In pursuit of Cosmic Origins

NASA Astro Road Map Town Hall Meeting

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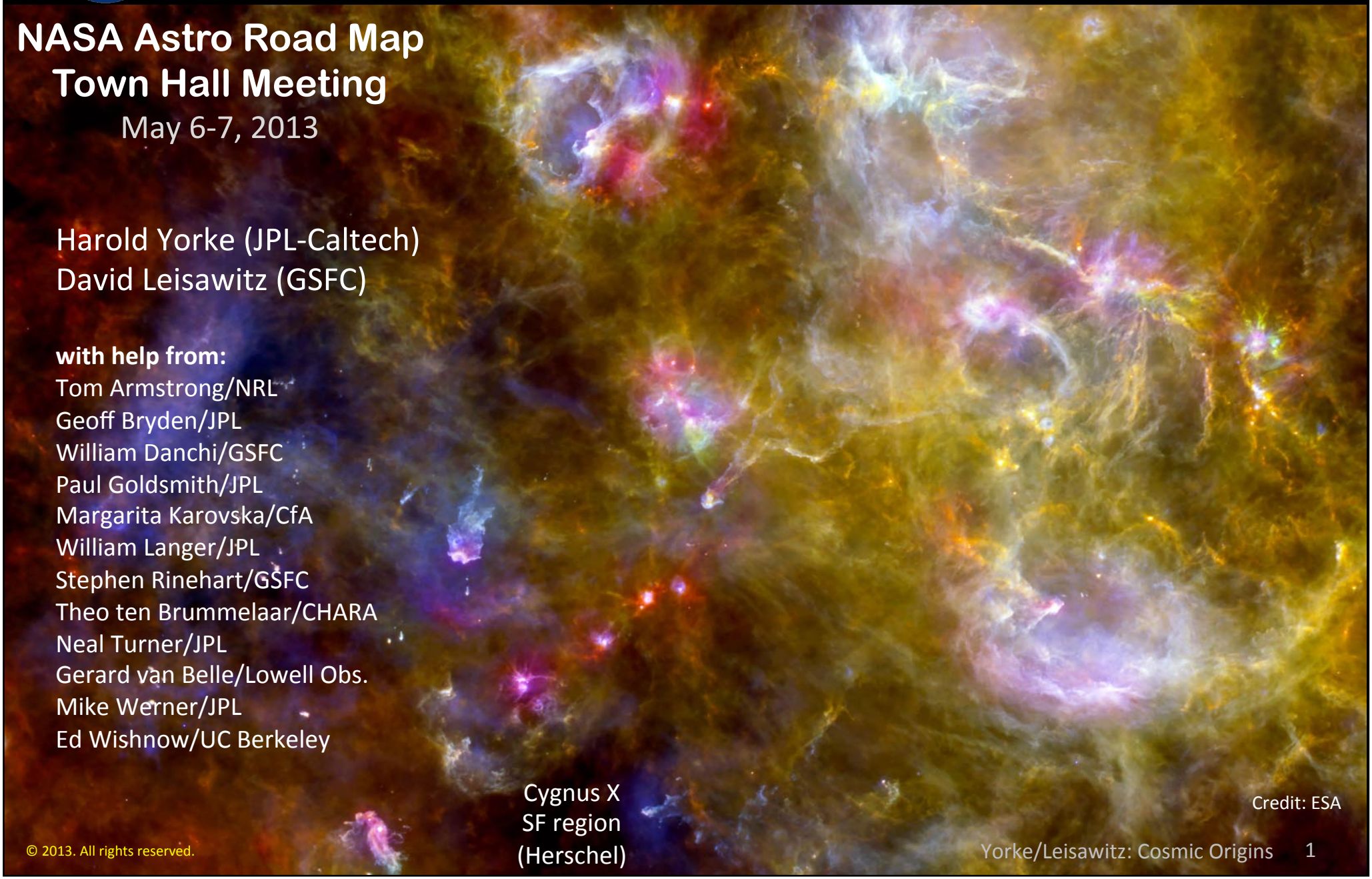

Cygnus X
SF region
(Herschel)

Credit: ESA

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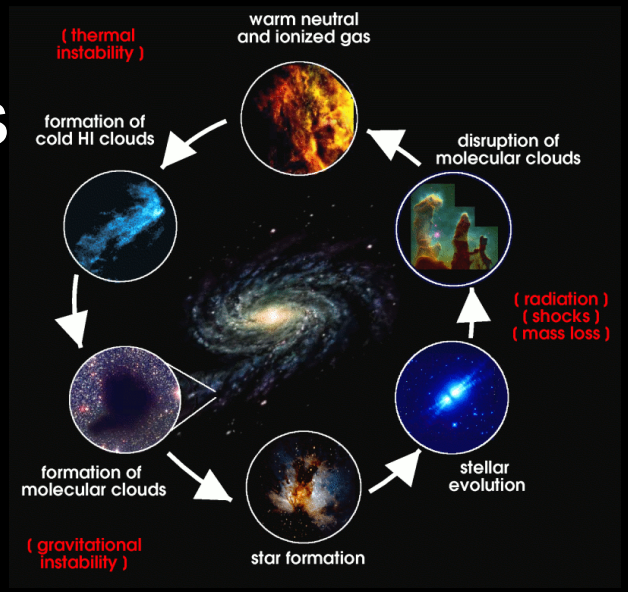
In pursuit of Cosmic Origins: The local universe

Q: Why do we care?



- Addressing NASA's Big Questions

  How did we get here?

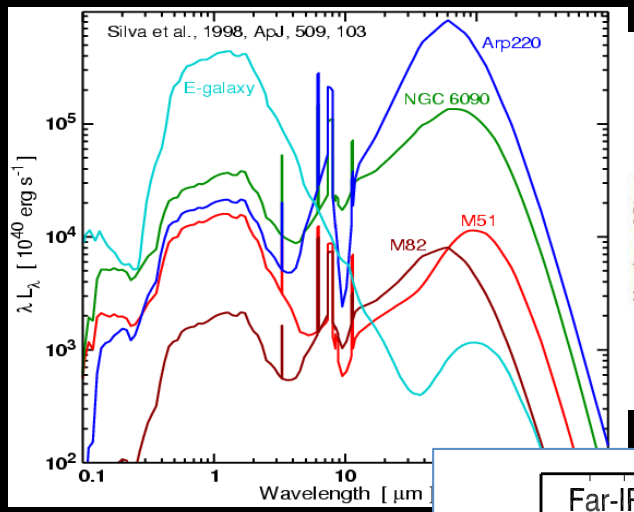
  Are we alone?

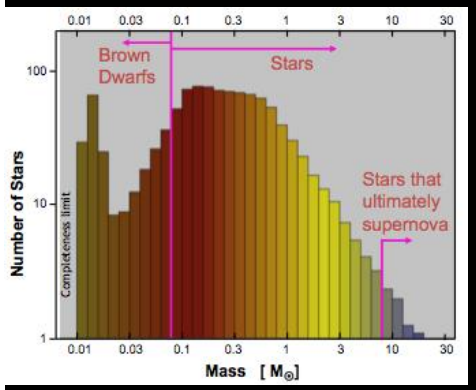
The local universe, namely the Milky Way and the nearest galaxies provide an excellent laboratory for detailed studies of star formation, stellar evolution and interactions of stars with their local environment, but higher spatial resolution, higher spectral resolution, better temporal coverage over a broader spectral range than possible today are all necessary ingredients for progress.

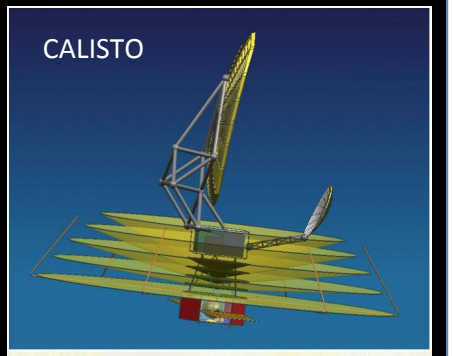
The easiest way to improve spatial resolution: look at nearby objects

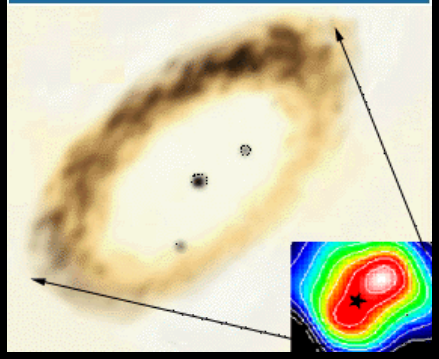
In pursuit of Cosmic Origins: The cold universe

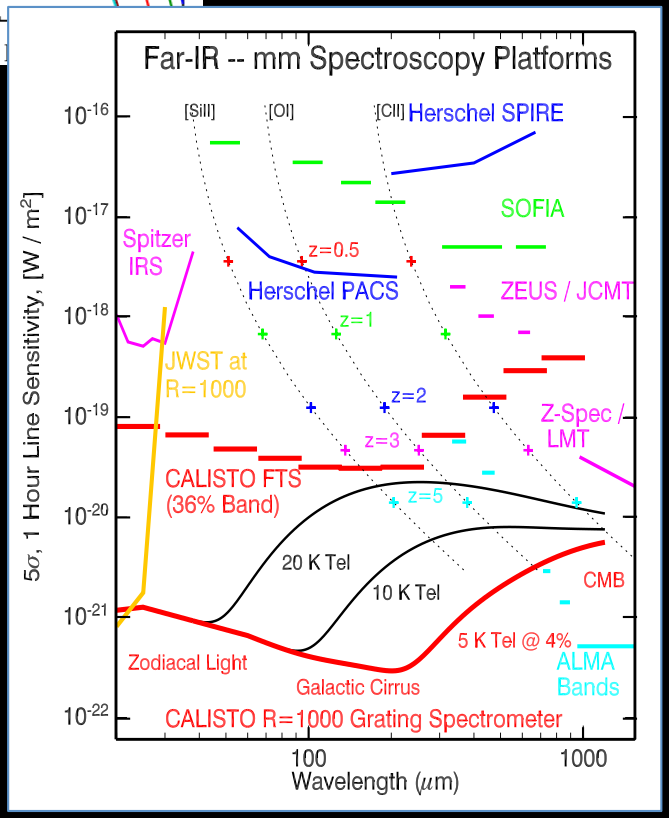
Q: How do stars (and planets) form?











Science objectives

- Determine how molecular clouds develop necessary substructure and evolve into a star-forming mode
- Determine how molecular cores collapse, fragment and form clusters of stars
- Explain the IMF and its dependency on local conditions
- Investigate how individual stars and binaries form and how they create an environment conducive to planet formation

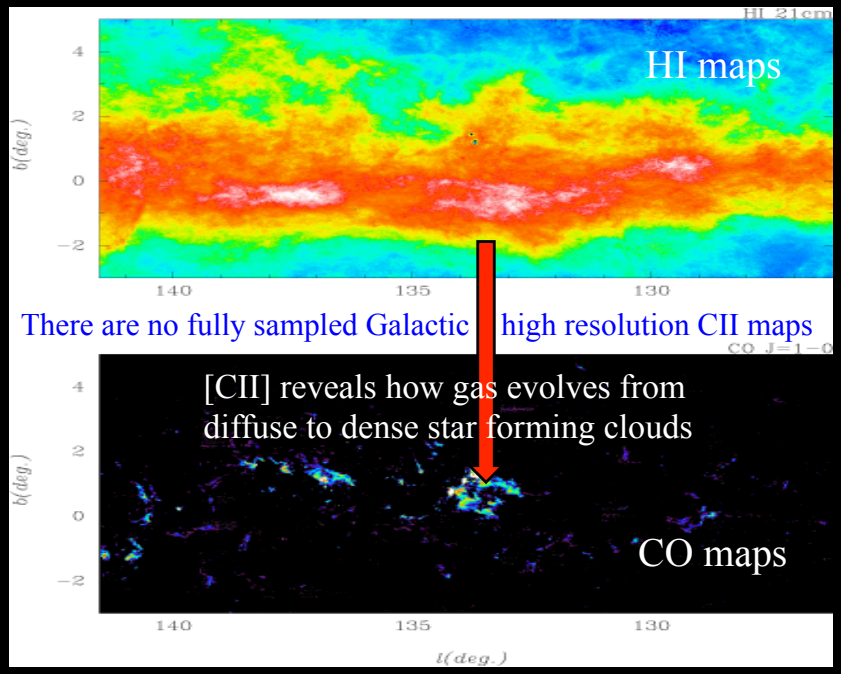
Necessary measurements

- Need detailed understanding of ISM (next slide)
- Star formation - near and far, now and long ago - is a far-IR problem; want R~1000 far-IR maps of star forming regions
- Require far-IR interferometer for studies of earliest stages of planet formation (see slide #7)

Technology needs

- Cooled FIR 4+m-class off-axis space telescope
- Large array far-IR detectors 20-300μm
- Efficient cryo-coolers to 4K

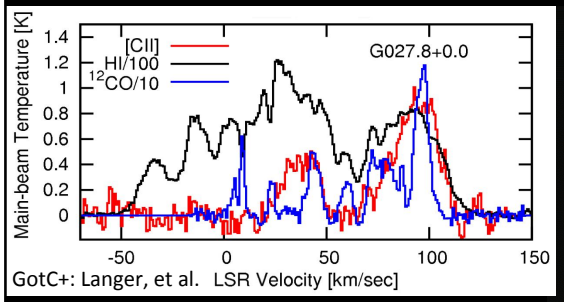
In pursuit of Cosmic Origins: The dynamic ISM



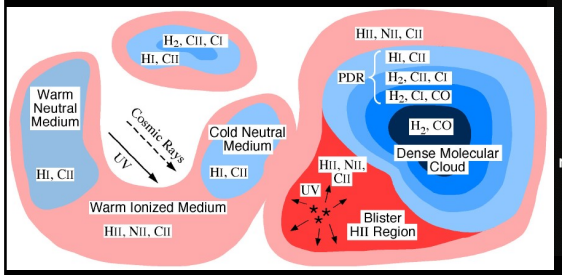
Top: HI 21cm emission from galactic plane

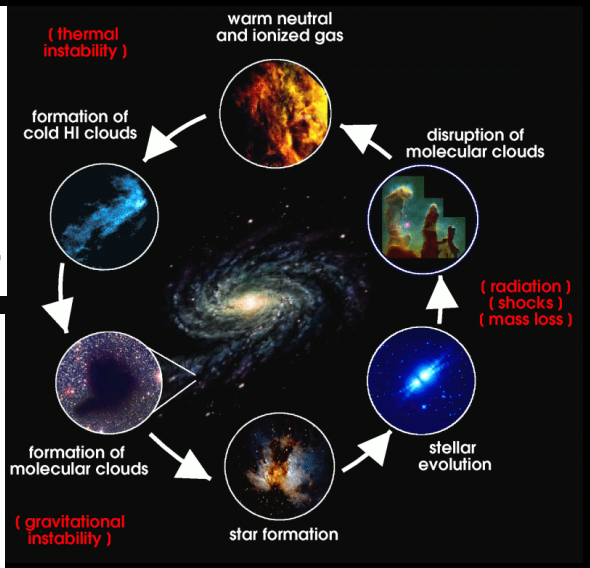
30-50% of ISM material in galactic plane not seen in HI or CO; it is revealed by [CII] emission

Bottom: CO J=1-0 emission from galactic plane



GotC+: Langer, et al.





Q: What is the life cycle of the ISM?

Science objectives

- Investigate the 3D structure and kinematics of the interstellar medium of the Milky Way and nearby galaxies
- Characterize the intermediate density "hidden molecular component" of the ISM (so-called "CO-dark molecular gas") to reveal how galactic gas evolves from diffuse HI clouds to the dense molecular clouds
- Understand what drives star formation on different Galactic spatial scales

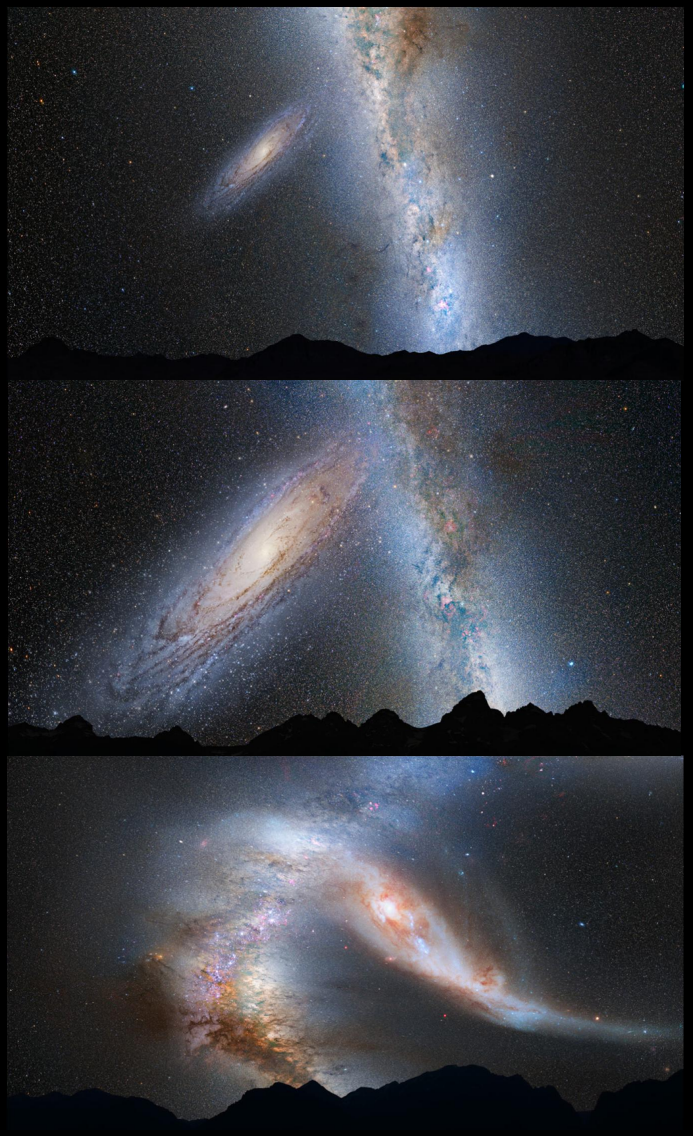
Necessary measurements

- Observe directly and/or develop new tracers for the molecular hydrogen component of dense molecular clouds; the main component of these clouds.
- High spectral resolution (1 km/s) maps of key transitions, e.g.: [CII]157μm; [OI]63μm; [NII]205μm; HD110μm; H_2O; …
- Obtain deep maps of entire Galactic plane and nearby galaxies over a wide velocity range

Technology needs

- Heterodyne array receivers in the THz
- Cryo-coolers to 4K

In pursuit of Cosmic Origins: The MWG structure



From: Hubblecast 55: Crash of the Titans
http://youtu.be/fqjSgZdo5XE credit: ESA/NASA/STScI

Q: What is the history of the MWG?

Science objectives

- Determine the star formation and merger histories of various stellar components of the Galaxy
- Investigate the 3D structure and kinematics of the stellar content of the Milky Way and nearby galaxies
- Analyze stellar and ISM abundances as a function of galactic position

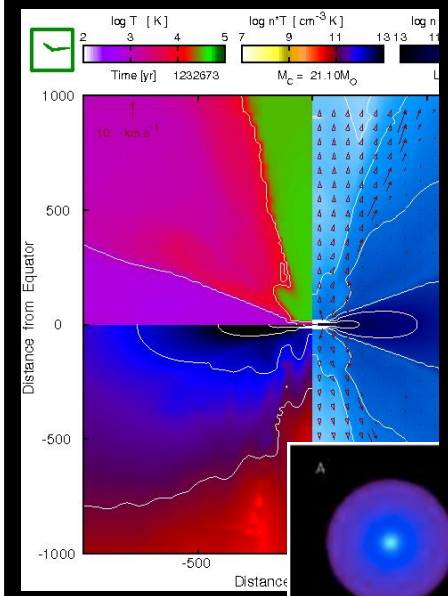
Necessary measurements

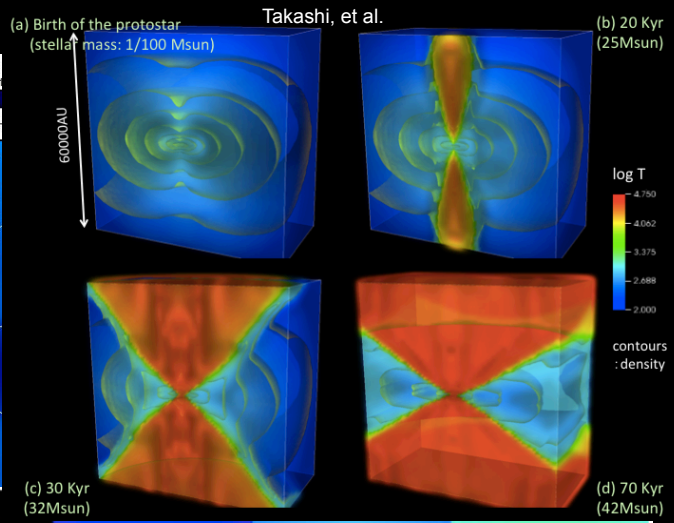
- Survey entire Galaxy and nearby galaxies in mid-IR at different epochs of varying time delays to detect and determine distances to Cepheids, Mira variables and RR-Lyrae stars via period-luminosity relationship
- Obtain radial velocities of large number of stars at known distances
- Obtain extinction maps using $>10^7$ stars at known distances to determine 3D structure of dusty gas
- Heterodyne survey in far-IR (see 3rd slide)

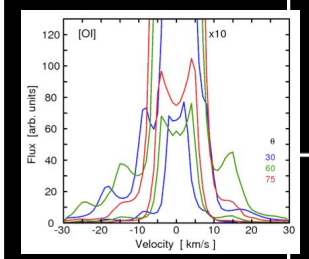
Technology needs

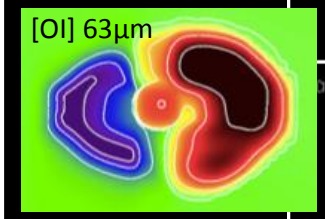
- Cooled IR space telescope optimized for repeatable surveys
- Large array IR detectors
- Cryo-coolers to 4K

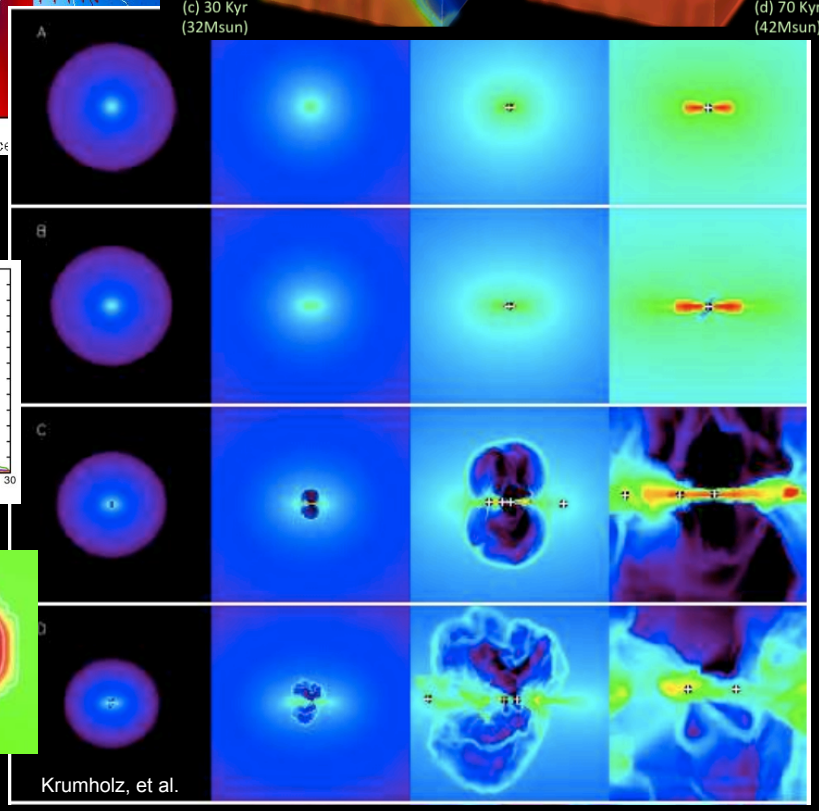
In pursuit of Cosmic Origins: Theory











Q: How do we connect the dots?

Science objectives

- Convert telescope output into physical parameters
- Disentangle the "snapshots" of cosmic evolution into a sequence of events from the Big Bang until the creation of life on Earth

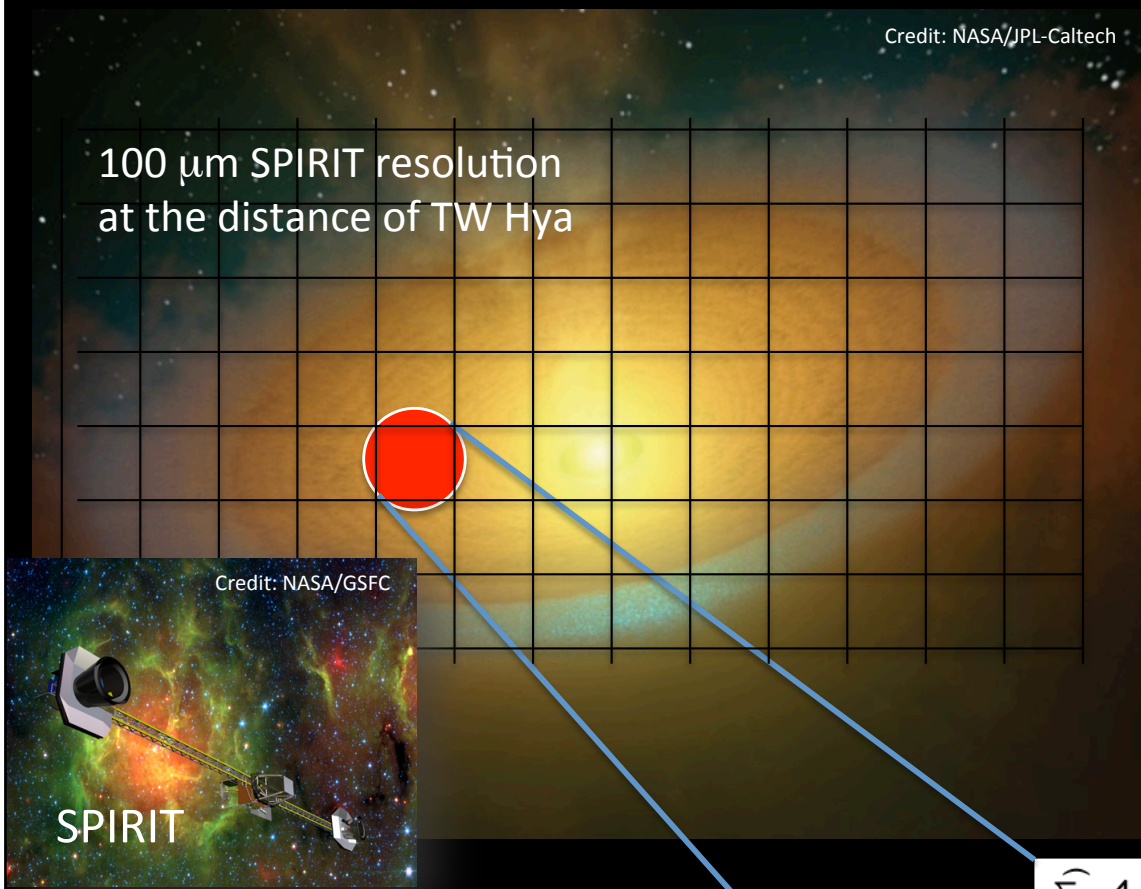
Necessary measurements

- Improved diagnostic tools and laboratory data
- High spatial resolution 3D simulations of cosmic phenomena with detailed microphysics
- Simulations of observables: use of "numerical telescopes" to allow comparison to observations

Technology/organizational needs

- Increased computing power (speed, memory) by 1000 (Moore's Law: attainable in 30 years)
- Much improved algorithms to optimize available computing power
- Large consortia to manage and maintain huge program packages and define standards and interfaces for specialized modules
- NASA's current grant structure (summer salary + post-doc) is not geared for these future needs.
- A virtual observatory for easy access to observations

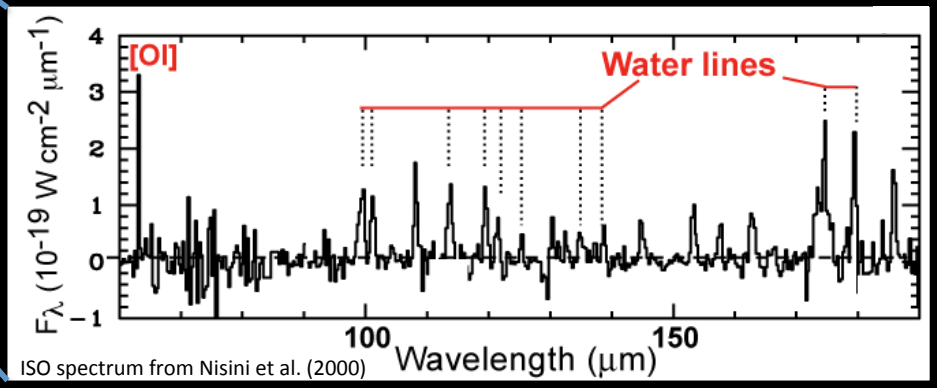
In pursuit of Cosmic Origins: Follow the water



Q: How do habitable planets form?

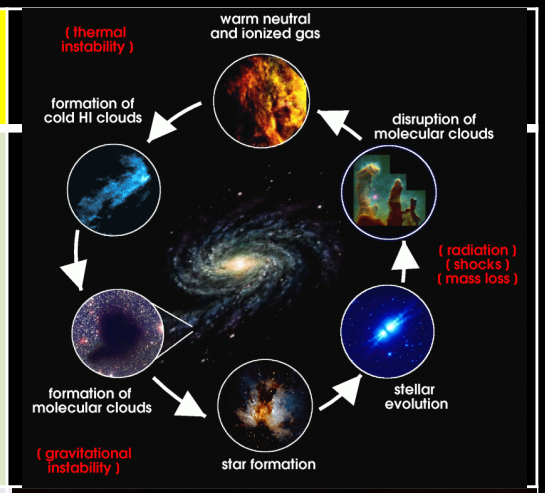
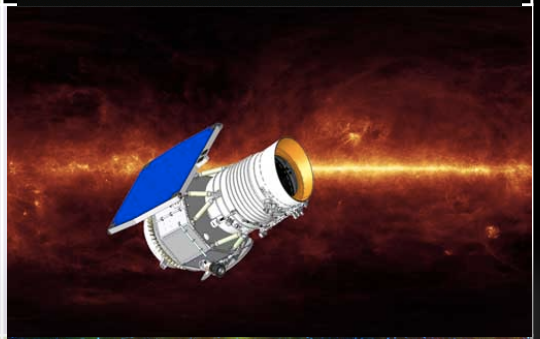
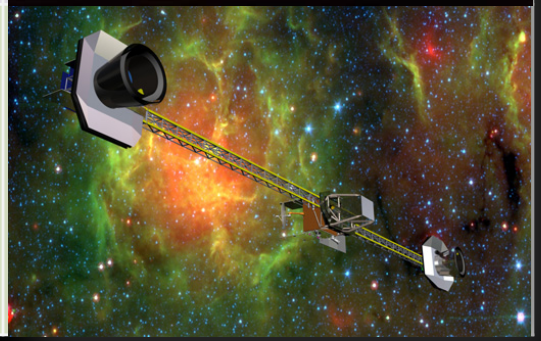
- Needed: sub-arcsecond image resolution and R > 3000 spectroscopy in the far-IR (25 – 200 μm), with ~10^{-19} W m^{-2} line sensitivity; image (spatially map) H_2O line emission and water ice spectral features in a large sample of protoplanetary disks.
- Technical needs: sensitive far-IR detector arrays; cryocoolers; image reconstruction algorithms.
- Has all necessary ingredients for success: scientifically compelling, widespread support in the international community and the public, technically feasible and affordable far-IR interferometry mission, can only be done in space.

Far-IR integral field spectroscopic observations of developing planetary systems with sub-arcsecond angular resolution will enable us to learn how water reaches habitable zone planets.



ISO spectrum from Nisini et al. (2000)

In pursuit of Cosmic Origins: The 30yr Roadmap

Way-station	Scientific Challenge	
10 yr	3D structure and kinematics of ISM; initial studies of galactic Cepheids and galactic dust distribution with JWST	
20 yr	3D structure and kinematics of stellar components of the Milky Way and nearby galaxies	
30 yr	Resolve the sites of star and planet formation during the early phases of evolution