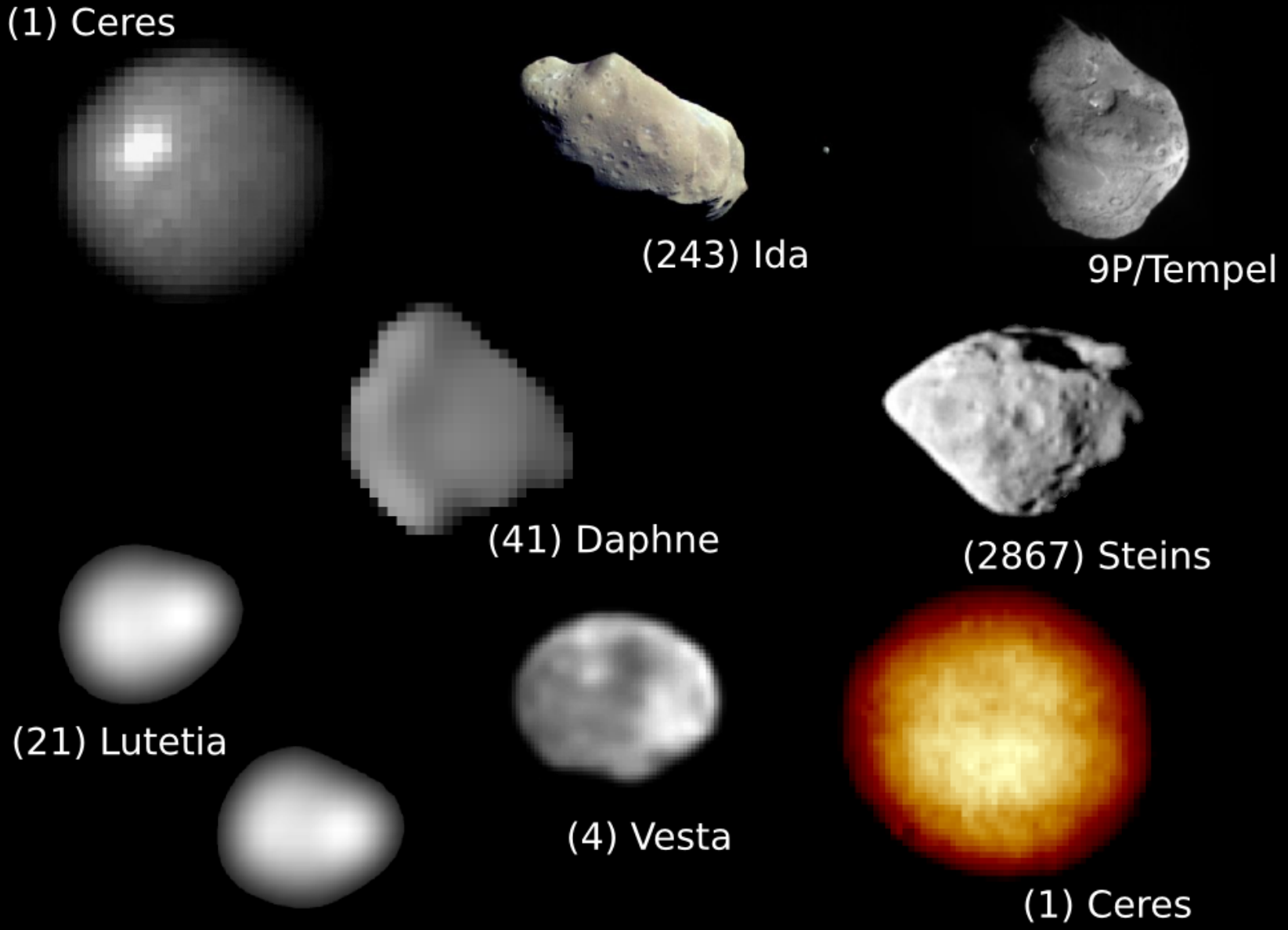
The Shape of Asteroids from Disk-Resolved Imaging

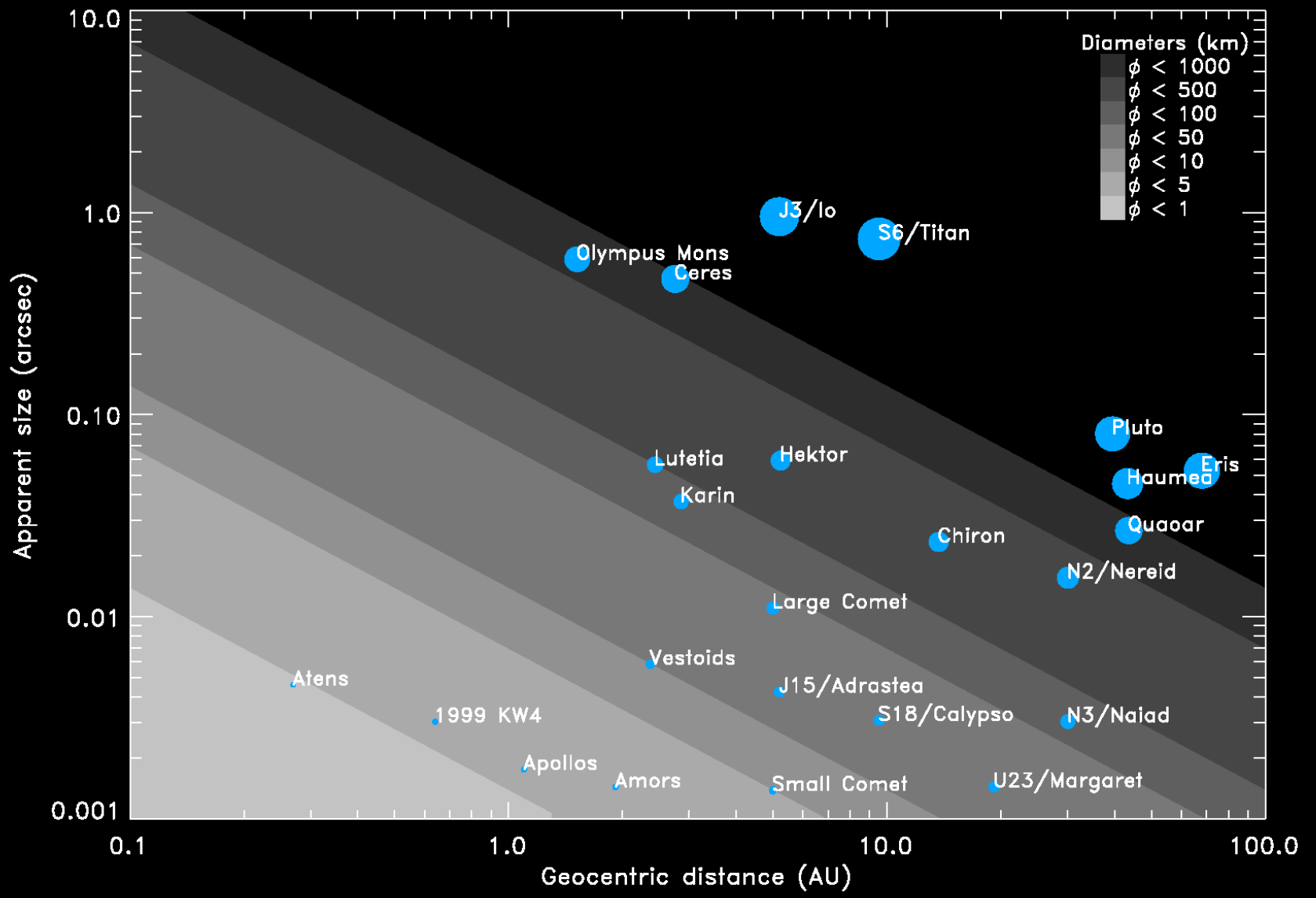
by
Benoît Carry[1]

[1]LESIA, Observatoire de Paris

Typical Disk-Resolved Images



Small Bodies in the Solar System 1



Resolving the apparent disk

- Required angular resolution
  - Need better resolution than apparent size : $\Theta < \phi$
  - Resolution limited by diffraction or AO-corrected seeing
  - $\Theta \sim 0.05''$ for HST in the visible
  - $\Theta \sim 0.05''$ for VLT,Keck... in the near-infrared (AO)
  - About 200 available targets

- Required brightness
  - Asteroids reflect sunlight
  - Large ($\phi > 0.1''$) means bright
  - No trouble currently

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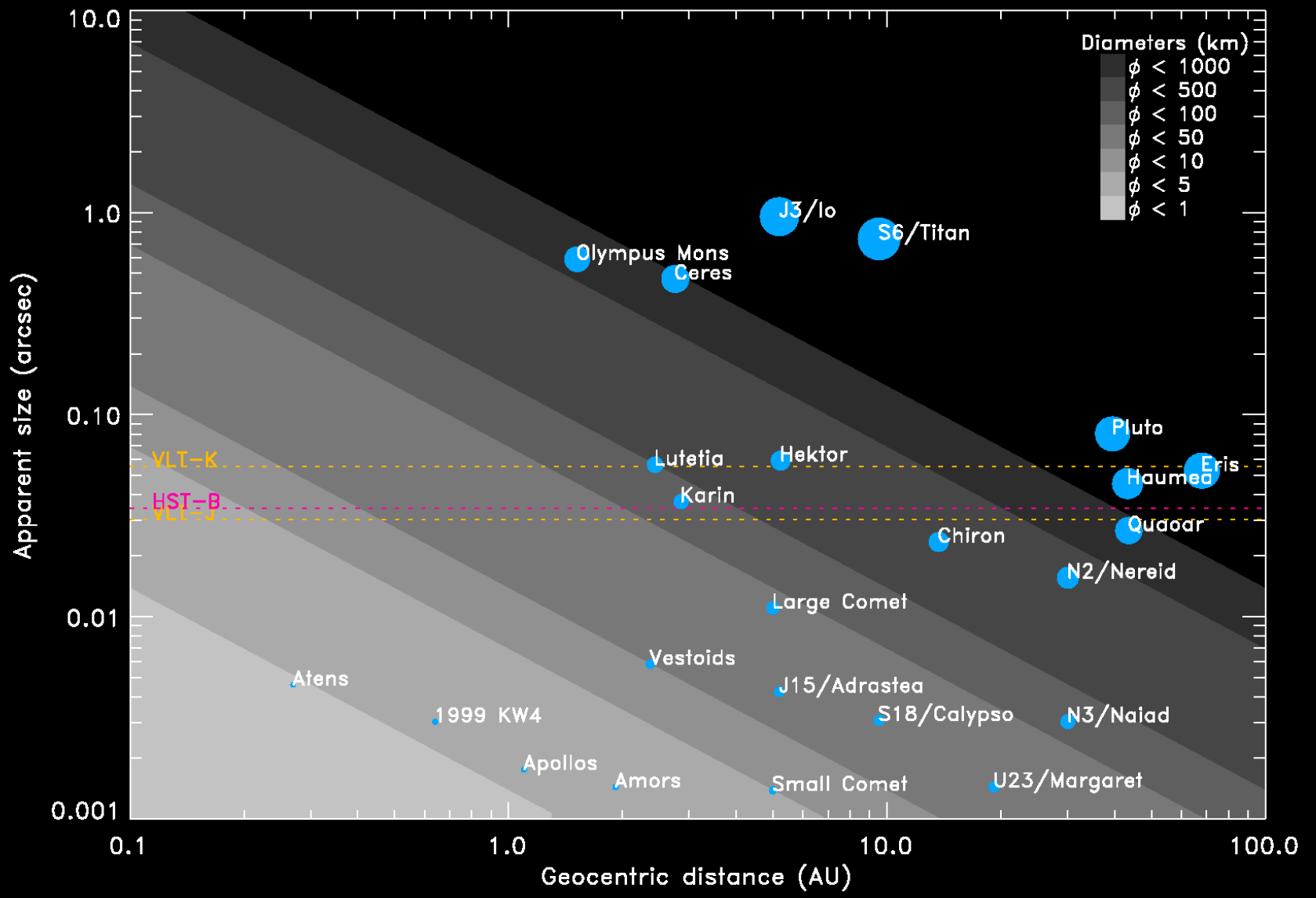
Small Bodies in the Solar System 2



And in the future

- Angular resolution : the next generation
  - JWST (6.5m/V), TMT (30m/NIR), ELT (42m/NIR)
  - $\Theta \sim 0.01''$ for JWST in the visible
  - $\Theta \sim 0.01''$ for TMT, ELT in the NIR
  - $\Theta \sim 0.002''$ for ELT in the visible (AO)
  - About 2000+ available targets
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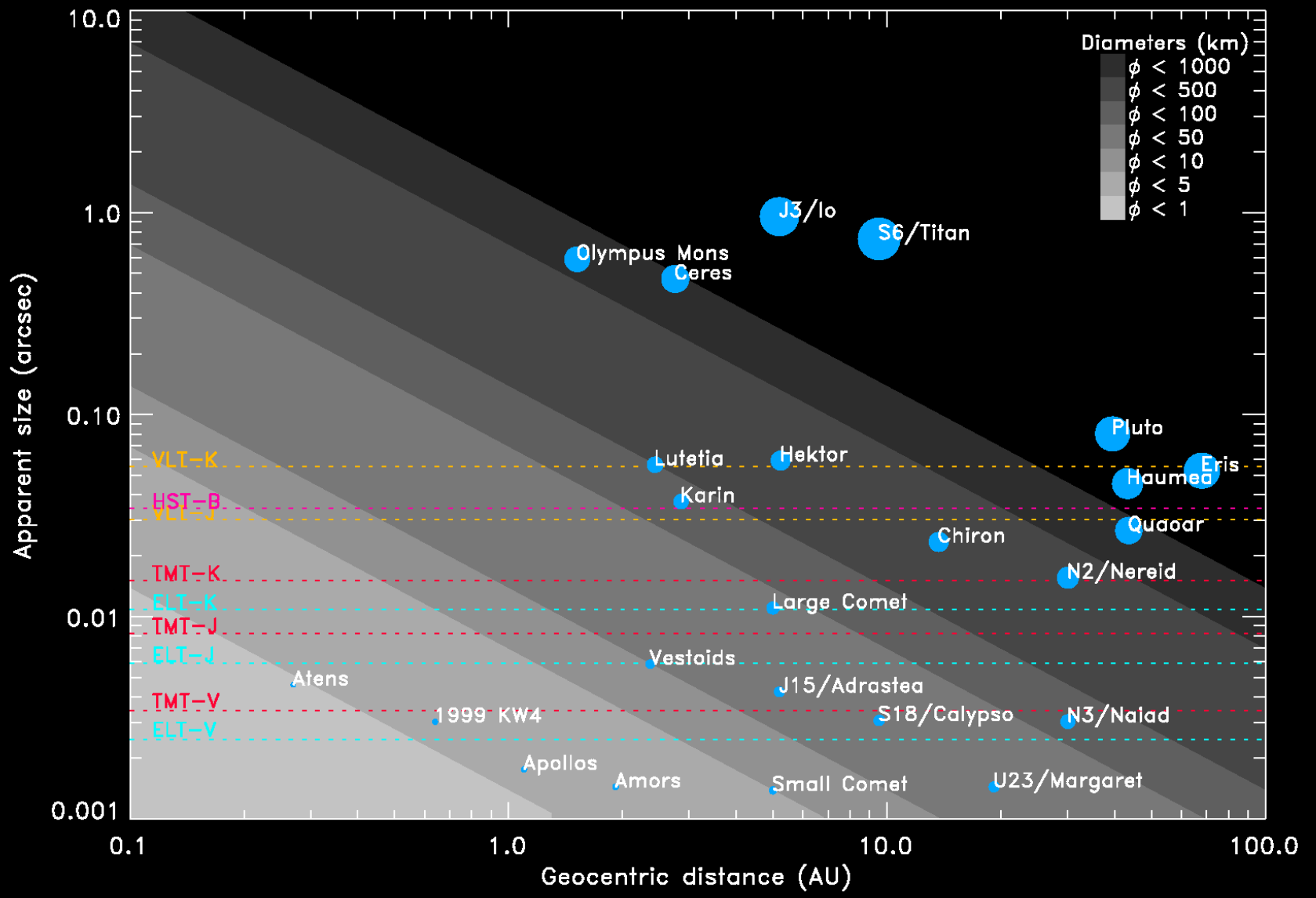
Available targets



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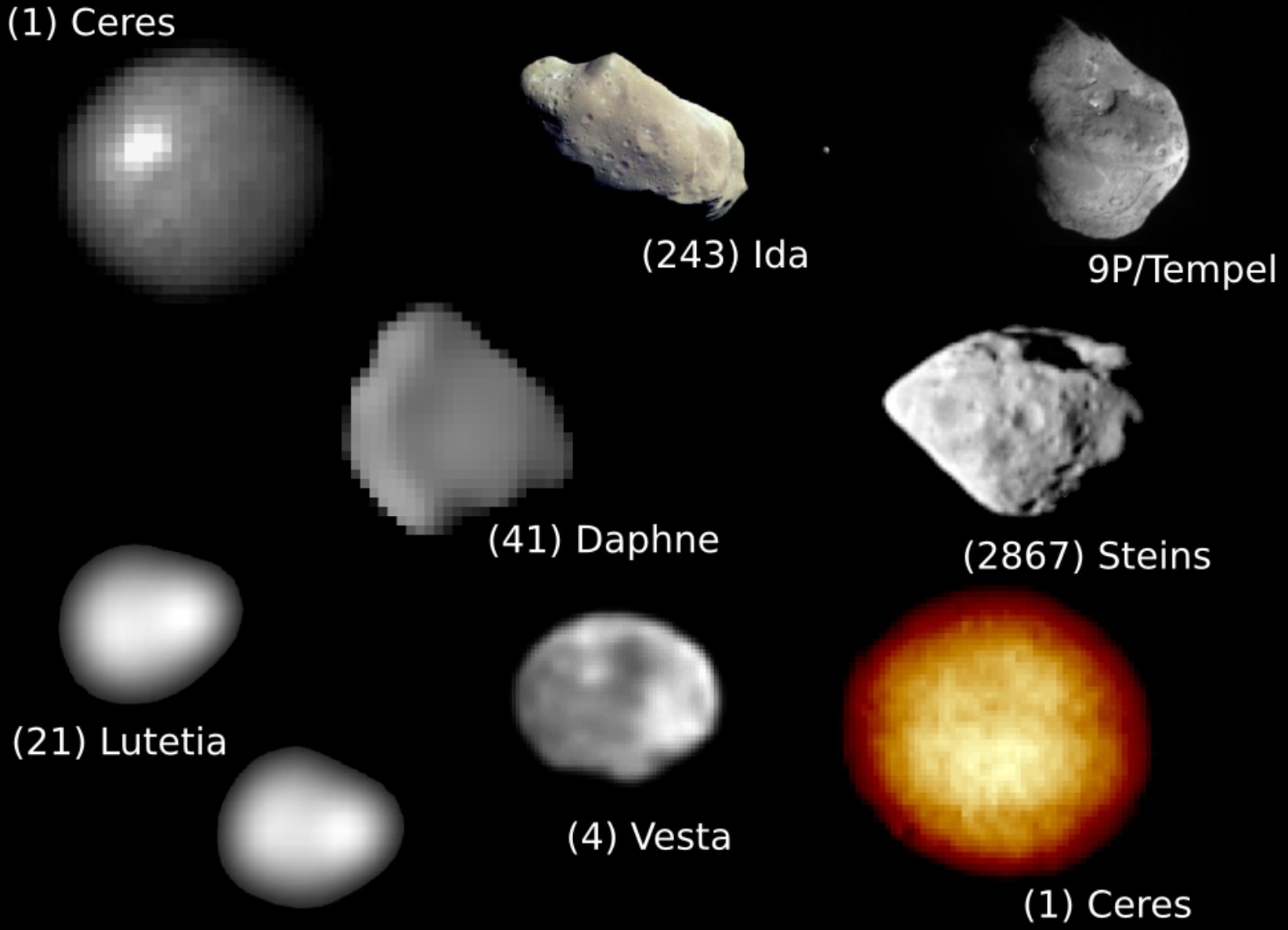
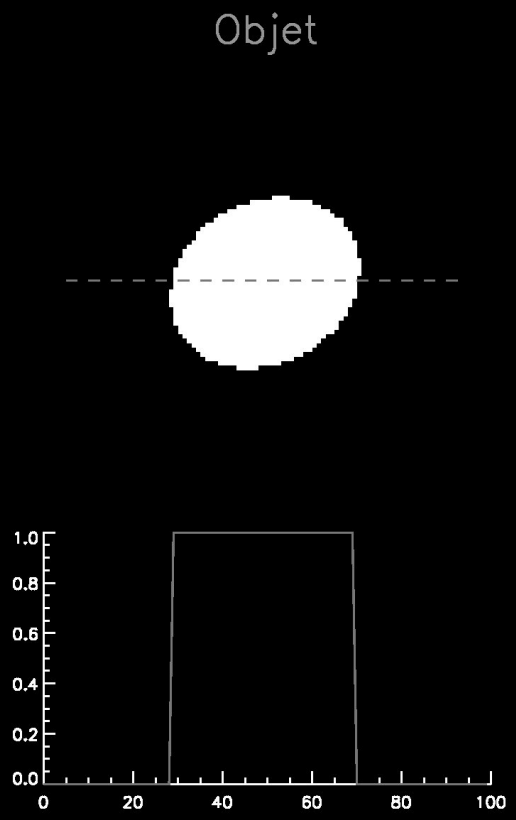


Creation of an image



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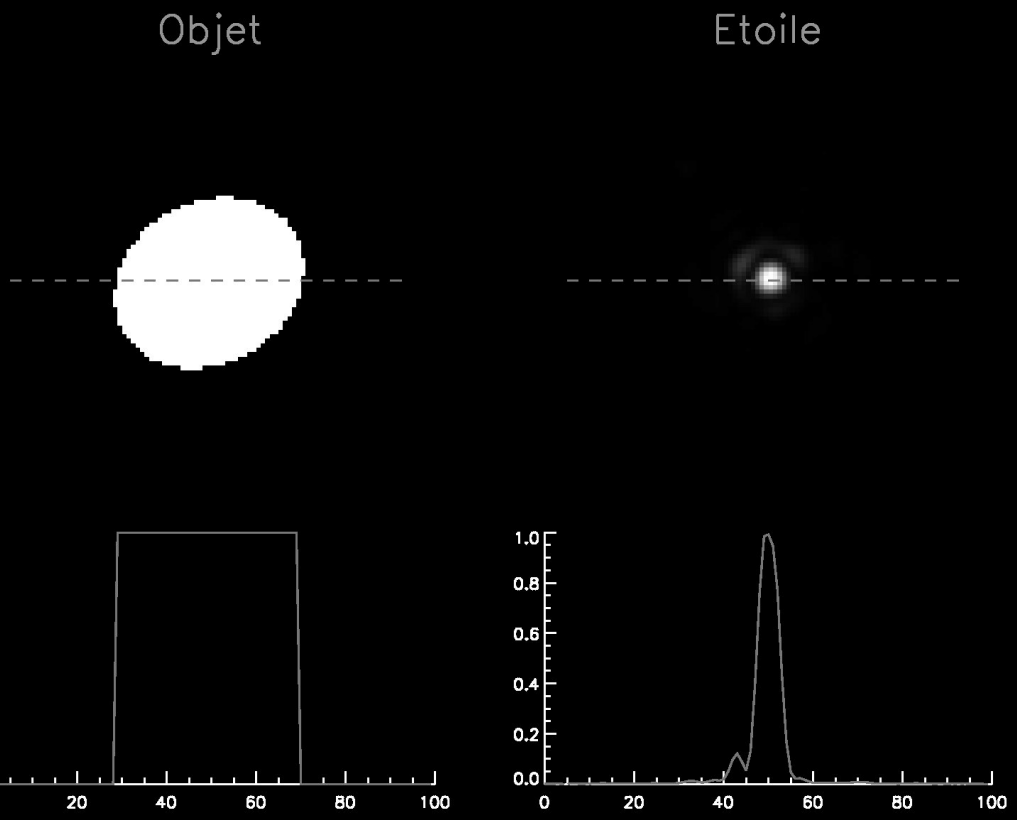

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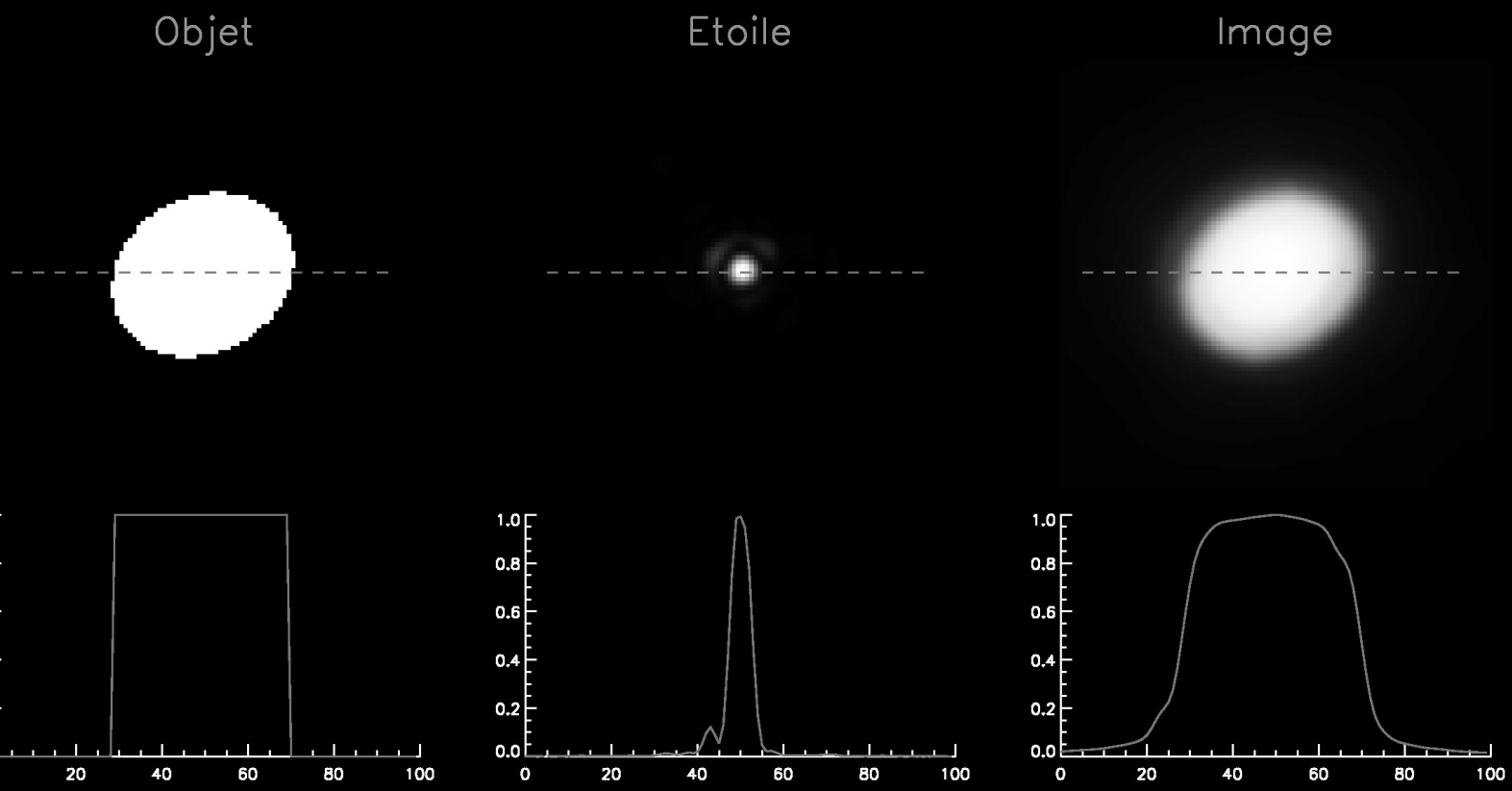

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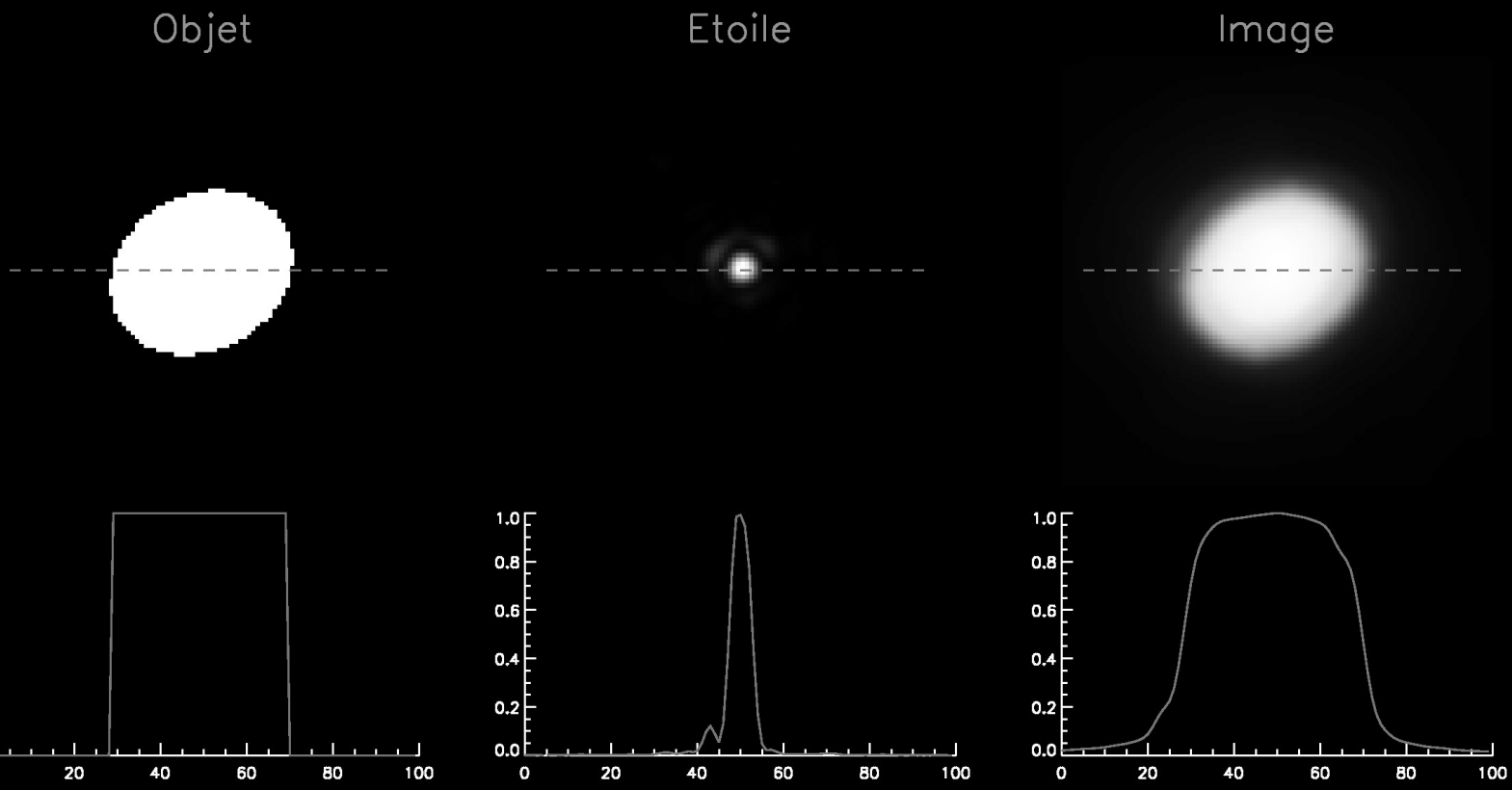

Not a trivial task → Each group should take care of its data

Shape extraction : principles

1. Observing plan
   - Several exposures in few minutes
   - "Lucky imaging" by trashing bad data
2. Individual contour extraction
   - Gradient detection algorithm
   - Precision ?
3. Creation of average contours
   - "Statistical" approach
   - Remove outliers (= *crap*)
   - Provide confidence interval
4. Contour contains shadow information
   - Limb
   - Terminator
   - High-phase-angle interesting

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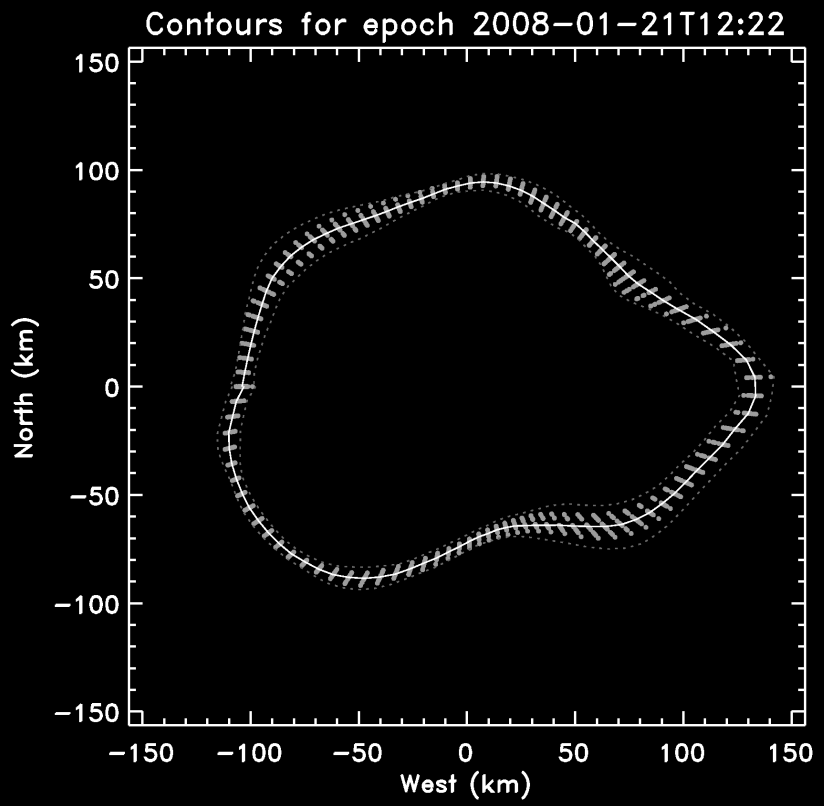
Shape extraction : results



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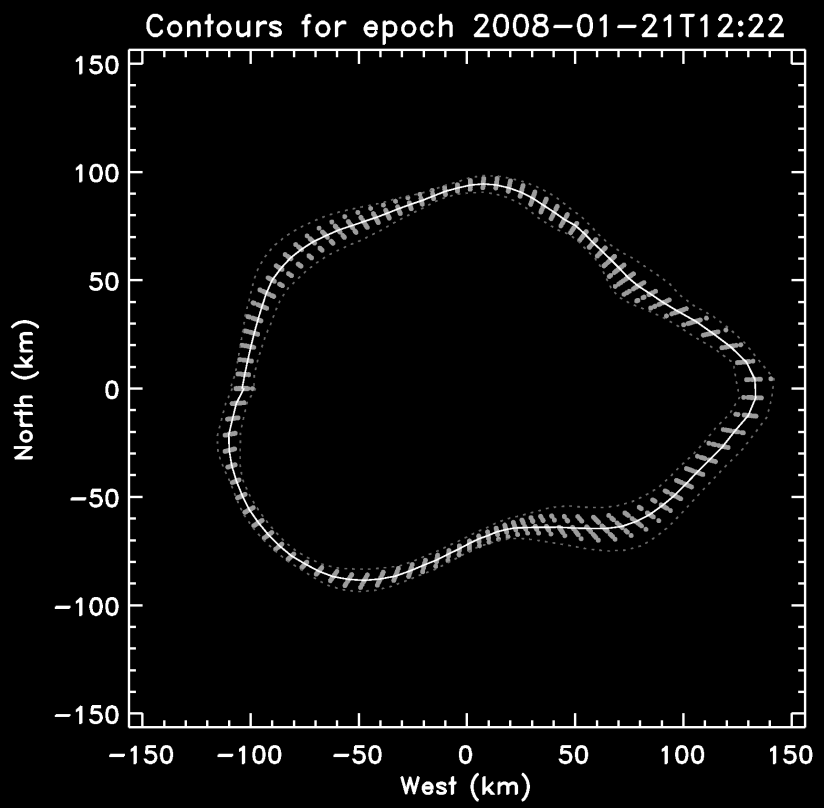

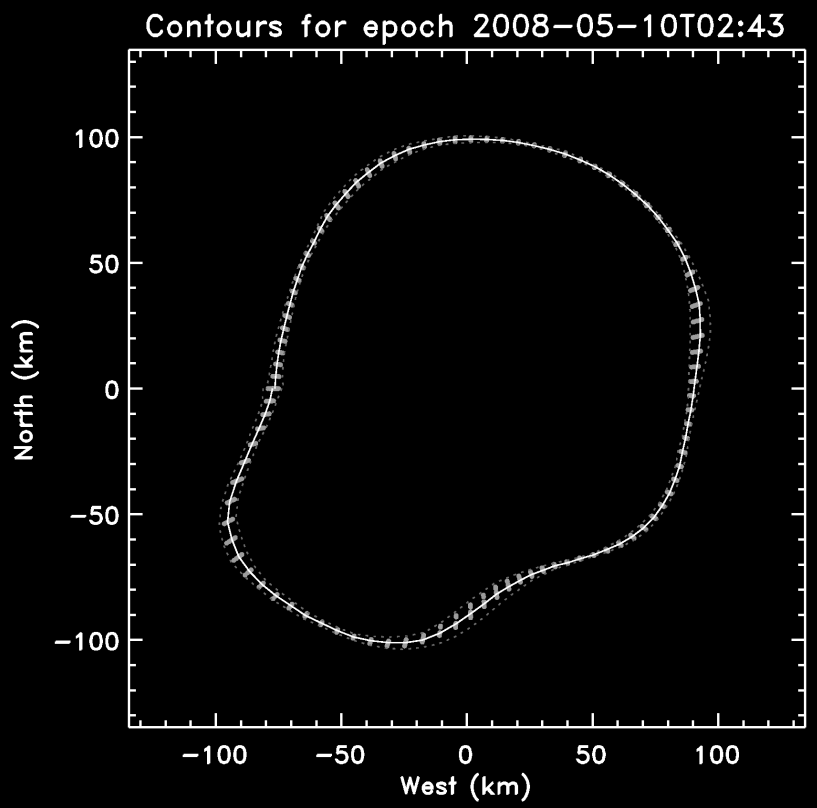

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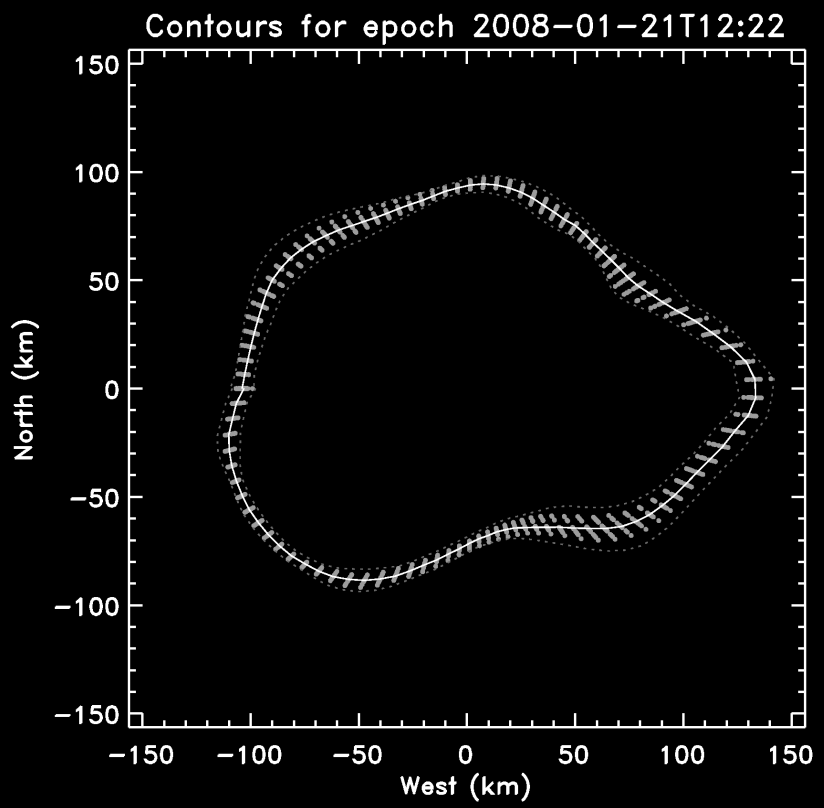
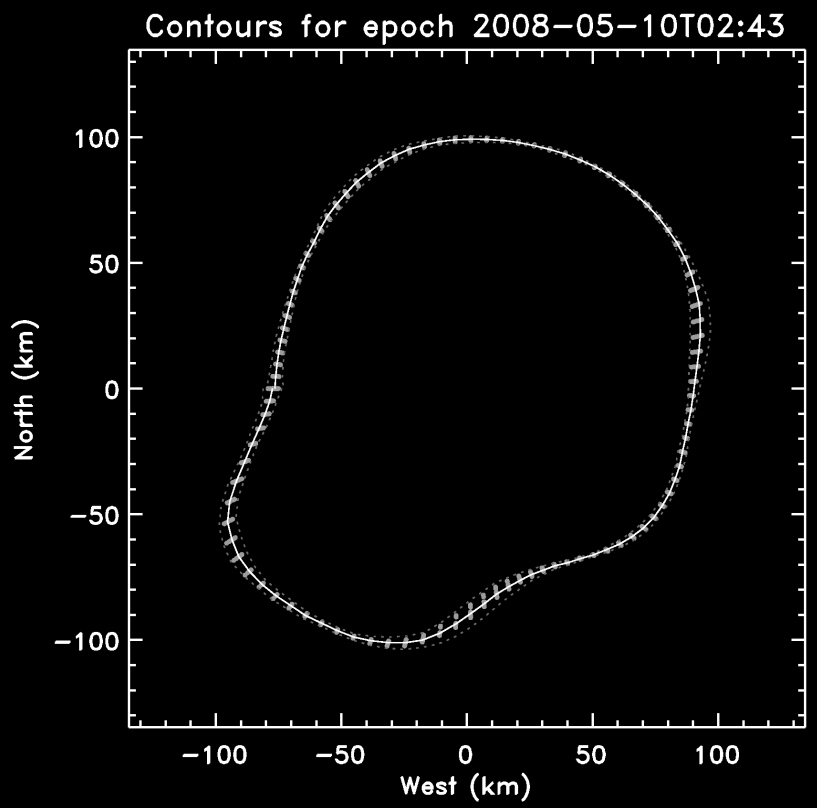
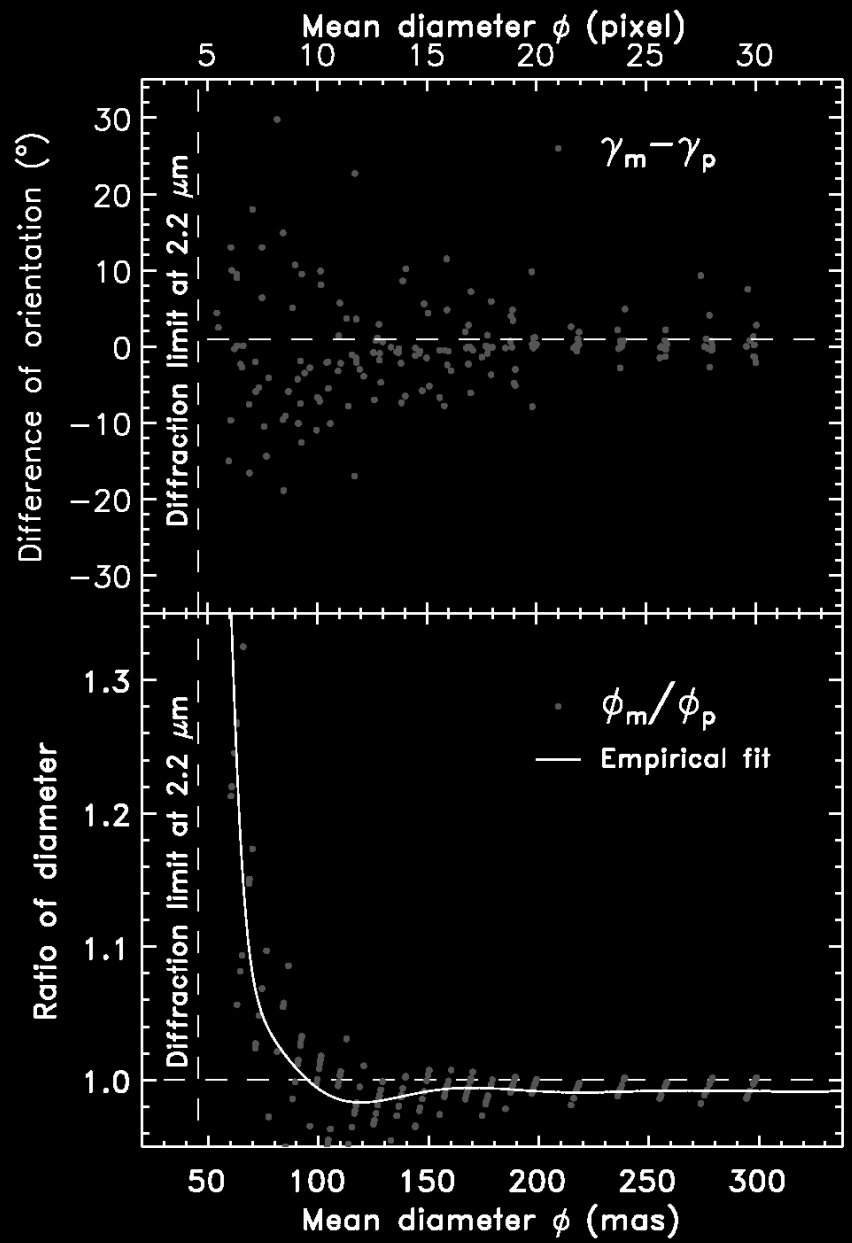




Contour for each epoch with confidence interval

Reachable precision



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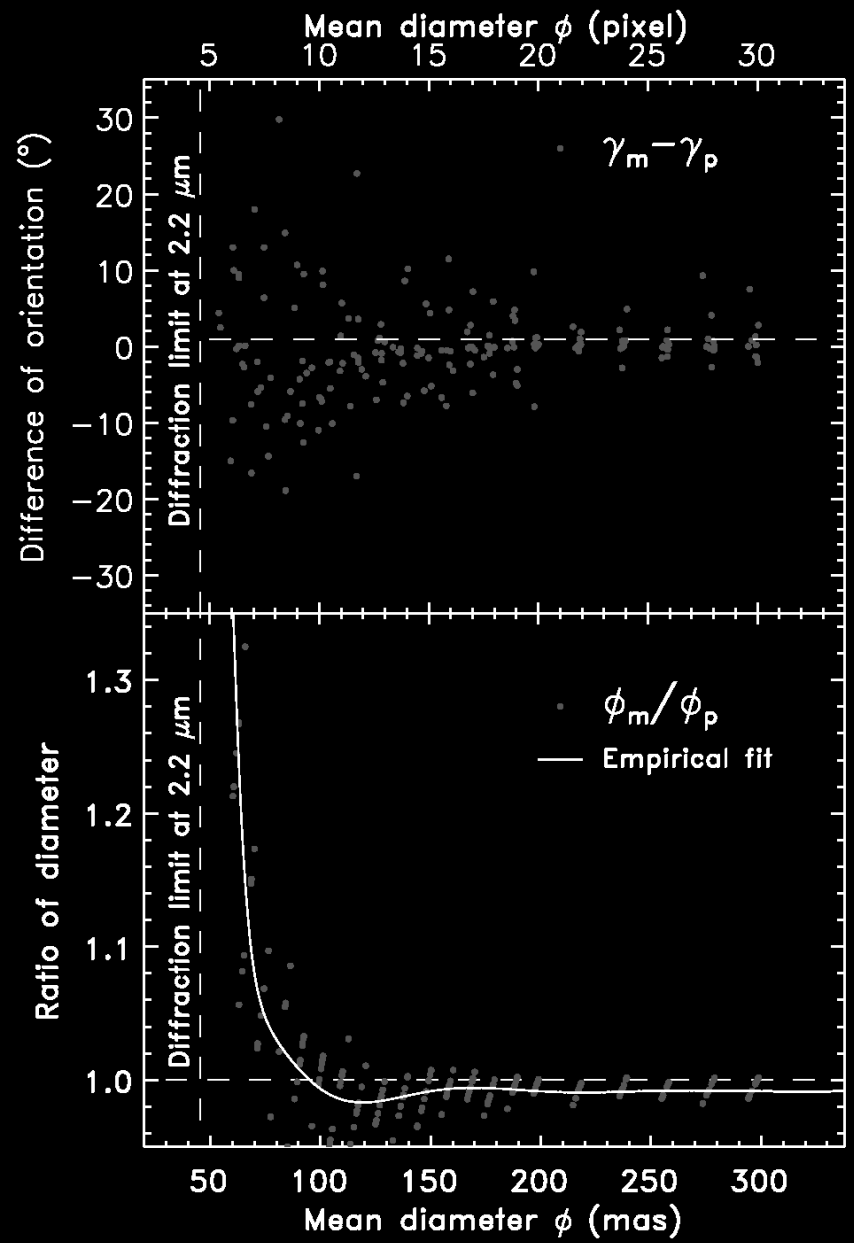
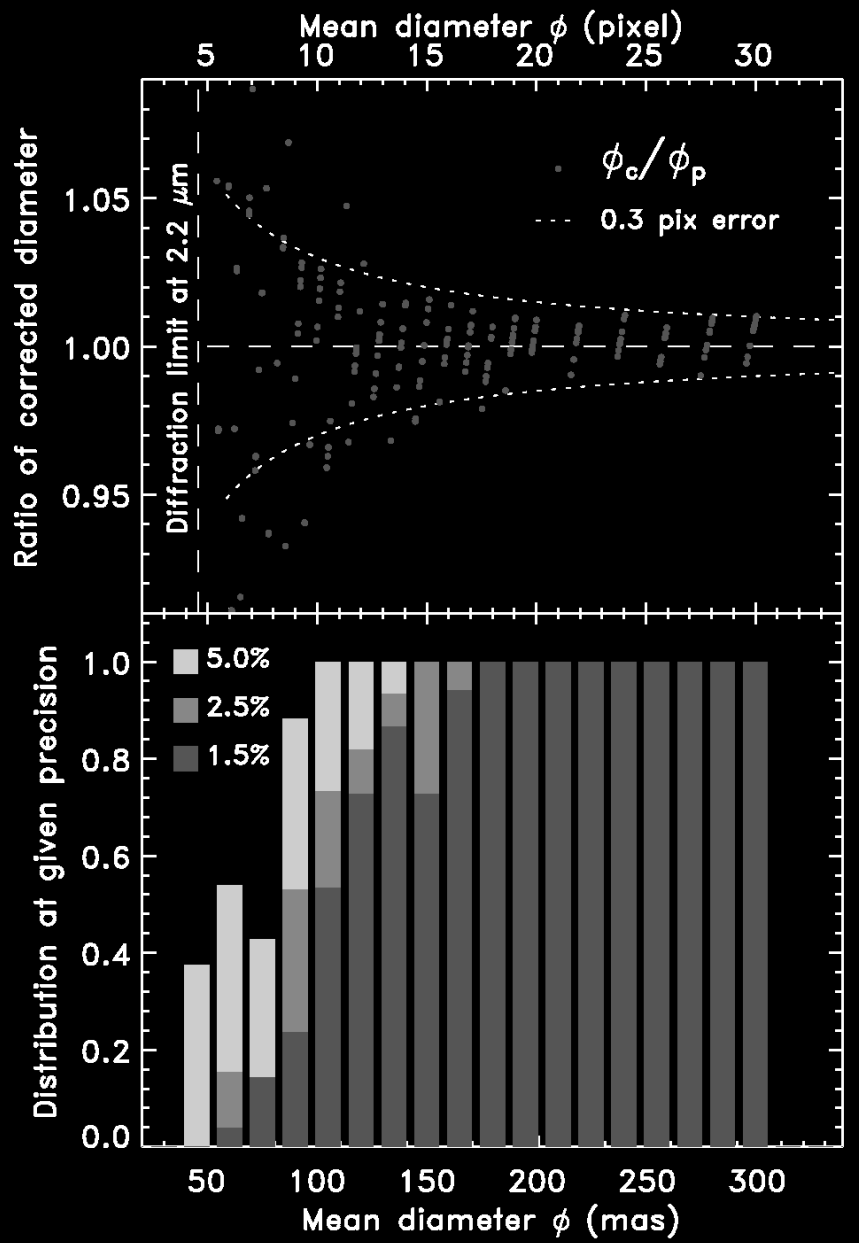
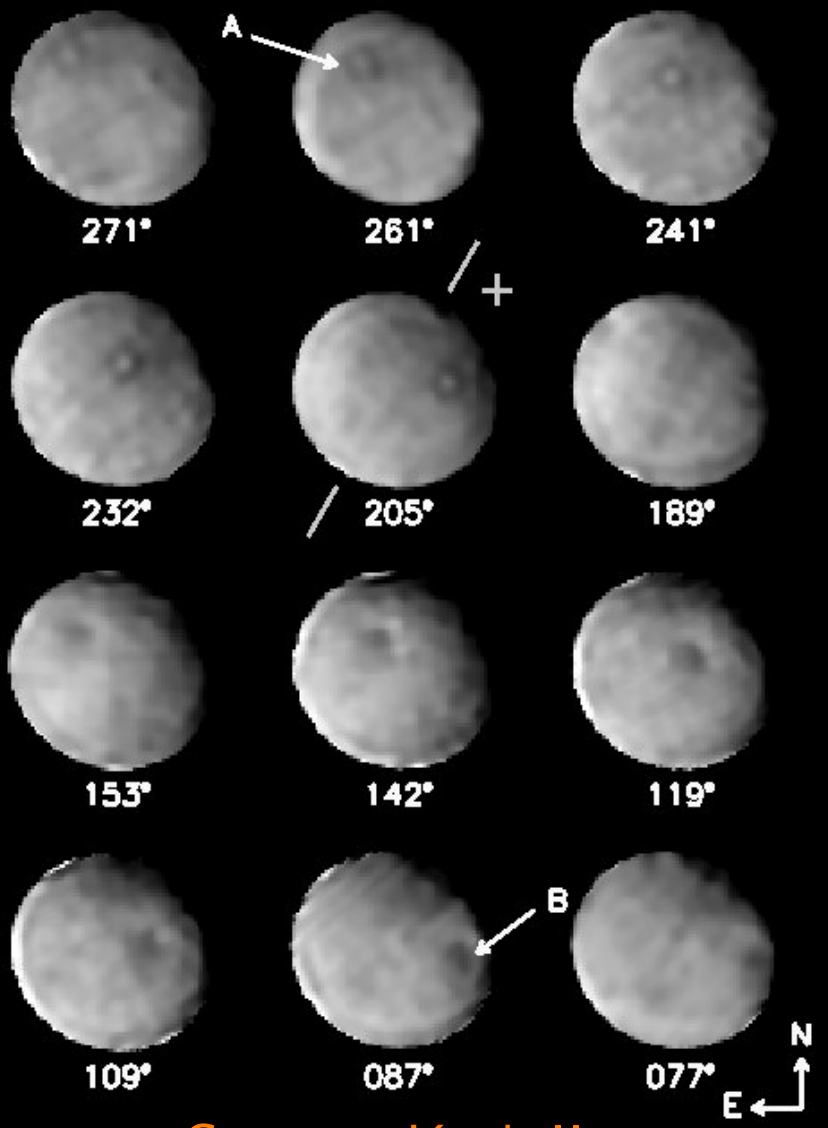




Albedo measurements



Ceres at Keck II

- ∃ albedo variations
  - Visible on many images
  - Few percents
  - Ceres, Pallas, Vesta...
  - Smaller ?
- Precision *vs* artifacts
  - Ringing effects
  - May be...
- Solution ?
  - Combination of... images
  - Mapping
  - Iteration with shape

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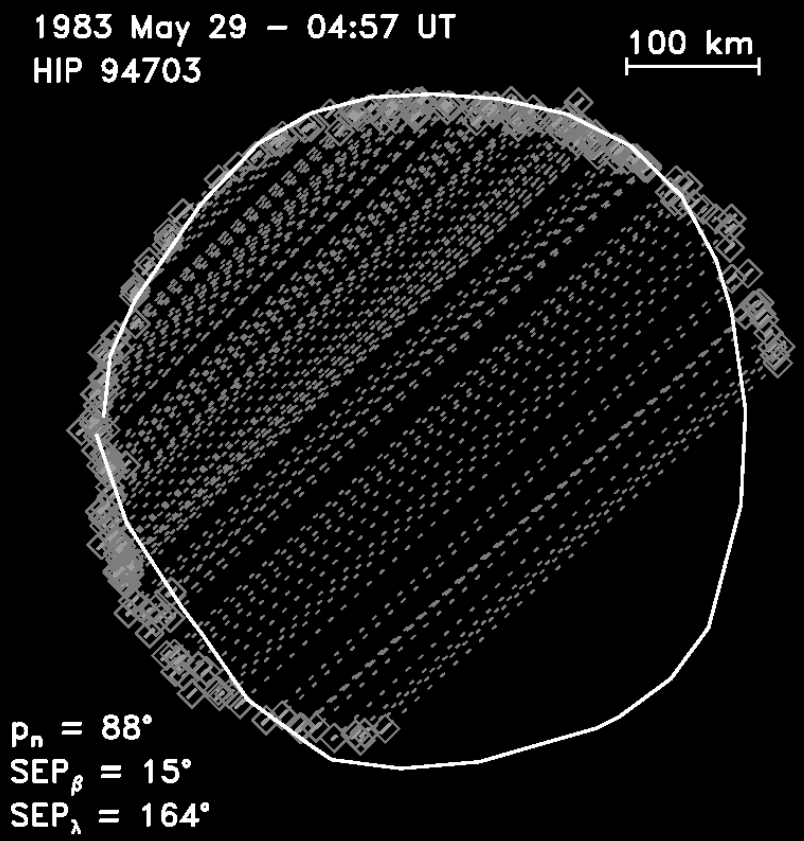

Pallas shape

One concavity leaded by artifact

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  - Deconvolution
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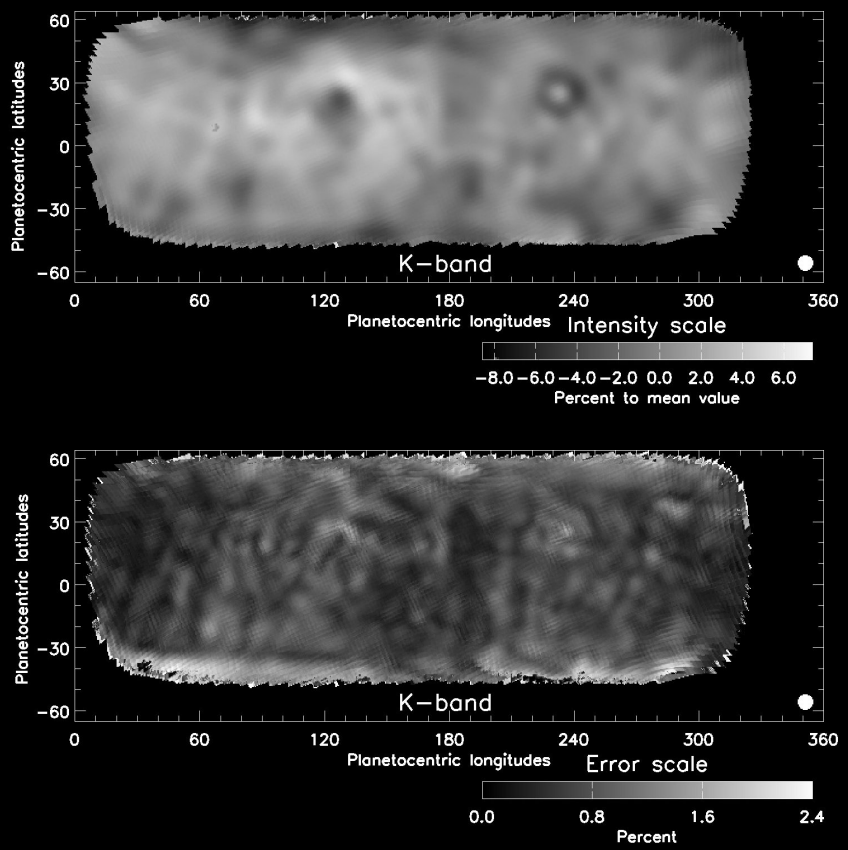

Ceres in the near-infrared

Smooth (remove) artifacts

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  - Visible on many images
  - Few percents
  - Ceres, Pallas, Vesta...
  - Smaller ?
- Precision *vs* artifacts
  - Deconvolution
  - Ringing effects
  - May be spurious
- Solution ?
  - Combination of # images
  - Mapping = f(shape)
  - Iteration with shape

Conclusions

- Pros of Disk-Resolved Imaging
  - Debiased, direct measure of apparent size and shape
  - Very precise : few percent on radius
- Cons of Disk-Resolved Imaging
  - Data "hard" to obtain
  - Limitation on targets (size & time)
- Output for shape reconstruction
  - x,y & δr
  - Albedo $\longrightarrow$ L. Jorda's talk
- Available targets
  - $\sim$200 with VLT, HST
  - $\sim$2000 with JWST, TMT, ELT
  - NEAs, Centaurs and TNOs