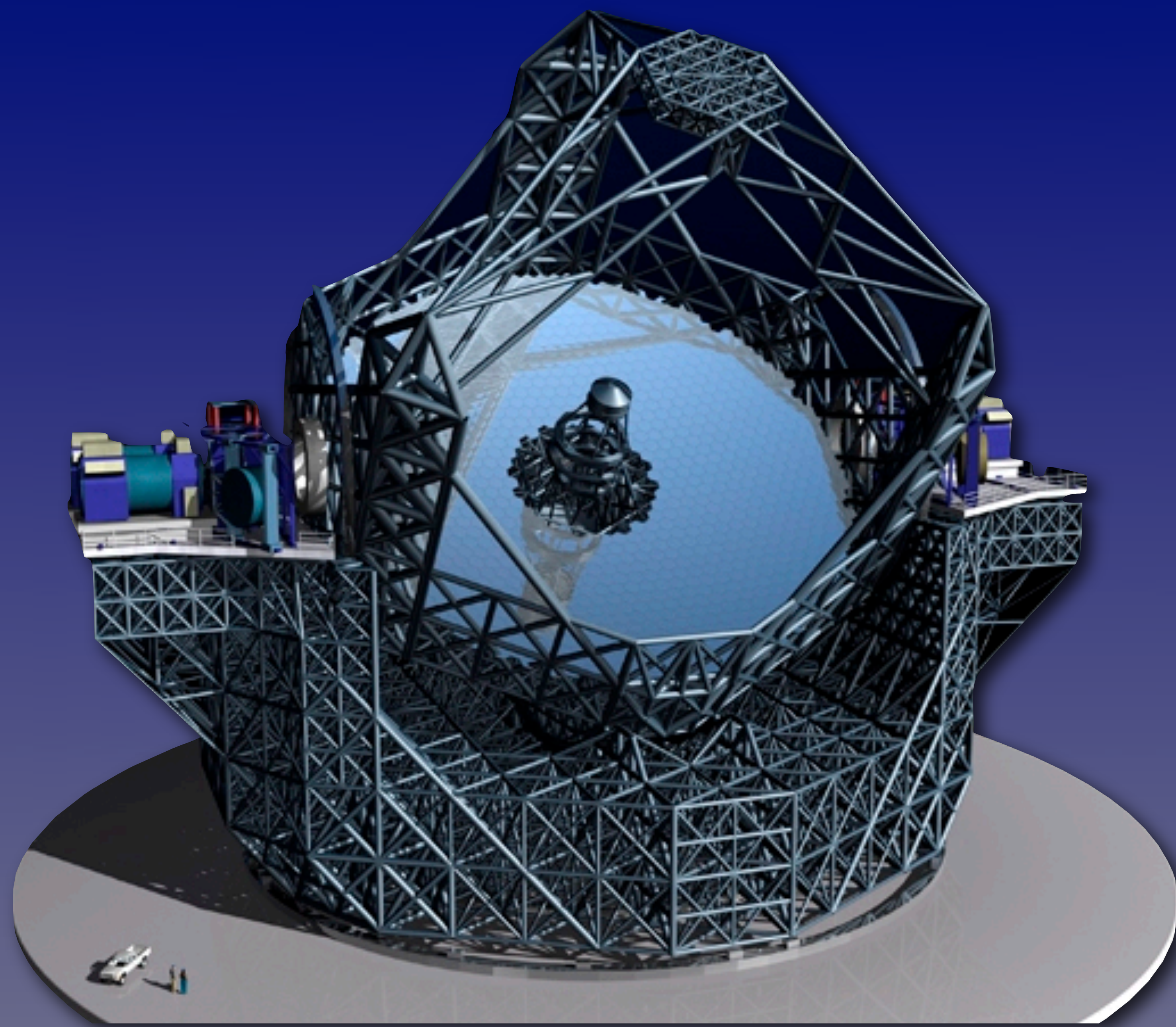

# "First light" coronagraphic specifications

UNIVERSITY OF EXETER

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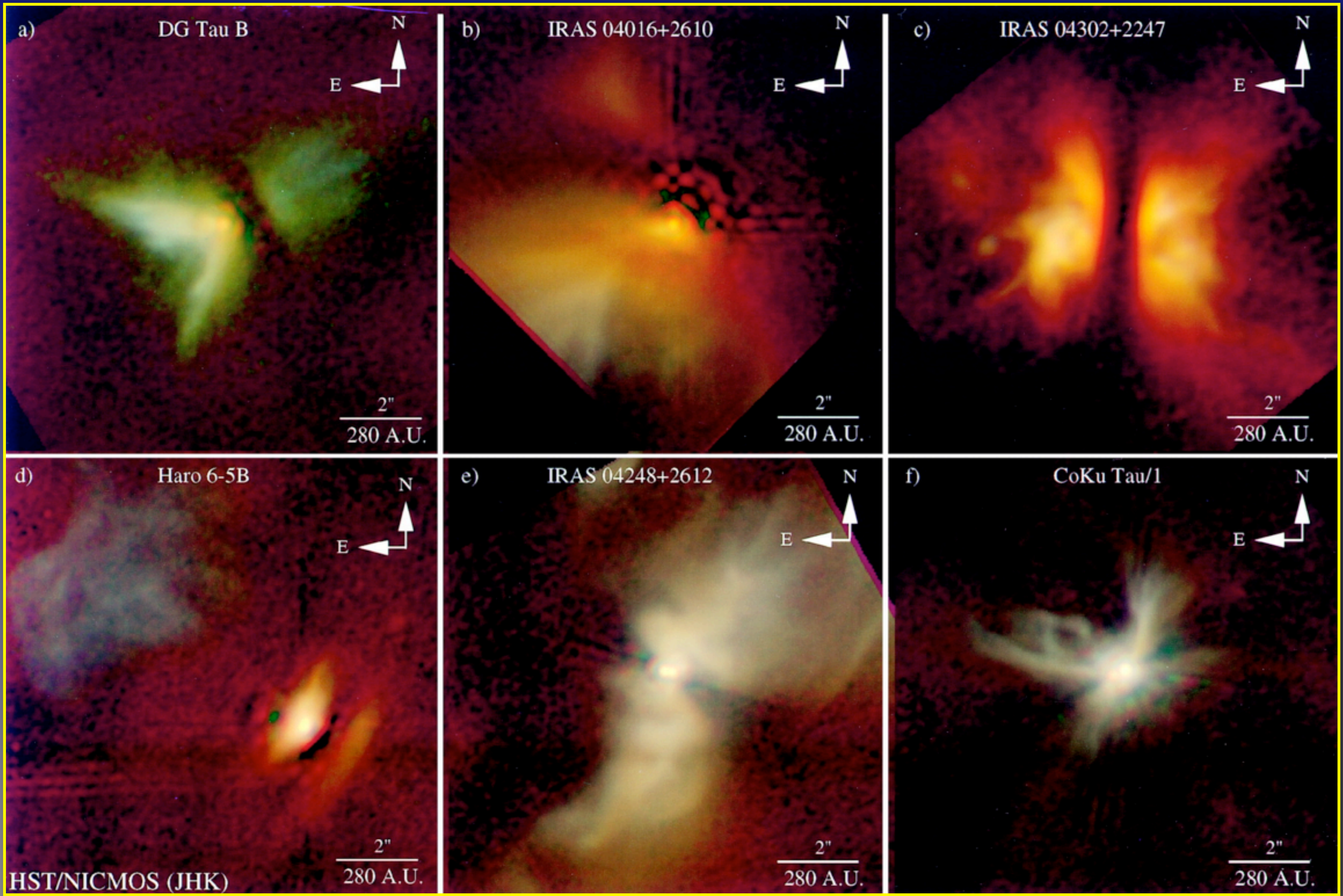
# Aim

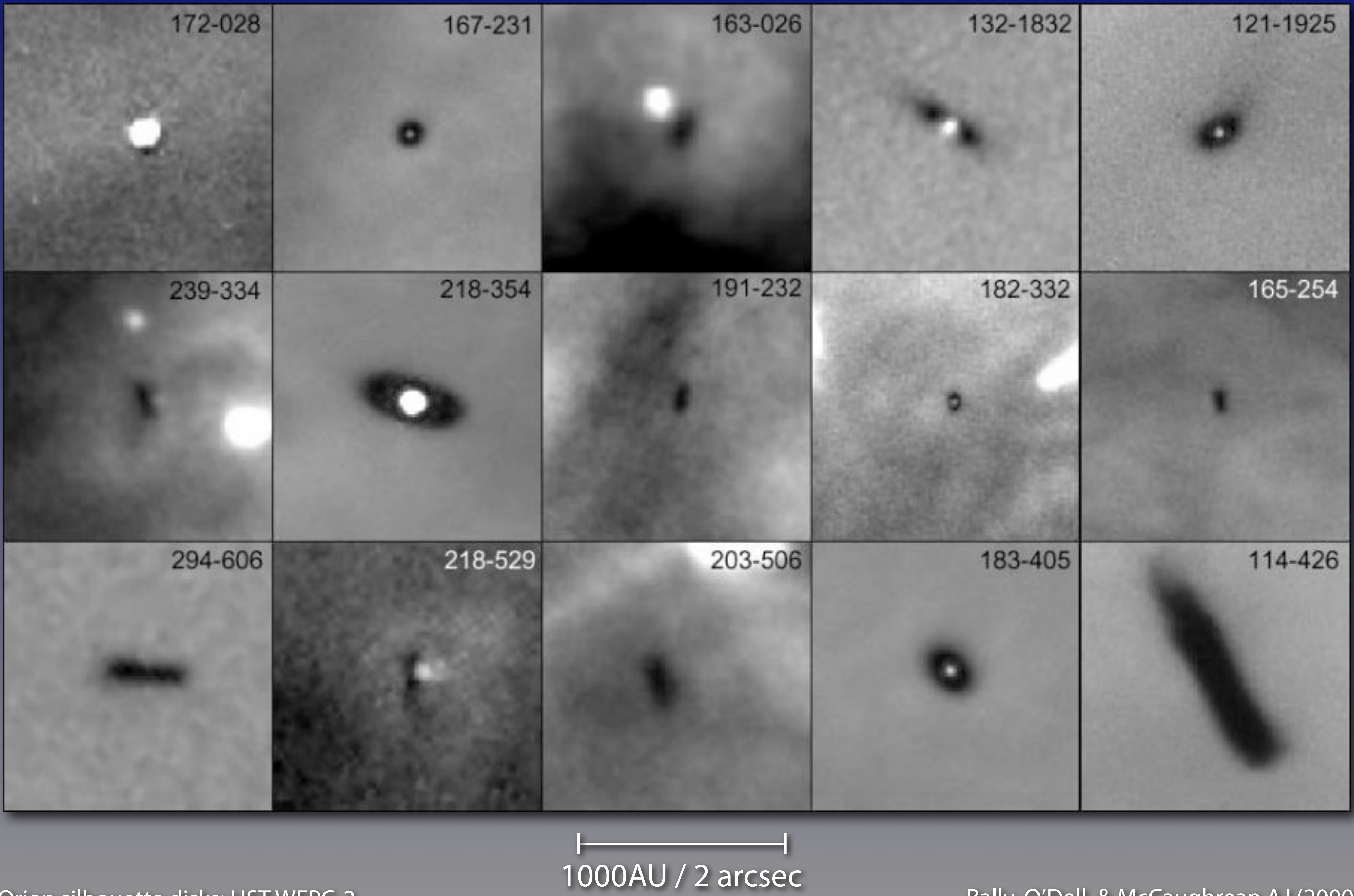
- Some high contrast imaging capability in MICADO
  - First-generation near-IR camera for E-ELT
  - Diffraction-limited imaging over small FOV
  - Not a dedicated / specialised high-contrast system
- Direct imaging of circumstellar disks
  - Search for structures in disks indicative of ongoing or completed planet formation: gaps, rings, spiral density waves
  - Young, optically-thick disks in star forming regions
  - Older, optically-thin dust debris disks in solar neighbourhood
- Requirements
  - Diffraction-limited broad/medium/narrow-band imaging
  - Single object, small FOV
  - Need to suppress central star with coronagraph

# Young disks in scattered light




NICMOS imaging: Padgett et al. (1999)

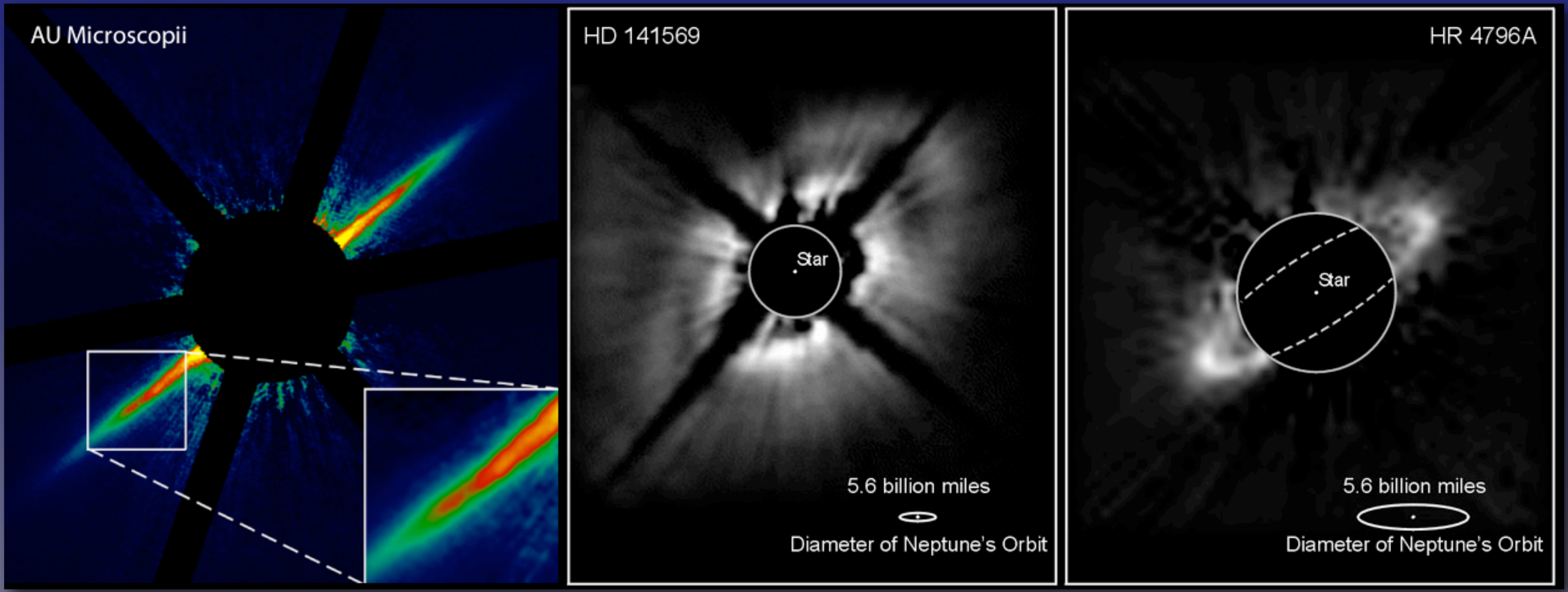
# Pure silhouette disks in Orion




Orion silhouette disks: HST WFPC-2

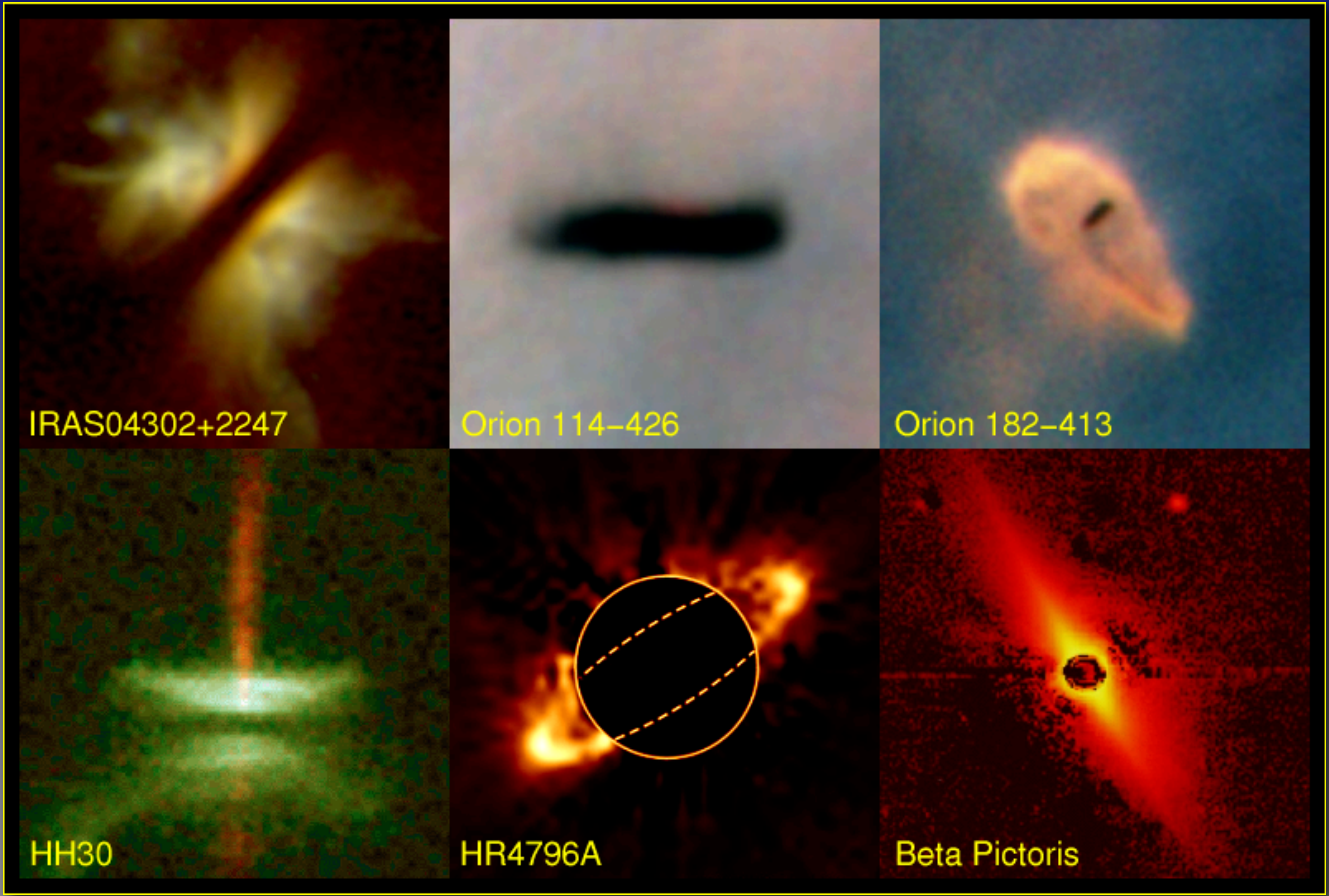
Bally, O'Dell, & McCaughrean AJ (2000)

# Scattered light imaging of debris disks




Keck (left) & NICMOS (centre, right) near-IR images of three nearby debris disks
(Kalas et al 2004; Weinberger et al. 1999; Schneider et al. 1999)

# Transition from disks to planetary systems




McCaughrean, Stapelfeldt, & Close PPIV, 2000

# Setting specifications (I)

- Start with "easier" case: YSO disks
  - Optically-thick, higher scattered light ratio
  - Surface brightness of scattered light is ~7 mag/sq arcsec fainter than central star at 100AU radius (~0.7 arcsec at 150pc)
  - Reflected flux goes as $1/r^2$ from central star
- E-ELT parameters
  - Diffraction-limited resolution of 42m telescope at 2μm is 12 mas
  - Take 10 mas pixel scale as fiducial; thus area = 0.0001 sq arcsec
  - Dilutes surface brightness by 10 mag
  - Thus surface brightness/pixel = 17 mag fainter than star at 100AU
- Compare with existing / future coronagraphs
  - Present 8m telescopes deliver 10-12 mag contrast at ~3λ/D radius
  - SPHERE/GPI aim to deliver 15 mag contrast at ~2-3λ/D

# Setting specifications (II)

- Thus nominally challenging compared to state-of-art
- However, can regain advantage
  - Can bin up background-limited pixels to increase S/N
  - Non-uniform structure on scale of diffraction-limit (~2AU at 150pc) will have higher S/N
  - Can operate at smaller inner working angle helped by $1/r^2$
- Take latter case
  - Assume coronagraph with $5\lambda/D$ radius = 60 mas ~10AU at 150pc
  - Surface brightness 5 mag brighter at 10AU than at 100AU
  - Contrast ~12 mag relative to star
  - At $3\lambda/D$ = 36 mas ~ 6AU, would need 11 mag contrast
  - These are workable by present standards

# Setting specifications (III)

- "Harder" case: debris disks
  - These are optically-thin; much lower scattered flux
  - At least 5 mag fainter than YSO disks
  - Only three debris disks imaged from ground due to special case of edge-on orientation
- Recommendations
  - Concentrate on structure of inner YSO disks
  - Need 12 mag of contrast at 5λ/D radius = 60 mas
  - Coronagraphic spots of with radii 2, 5, 10λ/D needed (24, 60, 120 mas at 2μm)
  - Yields inner working angles of 3.6, 7.2, 14.4AU at 150pc
- Ultimately this may be the business of EPICS
  - But important to consider if we want a "first light" capability

# Post-presentation notes (I)

- Jason: E-ELT PSF different to (say) VLT PSF
  - At 5λ/D on VLT, you're beyond most of the seeing PSF
  - At 5λ/D on E-ELT, there's a lot of the seeing PSF outside the coronagraph
  - Need more detailed simulations of real E-ELT PSF residuals
- Raffaele: EPICS may not do this
  - EPICS has specialised ExAO hardware which requires bright stars
  - YSO target stars may be too faint in general
- Raffaele: consider IFS option
  - HARMONI may be a way of doing this as well cf. planet detection
  - Problem is image reconstruction for subtle structures in disks
  - Also reflection nebulae have no strong spectral discriminators
  - Coronagraph being added to SINFONI, for example

# Post-presentation notes (II)

- Raffaele: what about JWST in this domain?
  - MJM: really all about inner working angle
  - JWST looks at larger angles
  - JWST good for debris disks which are nearby and large
  - Probing giant planet forming regions of YSO disks requires ~10AU resolution at 150pc, ~65 mas