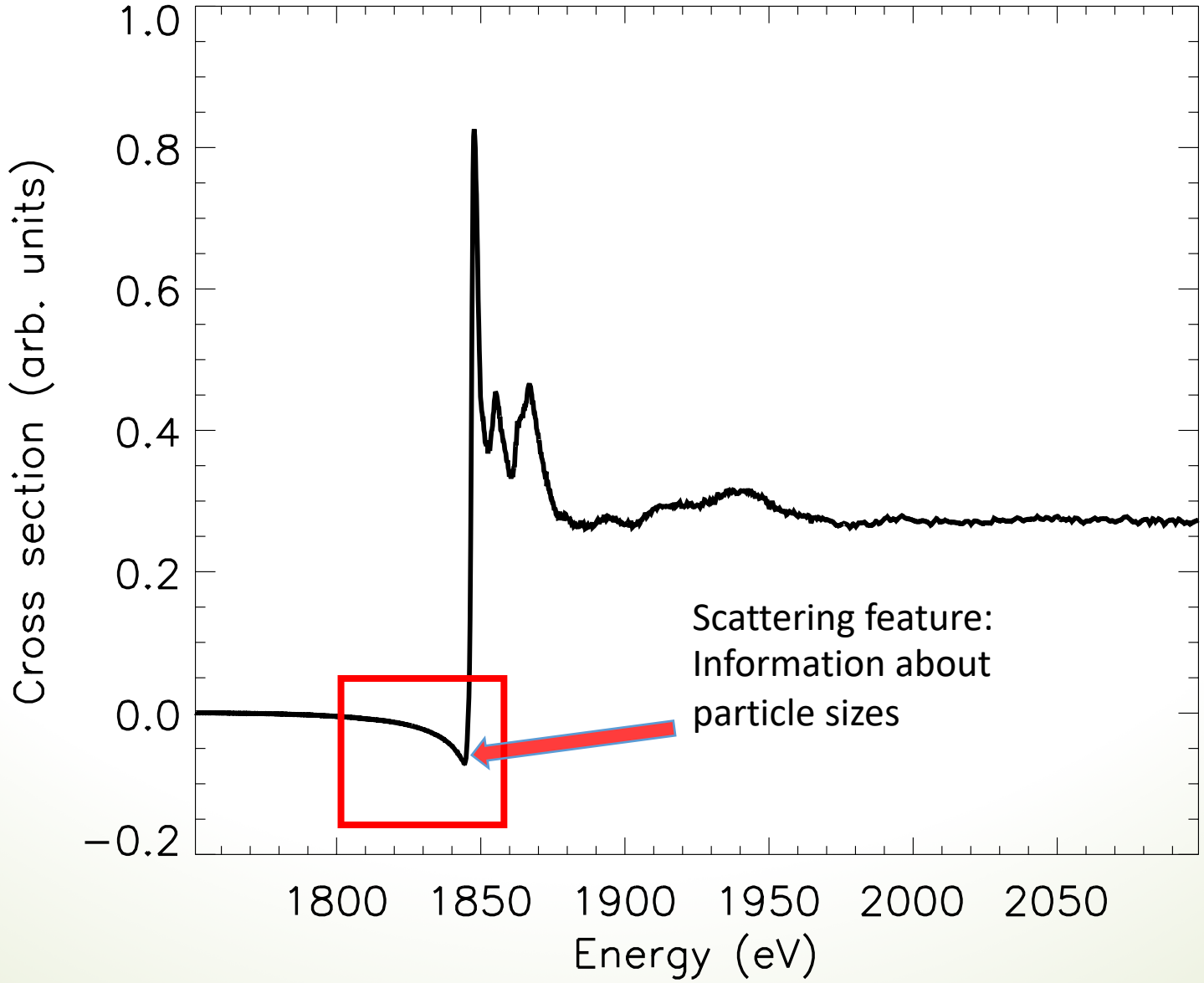
- Best fitting dust mixtures: 60-90% amorphous olivine and **4-12% crystalline dust**

- Best fitting dust mixes contain within 3 sigma <30% :
  - Quartz
  - Iron poor pyroxenes



Zeegers et al. 2019, Rogantini 2019 accepted

What can we learn from X-ray edges?



Grain size distribution

New method to investigate grain sizes of interstellar dust

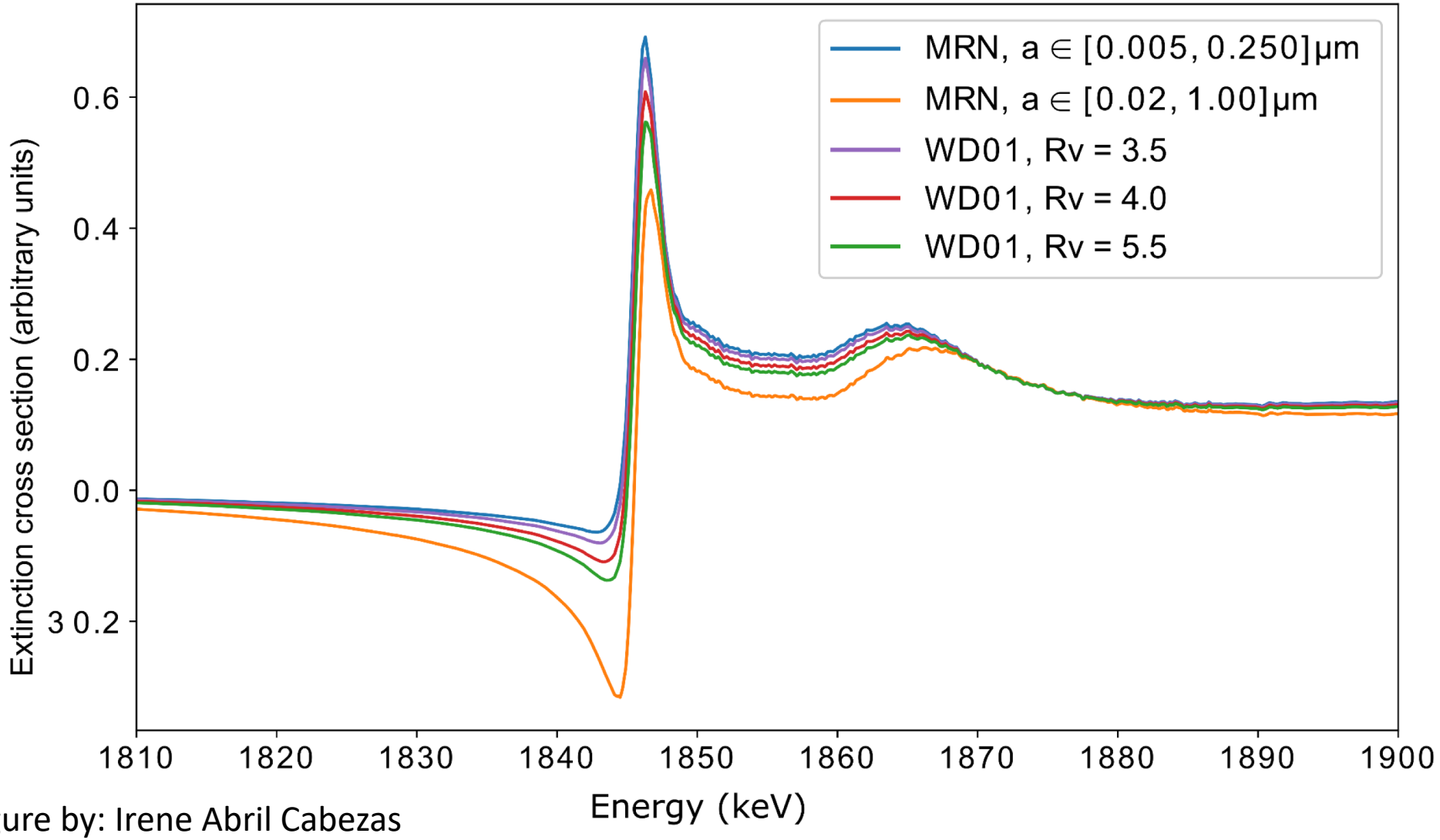
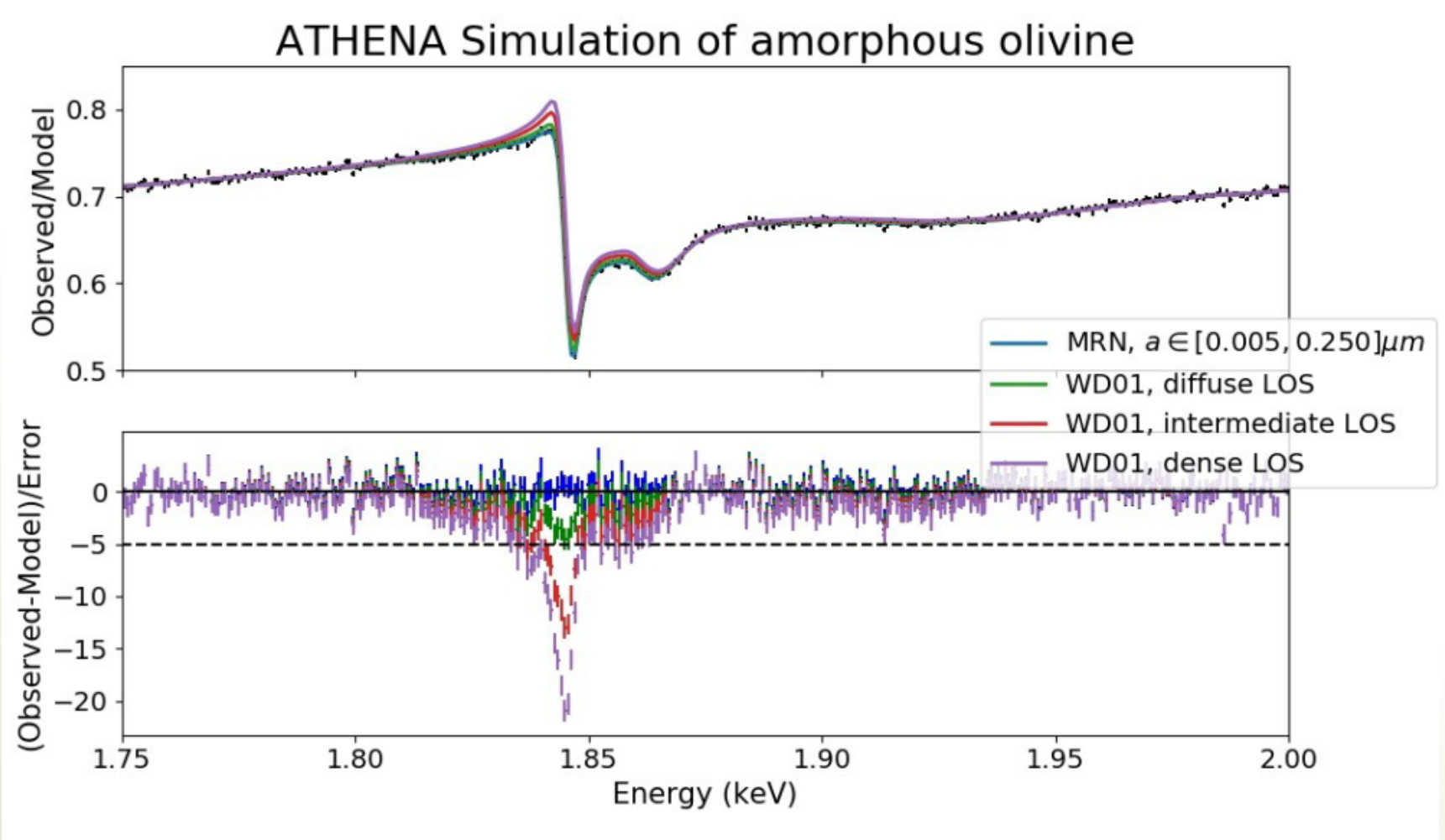
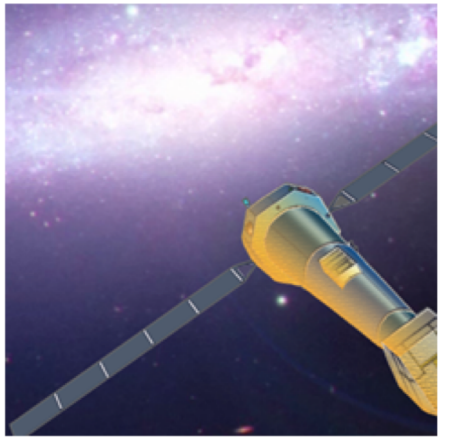


Figure by: Irene Abril Cabezas

Grain size distribution

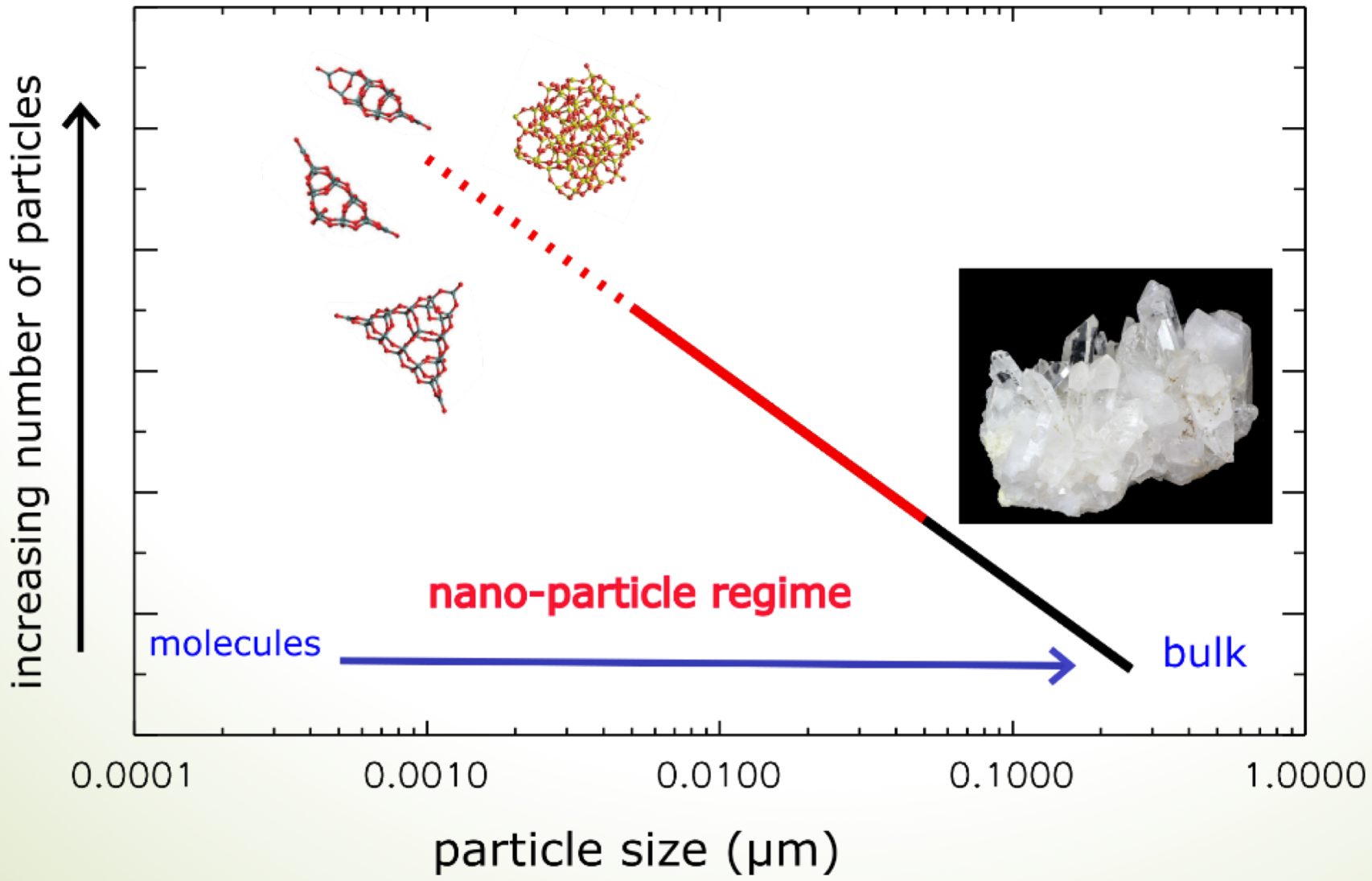




Expected launch:
early 2030s

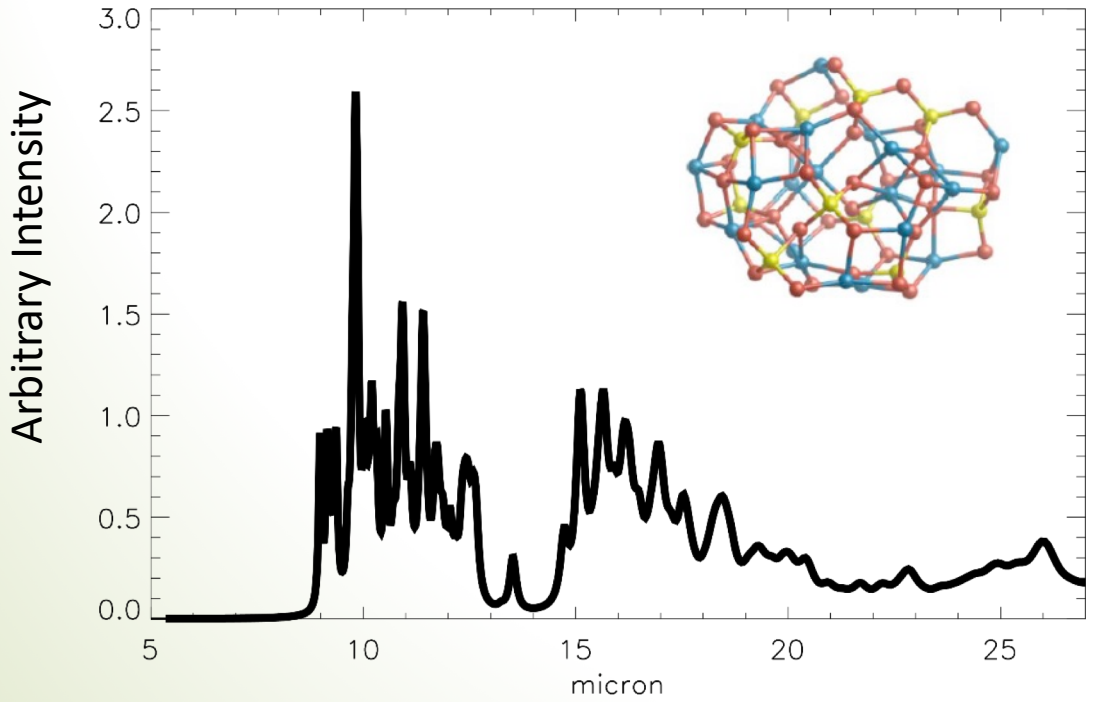
Figure by: Irene Abril Cabezas

The properties of small silicate grains



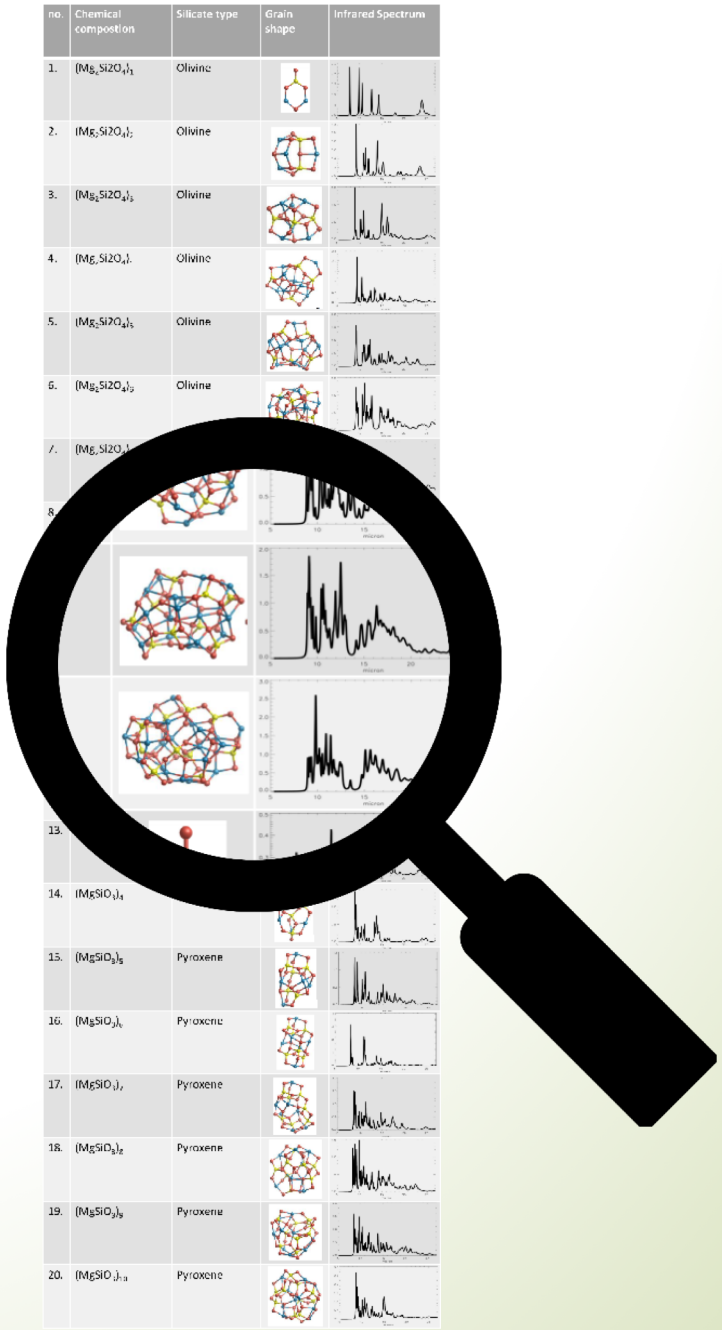
Small particles in the infrared

Olivine $(Mg_2SiO_4)_{10}$



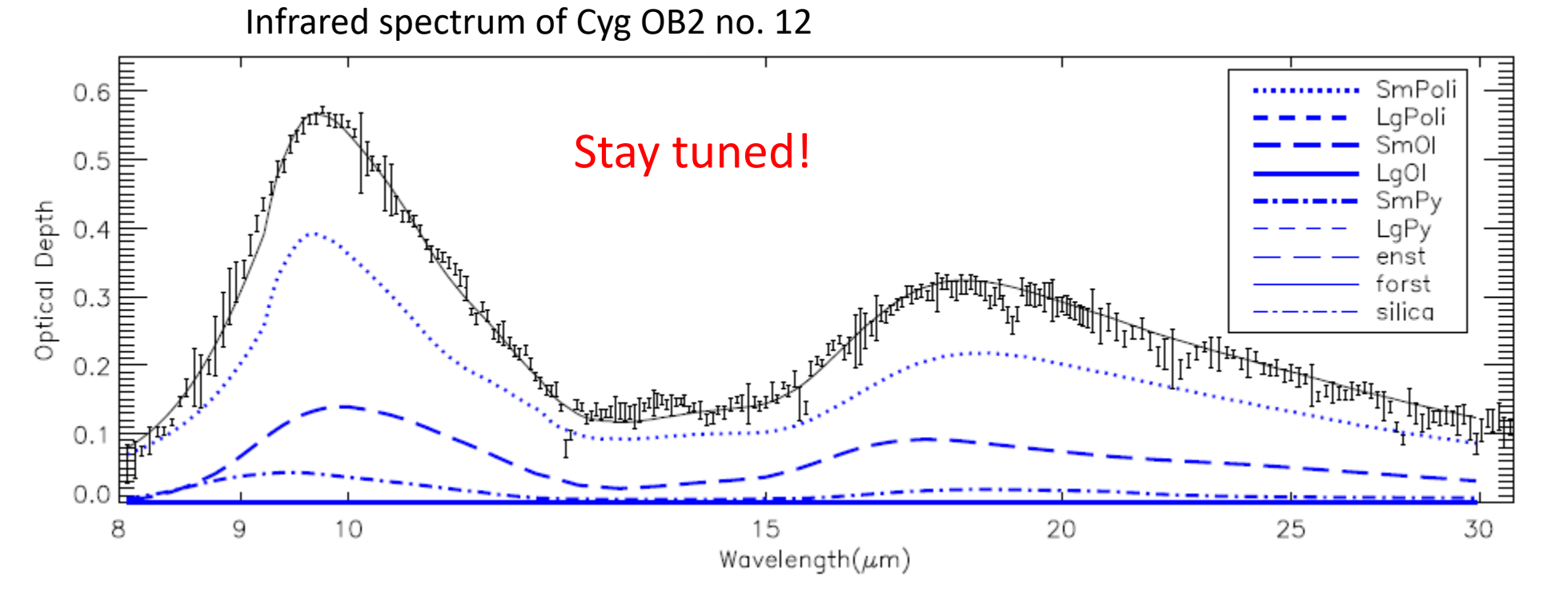
Small Silicates database:
10 olivines
10 pyroxenes

Calculations by:
A. Macià Escatllar et al. ACS Earth and Space Chemistry 2019



Small silicates in the infrared

The presence of small silicates can tell us about the formation history of grains



Fogerty et al. 2016

Summary & conclusion

- Multi wavelength approach necessary to constrain the dust properties:

➢Small silicate particles can give new insights in the formation and destruction processes of interstellar grains, as well as crystallinity

➢X-ray provide complimentary information on the properties of silicates:
- crystallinity
- composition
- grain size

- Bright future with upcoming observatories and new dust models in both X-rays and infrared!

Diffuse and Dense sightlines

Depending on the environment we can observe different edges