

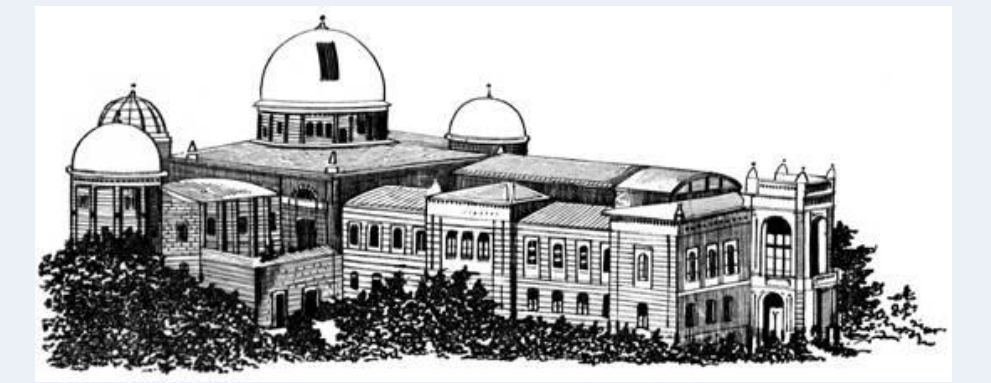
# Low Temperature and Far Infrared to Sub-mm Spectra of Phyllosilicates



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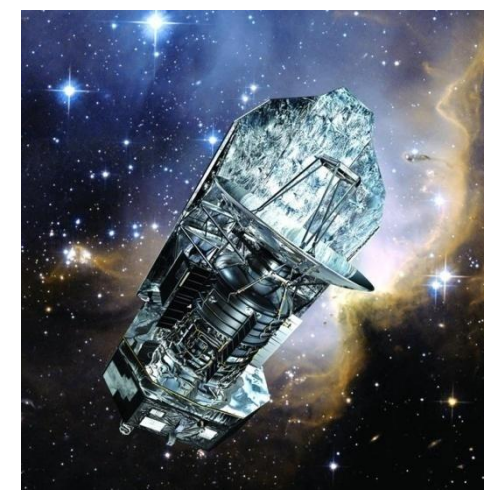
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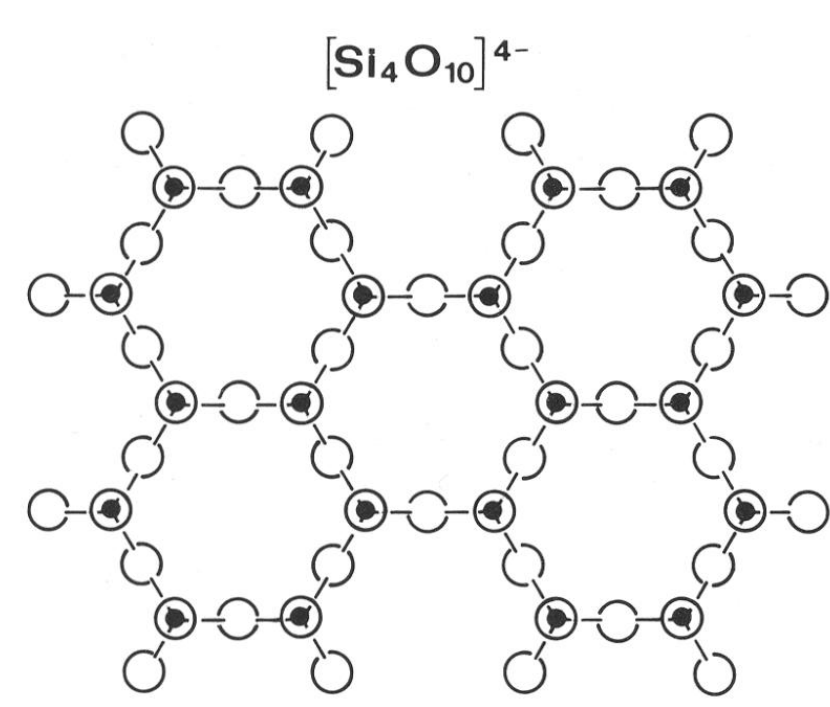
## 1. Background

Phyllosilicate is the name of a special class of silicates with a layer or leaf structure which contains OH<sup>-</sup> or even H<sub>2</sub>O (because of that it is often called hydrous silicate). Many of them (especially clay minerals like the chlorite or smectite group) are weathering and alteration products of other silicates like olivines or pyroxenes. Phyllosilicates are very popular as a possible water reservoir in space since one finds them in IDPs (Sandford et al. 1982) but until now we have no evidences that they can be found in other planetary systems too. However, the possibility for their existence outside our planetary system is very high and also the number of questions about their formation and development and of course their relationship to amorphous silicates.

According to that, we see our measurements as a kind of preparation work for the HERSCHEL program which probably will start in spring next year (spectroscopy-range: 57-627μm)

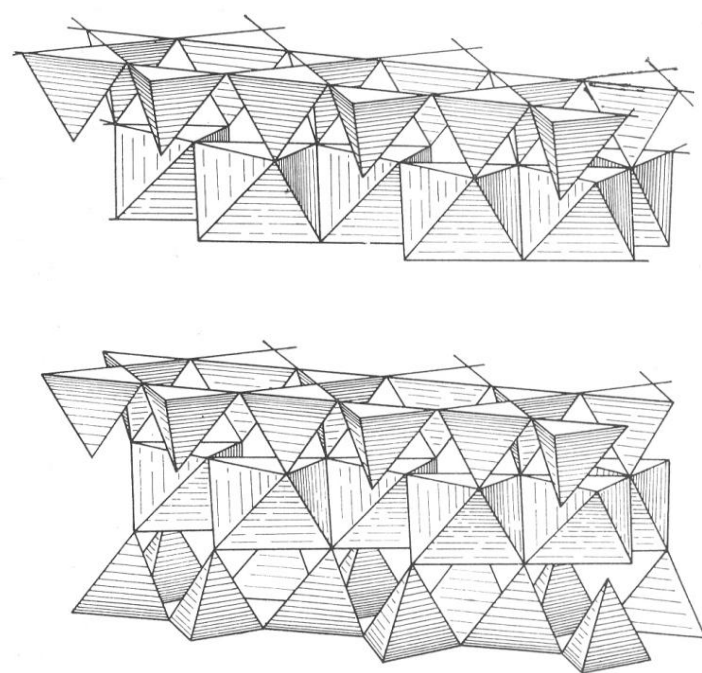


### Principal structure:



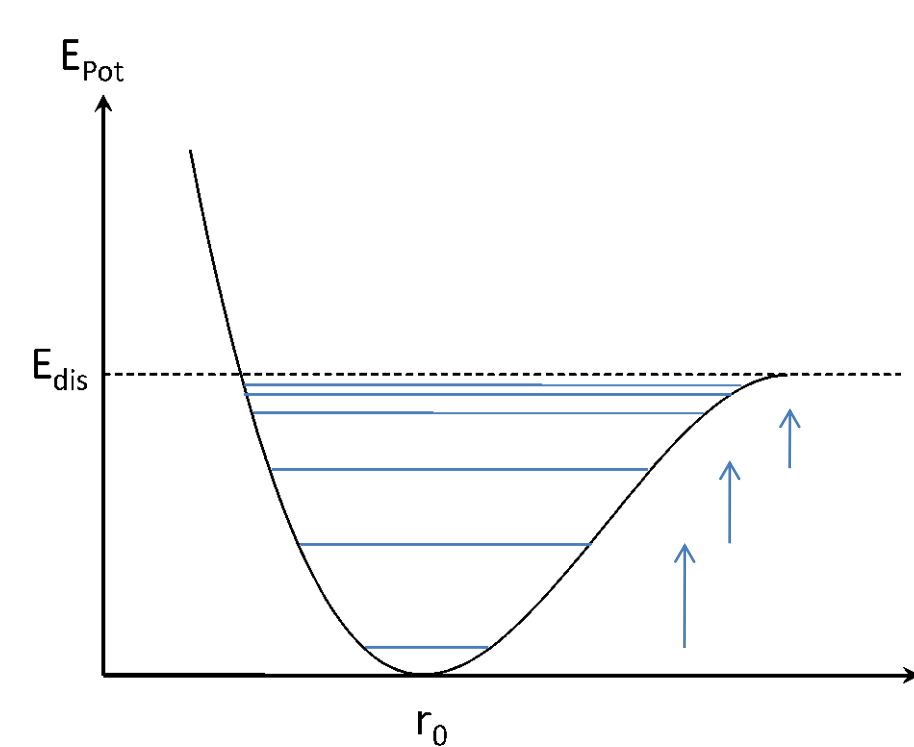
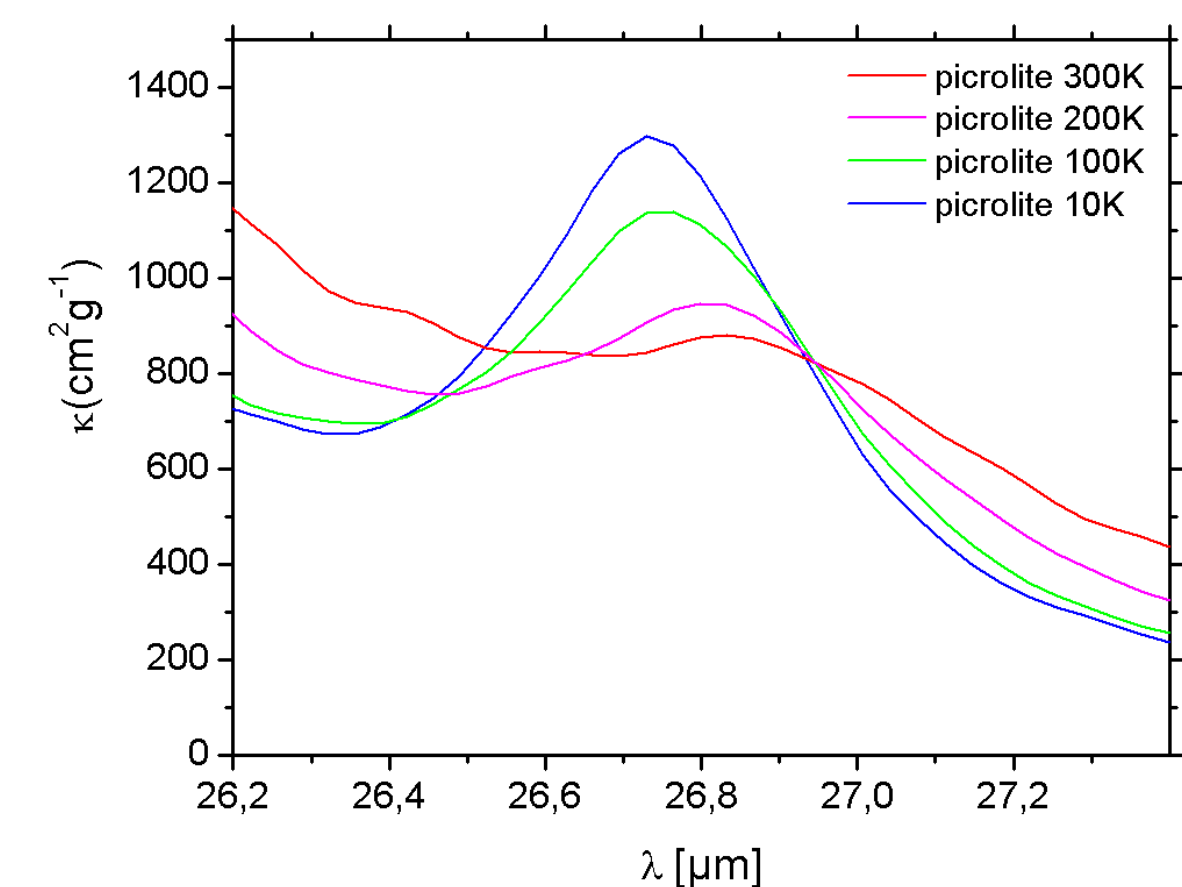
Left: top view of one layer (rings: Oxygen atoms, full dot: Silicon atom); under each silicon atom the fourth oxygen atom of one SiO<sub>4</sub><sup>4-</sup> Tetrahedron can be found.

Right: 2-layer-lattice (top) and 3-layer-lattice (below) structure; two different geometrical structures can be seen: the Tetrahedron and the Octahedron. The Tetrahedra build up the SiO<sub>4</sub><sup>4-</sup> layer while the Octahedra contain metallic anions in the center with O, OH<sup>-</sup> as ligands and build up the anionic layer.



### What happens at low temperatures?

Due to the complex inner structure of many crystals one can not calculate the specific shape of the potential which can be „seen“ by an atom, but we can approximate these local potentials via anharmonic oscillators. The quantum mechanical calculation of energy states of an anharmonic oscillator potential shows that with decreasing energy level the energetical distance between two states increases. Therefore when the temperature and with that also the mean occupied energy level decreases, more energy is required for a vibrational excitation. Consequently we obtain a shift of bands to shorter wavelength with decreasing sample temperature and additionally a change in shape to sharper and more intense bands, due to the decreasing energy state distribution at lower temperatures.



Left: measurement data of a weak band of picrolite (~26,8 μm at room temperature); while decreasing the temperature, the band becomes narrower and more intense and switches to shorter wavelength

Right: sketch of a potential of an anharmonic oscillator with the quantum mechanical energy states (blue). The distance between different energy states is decreasing when the energy level is increasing

## 2. Experimental setup

### Samples:

We used four different members from four different groups of Phyllosilicates for our measurements:

- talc for talc-pyrophyllite-group
- montmorillonite from the montmorillonite-group
- chamosite as a member of the chlorite-group
- picrolite for the serpentines

They all have a 3-layer-lattice structure, except picrolite with its 2-layer-lattice structure

### Fourier Transform spectrometer Bruker 113 v

Si-Bolometric Detector at 1.5K

Spectral coverage: 25μm-400μm

Spectral resolution: 0.5-1cm<sup>-1</sup>

### Continuous-flow liq. He Kryostat

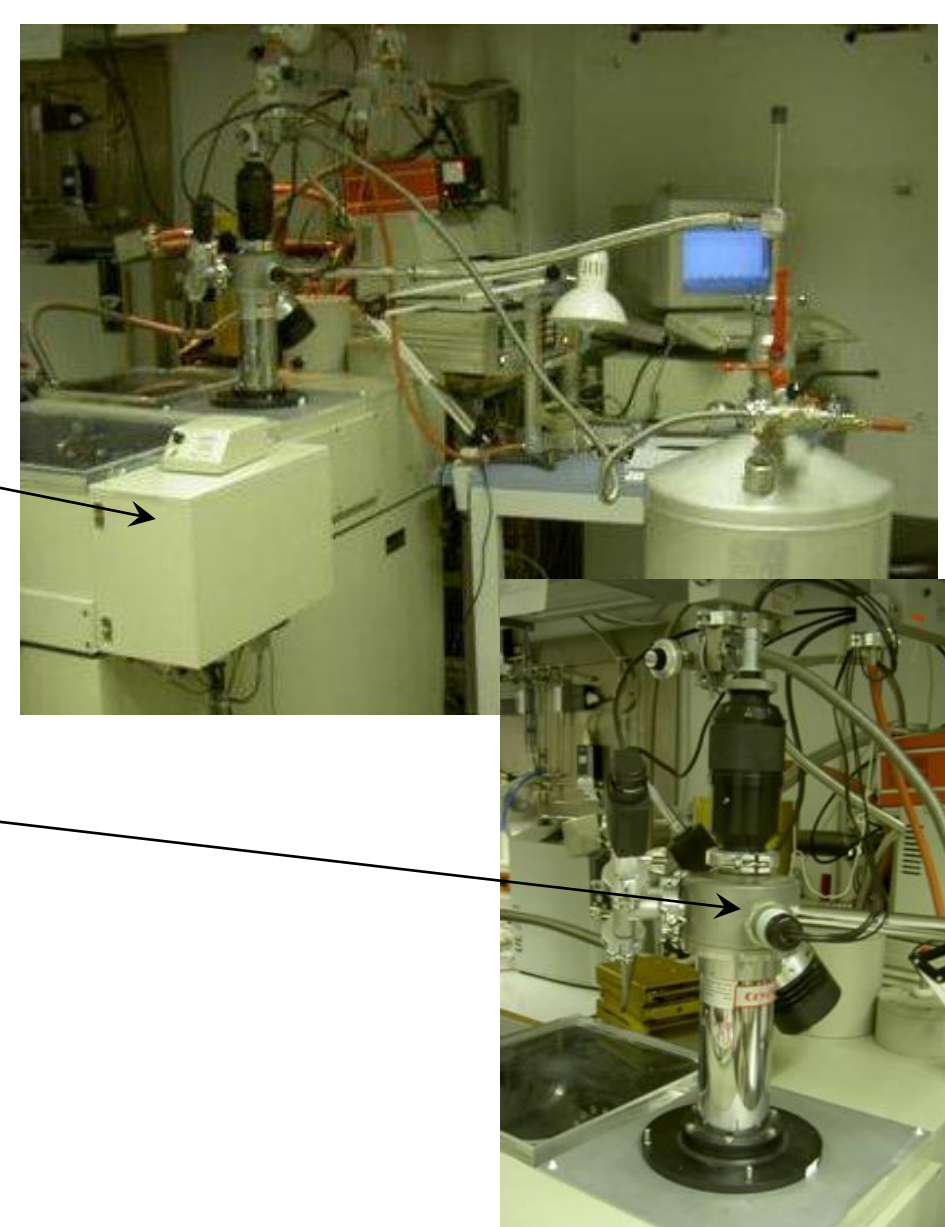
(Cryovac-Konti Spectro B)

Considered temperatures: 300K, 200K, 100K, 10K

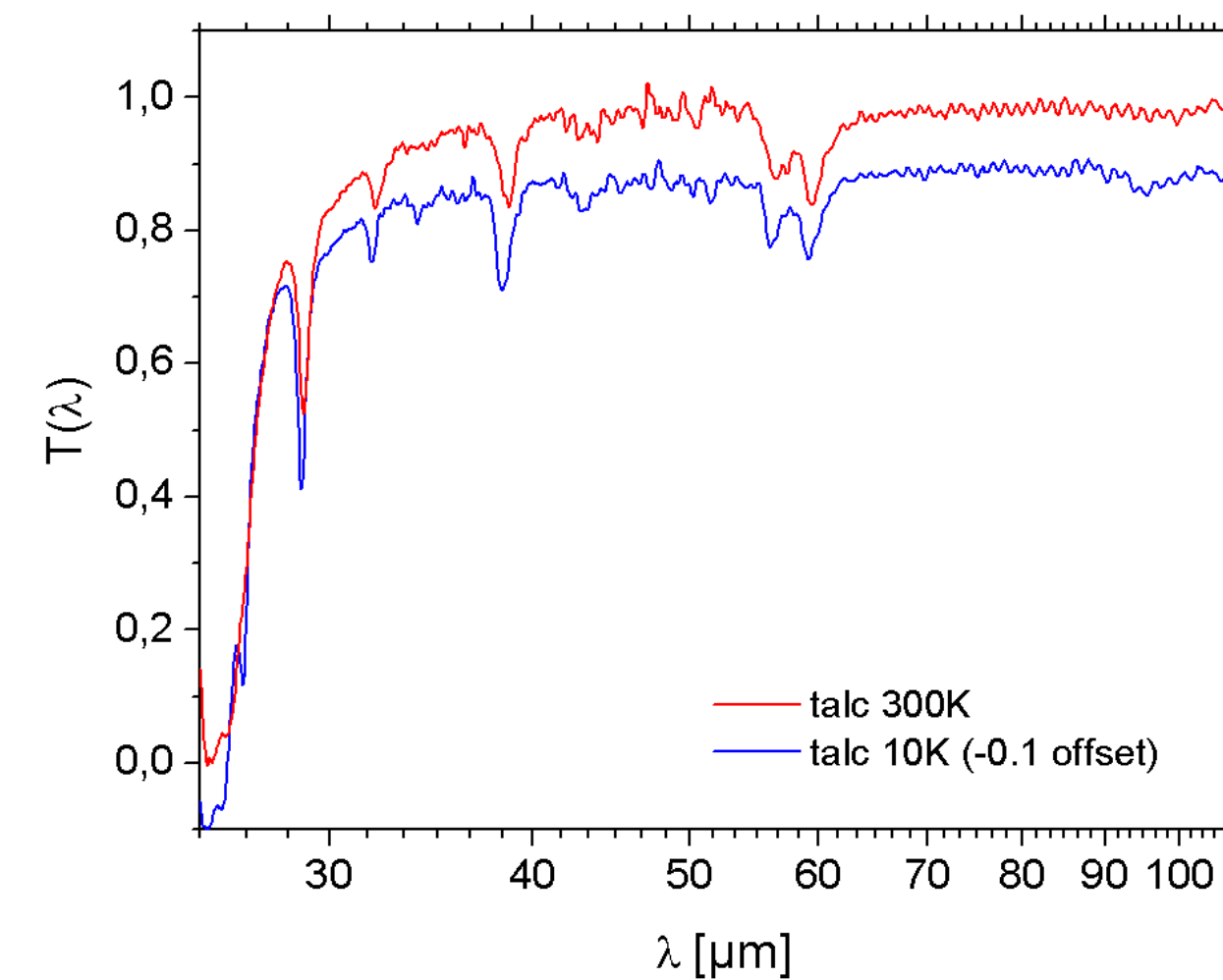
### Sample preparations

The samples are embedded in a Polyethylene matrix with a mass ratio of 1:100 for measurements between 25-100μm and 1:10 for measurements up to 400μm wavelength (corresponding to a column density of 1.51 and 15.1 mg/cm<sup>2</sup> respectively);

The grain size of our samples was appointed to be <5μm (achieved by grinding in a mortar/ball mill and sedimentation in acetone).

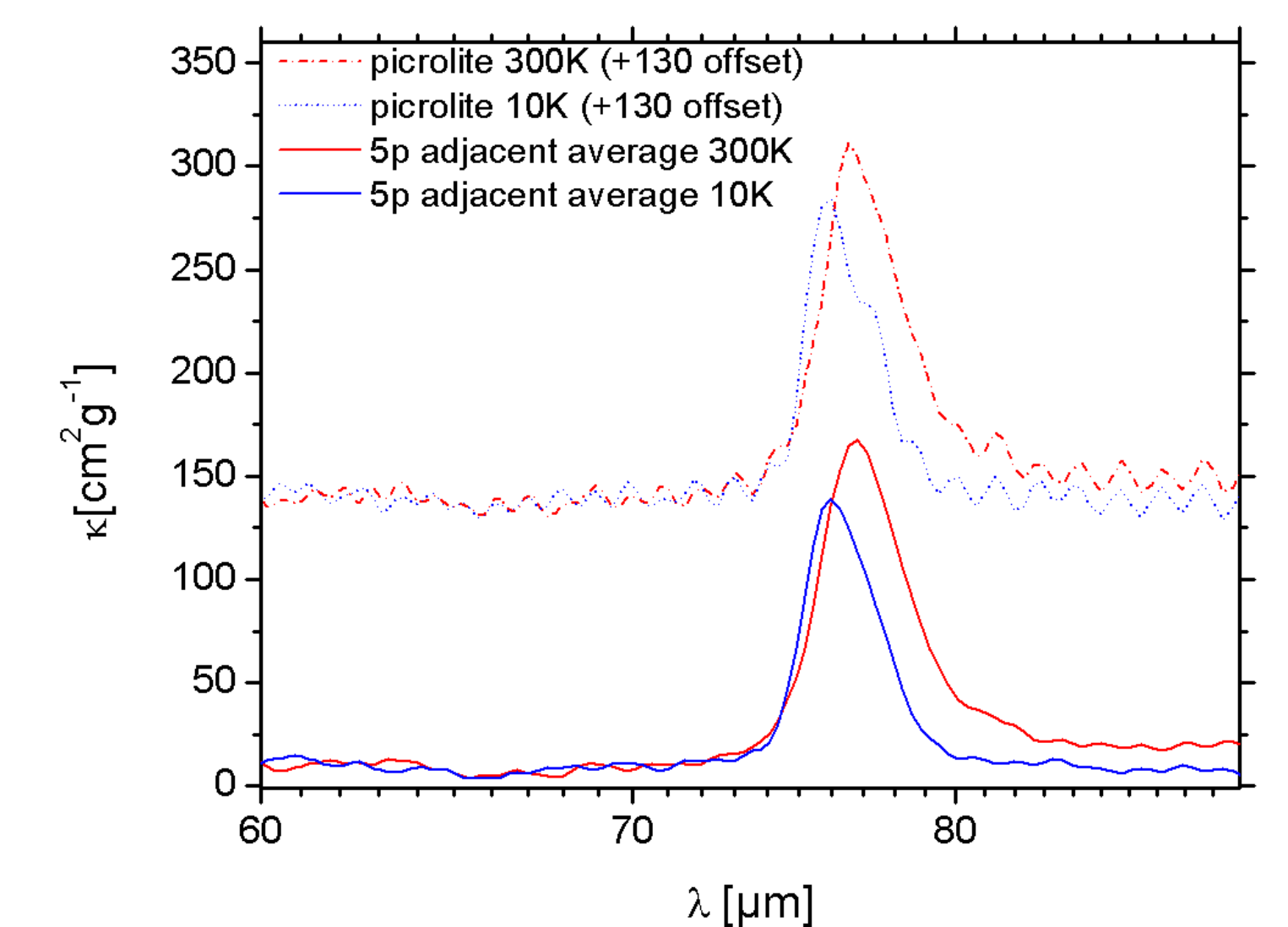


## 3. Main results

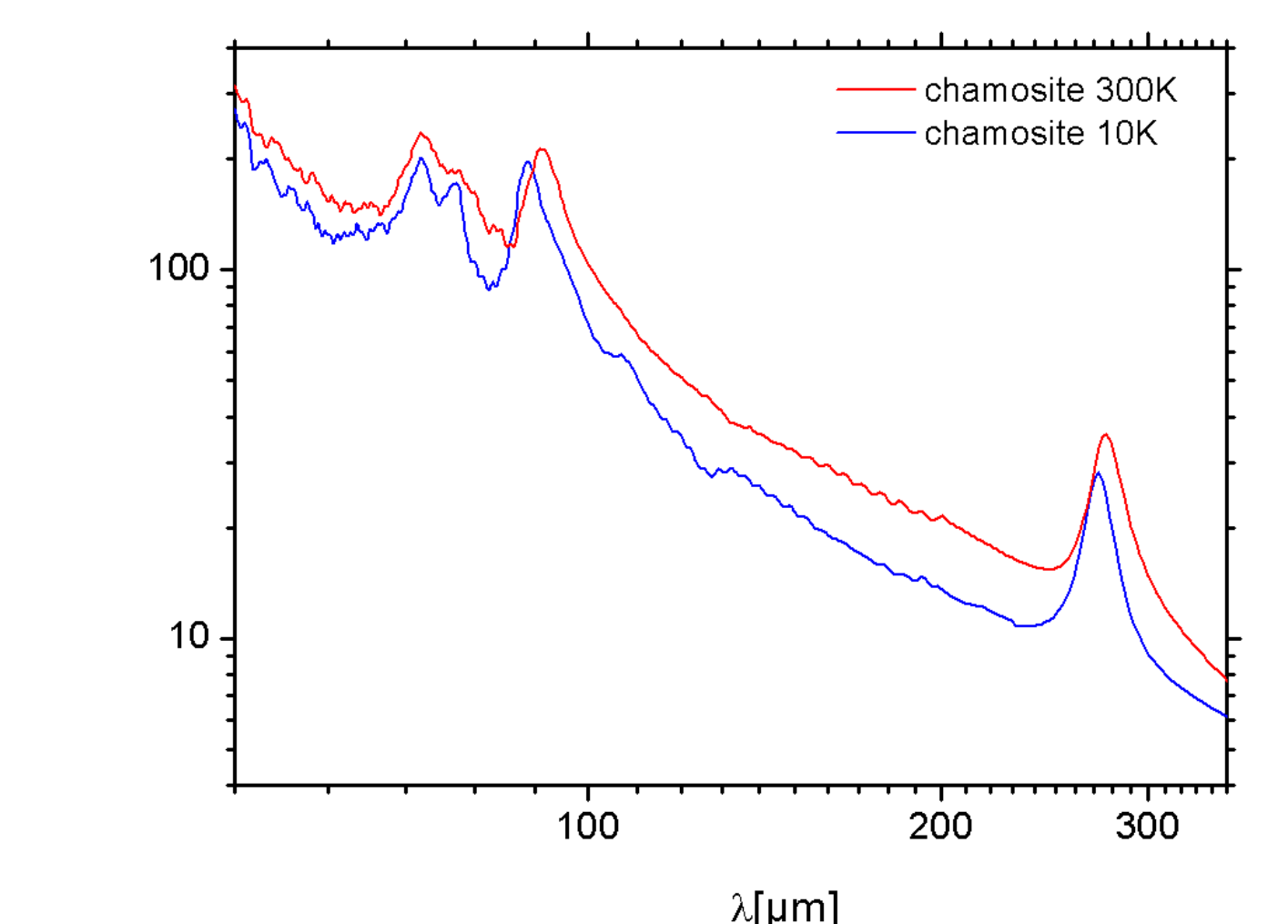
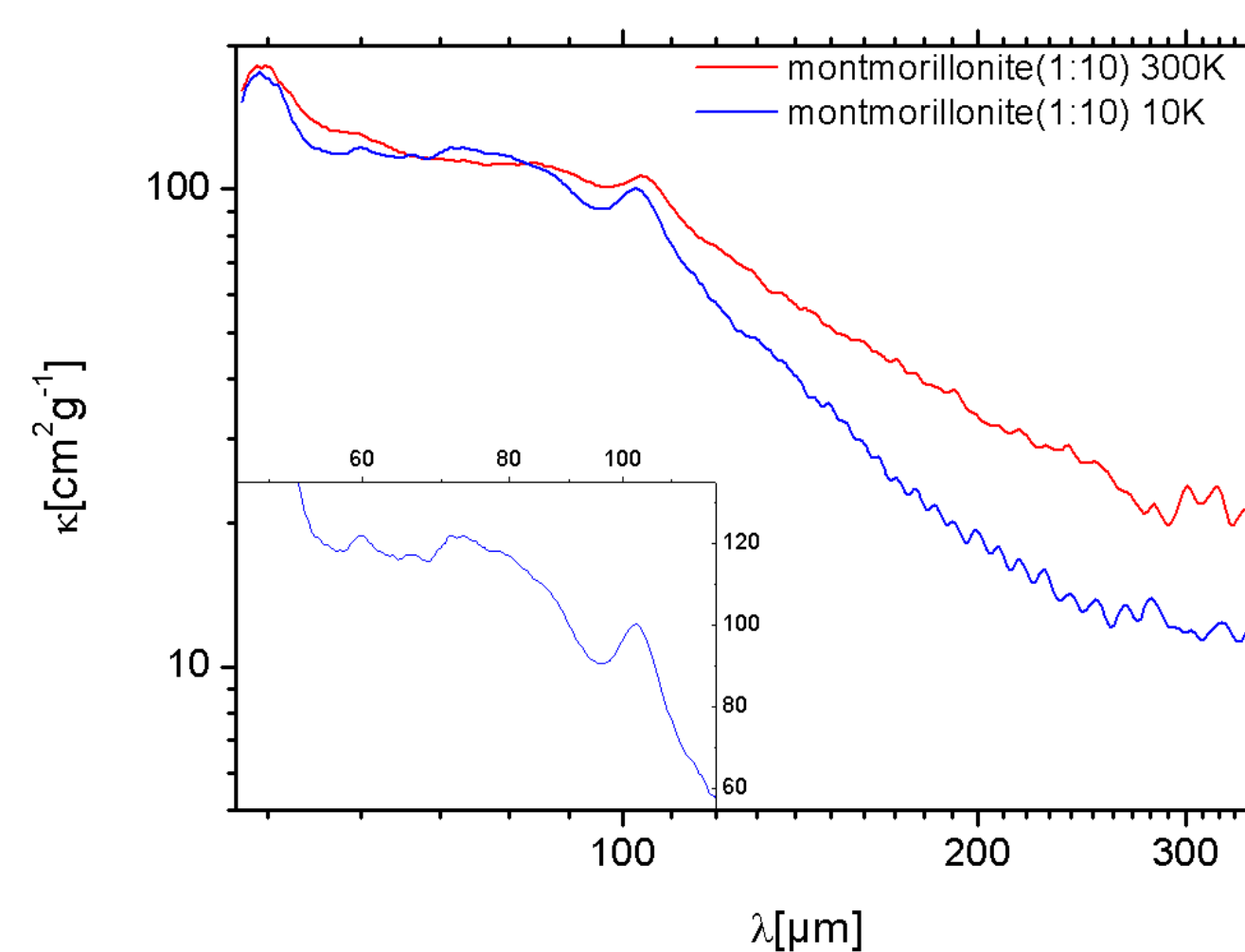
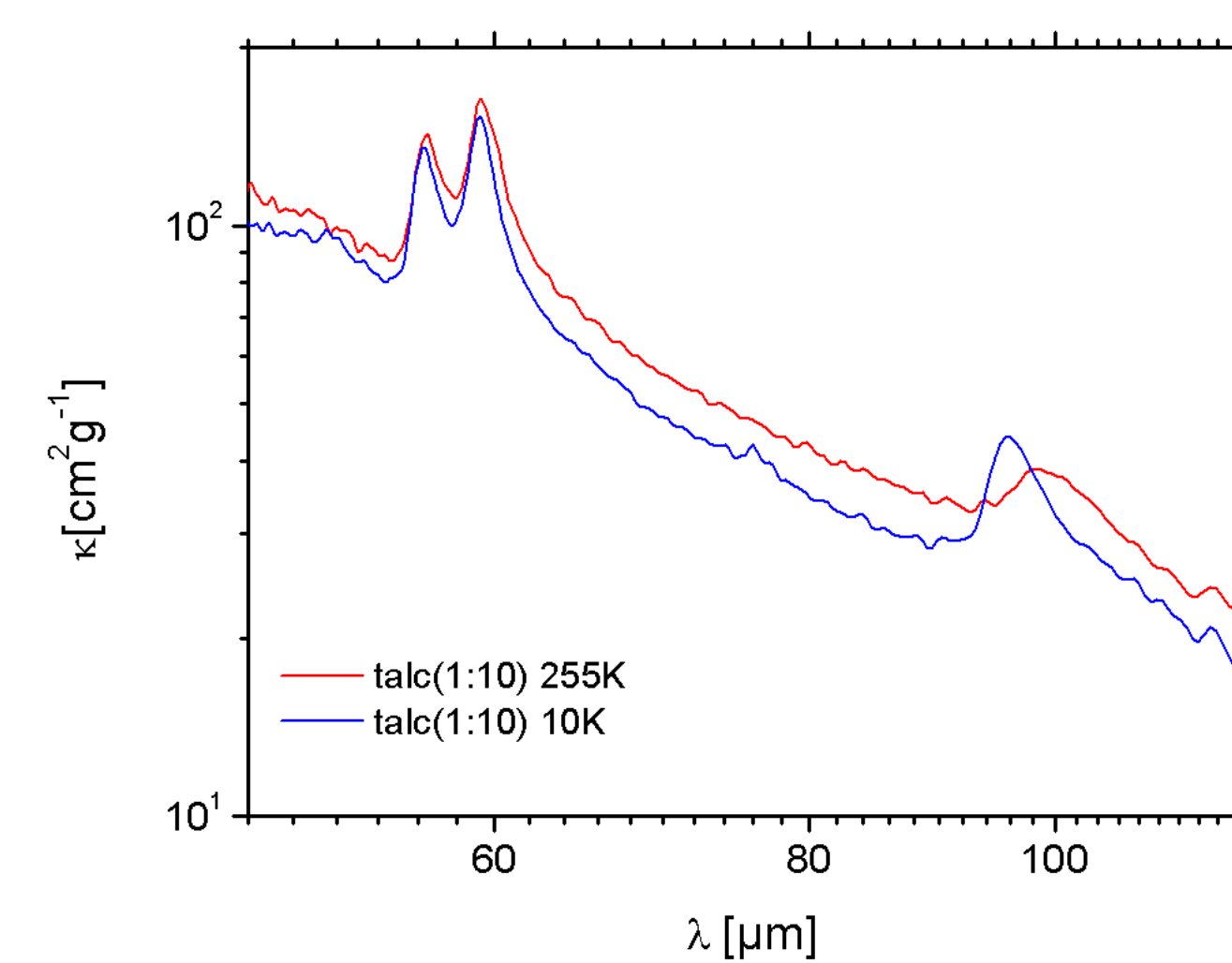


**Raw data manipulation:** On the left: typical transmission spectra that we obtained for our 1:100 ratio pellets (here talc, blue curve shifted), sharp bands are easily detected up to a wavelength of 60μm. However, the signal to noise ratio is not high enough to observe very weak bands especially at larger wavelength. For this purpose we used the 1:10 ratio pellets.

Although the 1:10 ratio pellets lead to a higher signal intensity, often it was not easy to characterise the bands precisely. Interference fringes appear in the FIR due to multiple reflection within the pellet. To remove these fringes we decided to use a 5 point adjacent average smoothing procedure, this means we replace one point by the average of itself and the 4 most adjacent points. On the right side one can see the result for a band of picrolite (77μm at room temperature (RT)).



**New bands:** on the left the absorption coefficient of talc between 48-120μm is displayed. We discovered a previously unknown band at 98μm (RT) which shows a relatively strong change in shape and position (shift to 95μm at 10K) at decreasing temperature while the double band further left hasn't changed so much its position and shape when reaching 10K.

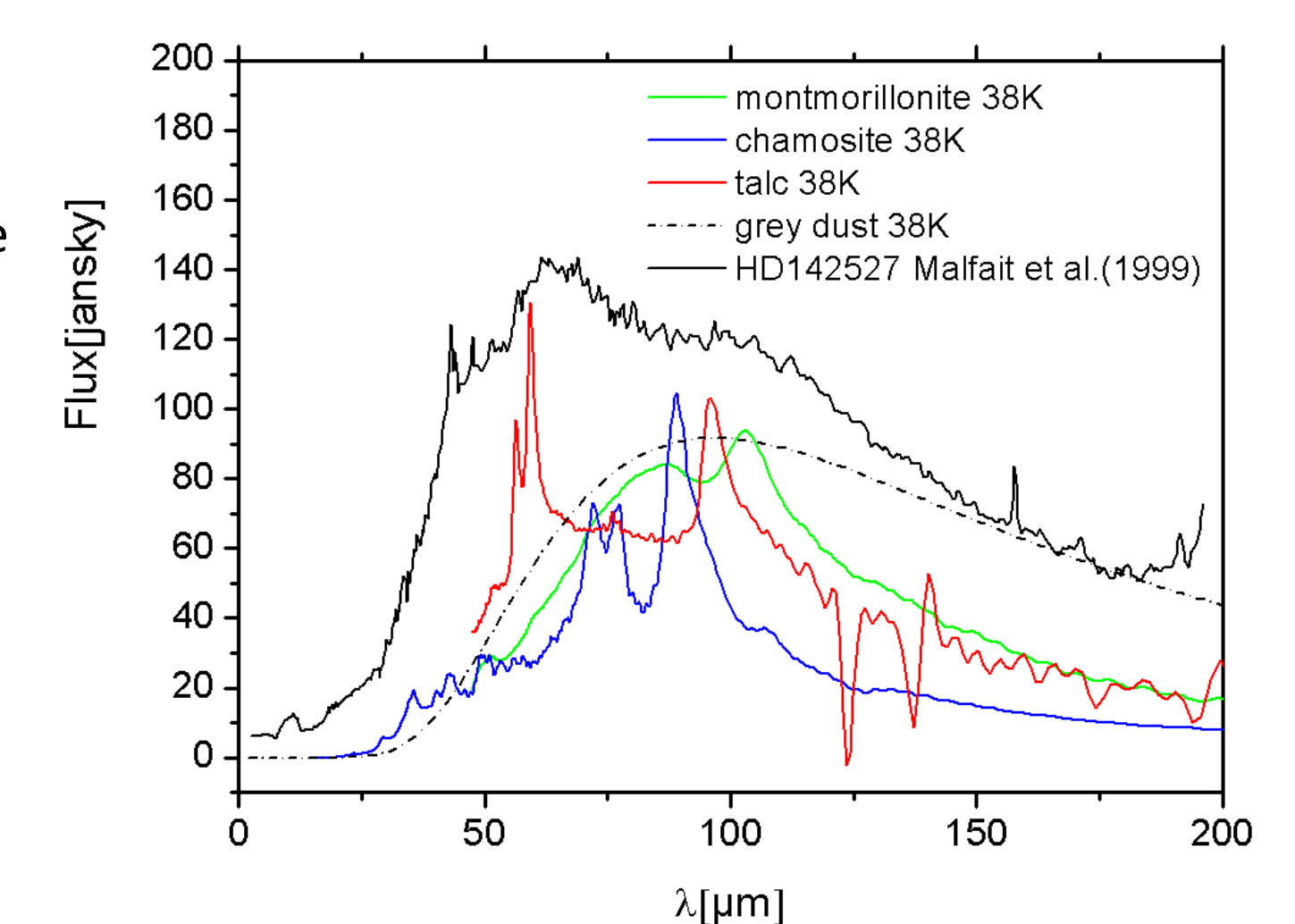


**Very long wavelength bands:** chamosite possesses a feature at 277μm (RT) which is the band at longest wavelength ever being observed for silicates.

**Hidden bands:** in the two upper pictures chamosite and montmorillonite spectra between 50-350μm can be seen. Obviously some bands show not only a change in position and shape but also a split of in several hidden bands while decreasing the temperature (attend the small picture in the montmorillonite spectrum, it shows the 10K curve in a linear scale). A change of continuum absorption in the montmorillonite spectra (at 110-350μm) by reaching 10K has been observed. At room temperature the decrease follows a function:  $\gamma \sim \lambda^{-1.8}$  and at 10K:  $\gamma \sim \lambda^{-3.04}$ .

## 4. Comparison with astronomical data

In 1999 Malfait et al. compared a FIR spectrum of the outer region of the protoplanetary disk of the young star HD 142527 with calculated spectra of amorphous silicates, water ice and phyllosilicates (in particular montmorillonite). They concluded that the shape of the spectrum (measured with the ISO SWS and LWS spectrometer) at 100μm can be ascribed to the emission of montmorillonite particles in the protoplanetary disk. Our results show that the feature of montmorillonite at 100μm is too sharp compared with that of the ISO spectrum. Also the other phyllosilicates can't explain the observed spectrum. The broad band around 100μm could be reproduced by the emission of dust at 38K with a featureless (grey) emissivity proportional to  $\lambda^{-1}$ .



## References

- K.Malfait, C. Waelkens, J. Bouwman, A. de Koter, L. B.F.M. Waters; Astron. Astrophysics 345, 181 (1999)
- H. Mutschke, S. Zeidler, Th. Posch, Th. Henning; Astron. Astrophysics (in prep.)