The Near-Infrared Spectrograph on JWST:
Killer Science Enabled by Amazing Technology

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STScI
Hubble Science Briefing
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1.) Seek the first stars and galaxies that formed in the early Universe

2.) Determine how galaxies evolve from the early Universe to the present day

3.) Solve the mysteries of star formation and birth of protoplanetary systems

4.) Probe the chemistry of solar systems (including our own) to constrain the building blocks of life
The Largest Telescope Ever in Space
The Largest Cryogenic Telescope Anywhere

Requires 100 times the sensitivity of Hubble
Requires 10 times the image sharpness of Hubble in the infrared
Requires wavelength coverage out to 27 microns
A gold plated telescope!
A Tennis-Court Sized 5-Layer Sunshield

Keeps the Telescope at 50 K and the Instruments at 39 K
(-390 F!)
Tested in the NASA/Johnson Thermal Vac Chamber
Launch and Deployment

http://www.jwst.nasa.gov/videos_deploy.html

Ariane 5 (ESA)
Four Science Instruments

NIRCam

MIRI

NIRISS

NIRSpec
The Fact About JWST That Most Amazes Me!

We plan to launch a 20-foot gold plated mirror and a tennis-court sized array of mylar to a million miles away from earth...

...to detect a bunch of photons (light particles) with a TOTAL energy equivalent to dropping a quarter about 8 inches into your hand.
Why So Little Total Energy? The Infrared

**Infrared sensitivity of Webb's instruments**

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**Visible:** The light we can see

**Reveals:** Cooler red stars, Dust is transparent

**Reveals:** Planets, comets, and asteroids, Dust warmed by starlight, Protoplanetary disks
A Brief History of Astronomical Spectroscopy

Newton 1700s
Fraunhofer Kirchoff 1850

Hubble 1900-1950

JWST NIRSpec 2018
The Technology of NIRSpec

- Microshutters
- Integral Field Unit (IFU)
- Detectors

Two dimensional original on-sky image

Optical slicing of the on-sky image

Spectral dispersion of the sliced image

Computer reconstruction of the 3D data cube

Spectrum of each 2D pixel

Spatial in X

Spatial in Y

Spectral Dimension

Computer reconstructed image
The Microshutter Array (MSA)

Human Hair 90 um Dia.

shutter pixel clear aperture, 267 x 528 mas pitch, 4 x 171 x 365 array

Human Hair 90 um Dia.
How old are these stars? Did they form all at once, or slowly over time? How are they related to one another?
Full MSA has a quarter of a million shutters!
This configuration gives spectra of 9 stars simultaneously > 100 possible using the full microshutter array.
Hubble can already see galaxies formed within 500 Myr of the Big Bang (redshift, or $z$, of 11). But neither Hubble nor JWST imaging will be able to measure the star formation rate or chemical evolution of these early galaxies. NIRSpec will let us use spectral lines of hydrogen and oxygen to measure the detailed properties of the very first galaxies assembling from the products of the first stars.
The Targets

Planetary candidates from NASA’s Kepler mission (RIP)

- 1235 candidates
- 68 Earth-sized planets
- 54 candidates in habitable zone
- 5.4% of stars host Earth-sized planetary candidate
- Kepler 22b announcement recently!
Exoplanet Atmospheres in Transit and Eclipse

- Transit: See radiation from star transmitted through the planet’s atmosphere.

- Secondary Eclipse: See thermal radiation and reflected light from planet disappear and reappear.

Detection of:
- Atoms & Molecules
- Stratospheres
- Clouds
- Winds
What Would the Earth’s Spectrum Look Like?
- Every planet has a unique fingerprint, produced by its atmosphere.
- The Earth shows nitrogen, oxygen, carbon dioxide, and water vapor.
JWST: Exoplanet Atmospheres

A Hydrogen-Rich Super Earth (1.4 \( R_{\text{EARTH}} \), 5 \( M_{\text{EARTH}} \))

NIRSpec – 20 transits
(Binned to \( R \sim 300 \))
Water Worlds?

The incredible sensitivity and stability of JWST and NIRSpec will enable measurements of features that only absorb 0.05% of the host star’s light. Hence astronomers will be able to detect water, carbon dioxide, and ozone in the atmospheres of nearby exoplanets.