The Molecular and Dusty Universe

(ISO and) Herschel

Space Science Horizon 200: A Retrospective View
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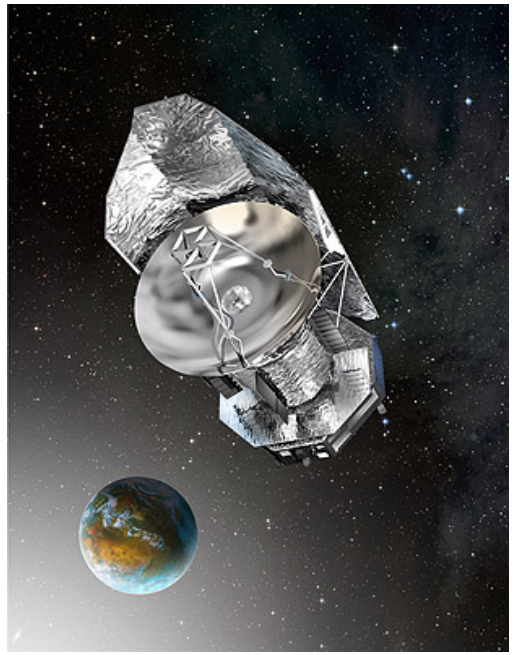
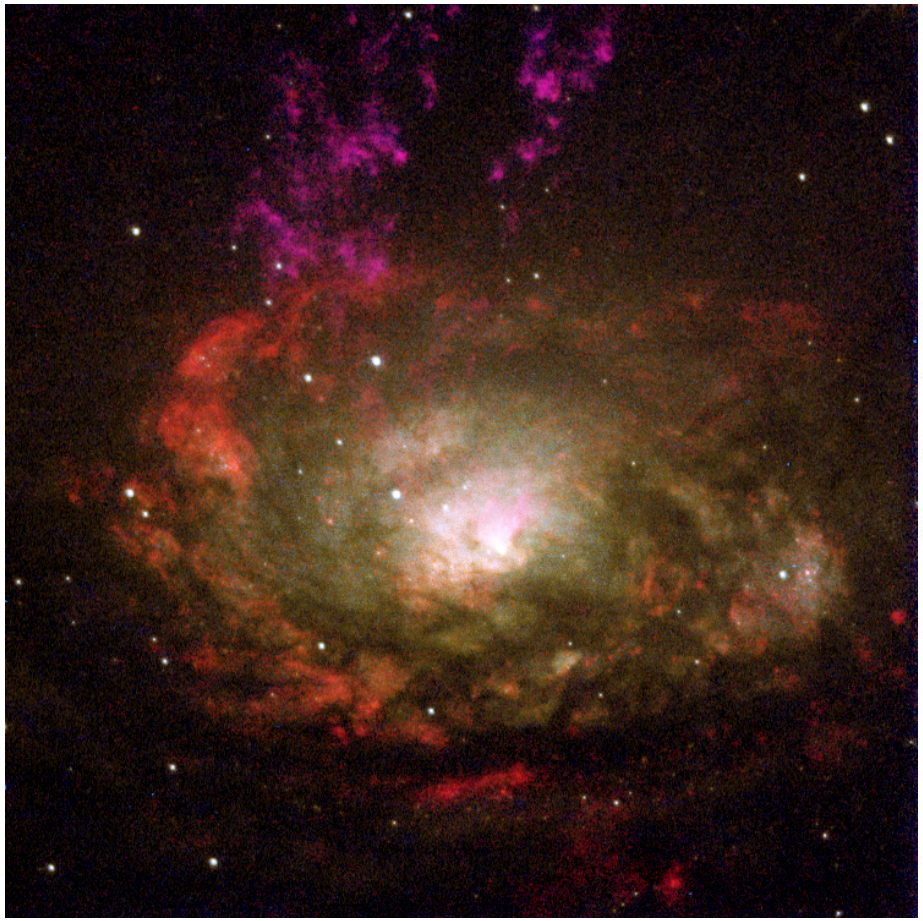
Christoffel Waelkens, KU Leuven

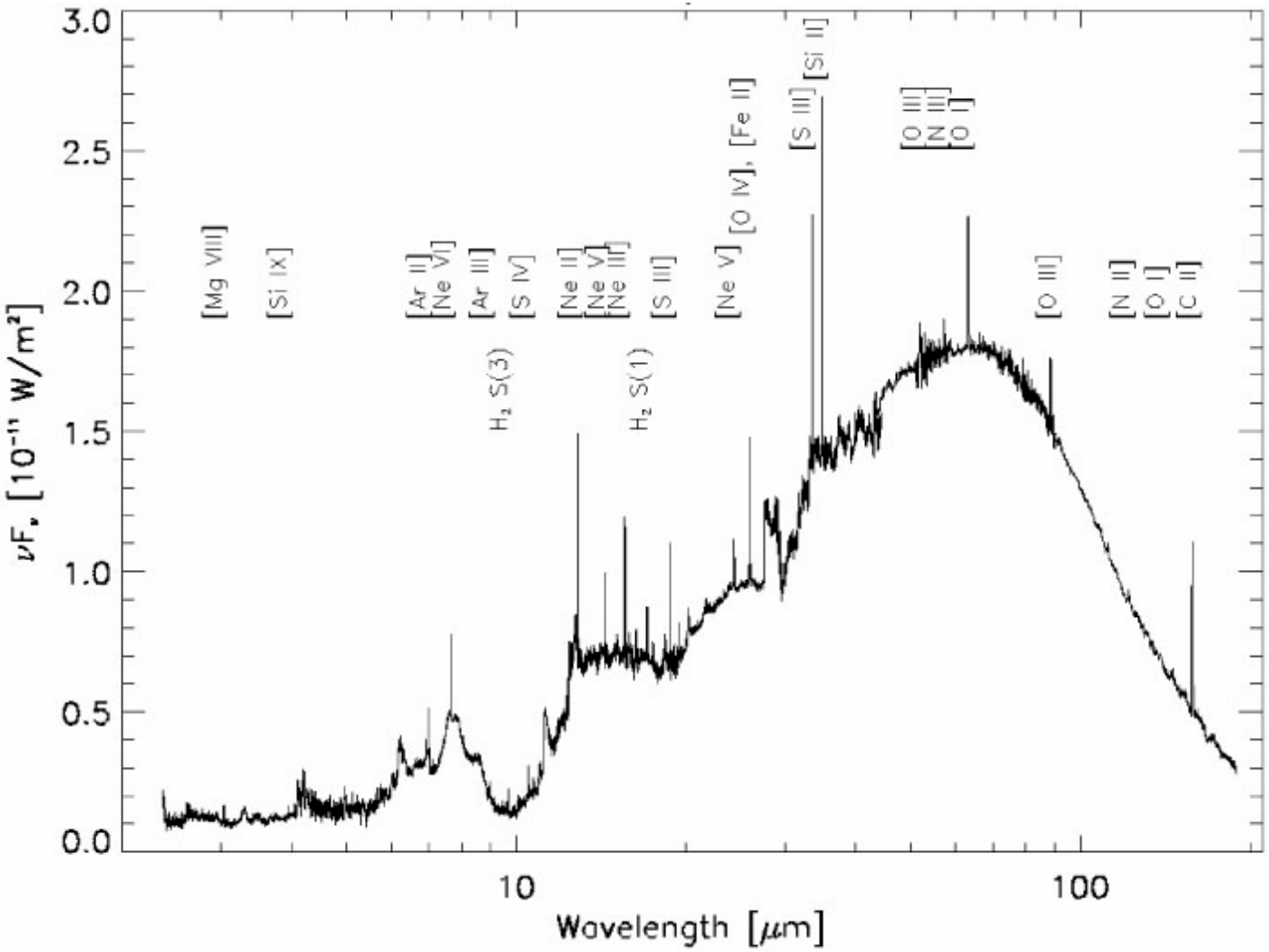


Overview

- Introduction
- Summary of conclusions
- Astronomy at IR wavelengths
- ISO and Herschel
- Science breakthroughs and highlights
- Horizons 2000: much more than the sum of its parts
- Lessons learnt

Introduction





ISO and Herschel within Horizon 2000

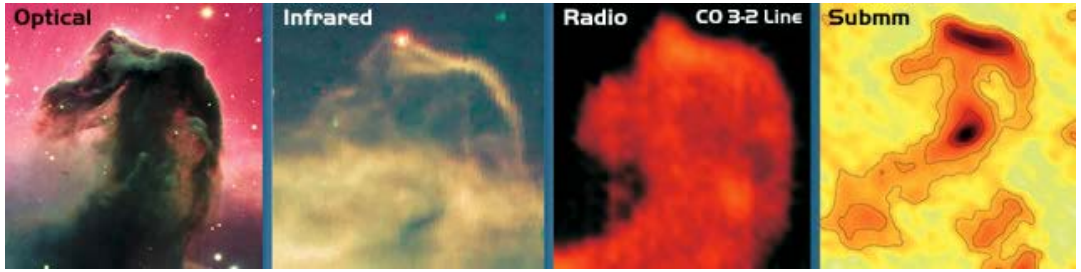
- A new (last?) spectral window successfully opened.
- The science goals transcend the specific IR domain and have brought together different approaches within space astronomy.
- A very fruitful cross talk has occurred between ‘astronomy’ and ‘solar system research’.
- Typical Herschel scientists have a strong background in ground based astronomy, and also there important cross fertilization has occurred and continues.
- Herschel has been a successful test case for managing large instrument consortia and ambitious technology requirements.
- Combining Herschel and Planck has bolstered the programme.

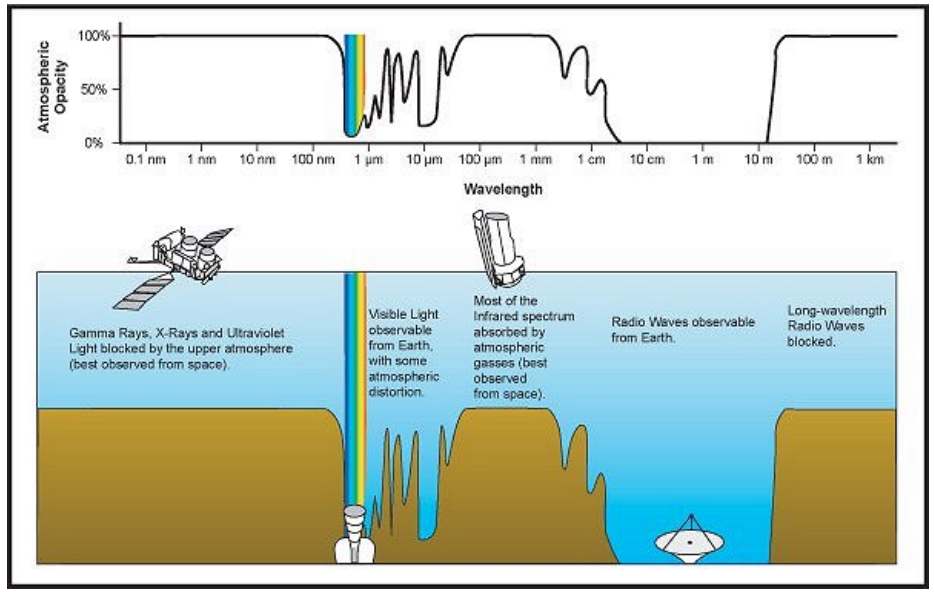
Astronomy at IR wavelengths

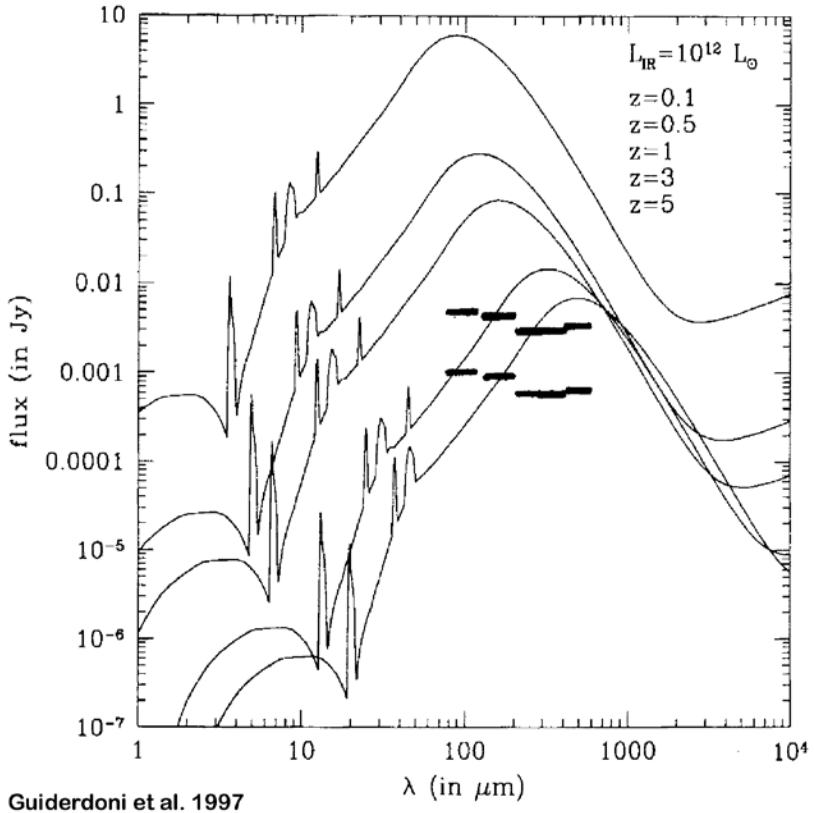
- The cold (‘cool’) universe is the place where stars and planets are born.
- It is also the place where astro-chemistry occurs.

- Dust in the universe absorbs hot radiation, which finally emerges in the infrared.
- The expansion of the universe shifts distant radiation to infrared wavelengths.

Astronomy at IR wavelengths

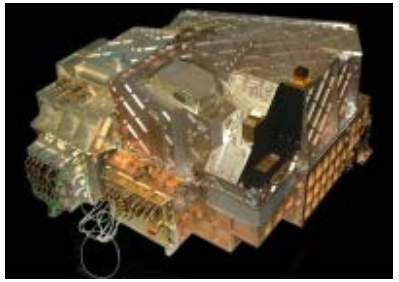


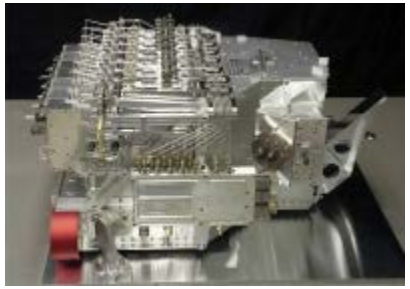


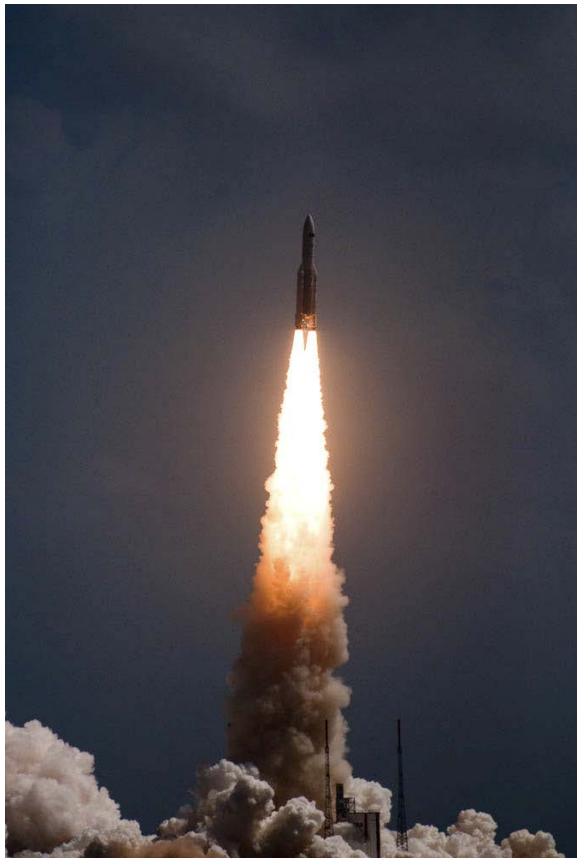


Guiderdoni et al. 1997

Herschel







An anthology of Herschel highlights

- Understanding observationally the basic mechanisms on how stars form in the dense interstellar medium.
- Resolving the cosmic infrared background in star-forming galaxies and the detailed study of the history of star formation rates.
- Feedback between starbursts and active galactic nuclei.
- The ubiquitous presence of water, also in hot cores.
- The diversity of molecular excitation modes and their diagnostic value, in our and other galaxies.
- Remarkable results on (water in) solar-system objects, dust formation in supernovae, debris disks, outflows from old stars, lensed galaxies, …

Star Formation matters …

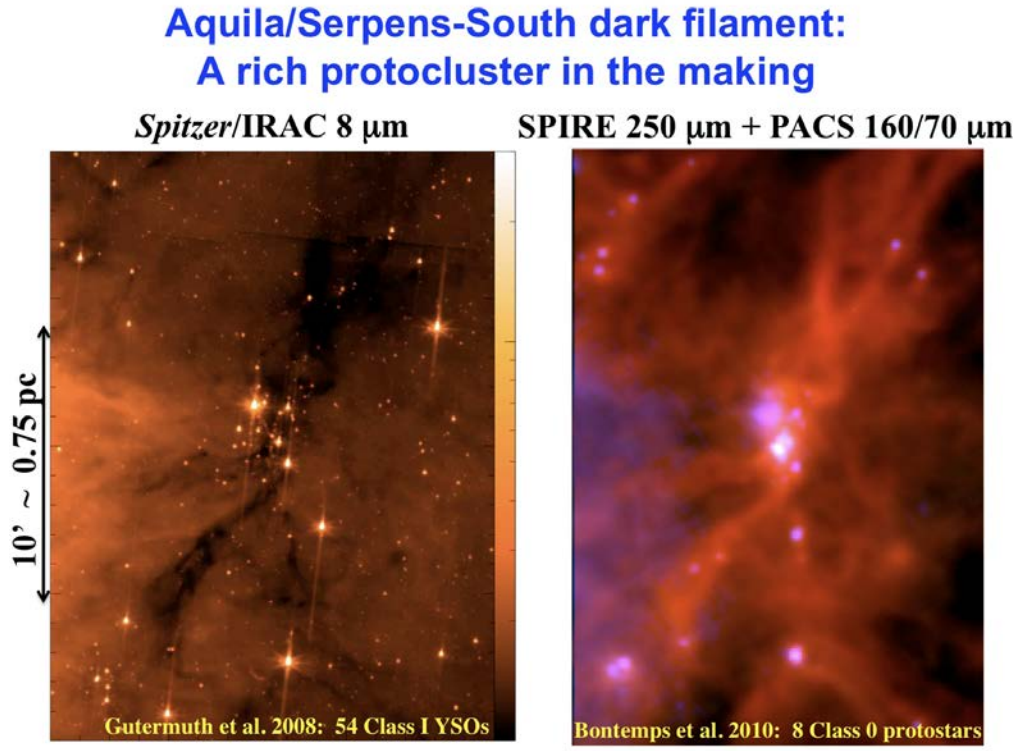
- Galaxy formation cannot be understood without incorporating a detailed theory of star formation. We have only a rudimentary grasp of such theory, however, which means that galaxy formation is destined to be a semi-phenomenological theory for the foreseeable future (J. Silk, 1997, first ‘FIRST’ conference at Grenoble).

- We will never fully understand planet formation if we do not understand star formation in the first place (J. Silk, 2004, Cosmic Vision Event at Unesco, Paris).

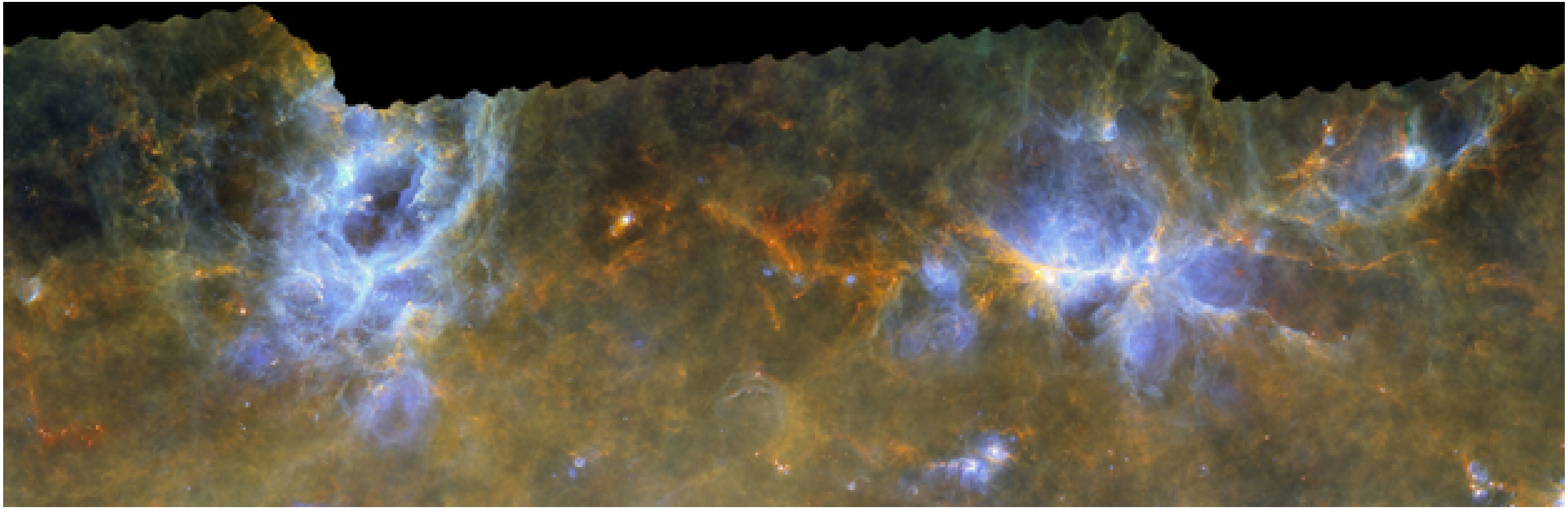
… but its (classical) physics is complex.

- What causes the pressure which competes with gravitation?
  - Turbulence?
  - Magnetic fields?

- The Herschel answer: magnetoturbulence!

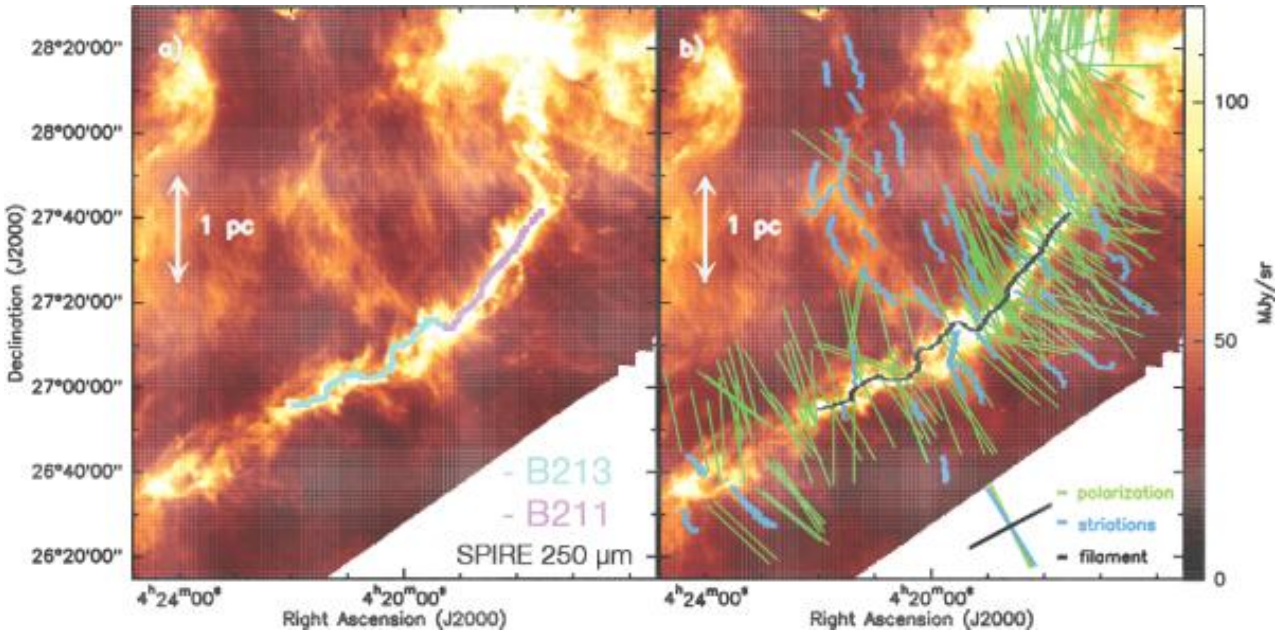


Filamentary structure of SF regions

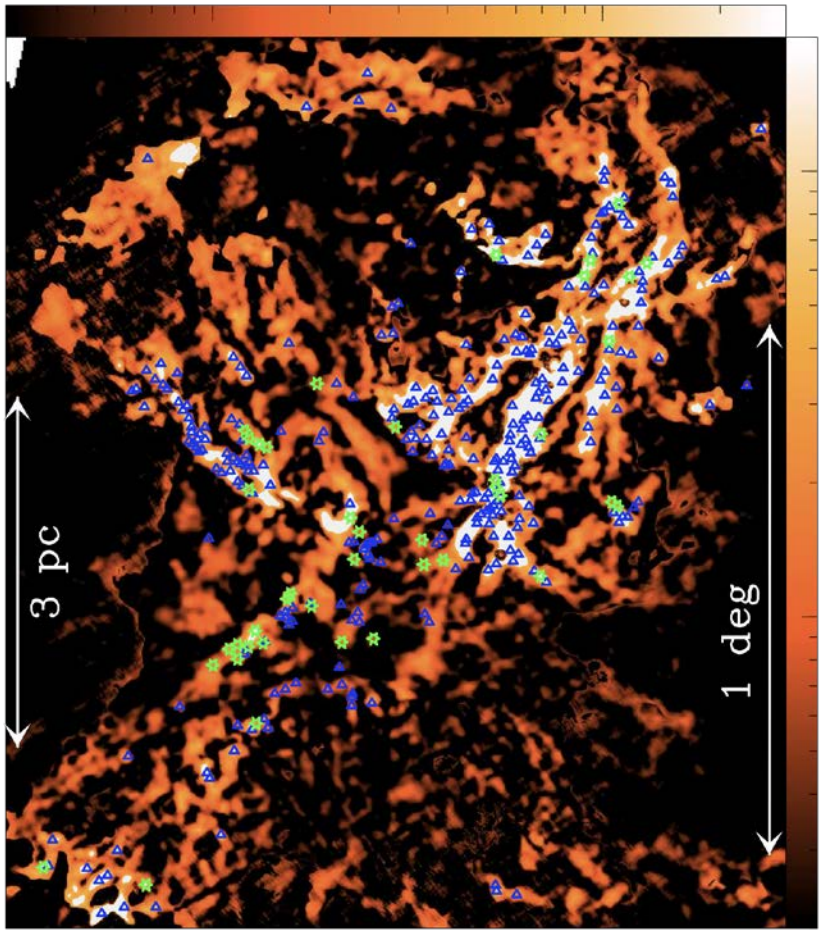


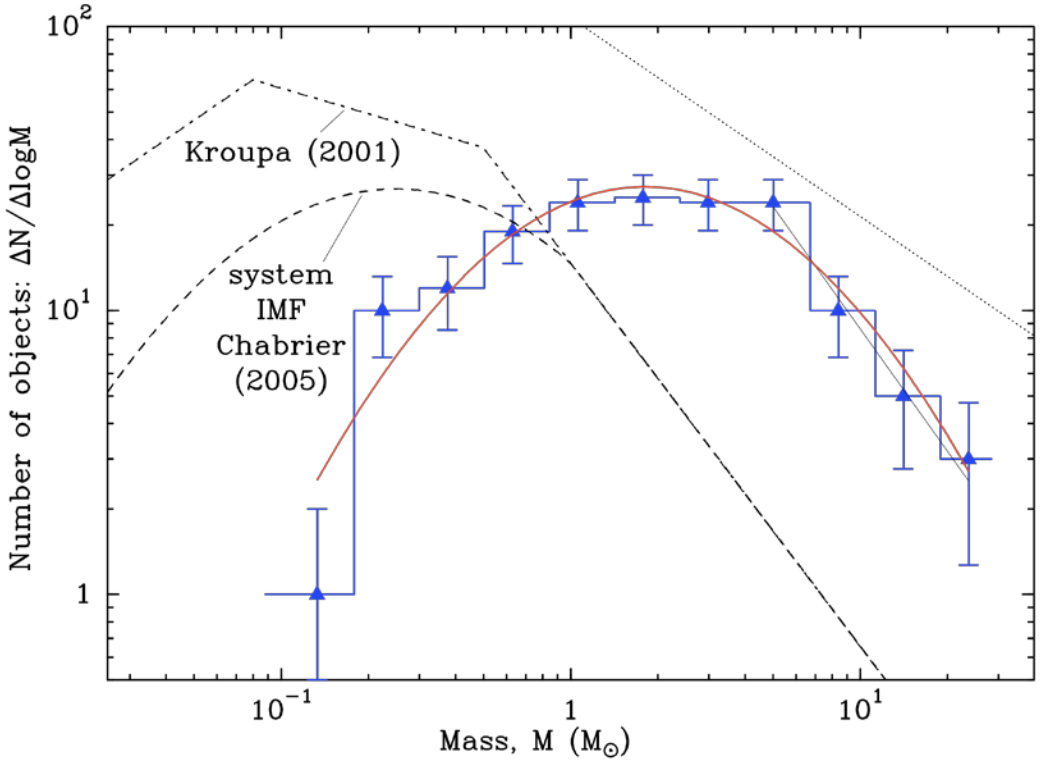
Star formation: how it works

- Magneto-turbulence generates filamentary structures.
- These have a universal thickness of about 0.1 pc.
- Perpendicular to the filaments, matter falls in along magnetic field lines.
- Stars are born if the density exceeds a critical value.



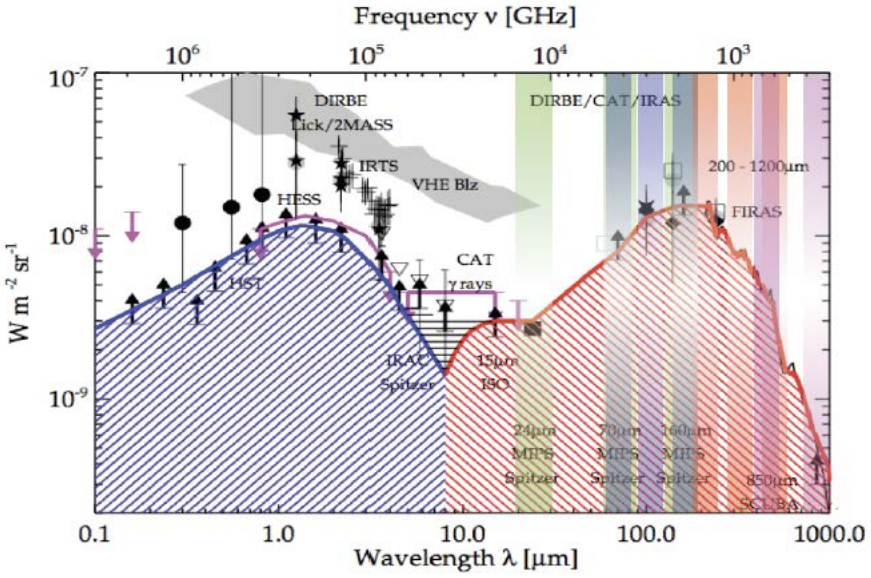
Initial mass function of dark cores

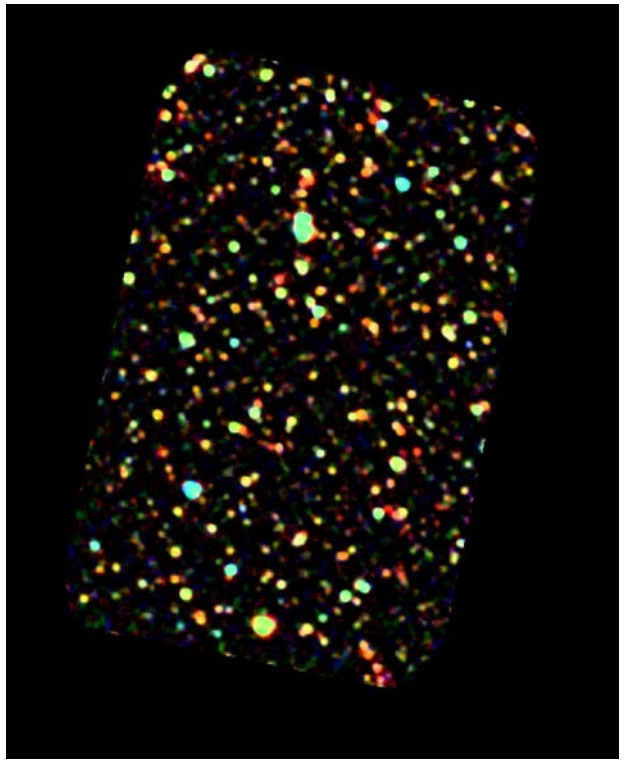


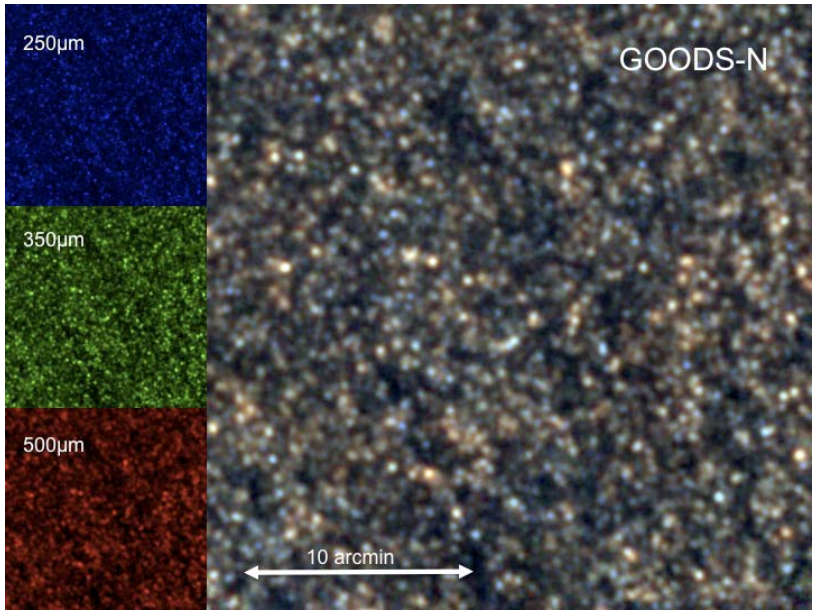


Resolving the cosmic IR background

View that it is composed of star-forming galaxies largely confirmed.

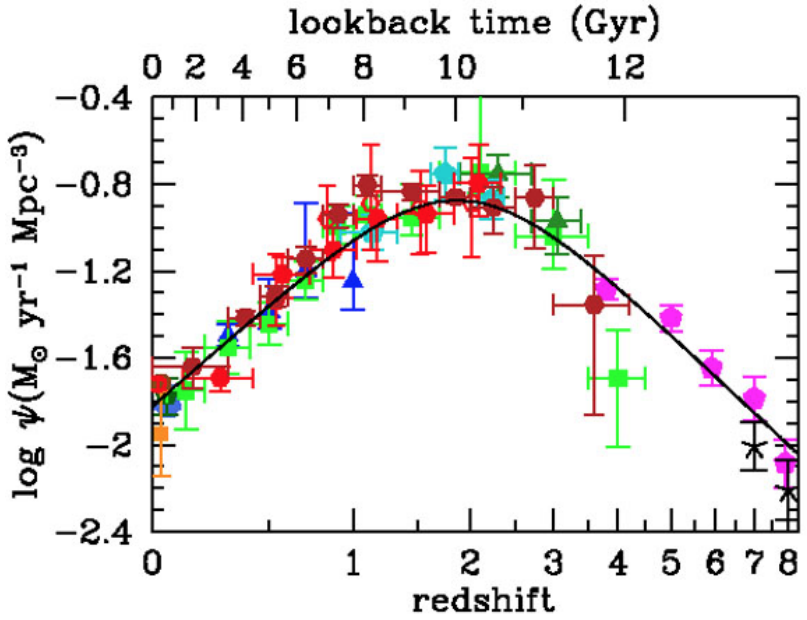


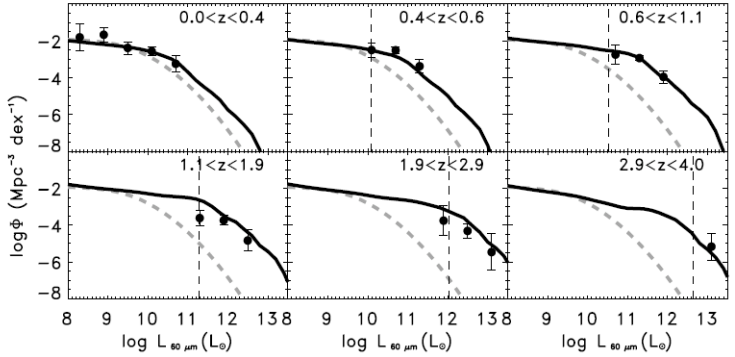




Star formation history of the universe

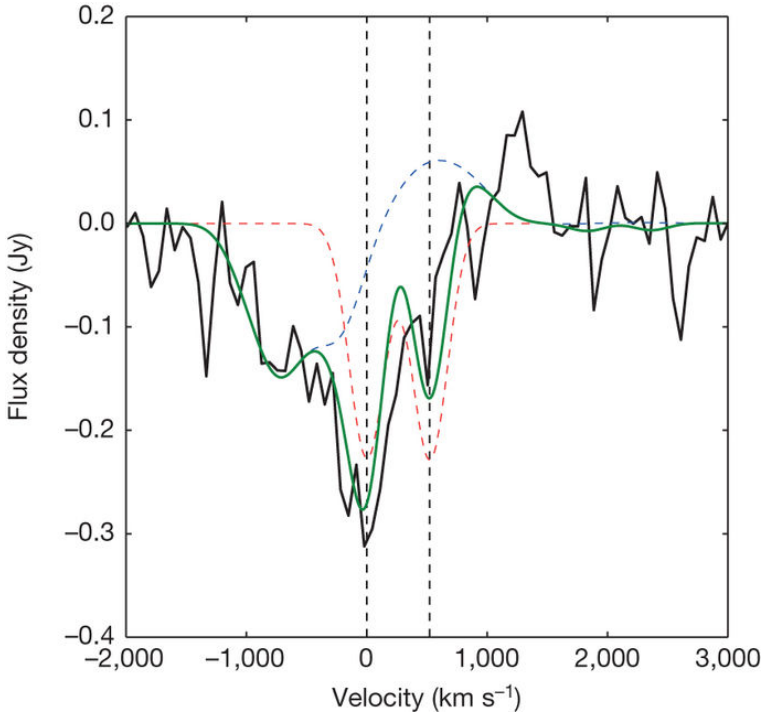
- Clear description of SFR since its maximum about 10 Gyr ago.
- Not only the biggest galaxies matter: not only mergers, but also galaxies steadily growing through accretion.

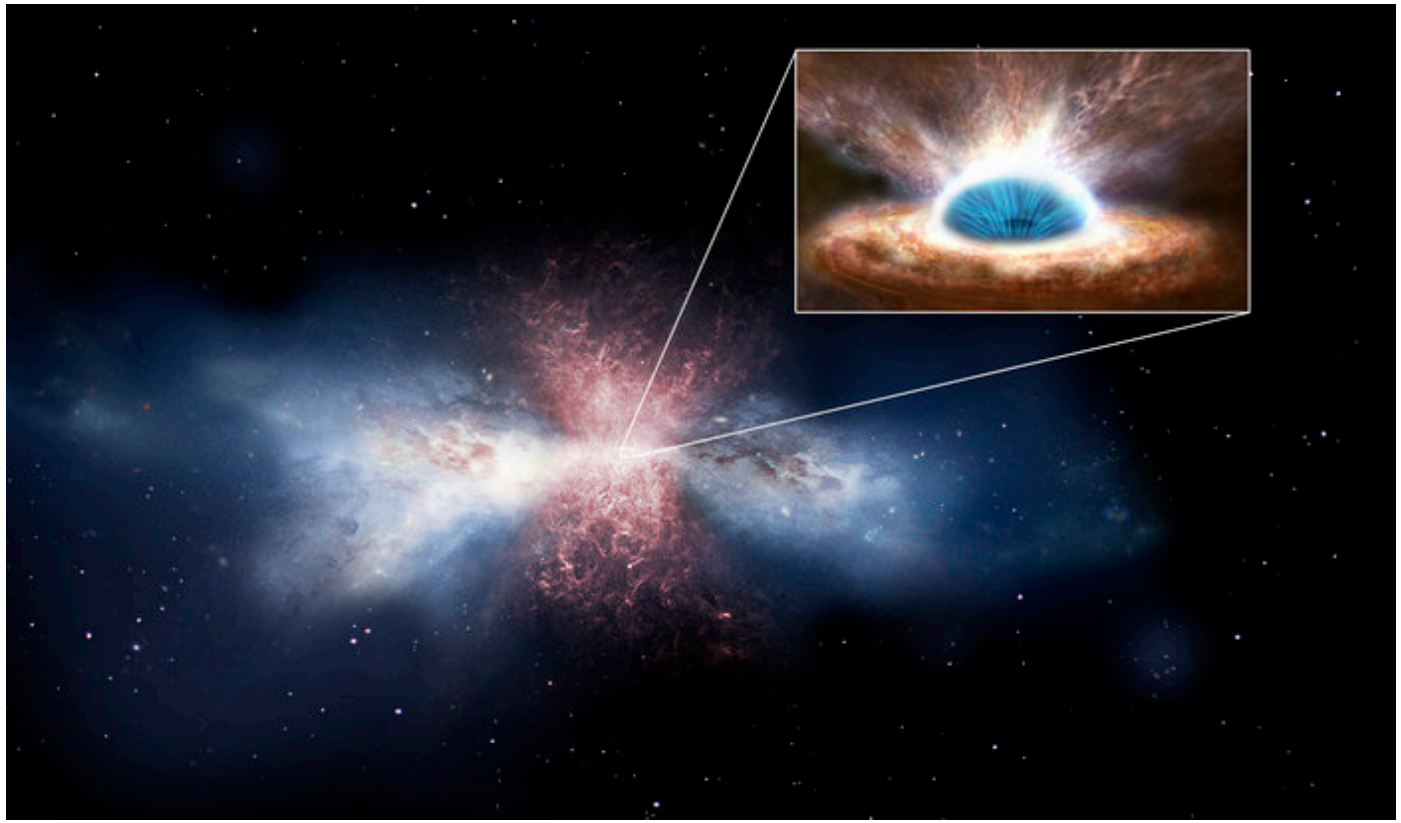




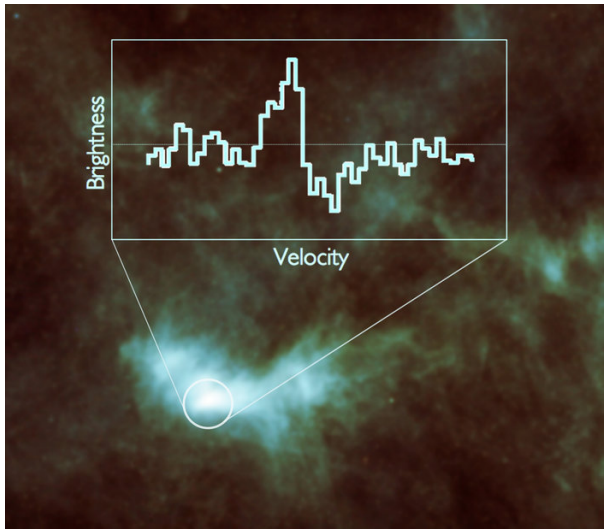
AGN – starburst feedback

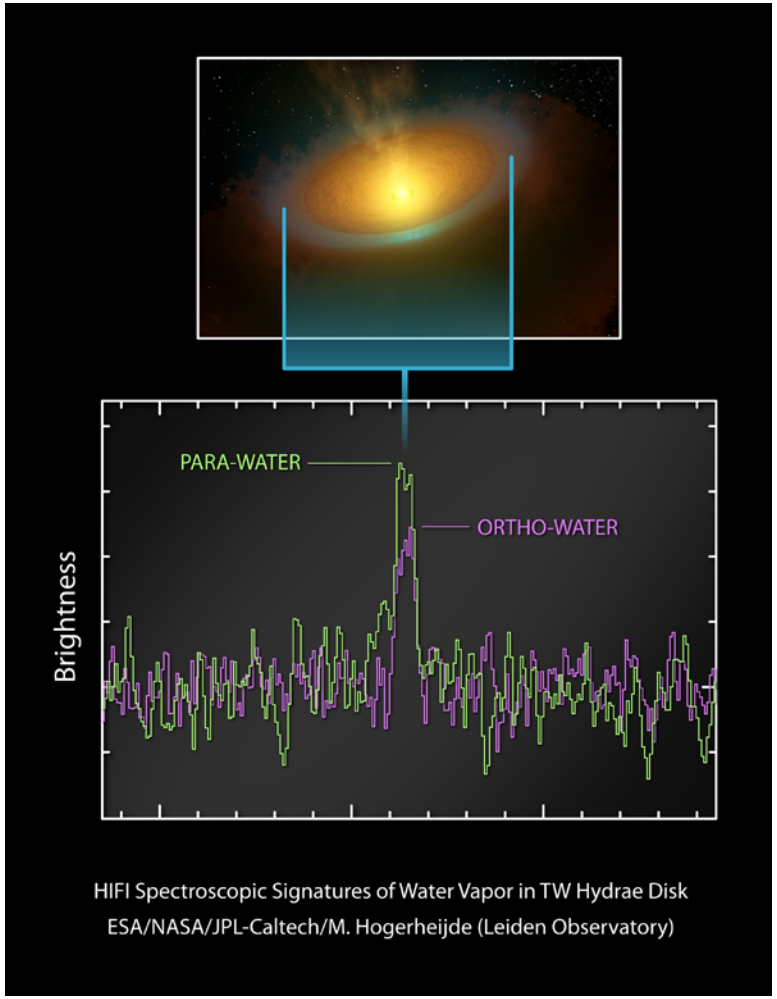
- Correlation between molecular (OH) outflows and the wind from the central engine confirms that AGNs eject molecular clouds and hence quench star formation.

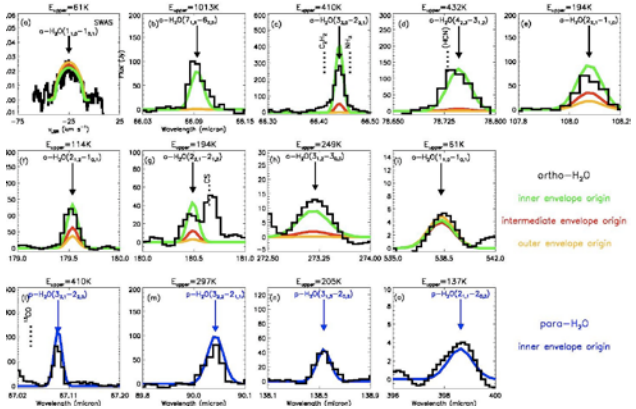


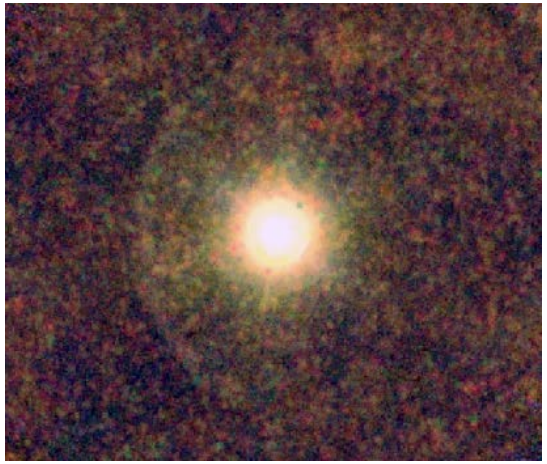


Water everywhere …

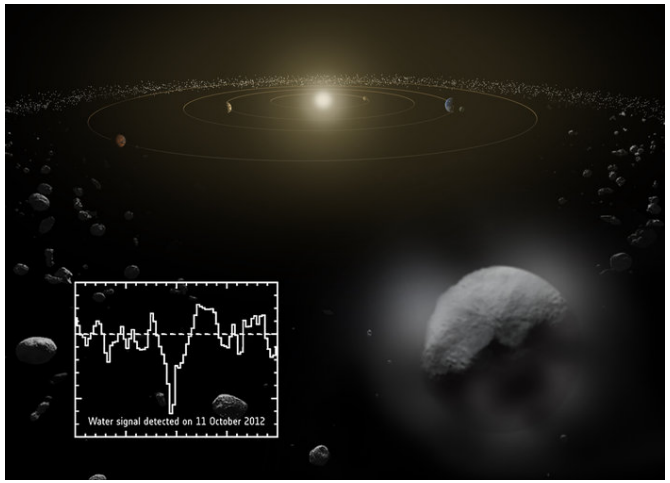


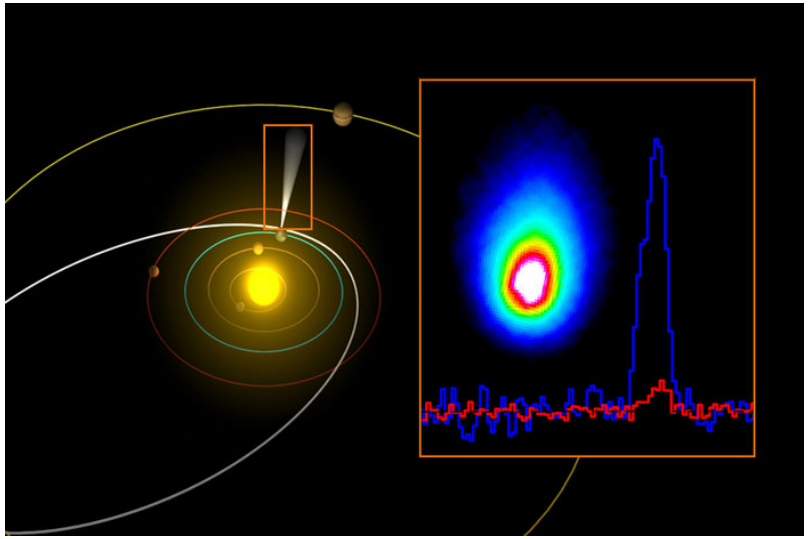


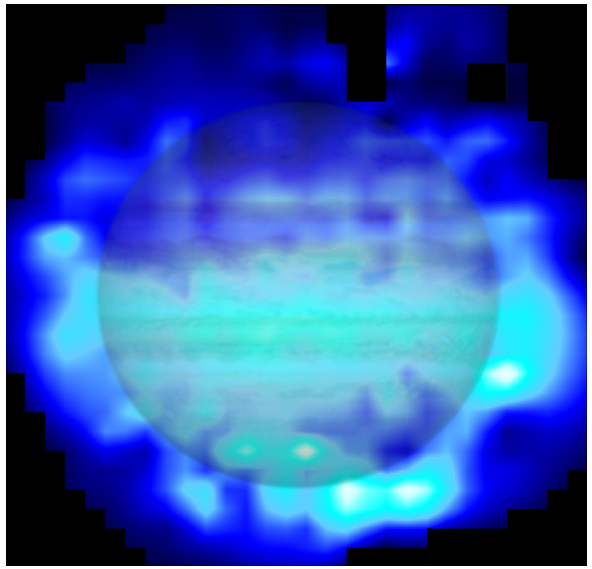


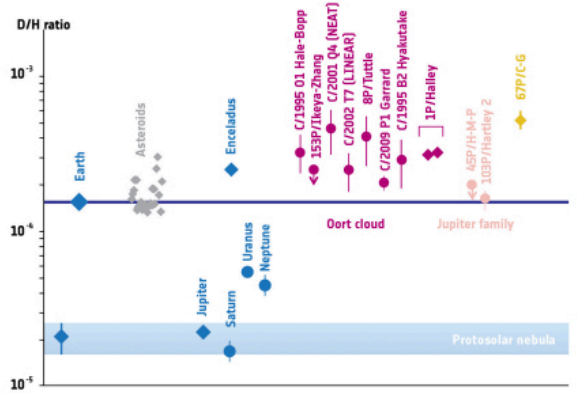


… also in the solar system

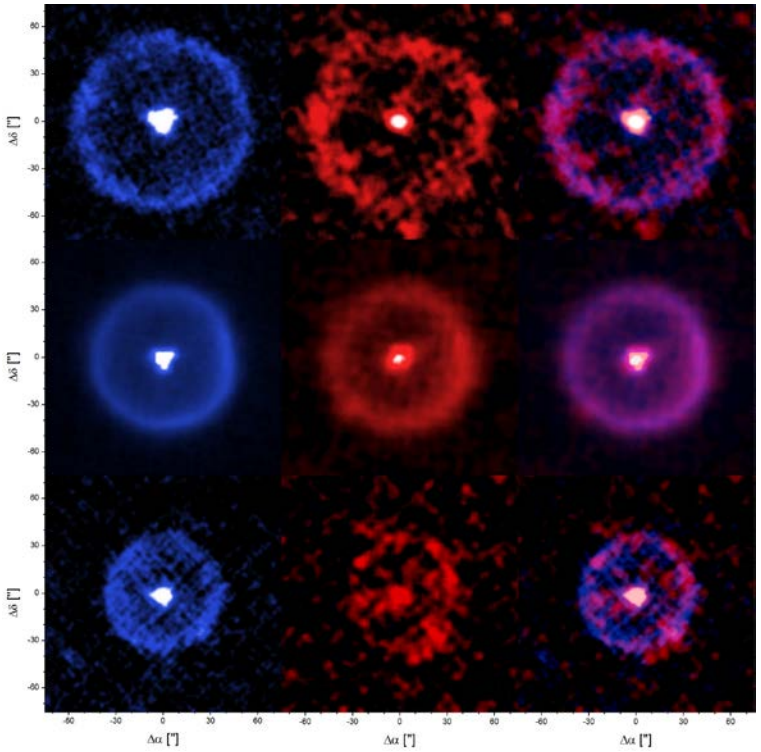


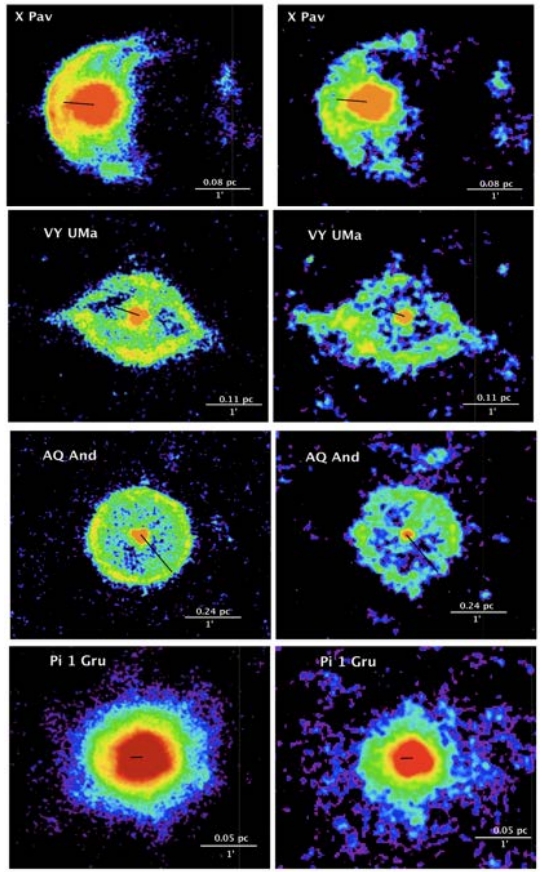


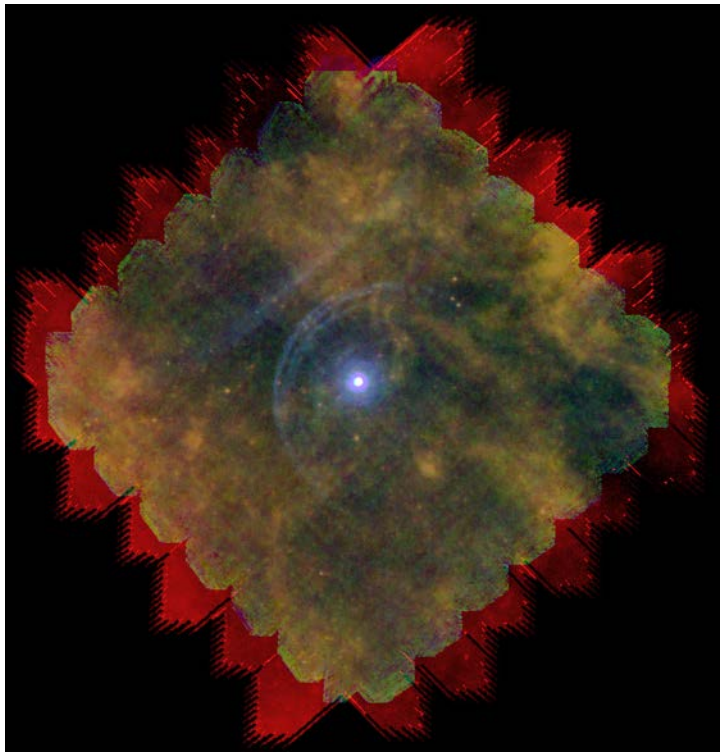




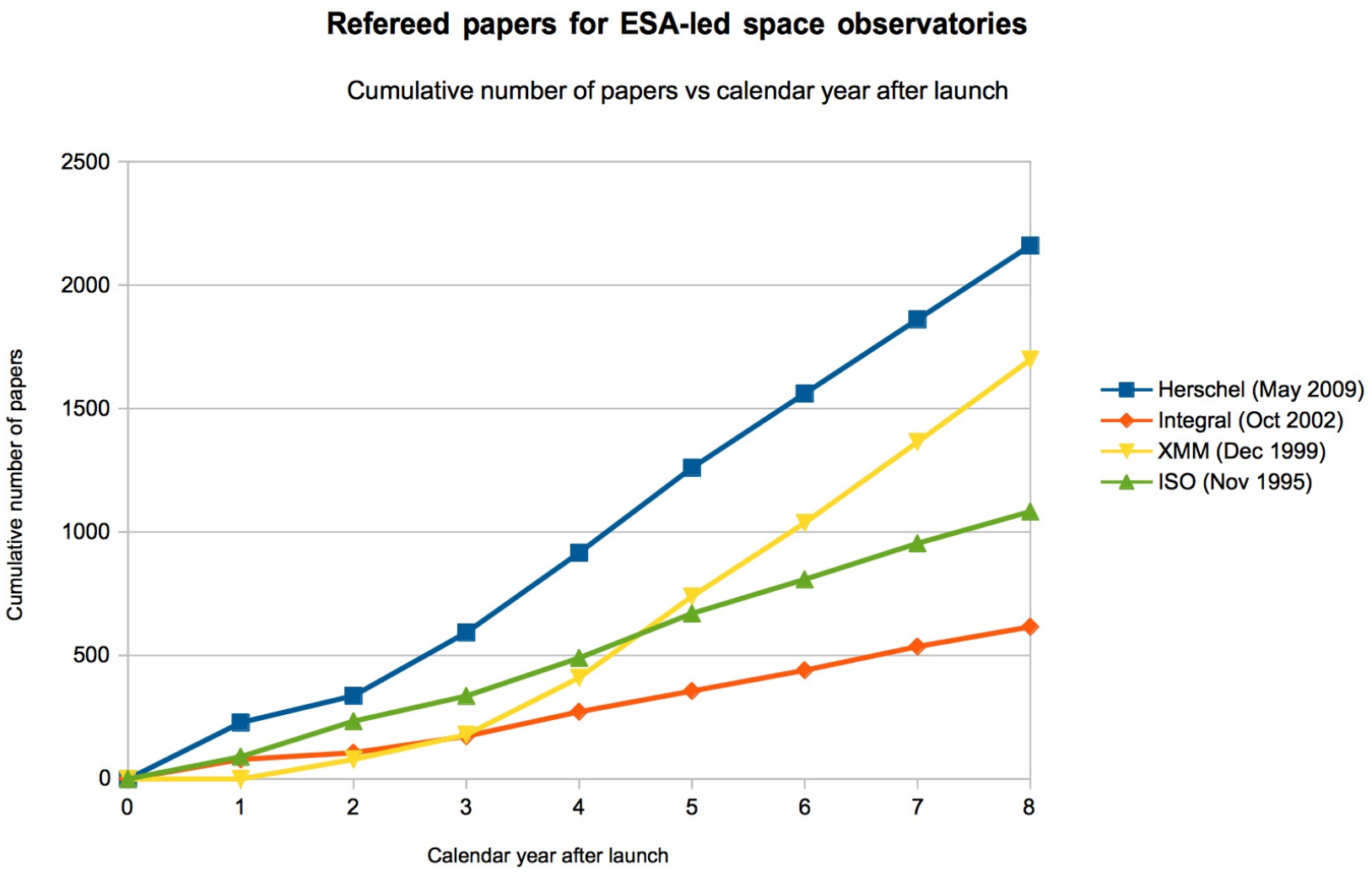
Interaction of stellar winds with the ISM







Impact of Herschel



ISO and Herschel within Horizon 2000

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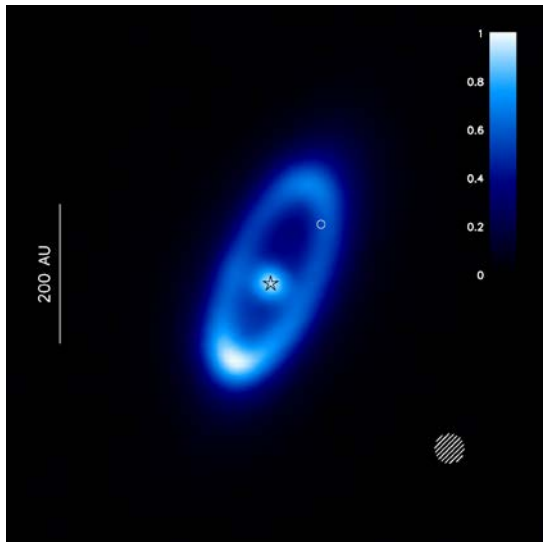
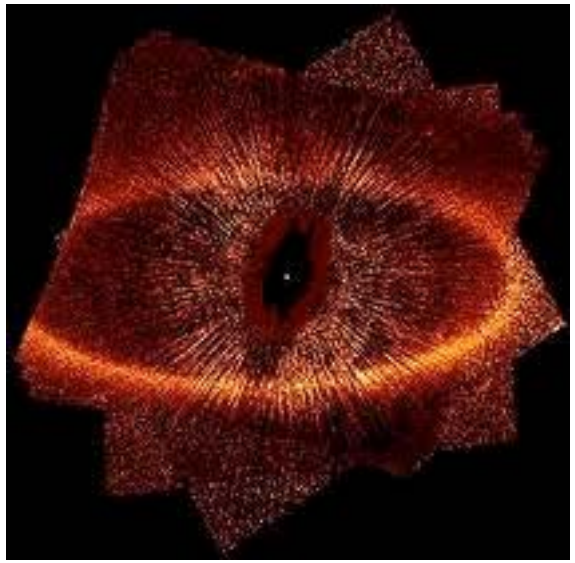
Complementarity between space missions





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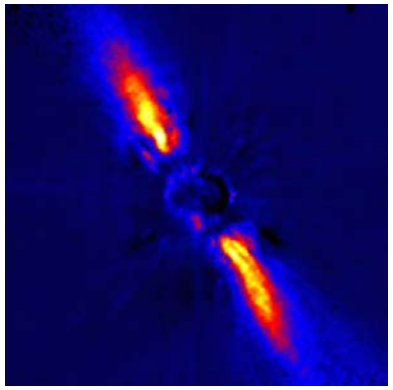
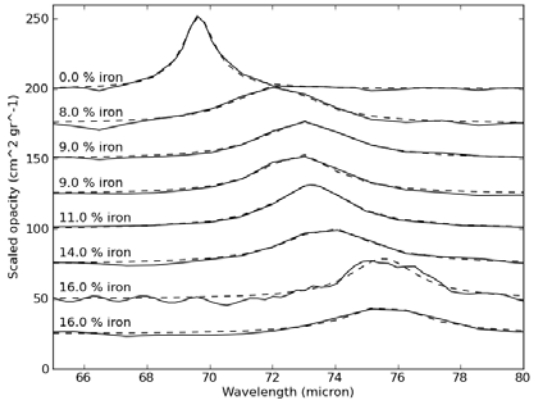
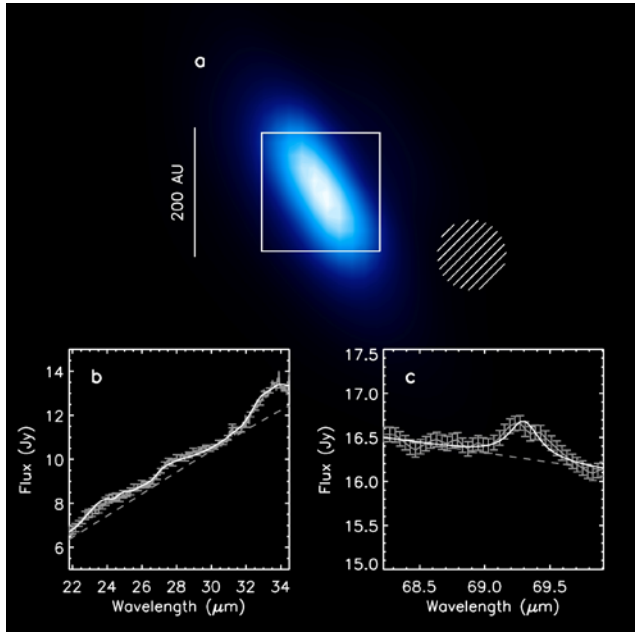
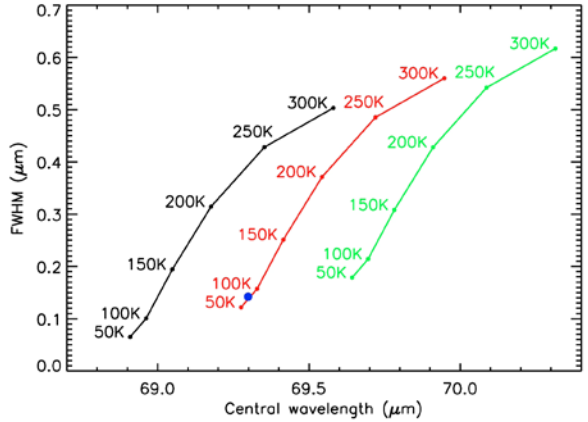
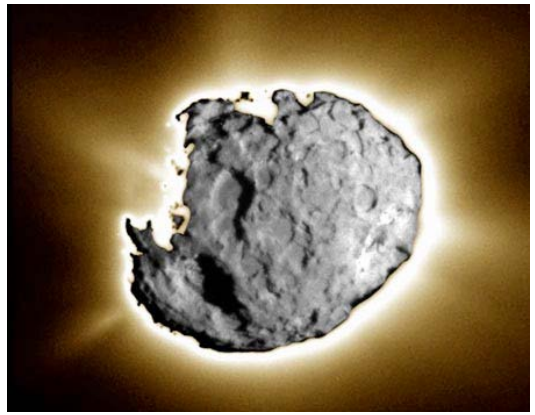


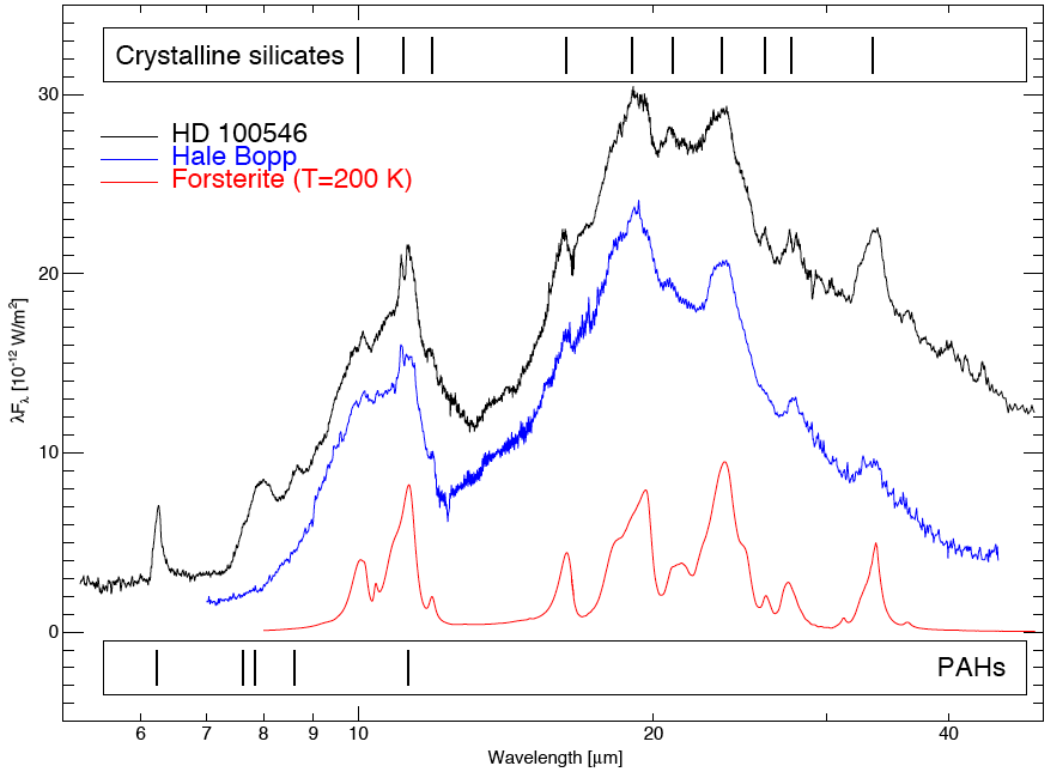




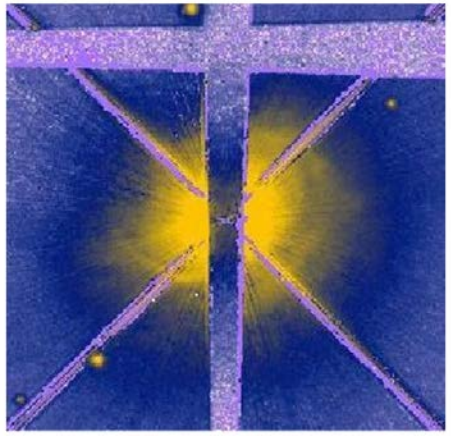




‘Astronomy’ versus ‘Solar System’



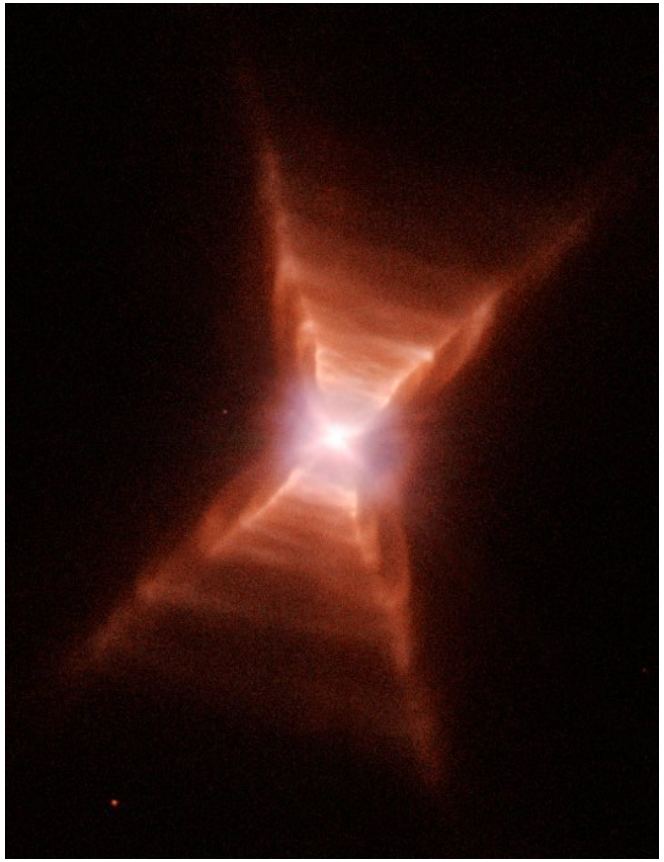
Images of isolated disks: scattered light

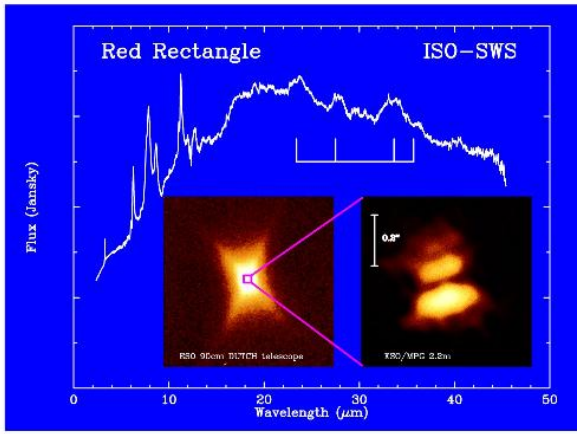


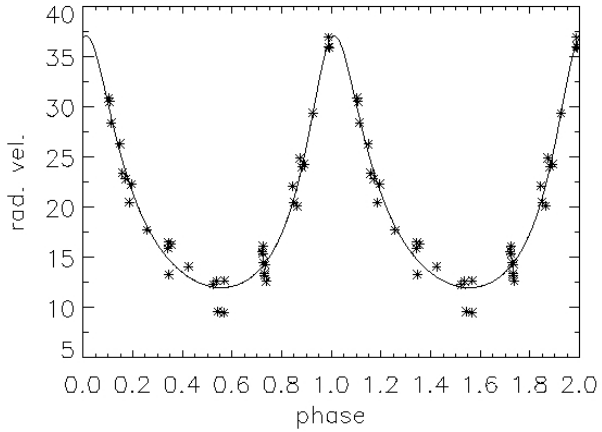
HD100546

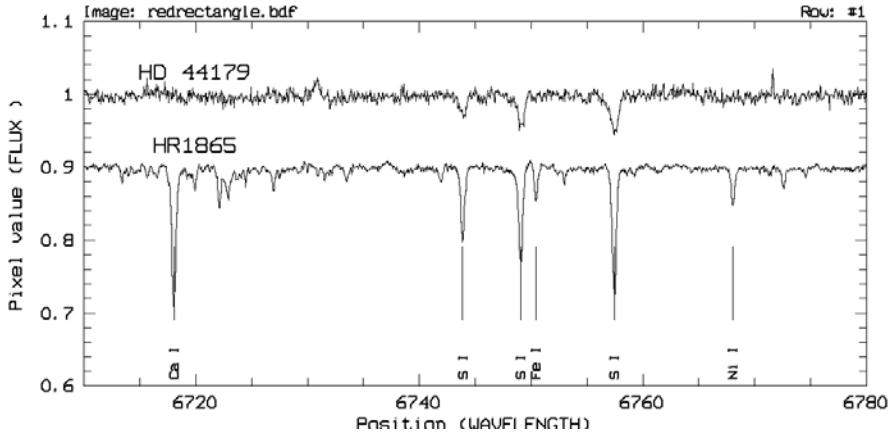
C. Grady

Complementarity of ground and space

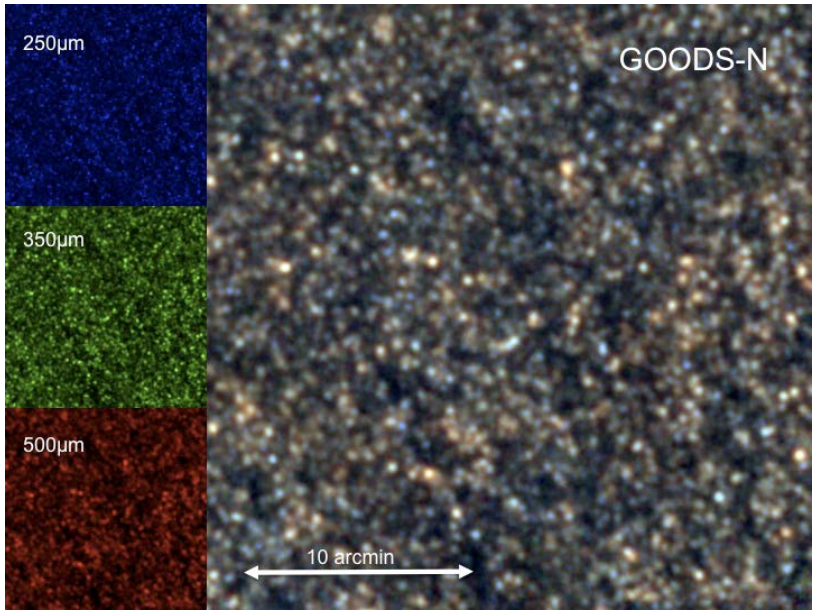


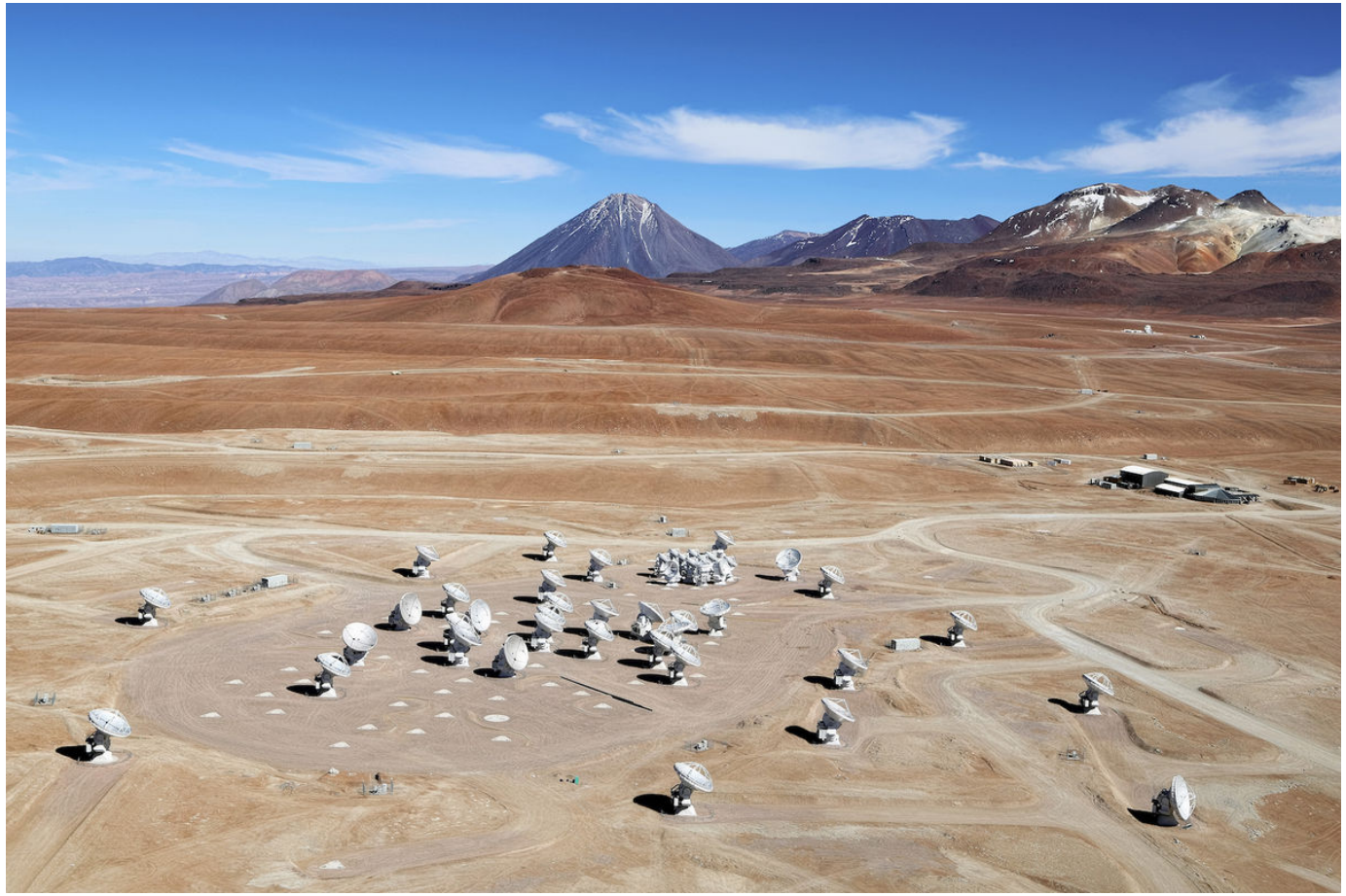






Complementarity of ground and space





Successes at the project level

- Building and managing large instrument consortia, with strong leadership from ESA, instrument PIs and PMs, and involved agencies.
- Combining Herschel and Planck was constraining, but finally enabled both missions to be realized within the sum of the original cost caps.
- Risks were taken at the technological level, but were overcome and did contribute significantly to innovative science.
- Observation efficiency was high, and the goal to be both a survey and an observatory mission was fulfilled.
- Pipeline and archive development essential for the mission and its legacy.

An incredible dream become true …

… within Horizon 2000

- Thanks to
  - The ‘cosmic vision’ of Horizon 2000 and its developers.
  - Superb ESA staff and superb PIs, and many other people involved.

- What Herschel did in return
  - Setting the scene in the far-IR
  - Bridging communities
  - Enabling – with Planck – the whole programme to succeed