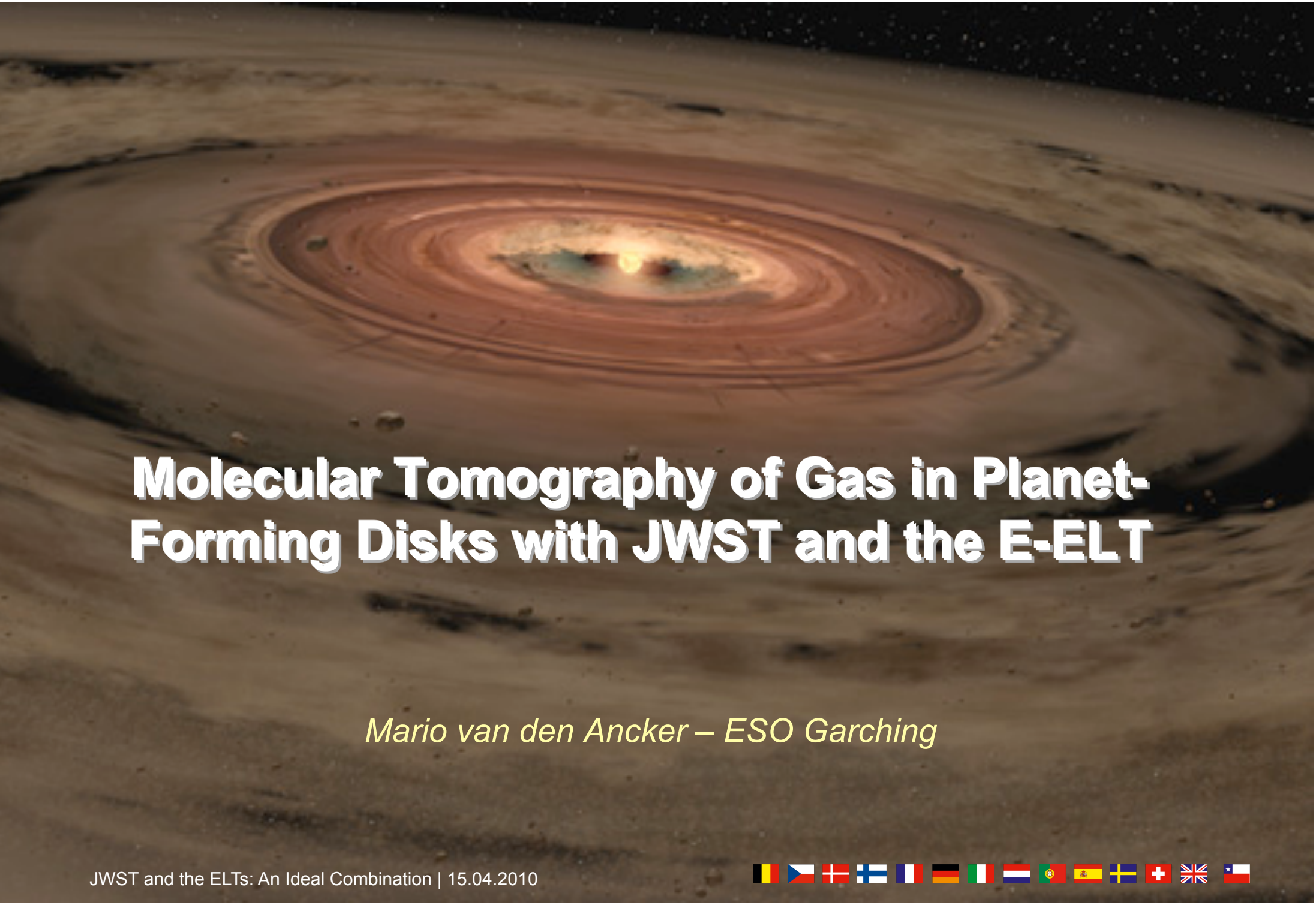

Molecular Tomography of Gas in Planet-Forming Disks with JWST and the E-ELT

Mario van den Ancker – ESO Garching

Planet Formation Studies with the ELTs

ESO
European Organisation for Astronomical Research in the Southern Hemisphere

Central Question: How common is the architecture of our own solar system in the universe?

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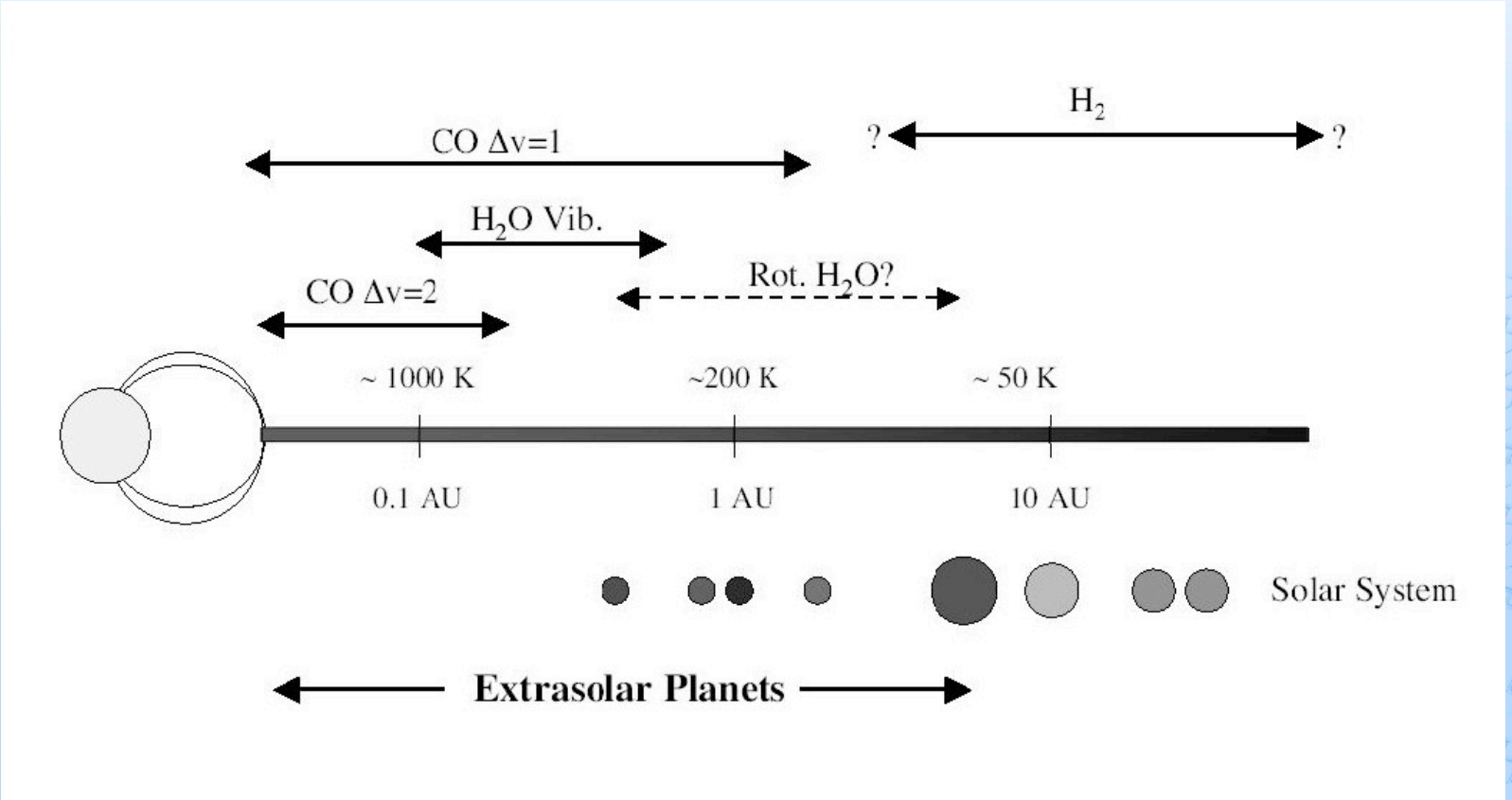
Solution: Spectral Tomography = Image Reconstruction from spatially and spectroscopically resolved emission lines from the disk

Infrared Emission Lines from Planet-Forming Disks



CO ro-vibrational lines especially important, as they are relatively bright and accessible from the ground.

Current Instrumentation: CRIRES at the VLT

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CRIRES: AO-fed High-Resolution Infrared (0.95-5.2 μm) Spectrograph

Spectral Resolution R = 100,000

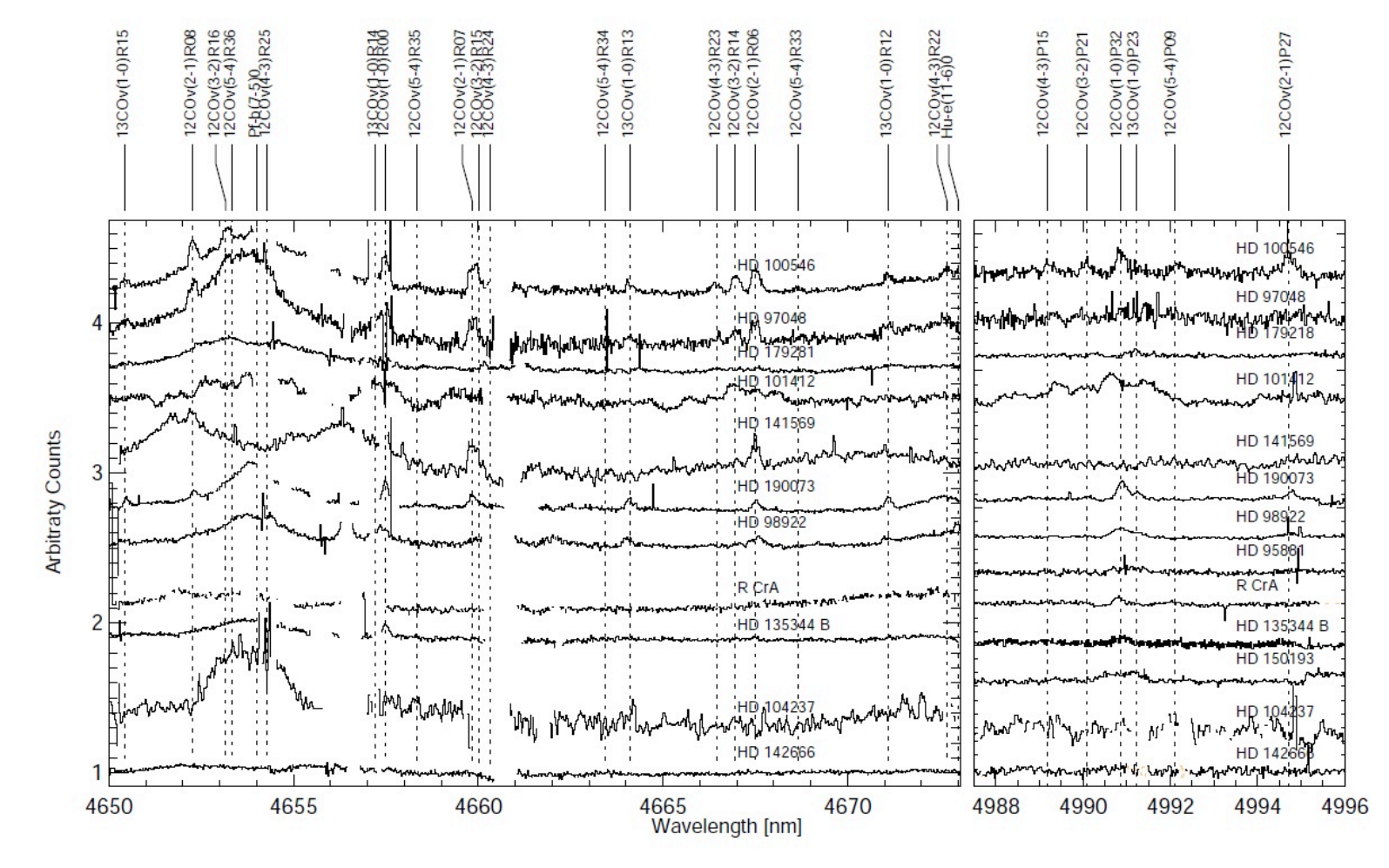
AO using MACAO (FWHM ~ 0.2” at 4.6 μm)

Observations of Disks Surrounding 13 Herbig Ae/Be Stars (van der Plas et al. 2009, 2010).

CO spectrally resolved in all cases.

Two disks spatially resolved.

CO Fundamental Line Emission: CRIRES @ the VLT



van der Plas et al. (2010)

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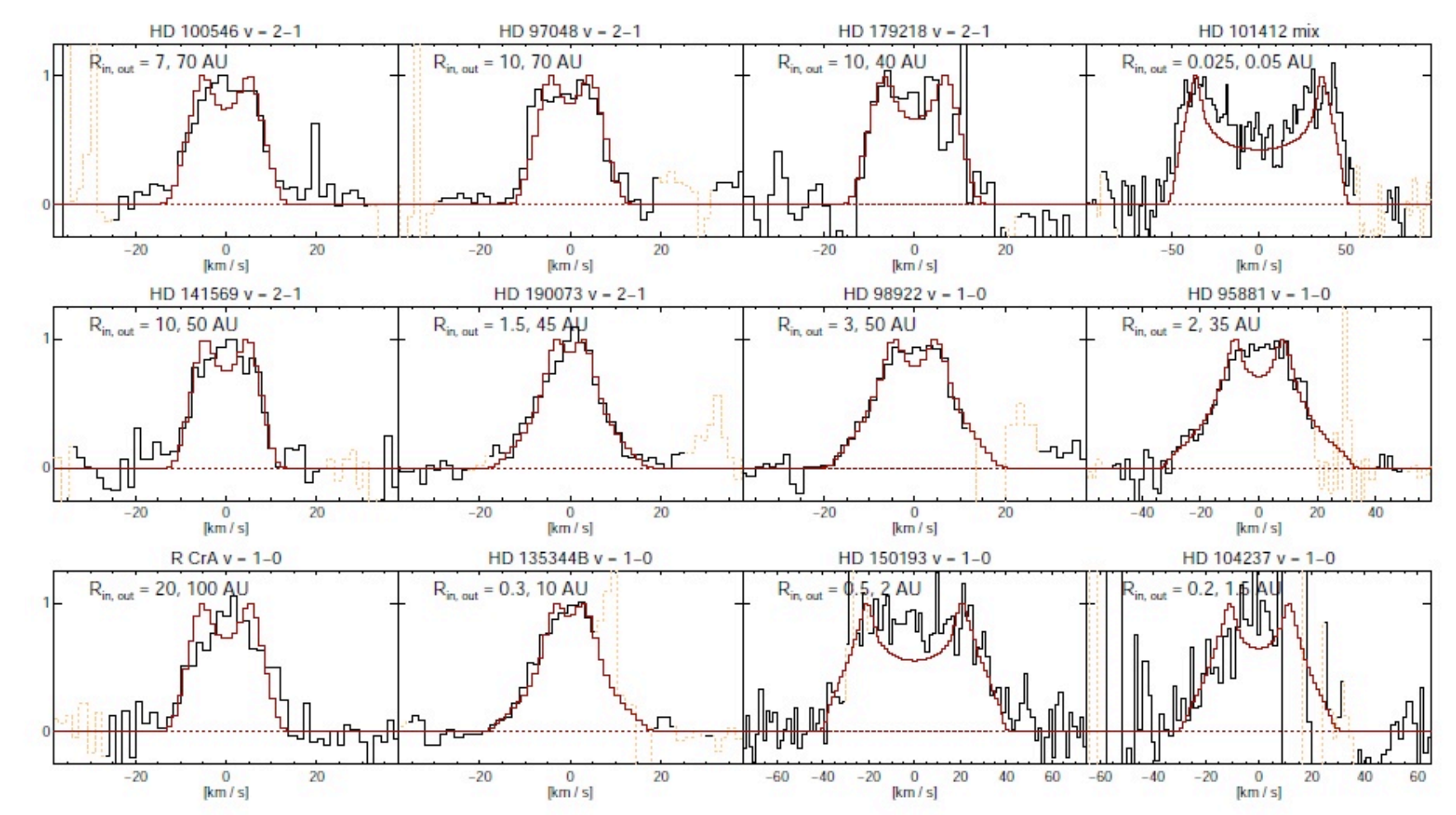

van der Plas et al. (2010)

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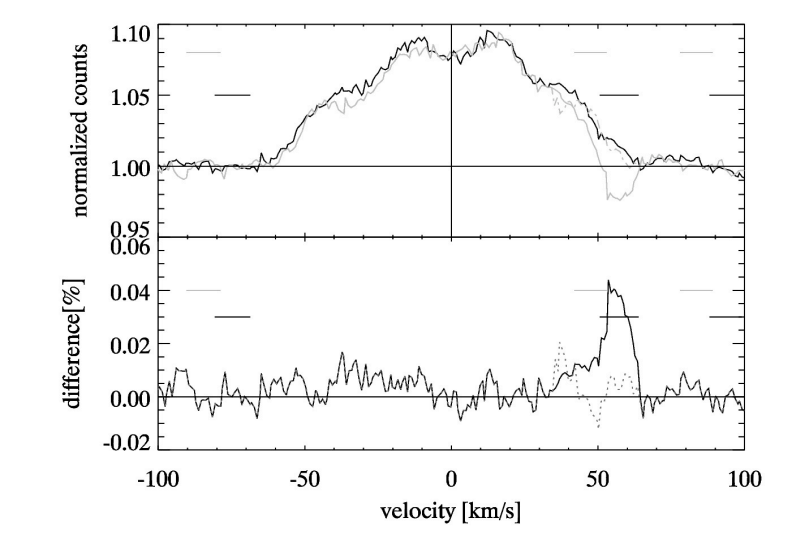
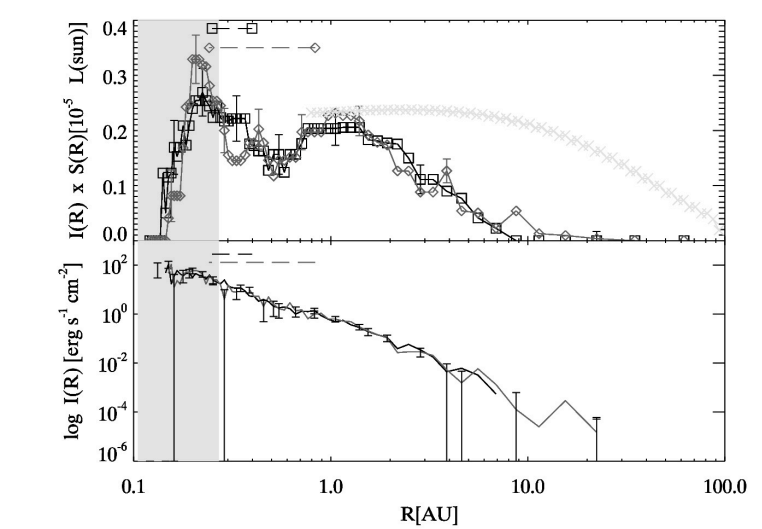
Reconstruction of Disk Surface Brightness from Line Profiles

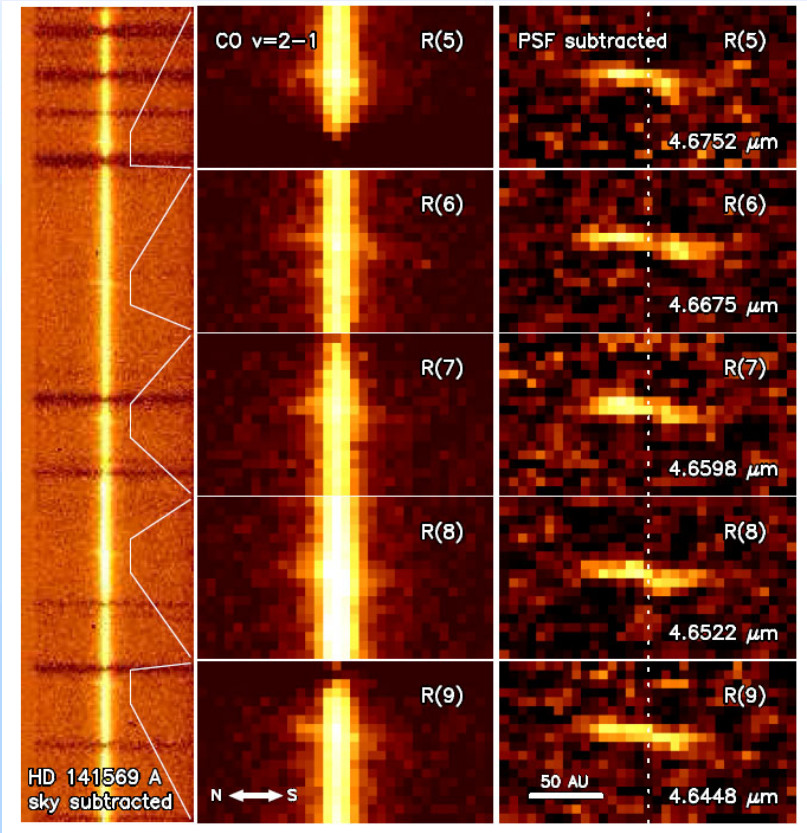




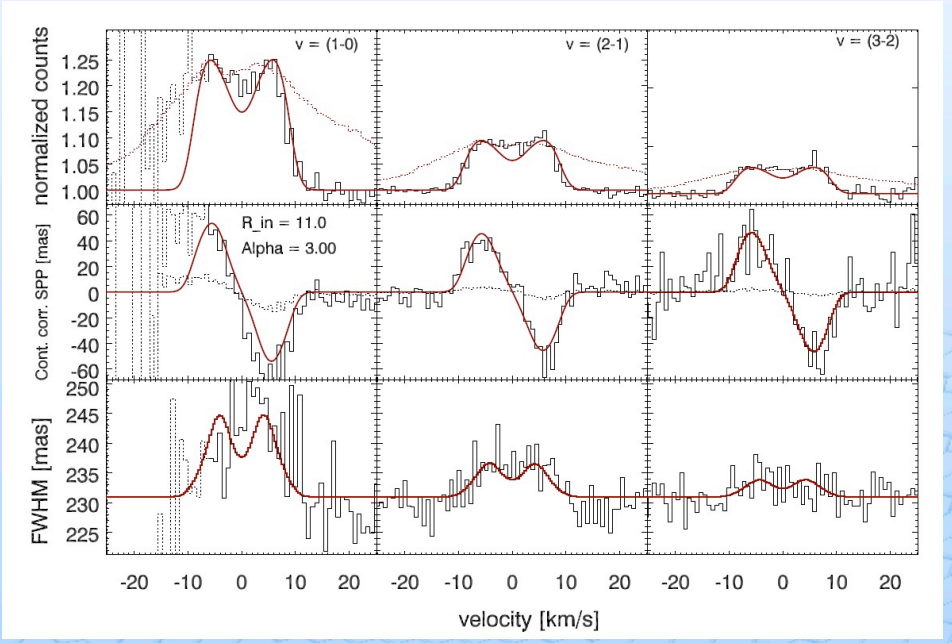
van der Plas et al. (2008)

Stellar mass and disk inclination need to be known…

Spatially Resolving Emission Lines



Goto et al. (2006)



van der Plas et al. (2009)

Spectro-astrometric analysis does not take full advantage of information embedded in line profiles.

Spectral Tomography: The Full Reconstructed Image

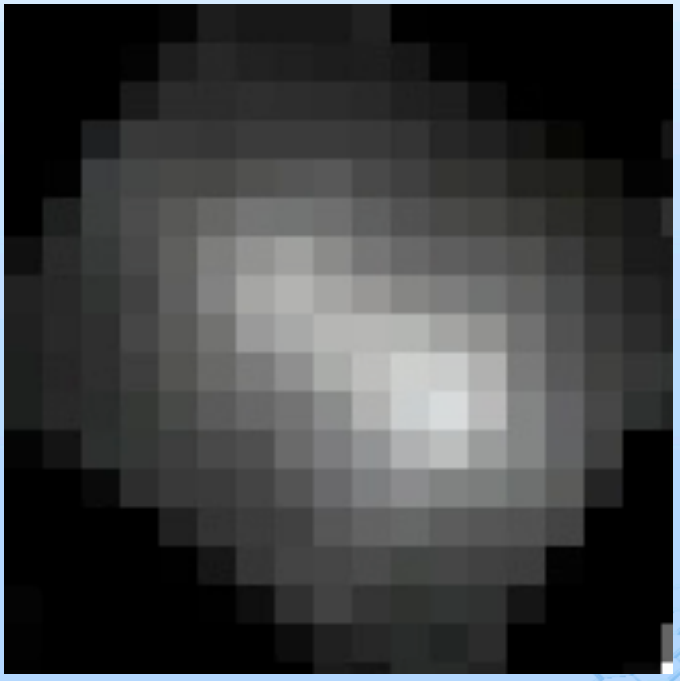


Image Scale: 50 x 50 AU

Assumptions:

Keplerian Rotation

Orientation of Disk on Sky Known

Stellar Mass Known

Current Limitations of Spectral Tomography

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Limited Spatial Resolution: Disks only marginally resolved: poor constraints on disk orientation. Rotation pattern has to be assumed.

Limited Spectral Resolution: Translates to smallest spatial scales at which gaps can be detected.

Weak Lines on Top of Strong Continuum: Limited S/N: radial averaging necessary to see signal from gap.

At current 8-m class telescopes: Possible to infer presence of gaps due to several M_J planet at several AU from the star.

Prospects for the E-ELT

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Spatial Resolution < 0.05": Direct derivation of rotation pattern (deviations from Keplerian rotation detectable).

Spectral Resolution: Determines Radius out to which gaps are detectable *(*~ 10 AU for *R* = 100,000).

Large Aperture: Higher S/N: smaller gaps detectable.

➔ It will be possible to infer the presence of a gap due to a 0.1 M_J planet at 1 AU around a Herbig Ae/Be star with METIS and SIMPLE at the E-ELT.

Synergies With JWST

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Best tracers of cooler gas in the outer disk (R > 10 AU) not detectable from the ground (H_2, H_2O).

MIRI at the JWST perfectly suited to detect these; however JWST poorly suited for studies of inner disk.

Combination of JWST and E-ELT necessary to produce full picture of disk structure over the entire range of radii relevant to planet formation.