



*Keck laser guide star:
Science case*

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Science case: Central issues



- How do Keck NGS and LGS AO compare with AO systems on other 8-10 m telescopes?
- How does Keck AO compare with HST NICMOS?
- What is the unique science that can be done with Keck laser guide star?
- What is the relevant time window?



AO systems on 8-10 m telescopes in next few years



- Gemini:

- N: Hokupaa (curvature, 36 deg's of freedom now, 85 in 2001)
- N: ALTAIR (Shack-Hartmann, 2002, *laser in ~2003*)
- S: Hokupaa 85 with *~2 watt CW dye laser (~2003, no funding yet)*

- VLT:

- NAOS (Shack-Hartmann, summer 2001)
- SINFONI (curvature, 60 deg's of freedom, late 2002)
- *Laser for both: not yet decided (quote 2003). Probably dye laser.*

- Subaru:

- Curvature, \leq 36 degrees of freedom



AO systems on 8-10 m telescopes in next few years



- Gemini:

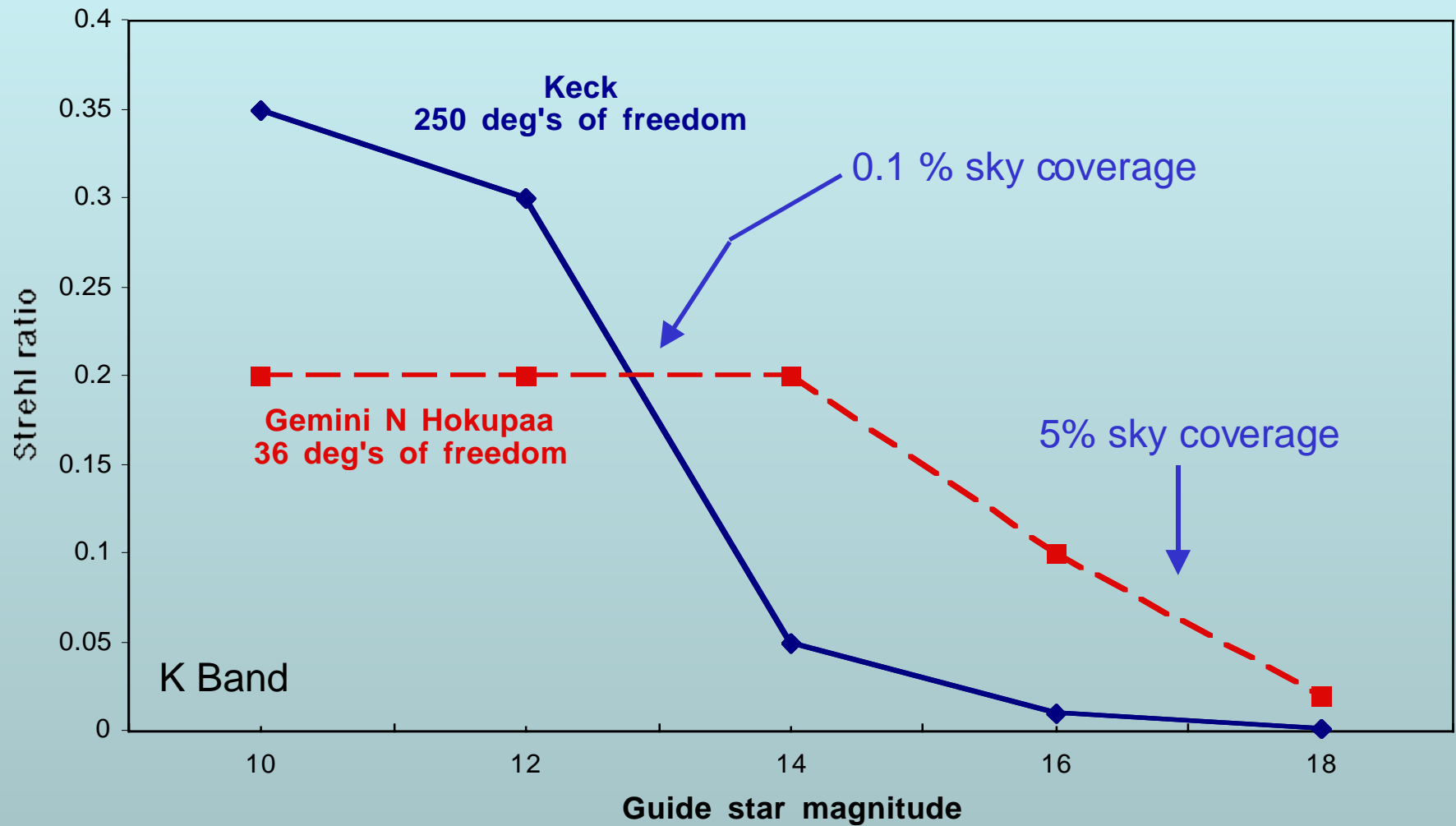
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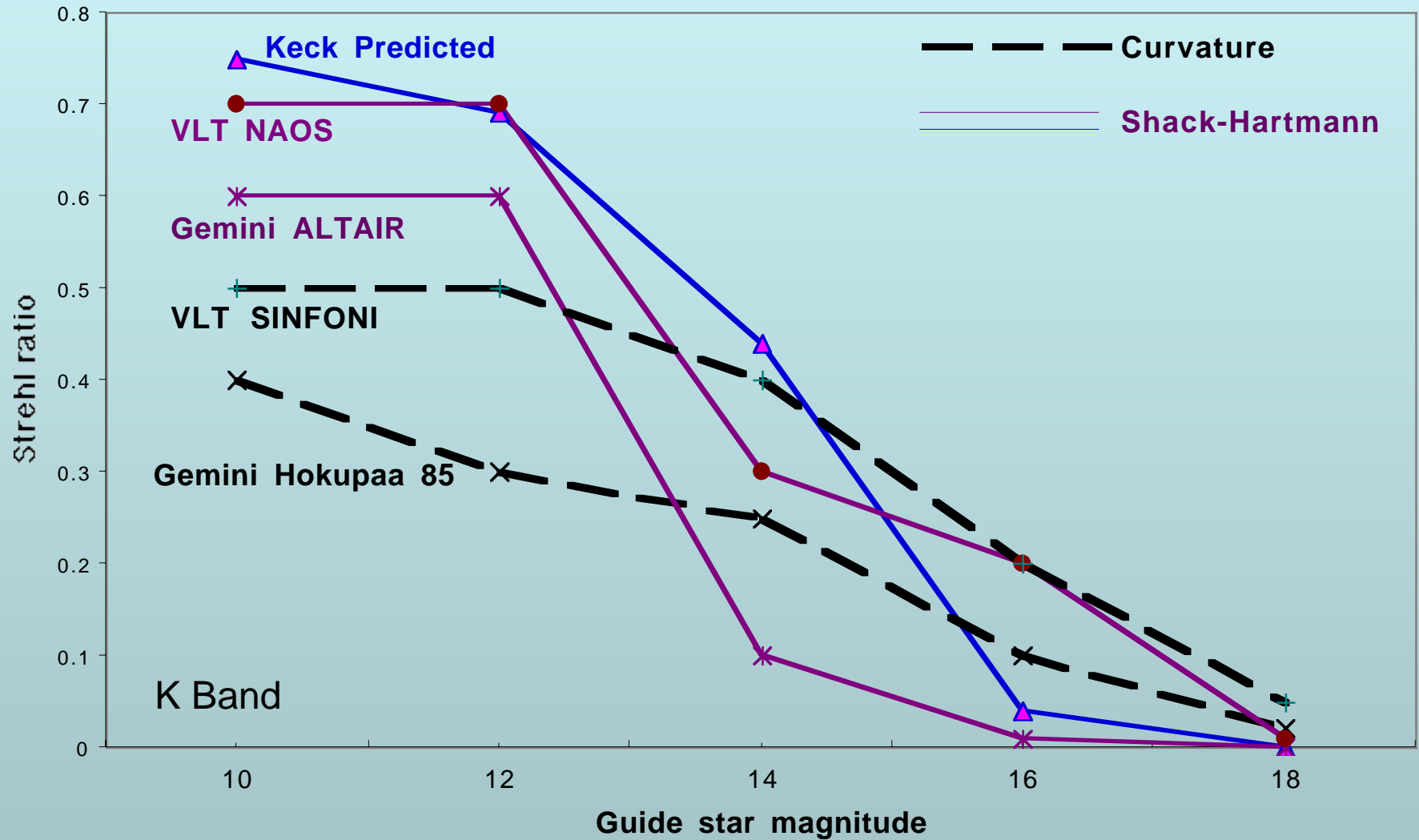
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Lasers are all officially estimated for 2003;
likely "first science" is probably a year later

NGS Strehl Ratio for Existing AO Systems on Keck and Gemini



Predicted NGS Strehl, New AO Systems





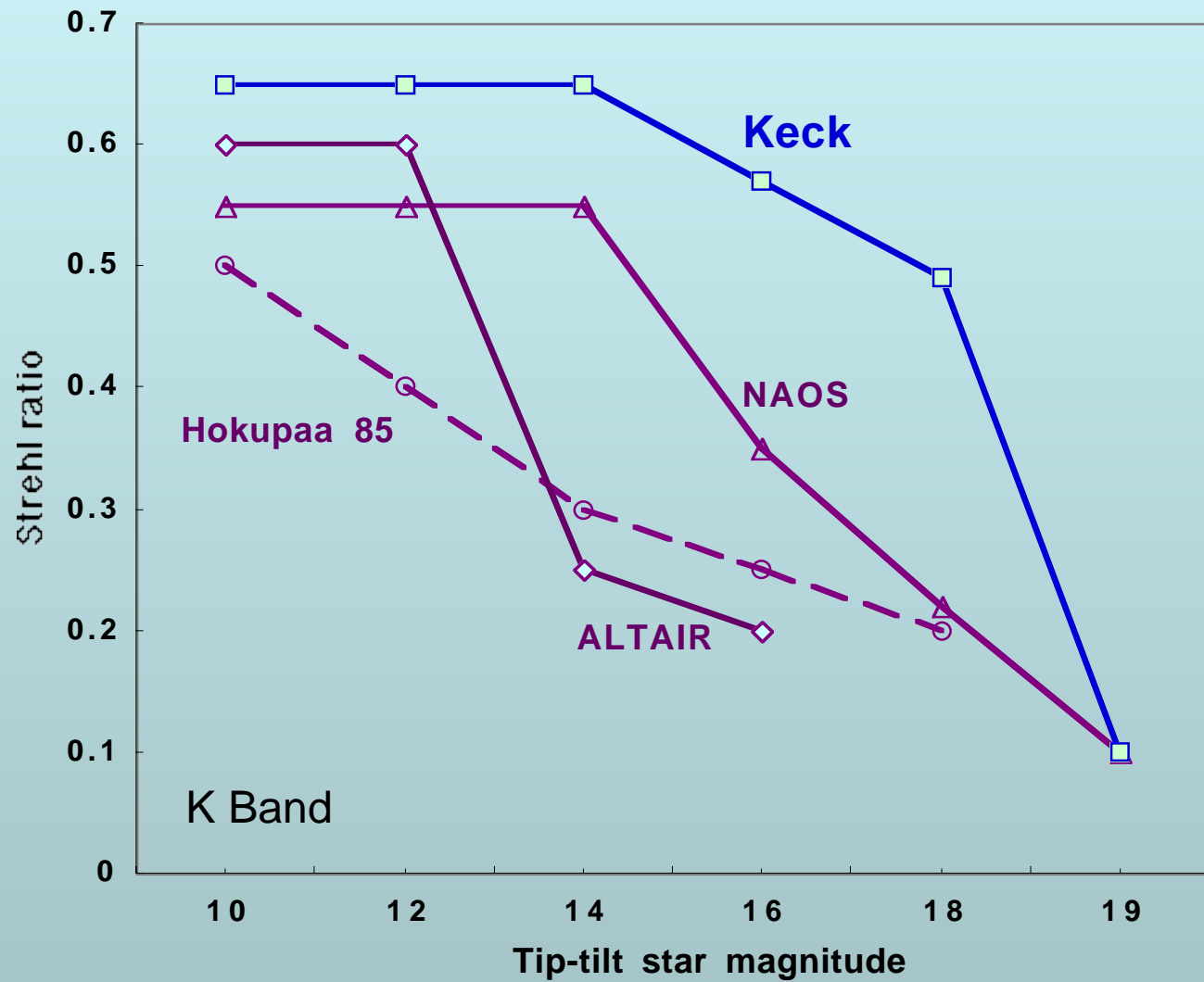
Lessons from graphs



- Curvature AO systems:
 - Lower Strehl ratios for bright guide stars
 - Retain some performance ($S \sim 0.1$) for $M = 17$ stars
- Shack-Hartmann AO Systems:
 - Higher Strehl ratios for bright guide stars ($M < 13$)
 - Need laser to work well with faint guide stars

Keck AO system was designed to work with a laser

Predicted LGS Strehl



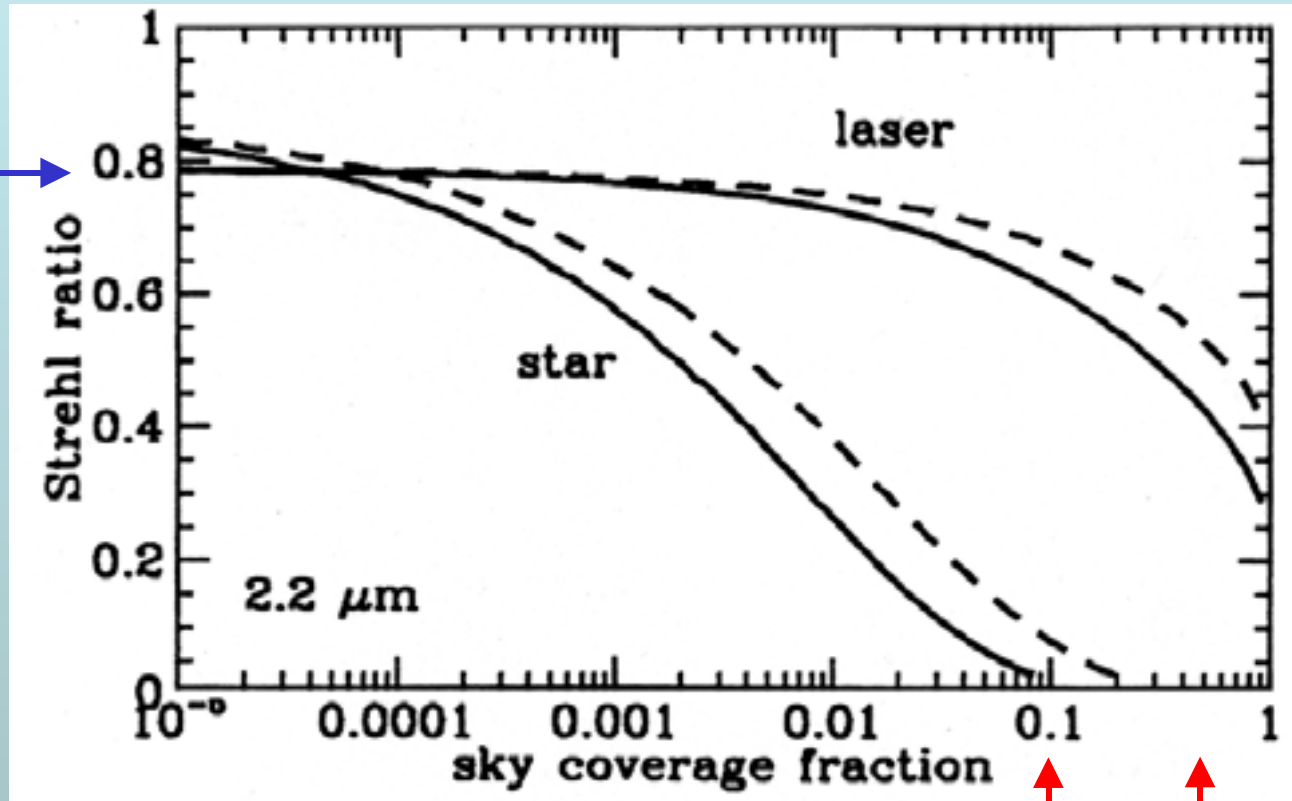


Laser will strongly increase Keck AO sky coverage



From Keck AO "Blue Book"

Current Strehls
are 1/2 this value



M ~18

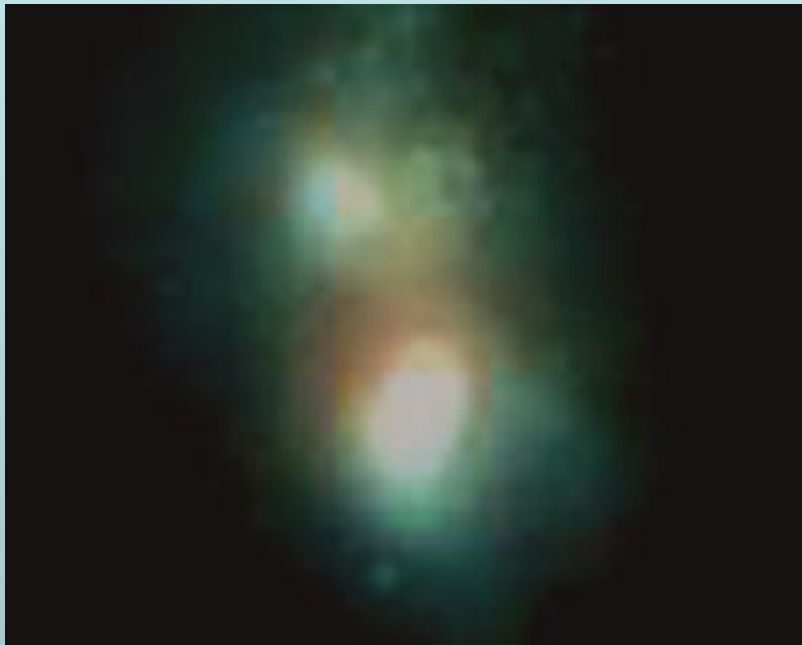
M ~19



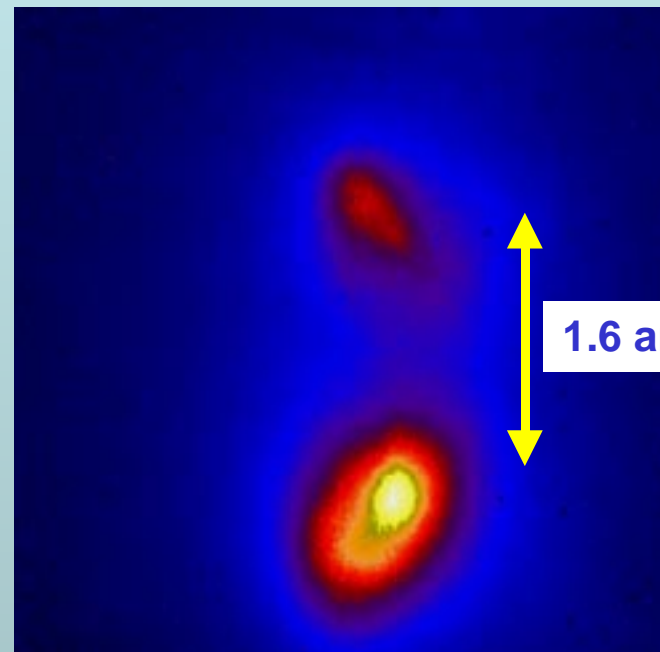
*Keck AO imaging is better than
NICMOS, for bright guide stars*



Example: Double nucleus of NGC 6240, a galaxy merger



Hubble Space Telescope:
NICMOS image in J, H, K



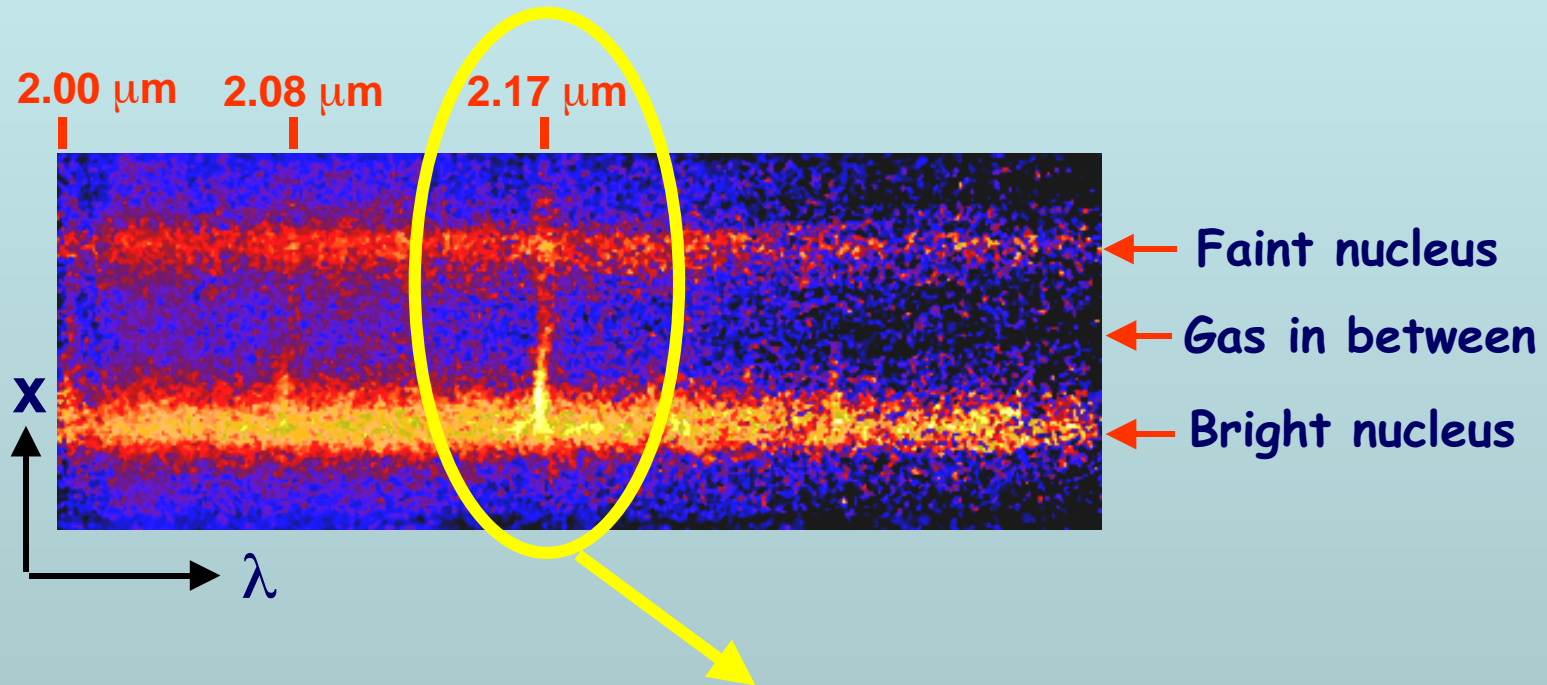
Adaptive optics image at Keck:
K band



Keck AO NIRSPEC spectra are unrivaled by NICMOS on HST



NIRSPEC spectrum: dual nucleus of NGC 6240



H_2 emission line 1-0 S(1)
from shocked or ionized gas
shows clear velocity structure



What unique science can be done with laser at Keck?



- Laser is key enabler for extragalactic work
 - For Keck at K band, laser increases sky coverage from 0.1% to ~ 50% (half-maximum Strehl values)
- Extragalactic science:
 - Extragalactic distance scale (Cepheids, IR surface brightness fluctuations, planetary nebula luminosity functions, supernovae)
 - Galaxy morphology and evolution at high and moderate Z
 - Gravitational lensing by individual galaxies
 - Quasars, starburst galaxies, Seyferts, radiogalaxies, mergers



Galactic science enabled by laser guide star AO



- Globular clusters
 - Central regions, mass segregation, low-mass stars, binaries
- Galactic bulges
 - Stellar populations in Milky Way, nearby galaxies
- Protostellar objects and young stars
 - Could also be done with IR wavefront sensor (if we had one)
- Solar system
 - Io volcanos, asteroids, Pluto spatially resolved spectroscopy



Next-generation laser is too far away



- Next 3-4 years: dye lasers will be only game in town
 - VLT's first laser will probably be pulsed dye laser (Max Planck)
 - Gemini's first laser will probably be commercial CW dye
- Next generation: solid-state sum-frequency lasers
 - Full-up lab prototypes should be working in 1 - 2 years
 - After lab prototype, anticipate another 1 - 2 years for engineering, facilitization (Dee Pennington @ Keck; Bob Byer + Lightwave @ LIGO)
 - All-fiber lasers are a couple of years behind "bulk" lasers



What is relevant time window?



- Gemini, VLT: goal is to have lasers ready in 2003
 - I think 2004 is probably more realistic for first science
- Next-generation technology ready for summit ~2005
- If Keck laser commissioning can be done within ~ 1 yr, Keck will be primary 8 - 10 m telescope with laser for 2 - 3 years
- Allows us to do important science; allows CARA to build up expertise needed for next-generation laser



Conclusions



- Keck laser guide star will access unique science
- Timeliness is important
 - Unique time window for LGS science at Keck
 - In my judgement it will not be possible to keep LLNL + CARA laser team together unless laser goes to summit promptly
 - Timeliness is also important to lay foundation for next-generation laser at Keck
 - Next generation is ~ 5 years away, but won't be accessible unless there is a knowledgeable CARA team in place