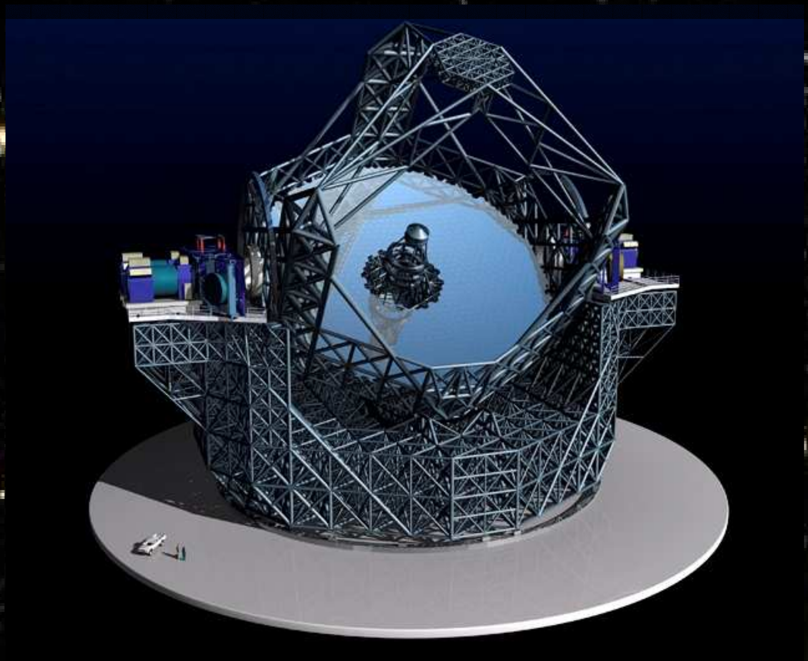
Cosmology with the European Extremely Large Telescope

Isobel Hook (U. Oxford)

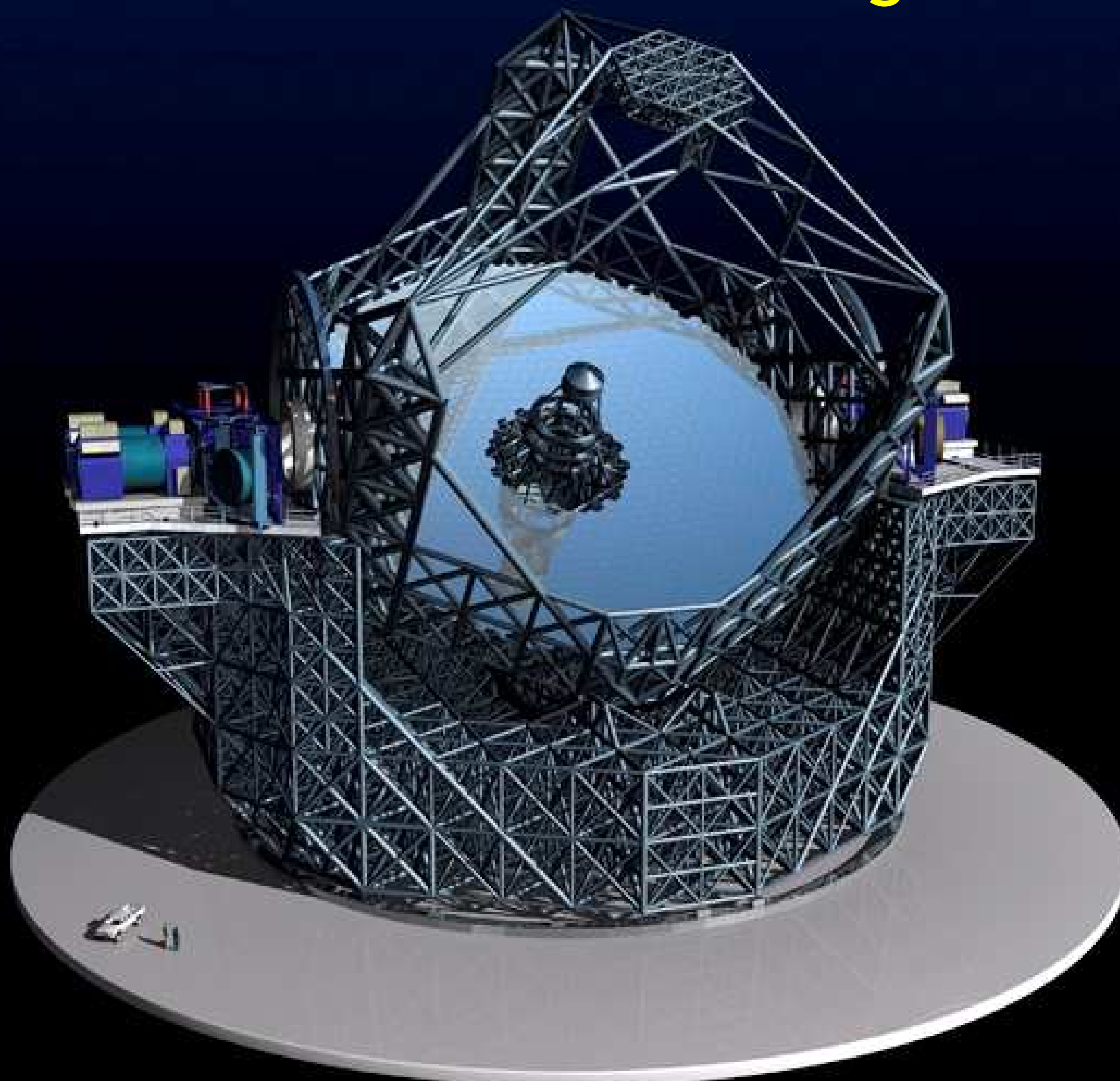


1) Outline of the E-ELT Project
2) Science case overview
3) A few selected cosmology cases

Recent developments towards the E-ELT

- Nov 2005: OWL concept review
- Dec 2005: New E-ELT WGs formed (community + ESO)
  - Science, AO, Telescope design, Instrumentation and Site
  - Reports in April 2006
- Nov 2006: E-ELT Marseilles Conference
  - Baseline 42m E-ELT concept presented to community
- Dec 2006: E-ELT Phase B approval by ESO council
  - Detailed design phase runs until end 2009

Basic Reference Design



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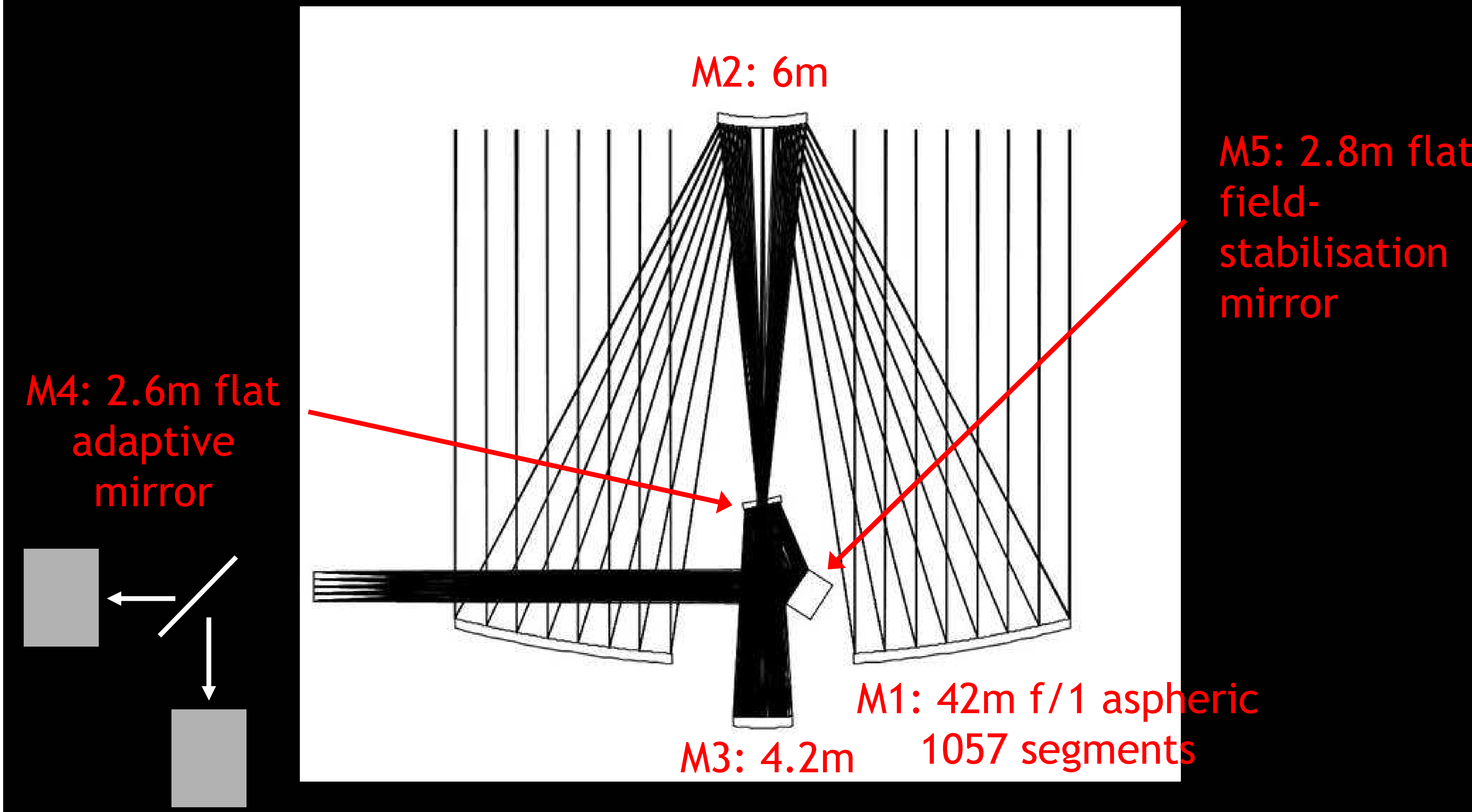


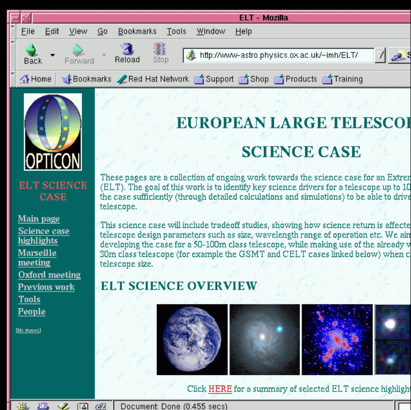
Scientific gains of an ELT

- Increased collecting area
  - Fainter sources: brings new populations within reach
- Increased diameter
  - Increased spatial resolution (with AO)

- Filled aperture ELT combines these advantages

ELT science case development in Europe

Florence 2004



Web site

Marseilles 2003

Science case documents

Marseilles 2006

E-ELT Science Working Group

Marijn Franx (co-Chair)
Isobel Hook (co-Chair)
Bruno Leibundgut
Mark McCaughrean
Eline Tolstoy
Andrea Cimatti
Hans-Uli Kaeufl
Rafael Rebolo
Didier Queloz

Stephane Udry
Fernando Comeron
Jacqueline Bergeron
Wolfram Freudling
Markus Kissler-Patig
Hans Zinnecker
Arne Ardeberg
Piero Rosati
Martin Haehnelt
Raffaele Gratton

With thanks to previous members

Peter Shaver
Bob Fosbury
Willy Benz
Magda Arnaboldi

Dec 2005: ESO SWG formed
Science case re-evaluated for 30-60m (April 2006)
ESO SWG merged with OPTICON activity

Exo-Planets

Mass, orbits, frequency

Direct detection (spatial resolution, Ex-AO)

Radial velocity detection (to Earth Mass)

Proto-planetary Disks: Formation mechanism

near-IR imaging of reflected light

Mid-IR imaging/spectroscopy of dust

Galaxy Formation

Physics of galaxy formation

Relation to mass assembly, feedback

Multi-IFU observations: resolved kinematics,

SFR, mass $1 < z < 6$

Resolved stellar populations:

merger history, detailed kinematics

Highest redshift galaxies

Reionisation

Metal enrichment in the IGM

Fundamental Physics and Cosmology

What is the Dark Energy?

Type Ia SNe spectroscopy to z~4

Direct measurement of expansion via QSO abs lines 1.5 < z < 4

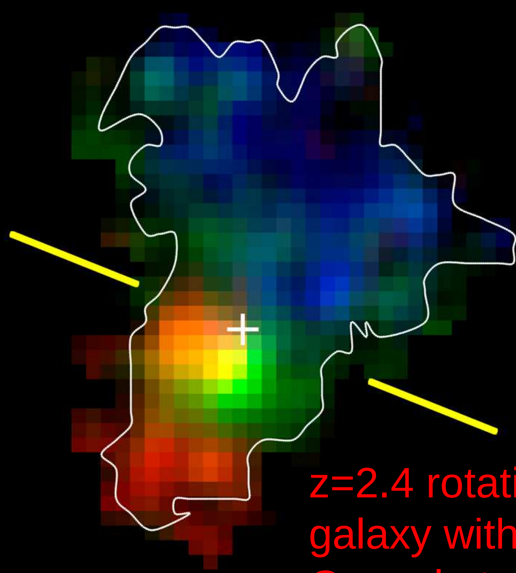
"CODEX", R~150,000, ultra-high stability

Variation of fundamental parameters

Physics in extreme conditions (Black holes)

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)
- Relate this to build-up of dark matter in galaxy haloes
- Large sample requires multiple – IFU instrument, fed by AO

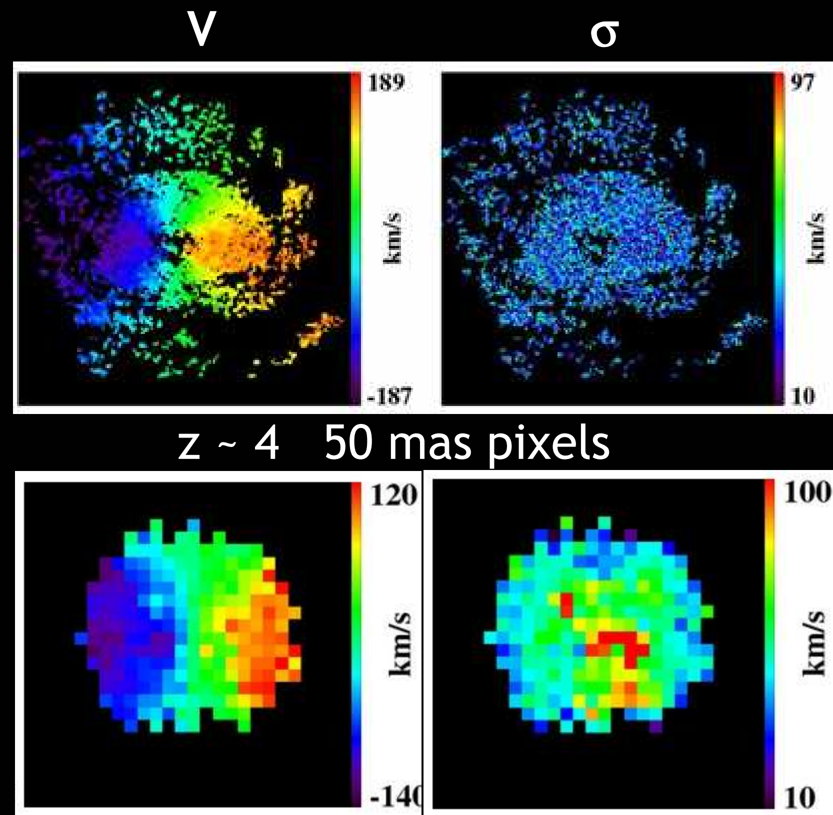


z=2.4 rotating disk galaxy with SINFONI Genzel et al 2006

DRM Demo Case 3:

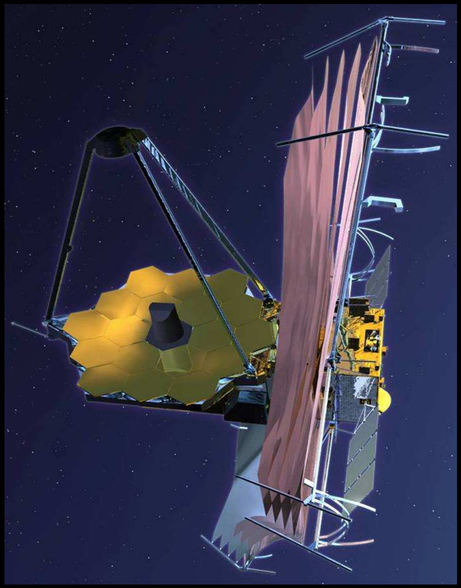
The physics and mass assembly of galaxies out to z~6

- Goal: Kinematics of ~10^3 massive 2<z<6 galaxies
- Simulations (M. Puech/ESO)
  - from high-z galaxy modelling
  - Merger vs rotating disk
- Provisional conclusions
  - Reliable kinematic studies of super-L* galaxies to z~6
  - down to 0.1M* at z~2.

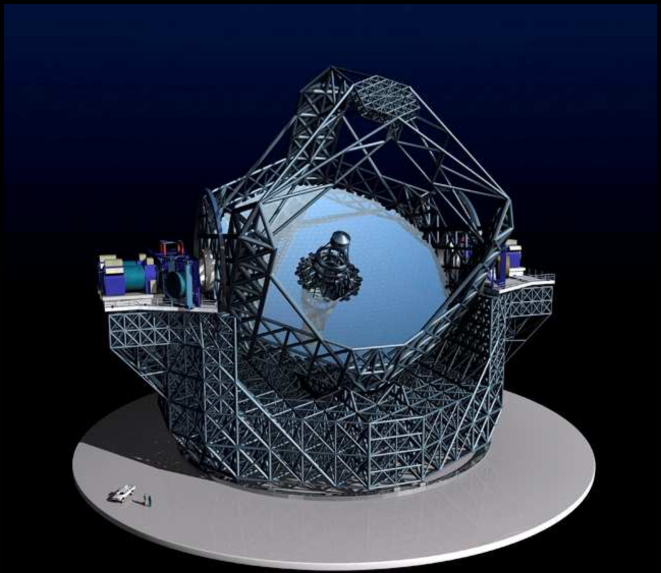


z=0 rotating disk simulations (M. Puech)
42-m, 10-hr integration, MOAO (MCAO)

High-z SNeIa with the E-ELT
(IMH + W. Taylor)



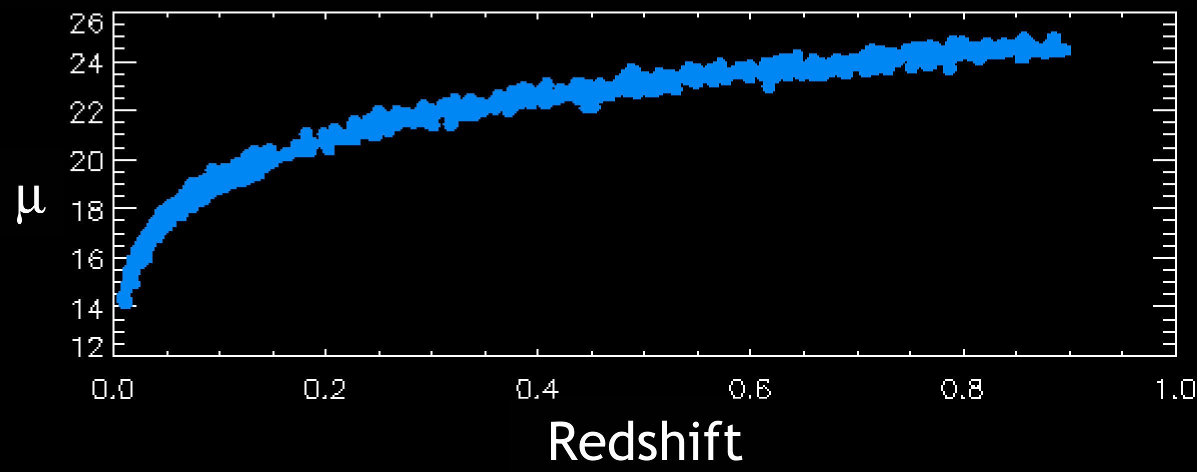
- 42m ELT can do spectroscopy to z~4 (assuming AO and OH suppression)
  - Based on E-ELT Exposure time calculator
- JWST imaging to find the SNe
  - 10,000s 10σ limit reaches z~4 in K, 2 mags down the light curve
  - Continuous monitoring of 10 NIRCam fields for 5 years gives ~ 150 SNe.
- Using rates from Sullivan et al (2006) extrapolated to z~5

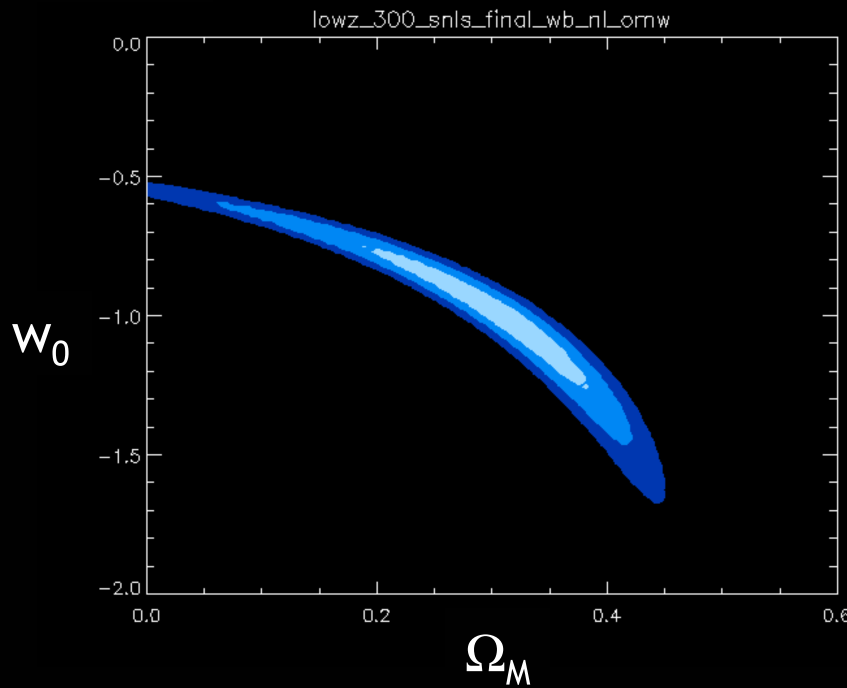


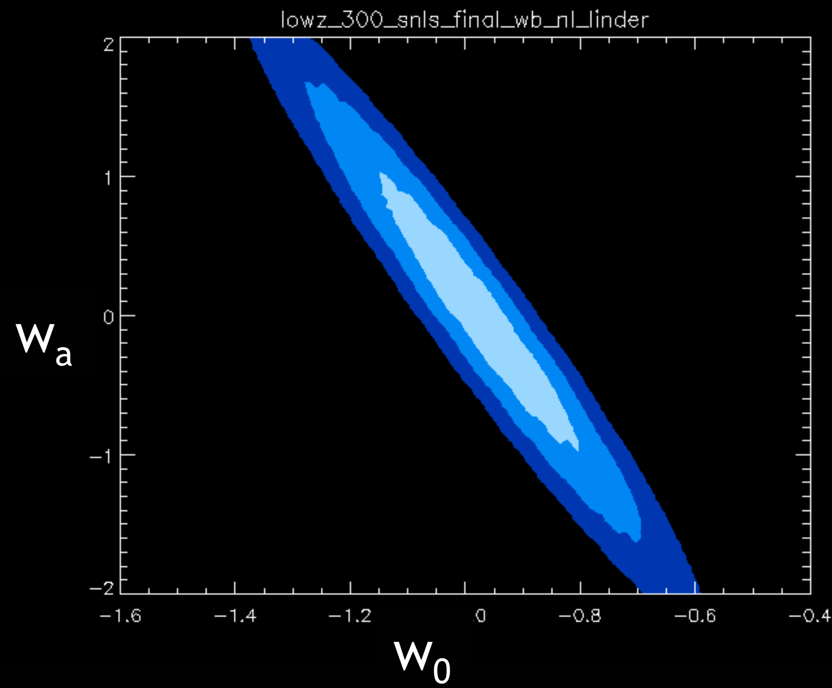
Fake SN samples

- Generated using SNOC (Goobar et al 2002, A&A)
- Assumed cosmology: Ω_M=0.3, Ω_Λ=0.7, w_0=-1, w_a=0
  - i.e. Dark-energy dominated, flat cosmology with non-varying w
  - Fit for Ω_M, Ω_Λ, w_0, w_a
- No systematic effects included (yet)
- Created 3 samples:
  - 300 low-z (e.g. SN factory)
  - 500 $0.2 < z < 0.9$ (e.g. SNLS, ESSENCE)
  - ~50 JWST / ELT $1 < z < 4$

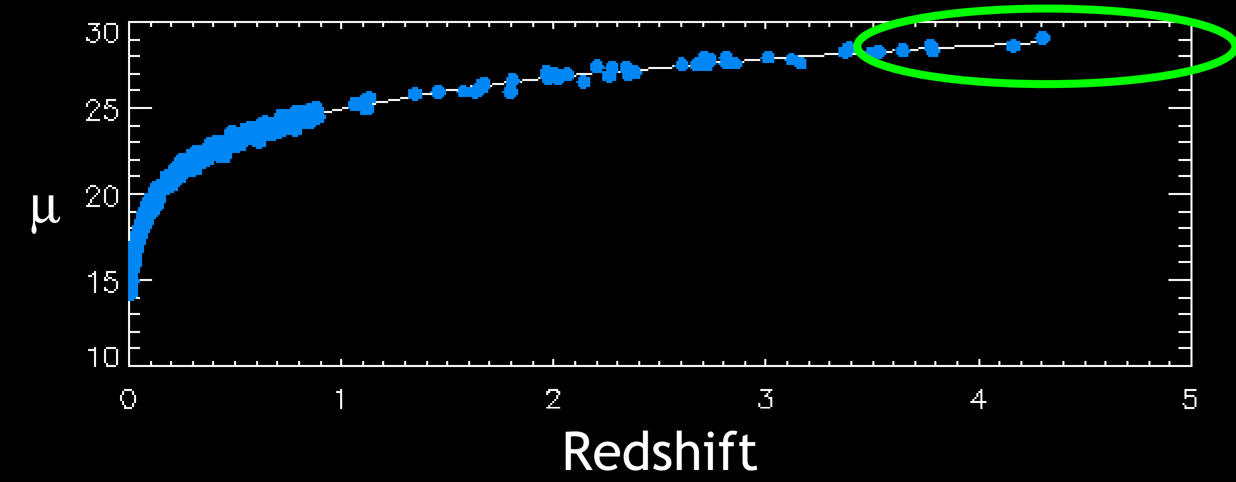
300 Low-z + 500 SNLS



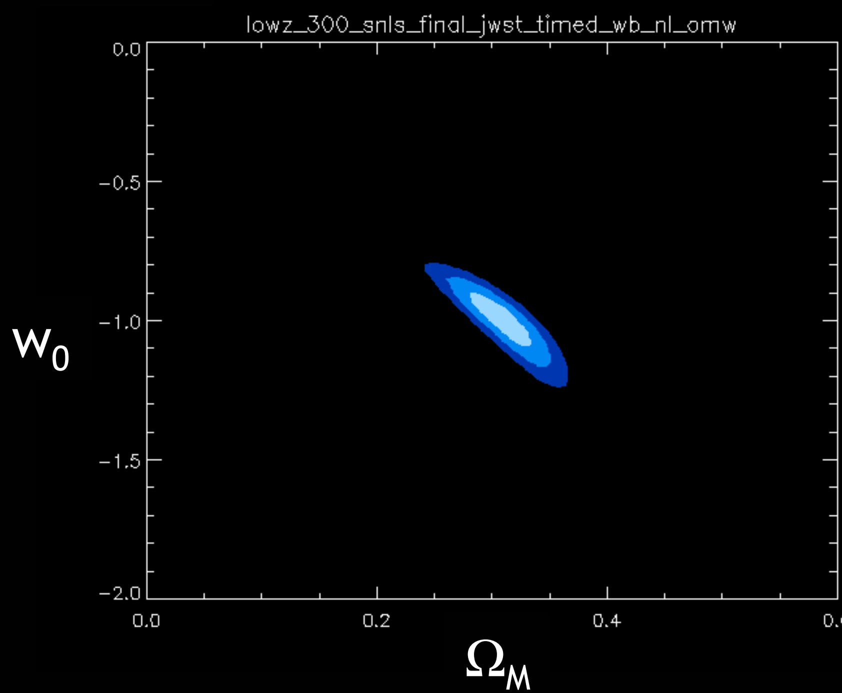


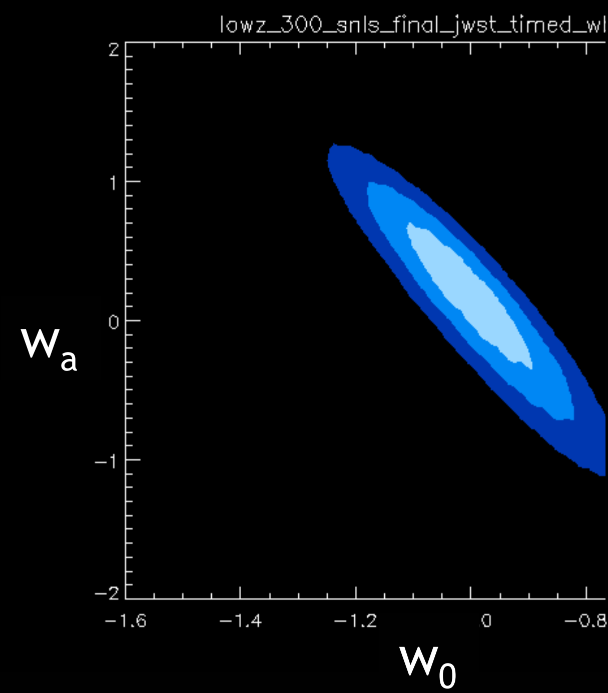


300 Low-z + 500 SNLS + 50 ELT/JWST



Numbers tail off at very high-z



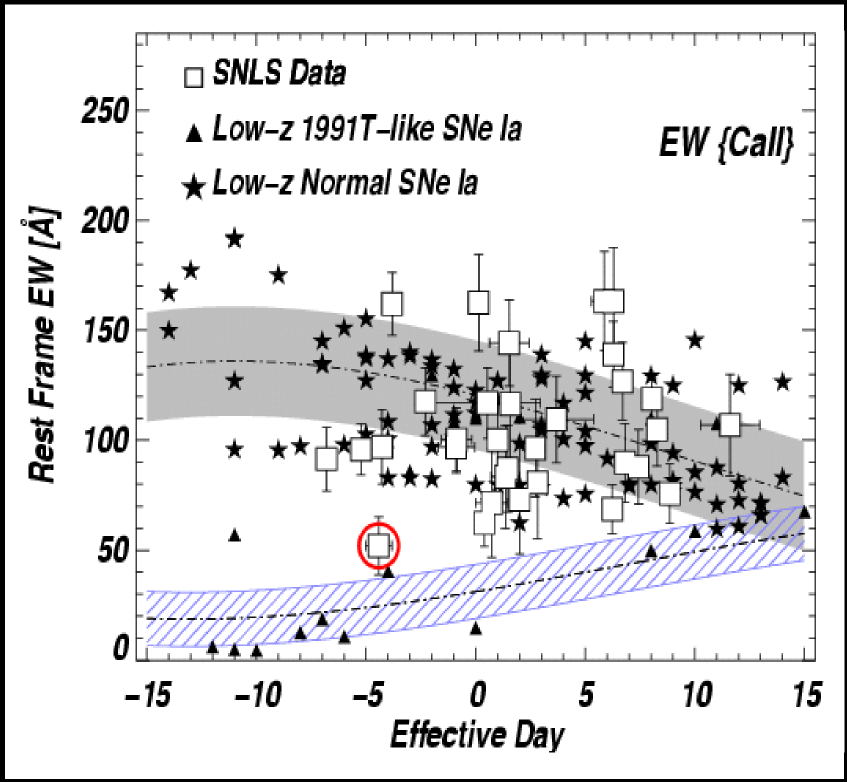


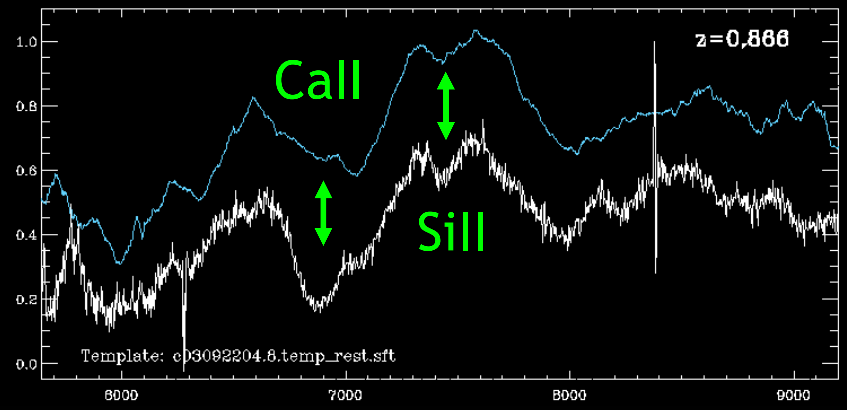
Factor ~2 improvement in DETF figure of merit

More interesting if something odd happens at high-z!

Quantitative SNIa Spectroscopy

SNLS Gemini data: (Bronder et al 2007)





- Similar trends of spectral features at high & low-z
- The two populations are consistent
  - Possible exception of one feature

- Quantitative measurements of features (EWs and velocities)
- Test for evolution with z
- Measure weak SiII feature – luminosity indicator? (Bronder et al 2007)
- ELT can do this to z ~ 4

Cosmic Dynamics Experiment

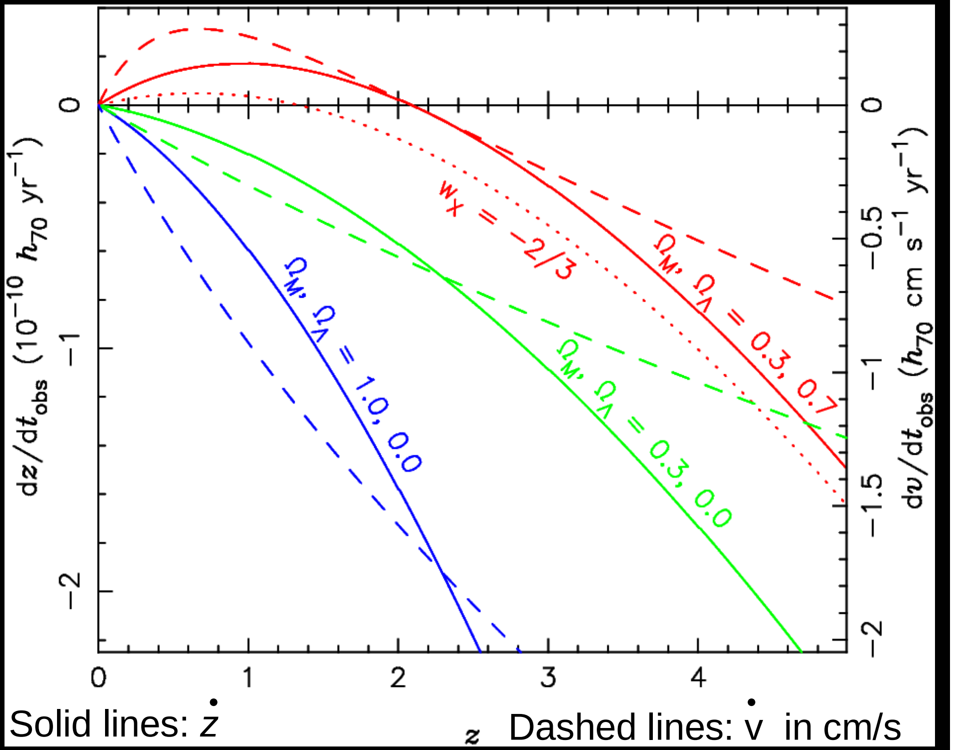
J. Liske and the CODEX team

De- or acceleration of the universal expansion rate causes a small change in observed redshifts as a function of time:

$$\dot{z} = (1+z)H_0 - H(z)$$

Measuring $\dot{z}(z)$:

- Allows us to watch, in real-time, the Universe changing its expansion rate.
- Most direct and model-independent route to the expansion history and acceleration.
- Non-geometric measurement of the global RW metric.
- Independent confirmation and quantification of accelerated expansion.

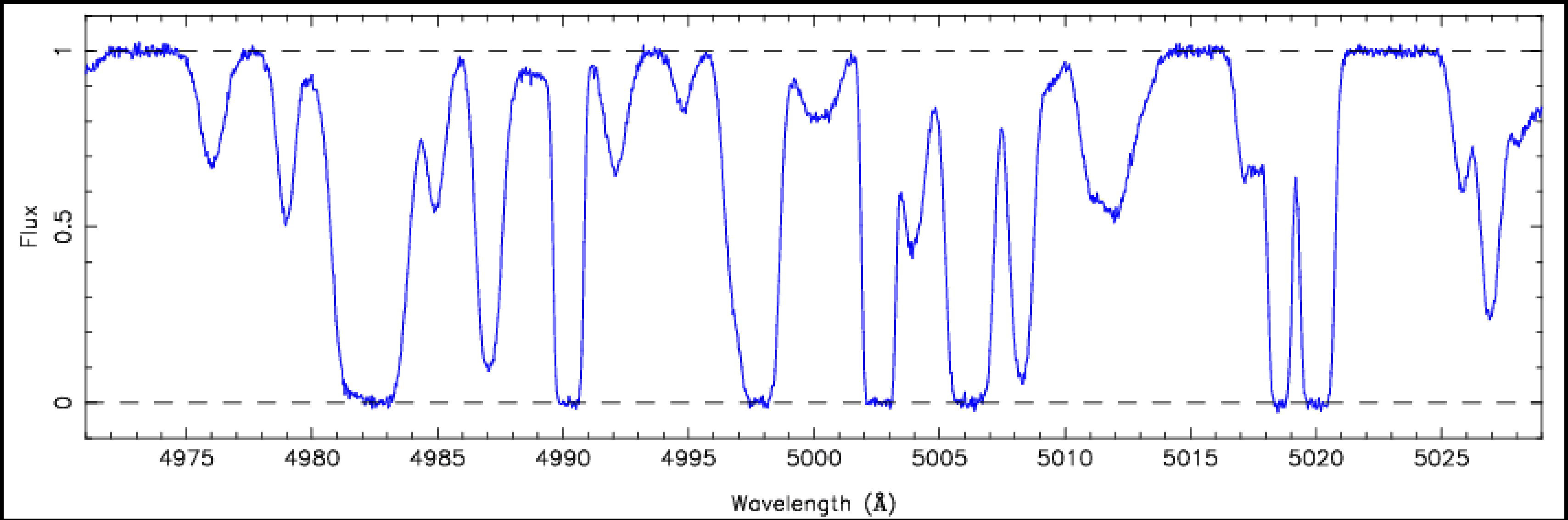


Cosmic Dynamics Experiment

Measuring the redshift drift requires:

- E-ELT
- High resolution, extremely stable spectrograph
- ~20 yr long spectroscopic monitoring campaign

Best place to observe the redshift drift: the Lyman-α forest.



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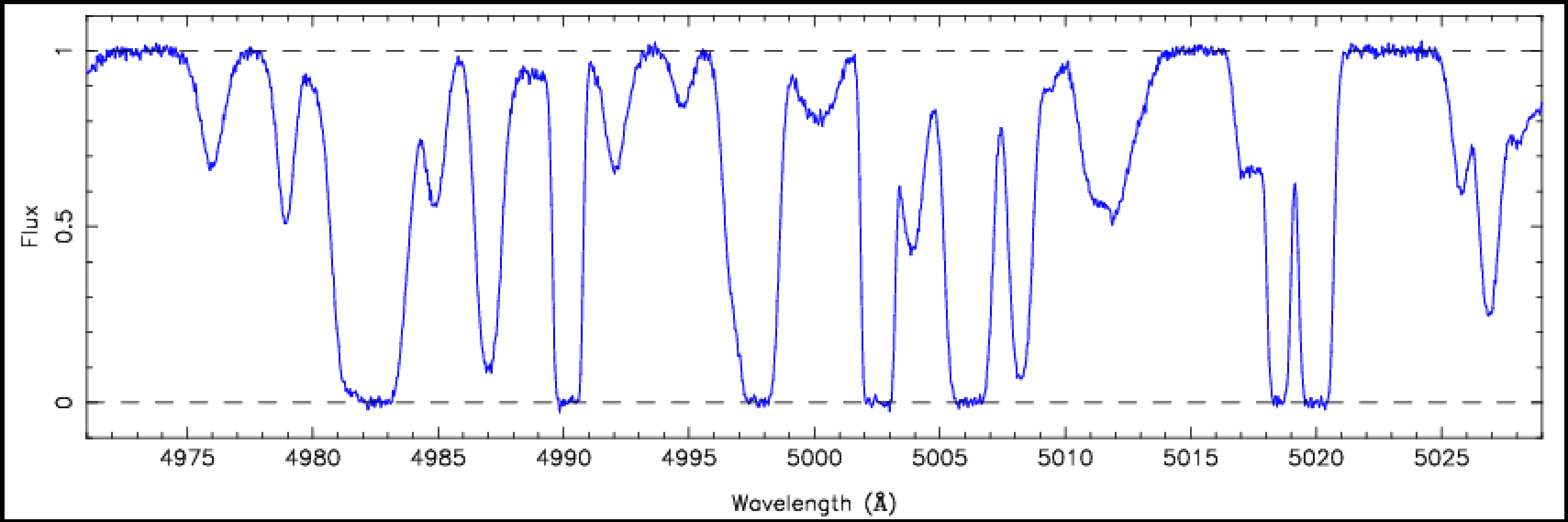

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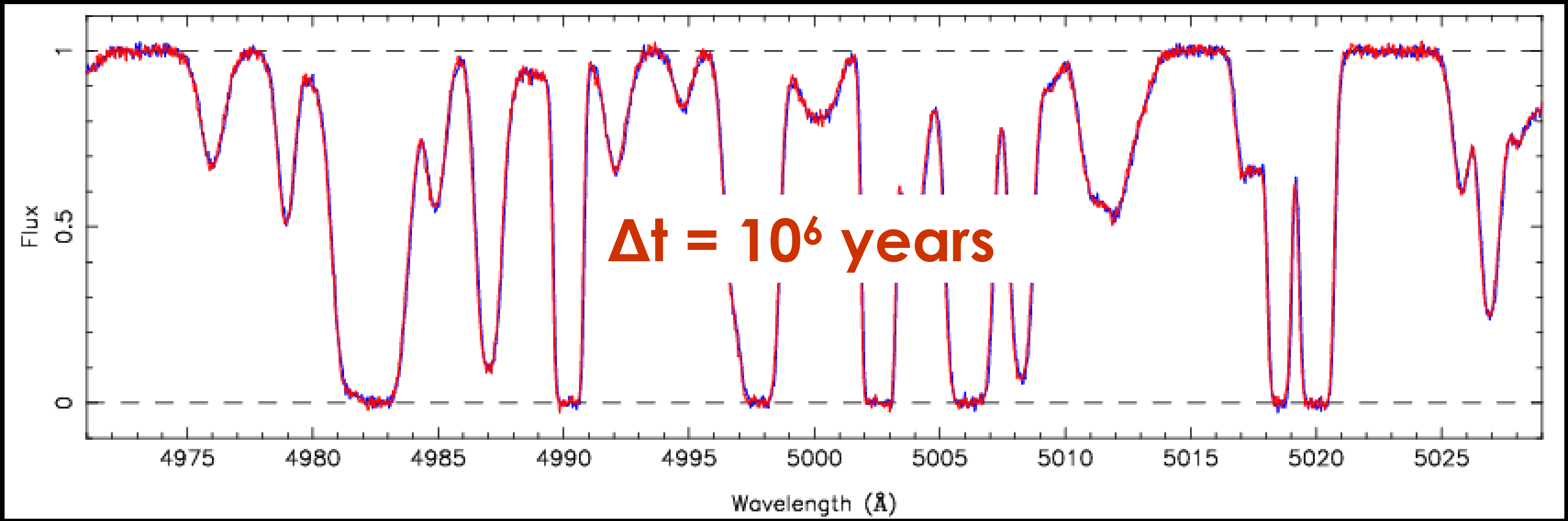
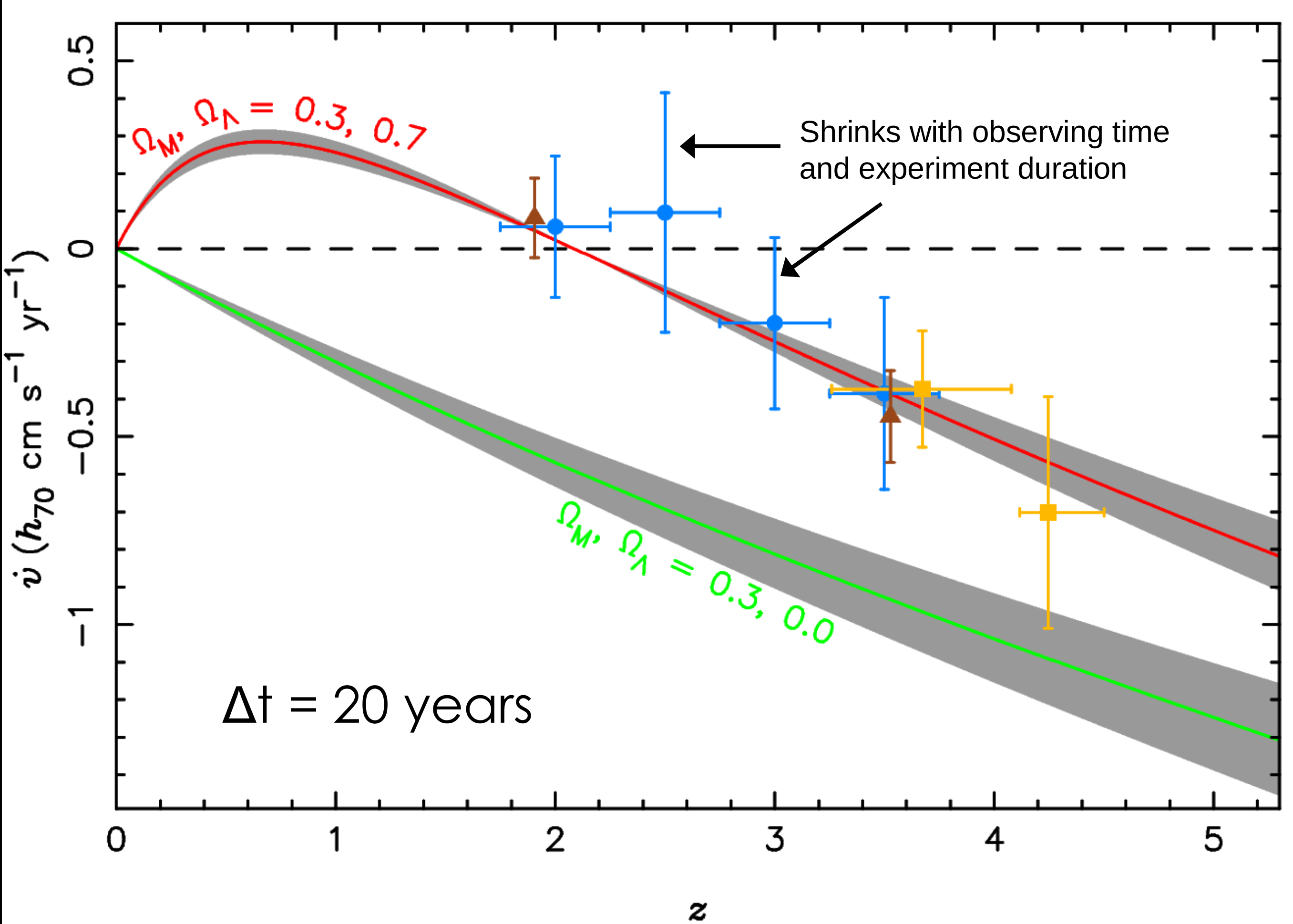


Cosmic Dynamics Experiment

Simulations:

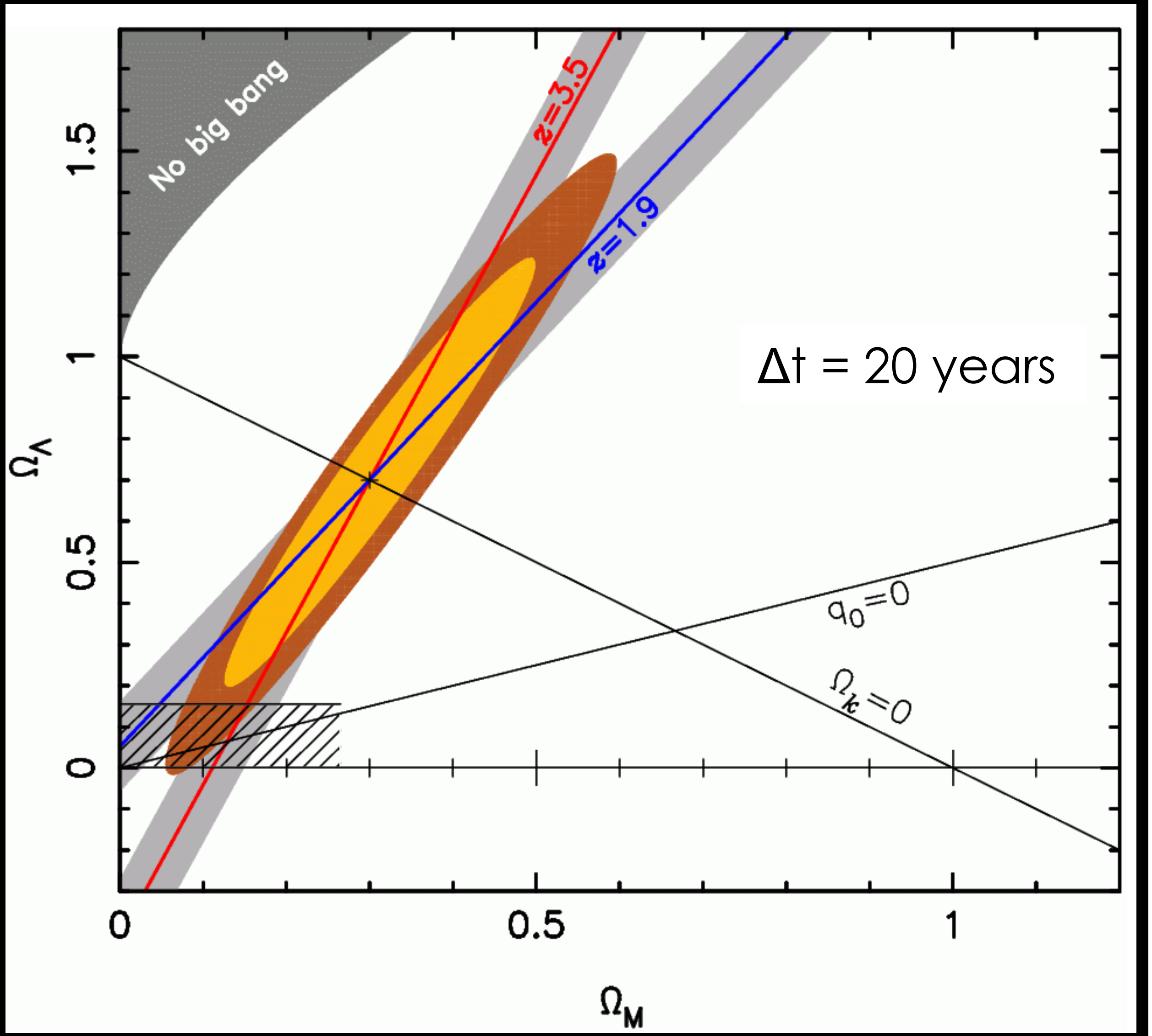
4000 hours over 20 years will deliver any *one* of these sets of points.

Different sets correspond to different target selection strategies.



Cosmic Dynamics Experiment

- 4000 hours over 20 years will unequivocally prove the existence of dark energy without assuming flatness, using any other cosmological constraints or making any other astrophysical assumption.
- Provides independent confirmation of SNIa results, using a different method and complementary redshift range.
- Data will enable lots of other science (e.g. varying α), enormous legacy value.



Conclusions

- European ELT is in detailed design phase
- Multi-purpose telescope with very broad science case
- Selected applications to cosmology presented- Not exhaustive!
  - Varying α, primary distance indicators at large distances, surface brightness fluctuations, IGM enrichment, reionisation…
- www.eso.org/projects/e-elt

The End