Adaptive Optics follow-ups
future AO Facilities

Julien Girard (IA-UNAM)
Hervé Bouy (IAC)

Guillermo Haro Workshop
Aug 13-20, 2008
SASIR, the Synoptic All-Sky Infrared Survey
INAOE, Tonanzintla, Puebla, Mexico

Adaptive Optics follow-ups
future AO Facilities

"Opportunity to build high-profile, scientific, educational, technological collaborations between UC/State of California and Mexico."

M. Bolte

High Angular Resolution Follow-ups

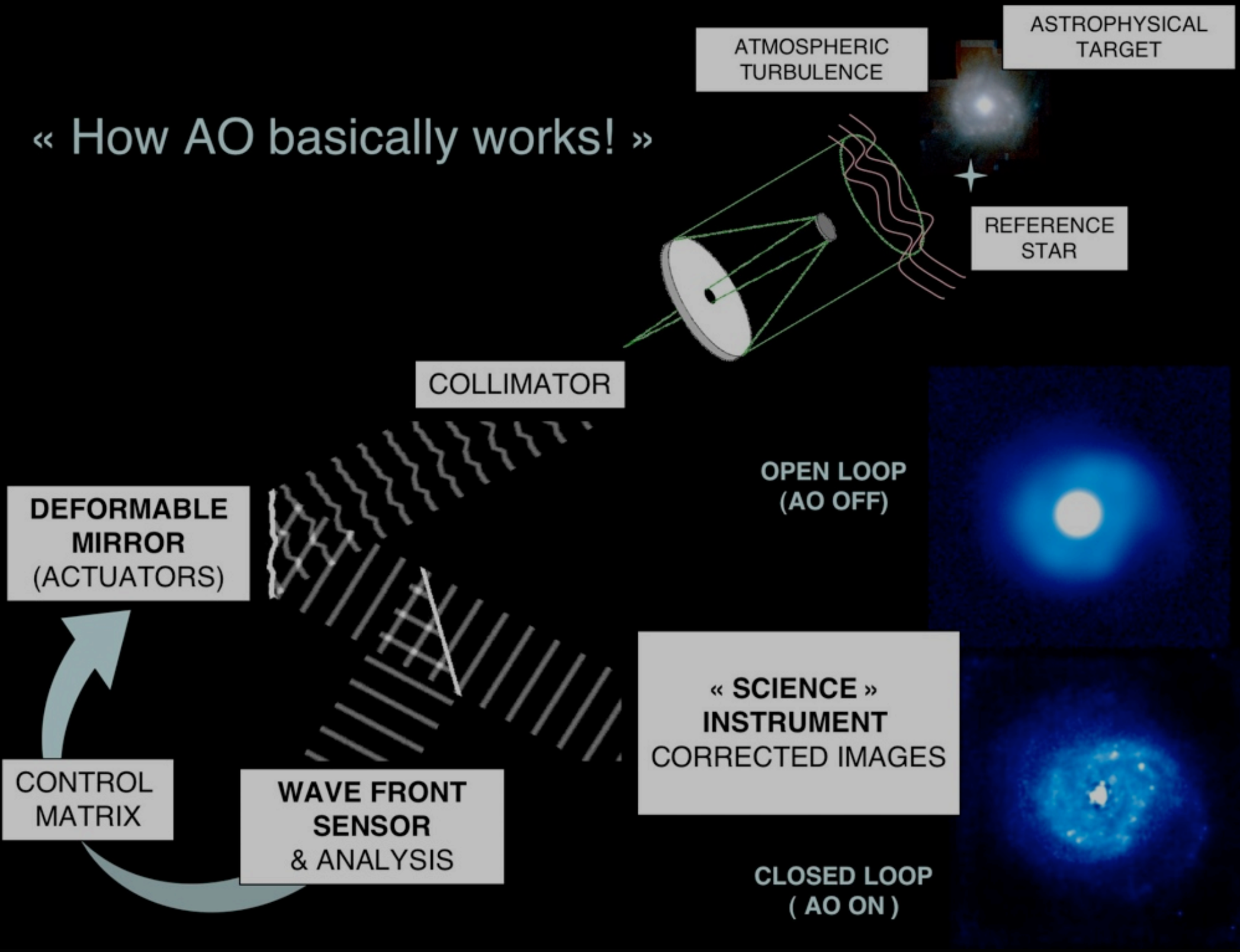
- HST (not there anymore after 2011,12..?)
- JWST (NIR and IR from 2013+)
- Mid-IR (diffraction limit) from the ground
- Long Baseline Interferometry: best R but poor sensitivity.
- Mid-IR (diffraction limit) from the ground
- NIR & Visible AO from the ground!!

Adaptive Optics

- On all major optical ground based observatory
- Allows diffraction limit with limited FOV or seeing improvement with larger FOV
- Laser Guide Star improves the sky coverage and makes NIR AO available to larger community (Lick, Keck, ..., now Gemini, VLT, Subaru, ..., then GTC)
- Multiple LGS, visible AO, under development.
- AO, MCAO, MOAO, GLAO, OLAO, etc.
- Rapidly evolving field!

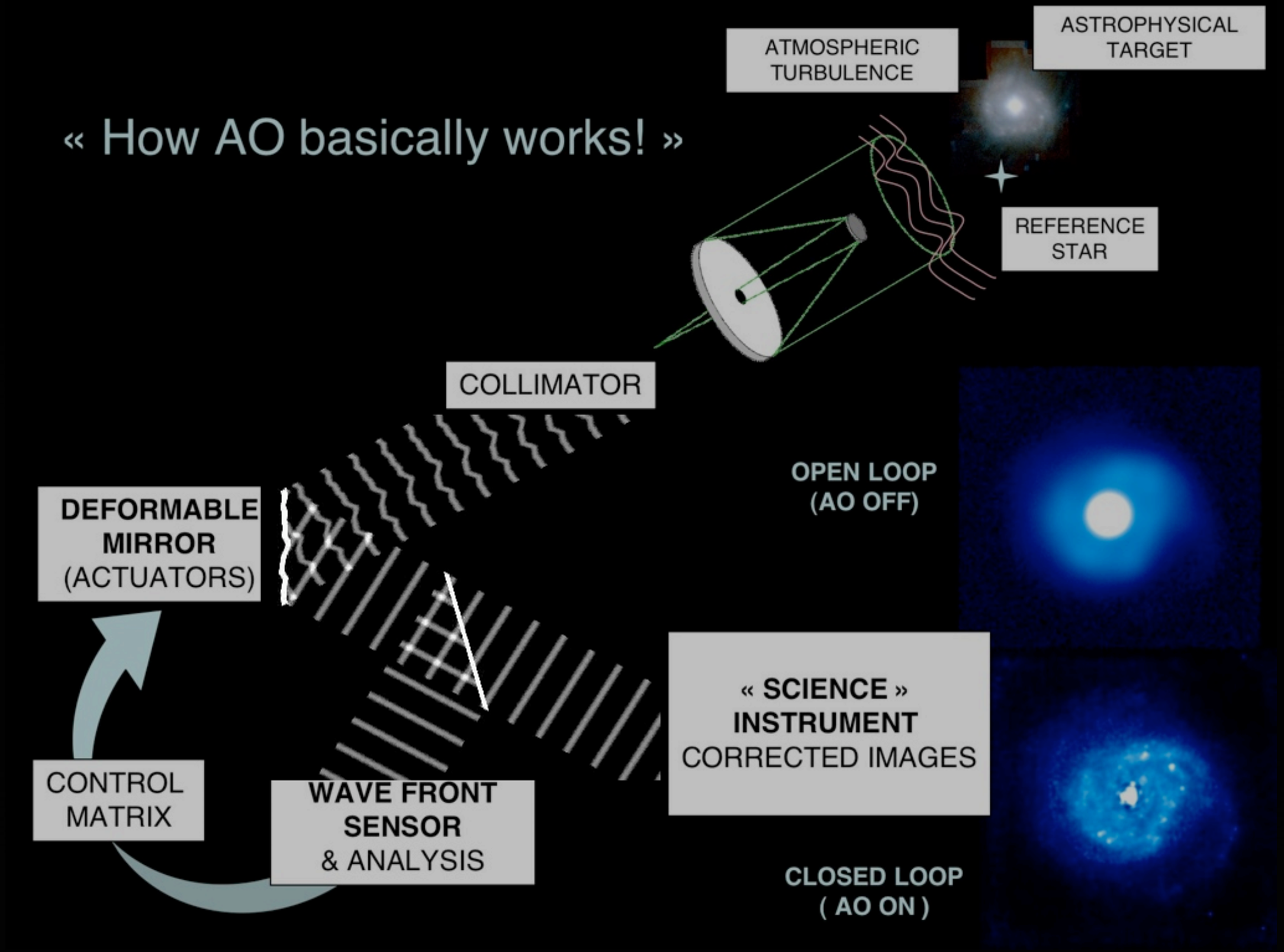
Adaptive Optics

« How AO basically works! »



Adaptive Optics

« How AO basically works! »



Adaptive Optics

DIFFRACTION

Point source
infinite d

λ

Ideal
Telescope

FT

D

PSF = Airy function

$$resolution \simeq \frac{\lambda}{D}$$

Imaging through atm. turbulence

Star
Non-resolved

~0-15 km

turbulent
atmospheric
layers

$\otimes$

Dome
Turbulence

(r_0, θ_0, τ_0)

$\otimes$

Telescope OTF

Speckles

λ/D

short
exposure

long
exposure

λ/r_0

Adaptive Optics

DIFFRACTION

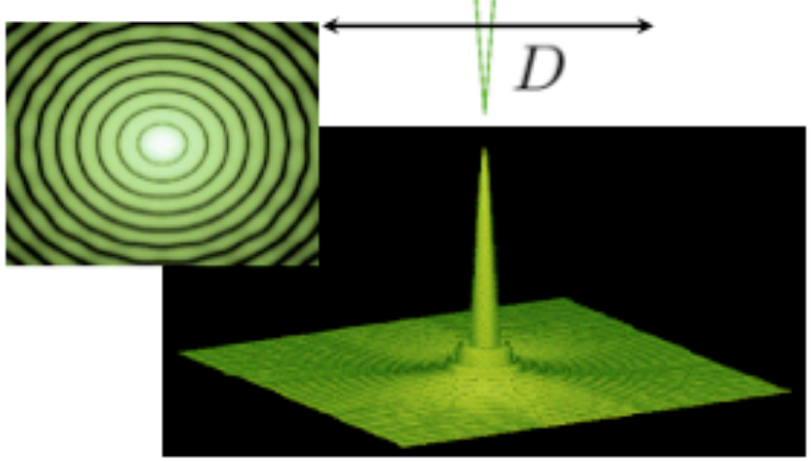
Point source
infinite d

λ

Ideal
Telescope

FT

D



PSF = Airy function

$$resolution \simeq \frac{\lambda}{D}$$

Imaging through atm. turbulence

Star
Non-resolved

~0-15 km

turbulent
atmospheric
layers

$\otimes$

Dome
Turbulence

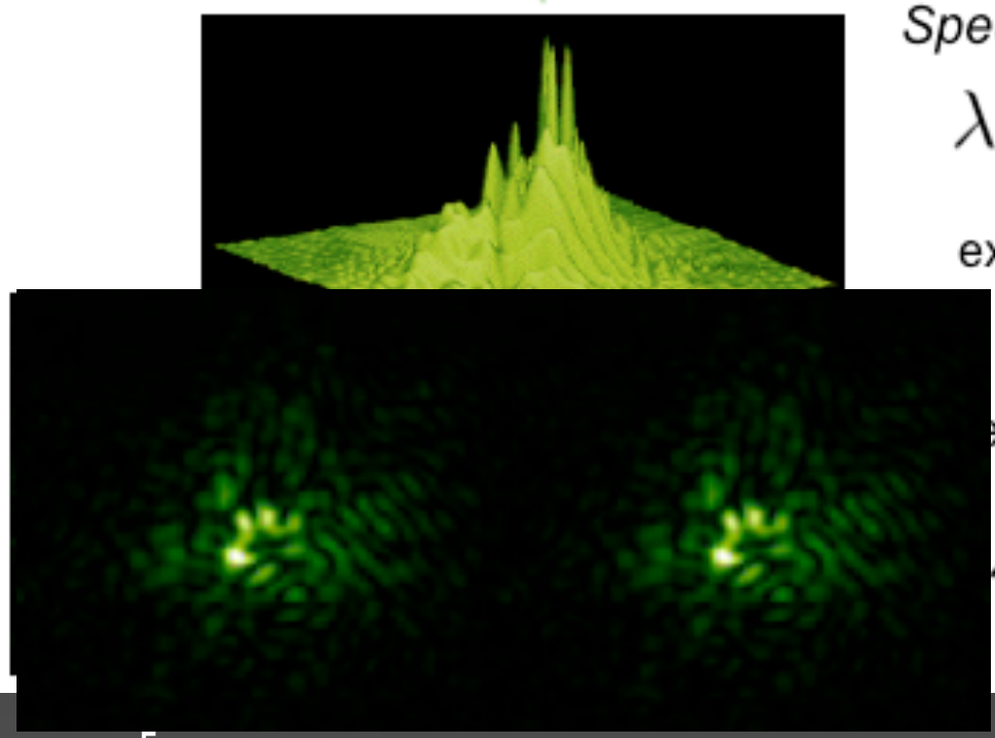
(r_0, θ_0, τ_0)

$\otimes$

Telescope OTF

Speckles

λ/D
short
exposure



long
exposure

λ/r_0

Adaptive Optics

DIFFRACTION

Point source
infinite d

λ

Ideal
Telescope

FT

D

PSF = Airy function

$$resolution \simeq \frac{\lambda}{D}$$

Imaging through atm. turbulence

Star
Non-resolved

~0-15 km

turbulent
atmospheric
layers

$\otimes$

Dome
Turbulence

(r_0, θ_0, τ_0)

$\otimes$

Telescope OTF

Speckles

λ/D

short
exposure

long
exposure

λ/r_0

Near future Optical facilities
with HAR capabilities

- Keck: second LGS, NGAO under study
- VLT: 7 AO system working, AOF coming!
- Gemini N/S (MCAO coming), Subaru, etc.
- Several GLAO system soon available!
- TMT (2018+)
- E-ELT (2020ish?)

Near future Optical facilities
with HAR capabilities

- Keck: second LGS, NGAO under study
- VLT: 7 AO system working, AOF coming!
- Gemini N/S (MCAO coming), Subaru, etc.
- Several GLAO system soon available!
- TMT (2018+)
- E-ELT (2020ish?)

SASIR will provide a catalog of tip/tilt stars for all the above

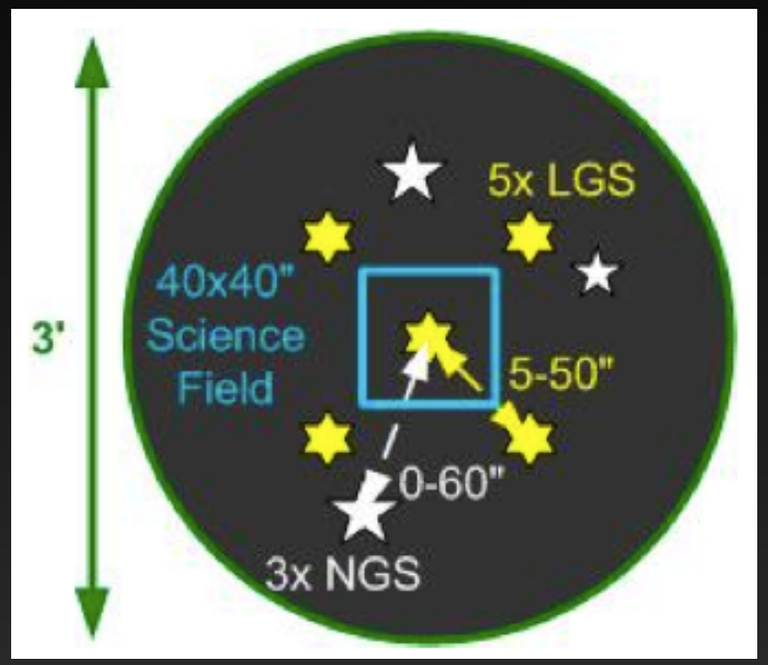
Near future Optical facilities
with HAR capabilities

- Keck: second LGS, NGAO under study
- VLT: 7 AO system working, AOF coming!
- Gemini N/S (MCAO coming), Subaru, etc.
- Several GLAO system soon available!
- TMT (2018+)
- E-ELT (2020ish?)

→ SASIR will provide a catalog of tip/tilt stars for all the above

Keck/NGAO

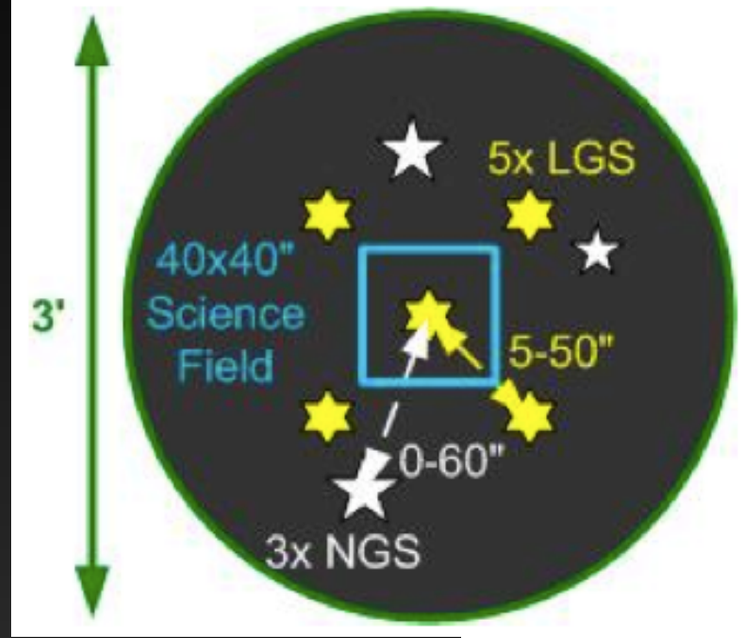
http://www2.keck.hawaii.edu/optics/ScienceCase/index.htm#NGAO



Text

Keck/NGAO

http://www2.keck.hawaii.edu/optics/ScienceCase/index.htm#NGAO



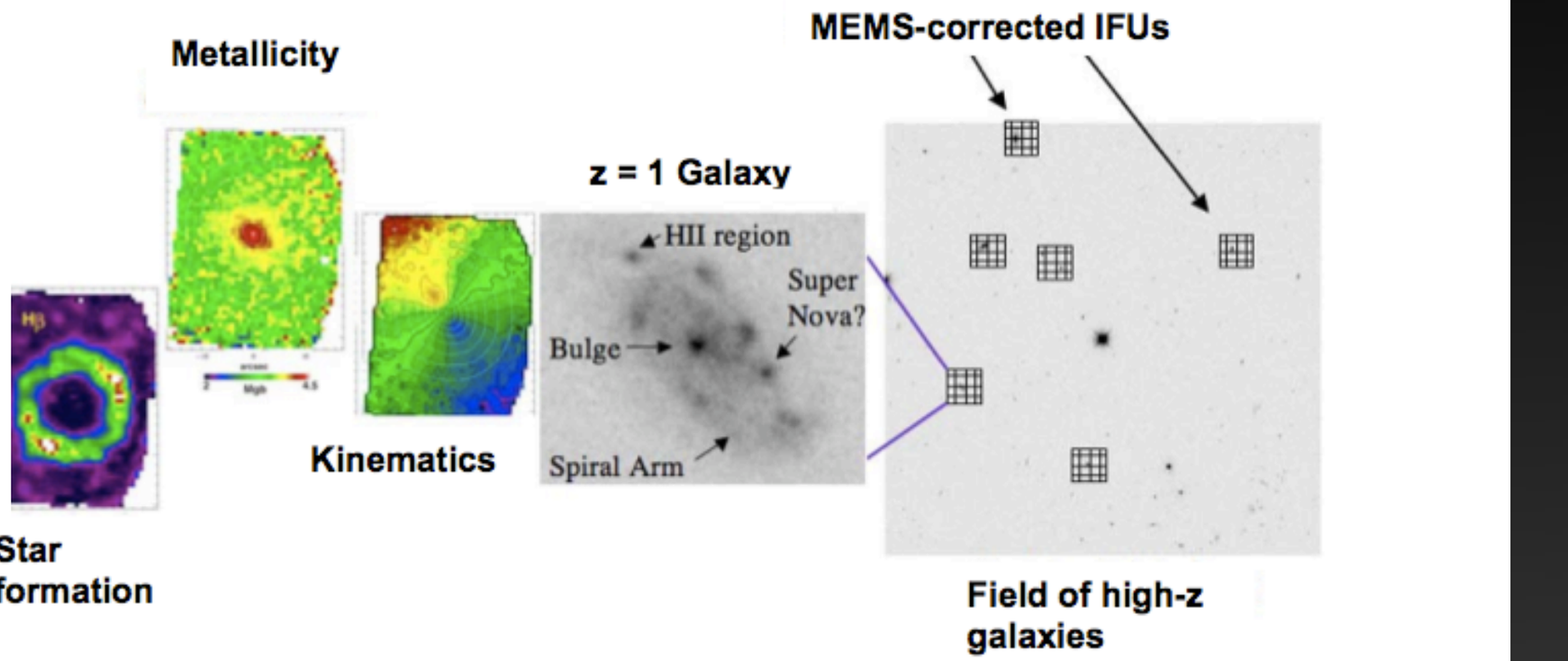
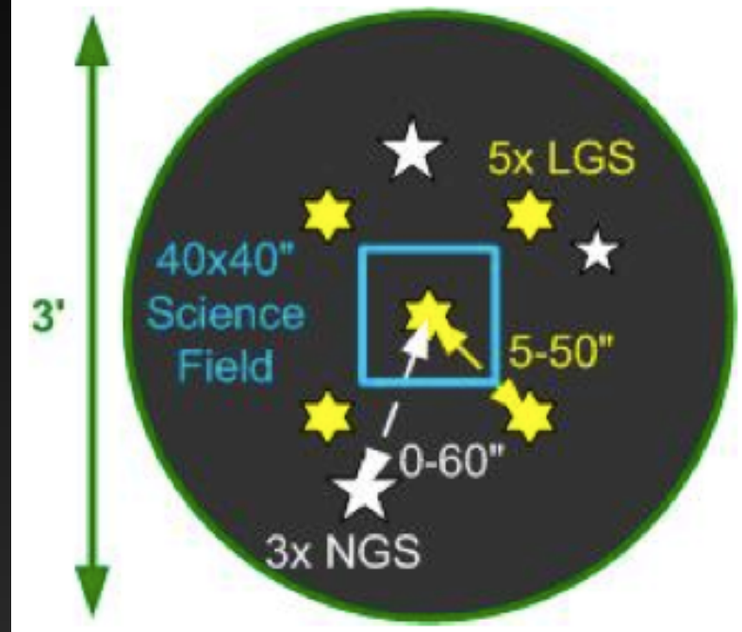
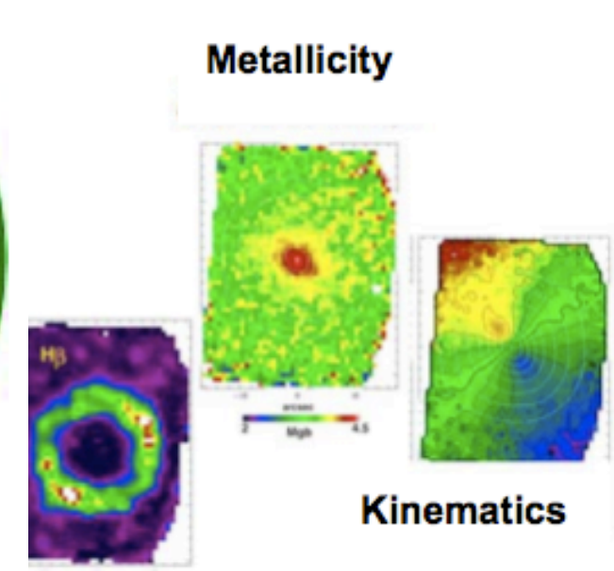


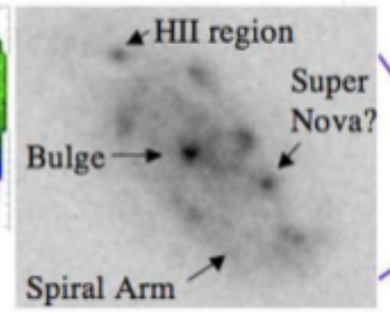
Figure 3: Schematic illustration of the benefits of Multi-Object Adaptive Optics.
Resolved maps of velocity, metallicity, and star formation rate are shown from SAURON IFU data obtained in seeing-limited mode. NGAO will carry out large surveys of high angular resolution spectroscopy for high-redshift galaxies, heretofore impossible with any existing telescope.

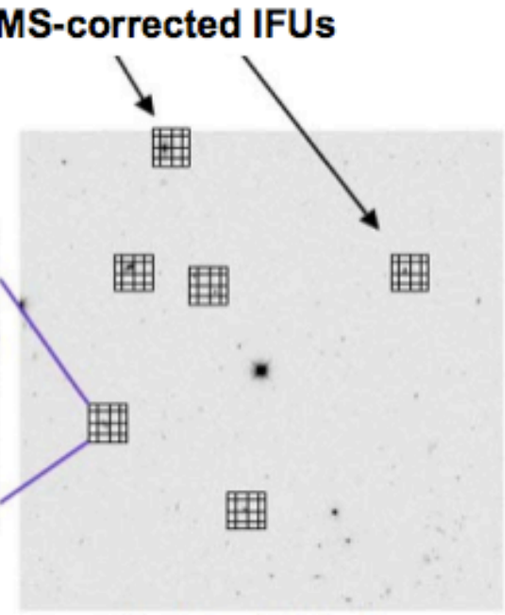
Keck/NGAO

http://www2.keck.hawaii.edu/optics/ScienceCase/index.htm#NGAO





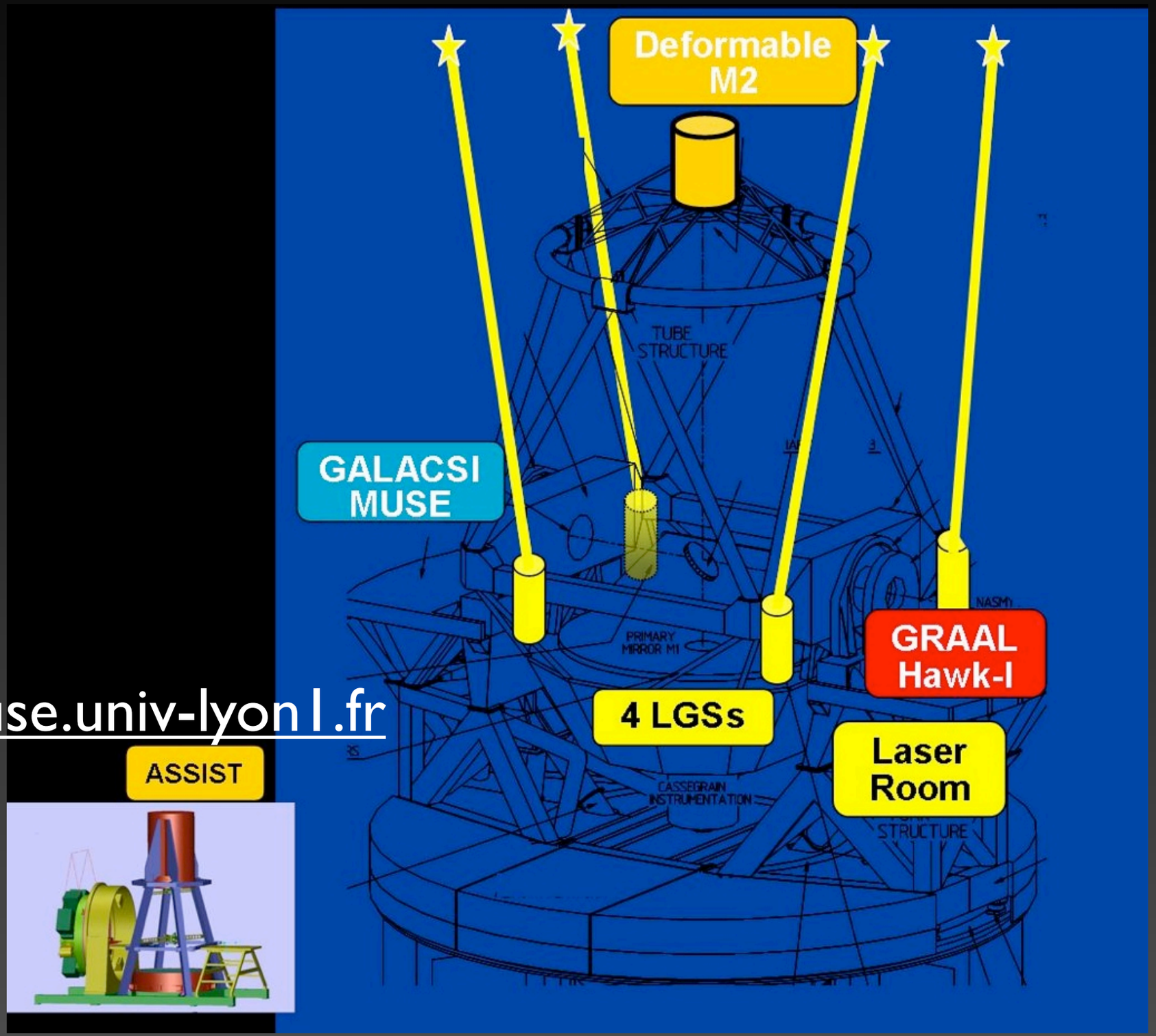




	Optical *narrow field, modest Strehl*	Near-IR *narrow field, high Strehl*	Thermal-NIR *narrow field, v.high Strehl*	High Contrast	Wide-Field, Multi-Object
Solar System	**Key**	Yes	Yes	Maybe	-
Galactic	Yes	**Key**	Maybe	**Key**	-
Extragalactic	**Key**	**Key**	-	Yes	**Key**

VLT AOF (~2012)

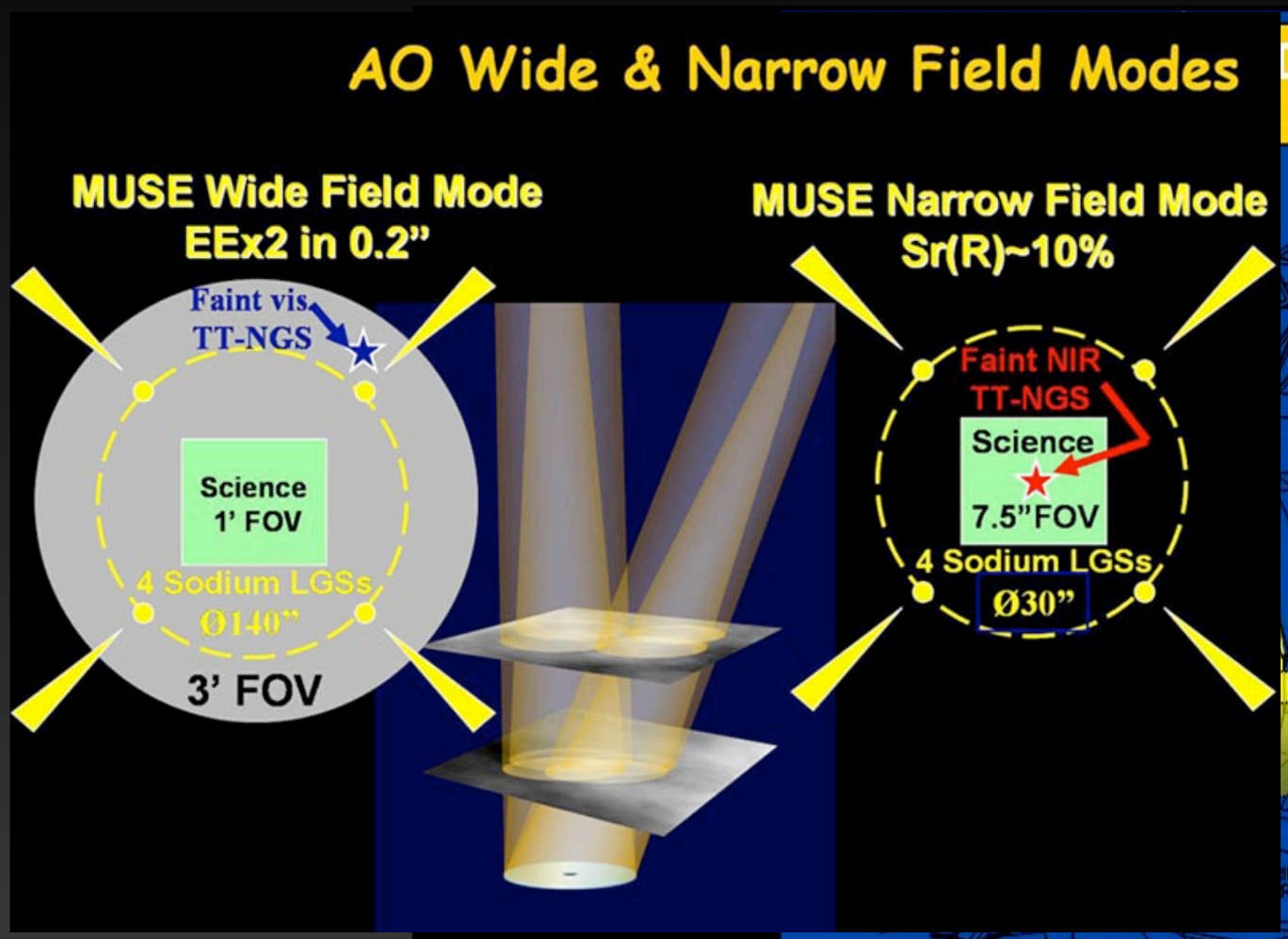
http://www.eso.org/projects/aot/DSM/



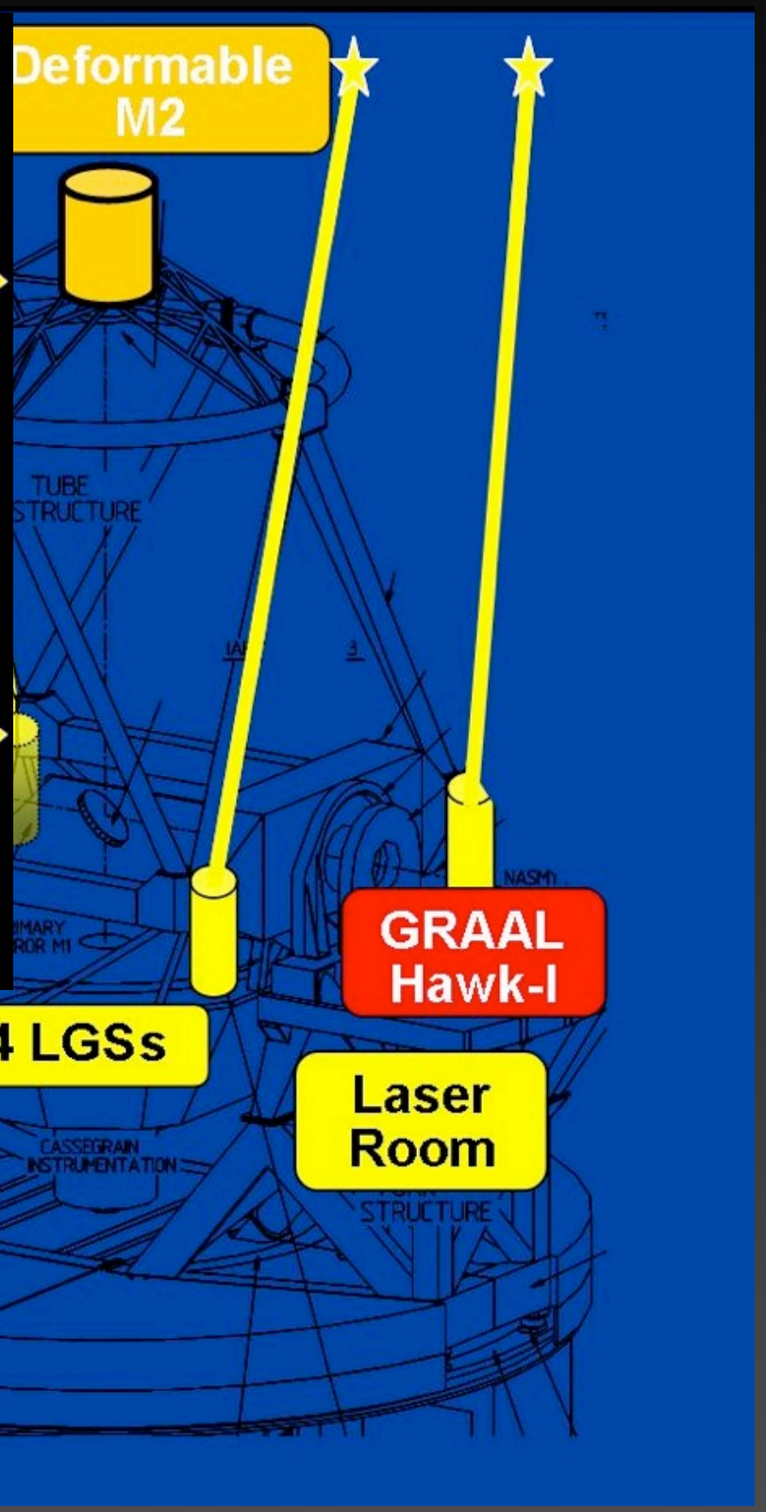
http://muse.univ-lyon1.fr

VLT AOF (~2012)

http://www.eso.org/projects/aot/DSM/

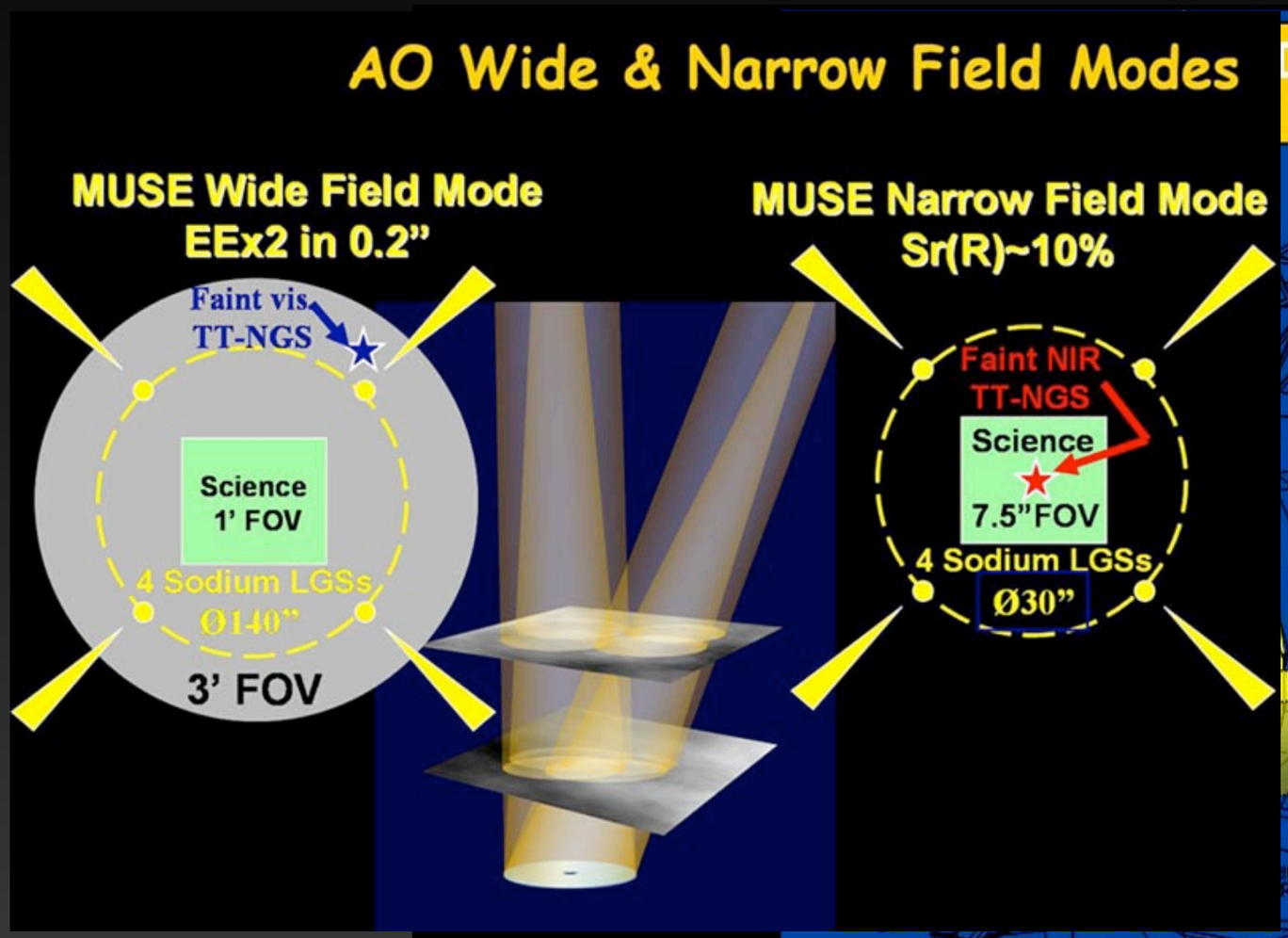


http://muse.univ-lyon1.fr

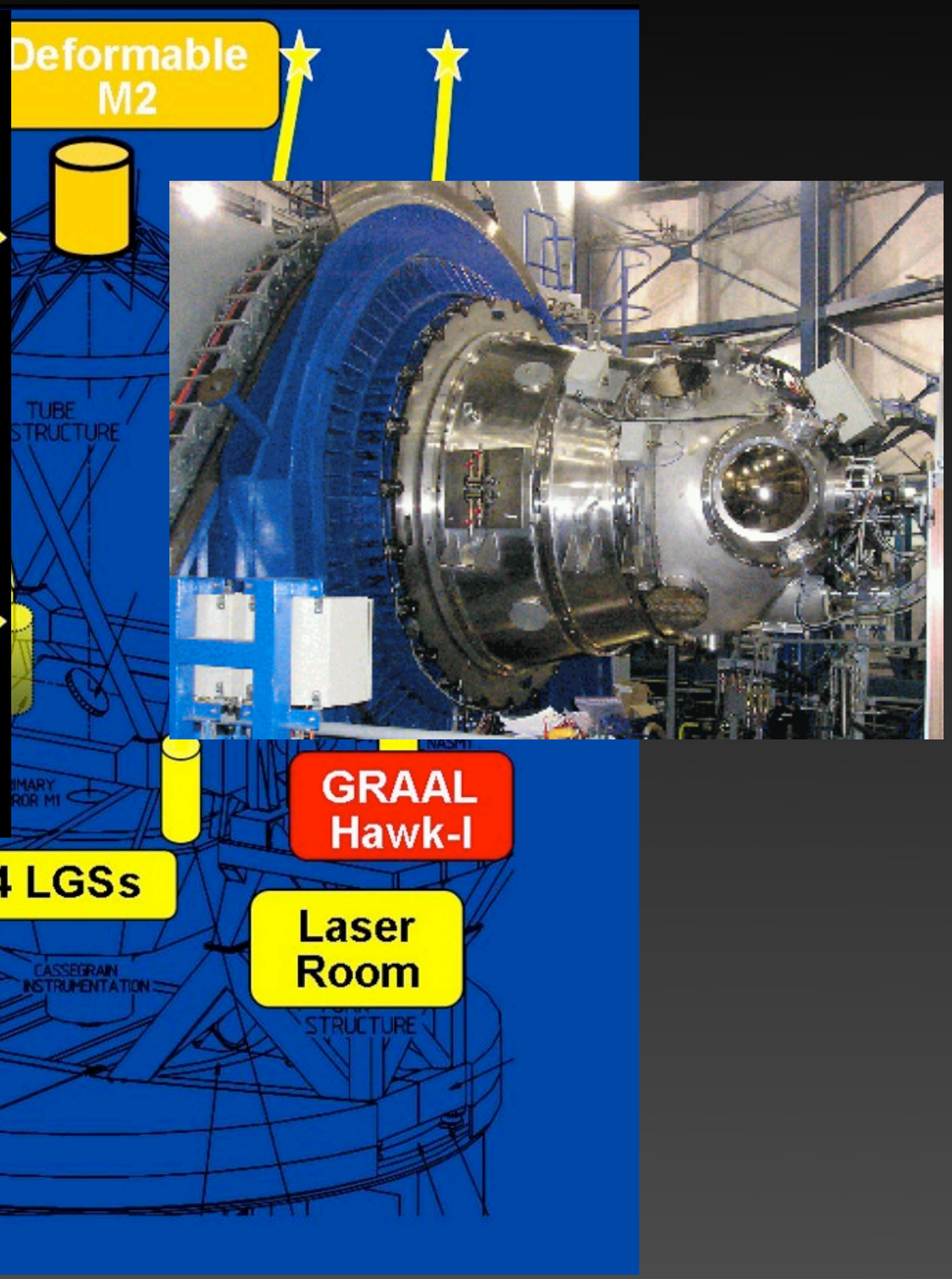


VLT AOF (~2012)

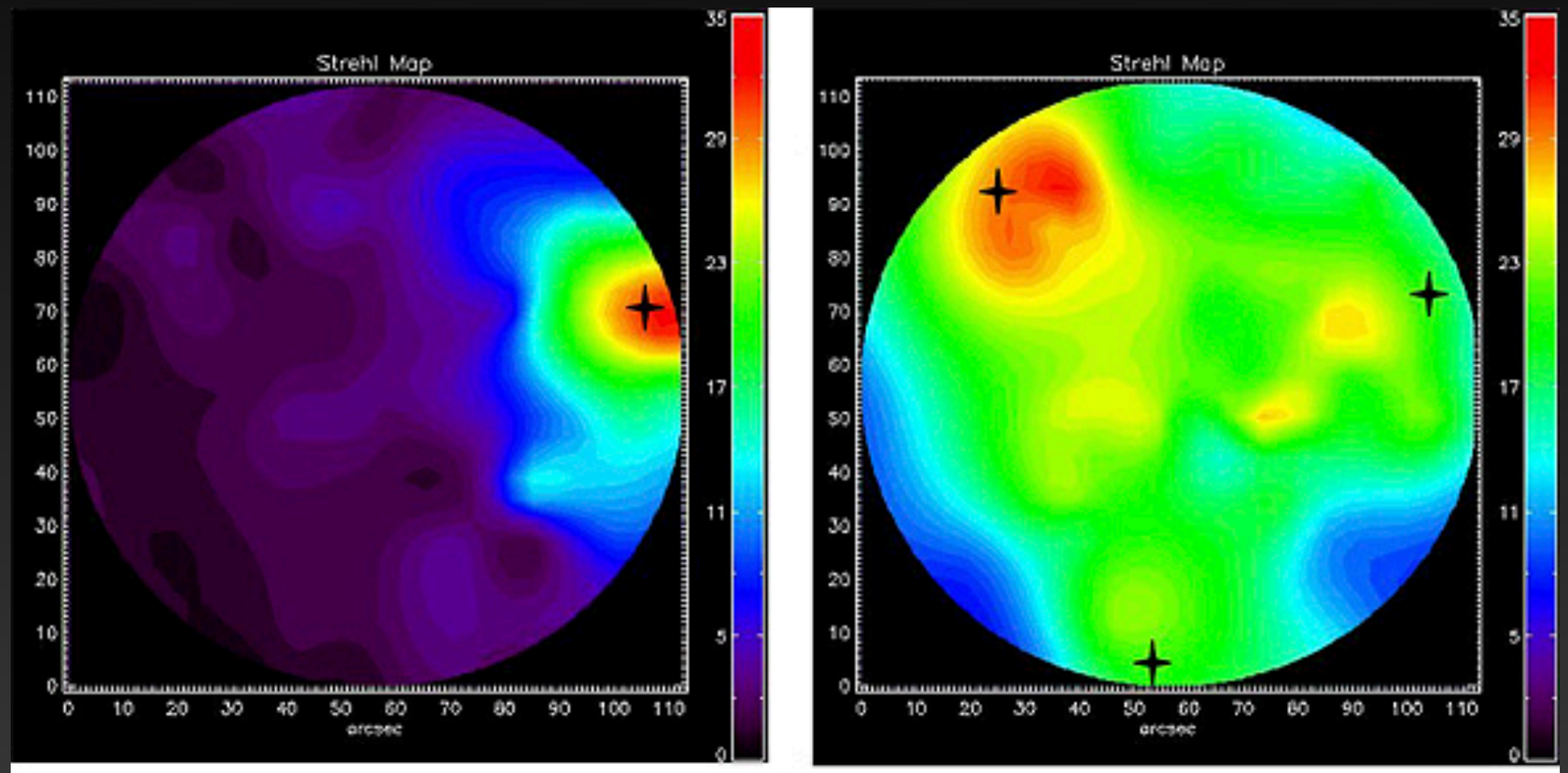
http://www.eso.org/projects/aot/DSM/



http://muse.univ-lyon1.fr



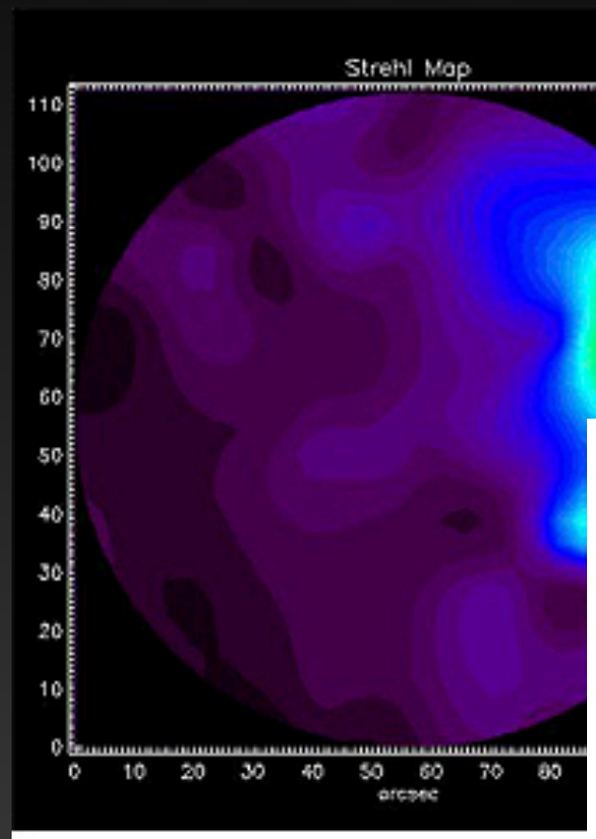
MCAO
VLT MAD + Gemini S

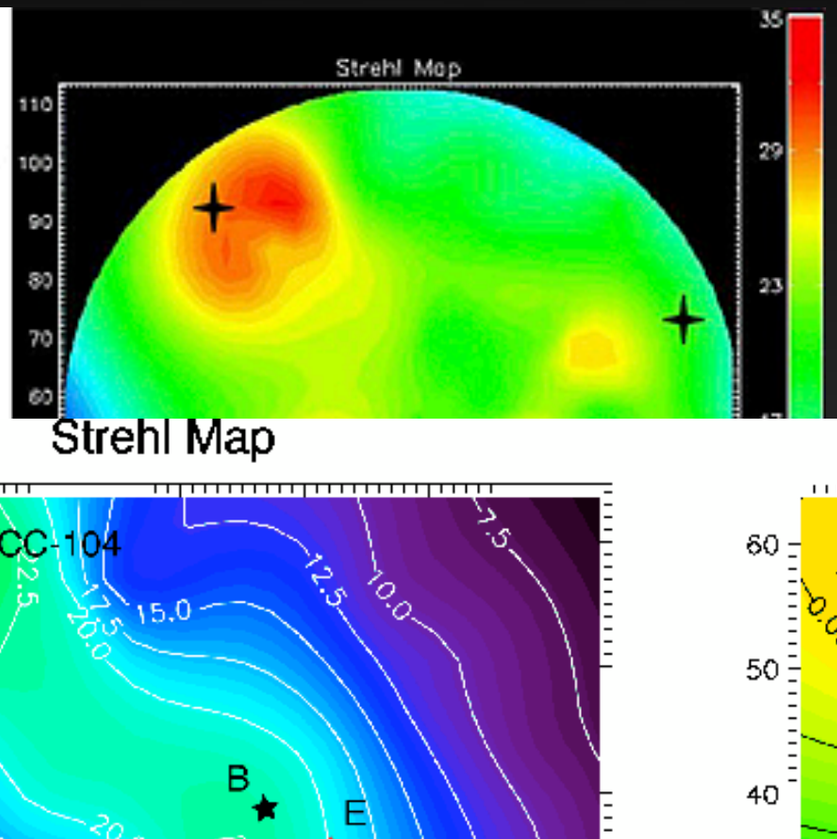


AO Strehl Maps

ESO Press Photo 19d/07 (30 March 2007)

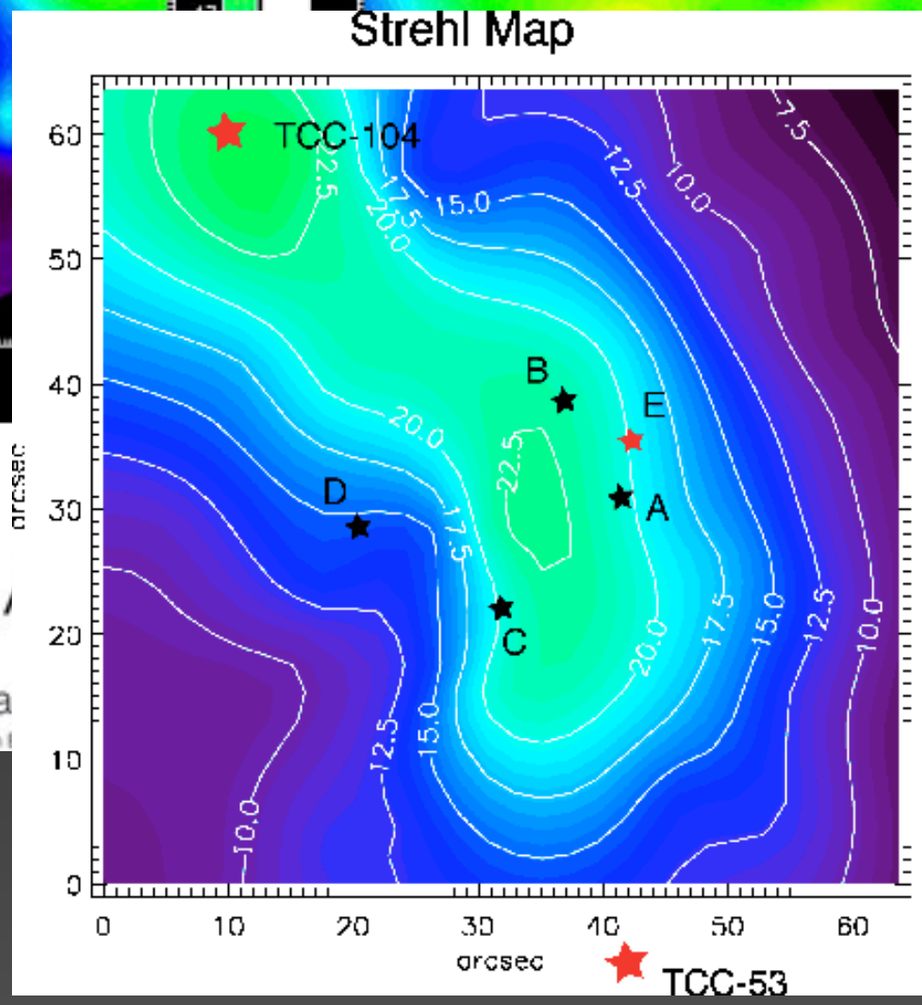
MCAO
VLT MAD + Gemini S

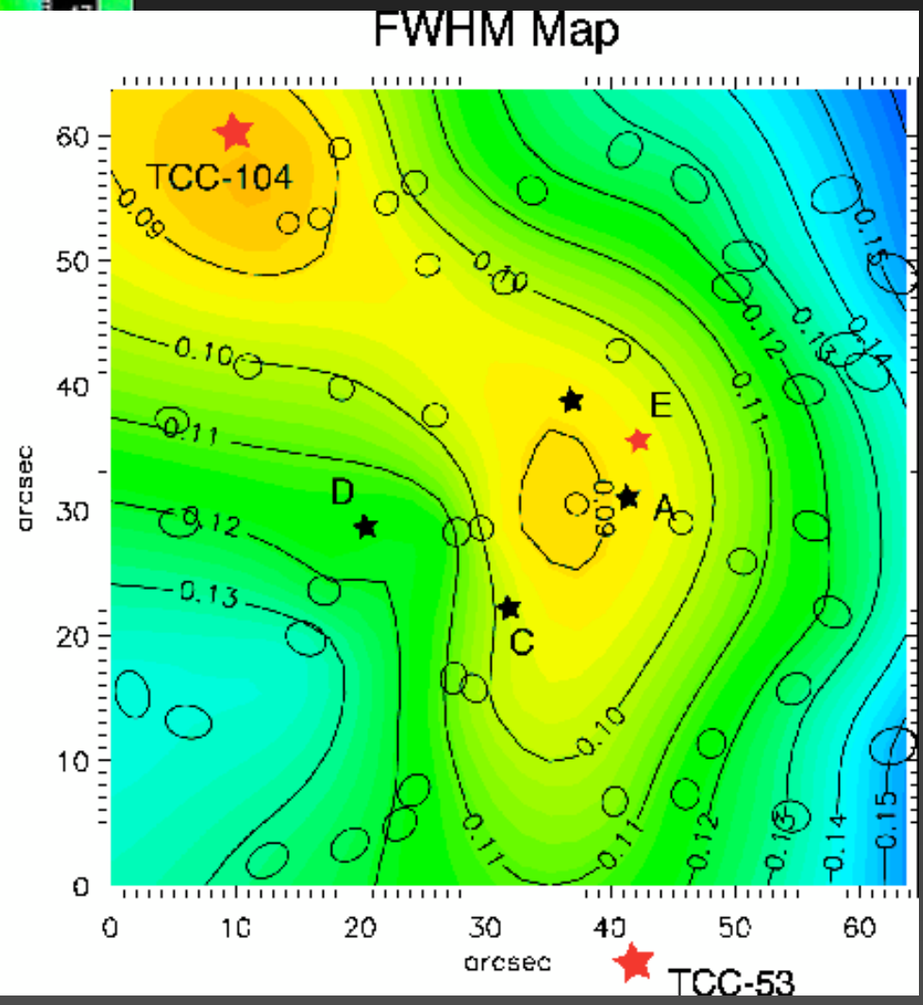




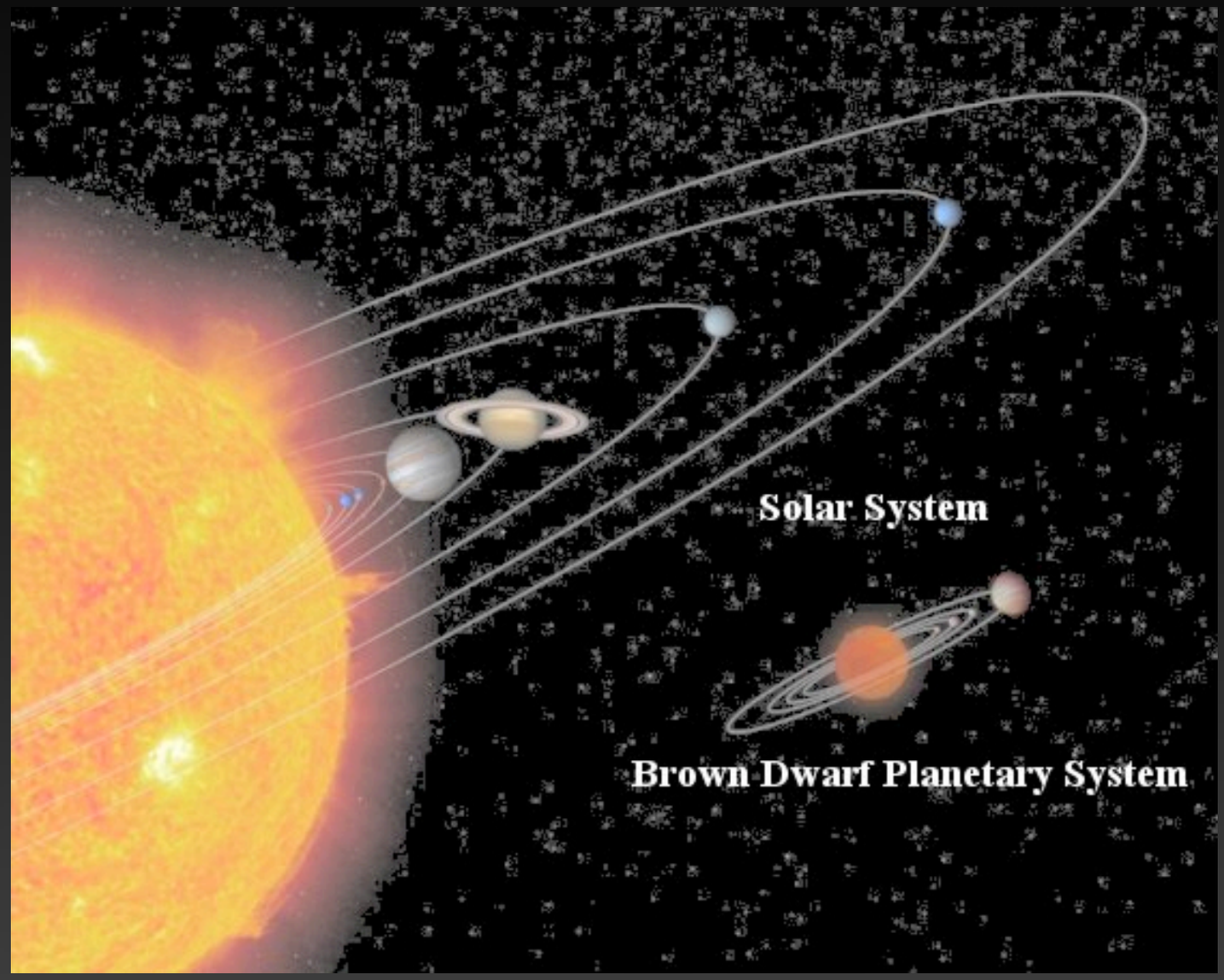
ESO Press Photo 19d/07 (30 Ma

This image is copyright © ESO. It is released in connection with an



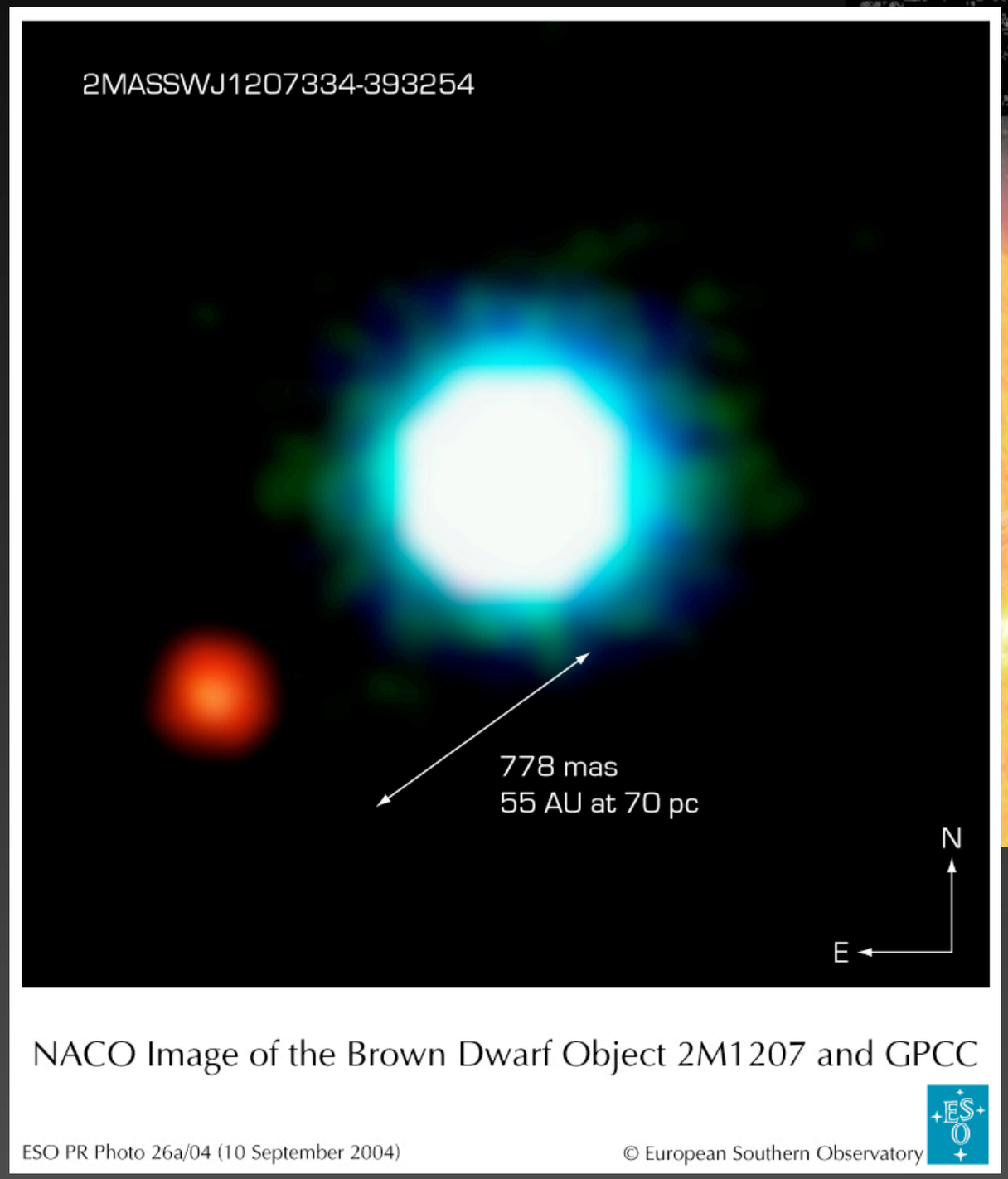


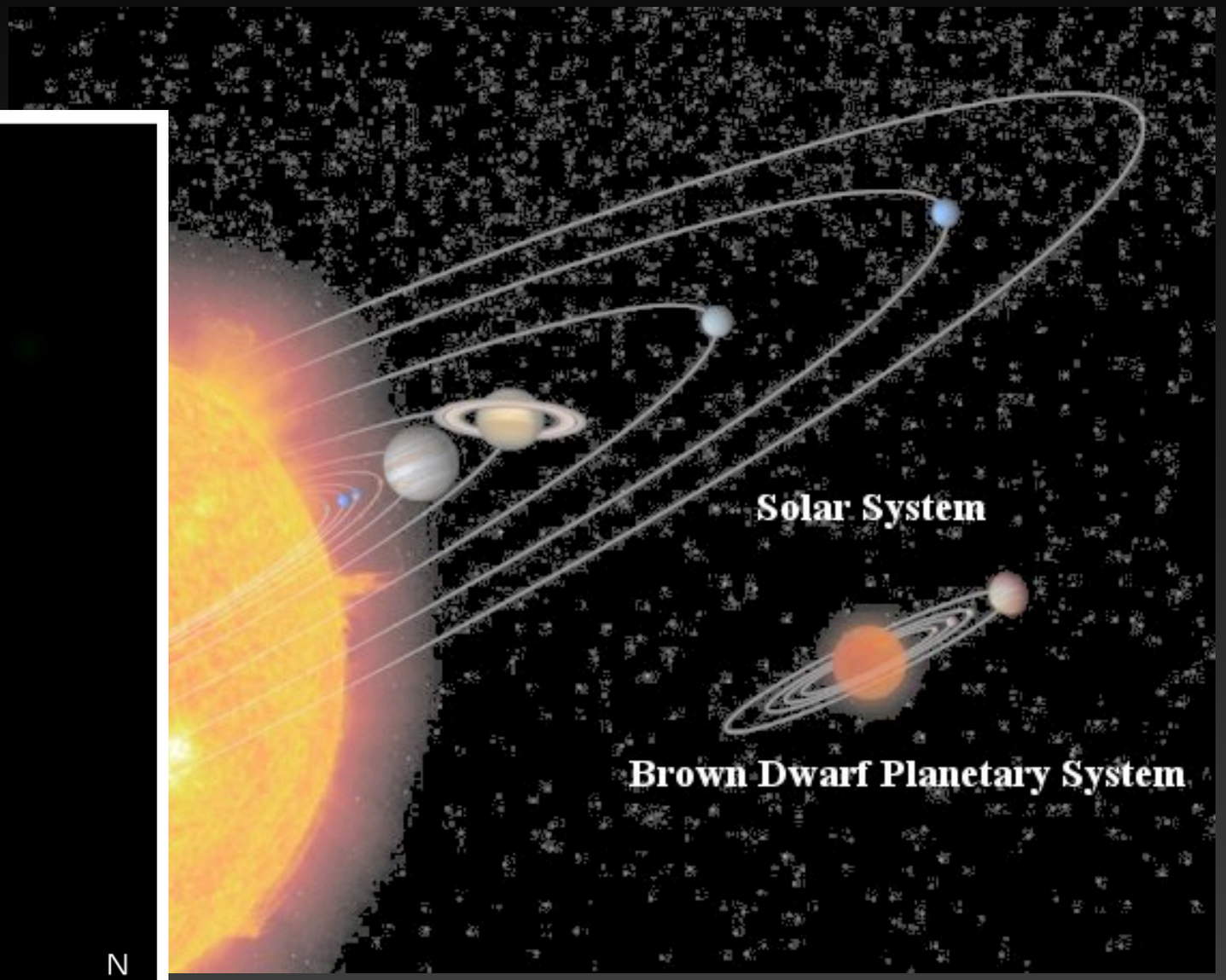
Application: Brown Dwarfs!



(Chauvin 2004)

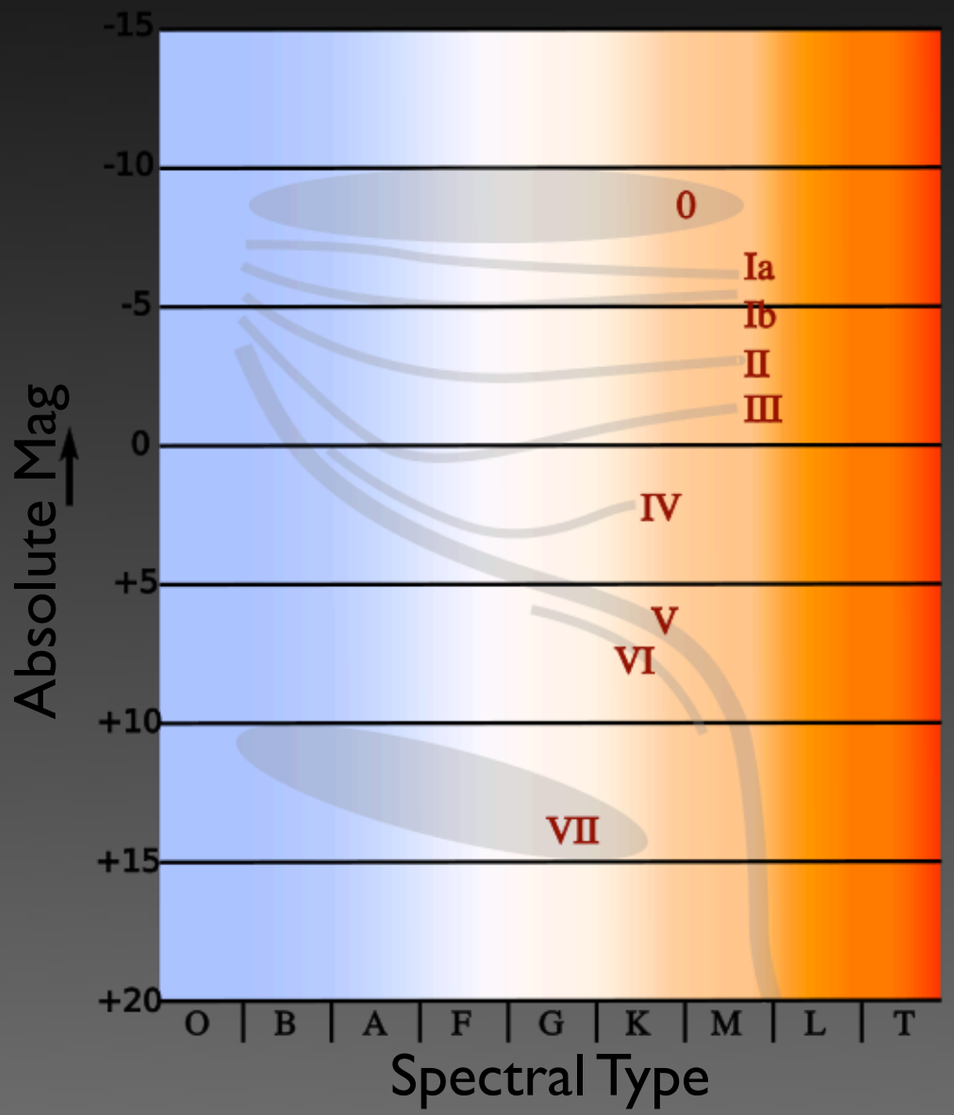
Application: Brown Dwarfs!





(Chauvin 2004)

Brown Dwarfs
find them all!



AO follow-ups of ultracool BD
= well understood techniques
(e.g. Bouy et al. 2008)
with 8-10 meter telescopes
better intrinsic resolution than
HST and even.. JWST

SASIR?

deeper, colder, IMF (talk Alicia Po
Down to what mass can these o
be formed by gravitational contraction?

Application to brown dw

AO follow ups of ultracc
dwarfs
Techniques well unders
With 8/10m class teles
instrinsic resolution is s
the one of HST.
Bouy et al, A&A, 2008

Facilities available to th
mexican community:
GTC
via european colleague
VLT
via UC colleagues
Lick
Keckx2
Geminix2
Palomar?
TMT?
JWST?

Coolest Brown Dwarfs

Many M and T low mass stars (2MASS, SDSS) are followed with the actual NIRAO facilities
(e.g. Liu, Delfosse, Bouy, etc.)

Y type brown dwarfs!(Teff~600K)
(e.g. Delorme et al. 2008, detected at CFHT)
with 8-10 meter telescopes
better intrinsic resolution than HST and even.. JWST

With M_{yJHK}~22, SASIR will detet them all!

Two needs:
- confirm them by spectroscopy, photometry, and proper motion
- observe them in HAR to study their multiplicity

→ Contraction of small molecular cloud or more complex phenomena occur?

Question that could be answered by SASIR
down to what mass can objects be formed by gravitational contraction?

As for today, the models seem to converge toward 3 to 4 MJup

Even ~2-4 MJup isolated objects have been found recently in young star associations (Sigma Orionis, particularly SOri 70, see Zapatero Osorio)

Even cooler!

A Y dwarf detected at CFHT?
Delorme, P. et al 2008

With MJHK~ 23-24 SASIR will find them all!

Then there will be two needs, answered by large optical telescopes:
- confirm them by spectroscopy, photometry, and proper motion
- observe them in HAR to study their multipicity

the multiplicity is very important

Facilities available for the Mexican community

- GTC/AO+FRIDA, directly (or indirectly)
- VLT via european colleagues
- Lick, Keck x2, Gemini x2, Palomar(?), and later JWST, TMT, etc. Via UC collaborations and other US/Canadian colleagues
- etc.

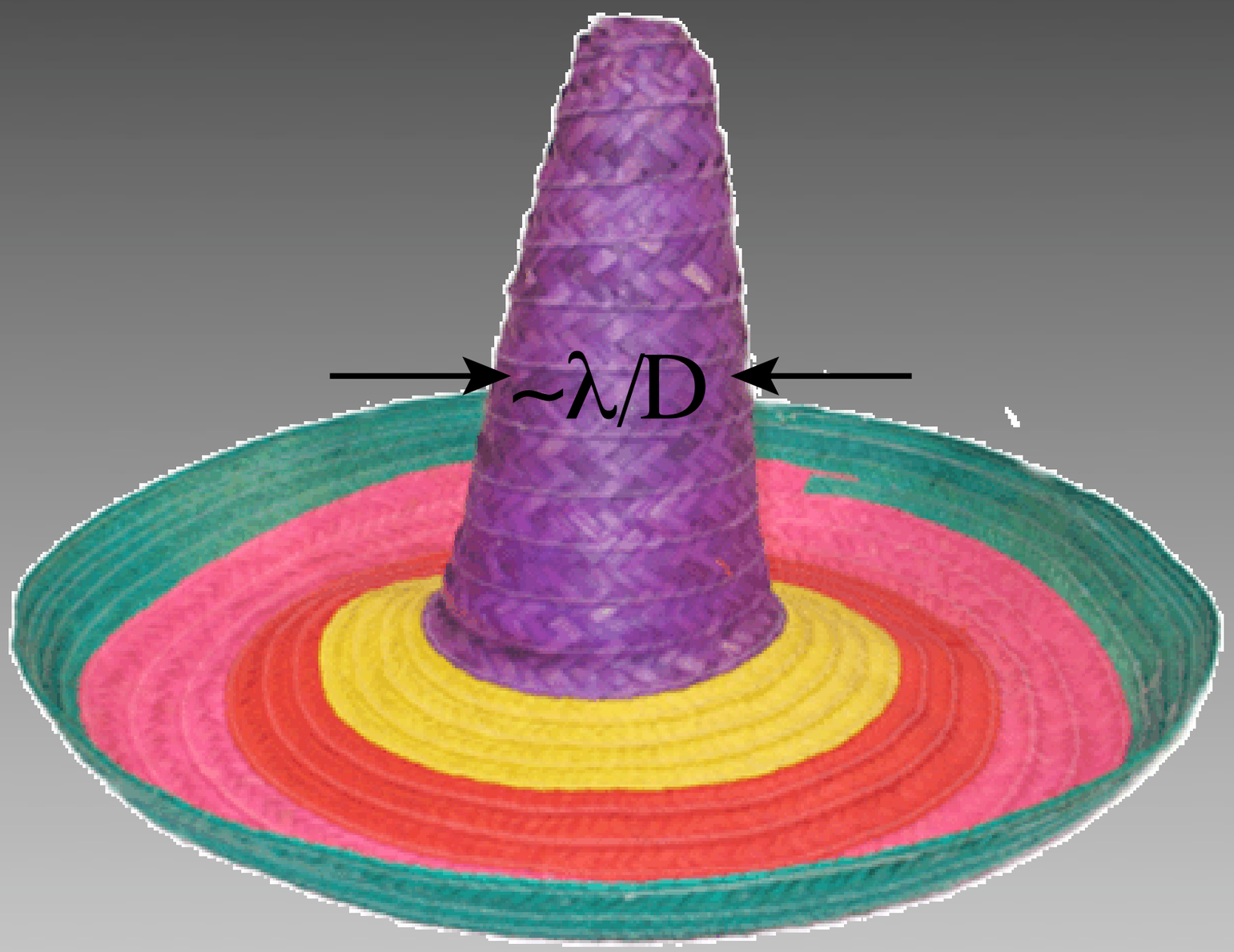
We need to learn AO corrected observations!!

Facilities available to the mexican community:
GTC
via european colleagues
VLT

via UC colleagues
Lick
Keckx2
Geminix2
Palomar?
TMT?
JWST?

High Angular Resolution in Mexico!

High Angular Resolution in Mexico!



GUIELOA
Mexican AO system for SPM

http://www.astrosmo.unam.mx/~a.watson/guieloa

- Learning experiment (HAR techniques, curvature sensing) for the IA-UNAM and the whole mexican community
- Prepare GTCAO/FRIDA
- Prepare SASIR follow-ups

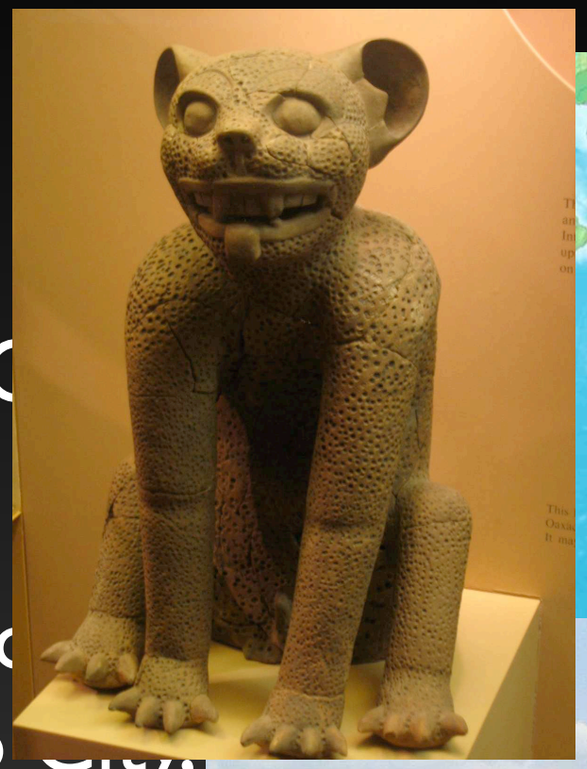
→ will allow the mexican astronomers to try new things with a rather easy access

GUIELOA

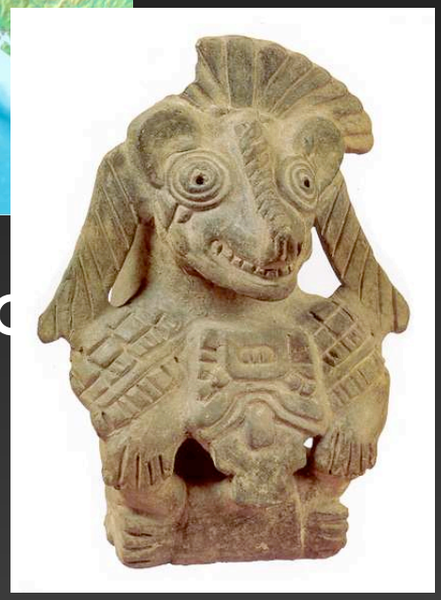
- GUIELOA: means "our eyes" in Zapotec
- for the 2.1 meter telescope at Observatorio Astronomíco Nacional, constructed at IA-UNAM, México City, scheduled for ????
- 19-element bimorph DM mounted on TT platform
- Curvature WFS working with NGS.

Watson et. al 2005 (RevMex), Girard et. al 2008 (SPIE)

GUIELOA



- GUIELO
- for the
  Astrono
  México
- 19-element b T platfo
-



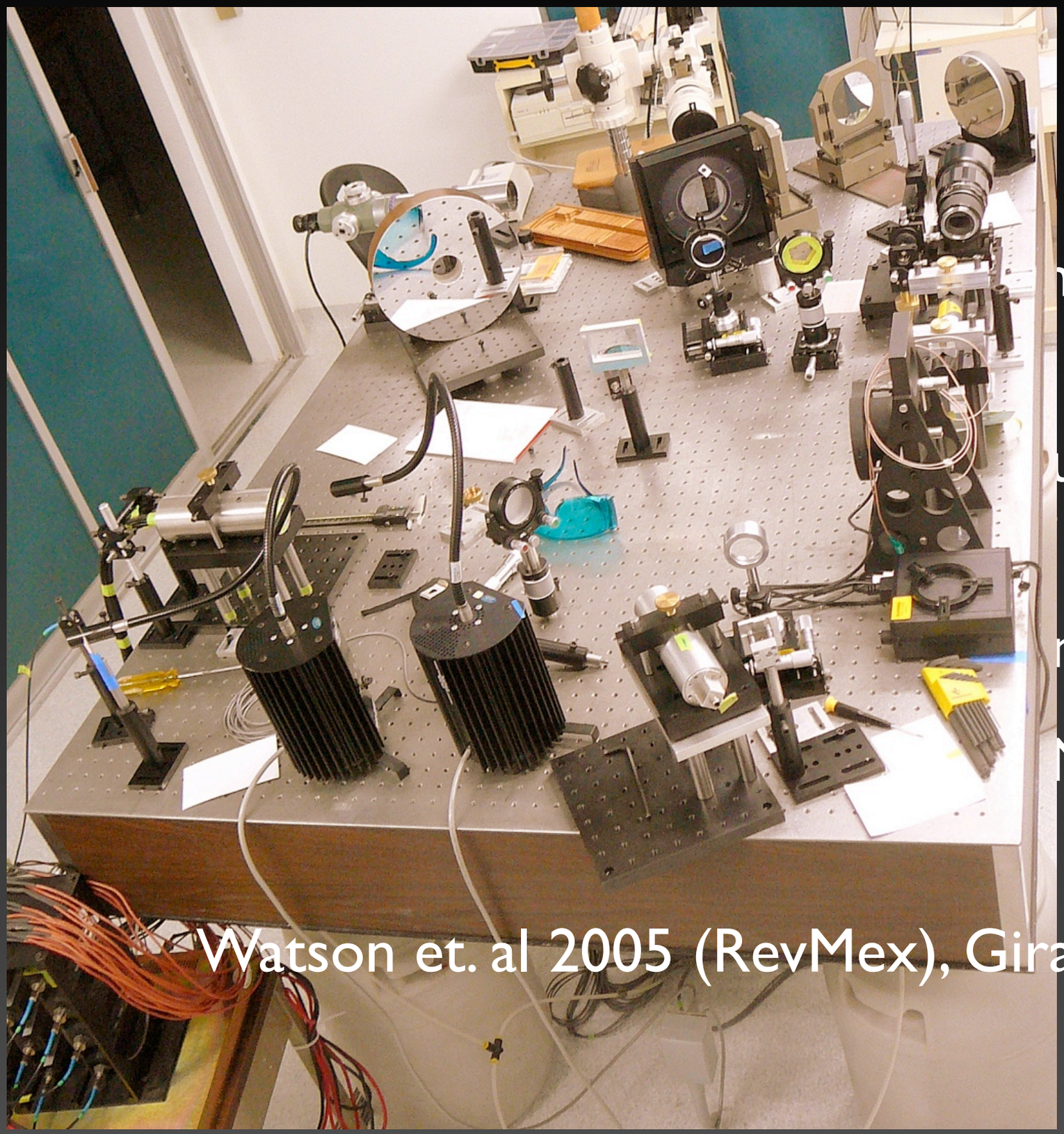
Watson et. al 2005 (RevMex), Girard et. al 2008 (SPIE)

GUIELOA

- GUIELOA: means "our eyes" in Zapotec
- for the 2.1 meter telescope at Observatorio Astronomíco Nacional, constructed at IA-UNAM, México City, scheduled for ????
- 19-element bimorph DM mounted on TT platform
- Curvature WFS working with NGS.

Watson et. al 2005 (RevMex), Girard et. al 2008 (SPIE)

GUIELOA



n Zapotec

Observatorio

ucted at IA-UNAM,

nted on TT platform

NGS.

Watson et. al 2005 (RevMex), Girard et. al 2008 (SPIE)

GUIELOA

- GUIELOA: means "our eyes" in Zapotec
- for the 2.1 meter telescope at Observatorio Astronomíco Nacional, constructed at IA-UNAM, México City, scheduled for ????
- 19-element bimorph DM mounted on TT platform
- Curvature WFS working with NGS.

Watson et. al 2005 (RevMex), Girard et. al 2008 (SPIE)

SASIR-II
AO enhanced, deeper survey?

AO equiped, GLAO with adaptive secondary
take advantage of the IR detector, staff experience and infrastructure/orgnization
SASIR-II could have slightly reduced FOV with an enhanced resolution (0.1")
thus would go deeper.
it could operate with a

- Change for an adaptive secondary
  + (a set of) Na or Rayleigh LGS?
- Recycle detector and dichroïc filters
- Take advantage of staff experiment and infrastructure/organization from SASIR-I
- MCAO in the NIR with 2' FOV
- GLAO for wide field 0.1" resolution in the visible?
- Add filters: CH_4, etc.

Give me money!

THANKS !!!