Lessons Learned from Past and Current ESA-NASA Partnerships

Astronomy & Astrophysics Advisory Committee

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OUTLINE

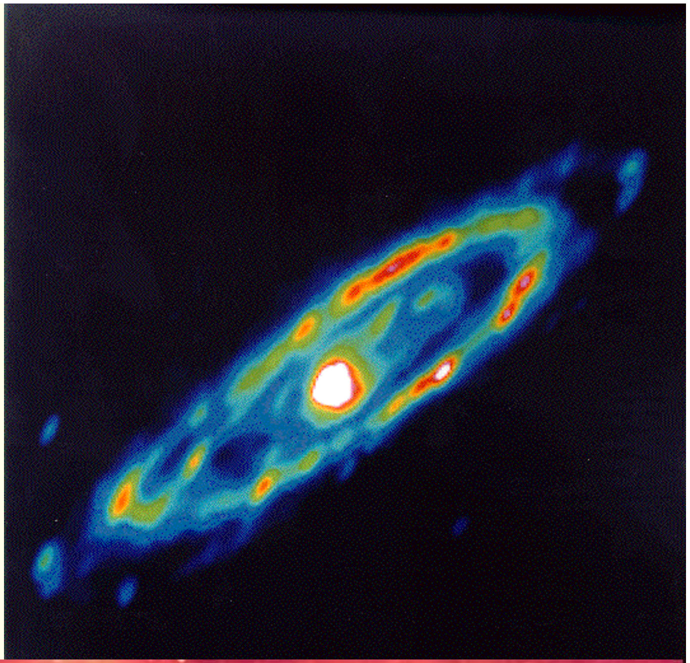
Question: What lessons from previous missions where NASA astrophysics has contributed to an ESA mission (especially Herschel, Planck)?

- Study Cases:
  - *Infrared Space Observatory (ISO)*
  - *Spitzer Space Telescope*
  - *Herschel Space Telescope*
  - *Planck Cosmic Surveyor*
- Lessons Learned: Big Picture, Elements of Partnership
- Further Thoughts

Question: How do these lessons relate to the draft “principles for access to large astrophysics projects and facilities”?

- Relevance to large surveys of the next decade

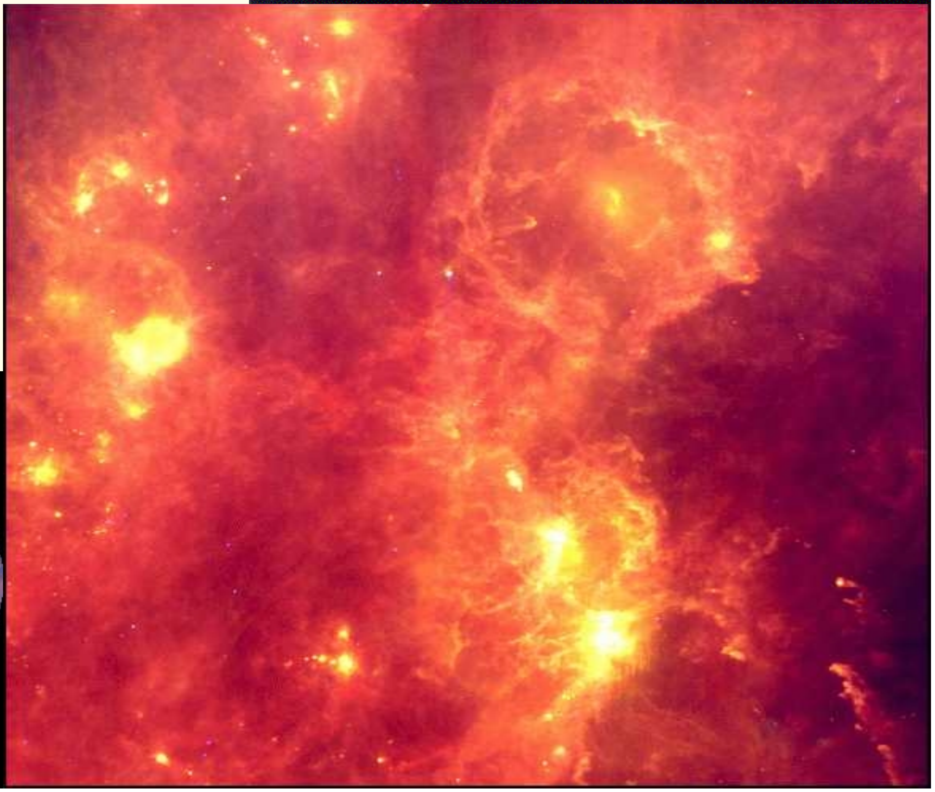
IRAS: First mid-to-far-IR All-Sky Survey

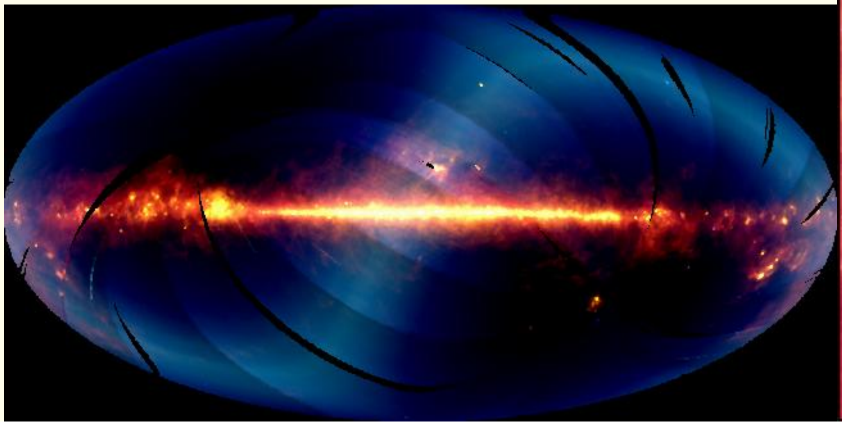


- IRAS was the first IR all-sky survey, at 12, 25, 60 and 100μm: Si and Ge photo-conductors
- Collaboration between US, Netherlands, UK, 1983

Main data products:

- Point Source Catalog ~1 Jy sensitivity
- Faint Source Catalog, a few times deeper
- All-Sky Image Atlas at 4' resolution
- On-demand co-added survey data
  - *Compact sources*
  - *Resolution enhancement*

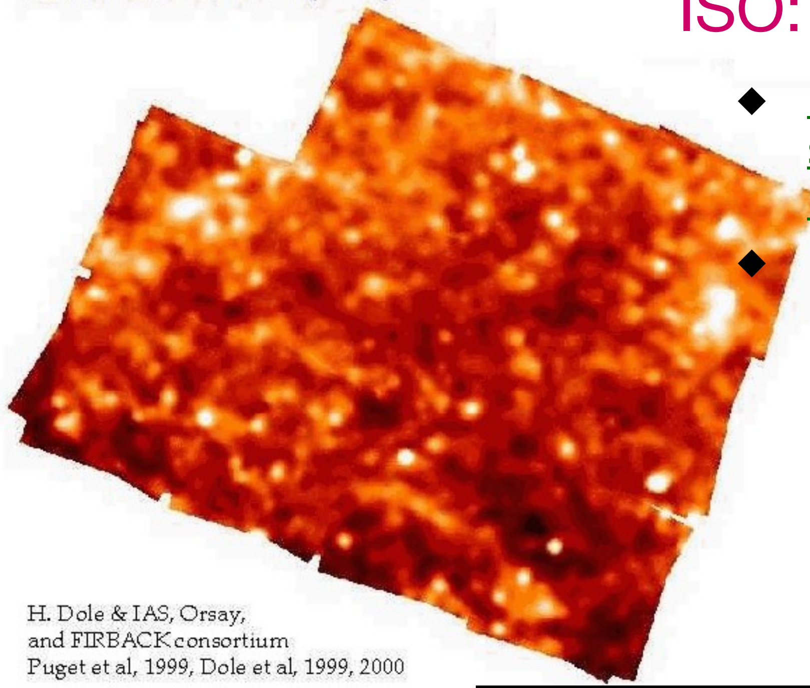


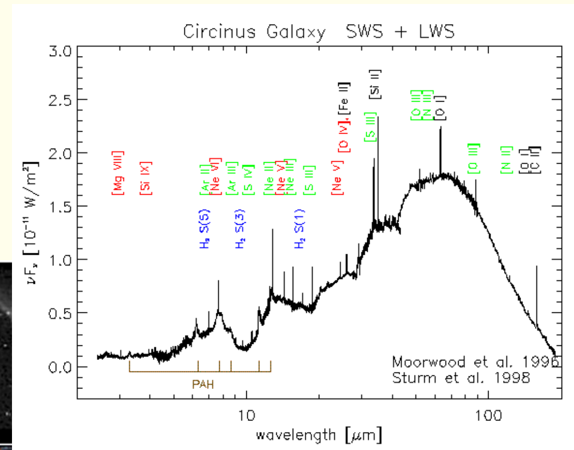


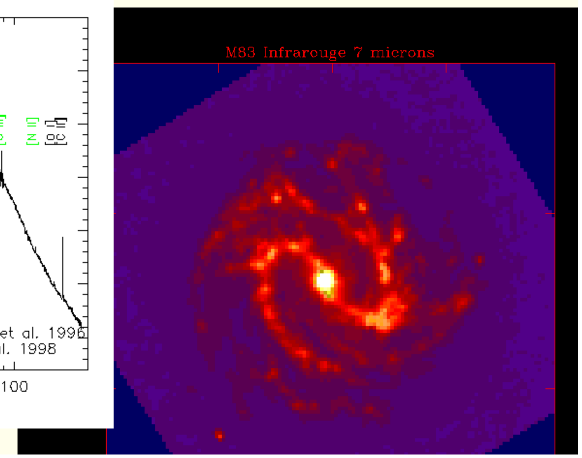
ISO: First Pointed IR Observatory in Space

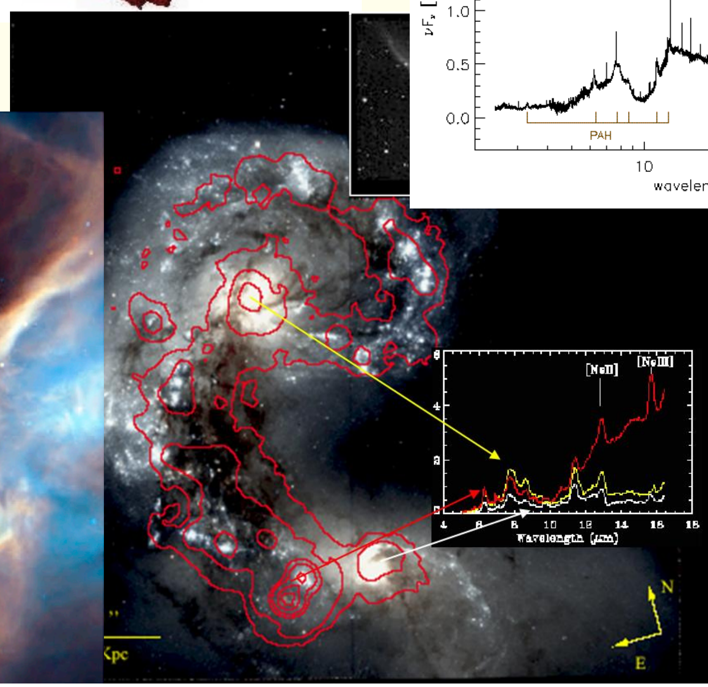
- Four versatile instruments, 2 imagers, 2 spectrometers, covering 3-240μm: Si, Ge photoconductors (1995-98)
- ESA mission with minor NASA, ISAS participation

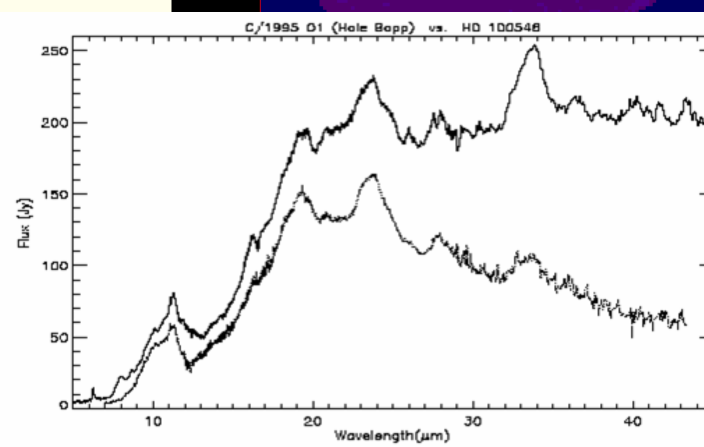
FIRBACK North 1 (FN1)





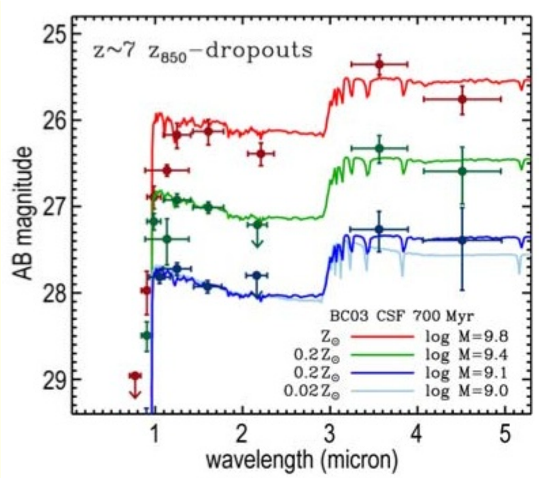


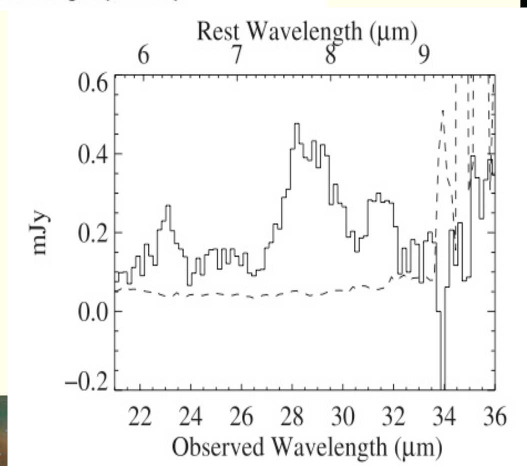


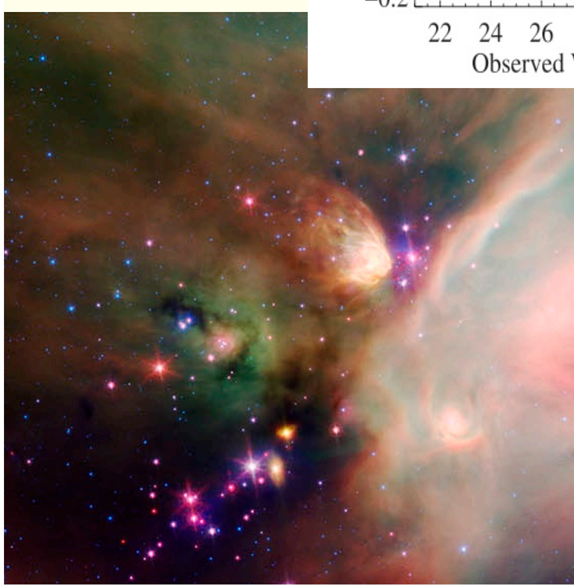


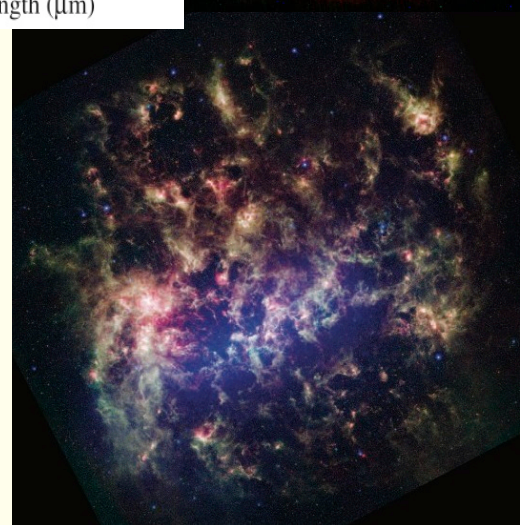
Spitzer: the NASA IR Great Observatory

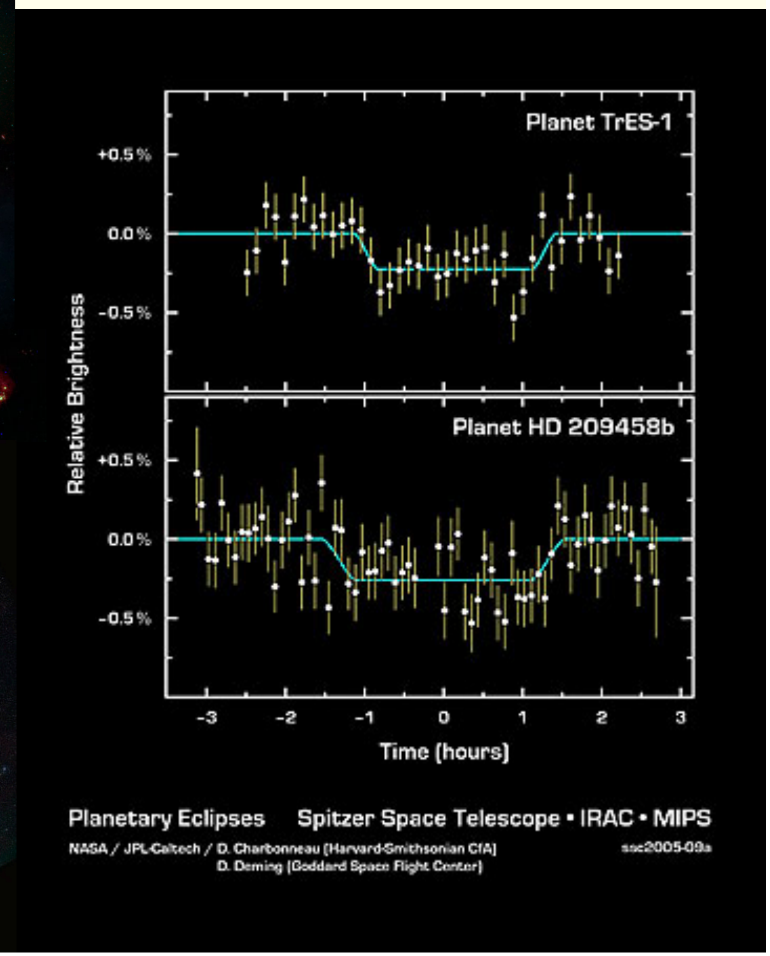
- Three instruments, imaging at {3.6, 4.5, 6.8, 8}, {24, 70 and 160} µm, 1 spectrometer 5-38µm, SED mode 60-120µm: Si, Ge photoconductors
- NASA mission, August 2003 – May 2009 cold
- Warm mission since 2009: 3.6, 4.5 µm imaging





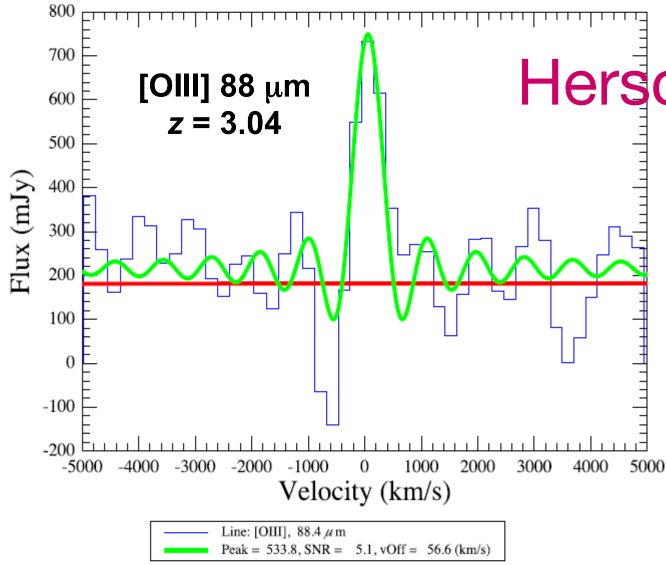


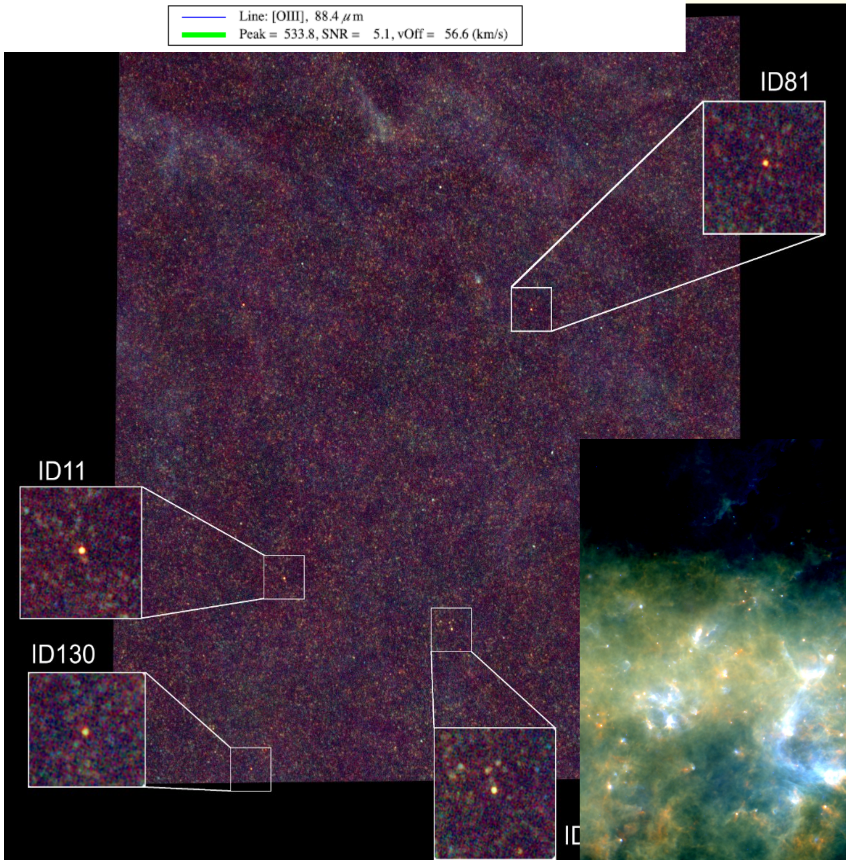


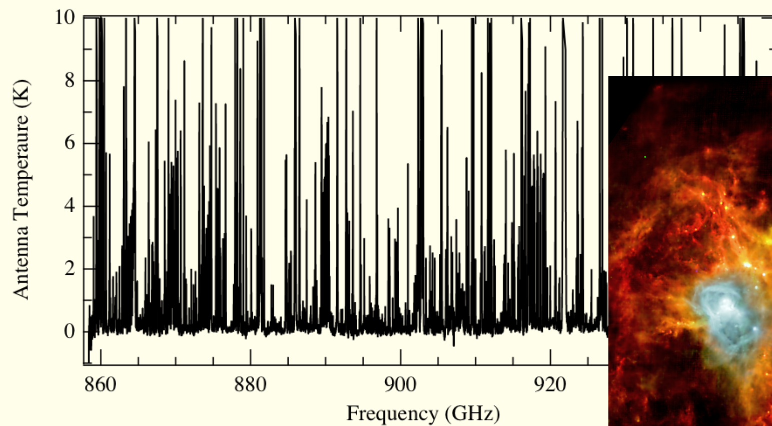


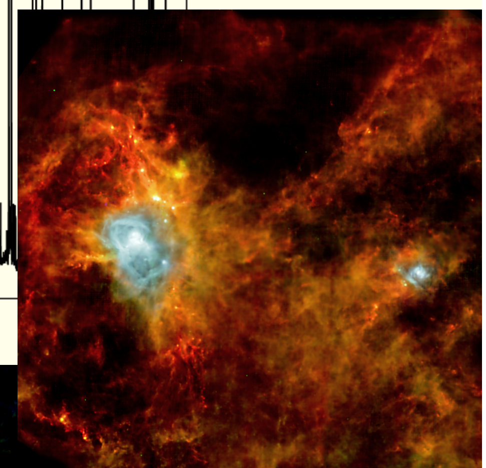
Herschel: Cornerstone FIR/Submm Observatory

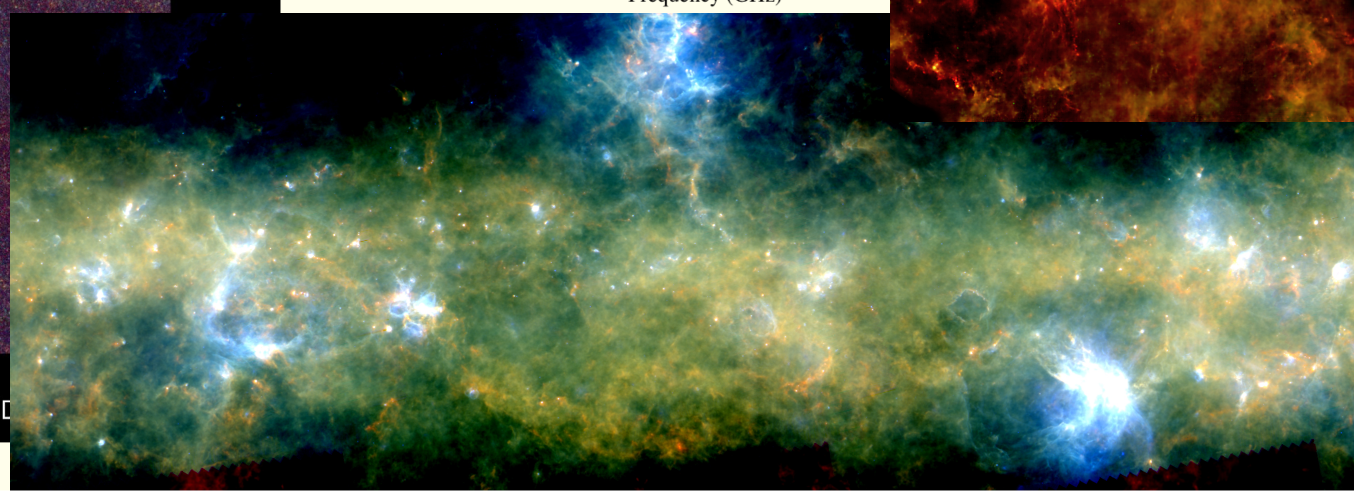
- Three instruments: imaging at {70, 100, 160}, {250, 350 and 500} μm; spectroscopy: grating [55-210]μm, FTS [194-672]μm, Heterodyne [157-625]μm; bolometers, Ge photoconductors, SIS mixers; **3.5m primary at ambient T**
- ESA mission with significant NASA contributions, May 2009 – April 2013 cold



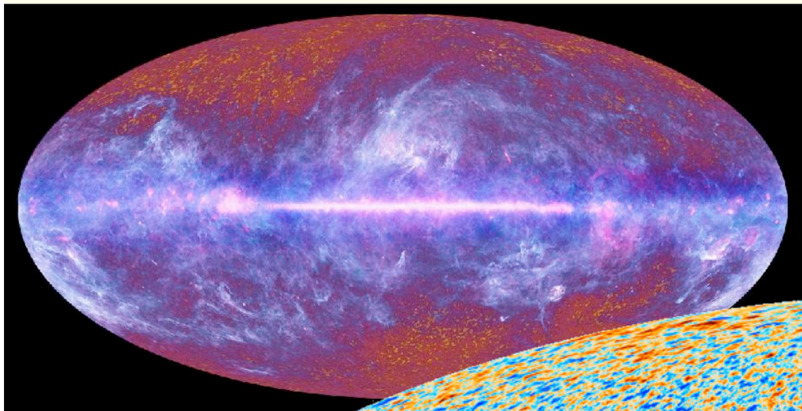






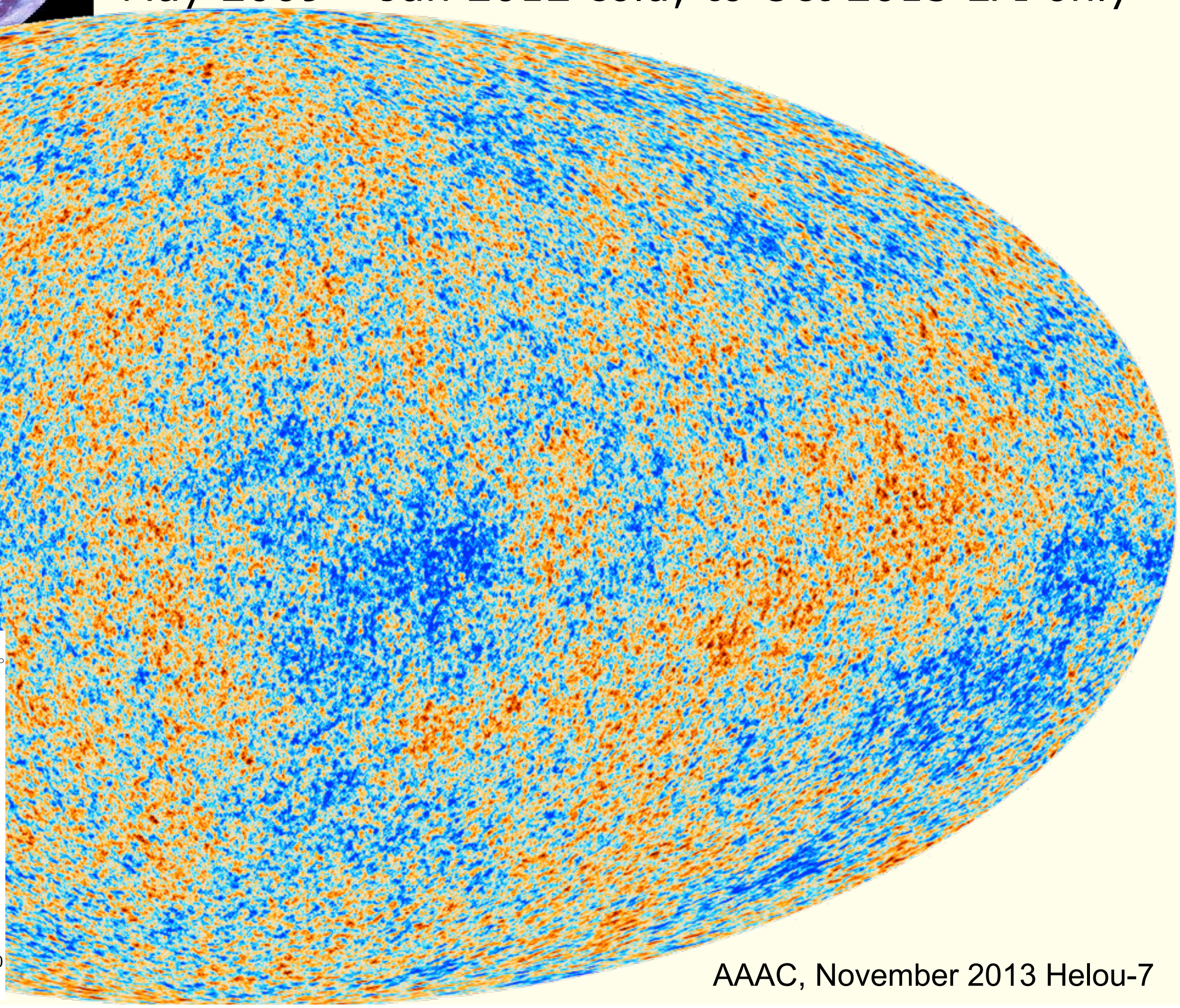


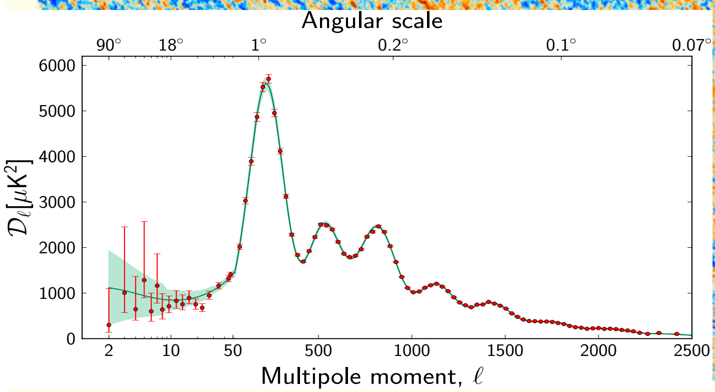
Planck: State-of-the-Art CMB+Astrophysics Survey



Two instruments, nine bands: HFI {857, 545, 353, 217, 143, 100} GHz, LFI {70, 44 and 30} GHz; bolometers cooled to 100mK, HEMT

ESA mission with significant NASA contributions, May 2009 – Jan 2012 cold; to Oct 2013 LFI only





ISO: Deal and Outcome

- ISO was an ESA-only mission, with some US individual participation as co-investigators on instrument teams and on the ISO Science Team, and some "scientific associates"
  - *Individual access to Guaranteed Time*
- Late-breaking agreement: DSN time for 30min/orbit (~30min/day) of Guaranteed Time, plus access to Open Time competitions (no quota)
  - *ISAS funded additional operations shift, also for 30min/orbit of GT*
  - *NASA & ISAS named 1 representative each to the ISO Science Team*
  - *Two or three US-based scientists were invited to join the TAC*
- NASA competed its GT independently, selecting 4 Key Projects
- In Open Time, the US community was allocated ~30% of the time (PI), and participated on many more selected proposals
- <u>Net result: US community was responsible for ~25% of ISO time</u>
  - *NASA Astrophysics investment was all in Data Analysis funding and community support at IPAC*
  - *Data quality issues, slightly ameliorated by IPAC help (late arrival)*

Spitzer: Deal and Outcome

- Spitzer is a NASA Great Observatory.

- Spitzer TAC and review committees included non-U.S. scientists as a matter of course, and all calls were open worldwide

- European scientists were responsible for ~20% of Open Time (PI) on cryo-Spitzer, and participated on many more selected proposals
  - *For Cycle 10 (Oct 2013) 15% of successful PI's were foreign-based*

- NB: ISO-SIRTF, XMM-AXAF debates were similar to debate on Euclid-AFTA/WFIRST
  - *Lesson 1: NASA participation in "similar" ESA missions does not kill prospective NASA-led missions*
  - *Lesson 2: XMM, ISO prepared US community for Chandra, Spitzer, and provided experience for design of mission and operations*

Herschel: Deal and Outcome (1)

- Herschel is an ESA Cornerstone Mission (~B$ class) with significant NASA contributions (10-15% of mission cost up to launch)
- Community advocacy for Herschel-like mission was a Transatlantic movement, and ESA moved on it first
  - *Instrument proposals to ESA had US co-I's and hardware components*
- NASA primary H/W participation was in <u>enabling detector technologies for 2 instruments</u>
  - *Bolometers and amplifiers assembly for SPIRE, plus expertise*
  - *SIS mixers and other components for HIFI, plus expertise*
- Instrument Team participation results in access to GT

- Two US-based mission scientists and one optical system scientist were selected in open competition, with additional access to GT

Herschel: Deal and Outcome (2)

- Aside from the above, ESA and NASA exchanged LoA:
  - *NASA provides Science Operations expertise and software (Spitzer heritage), shares any s/w or documentation developed at NHSC/IPAC*
  - *NASA provides resident astronomer at Herschel Science Center in Spain*
  - *ESA provides "appropriate US scientist representation on HOTAC"*
  - *ESA provides NHSC with full access, as "integral part of the Herschel Science Ground System"*
  - *NB: ESA-NASA reciprocally open proposal calls; no quotas on Herschel*
- Net result: Open Time calls on Herschel have resulted in U.S. PI's carrying about half the Open Time, in addition to GT participation
  - *Additional participation by US co-I on ~35% of Open Time*
  - *A third of all Key Projects had U.S. PI's and all had U.S. participation*
- Data quality issues were addressed quickly, and NHSC has much more insight, ability to help (compared to ISO)
  - *U.S. activity on publications so far reflects proposal success rate*

Planck: Deal and Outcome (1)

- Planck is an ESA Mid-Sized Mission with significant NASA contributions (10-15% of mission cost up to launch)
- Community advocacy for Planck-like mission was a Transatlantic movement, and ESA moved on it first
  - *Instrument proposals to ESA had US co-I's and hardware components*
- NASA primary H/W participation was in <u>enabling new technologies</u>
  - *Spider-web bolometers and amplifiers for HFI, including polarization-sensitive bolometers, plus expertise*
  - *HEMT radio amplifiers for LFI, plus expertise*
  - *Hydrogen sorption coolers to get down from passive (~50K) to ~20K*
- One (2) US member on the Science Team, ~80 US Planck scientists
  - *Fully integrated team, access to data, software, discussions, analysis and results*
  - *E.g. Planck Editorial Board co-chaired by U.S. scientist*

Planck: Deal and Outcome (2)

- Agreements between NASA and CNES and ASI
  - *NASA provides engineering support for delivered H/W*
  - *NASA provides support for mission design & planning, data analysis*

- US Planck scientists account for 20-25% of data analysis activity
  - *Lead many activities and papers, and participate in essentially all*
  - *Planck papers are mostly "Planck Collaboration, authors-alphabetical"*
  - *DoE-NASA agreement provides main simulations capability for Planck (supercomputing at NERSC)*
- First Planck data release, "Early-Release Compact Source Catalogue (ERCSC)", was produced in US
  - *First look at all-sky catalog at λ>300μm, ~10^4 sources, very fast release*
- The Planck Archive is available at both ESA (ESAC) and NASA (IPAC)
  - *NASA Archive has unique tools for enhanced data usability, especially by non-CMB community (local detector time-lines for sources, local map construction)*

Lessons Learned: Big Picture

- NASA and ESA can both fund, build and operate major missions
  - *Euclid is happening, as will other major missions on both sides*
- ISO, XMM did not kill SIRTF, AXAF, and WMAP did not kill Planck
  - *Euclid by itself will not kill AFTAWFIRST, nor will NASA buying into Euclid*
  - *Research communities function largely as global entities, will push missions towards complementarity, will optimize across boundaries*
  - *Principle 1 captures this. Need to recognize critical role of community*
- The U.S. has great strengths in leading-edge technologies, but more especially in human resources, and institutional traditions of research support by agencies and universities
  - *With access & support, U.S. community will get its share of the science*
- U.S. contributions, properly targeted, will yield rich science dividends for U.S. community and enrich the science globally
  - *Ultimately, a richer science return from the mission is good for everyone*
  - ***Similarity of science goals worldwide is an opportunity:** partnerships are very valuable stepping stones between US-led missions, for community and for project-level planning*

Lessons Learned: Elements of Partnership (1)

- Proven formula: combine grass-roots science collaboration, special or unique hardware contributions, and a NASA Science Center (community support based on participation in science data system)
  - *Agencies' role: create a high-level framework appropriate for the specific mission and supportive of grass-roots collaboration*
- Good relations at working level are crucial, so high-level framework should encourage participation, and let working relations develop:
  - *Among scientists: build a science community for the mission*
  - *Among instrument/payload builders: optimize interfaces locally*
  - *Among Science Centers: learn by doing, add value for all users*
- Agency-level framework should recognize community needs, and stress reciprocity not detailed deal-making
  - *Scientists then focus on science rather than worry interpretation of rules*
  - *Framework is needed very early: leave room for flexibility, evolution*
- Critical Mass of participation is important:
  - *Thin presence makes for difficult interactions; 10% share seems to be a reasonable threshold*

Lessons Learned: Elements of Partnership (2)

- An integrated mission community sets stage for "level playing field" and is best guarantee of "fair science return"
  - *No quotas on science exploitation helps U.S. and global science return*
  - *Principle 4 captures this*

- However, capturing science return in a global competitive environment requires proper support for the home team

- U.S. agencies have diverse approaches for this support, but ultimately two aspects are needed to "level the playing field"
  - *Funding people to analyze data and publish results*
  - *Shared structure and services to support common needs robustly, efficiently e.g. supercomputing, observing facility or mission science center*

Agency Support: Role of NASA Science Centers

- NASA Science Centers were created to enable broadest access
  - *National Academy of Sciences advised that major telescopes "not be used by only a few astronomers, but [that] a large part of the community must be closely involved with the instrument over a long period of time." (Institutional Arrangements for the Space Telescope, 1976)*
- Efficacy recently validated by NAS in "Portals to the Universe" report
  - *The "NASA Science Centers have transformed the conduct of much of astronomical research and set in place a new paradigm for the use of all large astronomical facilities", remedying "what had become an insular culture for accessing space astronomy data." (2007)*
- Science Centers (CXC, IPAC, STScI) have created a competitive edge for U.S. in science exploitation, one of few remaining
  - *Advantage of national scale*
  - *Principles 2 & 3 will enhance importance of Science Centers: Value of Open Access to data (increasingly Big Data) and facilities (increasingly sophisticated) is limited by ability of individuals to exploit that access*

Further Thoughts on the "Principles"

- Principle 4: "openly advertised criteria that are equally applied"
  - *This point should apply more broadly, especially for #2 (Open Data) and #3 (Open Facilities)*
  - *Should be articulated early*

- Principle 2 correctly addresses Open Data, "standard data products made public in a timely and usable manner"
  - *The ability to extract more advanced information is left in the competitive sphere. This ability is critical in the era of Tera-scale and Peta-scale surveys*
  - *Providing support to enhance this ability is critical, through targeted community funding and through targeted Science Center activities*
    - e.g. NHSC virtual machines, supercomputing resources

Footnote: Where I Learned my Lessons

- Member or leader of many observing projects, science investigations
- Served as NASA representative on ISO Science Team, led one of the U.S. Key Projects on ISO (resulted in ~20 refereed papers)
- Co-I on original proposals that grew into Herschel and Planck
  - *Active Planck "Core Team Scientist", member of Editorial Board*
  - *Advised NASA on Herschel participation agreement*
  - *Frequent attendee of Herschel Science Team meetings as observer*
- As IPAC Director
  - *Responsible for NASA Herschel Science Center*
  - *Responsible for U.S. Planck Data Center (Data availability to U.S. team, ERCSC generation, U.S. Planck Archive construction)*


IRAS (1983), 12–100 microns
ISO (1995), 7–15 microns
2MASS (1997), 1.3–2.2 microns
Spitzer (2003), 3.6–24 microns
A Quarter Century of Infrared Astronomy
The Rho Ophiuchus Star-Forming Region