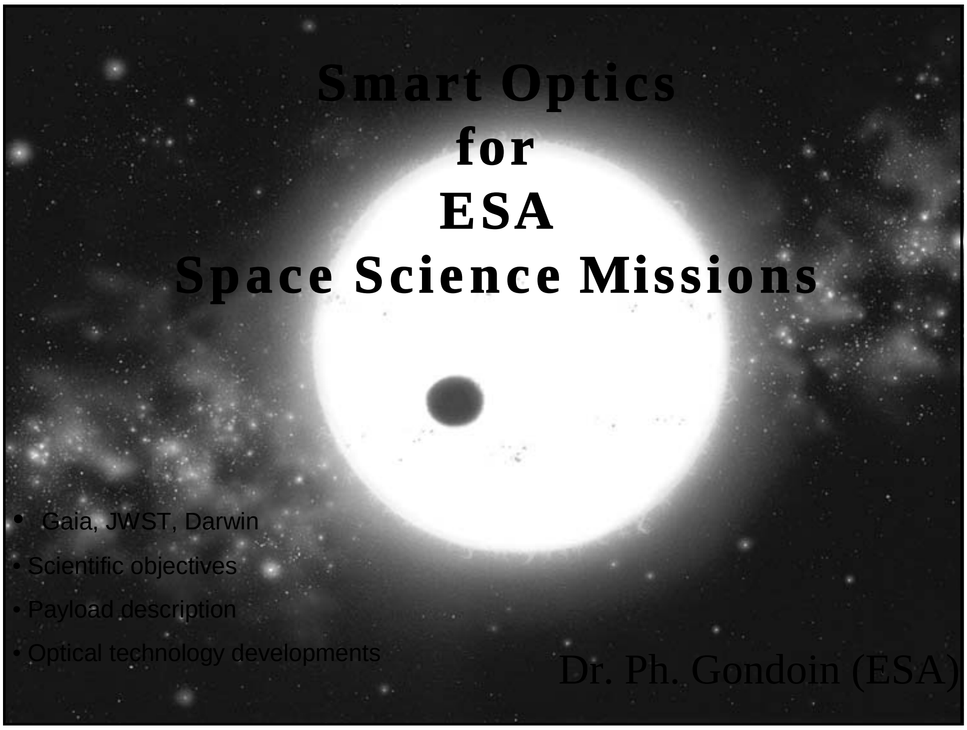
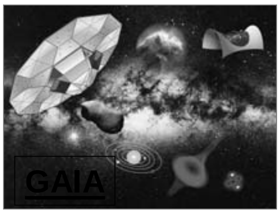


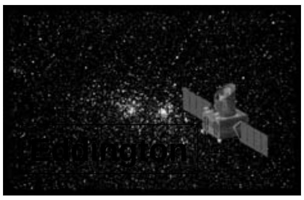
Smart Optics for ESA Space Science Missions

- Gaia, JWST, Darwin
- Scientific objectives
- Payload description
- Optical technology developments

Dr. Ph. Gondoin (ESA)

ESA’s IR and visible astronomy missions





esa

GAIA Science Objectives

Understanding the structure and evolution of the Galaxy, i.e.:

- census of the content of a large part of the Galaxy
- quantification of the present spatial structure from distance (3-D map)
- knowledge of the 3-D space motions

→ Complementary astrometry, photometry and radial velocities:

- Astrometry: distance and tranverse kinematics
- Photometry: extinction, intrinsic luminosity, abundances, ages,
- Radial velocities: 3-D kinematics, gravitational forces, mass distribution, stellar orbits

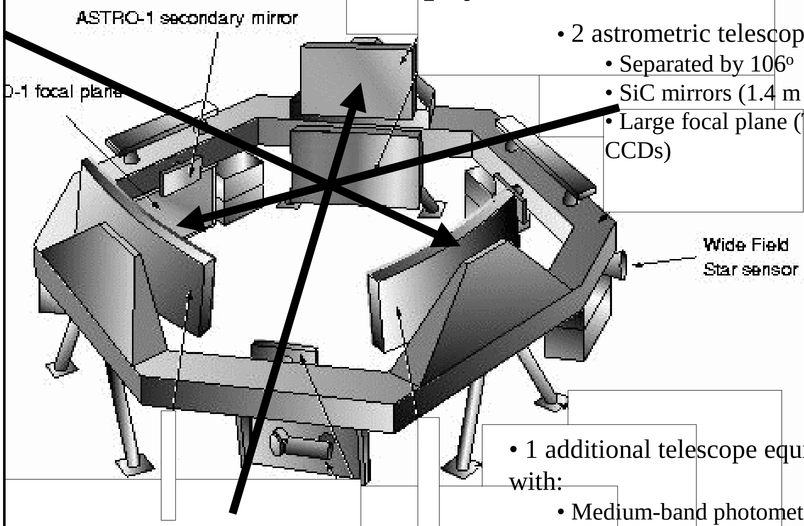
esa

GAIA (compared with Hipparcos)

	Hipparcos	GAIA
Magnitude limit	12	20-21 mag
Completeness	7.3 – 9.0	~20 mag
Bright limit	~0	~3-7 mag
Number of objects	120 000	26 million to V = 15 250 million to V = 18 1000 million to V = 20
Effective distance limit	1 kpc	1 Mpc
Quasars	None	$\sim 5 \times 10^5$
Galaxies	None	10^6 - 10^7
Accuracy	~1 milliarcsec	4 μarcsec at V = 10 10 μarcsec at V = 15 200 μarcsec at V = 20
Broad band	2-colour (B and V)	4-colour to V = 20
Medium band	None	11-colour to V = 20
Radial velocity	None	1-10 km/s to V = 16-17
Observing programme	Pre-selected	On-board and unbiased

esa

GAIA payload



- 2 astrometric telescopes:
  - Separated by 106°
  - SiC mirrors (1.4 m × 0.5 m)
  - Large focal plane (TDI operating CCDs)
- 1 additional telescope equipped with:
  - Medium-band photometer
  - Radial-velocity spectrometer

Optical technology for GAIA

- **CCD's and focal plane technology:** (ASTRIUM.GB+E2V under ESA TRP contract)
  - Astrometry: 3 side buttable, small pixel (9 μm), high perf. CCDs
  - Spectrometer: wide size, ultra low-noise, high perf. CCDs
  - Photometer: wide size, high perf. CCDs
  - Representative focal plane breadboard (TDI operation test)

- **Telescopes and optical bench:** (ASTRIUM Fr. + Boostec under ESA TRP contract)
  - large size (1.4 x 0.5 m) SiC mirrors (highly aspherized for good off-axis optical performance)
  - Ultra-stable large size SiC structure

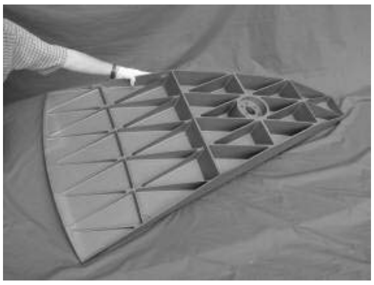
Large SiC mirror for space telescopes (Boostec)

ESA Herschell telescope:

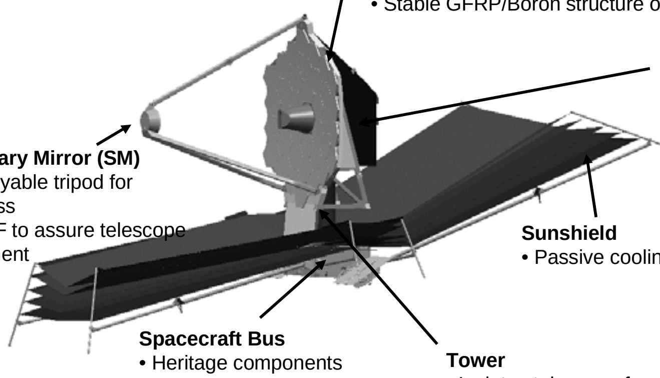
1.35 m prototype

3.5 m brazed flight model

(12 petals)



James Webb Space Telescope (JWST)



JWST specifications

- 7m deployable primary
- diffraction-limited at 2 µm
- wavelength range: 0.6-28 µm
- passively cooled to <40 K
- operating at Sun-Earth L2 orbit
- 3 core instruments:
  - NIRCam: 0.6-5 µm wide field camera (US-Canada)
  - **NIRSpec: 1-5 µm multi-object spectrometer (ESA)**
  - MIRI: 5-28 µm camera/spectrometer (US-Europe)
- 5 year lifetime (10 year goal)
- launch in 2010

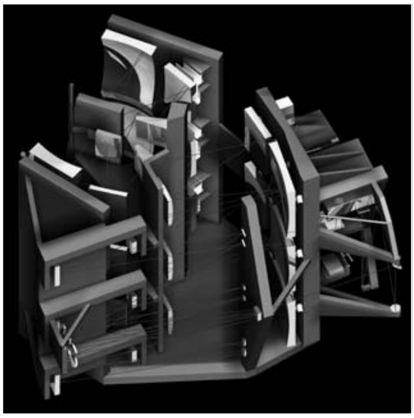
ESA NIRSpec Studies

- Two ongoing Definition Studies
  - Two competing consortia
  - Completion: February 2003
- Related Technology Developments
  - C/SiC Optical Bench
  - SiC Mirrors
  - Image Slicer
  - Backup Mechanical Slit Mask

NIRSpec specifications and candidate concepts

Specifications:
- 1-5 µm coverage
- 3 x 3 arcmin FOV
- R ~ 1000 and R ~ 100 mode
- > 100 sources simultaneously

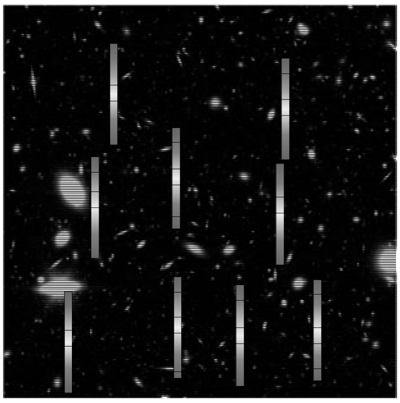
Candidate concepts:
- Image slicer (IFS)
- Mechanical slit mask (MOS)
- MEMS array (MOS)

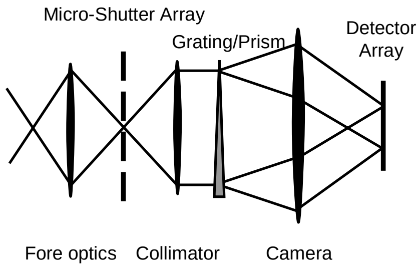


Technology development for NIRSpec

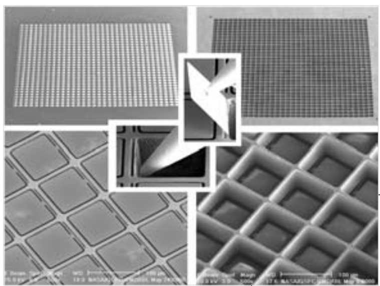
- Image slicer:
  - design, manufacture of a breadboard
  - characterization (e.g. alignment stability) at cryogenic temperature
  - optical performance (cross-talk) and stray-light measurements
- Pre-development of a mechanical slit mask

Multi-object Spectroscopy (MOS)

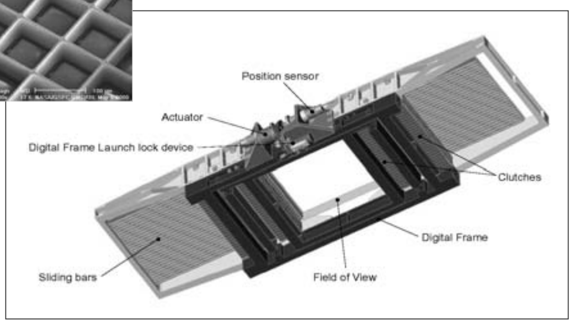




NIRSpec Slit Selector Mechanism



GSFC Micro-shutter



Backup
CSEM Mechanical
Slitmask

The Darwin Space Interferometer (ALCATEL 2000 study)

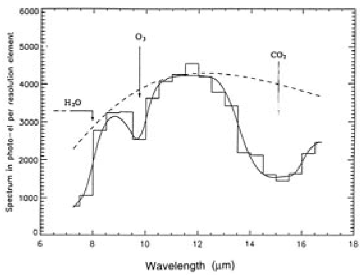
- 6 Telescope free-flyers
- 1 Beam combiner
- 1 Master spacecraft

DARWIN science objectives

1) Nulling interferometry

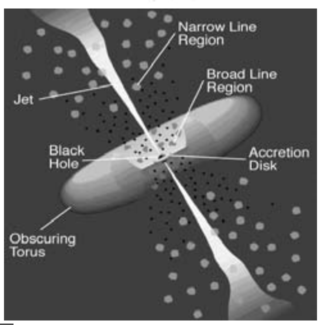
to detect and characterize Earth-like planets around nearby star (i.e. how unique is the Earth as a planet?)

to search for exo-life around nearby stars (i.e how unique is life in the universe?)



2) Imaging at high spatial resolution

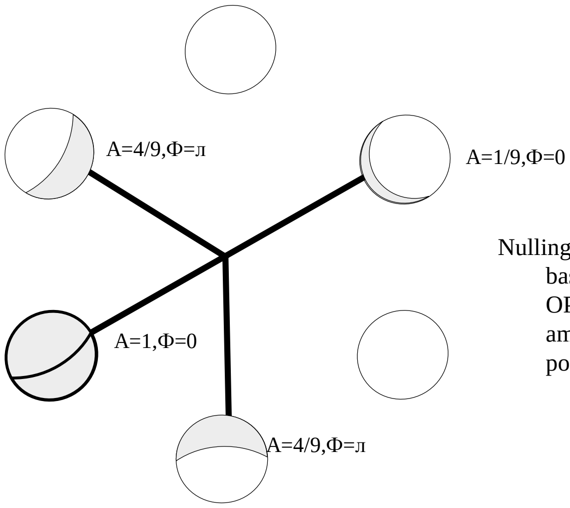
e.g active galaxy nuclei



The IRSI-Darwin configuration

Beam Combination (3)

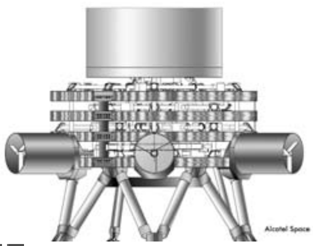
Nulling (Generalized Angel's Cross) + Internal modulation



Nulling rejection: $>10^5$
- baseline accuracy: 1cm
- OPD control: < 20 nm
- amplitude matching: $< 10^{-2}$
- pointing accuracy < 20 mas

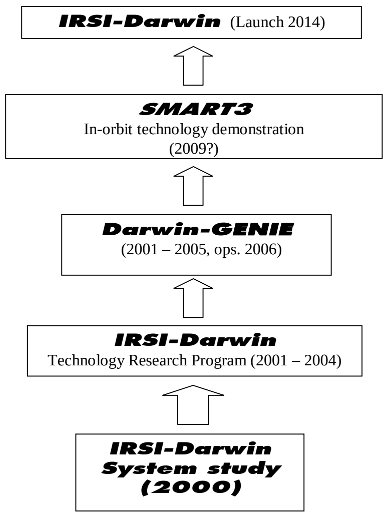
Darwin telescopes and beam-combiner

- **6 telescope free-flyers**
  - 1.5 m Korsch telescopes (+ transfer optics)
  - Wide-field camera (attitude sensing)
  - Dual-field capability (reference+target)
  - Hub alignment device
- **1 beam combiner** (Imaging or nulling mode)
  - Metrology
  - Delay lines+fringe sensors
  - Amplitude+polarisation control
  - Achromatic phase shifting
  - Spatial filtering
  - Beam combination
  - Spectroscopy, detection



esa

The Darwin development programme

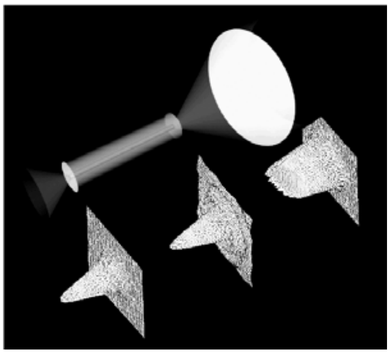


DARWIN Technology Research Programme

- **Pre-cursor flight technology (--> In-orbit testing?)**
  - Control and operation system for constellation deployment and formation flying)
  - Positioning RF subsystem, milli- and micro- Newton thrusters (FEEP)
  - High precision inter satellite metrology (interferometer coherencing)
  - Fringe sensors , delay lines (interferometer co-phasing)
- O**ptical components and subsystems (--> Ground-based testing)**
  - Achromatic phase shifter
  - Integrated optics
  - Wavefront filtering, IR single mode fibres
  - IR detectors , cooler
  - Optical components (coatings, manufacturing reproducibility)
  - Multi-aperture laboratory breadboards

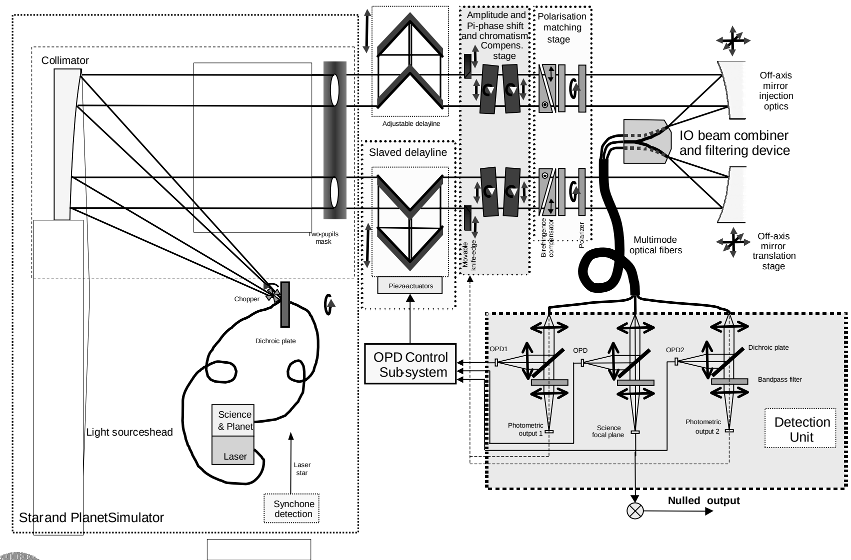
IR single mode fibres for spatial filtering

Development of IR single mode waveguides and fibres initiated:
Astrium Germany + ART/Photonics, TU Wien, IRCOM **(under ESA TRP contract)**

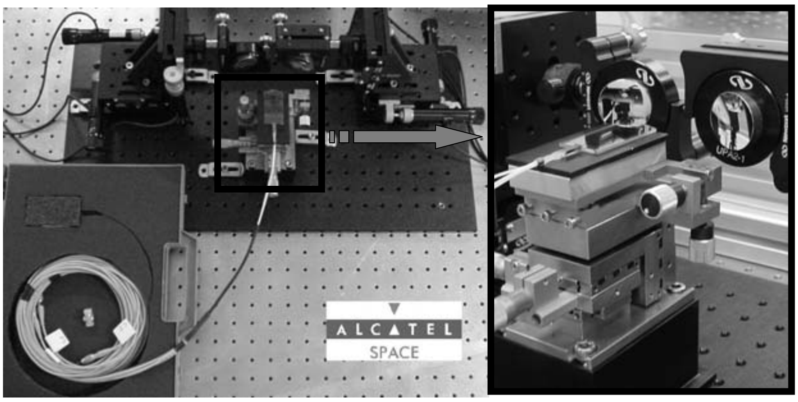


Candidate technology:
e.g. poly-cristalline single or double step index silver halide fibres (4 to 20 µm)

Laboratory breadboard (Alcatel under ESA TRP)



Integrated optics beam combiner



IR integrated optics for DARWIN

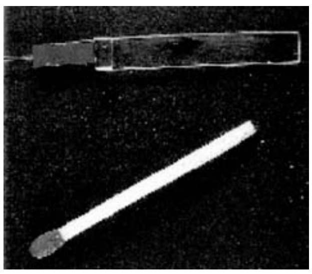
Development of IR integrated optics components for Darwin initiated:
IMEP + LETI-CEA, LAOG, Alcatel Space **(under ESA TRP contract)**

Why ?

- compactness
- weight
- volume
- modularity
- low sensitivity to environment (temperature, vibrations, etc.)

Potential Materials

- Chalcogenide glasses
- Silicon
- Si/SiGe
- Germanium
- CdTe
- ZnS/ZnSe
- GaAs/AlGaAs
- "Vacuum"

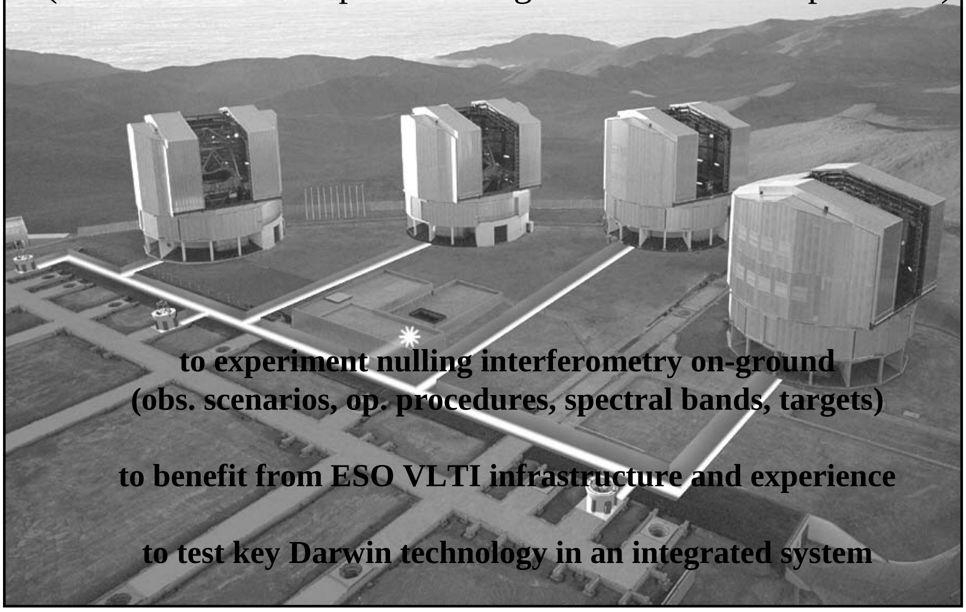


Potential Technologies

- Thin film deposition and etching
- Doping of bulk material
- Photo-exposition
- MEMS technologies

Darwin-GENIE: an ESA-ESO collaboration

(Groundbased European Nulling Interferometer Experiment)



to experiment nulling interferometry on-ground (obs. scenarios, op. procedures, spectral bands, targets)

to benefit from ESO VLTI infrastructure and experience

to test key Darwin technology in an integrated system

Smart Optics for ESA Space Missions Summary

1) ESA Space Science Missions require and stimulate the development of smart optical components and subsystems

2) **ESA Technology Research Program (TRP) implement the development of smart optical components and subsystems**

3) Major requirements for future ESA space missions:

- Improvement of space observatories performance requires large, lightweight telescopes (e.g. Herschell, JWST, Gaia)
- Future space observatories requires large focal plane arrays (Gaia, Eddington, JWST)
- New instrument concepts (NIRSpec, Darwin) requires (e.g.) IR optical fibers, MEMS, IR integrated optics …

4) Interferometry in space (Darwin - exo-planets) is a driver for the development of smart optical components and subsystems.