Future Strategies for OIR Astronomy

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OIR Astronomy

- Part of the multi-wavelength universe
  - central region for many processes

> Almost every new astronomical source, whether discovered by radio telescopes on the ground or by infrared, ultraviolet, X-ray, or gamma-ray telescopes in space, must be observed by ground-based OIR telescopes to understand its physical nature and significance.

McCray et al. 1995
A Strategy for Ground-Based Optical and Infrared Astronomy

Bright Present and Future

- A plethora of facilities
  - Optical-Infrared ground-based telescopes up to 40m aperture
    - surveys, interferometry, synoptic programmes
  - mm and sub-mm telescopes
    - ALMA, NOEMA, SMA, APEX, Planck, Herschel, SOFIA
  - Radio telescopes of all sizes covering many frequencies
  - Space-based telescopes
    - Gaia, HST, JWST, Euclid, WFIRST-AFTA
    - Spitzer, Kepler, CoRoT, Cheops, TESS, PLATO, SVOM, …
  - X-ray sky available through
    - XMM/Newton, Chandra, eROSITA and Athena
  - Gamma-ray sky
    - INTEGRAL, MAGIC, HESS, CTA


ESA-ESO Working Gr
Report No.3 Fundamental Cosmology
Radio Astronomy in the
Up to, and beyond, 2
A report by AS
European Radio Telescope
Review Committee
PREPUBLICATION REPORT—SUBJECT TO FURTHER EDITORIAL CORRECTION
Optimizing the U.S.
Ground-Based Optical and Infrared
Astronomy System
Committee on a Strategy to Optimize the U.S. Optical and Infrared System in the Era of the
Large Synoptic Survey Telescope (LSST)
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Science Priorities at ESO
ASTRONET:
Infrastructure Roadmap
Update
Ian Robson
Report No.2
NATIONAL RESEARCH COUNCIL
European Space A
Agence spatiale européenne
dmap:
pean Astronomy

Major Science Topics

- Nature of Gravity
  - strong gravity → Galactic Centre
  - weak gravity → Dark Matter, Dark Energy
- Stars and Galaxies
  - formation, evolution, baryon cycle
- Other Worlds
  - characterisation of exo-planets and exo-planetary systems
- Transient Sky
  - variability as signature of physical processes
  - discovery enabled through many (near-)all-sky surveys

European Science Vision (2007)

- How do stars form?
- Do we understand stellar structure and evolution?
- What is the life-cycle of the interstellar matter and stars?
- How do planetary systems form and evolve?
- What is the diversity of planetary systems in the Galaxy?
- How did the Universe begin?
- What is Dark Matter and Dark Energy?
- Can we observe strong gravity in action?
- How do supernovae and gamma-ray bursts work?
- How do black hole accretion, jets and outflows work?
- What do we learn from energetic radiation and particles?
- How did the Universe emerge from its Dark Ages?
- Where are most of the metals throughout cosmic time?
- How were galaxies assembled?
- How did our Galaxy form?

European Science Vision (2007)

Changes from 1995 to 2007 (in black)

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OIR in the 2020s

- Exquisite angular resolution
  - 40m telescopes, interferometry
- Deep (all-)sky information
  - LSST and Euclid
- Deep infrared observations possible
  - JWST
- Dynamic Milky Way and Local Group
  - Gaia and spectroscopy

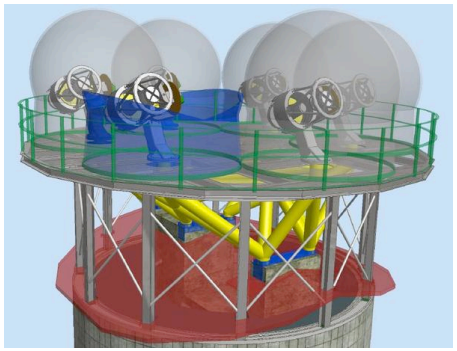
OIR in the 2020s

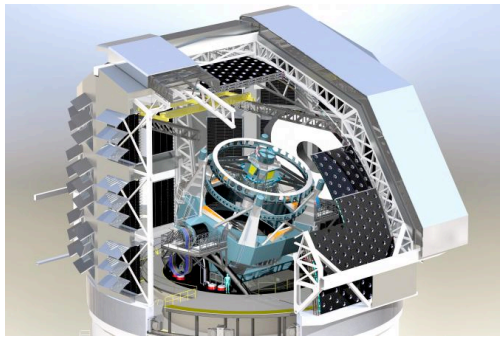
- Thousand of planet candidates
  - Transient searches
    - WASP, HAT, CoRoT, Kepler, NGTS, Cheops, PLATO
- System to follow-up alerts from other wavelengths and messengers
  - Optical surveys
    - Pan-STARRS, Zwicky Transient Factory, LSST
  - X-rays, radio
  - Gravitational waves and neutrinos

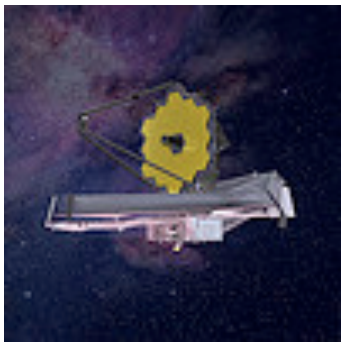
Transients in the 2020s

Alerts from many different sources:
gravitational waves, neutrinos,
electromagnetic searches

FoV:
10-30°







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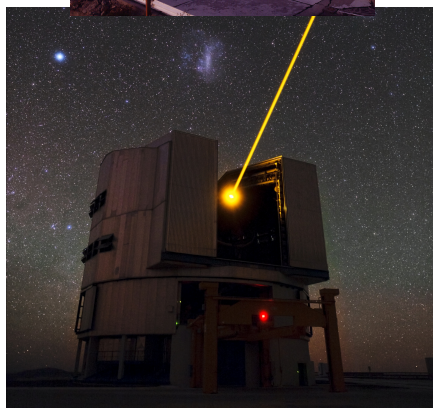

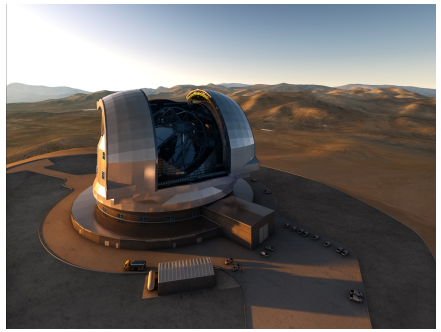

Flexibility

Planets in the 2020s

- Complementarity of the different methods
  - radial velocities, direct imaging, transits
  - needed for full characterisation of masses, densities, atmospheres, formation scenarii
  - Cheops, PLATO, HARPS, ESPRESSO, NIR spectrograph
- Coordination of the different facilities will be essential

Strategic Changes

- Move towards a systems approach
  - Big problems need coordinated observations
    - Milky Way dynamics
      → Gaia astrometry plus velocities and abundances
    - Cosmology
      → EUCLID and redshifts
    - Particle Physics
      → messengers and electromagnetic follow-up
  - Several astrophysical problems need observations across the electromagnetic spectrum
    - High-energy astrophysics
    - Complex astrophysical sites
      → e.g. star formation regions, SN remnants, galaxy clusters, distant universe

Future Strategies

- Facilities are part of observational system
  - Ground-space coordination (next talk)
  - Coordinated observations at many telescopes
    - Multi-wavelength programmes
      - ALMA - optical synergies
        - » star/planet formation, distant universe
      - radio - optical synergies
        - » non-thermal and thermal universe
    - Exo-planet search and characterisation
      - timed photometry, spectroscopic monitoring, multi-wavelength observations (planet-star contrast!)
    - Milky Way structure and local dwarf galaxies
      - spectroscopic follow-up of the photometric catalogues (SDSS, Gaia)

Future Strategies

- "Guidelines" for OIR observatories
  - Flexibility
    - adapt to new topics and discoveries
  - Uniqueness
    - explore features of your observatory others don't have
      - e.g. interferometry (VLTI)
    - provide unique capabilities for simultaneous coverage of large wavelength ranges
      - e.g. observations of Comet Shoemaker-Levy 9 or Hale-Bopp
  - Complementarity
    - spectral follow-up of imaging surveys
    - monitoring of special objects
    - complementarity to space missions
  - Supplementarity
    - support observations for other facilities

Future Strategies

- "Internet Astrophysics"
  - Most research based on databases
  - Coordinated programmes produce coherent data
  - Context for many new observations
  - Open Data proven to be key to success
    - SDSS, 2MASS/DENIS, Kepler, eventually LSST
    - observatory data archives

→ Make data available to the whole community

  - Easy to find
  - Easy to understand
  - Easy to use

OIR Observational System of the 2020s

- Flagship facilities
  - ALMA, ELTs, JWST, LSST, EUCLID, (SKA, ATHENA)
- Archives
  - Planck, Gaia, HST, Spitzer, Herschel, Kepler, XMM-Newton, INTEGRAL, Chandra, observatory archives
  - Literature
- General user facilities (with some specialisation?)
  - 6-10m telescopes (16 ground-based)
    - "people's observatories"
    - large variety of instrumentation, also interferometry
    - built-in flexibility
    - main resource for follow-up work
  - 2-4m telescopes
    - pick your specialisation
    - dedicate telescope to specific science question

ESO – an integrated system

- ALMA and E-ELT
  - Flagship facilities
- VLT
  - Unique capabilities
    - interferometry → VLTI special session on Friday
    - large instrument complement, flexibility, modern operations model
- La Silla/4m telescopes
  - Transients: NTT; exo-planets: 3.6m;
    multi-object spectroscopy: VISTA;
    platform for smaller experiments: La Silla
- ESO Archive
  - Rich resource of optical data
    - large coherent data sets from surveys
    - advanced data products

Recently in another community …

Part of ESO's mission is to organize collaborations; its instruments are developed in a coordinated way, with most built by consortia of institutes. ESO has a suite of smaller telescopes as well, which are mostly run by ESO member consortia. The ESO community has thus maximized its combined resources by having a strong support network of partnerships for instrument development and small and medium telescope operations, with ESO concentrating on operating and upgrading the largest facilities. The E-ELT, a planned 39-meter telescope, is expected to have first light in the early 2020s.

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Astronomy in the 2020s

- OIR sky measured to ~25 mag
- Thousands of transient alerts per day
- Matching capabilities at (almost) all other wavelengths
  - angular resolution
  - sensitivity
  - sky coverage
- Astroparticle detections
- Diverse astronomical community with considerable overlap with other sciences (chemistry, biology)

OIR Future Strategies

- Flexibility
  - Astrophysics covers many topics and techniques
  - Completeness of instrumentation
  - Reaction to interesting new events, object and topics
- Coordination
  - Instrumentations programmes at different facilities
    - either through a large pool or through collaboration between observatories
  - Planning between ground and space
  - Time allocation between observatories
- Operations
  - inbuilt flexibility
  - archive → open distribution of data