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01.James Webb Space Telescope (JWST)

Know.Astro_Env_Chem-01: Detection of CO_2 in atmosphere of an exoplanet (WASP-39 b)

KnowLab
rsr.chem1979

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Knowledge flower to "J. Applicable Chemistry" during Start of second decadal(2022-2031) publication era

Single Sentence Summary (SSS):CO2 is experimentally detected for the first time in the atmosphere of an exoplanet (WASP-39 b) revolving around a G7 type of Star (WASP-39) in Virgo constellation; The data is from IR transmission spectrum (range of 3 to 5.5-micron) acquired for over eight hours (on 10th July,2022) by NIR Spec instrument of JWST revolving in Sun-Earth-L2-orbit one-million-miles away from here.

Graphic brief of JWST

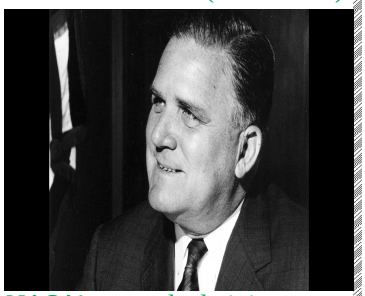
Dr. John C Mather(1946)

NL(Physics-2006)

Webb senior project scientist, NASA Goddard

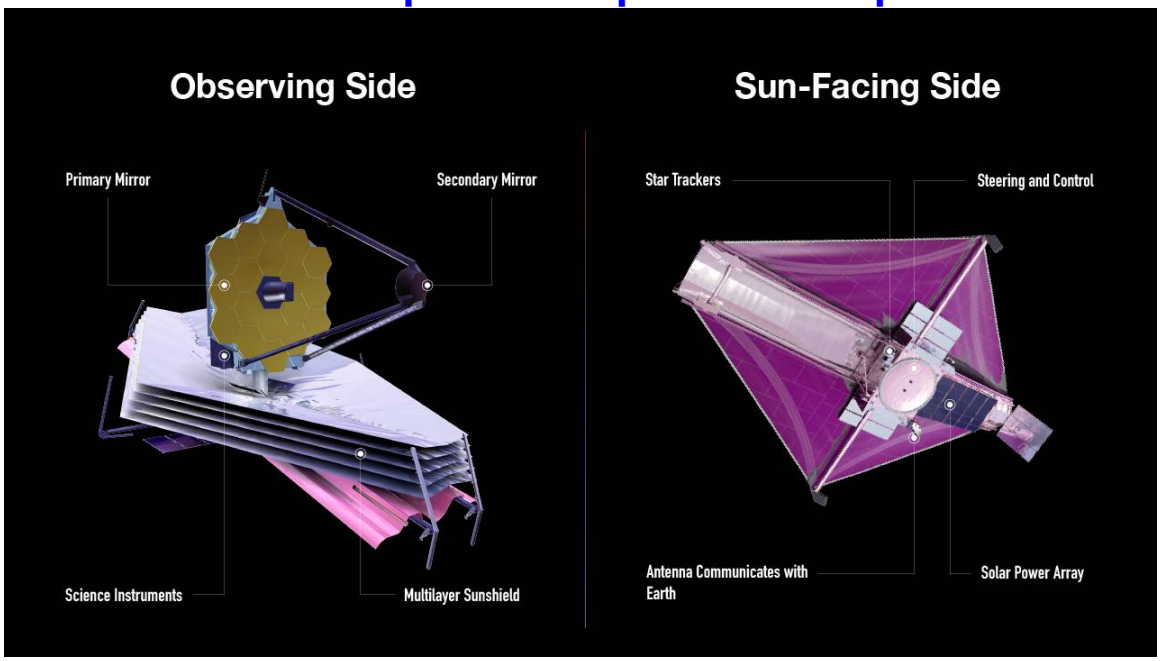
ESA
CSA

James Edwin Webb (1906–1992)

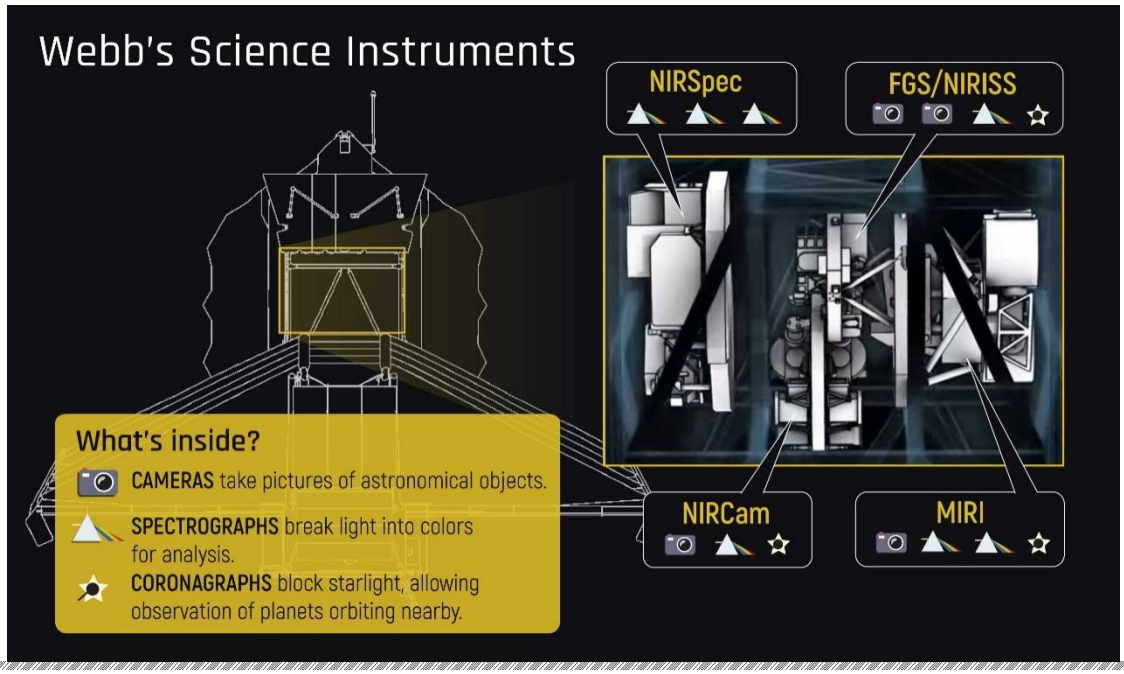


NASA's second administrator

James Webb Space Telescope's Main Components



James Webb Space Telescope's Main Components

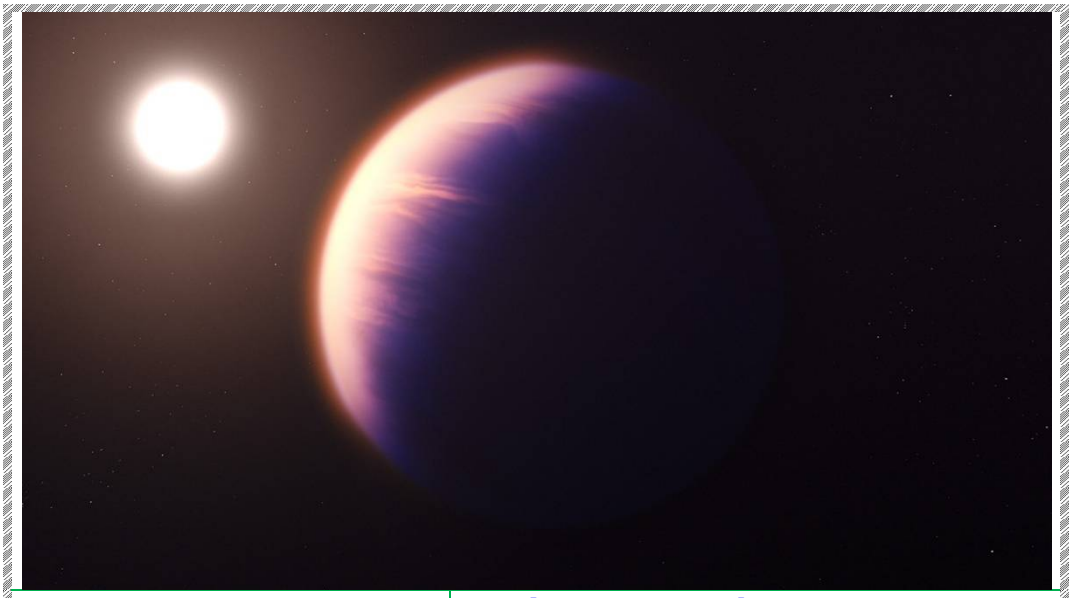


Keywords;Star: WASP-39 ; Exoplanet: WASP-39 b; Atmosphere; 3 to 5.5-micron range in an exoplanet IR-transmission-spectra; Time series; Confirmation of CO_2; Early- Release-Science-observations; JWST;NASA-ESA-CSA

1. Introduction

WASP-39, named as Malmok is a star of spectral class G in the Virgo constellation, residing in an equatorial region of sky. SuperWASP-North and WASP-South telescopes simultaneouslymonitor this

region.This late star is roughly of the same size, mass, temperature, and color as ourSun and 698 light-years away from Earth.WASP-39 b is an exoplanet orbiting around the star WASP-39 (G7 star, akin to our SUN) at a distance of 4.5 million-miles (or 0.0486 astronomical units). It completes one circuit in four Earth-days. It was discovered in 2011 based on ground-based telescope transit-data.WASP-39 b is a hot puffy gas-giant planet and was named as Bocaprins, after the beach Boca Prins in the Arikok National Park. Due to its proximity to its star, there is tidal locking resulting in one side of this exoplanet facing the star all the time.



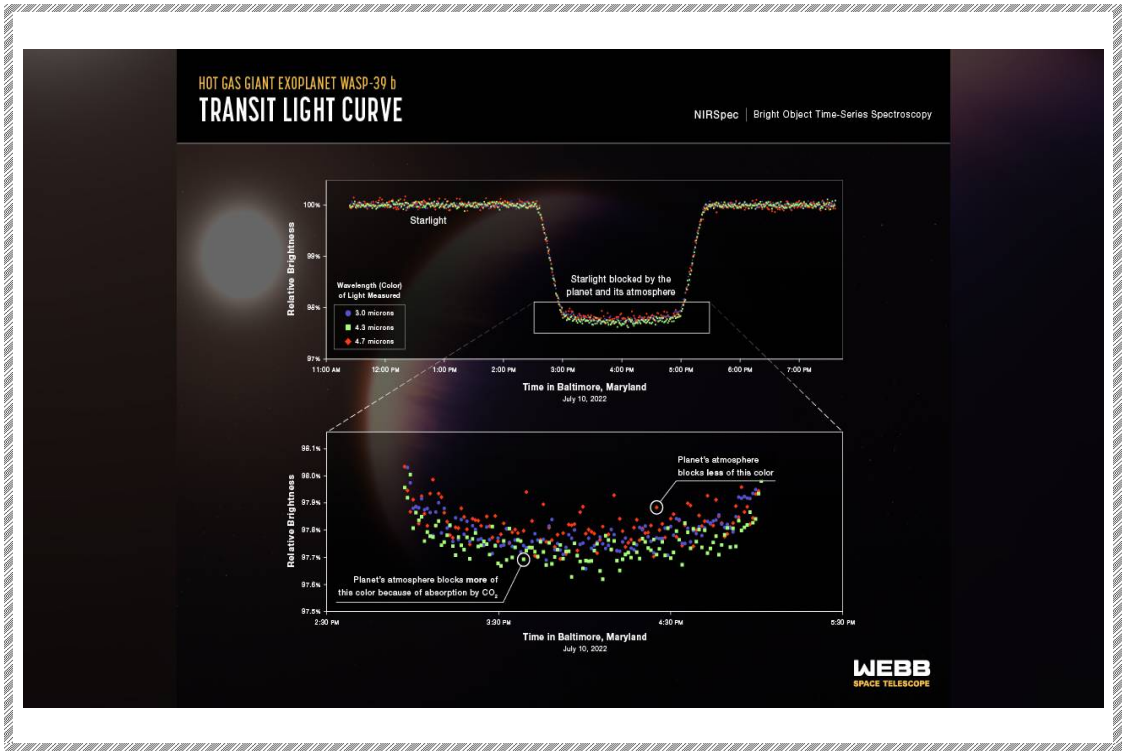
Star. WASP-39;	Exoplanet. WASP-39 b;

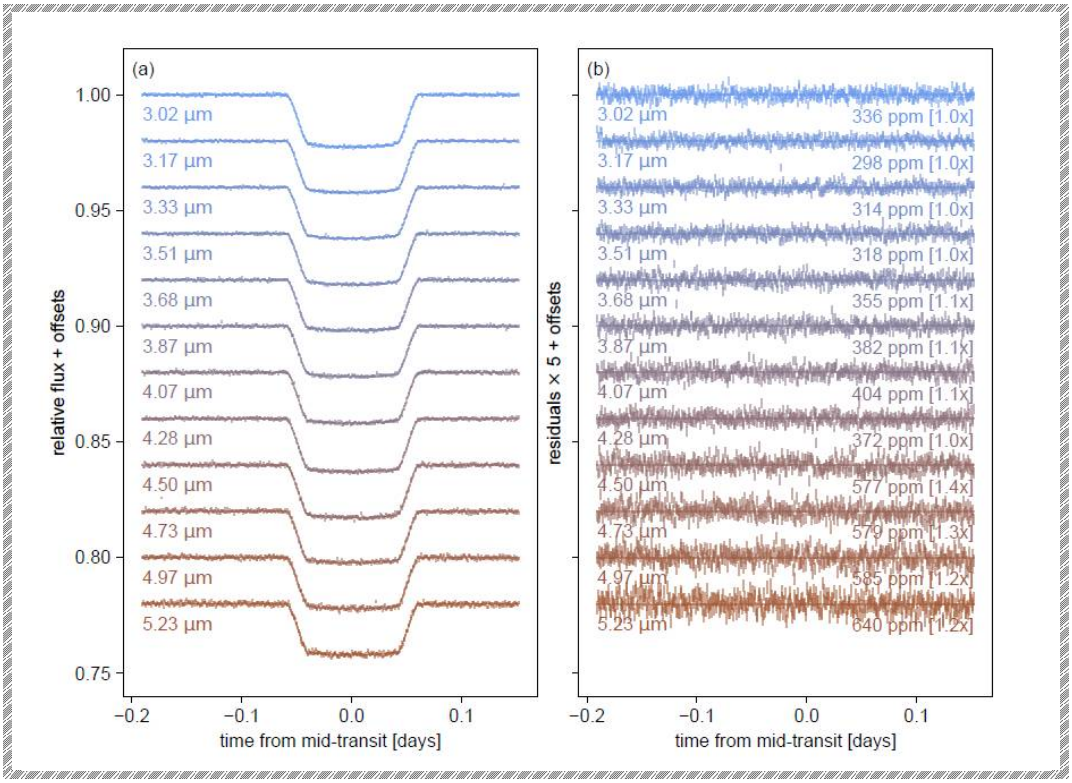
Data sheet

WASP-39 b, Exoplanet	
Exoplanet Name	WASP-39 b
Star	WASP-39
Object Description	Hot gas giantexoplanet
R.A. Position	14:29:18.42
Dec. Position	+03:26:40.2
Constellation	Virgo

WASP-39 b	
Mass	✓ 0.28 times Jupiter ✓ 0.94 times Saturn
Diameter	o 1.3 times Jupiter
Distance	o 700 light-years
Planetary equilibrium temperature	1170 K

Transit ofWASP-39 b:A transit occurs when an orbiting planet blocks some of the light from the star during it'smovement between the star and the telescope.Thechange in brightness of light curves recorded in July, 2022 by Webb's Near-Infrared Spectrograph (NIRSpec) revealed a transit in the WASP-39 star and WASP-39b exoplanetary system.During the transit of WASP-39 b, light with a wavelength of 4.3 microns is not as bright as at 3.0-micron or 4.7-micron light because it is absorbed by carbon dioxide.





Atmosphere of Exoplanetary system: The composition of chemical constituents of atmosphere throws light on origin and evolution of the planet. The profile of carbon dioxide is instrumental in arriving at how much gaseous material was used to form the gas giant planet.

Detection of water vapourand alkali metals: Previous observations from telescopes viz. NASA's Hubble and Spitzer, showed the presence of water vapor, sodium, and potassium in the planet's atmosphere. CO2 was suggested to explain the deep transit at 4.5 μm from Spitzer10 data.

2. Experimental

The transmission spectrum is studied by a comparative analysis of starlight filtered through a planet's atmosphere as it moves in front of the star with the unfiltered starlight spectrum when the planet is beside the star.Although all colors are blocked to some extent by the planet, some colors are blocked more than others. This occurs because each gas in the atmosphere absorbs different amounts at specific wavelengths. As a result, each color has a slightly different light curve. The range of 3 to 5.5-micronof IR spectrum is very selective and sensitive to water vapor and gases like methane and carbon dioxide,

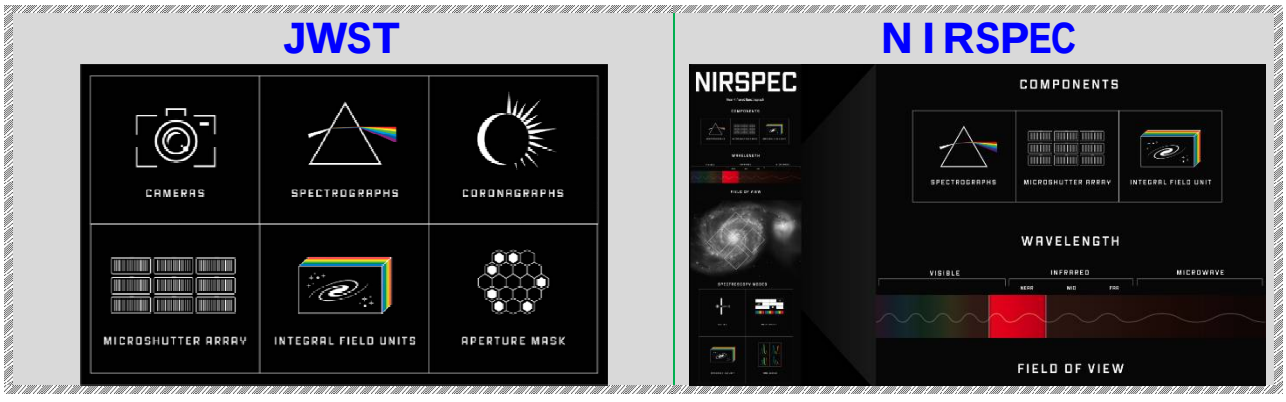
Unexplored IR range: Hither to no observatory has ever measured the subtle differences in brightness of full transmission spectrum across 3 to 5.5-micron range ofthe exoplanet in varied time-windows.

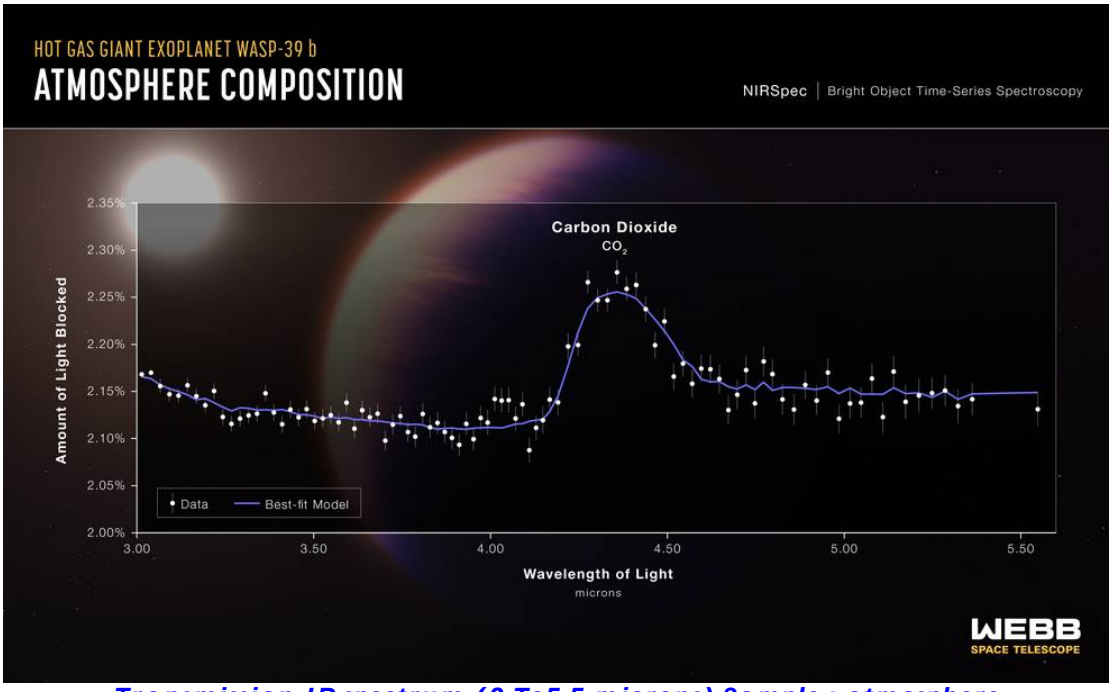
Data acquisition with JWST: Webb was scheduled to stare at the WASP-39-star system for more than eight hours on July 10, 2022 to capture NIR Spectrum. The data was acquired three hours before the transit, three hours during the transit and two hours after the transit. The data were recorded using the SUB512 subarray with fivegroups per integration and the NRSRAPID readout pattern. It resulted in integration times of 1.38s. NIRSpec obtained a total of 21,500 integrations over 8.23 hours of observations centered on the2.8-hour transit duration of WASP-39b.Each curve includes a total of 500 individual brightness measurements – about one per minute.

Data acquisition Probe

Near Infrared Spectrograph (NIRSpec)	
Mode	Bright Object Time Series (BOTS)
Fixed slit aperture	1.6" x 1.6" PRISM disperser
Wave length range	0.5 and 5.5 μm
Spectra	Brightness of each wavelength at set intervals of time

Sampling	
Single bright object	WASP-39 b
Sample	Atmosphere
Date	July 10, 2022
Time	15:24 To 23:37UTC





Transmission IR spectrum (3 To5.5 microns) Sample : atmosphere
Planet: Hot gas giant exoplanet WASP-39 b
Instrument: JWST; NIRSpec;prism mode ; Date: July 10, 2022

Credits: Illustration: NASA, ESA, CSA, and L. Hustak (STScI); Science: The JWST Transiting Exoplanet Community Early Release Science Team

Data points:	95(white circles)
White circle	o Amount of light that is blocked by the planet and absorbed by its atmosphere at specified wavelength
Gray lines	o Extending above and below each data point o Error bars : uncertainty of each measurement o On each observation, the error of measurements is extremely small
Blue line	Best-fit model for data based on o Known properties of wasp-39 b and its star (e.g., size, mass, temperature) o Assumed characteristics of the atmosphere

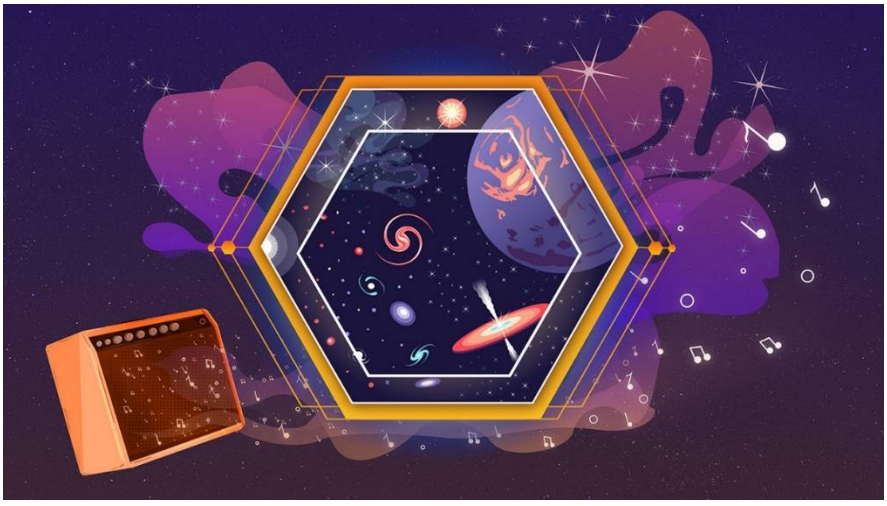
Model assumptions	o Planet is made primarily of hydrogen and helium o With small amounts of water and carbon dioxide o A thin veil of clouds
Peak centered around 4.3 microns	o Corresponds to the light absorbed by carbon dioxide ▪ 26σ significance
Model research	o Researchers can vary the parameters in the model – o Changing unknown characteristics like cloud height in the atmosphere and abundances of various gases • To get a better fit • Further understand what the atmosphere is really like

3. Inference

Detection of CO2: The small hill (peak)between 4.1 and 4.6 microns in IR spectra presents the first clear, unequivocal evidence for presence of carbon dioxide on WASP-39 b exoplanet (26σ significance). It has become a possibility due to unmatched infrared sensitivity of JWST, the-state-of-knowledge-Science-observatory of NASA, ESA and CSA. This discovery is of first of its kind in a planet outside our solar system.

Early Release Science observations: The goal is promoting, nurturing and taking to higher heights of human-knowledge-to-know-universe-including lifethrough inclusive, transparent, and collaborative deep-level scientific explorations. The Early Release Science work is the corner stone of NASA's open science guiding principles opening new vistas to- quick-analysis of golden-data. This paves way to develop open-source tools tenable for next-level-Science-research and explorations in coming decades.

Webb's Science Themes



- Probe: Webb's near- to mid-infrared sensitivity; high-resolution imaging; spectroscopic capabilities
- Outcome:Showed hitherto hidden parts of the universe to our eyes
  - Stars among clouds of dusts
  - Water in the atmospheres of other worlds
  - Deepest image of the universe ever taken

4. JWST Observatory in Future: The short-term (annual) and long-term (decadal) approved planned/designed scientific data-acquisition schedules will provide an insight into how planets, stars, galaxies form/evolve. The list also contains uniqueness of our solar-system including life and the like. The experimental, computational and theoretical contributions from all over the world will conglomerate into best possible science which is closer and closer to the known-known, known-unknown, unknown-known and unknown-unknown with realistic truth as well as false values.

Further Reading

NASA's Webb Space Telescope Detects Carbon Dioxide in Exoplanet's Atmosphere, NASA , August 25, 2022	
https://youtu.be/RQVDT8x2qlc?t=286	How Webb Found CO2 in an Exoplanet's Atmosphere

How much

An Ultra-modern chemist

Perceives

Ancient chemistry

in time and space

using state-of-knowledge-probes

From nature of Nature (.)

Imbibeyesterday's knowledge
Generate new knowledgetoday
Aspire/await for tomorrow's knowledge

Astro../macro/nano/micro/atto /zepto-/... plank time/size/separation/energy

when was yesterday, today, tomorrow?
what is knowledge?
What is evolution
Why and how
Energy

Who shows/ foreshows tells/foretells
What and how we learn /forget, don't learn
Do-interact/don't interact
Why? what for?
To nature of Nature (.)