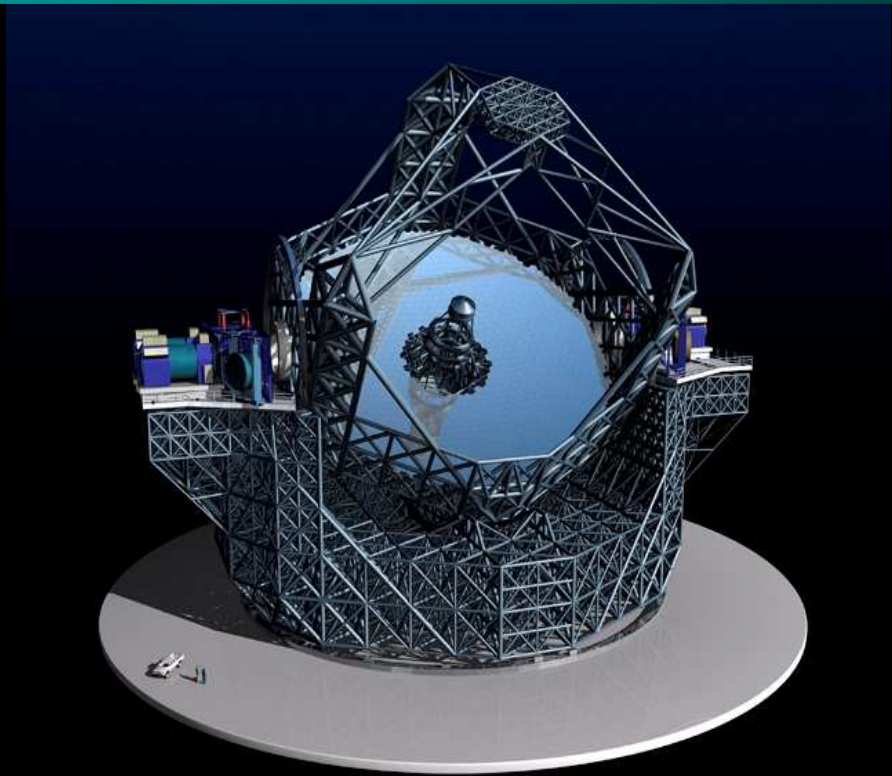
Science goals and priorities for ELTs
Isobel Hook (U. Oxford)



Note also later talks:

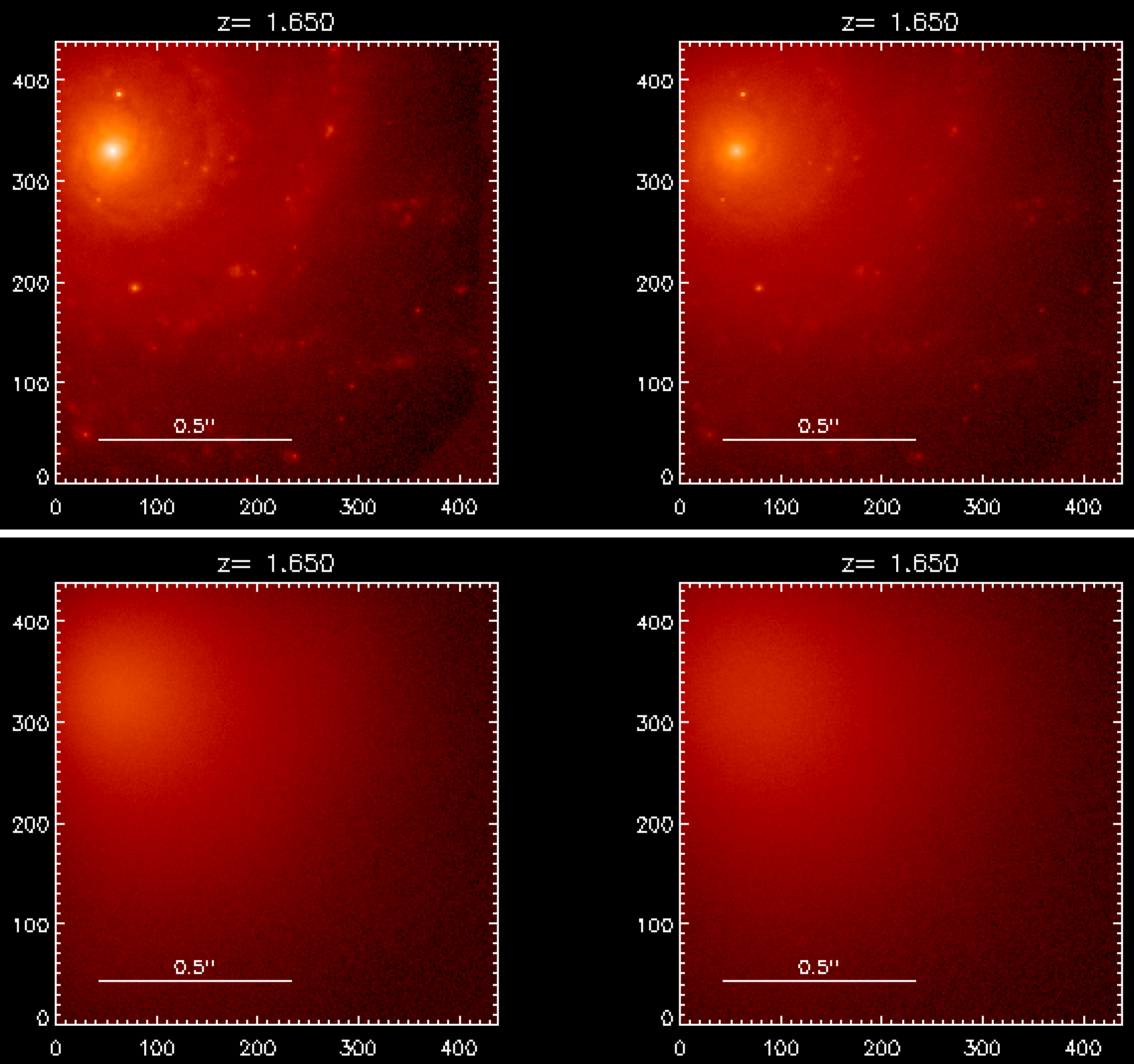
Guy Monnet - AO requirements for the European ELT

Norbert Hubin - ESO AO roadmap towards an ELT

Simulations for a 42m telescope
H band on axis, galaxy scaled to z=1.65

LTAO
Few arcsec

MCAO
(~ 2' FOV)



GLAO
(~5' FOV)

No AO

PSFs from ESO
(Le Louarn et al)

Two groups of science cases: those requiring…

- 1) Collecting area (light bucket)
  - Very high S/N observations of bright sources
  - Integrated spectroscopy of faint resolved sources
  - 40m / 8m = factor 25 in exp time
  - Light concentration (moderate resolution)
- 2) Resolution
  - Very high contrast observations
  - Crowded/ complex fields (high resolution)
- Most science cases for ELTs require both

E-ELT Science Working Group

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With thanks to previous members

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European ELT SWG
Prominent Science Cases

- Exo-planets
  - Direct detection ★
  - Radial velocity detection
- Initial Mass Function in stellar clusters
- Stellar disks
- Resolved Stellar Populations
  - Colour magnitude diagrams ★
  - Abundances and kinematics
  - Detailed abundances
- Black Holes
- The physics of galaxies ★
- Metallicity of the low-density IGM
- The highest redshift galaxies
- Dynamical measurement of the Universal expansion

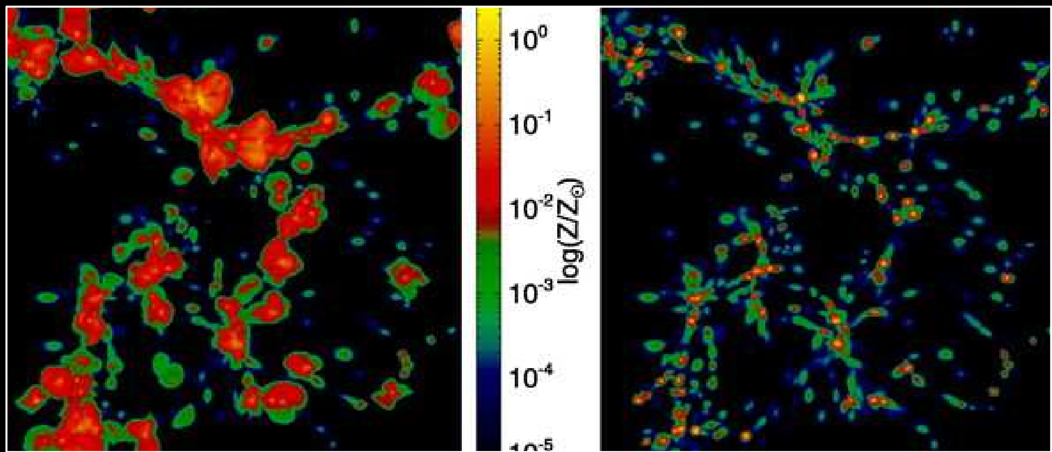
- Selected from larger set
- Input to Design Reference Mission
  - Observing proposals
  - Simulated data
  - (Demo cases ★)
- See www.eso.org

“Unresolved” science cases

- High spatial resolution not required
- Seeing limited (or GLAO for light concentration)
- Several cases using optical wavelength range

The low density IGM

- IGM metal enrichment depends on
  - density of sources ejecting metals during the reionisation epoch
  - galactic superwinds at later times (z<5)
- Hydrodynamical simulations predict CIV column densities 10^9–10^{10} cm^{-2} for regions with ~unity overdensity
- Require a factor 100 increase in detection limit of CIV doublets

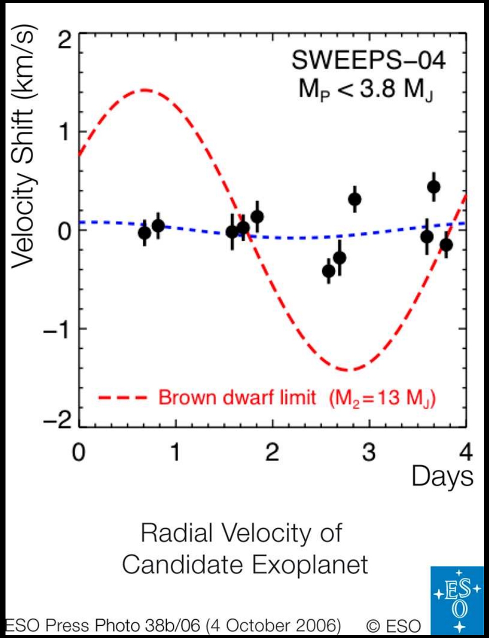


Metallicity of a 11 × 11 *x* 2.75 h^{-1} Mpc^3 slice at redshift z = 3 with (*left*) and without (*right*) GSWs (Cen et al 2005)

- Absorption-line spectra of z~3 QSOs or GRBs with V~16
- R=100 000
- 0.55 – 0.7 μm
- AO mode: None

Exo-planets
Indirect detection: Radial velocity

VLT/UVES mass limit < 3.8 M_J for an HST/SWEEPS transiting planet candidate



- Low mass planets: e.g. earth-like planets around solar type stars
  - New planets (and systems)
  - Physical parameters of planets detected by transit searches

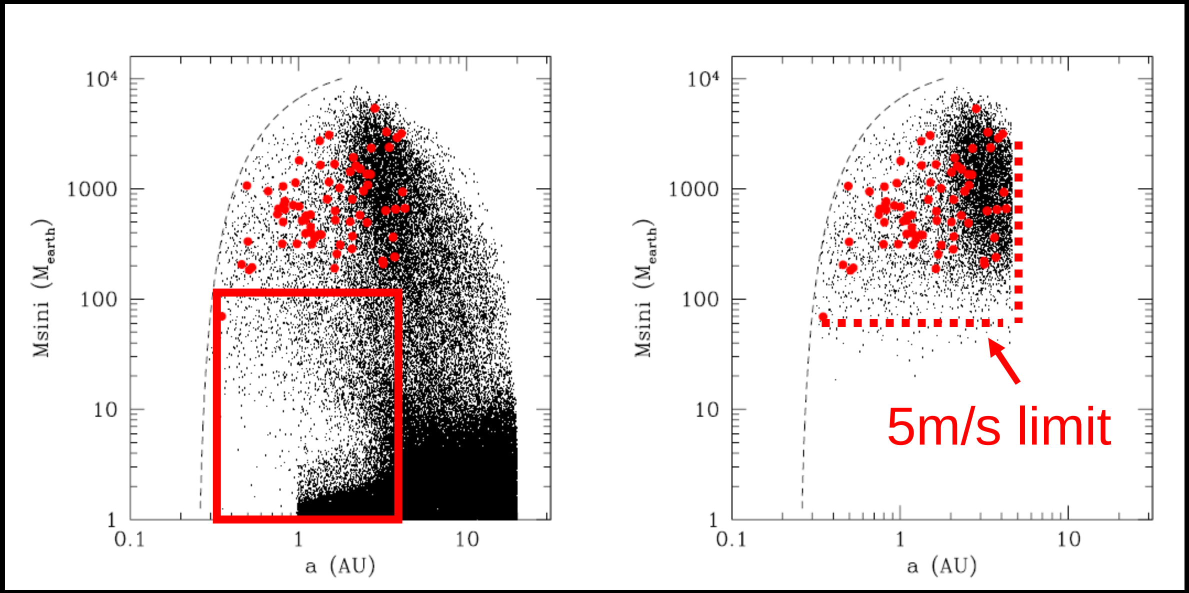


Figure: Benz, Mordasini, Alibert & Neaf, 2005

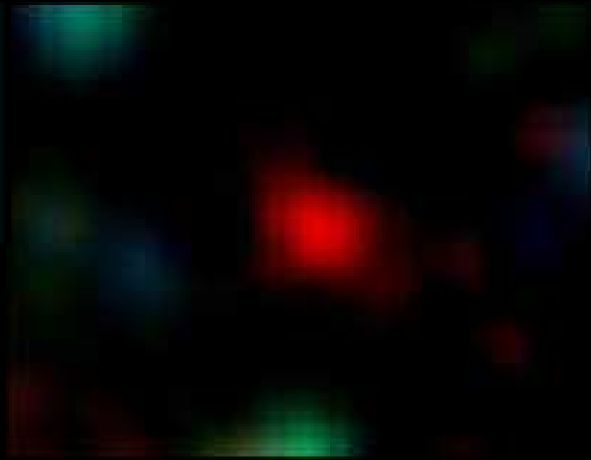
- ELT provides photons
  - 42m can reach 3 cm/s precision in 1 hr for V~10 K0 star (Earth has 8cm/s effect on Sun)
- High resolution, stable optical spectrograph

Very high-redshift galaxies

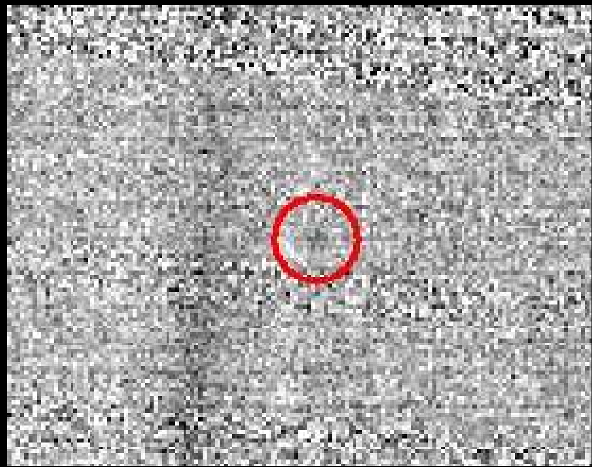
- What re-ionised the Universe at z > 6 ?
- Current limit z~7

- Higher-z - follow up JWST targets (?)
- NIR spectroscopy
  - Measure z & basic physical parameters
  - Maybe detect He lines (indicator of PopIII)
  - R>1000 competitive with JWST but requires large FOV and high multiplex (~100)

- AO MODE: None/ GLAO
  - optimal resolution depends on source size



IOK-1, z= 6.96
(Iye et al 2006)



z~7 galaxy candidate
Stark et al Keck/NIRSPEC

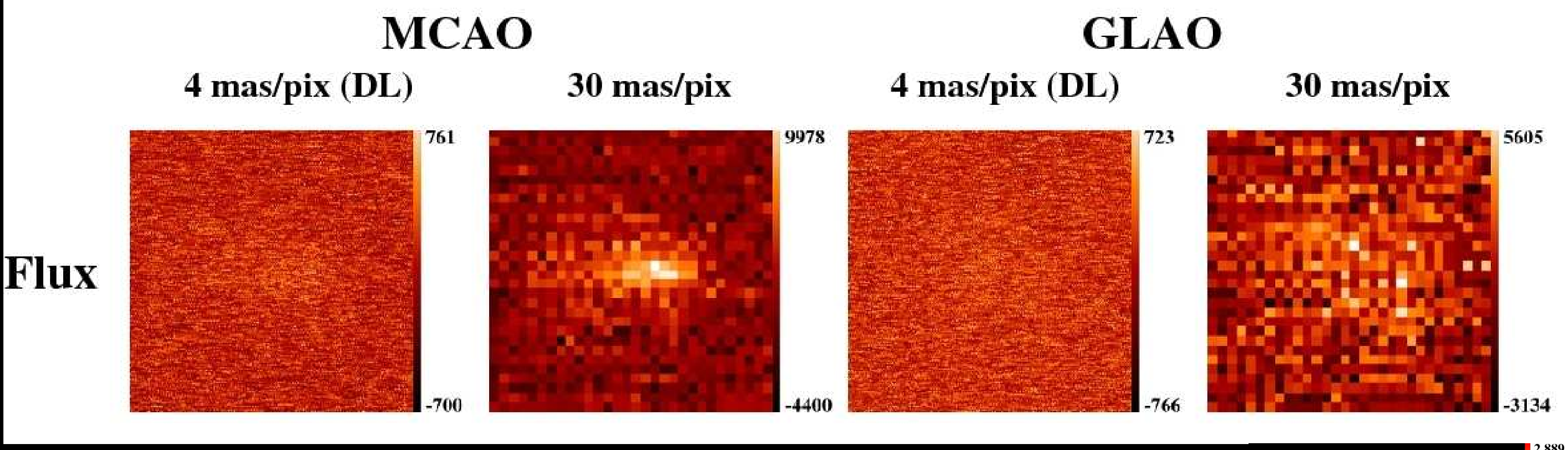
High resolution science

- Imaging complex structures
- Crowded fields
- Spatially-resolved spectroscopy
- High-contrast observations

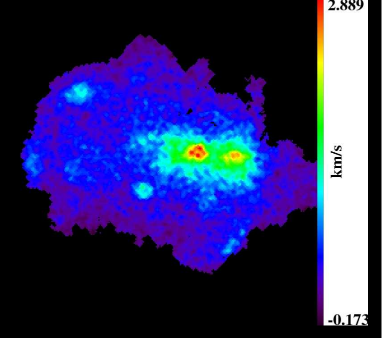
Imaging of high-redshift galaxies

- Mergers? Relaxed systems?
- Gas rich?

M* Galaxy at z=4 in H-band
Preliminary simulations by M. Puech (ESO)

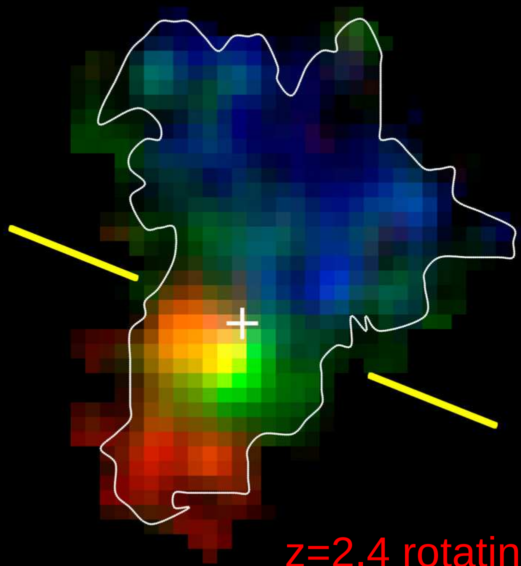


- AO MODE: GLAO / MCAO / LTAO
  - Depends on the (unknown) size of the objects
- Wavelength range: Near-IR



Evolution of galaxies:
Physics of galaxies 1 < z < 5

- Goal: to understand formation of galaxies & feedback processes (SNe, AGN)
- Want to spatially resolve on kpc scales:
  - Star formation history
  - Stellar mass
  - Extinction
  - Metallicity
  - Ionisation state
  - Line shapes (> winds)
  - Internal dynamics (dynamical masses)

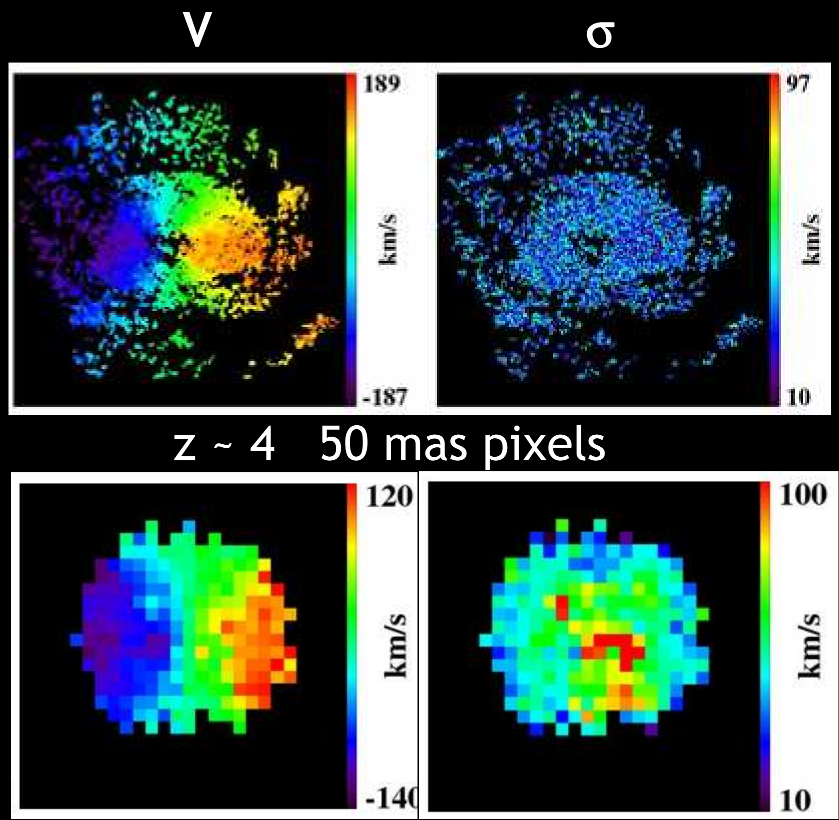


z=2.4 rotating disk
galaxy with SINFONI
Genzel et al 2006

- Large sample requires multiple–IFU instrument, fed by AO

E-ELT DRM Demo case:
The physics and mass assembly of galaxies to z~6

- Goal: Kinematics of ~10^3 massive 2<z<6 galaxies
- Simulations (M. Puech/ESO)
  - Input
    - Merger vs rotating disk
    - Sky spectrum, AO PSFs..
  - Conclusions:
    - GLAO OK to distinguish dynamical state of galaxies (merger vs rotation)
    - MOAO needed to see knots in clumpy disks for M* galaxies at z=4

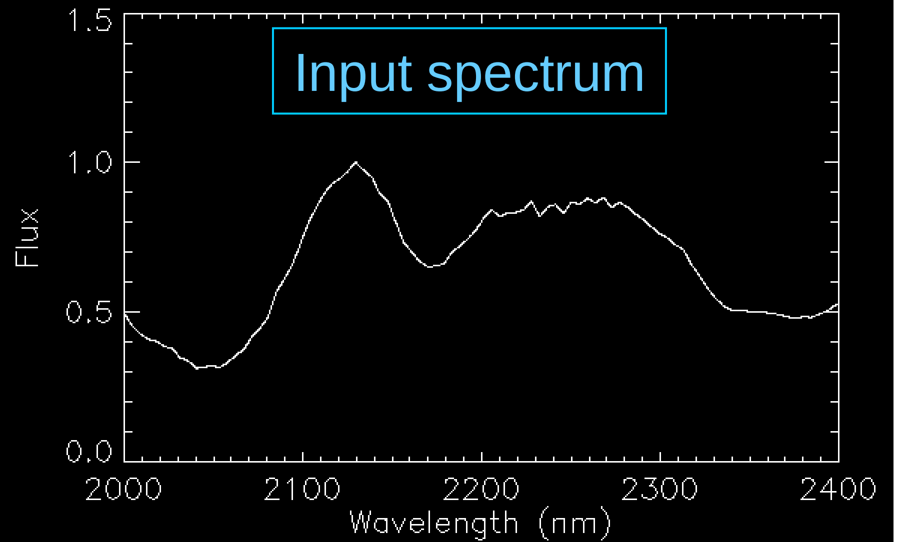


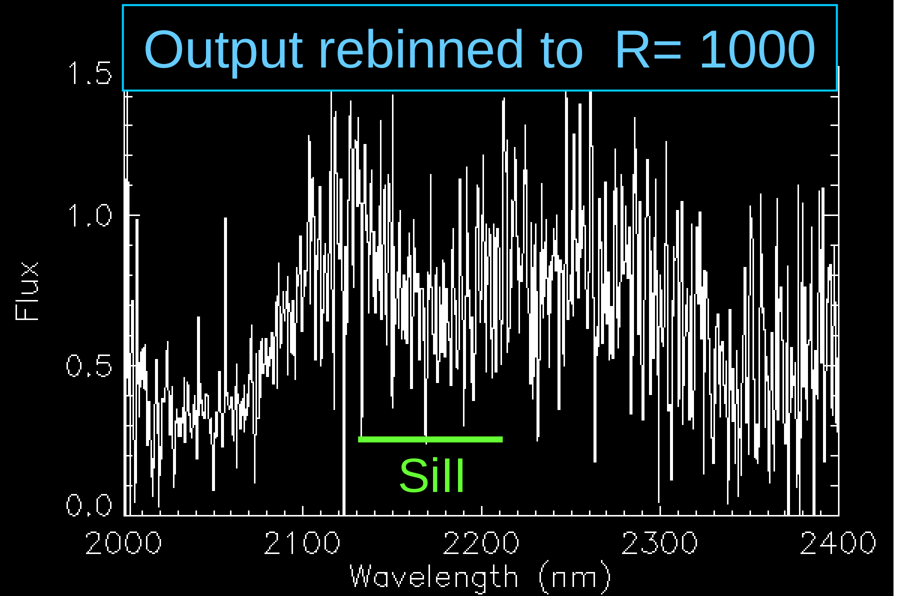
z=0 rotating disk simulations (M. Puech)
42-m, 10-hr integration, MOAO (MCAO)

Type Ia SN spectra

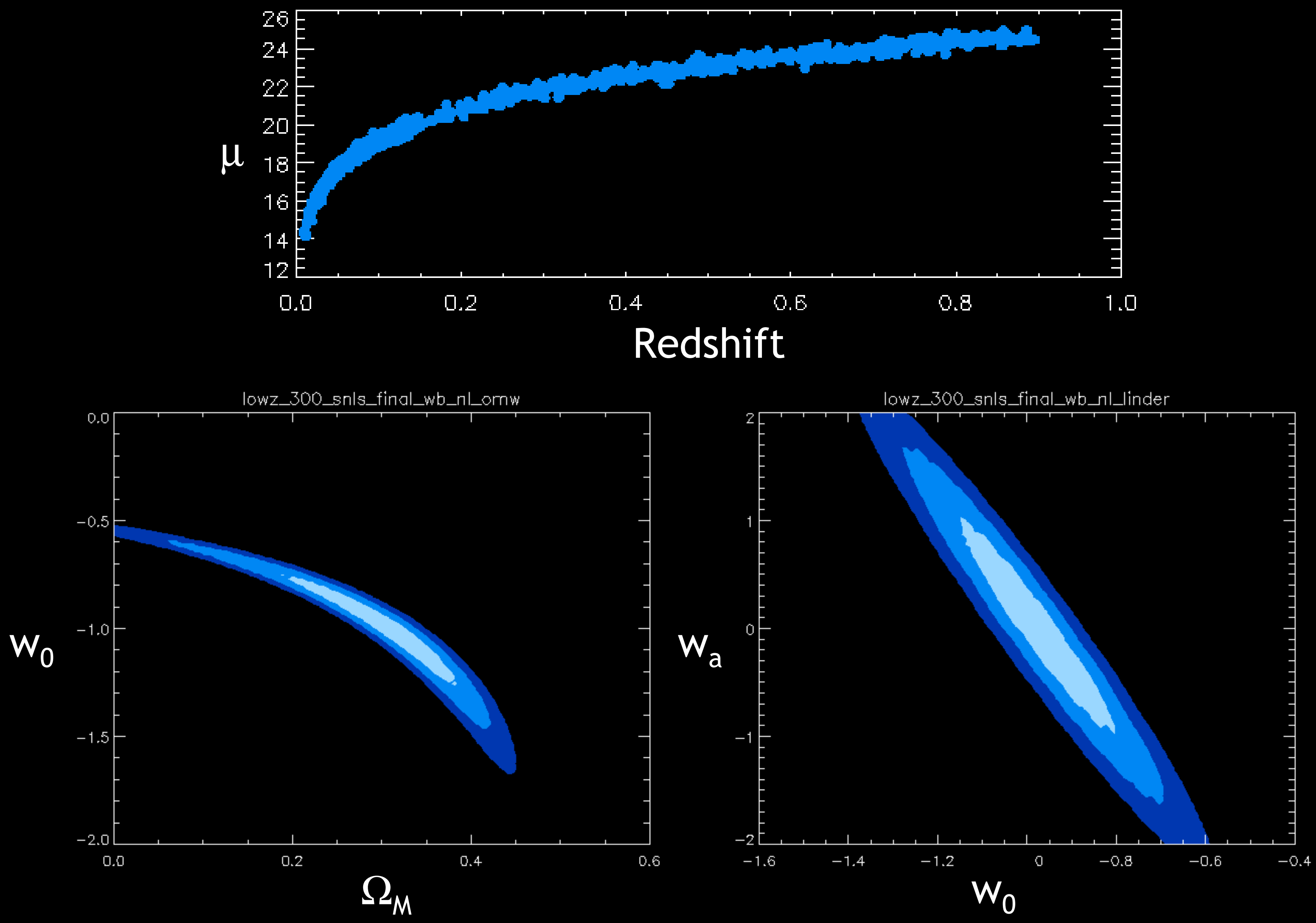
- Goal: measure z and types
- SNe found by JWST (or ELT MCAO imaging ?)
- Assumptions in ETC
  - LTAO
  - 30,000s (8 hrs)
  - K=25 point source (SNIa peak at z=4.4)
  - R=5000
  - Aperture = diff. limit core in K
- 42m ELT can detect SiII feature to z~4

z=4.4 (K=25.0 at peak)

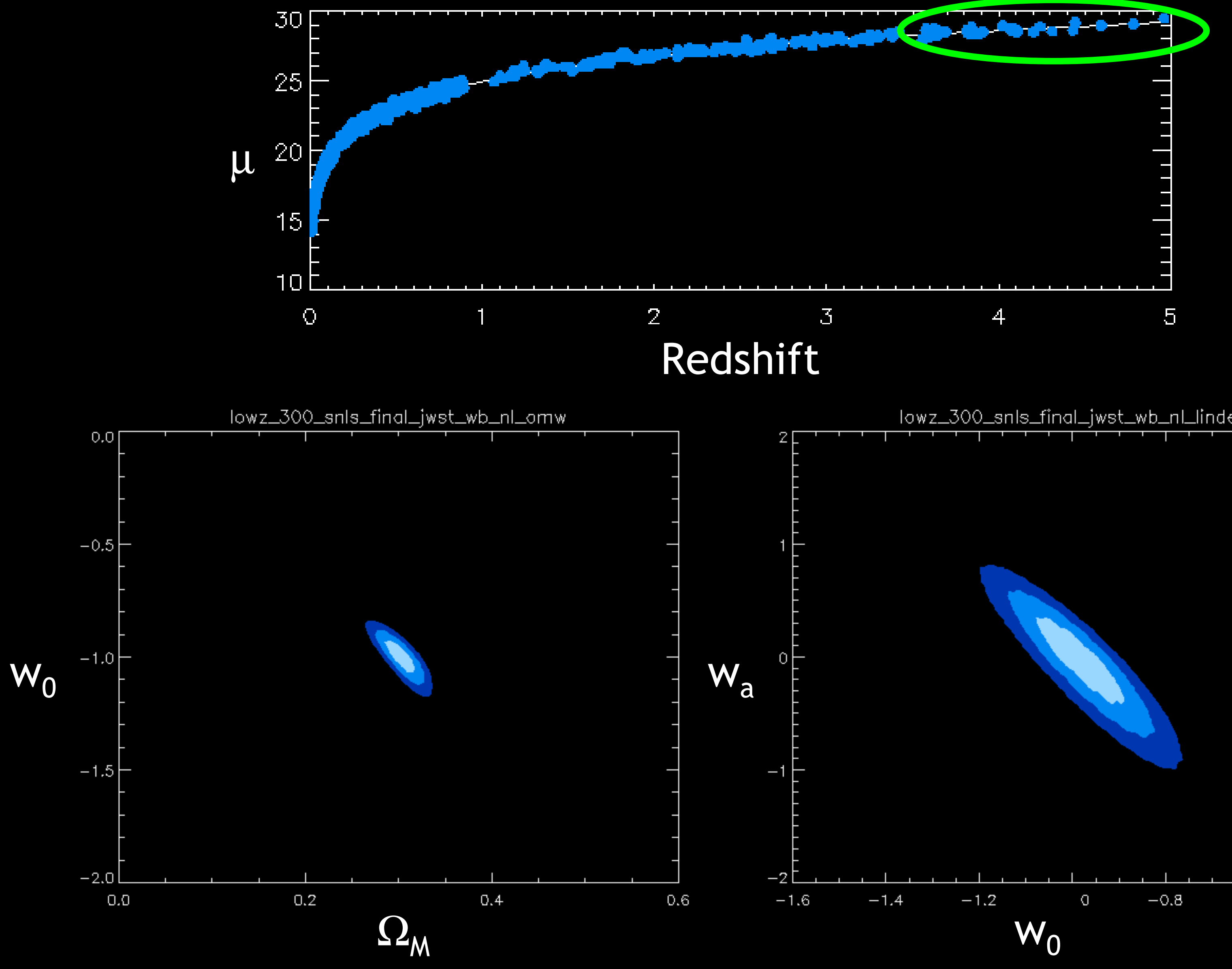




300 Low-z + 500 SNLS



300 Low-z + 500 SNLS + 150 ELT/JWST



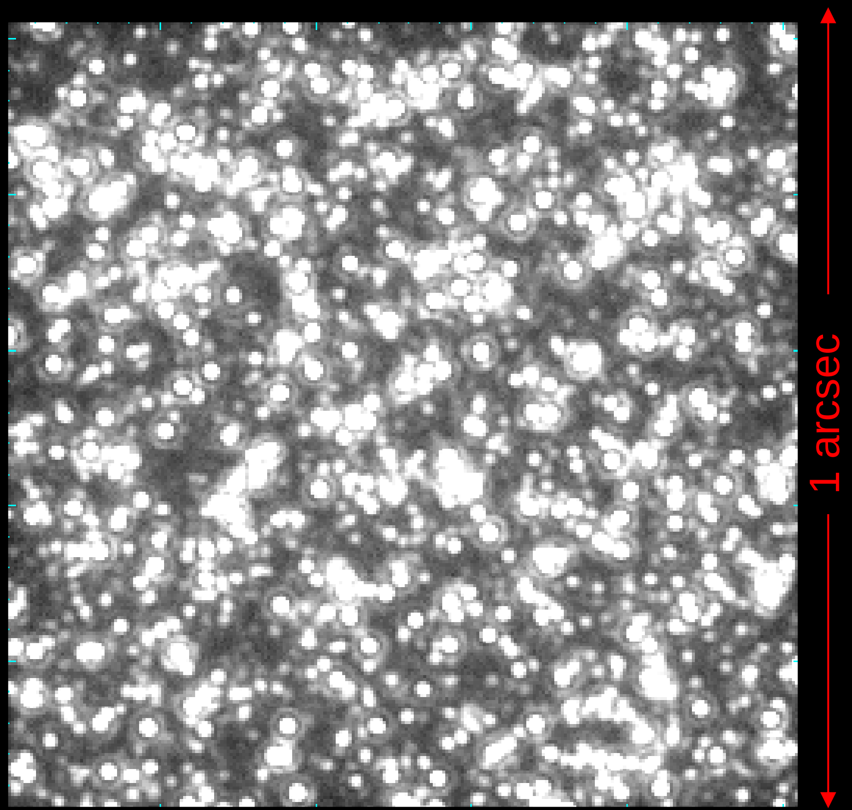
Numbers tail off at very high-z

Factor ~3 improvement in DETF figure of merit

More interesting if something odd happens at high-z!

Resolved Stellar populations - imaging

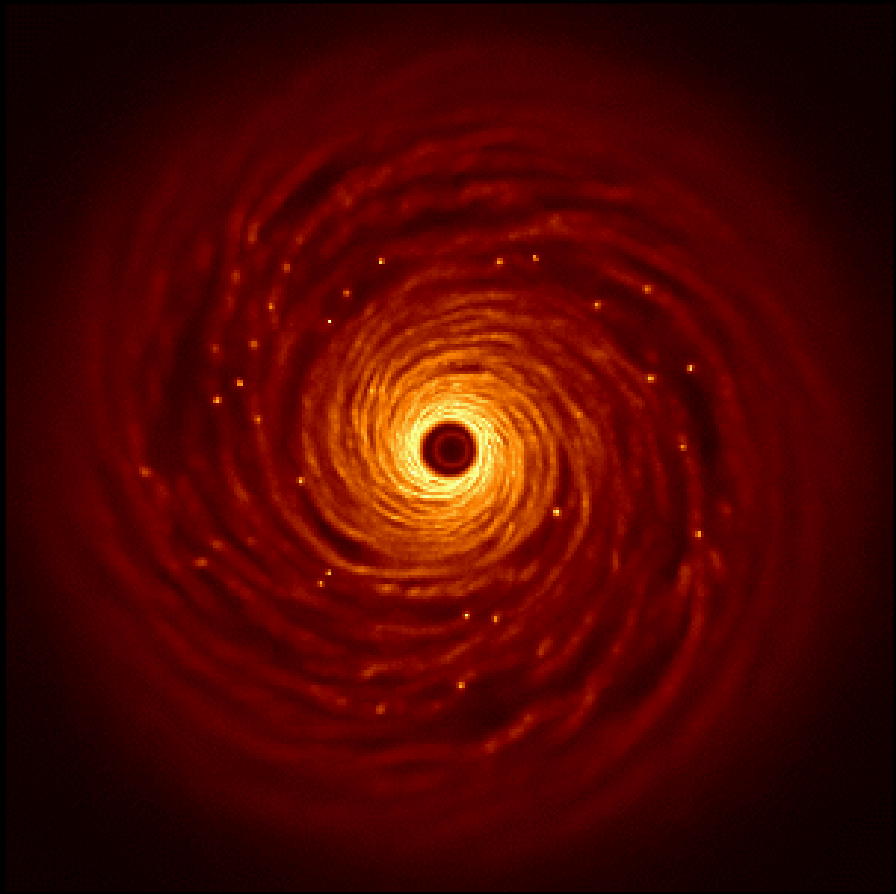
- Measuring age & chemical composition of individual stars > history of a galaxy
- Need a range of galaxy types, ideally reaching Virgo cluster
- Colour-mag diagram (photometry) requires:
  - Large collecting area
  - Resolution (diffraction-limited)
  - Near IR & I –band
  - goal of B and V band



Simulation by J. Liske
10hr K-band; LTAO

Stellar disks

- How does matter accrete onto a forming star?
- How do planets form in the disk?
- imaging
  - Optical/near IR: scattered light
  - Thermal IR: dust emission
  - 40m has resolution of 1AU at 20pc at 10µm = 5 x JWST
- Spectroscopy to probe dynamics and chemical processing
  - Range of R to probe dust, gas & ices (e.g. silicates, molecular gas, organic materials…)



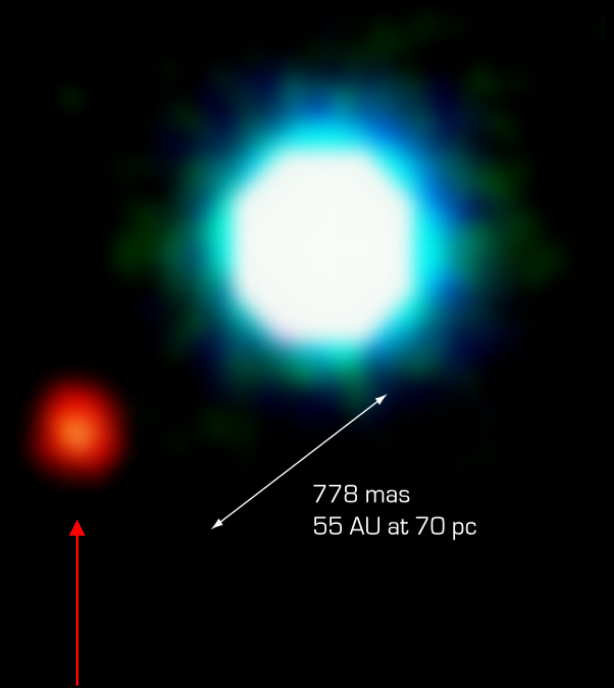
Simulation of the formation of planets via fragmentation of the disk *(Armitage et al)*

AO MODE: LTAO

Wavelength range: near + mid-IR

Exo-planets

- How common are systems like ours?
- How do planetary systems form?
- Direct detection:
  - Mass, orbit, temperature, composition
- Steps towards habitable planets:
  - Very high spatial resolution and contrast required: ~10^9
  - VLT/SPHERE and Gemini Planet Imager ~ 10^8
  - ELT provides higher resolution: planet-finding instrument is being studied

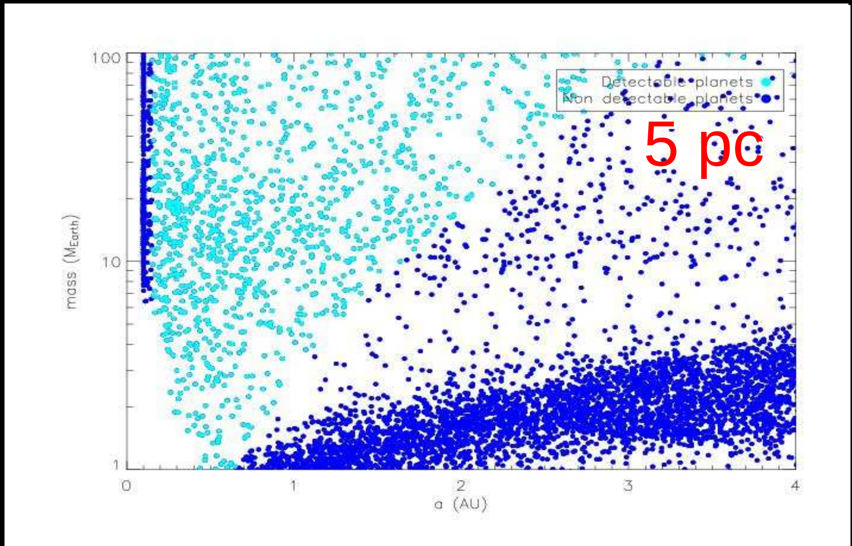


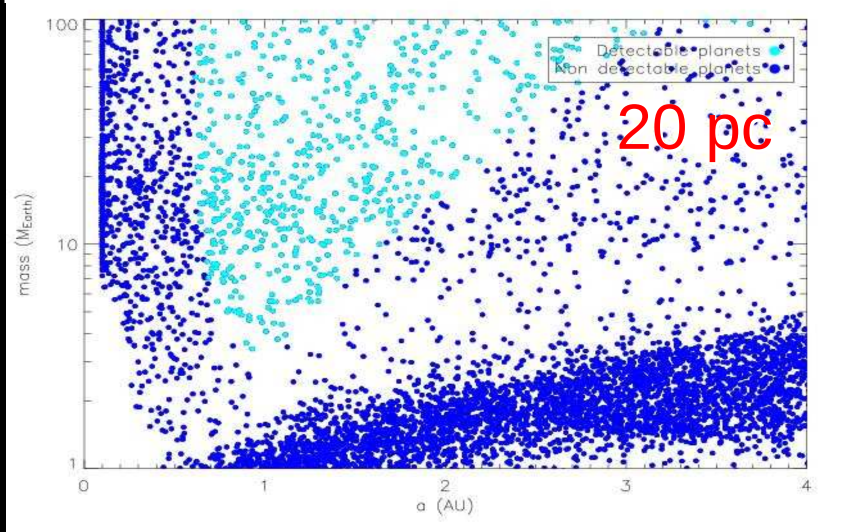
Young Giant ($5M_J$) Exo-planet observed with VLT/NACO (Chauvin et al 2004)

AO MODE: XAO

Wavelength range: 0.6 – 1.8 μm

Detection of Rocky Planets





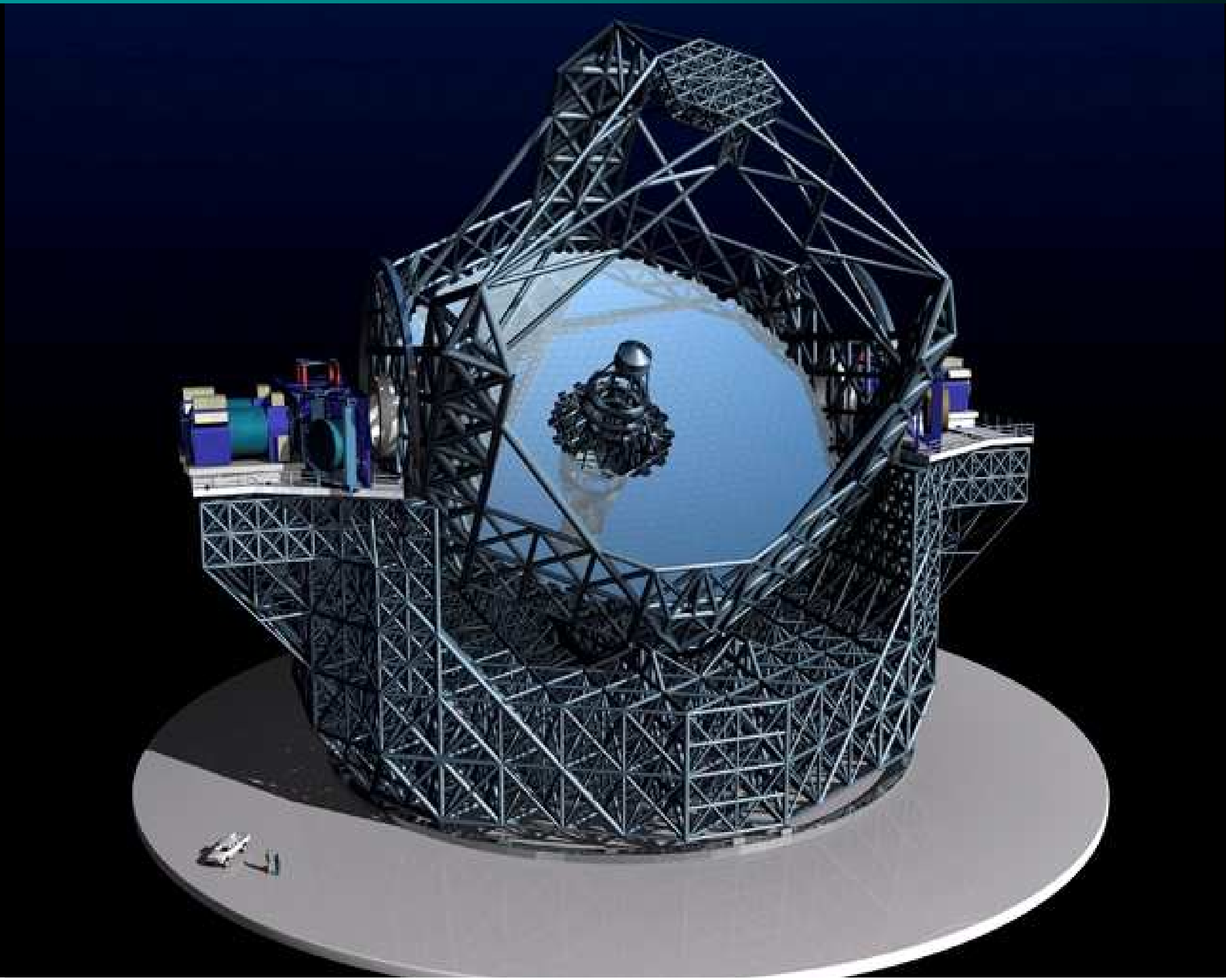
- Simulations by EPICS team
- Photon-limited case (idealised)
  - Theoretical distribution (Benz et al)
  - Detectable with EPICS
- Rocky planets detectable to 5pc (even 10pc)
- But
  - not many suitable stars
  - Systematic effects
  - (study underway)

Exo-planets Direct detection Radial Velocity	 Near-IR optical	 Ex-AO None
Initial mass function in stellar clusters	Near + mid IR	LTAO/ MCAO
Stellar disks imaging spectroscopy	 Near + mid IR Near + mid IR	 LTAO/SCAO LTAO/SCAO
Resolved stellar pops Colour magnitude diagrams Abundances and kinematics Detailed abundances	 Near-IR + I Optical (860nm) Optical	 LTAO LTAO None
Black holes	I + Near- IR	LTAO
Physics of galaxies	Near-IR	GLAO / MOAO
Metalicity of the IGM	Optical	None
Highest redshift galaxies	Near-IR	LTAO/ MCAO/GLAO
Dynamical measurement of the Universal expansion	Optical	None

E-ELT science case – next steps

- DRM development:
  - Finish Demo cases
  - Expand simulations to other cases (already started)
  - Prepare simulations for different site parameters
- 20-21 May 2008: DRM community workshop (EU FP7)
- Sep 2008: JENAM – E-ELT science session
- Q2 2009: Community Call for Proposals + Workshop
- End 2009: Updated Science Case with simulations

The End



The End