WISH

Water In Star-forming regions with Herschel

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Summary

We propose a comprehensive set of water observations using HIFI and PACS toward a large sample of well-characterized protostars, covering a wide range of masses and luminosities -from the lowest to the highest protostars -, and a large range of evolutionary stages -from pre-stellar cores to pre-main sequence stars surrounded by disks.

Lines of H_2O, $H_2^{18}O$, $H_2^{17}O$ and chemically related hydrides will be observed. In addition, selected high-frequency lines of CO isotopes and [O I] will be obtained, to be complemented by ground-based HDO, CO and continuum maps to ensure a self-consistent data set for analysis. Limited mapping on arcmin scale will also be done.

Motivation

★ **Water as a physical probe**
  ✓ Natural filter of warm gas
  ✓ Diagnostic of heating mechanisms: shocks vs radiative heating
  ✓ Diagnostics of UV and X-rays from young star
  ✓ Active role in energy balance: cooling and heating

★ **Water as a chemical probe**
  ✓ Main reservoir of oxygen ➡ affects all species
  ✓ Controls gas-grain interactions: freeze-out and evaporation
  ✓ Abundance variations during star- and planet formation, incl. deuteration

pre-stellar cores ➡ Young Stellar Objects ➡ disks (➡ comets)
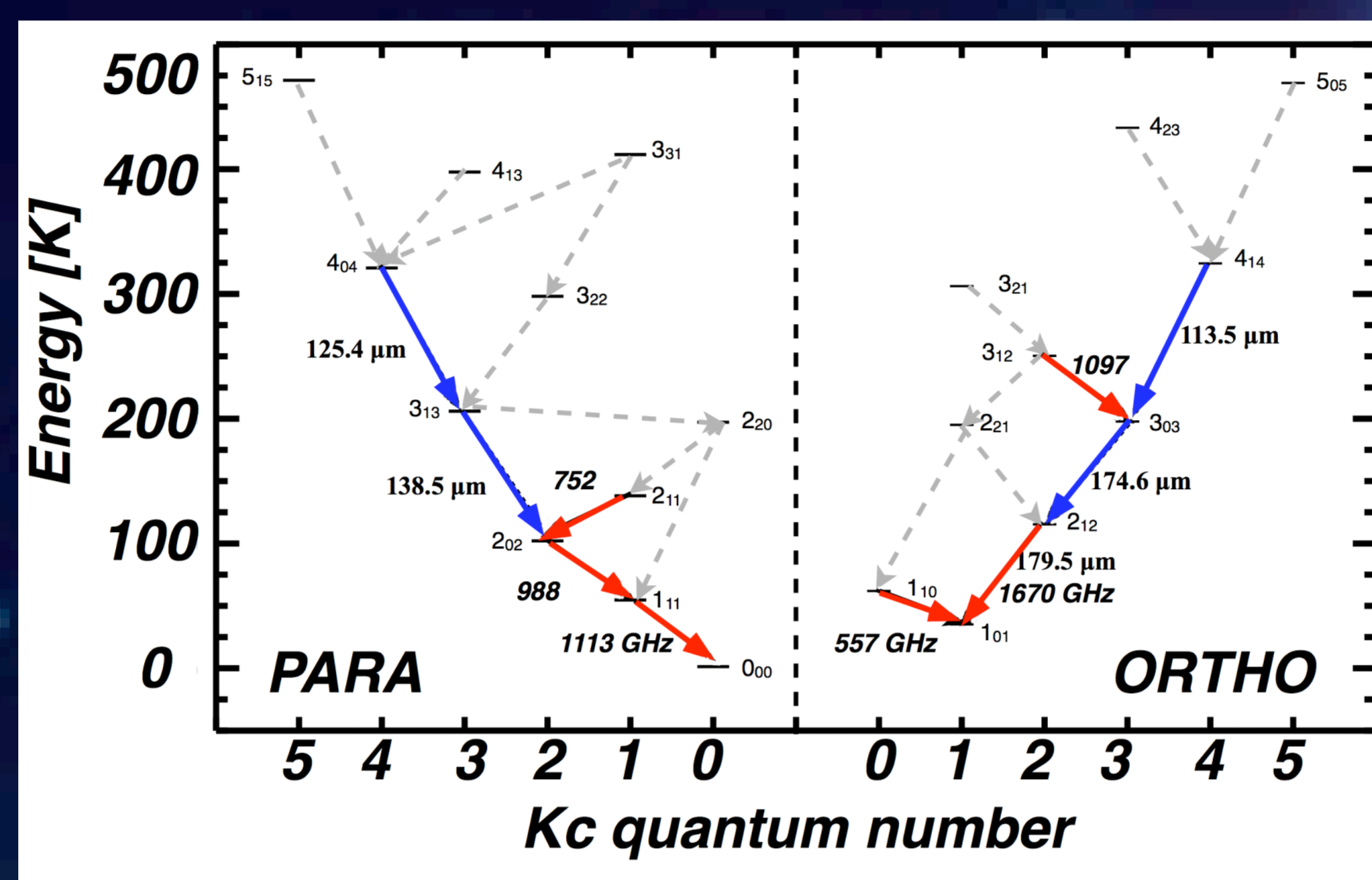

Fig. 1: Main WISH water transitions to be observed with HIFI (red) and PACS (blue) . Includes both para and ortho water and optically thin isotopologues

Summary of Key Program Observations

Type		# Sources	Time[a] (hr)	RMS (mK)
Low-mass	Pre-stellar cores	8	22	10
	Class 0	16	80	15-150
	Class 1	12	51	15-50
	Outflows	26	51	20-40
Int. Mass	Embedded	8	31	15-150
High Mass	Pre-stellar	4	8	10
	Protostars	19	115	50-150
	Cluster	6	24	50
Radiation Diagnostics	All YSOs	13	25	15-30
Disks	Young - deep	4	80	3
	Young - shallow	8	12	12
Total			499[a]	

[a] Including PACS time

Wide range of luminosities, masses and evolutionary stages within star-forming regions ⟷ Wide range of lines needed to study the water excitation under different conditions
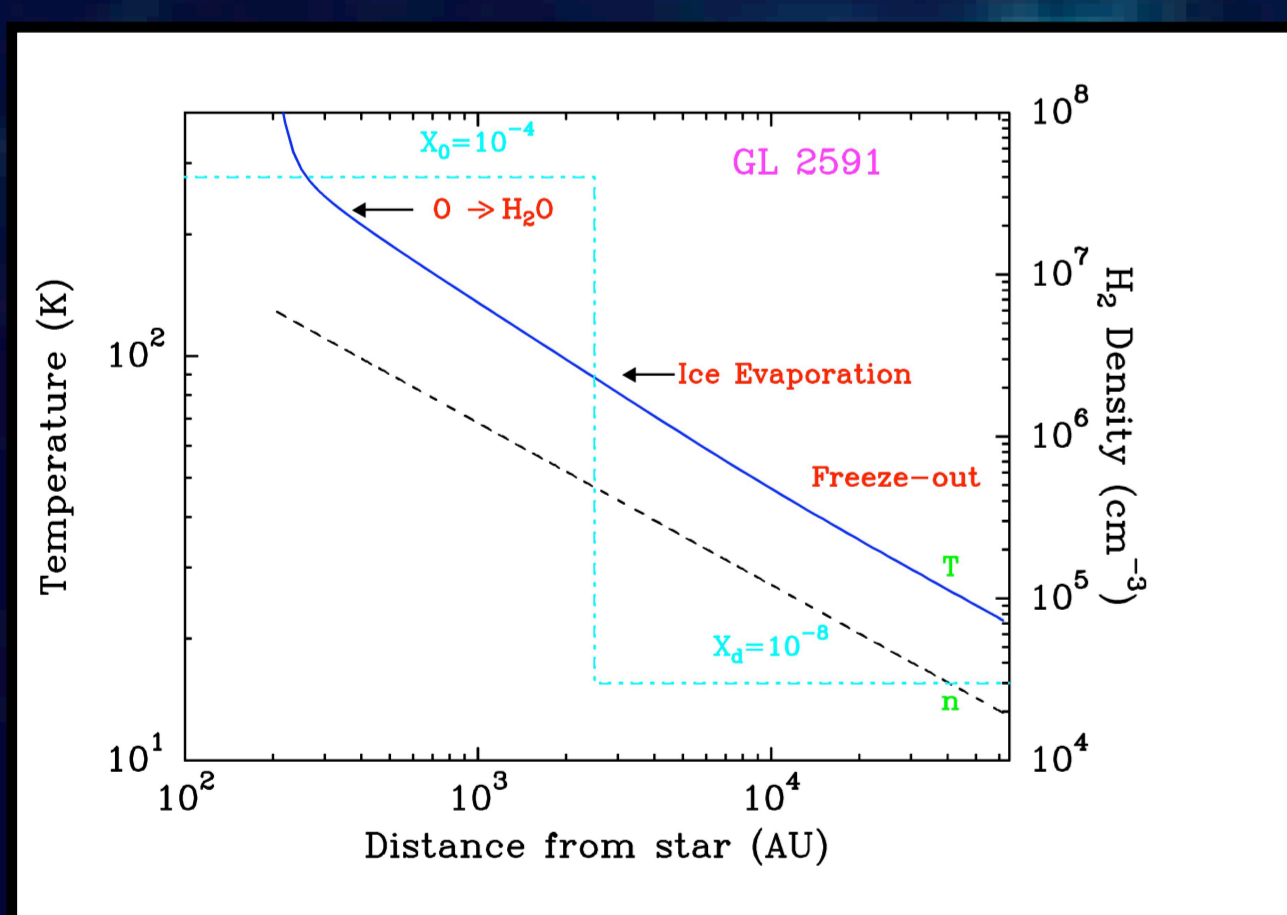
PHYSICAL and CHEMICAL STRUCTURE

Fig. 2: Structure of GL 2591, a high-mass YSO. Included is the freeze-out of water on the grains below 100 K, which causes a characteristic 'jump' abundance. Note the large range in both H_2 density (n) and temperature (T). Herschel will critically test these models.

COMPLEMENTARY OBSERVATIONS

Analysis of the water data relies heavily on complementary data. All sources are chosen to be isolated and well characterized using:

✓ Sub-mm single-dish: JCMT, APEX, IRAM, Onsala
✓ Sub-mm interferometry: OVRO, PdB, SMA, CARMA
✓ Mid-IR : Spitzer, VLT, ISO, Keck (water ice!)

MODELLING TOOLS

Water poses many challenges for the modelers, including high optical depths, masers and coupling with the dust radiation. The WISH team has developed several codes to model water and other molecules under a variety of conditions, including:

✓ Constant T and n: LVG, escape probability, ...
✓ Varying T and n: Monte Carlo, ALI, ...

See **http://www.sron.rug.nl/~vdtak/H2O/** for a test campaign of water codes. Some programs are made publically available, together with tables of collisional rate coefficients (**http://www.strw.leidenuniv.nl/~moldata/**)

DATA PRODUCTS

★ To Herschel science center
  ✓ Reduced and calibrated HIFI spectra
  ✓ Line profile parameters
  ✓ Small HIFI maps
  ✓ Data cube of calibrated images for PACS lines

★ On WISH website
  ✓ Quick-look browser of selected spectra
  ✓ Table with available complementary data
  ✓ Grid of model results
  ✓ Links to selected model programs
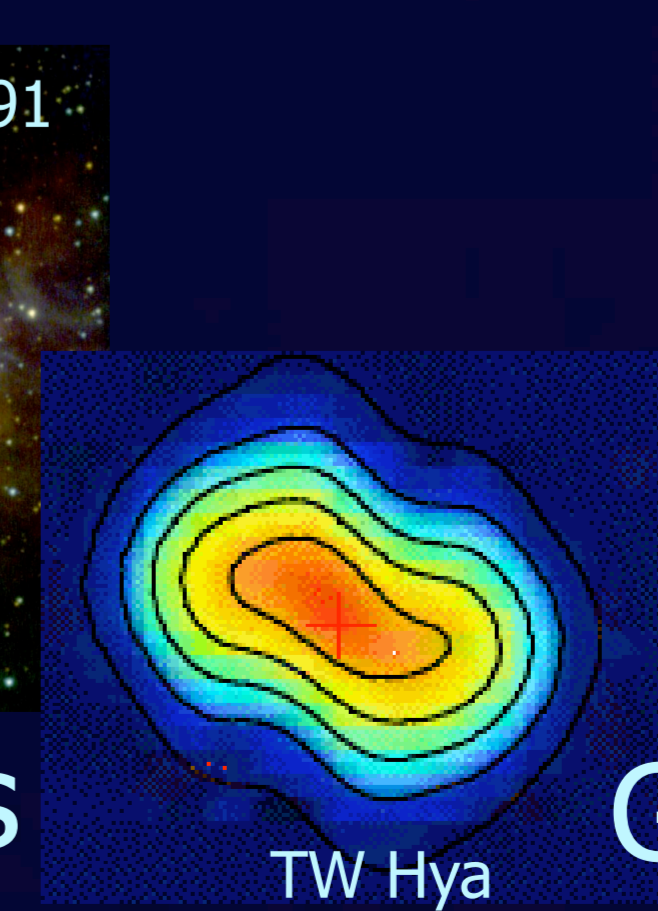
WISH Objects Include :

Pre-stellar cores

HH46-47

Intermediate mass YSOs

AFGL 2591
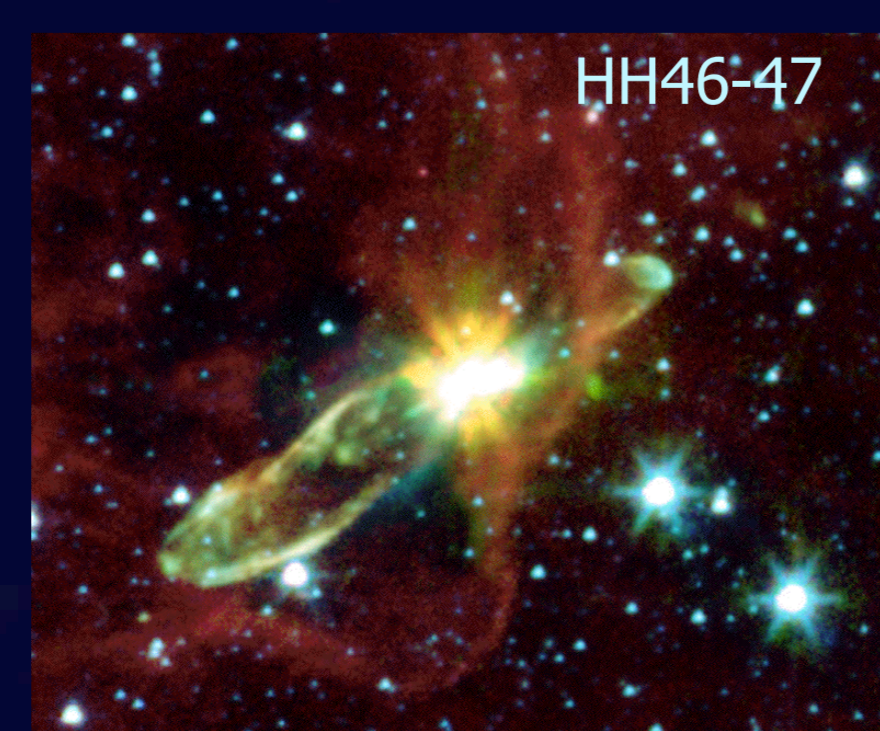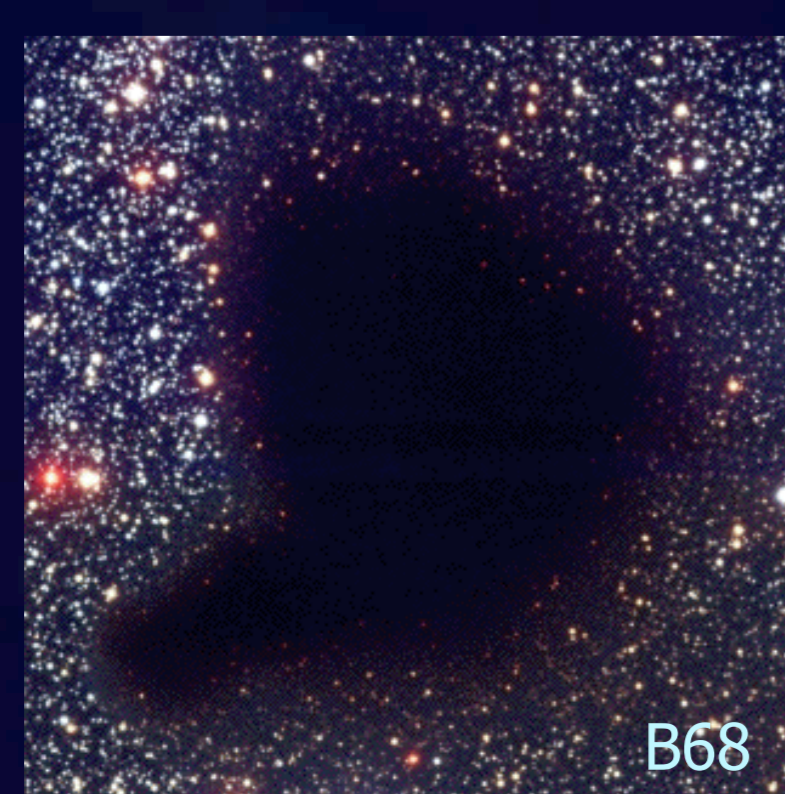
Low mass YSOs includes outflows

B68

IC1396

High mass YSOs

Gas disks

TW Hya