Top 10 Discoveries by ESO Telescopes

- European Southern Observatory – reaching new heights in astronomy
- Exploring the Universe from the Atacama Desert, in Chile since 1964
- ESO is the most productive astronomical observatory in the world
La Silla Observatory: ESO’s first observatory

• Two of the most productive 4-metre class telescopes in the world
  – ESO 3.6-metre telescope, since 1976
  – The New Technology Telescope (NTT, 3.58 m), since 1989
• 300 refereed publications per year
ESO’s top 10 discoveries

1. Stars orbiting the Milky Way black hole
2. Accelerating Universe
3. First image of an exoplanet
4. Gamma-ray bursts — the connections with supernovae and merging neutron stars
5. Cosmic temperature independently measured
6. Oldest star known in the Milky Way
7. Flares from the supermassive black hole at the centre of the Milky Way
8. Direct measurements of the spectra of exoplanets and their atmospheres
9. Richest planetary system
10. Milky Way stellar motions

1. Stars orbiting the Milky Way black hole
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- The discovery: unprecedented 16-year long study tracks stars orbiting the Milky Way black hole
- When: a 16-year long campaign started in 1992, with 50 nights of observations in total
- Instruments / telescopes:
  - SHARP / NTT, La Silla Observatory
  - NACO / Yepun (UT4), VLT
- More info in press releases eso0226 and eso0846:
1. Stars orbiting the Milky Way black hole

- The observations:
  - The highest resolution images available of the Galactic Centre
  - S2, the closest observable star to Sgr A*, is rapidly and closely orbiting the Galactic Centre (approaching within 17 light-hours)

- The conclusion: the centre of the Milky Way harbours a supermassive black hole, four million solar masses
1. Stars orbiting the Milky Way black hole

- In context:
  - X-ray emissions had previously suggested the existence of a supermassive black hole in the centre of the Milky Way
  - Quasars may be powered by supermassive black holes
- The implication: there may be supermassive black holes in the centre of many other galaxies
2. Accelerating Universe
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- The discovery: distant supernovae indicate ever-expanding Universe
- Telescopes: ESO 3.6-metre and NTT, La Silla
- Two separate teams of astronomers
2. Accelerating Universe

- The observations: distances to Type Ia supernovae are larger than expected
- The conclusion: the expansion of the Universe is accelerating
- Previous scenario: the Universe would either collapse in a “Big Crunch” or expand forever, but in both cases its expansion was thought to be decelerating
- The implications:
  - Age of the Universe ~ 14 billion years
  - Confirmation of inflation (very rapid expansion in the early stages of the Universe)
  - Dark energy: the additional mysterious repulsive force needed to explain the acceleration
2. Accelerating Universe

• Type Ia supernovae: the best distance indicators
  – They have very uniform properties and intrinsic brightness
  – They are bright enough to be detected at large distances
3. First image of an exoplanet
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- The discovery: the VLT captures the first image of a planet outside our Solar System
- The star 2M1207 is 230 light-years away, in the constellation of Hydra
- When: first detection in April 2004; confirmation in April 2005
- Instrument / telescope: NACO / Yepun (UT4), VLT
  - NACO works with adaptive optics
- The observations:
  - The object 2M1207b was imaged for the first time by the VLT in 2004
  - Its planetary identity and characteristics were confirmed after one year of observations in 2005
3. First image of an exoplanet

- The conclusions:
  - 2M1207b is a Jupiter-like planet, five times more massive than Jupiter
  - It orbits the brown dwarf 2M1207A at a distance 55 times greater than the distance between the Earth and the Sun
  - Its spectrum shows a strong signature of water molecules
3. First image of an exoplanet

- In context:
  - The first exoplanet discovered around a MS star: 51 Pegasi, in 1995
  - By 2004: about 120 exoplanets discovered
  - By 2011: more than 500 discovered (only about ten directly imaged)
4. Gamma-ray bursts — the connections with supernovae and merging neutron stars
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• The discoveries: long gamma-ray bursts (GRBs) are linked with the final explosion of massive stars, while short GRBs originate from the violent collision of two merging neutron stars

• When: a long GRB detected on 29 March 2003 and observed for one month; two short GRBs detected on 9 May and 9 July 2005

• Instruments / telescopes:
  - For long GRB: UVES, FORS1, FORS2 / Kueyen, Antu (UT1, UT2), VLT
  - For short GRBs: Danish 1.54-metre Telescope, La Silla; FORS1, FORS2 / Antu, Kueyen (UT1, UT2), VLT

• More info in press releases eso0318 and eso0533:
4. Gamma-ray bursts — the connections with supernovae and merging neutron stars

• The observations:
  – Long GRB
    • Detailed spectrum and images of GRB 030329 optical afterglow
    • GRB 030329 distance = 2650 million light-years
  – Short GRB
    • Optical afterglow from elusive short GRB is observed
    • GRB 050509B distance = 2700 million light-years
    • GRB 050509B duration = 40 milliseconds
    • No trace of SN explosion during the three weeks after the burst

• The conclusions:
  – The long GRB is produced by a hypernova, the explosion of a very massive star (> 25 times heavier than the Sun)
  – The short GRBs occurred in a non-star-forming elliptical galaxy, of the kind where:
    • The hypernova scenario is unlikely to occur
    • Many binary systems of compact stars are expected, as possible progenitors
4. Gamma-ray bursts — the connections with supernovae and merging neutron stars

• In context:
  – GRBs have been detected since the 1960s
  – GRB 030329 was a rare “type-defining” event that will be recorded as a watershed in high-energy astrophysics
  – Before 2005, the optical afterglow had been observed only for long GRBs (from a few seconds up to a few minutes).
5. Cosmic temperature independently measured
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- The discovery: first accurate measurement of the temperature of the cosmic background at an early epoch
- Instrument / telescope: UVES / Kueyen (UT2), VLT
- Pioneer study of interstellar chemistry at high redshift
5. Cosmic temperature independently measured

- The observations:
  - Carbon monoxide molecules detected in a galaxy ~11 billion light-years away
  - The only way this galaxy can be seen is through the imprint its interstellar gas leaves on the spectrum of an even more remote quasar, used as beacon

- The conclusion:
  - Temperature = 9.15 ± 0.7 K
  - The most precise measurement of cosmic background temperature, in excellent agreement with the theory
  - The physical conditions of the interstellar gas in this remote galaxy are similar to those seen in our Milky Way

- The implications: detailed study of the chemistry of the interstellar medium is an important tool for:
  - Understanding how galaxies form
  - Giving an independent measurement of the cosmic background temperature
6. Oldest star known in the Milky Way
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- The discovery: the age of the oldest star known in our Milky Way is measured
- Instrument / telescope: UVES / Kueyen (UT2), VLT
6. Oldest star known in the Milky Way

• The observations:
  – First-ever measurement of the beryllium content in two stars in the globular cluster NGC 6397
  – The time interval between the formation of the first generation of stars and the age of a known cluster was calculated from beryllium abundances

• The conclusion:
  – The first stars in the Milky Way formed during the 200 million years after the Big Bang
  – Data match with the age of the Universe calculated by cosmology

• The implication: the “beryllium clock” can provide us with unique and crucial information about the duration of the early stages of the Milky Way
7. Flares from the supermassive black hole at the centre of the Milky Way
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- The discovery: the first simultaneous detection in IR and submillimetre wavelengths of the flares from the supermassive black hole at the centre of the Milky Way
- Instruments / Telescopes:
  - NACO / Yepun (UT4), VLT
  - LABOCA / APEX
7. Flares from the supermassive black hole at the centre of the Milky Way

- The observations:
  - Variable IR emission with four major flares detected by the VLT in Sagittarius A* over a period of six hours
  - Sub-millimetre flares detected half an hour later than the IR ones
- The conclusions: a blob of gas orbiting close to the black hole is stretched out by gravity and expands, producing flares at different wavelengths
- In contest: IR flares from the Milky Way’s supermassive black hole first observed by NACO / Yepun (UT4), VLT in 2003 (see press release eso0330 http://www.eso.org/public/news/eso0330/)
- The implications: multi-wavelength observations will provide crucial data to understand the physics of the centre of our galaxy
8. Direct measurements of the spectra of exoplanets and their atmospheres
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- The discovery: the atmosphere around a super-Earth exoplanet is analysed for the first time using the VLT
- Instruments / Telescopes:
  - FORS, NACO / Kueyen (UT2), Yepun (UT4), VLT
  - HARPS / 3.6-metre Telescope, La Silla
- The observations:
  - Planet GJ 1214b confirmed by HARPS in 2009
  - IR spectroscopy of the GJ 1214 starlight through the atmosphere of the planet during transits is done with FORS in 2010
- The conclusions:
  - GJ 1214b is a super-Earth, 6.5 times as massive as the Earth and with a radius about 2.6 larger
  - The atmosphere of GJ 1214b is rich in stem or blanketed by clouds or haze
8. Direct measurements of the spectra of exoplanets and their atmospheres

• In context:
  – The very first direct spectrum of an exoplanet around the star HR 8799 detected by NACO in 2010
  – The exoplanet is a gaseous giant, with a mass 7-10 times that of Jupiter
9. Richest planetary system
The discovery: the system with the most planets yet discovered; it also seems to contain a planet with the lowest mass ever found

Instruments / Telescopes: HARPS / 3.6-metre, La Silla


The observations:
- The Sun-like star HD 10180 observed during a period of six years
- 190 individual HARPS measurements
9. Richest planetary system

• The conclusions:
  – The planetary system around the star HD 10180 is composed of:
    • 5 Neptune-like planets, with masses between 13 and 25 Earth masses, orbital periods from 6 to 600 days
    • 1 Saturn-like planet, with 65 Earth masses, orbital period of 2200 days
    • The least massive exoplanet ever discovered, with 1.4 Earth masses, orbital period of 1.18 days
  – The planetary system around HD 10180 compared with our Solar System:
    • Is more populated, with more massive planets in its inner region
    • Does not have any Jupiter-like gas giants
    • Shows a regular pattern of the distances of the planets from the star

• In context:
  – Massive planetary systems are found around massive metal-rich stars
  – The lowest-mass systems are found around lower-mass and metal-poor stars
10. Milky Way stellar motions
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- The discovery: detailed dynamic study reveals our Milky Way’s turbulent life
- More than 1000 nights of observations over 15 years
- Telescopes: Danish 1.54-metre Telescope, La Silla (and others)
- More info in press release eso0411:
  http://www.eso.org/public/news/eso0411/
10. Milky Way stellar motions

• The observations: motions of more than 14 000 neighbouring stars are determined
• The conclusions:
  – The evolution of the Milky Way was far more complex and chaotic than previously assumed
  – Supernova explosions, galaxy collisions, and the infall of huge gas clouds have made the Milky Way a very lively place
• Previous scenario: traditional, more simplified models
• The implication: the evolution of galaxies is complex and is the result of many different factors