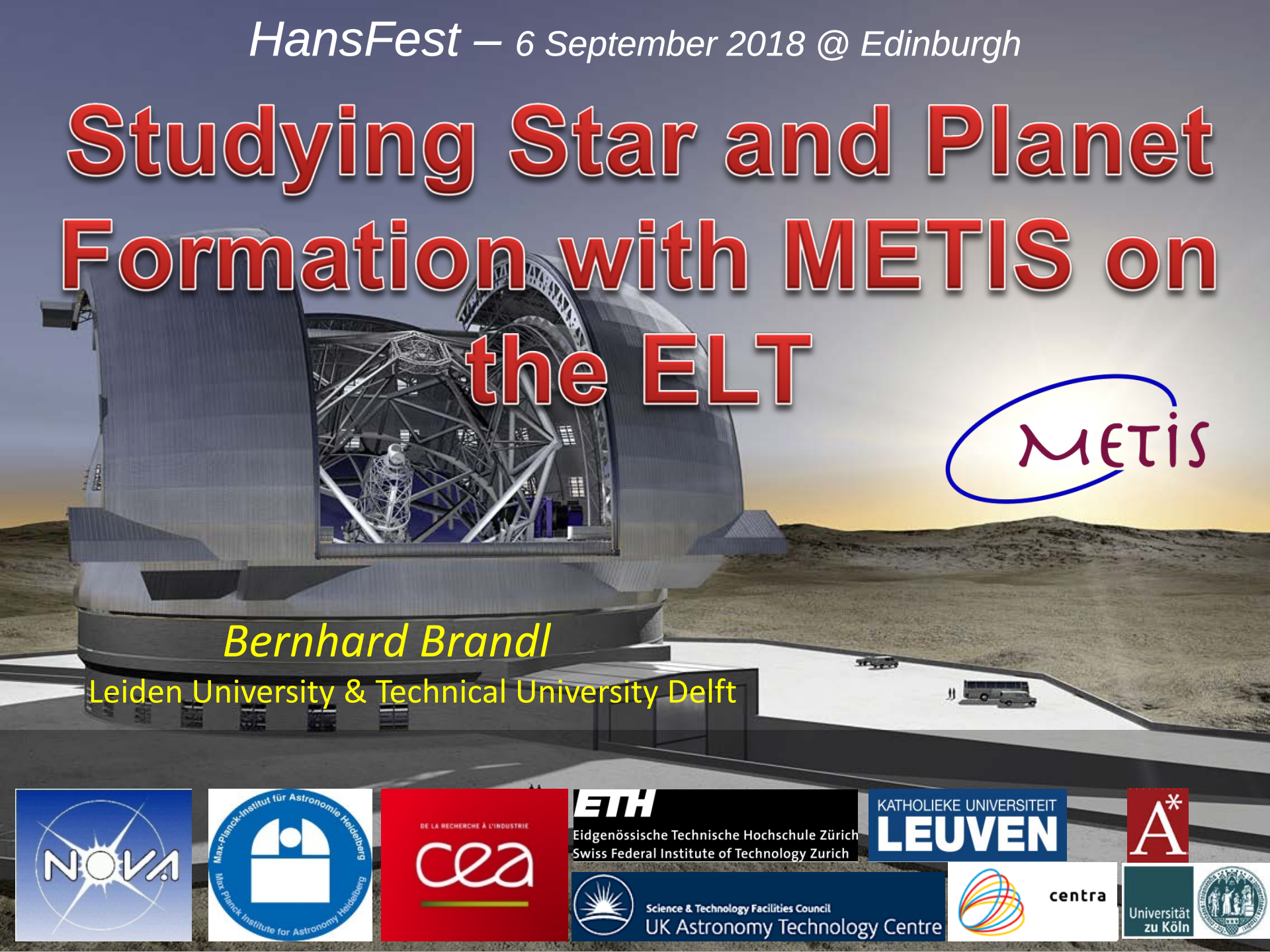
HansFest – 6 September 2018 @ Edinburgh

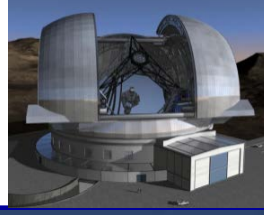
Studying Star and Planet Formation with METIS on the ELT



Bernhard Brandl

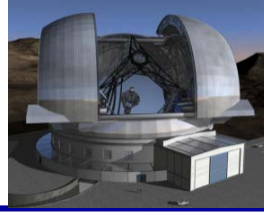
Leiden University & Technical University Delft

METIS ESO's Extremely Large Telescope (ELT)



- Largest optical-IR telescope: 39m aperture
- Novel 5 mirror telescope design, incl. Adaptive Optics
- Located on Cerro Armazones in Northern Chile
- First light in 2024

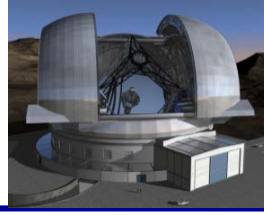
Hans and the ELT Science Working Group



Define its science drivers: *"(The ELT) will also enable us to directly study planetary systems during their formation from proto-planetary discs around many nearby very young stars. Furthermore, observations of giant planets in young stellar clusters and star forming regions will trace their evolution as a function of age."*

final meeting, Garching, February 27-28, 2012

METIS is one of the first three scientific instruments @ ELT!



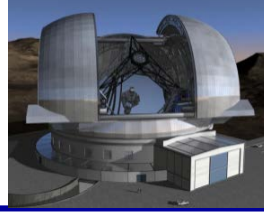
MICADO

HARMONI

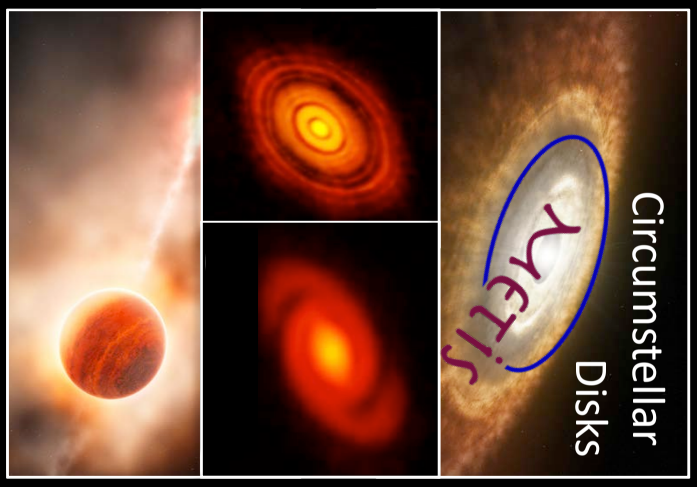
METIS

…and arguably the most important facility on the ground to study star formation in the 2020ies.

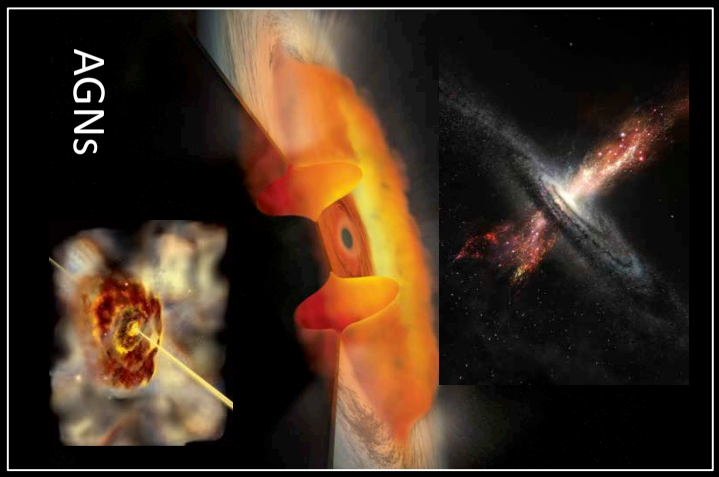
The Mid-Infrared ELT Imager and Spectrograph

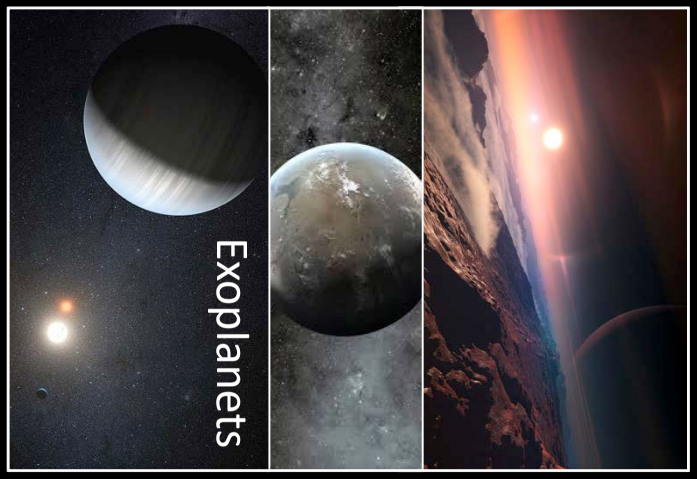


- **Imaging at 3 – 19 µm.** The imager (FoV ~ 12″), incl:
  - low resolution slit spectroscopy
  - coronagraphy for high contrast imaging
- **High resolution (R ~ 100,000) IFU spectroscopy at 3 – 5 µm**, over a FoV < 1″,
  - incl. a mode with extended $\Delta\lambda_{instant}$ ~ 300 nm
  - coronagraphy for high contrast IFU spectroscopy
- All observing modes work at the **diffraction limit** with a SCAO system (→ Θ = 0.023″ at 3.5µm).

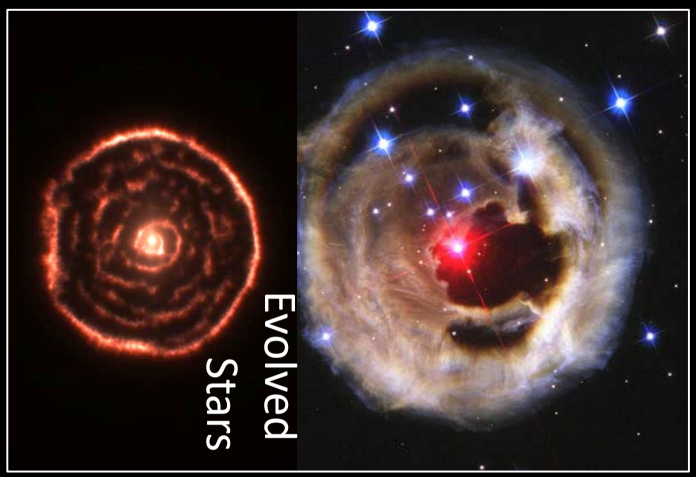


Angular resolution ~ 0.023″ at 3.5µm

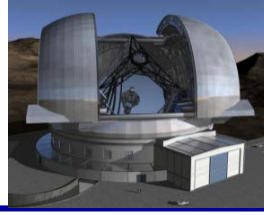




PS Sensitivity (10σ, 1hr) ~ 21.2 mag (1µJy) at L-band



Why METIS?

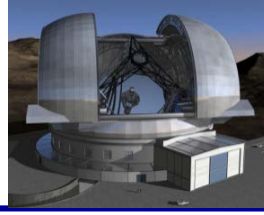


1. Angular Resolution

2. Point-source Sensitivity

3. High spectral Resolution at $\lambda_{mid\text{-}IR}$

1. Angular Resolution



W49A – the most luminous SF region in the Milky Way

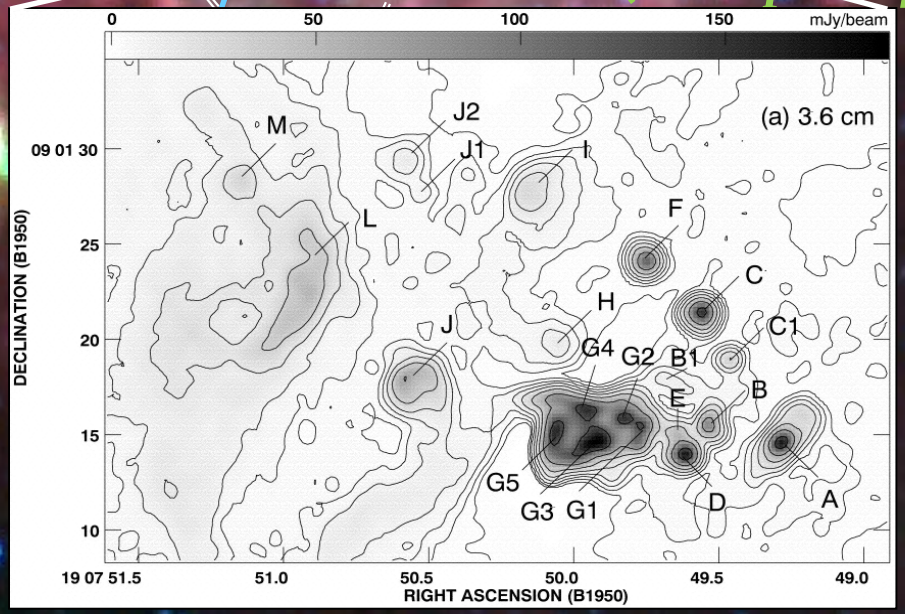
YSOs

wind-blown cavity

UCHIIRs

most powerful H_2O maser

Spitzer-IRAC	≥ 1.7″
VLA (3.6cm)	≥ 0.24″
METIS (10μm)	~ 0.065″



d = 11.1 kpc

A_V ~ 20

1 pc = 18.6″

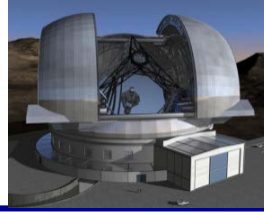
1″ = 11,000 AU

IRAC 3.2 – 4.0 μm

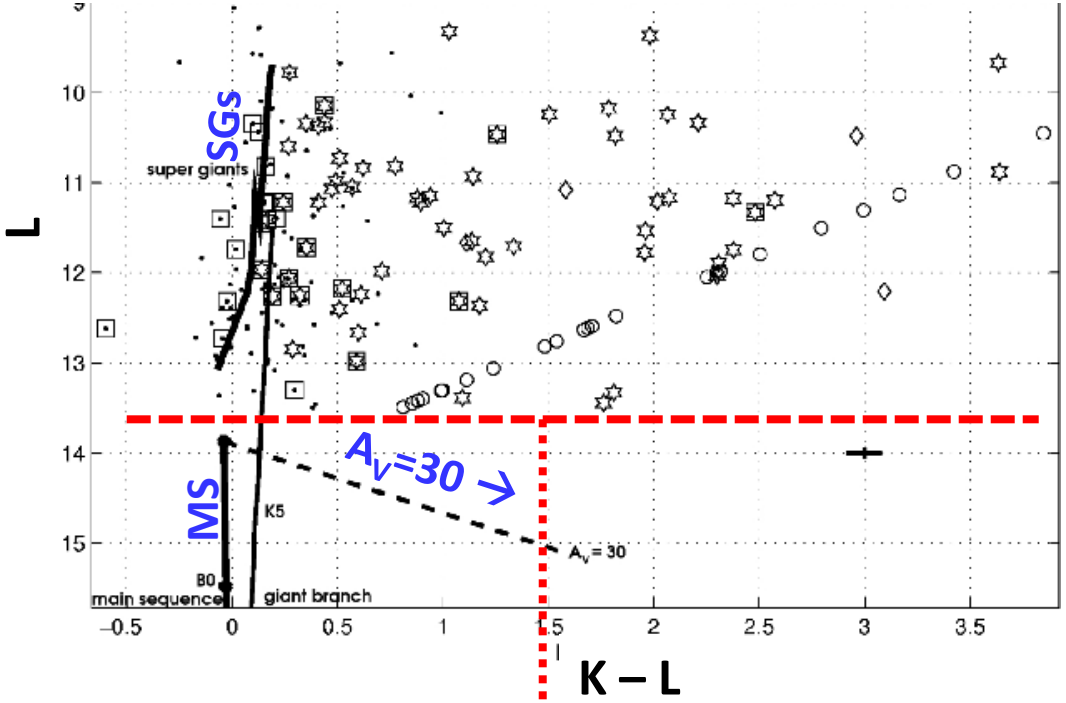
IRAC 4.0 – 5.0 μm

IRAC 6.5 – 9.4 μm

2. Sensitivity



Infrared L / (K-L) CMD for 30 Doradus (Maercker & Burton (2005))

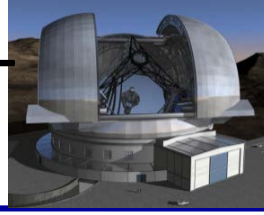


- sources with IR excess
- KL-band sources only
- L-band sources only

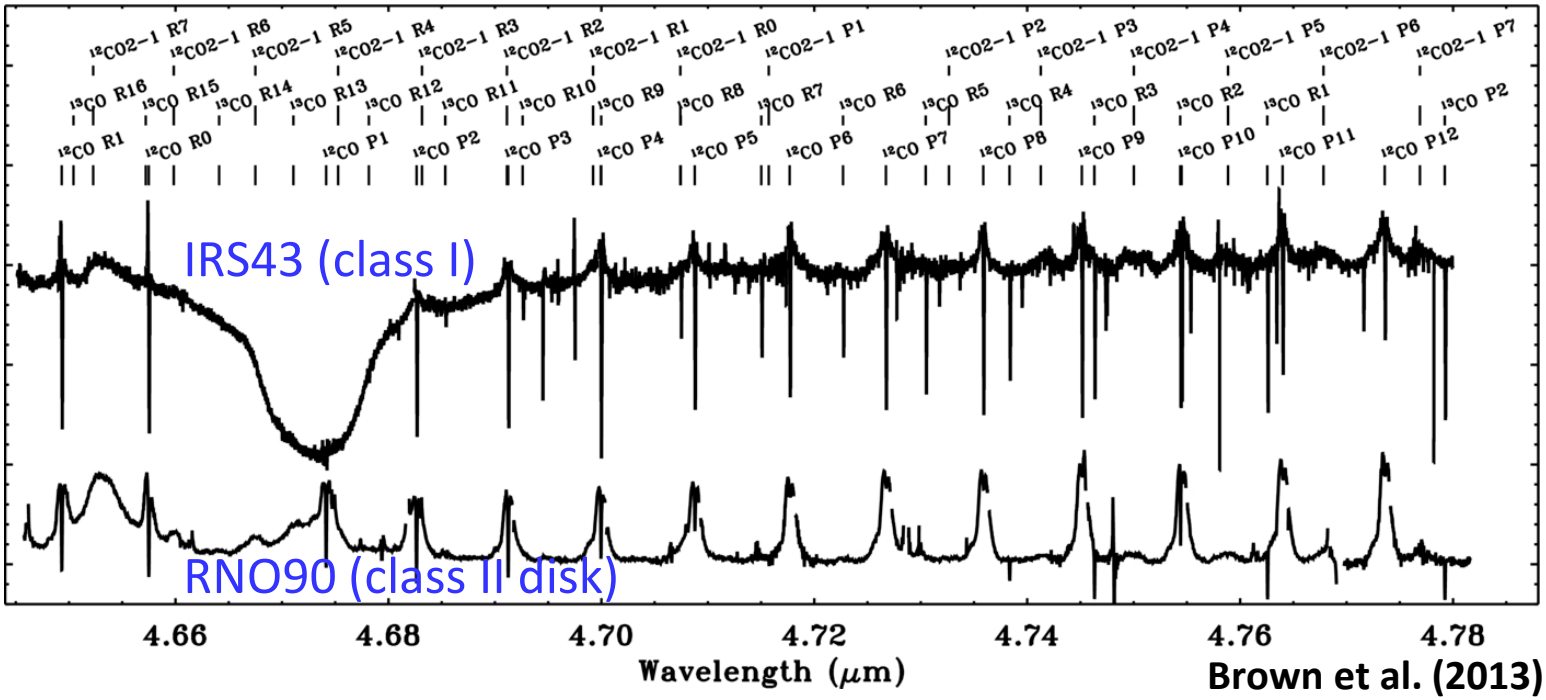
METIS will extend standard CMDs and CCDs to L-band!

METIS L-band 21 mag

3. High-resolution Integral Field-Spectroscopy



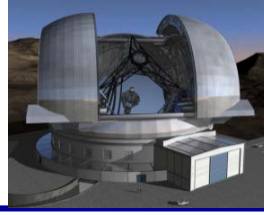
The 3 - 5µm range is extremely rich in spectral features:



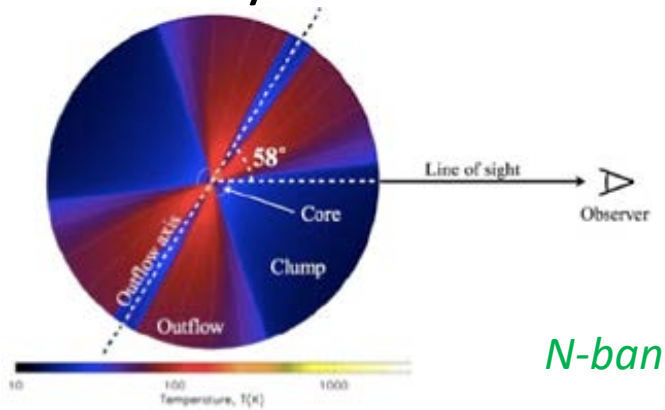
Brown et al. (2013)

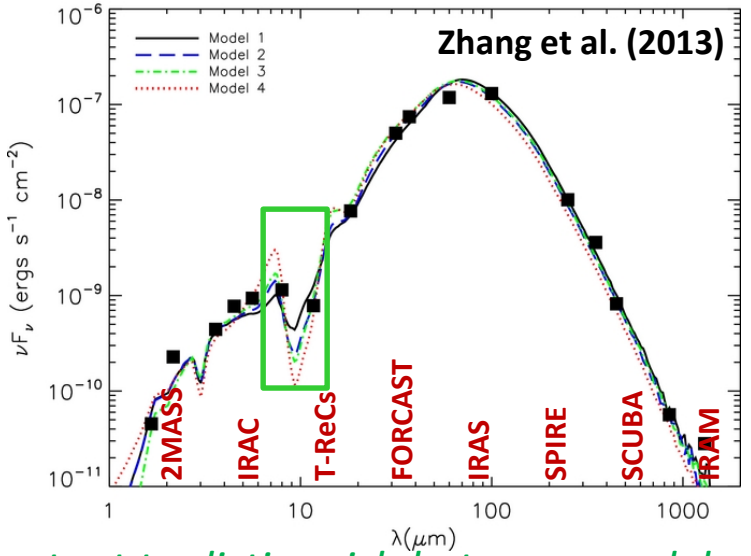
The METIS IFU will allow you to make maps in these spectral features at R ~100,000 → chemistry & kinematics

METIS Massive YSOs – 10µm Imaging

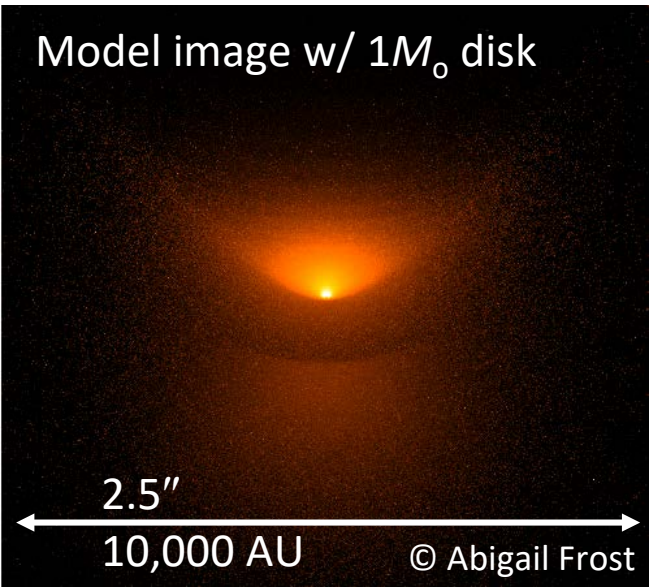


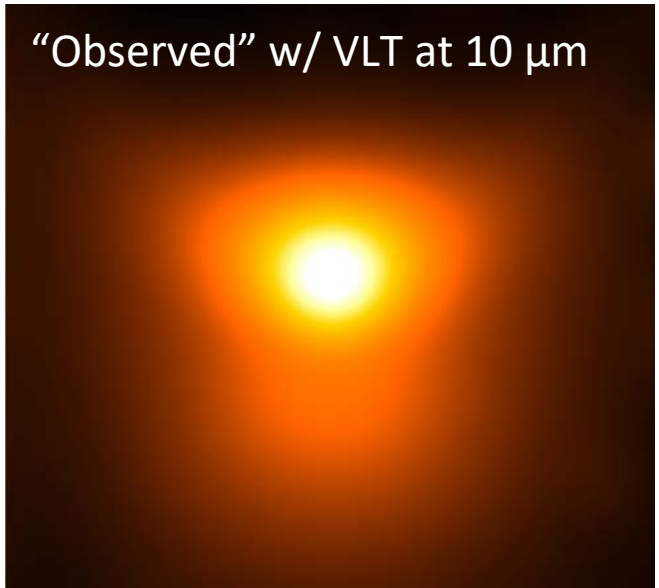
G35.2: massive protostar, embedded in large parental cloud, driving an outflow, which creates a cavity in the cloud.

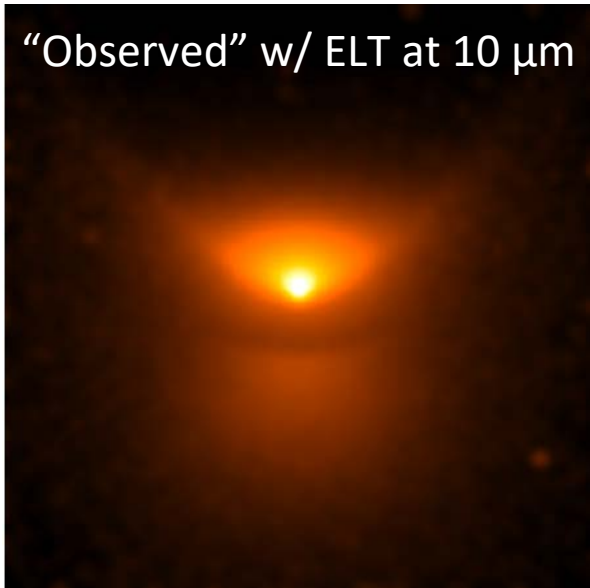




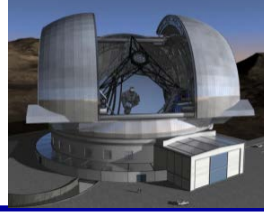
N-band is important to distinguish between models



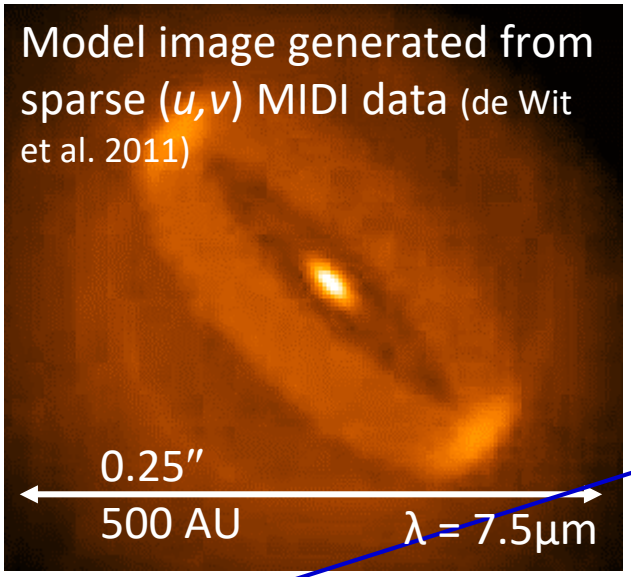


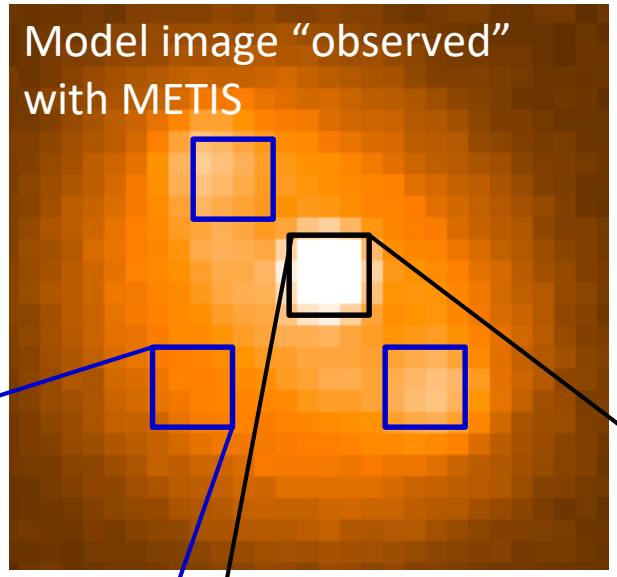


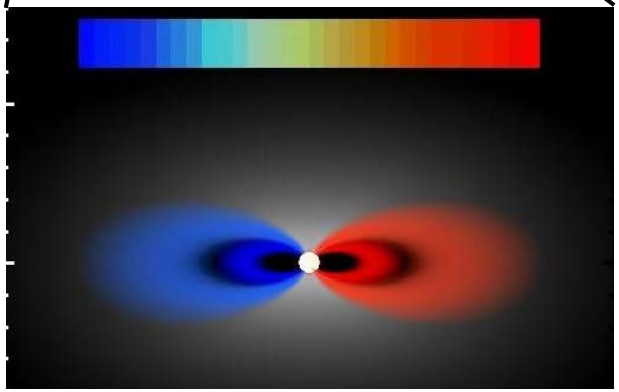
Massive YSOs – 3-5µm high resolution Spectroscopy



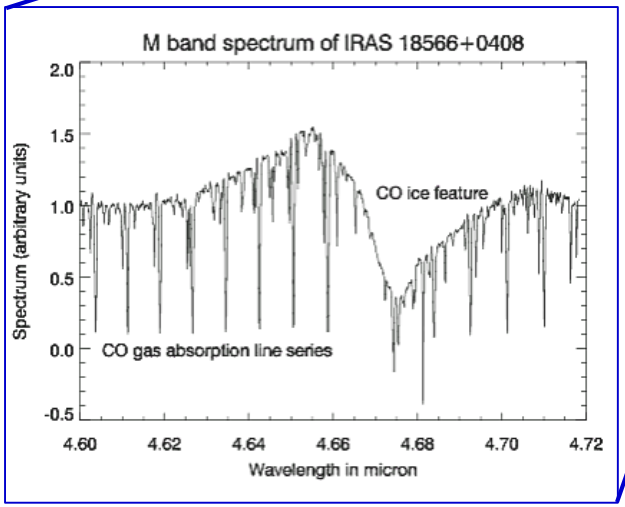
MYSO CRL 2136 / IRS-1: $L \sim 7\times10^4\ L_o$; $D \sim 2$ kpc





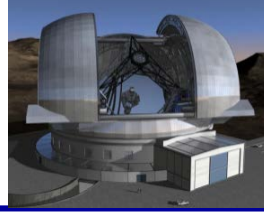


Studies of chemical composition and structure

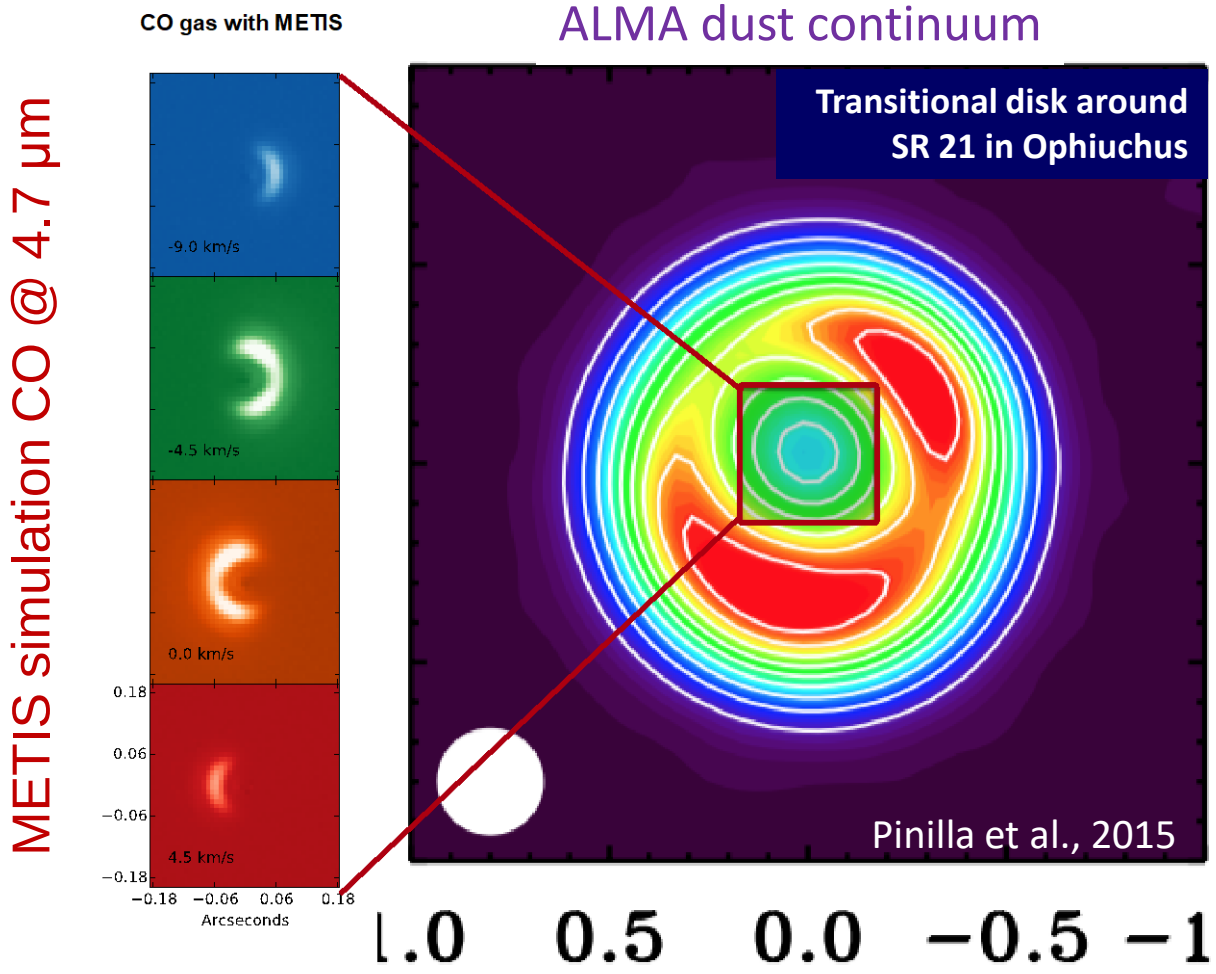


Dynamical studies with spectro-astro-metry → micro-arcsecond resolution

Imaging of Proto-Planets

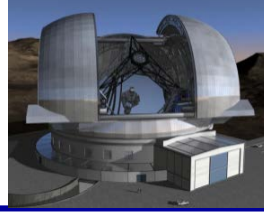


METIS will directly image the pp-disk and find rings, gaps, and embedded planets



CO gas traces an inner ring at ~7 AU (known from CRIRES spectro-astrometry – Pontoppidan et al. 2008)

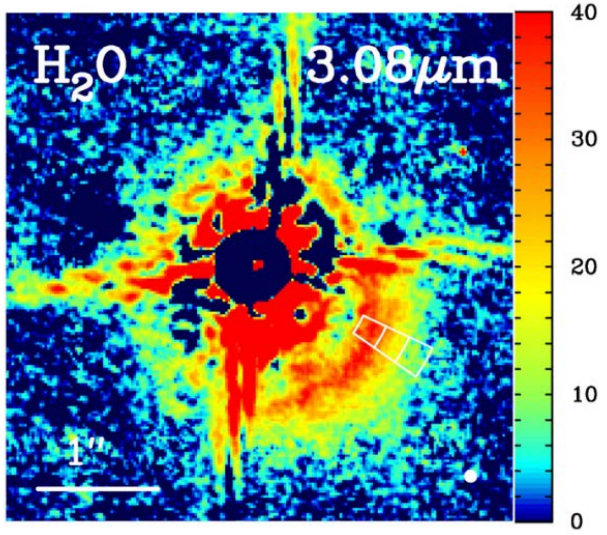
Water Ice in proto-planetary Disks



H_2O ice is driving the formation of planetesimals.

So far, only observed in:

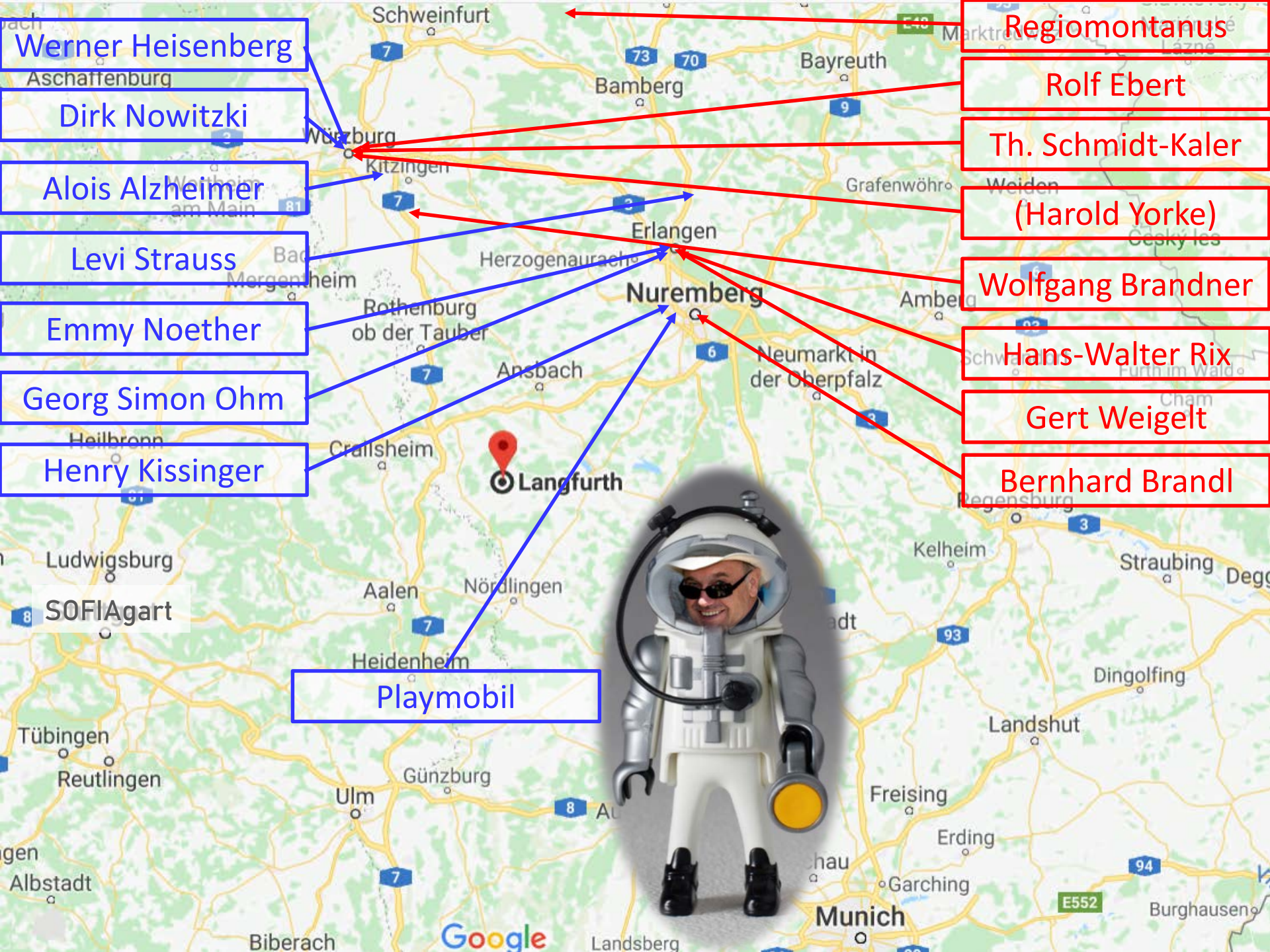
- emission at FIR **(Malfait et al. 1998, McClure et al. 2015)** only in spatially unresolved disks
- scattered light @3µm **(Inoue et al. 2009, Honda et al. 2009)**



→ METIS will resolve the surface snow line region (@3 AU ~ 0.030″) around solar-mass stars

→ METIS will image the distribution of water ice on small dust grains at great detail in more luminous systems.

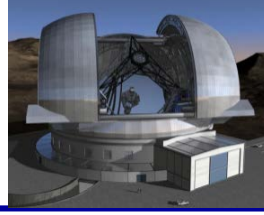

2025
METIS

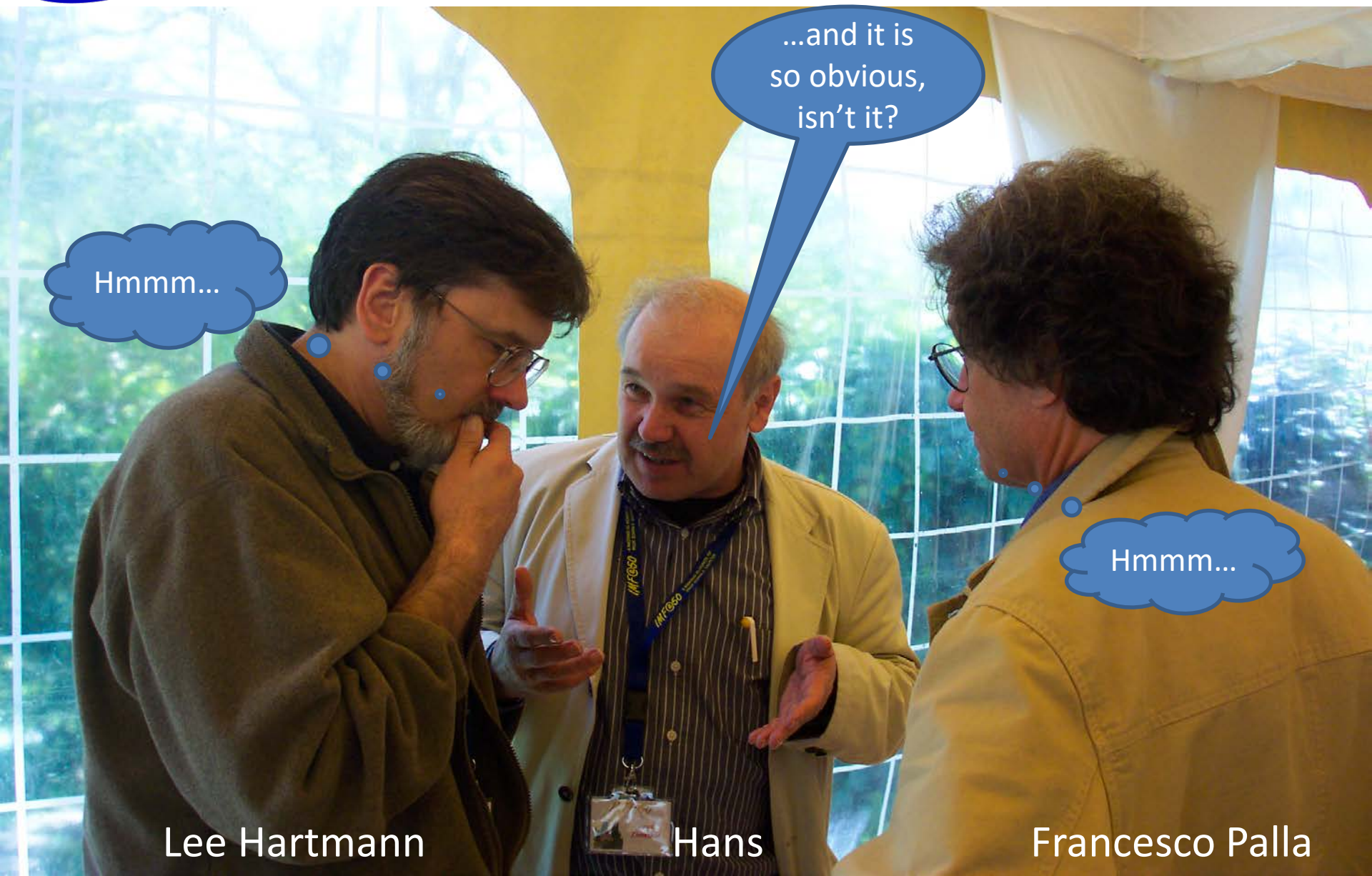

Werner Heisenberg
Dirk Nowitzki
Alois Alzheimer
Levi Strauss
Emmy Noether
Georg Simon Ohm
Henry Kissinger
Playmobil
Regiomontanus
Rolf Ebert
Th. Schmidt-Kaler
(Harold Yorke)
Wolfgang Brandner
Hans-Walter Rix
Gert Weigelt
Bernhard Brandl
SOFIAgart
Schweinfurt
Bamberg
Bayreuth
Würzburg
Kitzingen
Erlangen
Herzogenaurach
Nuremberg
Rothenburg ob der Tauber
Ansbach
Neumarkt in der Oberpfalz
Crailsheim
Langfurth
Heidenheim
Aalen
Nördlingen
Ludwigsburg
Tübingen
Reutlingen
Ulm
Günzburg
Biberach
Albstadt
Kelheim
Straubing
Dingolfing
Landshut
Freising
Erding
Garching
Munich
Landsberg
Burghausen
Regensburg
Amberg
Grafenwöhr
Weiden
Aschaffenburg
Google

The early Days at MPE Garching

↑ Body vs. Brain. In these football matches even MPE directors participated, either as referees or active players.

METIS IMF@50 – Tuscany, May 2004





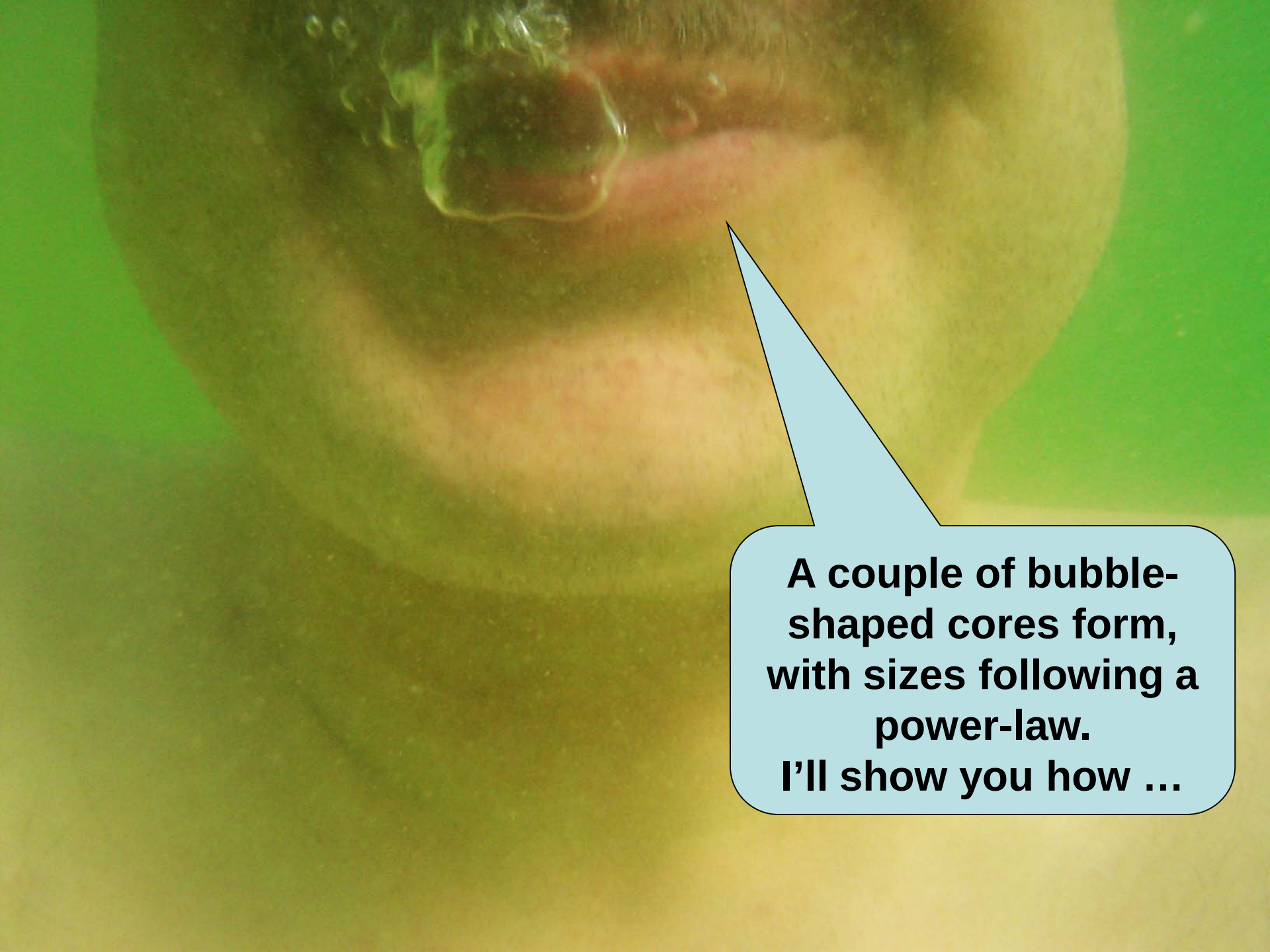
presents:

Star Formation 101

featuring Hans Zinnecker

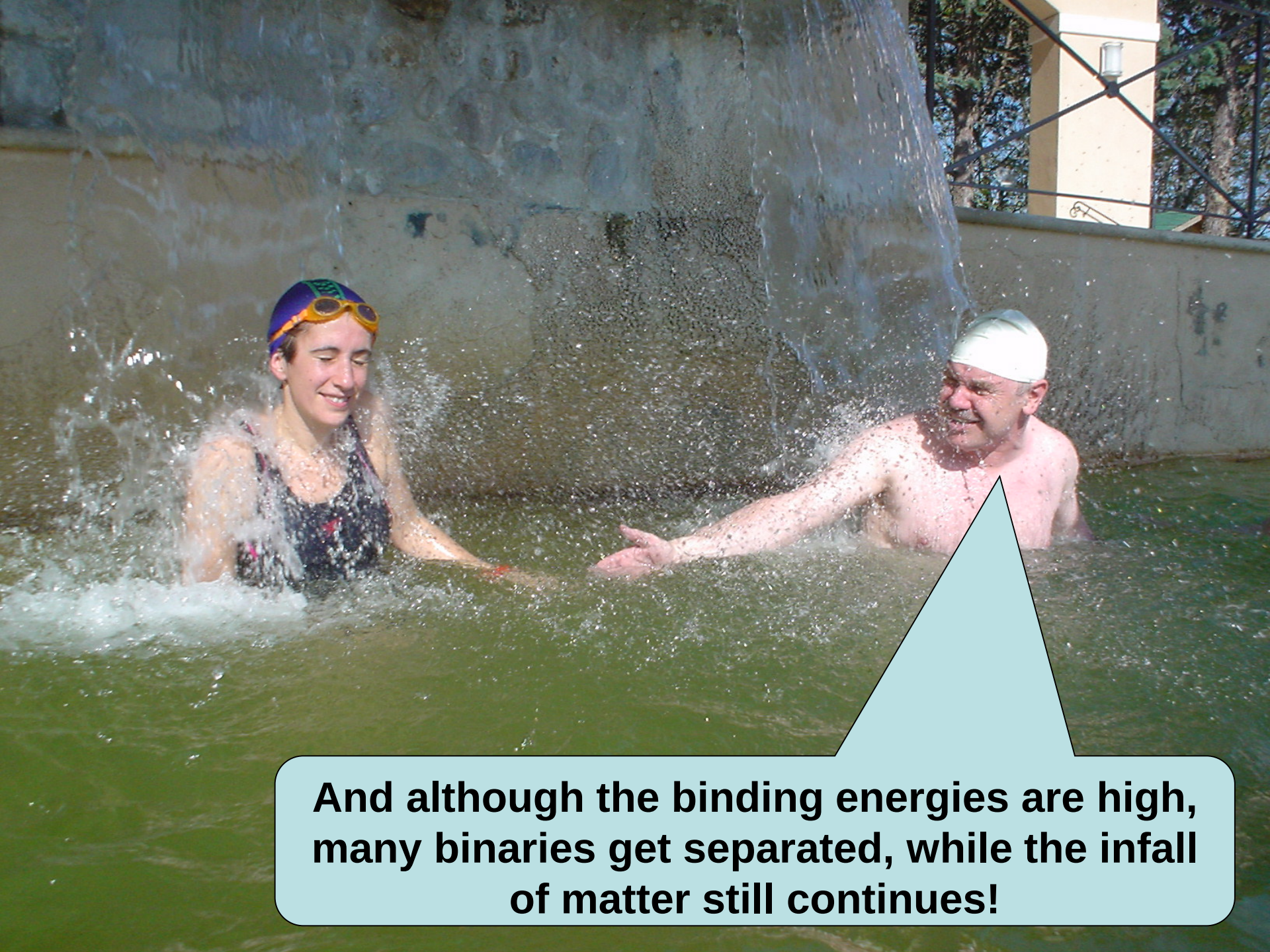

I’m gonna tell you now how star formation works.

To get started you need a dense medium, and cooling is very important!


A couple of bubble-shaped cores form, with sizes following a power-law.
I'll show you how …


The earliest stages are hard to observe, though, because they are highly obscured.


Many young stars have close companions!


And although the binding energies are high, many binaries get separated, while the infall of matter still continues!


Wow! Hans' skills as teacher surprise me every time…

Director	BERNHARD BRANDL
Camera	WOLFGANG BRANDNER

Actors

Lead Actor	HANS ZINNECKER
Stuntman	HANS ZINNECKER
Binary Star	EDVIGE CORBELLI
Supporters	MARK MCCAUGHREAN,
	MONIKA PETR-GOTZENS