NEXT GENERATION

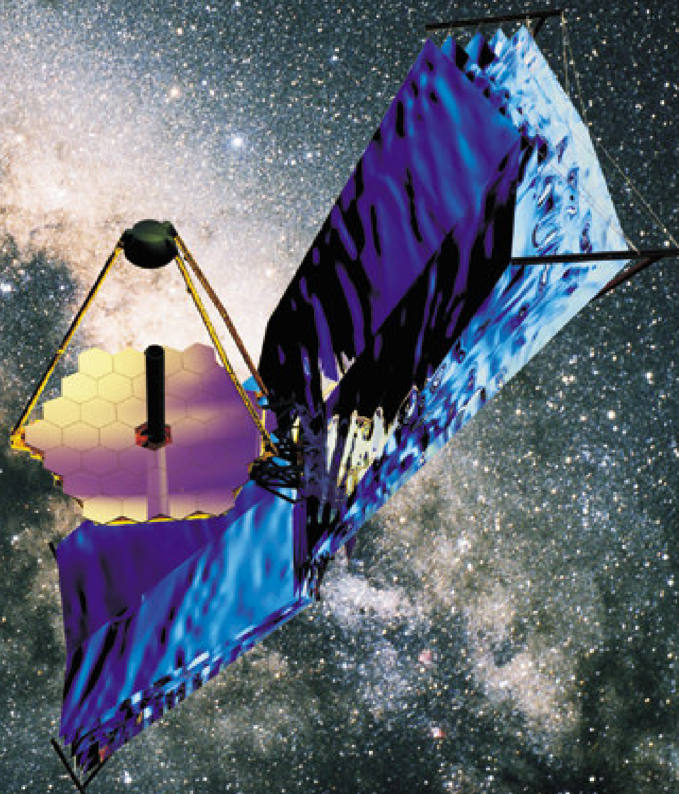
JW NGST

SPACE TELESCOPE

NASA

esa

CSA ASC



John Mather

Senior Project Scientist

James Webb Space Telescope

Origins Subcommittee, 12/02/02

JWST (James Webb Space Telescope)

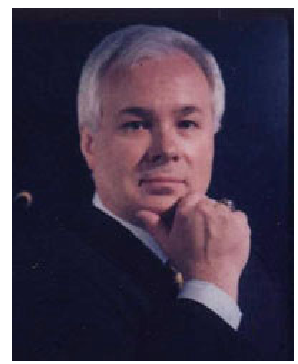
- 7 m tip-tip hex deployable primary mirror of 36 1 m hexes
- 0.6-28 μm wavelength range - near infrared optimized
- 5 year mission life (10 year goal)
- Passively cooled to ~40K
- L2 halo orbit
- TRW prime contract
- ESA, CSA partners

James Webb

Dan Goldin

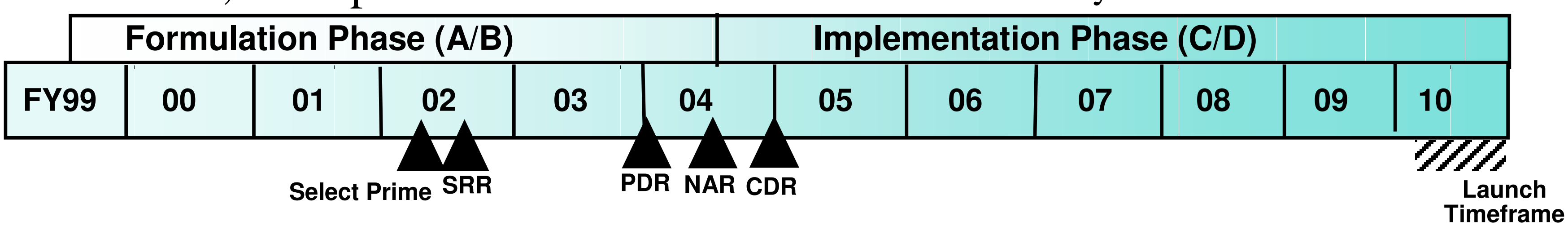
Alan Dressler

Ed Weiler



Bernie Seery

Phil Sabelhaus



Brief JWST Project History

- 1989 NGST conference at STScI
- 1995 Study initiated by Ed Weiler at GSFC
  - Directed to include STScI, broad NASA team, and international partnership as with HST; target $500M (FY96) for construction
- 1996, government + 2 industry teams report concepts
- Years of prime contractor studies, technology development, and 3 science working groups
- 2001, prime contract and SWG competitions start
- 2001, HQ selects JPL for US half of Mid IR instrument
- 2002, HQ selects flight SWG, and declines ESA offer of spacecraft bus
- 2002, Sept. 10, NASA selects TRW for $825 to design, build, test, and integrate the Observatory (telescope, sunshield, and spacecraft bus)
- 2002, October, HQ instructs Project to initiate replan effort

Major Responsibilities

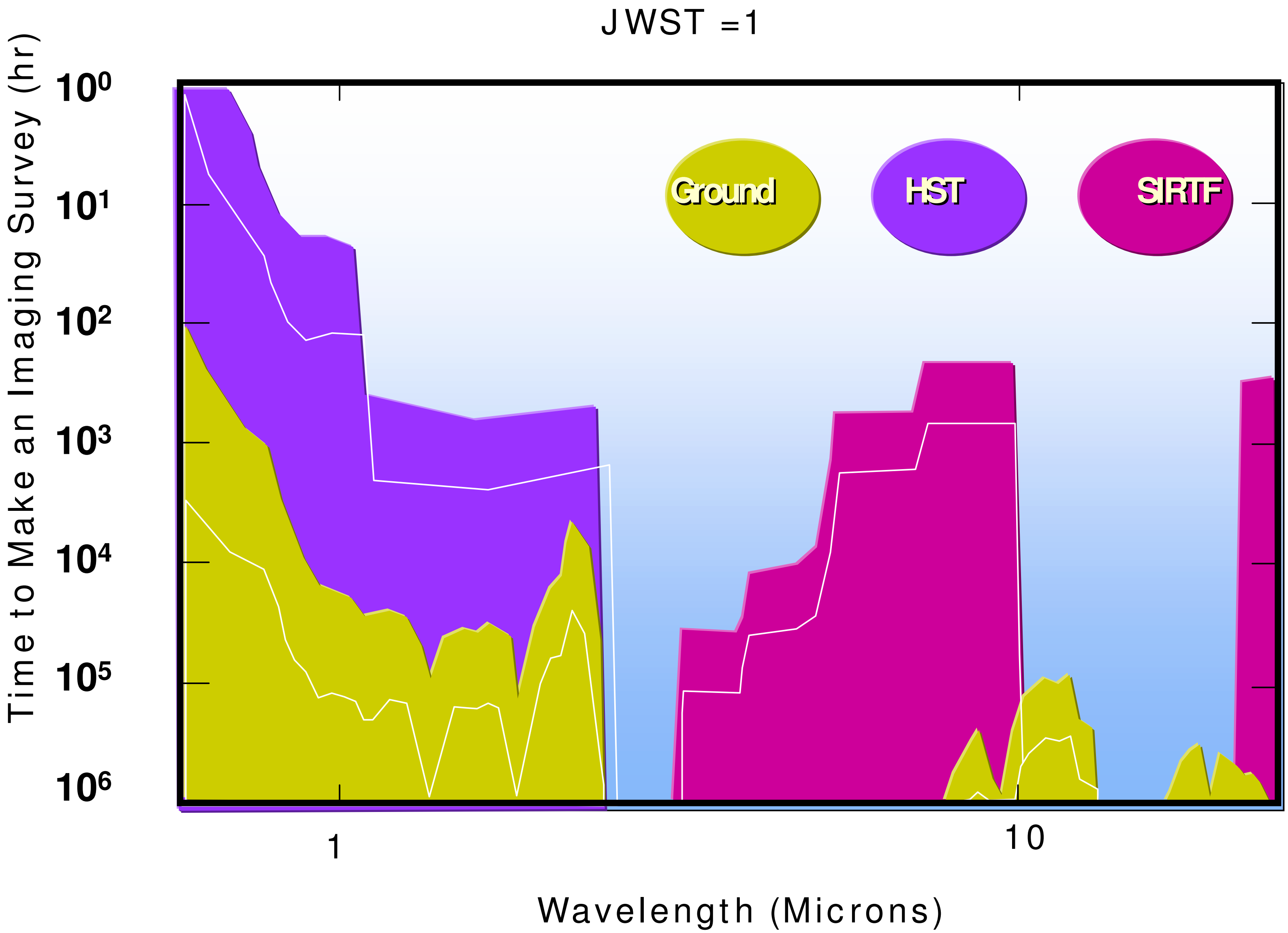
- GSFC manages entire Project, designs and builds ISIM (Integrated Science Instrument Module), builds microshutter array for NIRSpec (Near IR Spectrograph), integrates instruments into ISIM
- TRW team builds observatory, including telescope, and selects mirror technology
- ESA builds NIRSpec, optics module of MIRI (Mid IR Instrument), MIRI cryostat, may provide Ariane V
- JPL does rest of MIRI, and wavefront sensing algorithms
- MSFC tests demo mirrors (AMSD)
- U of Arizona/Lockheed Martin builds NIRCAM (Near IR Camera)
- CSA builds Fine Guider and portions of NIRCAM
- STScI builds operations software, provides science support
- TBD US vendors build detectors - select 2003

JWST Instrument Suite

JWST

- ~ 48 Mpixel NIR Camera
  - U of Arizona, CSA
  - Nyquist sampled at 2 μm, 0.6-5 μm, *R*~100 tunable filter, coronagraphic mode
- ~ 3´ x 3´ NIR *R*~1000 Multi-Object Spectrograph
  - ESA, with 8 Mpix NASA detectors and microshutters
  - Simultaneous source spectra (≥ 100), 1-5 μm
  - Possible integral field module
- 2´ x 2´ Mid IR Camera/*R*~1500 Spectrograph
  - Optics module ESA, balance NASA
  - Nyquist sampled at ~10 μm, 5-28 μm, grisms & slit, coronagraphic black spot
  - ~ 3 Mpix US detectors
- Fine Guider, 2 modules, ~ 16 Mpix
  - Produced by CSA and Herzberg Institute

Survey Speed Gain of JWST

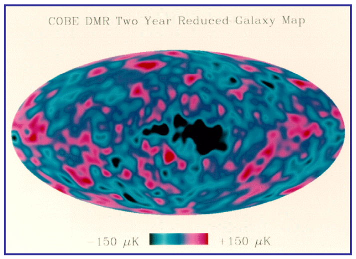


Possible History of the Universe

- Horrendous Space Kablooey - exponential expansion, primordial fluctuations, matter/antimatter, dark matter, dark energy, 14 Gyr ago
- Annihilation of antiparticles, 1 ppb matter remaining
- Formation of He [+ trace Li, Be, B] nuclei, 3 minutes, $z = 10^9$
- Formation of neutral gas "recombination", 300,000 yrs, z=1000
- Population III supermassive stars and super-supernovae, z=17, first re-ionization, suppressing further star formation (Renyue Cen, 10/21/02)
- Recombination # 2
- Galaxy formation in small parts
- Second re-ionization, z=6 (observed)
- Star formation, merging and clustering of galaxy parts, until z~1
- Earth and Sun form, 4.5 Gyr ago
- Humans, 1 Myr
- Telescopes, 400 yr
- Theory of Relativity, 100 yr

Top JWST Goal - Find the First Light after the Big Bang

as seen by COBE



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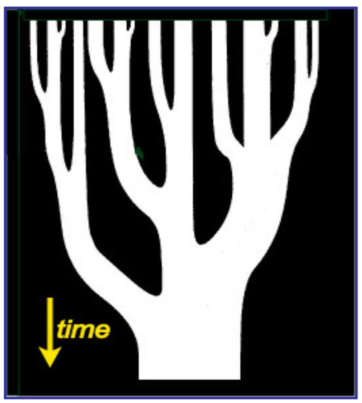
Galaxy assembly



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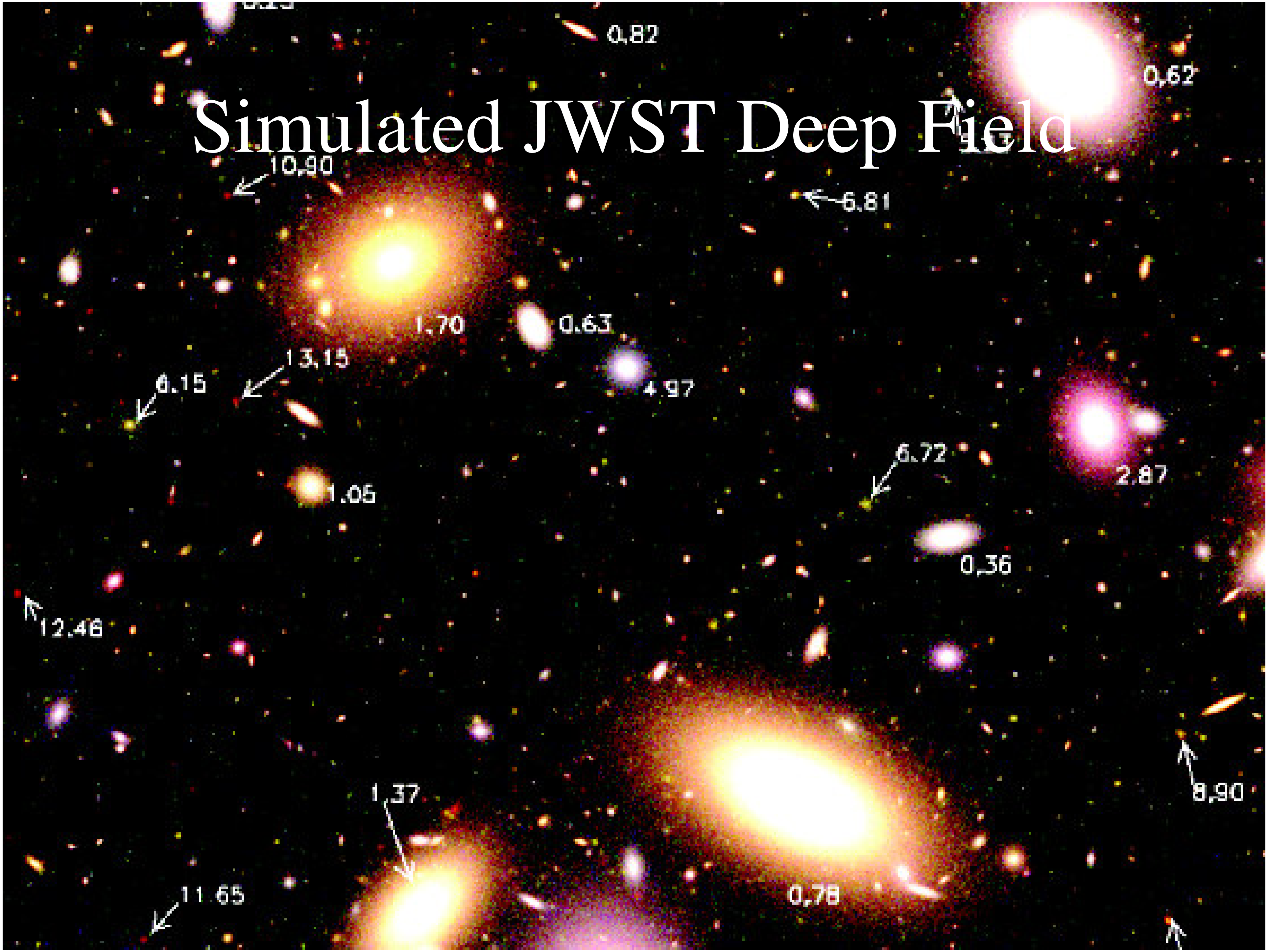
Galaxies, stars, planets, life

- How and from what were galaxies assembled?
- What is the history of star birth, heavy element production, and the enrichment of the intergalactic material?
- How were giant black holes created and what is their role in the universe?

Simulated JWST Deep Field



Simulating the First Star

- Ref: Science 2002, Abel, Bryan and Norman, January issue
- 1 kpc comoving box, see objects and sheets with 10^4-10^5 solar masses
- Central object forms with ~ 10^6 solar masses, runs 50 Myr at z=20
- Colors show surfaces of constant gas density in log scales
- Zoom in to 40 AU box to show forming star
- Movie from "The Unfolding Universe" Discovery Channel, Ralf Kaehler (ZIB), Donna Cox, Bob Patterson and Stuart Levy (NCSA), Tom Abel (PSU)
- All simulation data from Tom Abel (PSU), Greg Bryan (Oxford), Mike Norman (UCSD) (1998-2002)

Simulating the First Star

QuickTime™ and a Photo decompressor are needed to see this picture.

SWG Membership

- Reports to HQ Program Scientist: Smith
- 6 Interdisciplinary Scientists: Hamel, Lilly, Lunine, McCaughrean, Stiavelli, Windhorst
- Telescope Scientist: Mountain
- Instrument Science Leads: M. Rieke (NIRCam), G. Rieke (MIRI-US), P. Jakobsen (NIRSpec, acting), G. Wright (MIRI-ESA)
- Ex Officio: Mather, Greenhouse, Gardner, Stockman, Jakobsen, Hutchings

Introduction to NIRCam and its Science Program

Marcia Rieke
Principal Investigator
University of Arizona

mrieke@as.arizona.edu 520-621-2731
September 24, 2002

The NIRCam Team

Science Team:

Marcia Rieke(UAz)
David Crampton (HIA/DAO)
Tom Greene (NASA Ames)
Doug Johnstone (HIA/DAO)
Don McCarthy (UAz)
Tom Roellig (NASA Ames)
Erick Young (UAz)

Stefi Baum(STScI)
René Doyon (UMontreal)
Klaus Hodapp (UHawaii)
Simon Lilly (ETH)
Michael Meyer (UAz)
John Stauffer (SSC)

Chas Beichman(JPL)
Daniel Eisenstein (UAz)
Scott Horner (LMATC)
Peter Martin (UToronto)
George Rieke (UAz)
John Trauger(JPL)

Bold = Science Theme Leader

EPO Leader

Corporate Partners:

Lockheed Martin Advanced Technology Center, Palo Alto, California

EMS Technologies, Ottawa, Ontario

COM DEV, Cambridge, Ontario

Goddard Instrument Manager

Doug Campbell

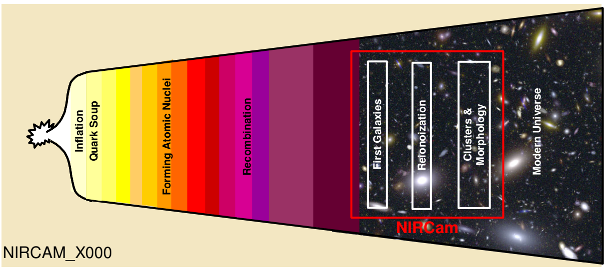
STScI Instrument Scientist

Stefano Casertano

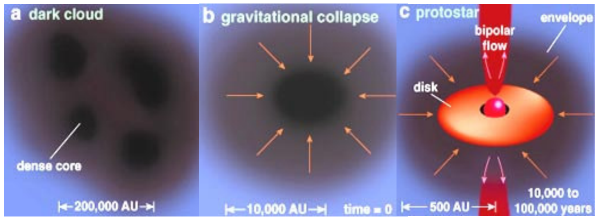
NIRCam for NGST

Our camera design is driven by the requirements derived from the Design Reference Mission and our team science needs.

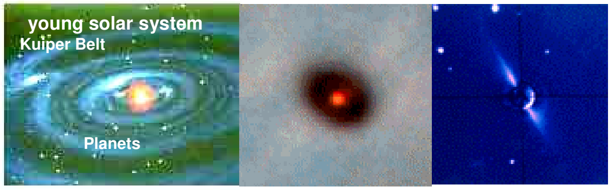
Team Science Program:



When Galaxies Were Young: Discovering the First Galaxies, Reionization, Period of Galaxy Assembly

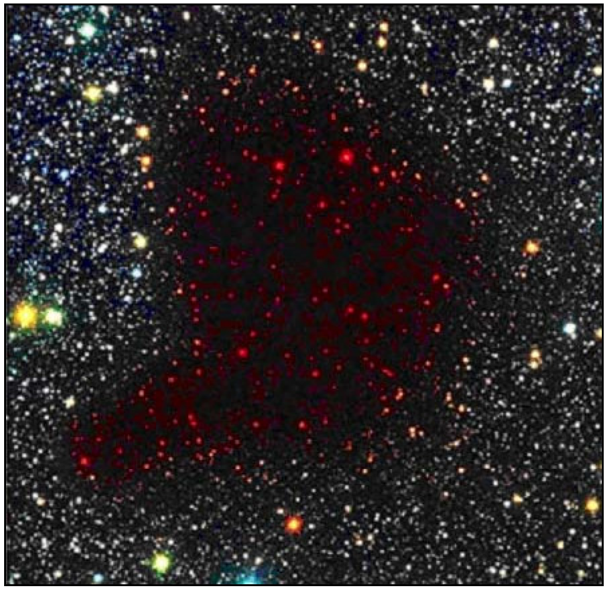


Making of a Star: Testing the 'Standard Model: Physics of the IMF, Structure of Pre-stellar Cores, Emerging from the Dust Cocoon

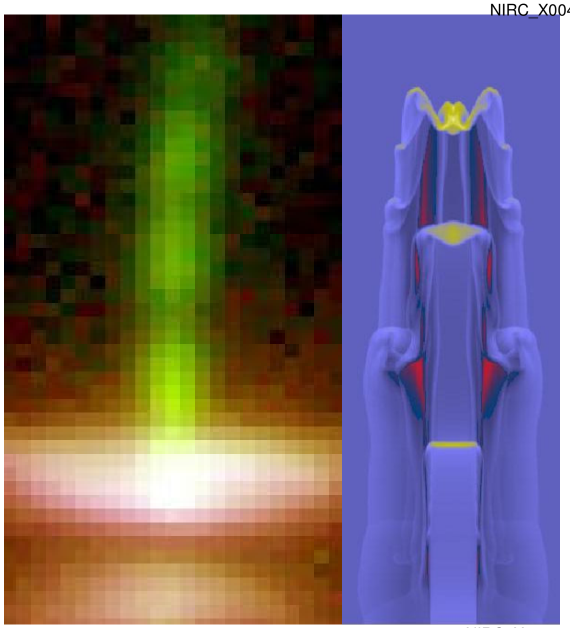


Debris Disks and Planetary Systems: Disks from Birth to Maturity, Survey of KBOs, Planets Around Nearby Stars

Making of a Star: Testing the Standard Model



NIRC_X0044

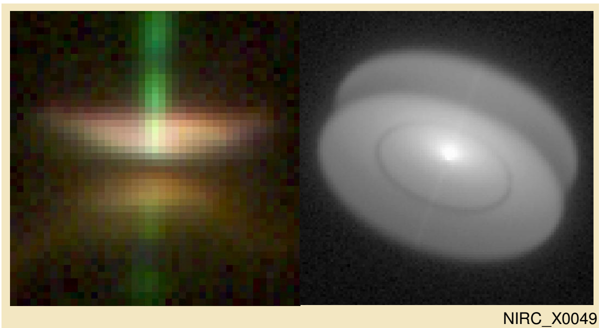


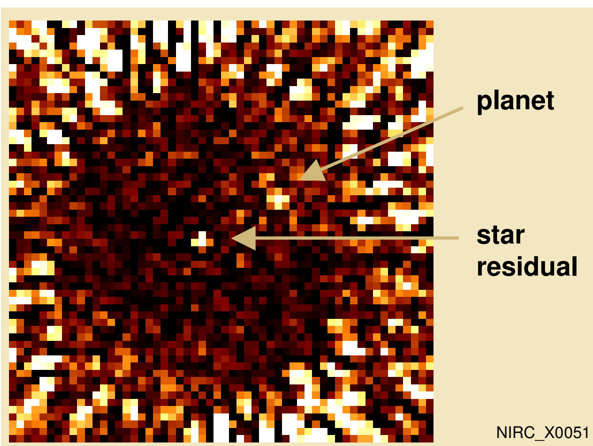
NIRC_X0046

The broad outline of star formation is reasonably well understood as the collapse of a cloud. This occurs quickly and in heavily obscured environments. But what controls the initial mass function? How do cloud cores collapse to form protostars? Does mass loss via jets play a crucial role in regulating star formation?

Team will combine surveys of star forming regions and dense clouds with detailed observation of selected protostars and disks to address these questions.

Debris Disks and Planetary Systems





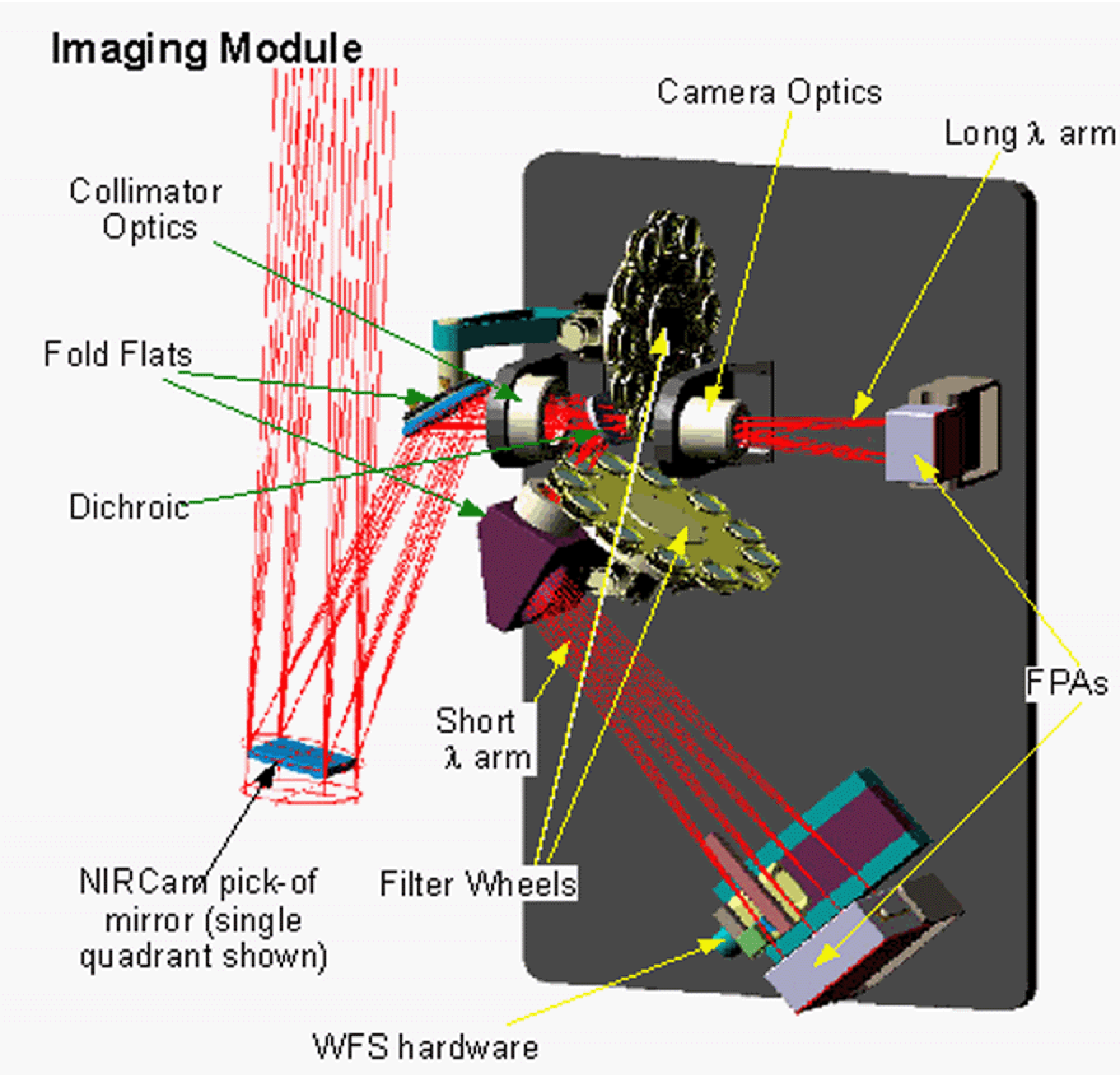
Many debris disks and planets around other stars have been discovered recently. However, these objects have not been characterized in any detail. How do debris disks form and evolve? How are they related to the Kuiper Belt in the Solar System? How many planets orbit nearby stars? What are the characteristics of these planets?

Team will use the coronagraph to observe the reflected light from disks. A survey for planets around nearby stars will be done with more detailed study of the brighter planets. A sample of Kuiper Belt objects will be surveyed to define their surface properties for comparison with debris disks.

EMS Technologies

COM DEV SPACE

An Imaging Module



A dichroic allows simultaneous observing at two wavelengths.

This module's dual filter wheels include pupils for wavefront sensing.

The two tunable filter modules are similar but require no dichroics or wavefront sensing hardware.

ESA NGST Study Science Team

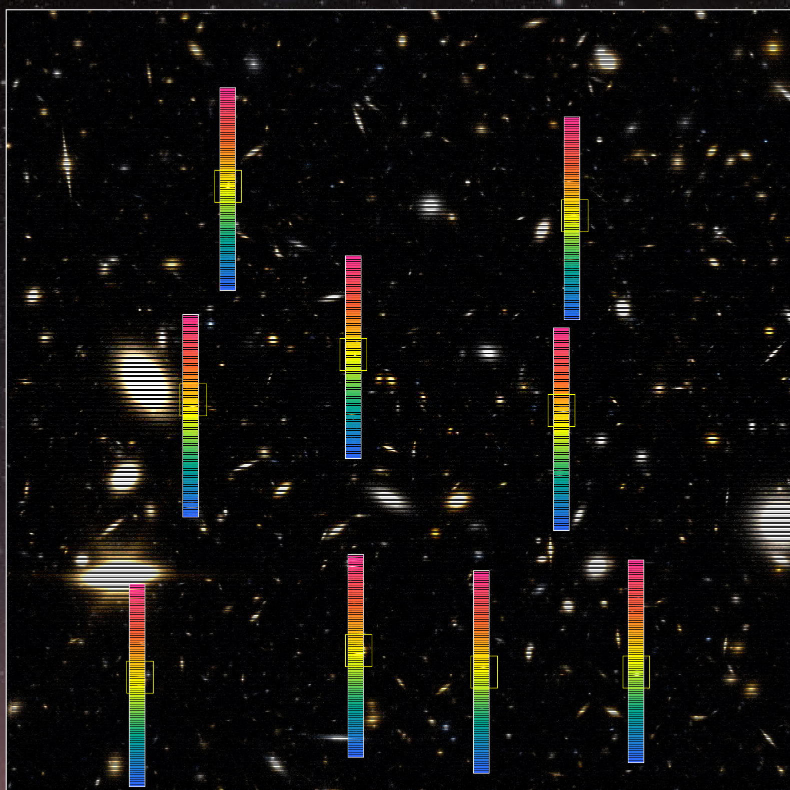
- **External:**
  E. van Dishoeck *(Leiden)*
  A. Ferrara *(Arcetri)*
  J. Hjorth *(Copenhagen)*
  M. McCaughrean *(Potsdam)*
  P. Schneider *(Bonn)*
  N. Thatte *(MPE)*
- **Study Consortia:**
  D. Burgarella *(Marseille)*
  P. Caraveo *(Milan)*
  R. Davies *(Durham)*
  O. Le Fèvre *(Marseille)*
  M. Ward *(Leicester)*
  G. Wright *(Edinburgh)*
- **ESA:**
  S. Arribas *(STScI)*
  R. Fosbury *(ST-ECF)*
  P. Jakobsen *(ESTEC – Chair)*
- **NASA:**
  M. Greenhouse *(NASA/GSFC)*
  H. Moseley *(NASA/GSFC)*
  M. Regan *(STScI)*
- **CSA:**
  D. Crampton *(DOA)*

NIRSpec (Near IR Spectrograph) Science: In the Beginning

- **Thus Spoke ASWG**
  - 3 x 3 arcmin FOV
  - 1-5 µm coverage
  - R~1000 and R~100
  - >100 sources simultaneously
  - Configurable slit width/length
  - MEMS array preferred

Origin and evolution of galaxies

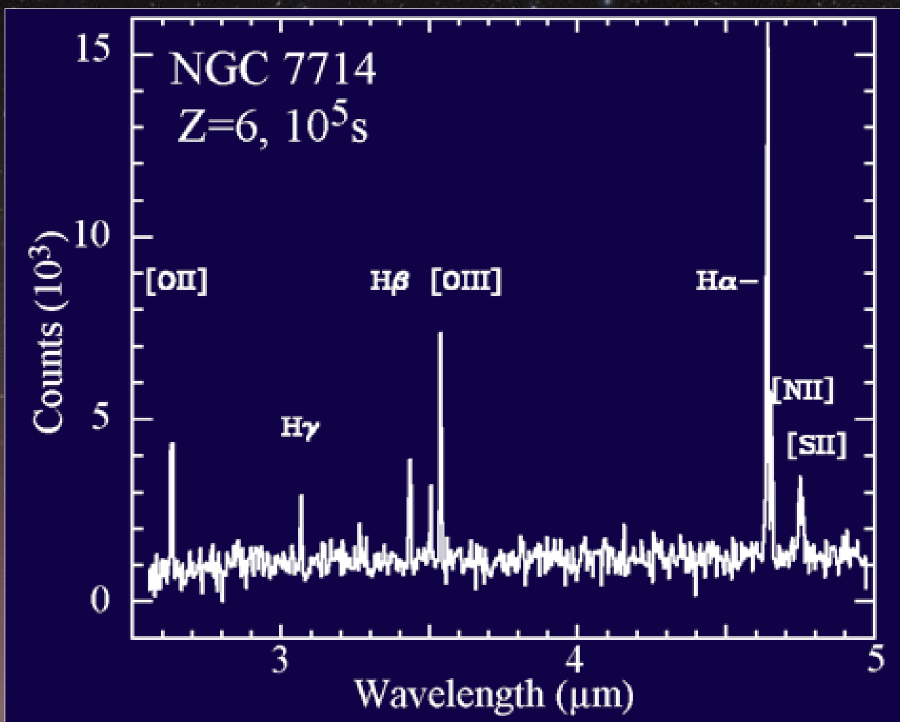
- **Survey approach**



- Deep Multi-color imaging
  - Morphologies
- Photometric redshifts
- Locate high z sample
- Multi-object Spectroscopy
  - Star formation rate
  - Abundances
  - Ages
  - Physical conditions

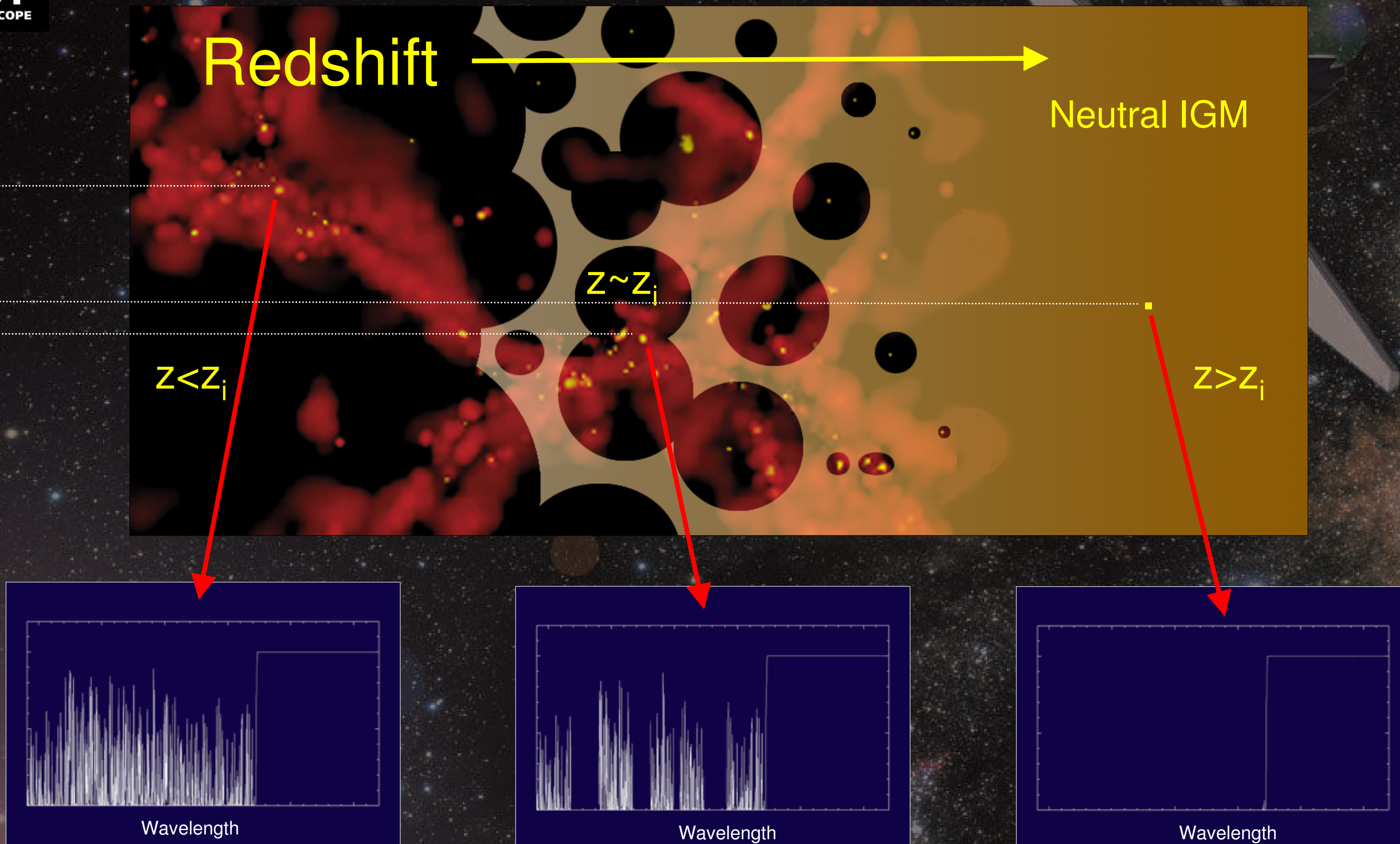
Origin and evolution of galaxies

- **R~100** – Continuum Spectroscopy
  - Calibrate/confirm photometric redshifts
  - Intervening absorption
  - High redshift supernovae



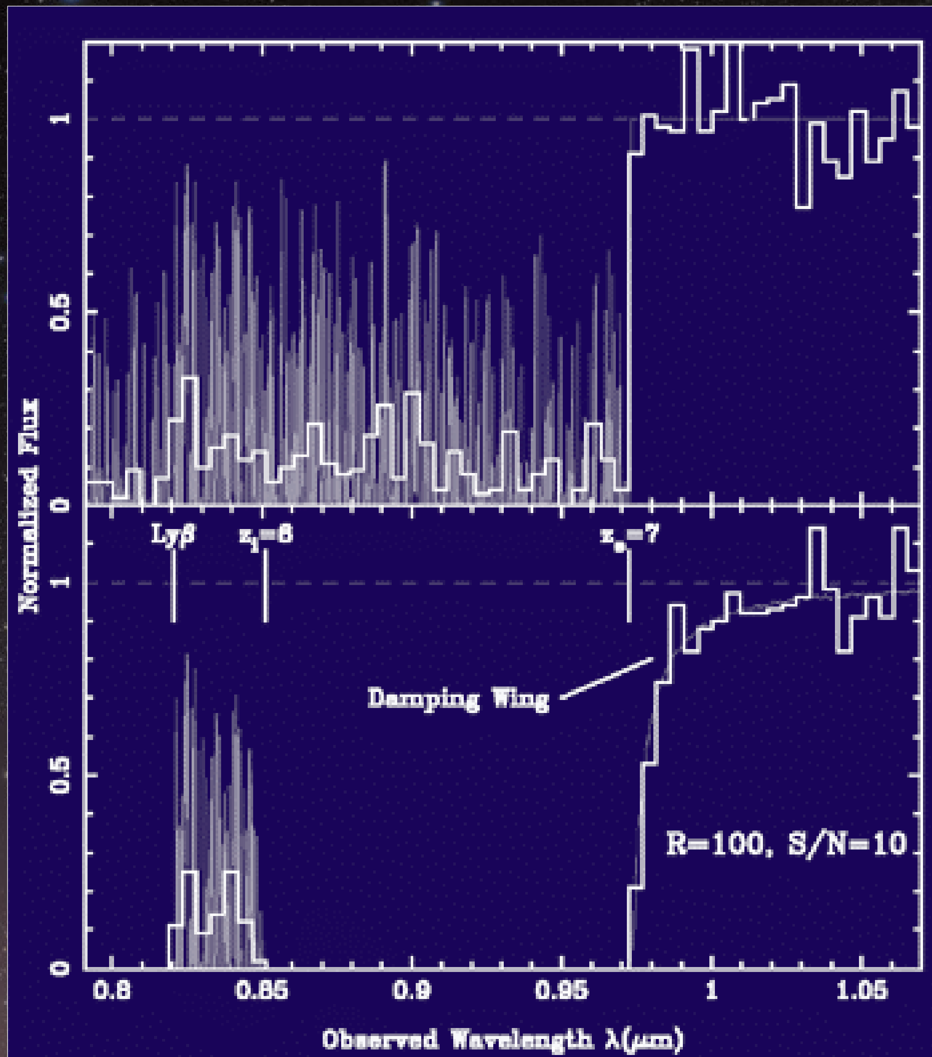
- **R~1000** – Emission Line Spectroscopy
  - Wide field – multiple objects
  - Redshifted optical diagnostics:
    - Star formation rate
    - Metallicity, Reddening, Ages
    - Physical conditions
- Wide field MOS approach

The Epoch of Reionization



Lyman Forest Absorption | **Patchy Absorption** | **Black Gunn-Peterson trough**

Signature of Hydrogen Reionization

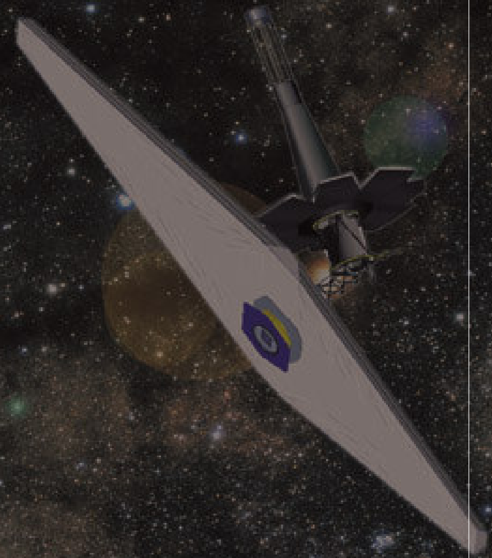


Extrapolated Lyman Forest Absorption at z=7

Gunn-Peterson trough if reionization occurs at z_i=6

Select Objects

(Detail)



QuickTime™ and a QuickDraw decompressor are needed to see this picture.

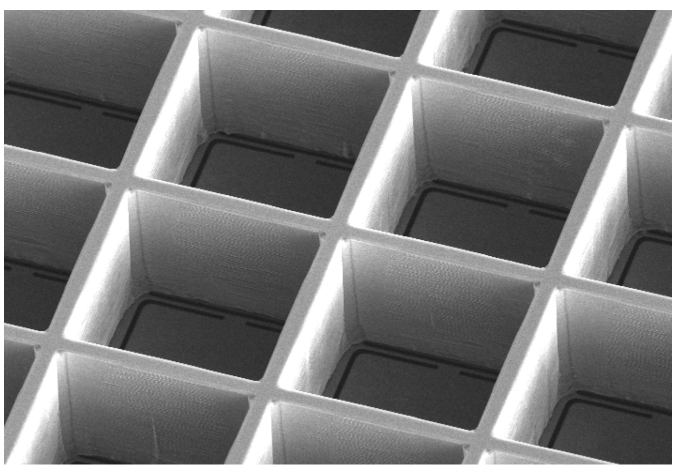
HDF-S Field

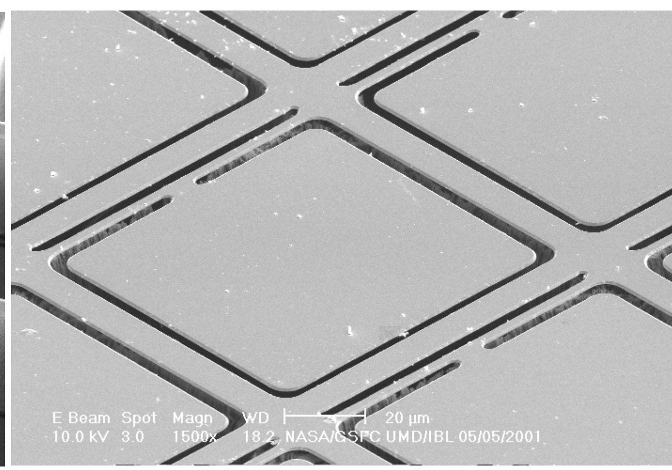
Insert Grating and Integrate

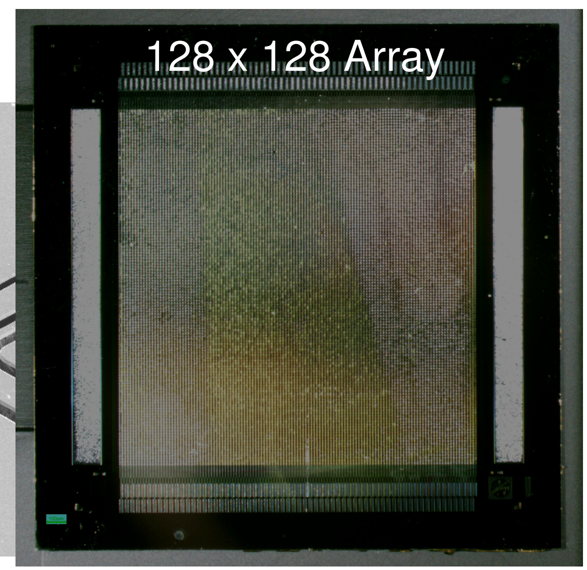
QuickTime™ and a
QuickDraw decompressor
are needed to see this picture.

NIRSpec Programmable Aperture Mask

- Format - 1800 x 900 elements, Cell Size - 100µm x 200µm
- Operating Temperature - 30 - 35 K
- Efficiency and Blocking
  - > 0.70 when open, < 0.00035 when closed
- Reliability - ~10^6 cycles
- Power - 35 mW average dissipation

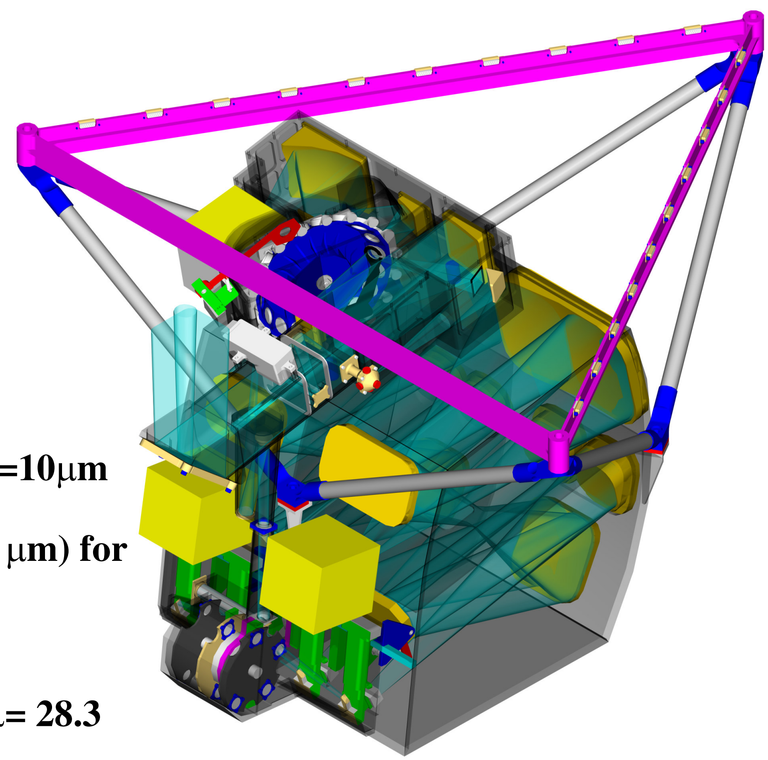






Mid-Infrared Instrument (MIRI)

- Science team now in place
  - G. Rieke (lead), G.Wright (co-lead), F. Bortoletto*, T. Greene, T. Henning*, P.-O. Lagage*, M. Meixner, & E. Serabyn (inst.scientist)
    *acting
- An approximately equal NASA/JPL-led partnership with a European Consortium sponsored by ESA
- Science Goals include
  - Search for the origins of galaxies
  - Birth of stars and planets
  - Evolution of planetary systems
- Functional capabilities include
  - Imaging
    - λ=5-27 μm wavelength range
    - Diffraction limited imaging with 0.1” pixels
    - ~1.7’ field of view
    - Able to image sources as bright as 4 mJy at λ=10μm
    - $\geq$12 bandpass filters
    - Low resolution spectrograph (R~100; λ=5-10 μm) for single, compact sources
    - Simple coronagraph
  - Spectroscopy
    - λ=5-27 μm wavelength range, goal to reach λ= 28.3 μm
    - Integral field spectroscopy with $\geq$ 2” field of view, goal =3” or more
    - R~1000-3000 from λ=5-27 μm
- Status: European instrument and cryostat Phase A studies to be completed September 13, focal plane development under way in the U.S.



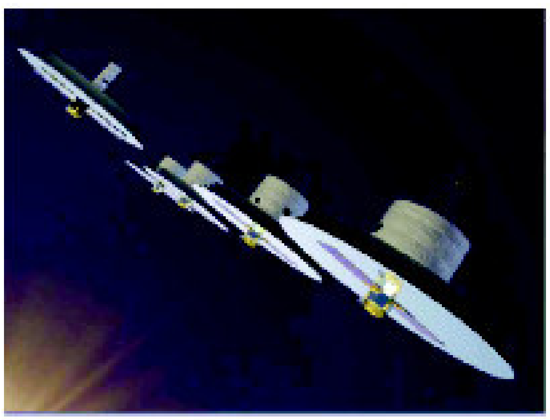
Optics Module concept developed by European Consortium

JWST

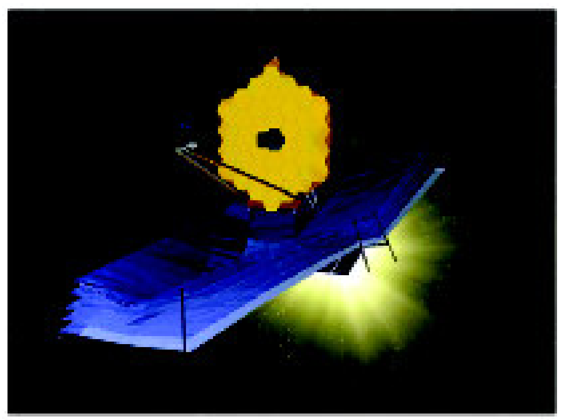
Cryocoolers

Consensus Top-level cooler requirements for TPF, JWST, and Con-X have been identified and reflected in a detailed ACTDP cryocooler specification. Key requirements include:

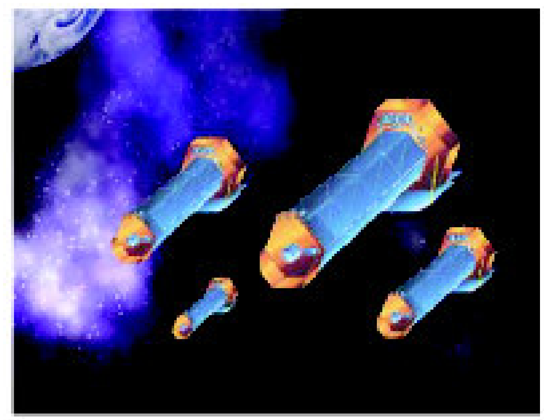
- **10 to 40 mW at 6K *plus* 50 to 250 mW at 18K**
- **<150 watts input power (<200 W at EOL)**
- **< 40 kg cooler system mass**
- **Accommodate 5 to 25 meter cold-end deployment length**
- **Low Generated Vibration and EMI, 10 year life**



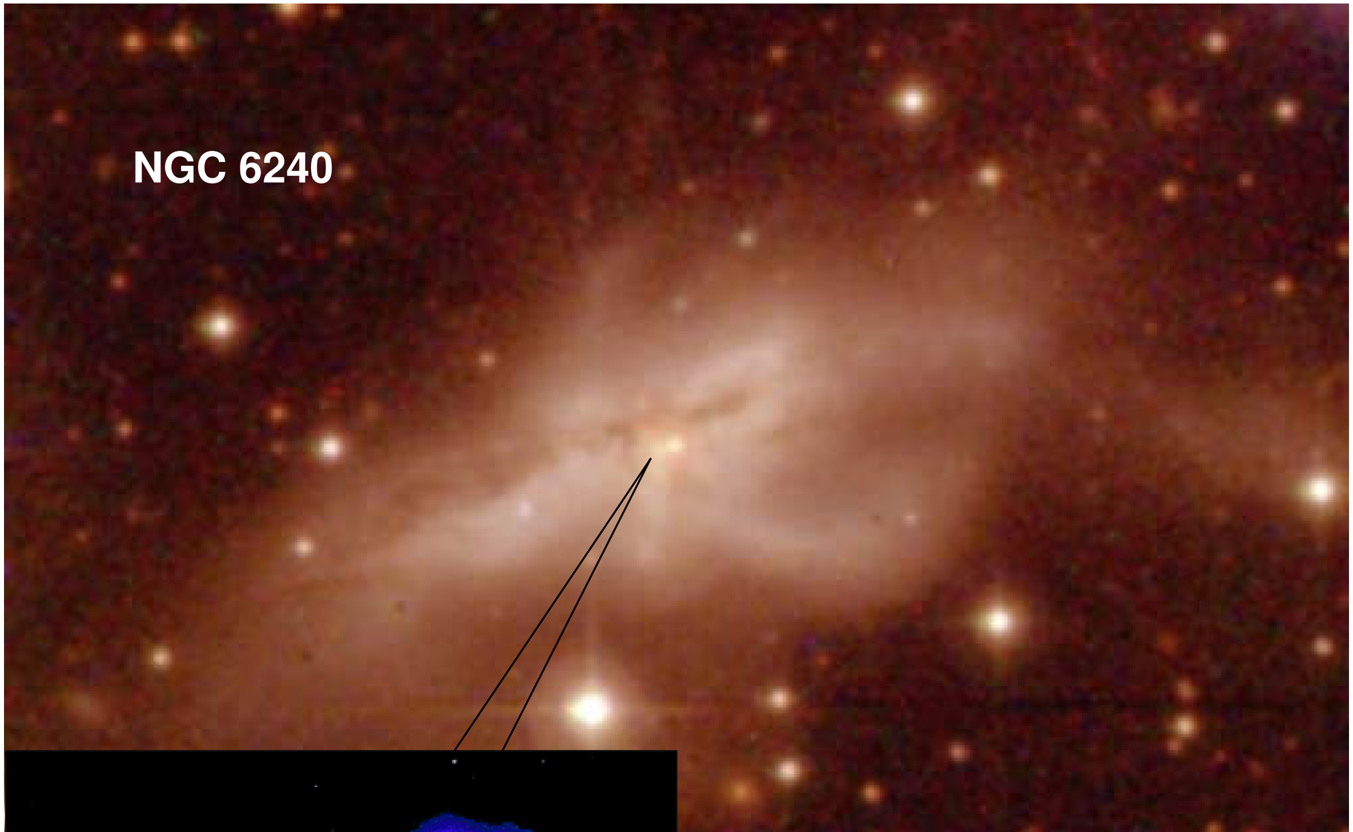
TPF

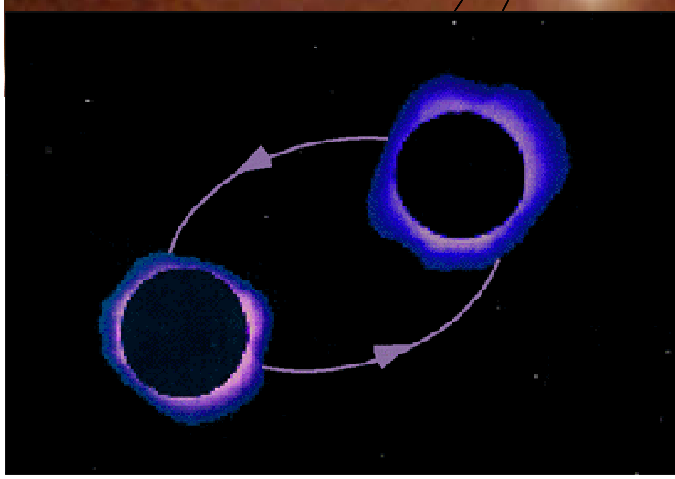


JWST



Con-X





Outstanding Questions in the Origin and Evolution of Galaxies

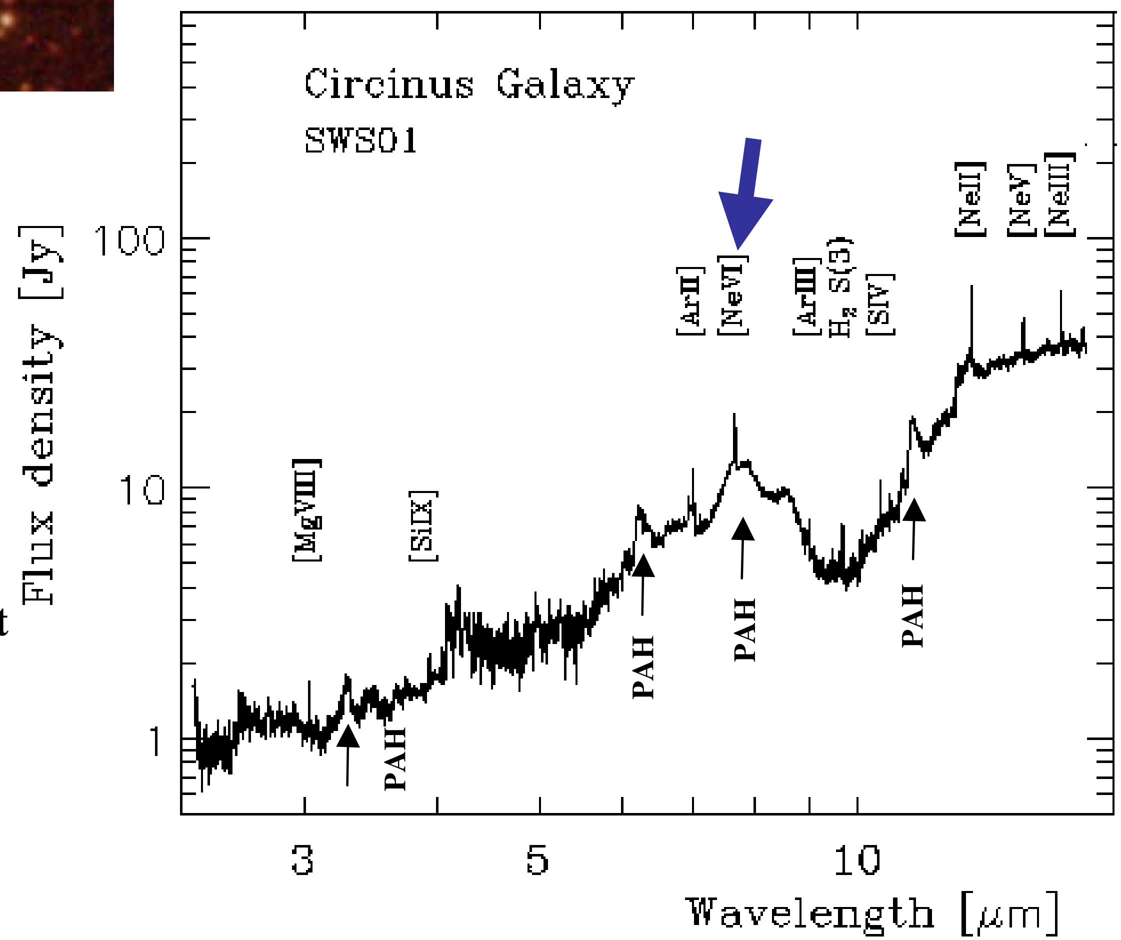
• *How many of the sources detected by NIRCam are true first light objects?* **How many are undergoing a second burst of star formation?**

• *How do quasars grow and galaxies evolve during the era of rapid mergers and the heyday of quasars at $2 < z < 3$?*

• *What is the nature of any peculiar objects discovered in NIRCam surveys?* **Are there previously undiscovered types of object that emit primarily in the mid infrared?**

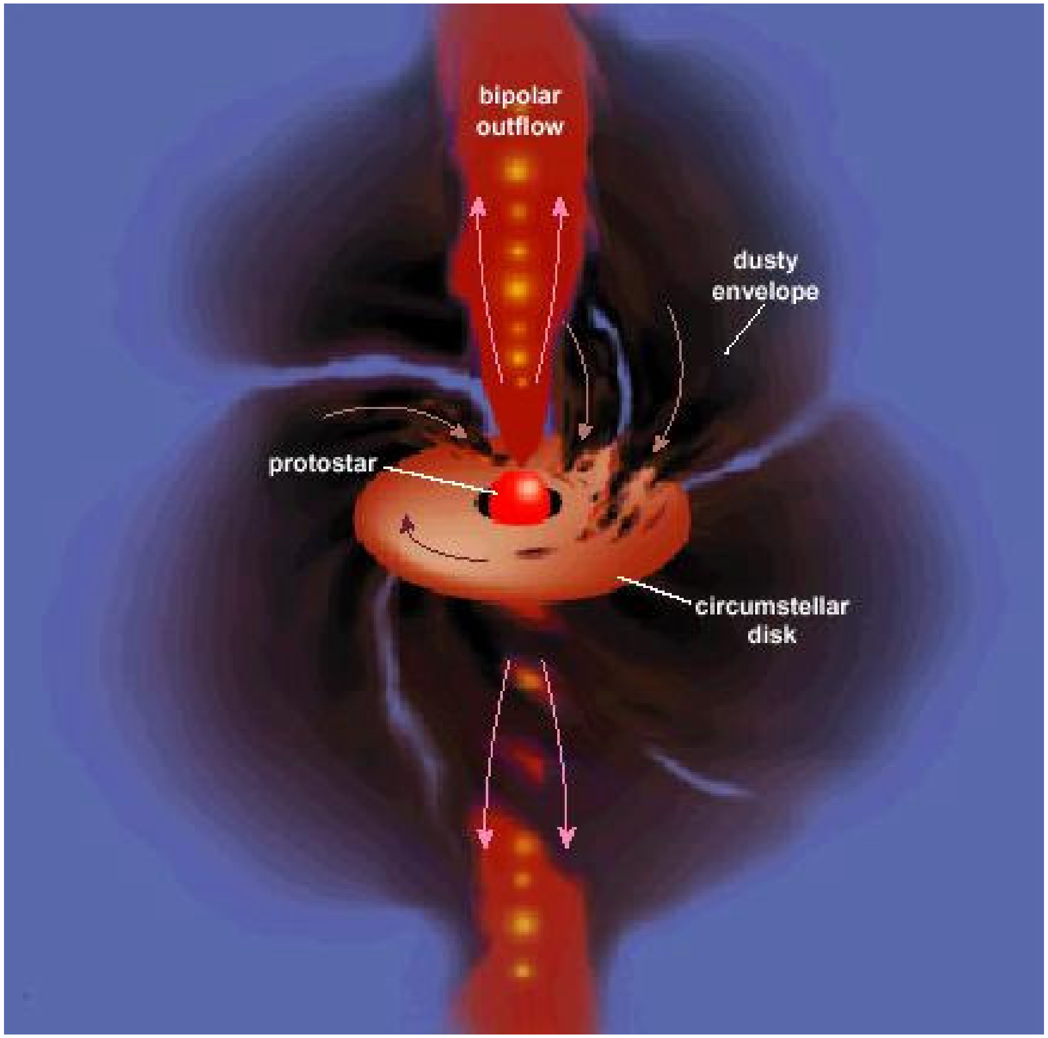
- ~90% of high redshift AGNs are heavily obscured
- Understanding AGN evolution requires Mid IR data

- **Ne VI line at 7.65µm allows measure of power of obscured AGNs ($A_{7.6\mu m} < 0.02\ A_V$)**
- **Ne VI line is in MIRI spectral range to z = 2.5**
- **Readily measurable to a luminosity of twice that of NGC 1068 at z = 2.5 (substantially lower luminosity limit at lower redshifts due to increase in MIRI sensitivity)**

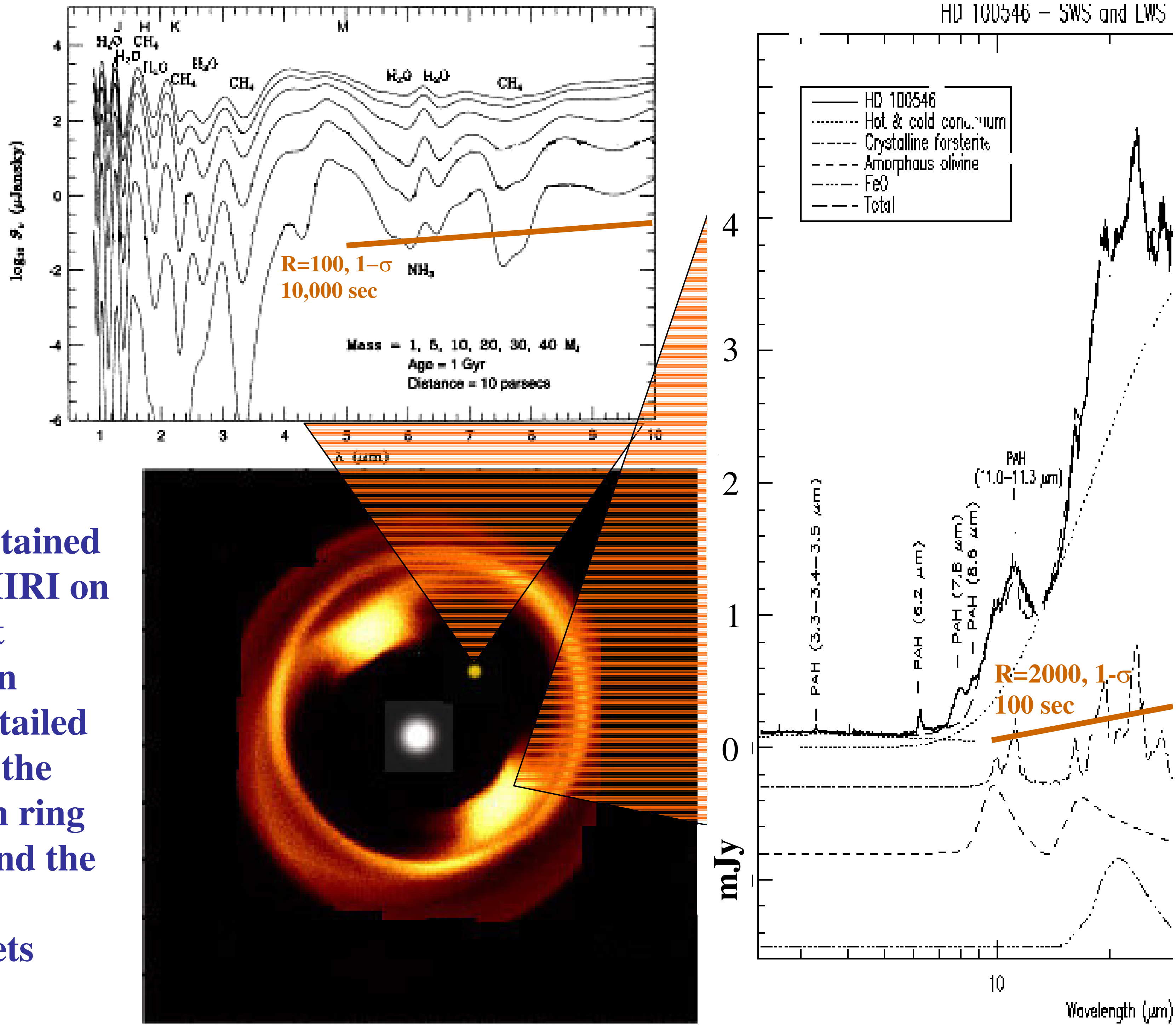


Outstanding Questions in Star Formation

- ***By what process do pre-stellar cores collapse to form stars?*** Are their density distributions consistent with the "standard model" of star formation, Bonner-Ebert spheres, or ambipolar diffusion support?
- ***What are the physical natures*** (effective temperatures, radii, etc.) ***of the nascent stellar cores of the youngest protostars?*** How does matter accrete onto them?
- ***What organic matter is present in the circumstellar environments of protostars?*** Is this matter more processed (more complex) than in the ISM, and is it located in planet-forming regions of disks? Similarly, ***is there water, and where is it located?***



JWST



Spectra obtained with the MIRI on the nearest systems can provide detailed insights to the minerals in ring particles and the nature of giant planets

Technology Status

- AMSD mirrors go to MSFC test next spring
- Wavefront sensing algorithms demonstrated in simulation (computer and hardware)
- Deployments of sunshield and primary mirror tested on models with good results
- Detector noise and dark current good for all 3 types, and proton tests beginning - selection in 2003
- Small microshutter arrays work cold with long life

JWST Replan: What Is It?

- Direction from HQ on October 8, 2002
- Main guidelines
  - Fit JWST program phases B/C/D within budget profile and entire mission within total cost cap ($1.6B, FY02) and use recommended reserve levels for each phase
  - $D_{\text{Primary}} \sim\geq$ 6m, mostly filled design
  - STScI remains operations center
  - If ESA provides launch vehicle, NASA cost cap will not be reduced - answer expected in late winter

Replan: Why Now ?

- Project is getting ready for transition from Phase A to Phase B
- Summer 2002 JWST Project estimate for mission cost/phasing exceeded Code SZ available budget
- JWST must undergo an Independent Cost Estimate (ICE: Langley); ICE must agree with Project estimate (20%) and be within HQ funding guidelines for go ahead to Phase B
- $\therefore$ Descope/Replan mission <u>now</u> to enable $\Phi A \rightarrow \Phi B$

Replan:Who Will Do It?

- Project + Industry + Scientists will do the replan
  - Participants : Project manager and scientist, TRW manager, Instrument PIs, …
- Full SWG will review all replan/descope options
- HQ convened Independent Review Team (IRT) will review final product

Replan: Expected Results

- Important point: Instrument PI's/team leads will actively participate and full SWG will review all options and indicate their preference!
- Identification and elimination of "easy" cost saving measures early on,
- Early identification of schedule driving parameters,
- Launch Date may move right, instrument complement may change, program organizational responsibilities may shift, …

Conclusions

- Project plan, team members, and technology development on track for phase A - phase B transition this year
- JWST meets the scientific challenge for which it was given the NAS Decadal Survey's highest priority