

Water In Star-forming regions with Herschel

- A 428 hr GT key-program with Herschel to study the physical and chemical structure of star forming regions focussing on H₂O and its related species
- Program covers ~100 sources ranging from pre-stellar cores, low- to high-mass protostars in different evolutionary stages as well as protoplanetary disks
- Both HIFI and PACS-spectroscopy are used
- Collaboration of ~60 scientists from 30 different institutes

See <http://www.strw.leidenuniv.nl/WISH>

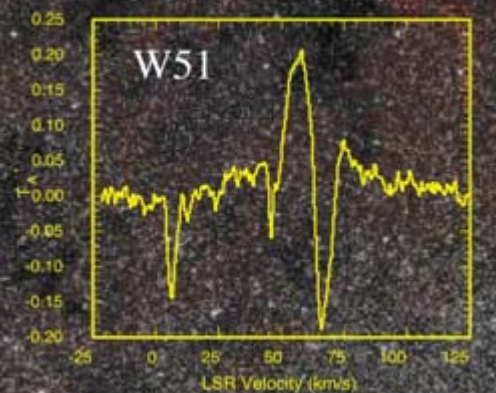
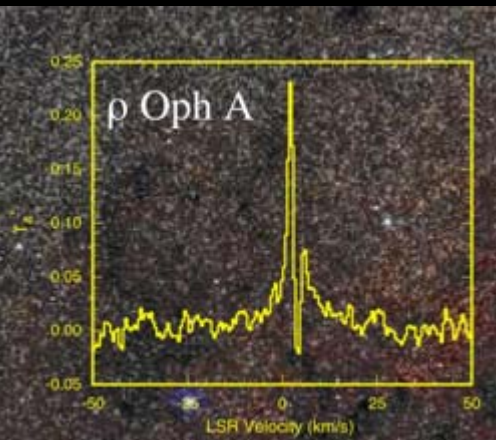
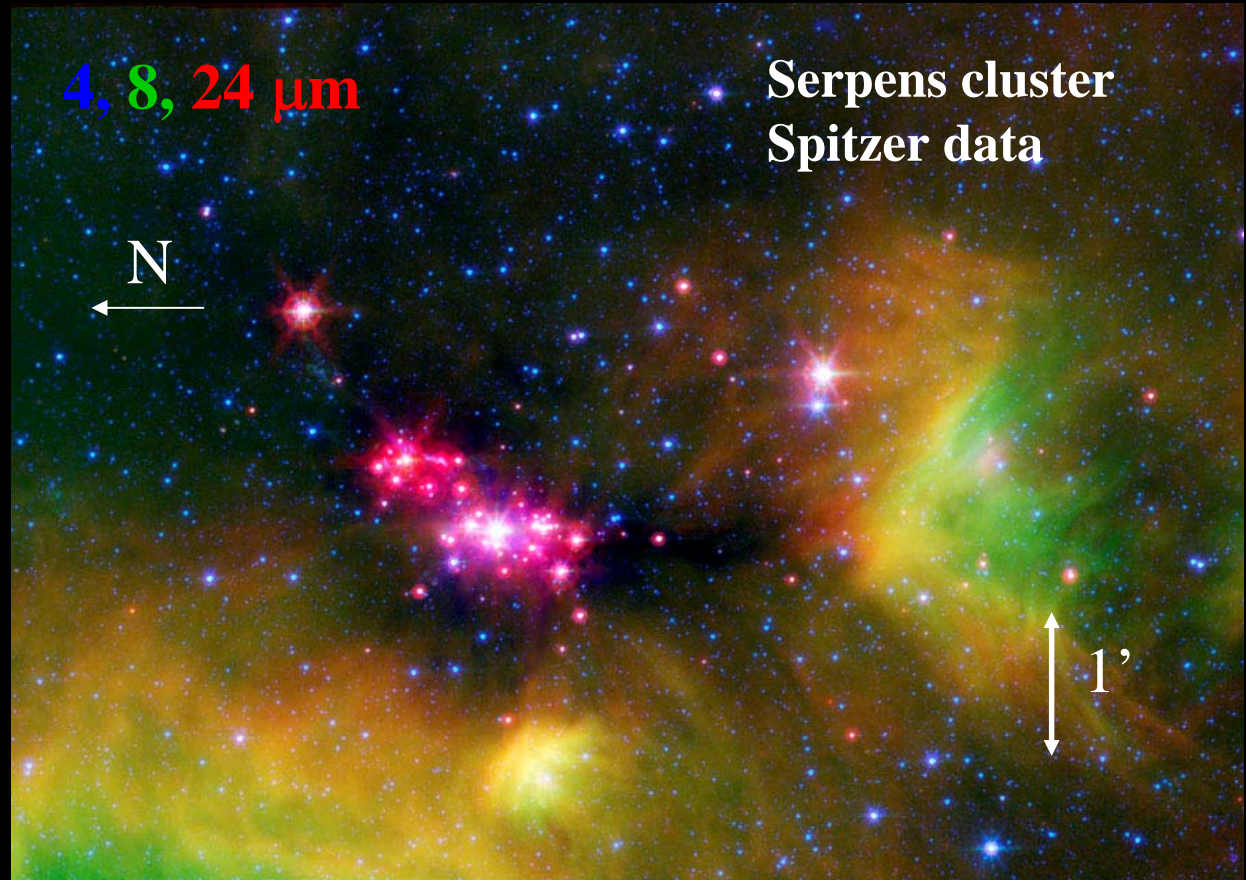


Motivation: H₂O as chemical and physical probe

- H₂O abundance shows large variations in SF regions: $<10^{-8}$ (cold) – $3 \cdot 10^{-4}$ (warm) => unique probe of different physical regimes
 - Natural filter of warm gas
- Main reservoir of oxygen => affects chemistry of all other species
 - Astrobiology: water associated with life on Earth => characterize water 'trail' from clouds to planets
- Traces basic processes of freeze-out onto grains and evaporation, which characterize different stages of evolution

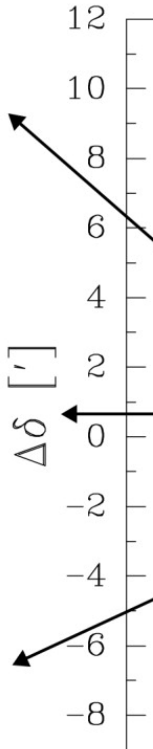
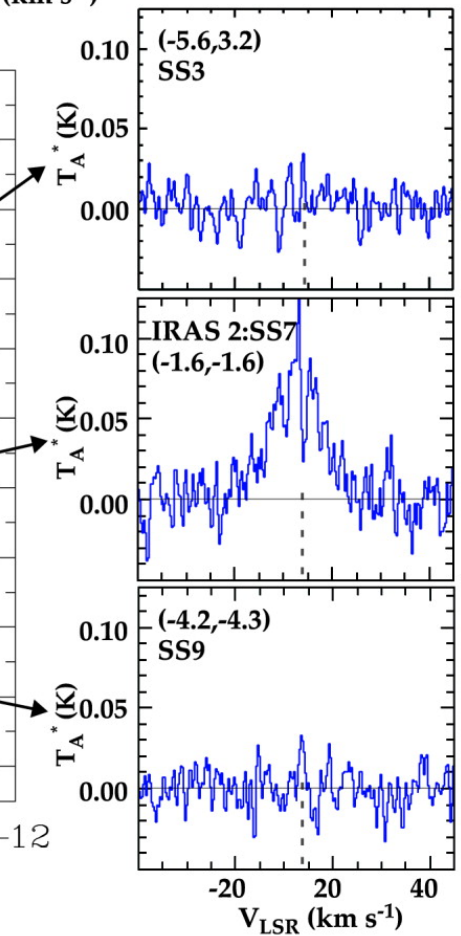
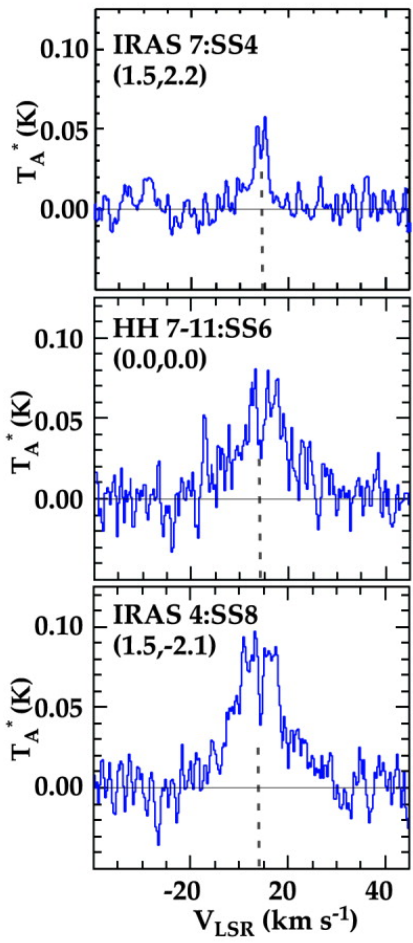
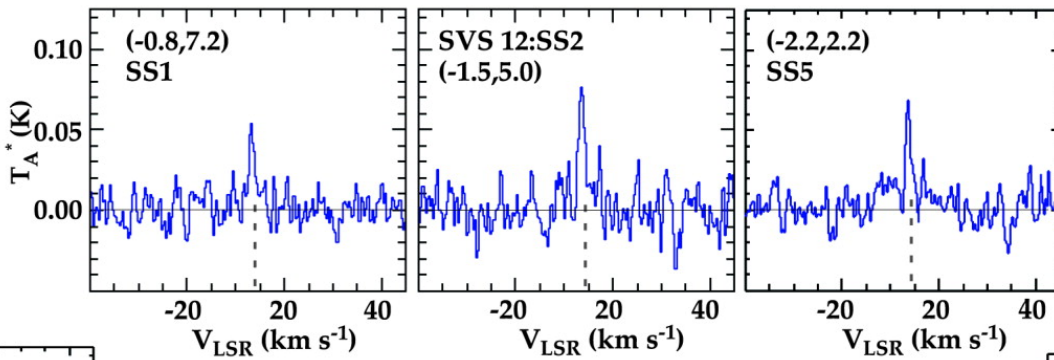
pre-stellar cores => YSO's => disks => comets

Example of star forming cloud to be observed



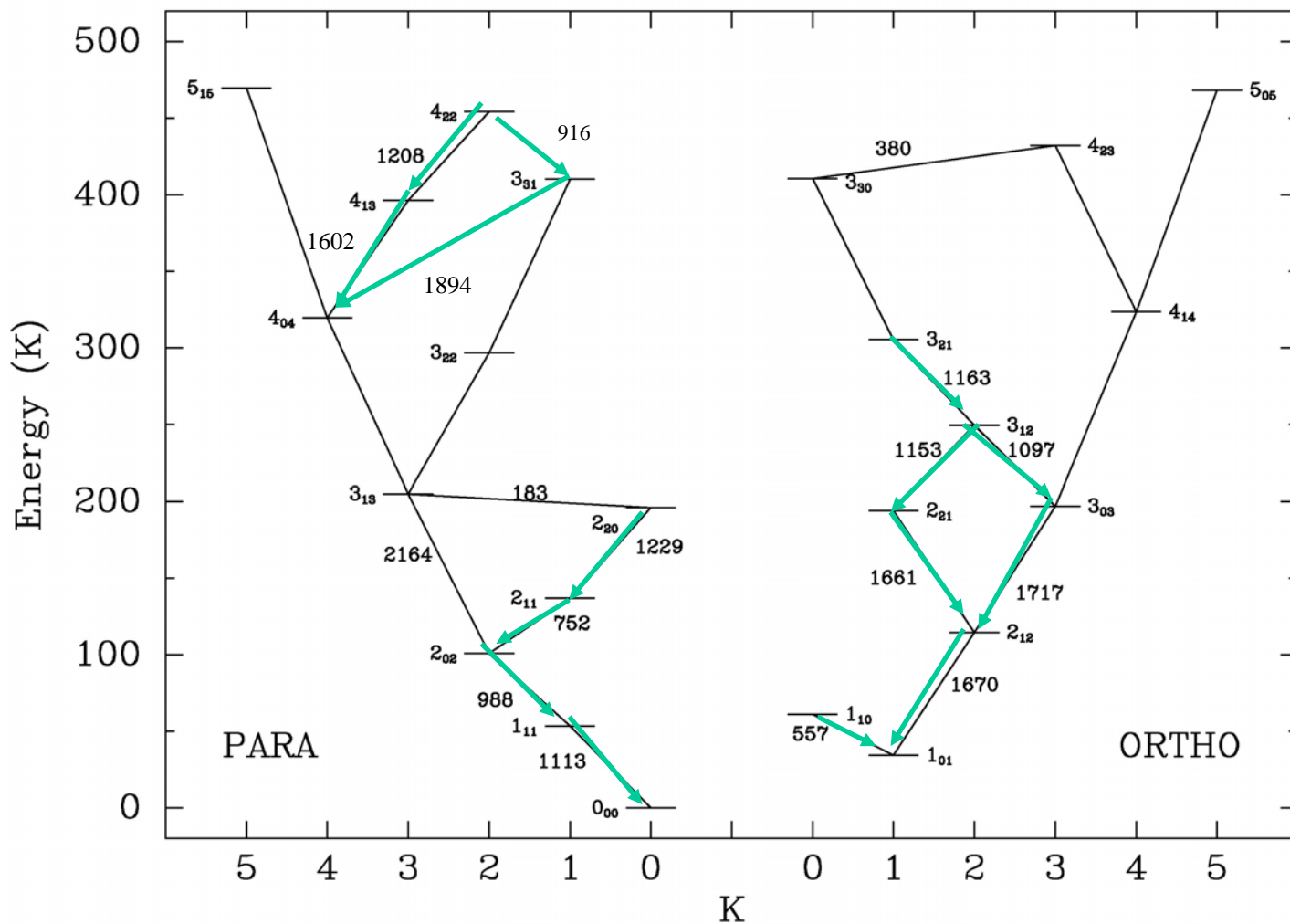
← Example (cold) water spectra observed with the SWAS satellite; Herschel can also probe hot water lines at much higher sensitivity and spatial resolution

SWAS



H₂O HIFI lines

Need accurate calibration between bands!



Observe common set of lines for all YSOs

Data analysis needs

- **Need basic spectral analysis functionalities**
 - *Simple* commands to sum/average spectra, smooth, remove baseline (window to be chosen by user), fit Gaussian(s), compute rms and integrated intensity, ...
 - Pushing HIFI to its limits: 16 hr on single line at single position!
 - Simple raster + OTF maps
 - PACS spectral cubes, full spectral scans
 - Not just GUI driven, need command line input
- **Import non-Herschel data to compare spectral profiles (e.g. CS 7-6 with H₂O) and overlay small maps**
 - Large data base of complementary data
- **Quick look important for rapid identification of problems and driving science**

Science analysis tools

- **Molecular data files**
 - LAMDA database: www.strw.leidenuniv.nl/~moldata
 - Schöier et al. 2005
 - Basecol database: basecol.obspm.fr/
 - See CASSIS tools
- **1D and 2D radiative transfer tools + molecular excitation**
 - RADEX program: www.strw.leidenuniv.nl/~moldata
 - On-line and offline versions, van der Tak et al. 2007
 - RATRAN program: www.sron.rug.nl/~vdtak/ratran
 - Hogerheijde & van der Tak 2000
- **Extensive modeling of water lines in YSOs**
 - Results being published in A&A; model grids to be made available on WISH website