



Zooming in on the Shocked and Turbulent Intergalactic Medium of Stephan's Quintet with JWST and ALMA

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Science paper

Appleton, Guillard, Emonts et al. 2023

<https://arxiv.org/archive/astro-ph>

Getting to know Stephan's Quintet in Galaxies!

NGC 7319

GIANT SHOCK WAVE
AS INTRUDER HIT GAS
IN GROUP

NGC 7318A

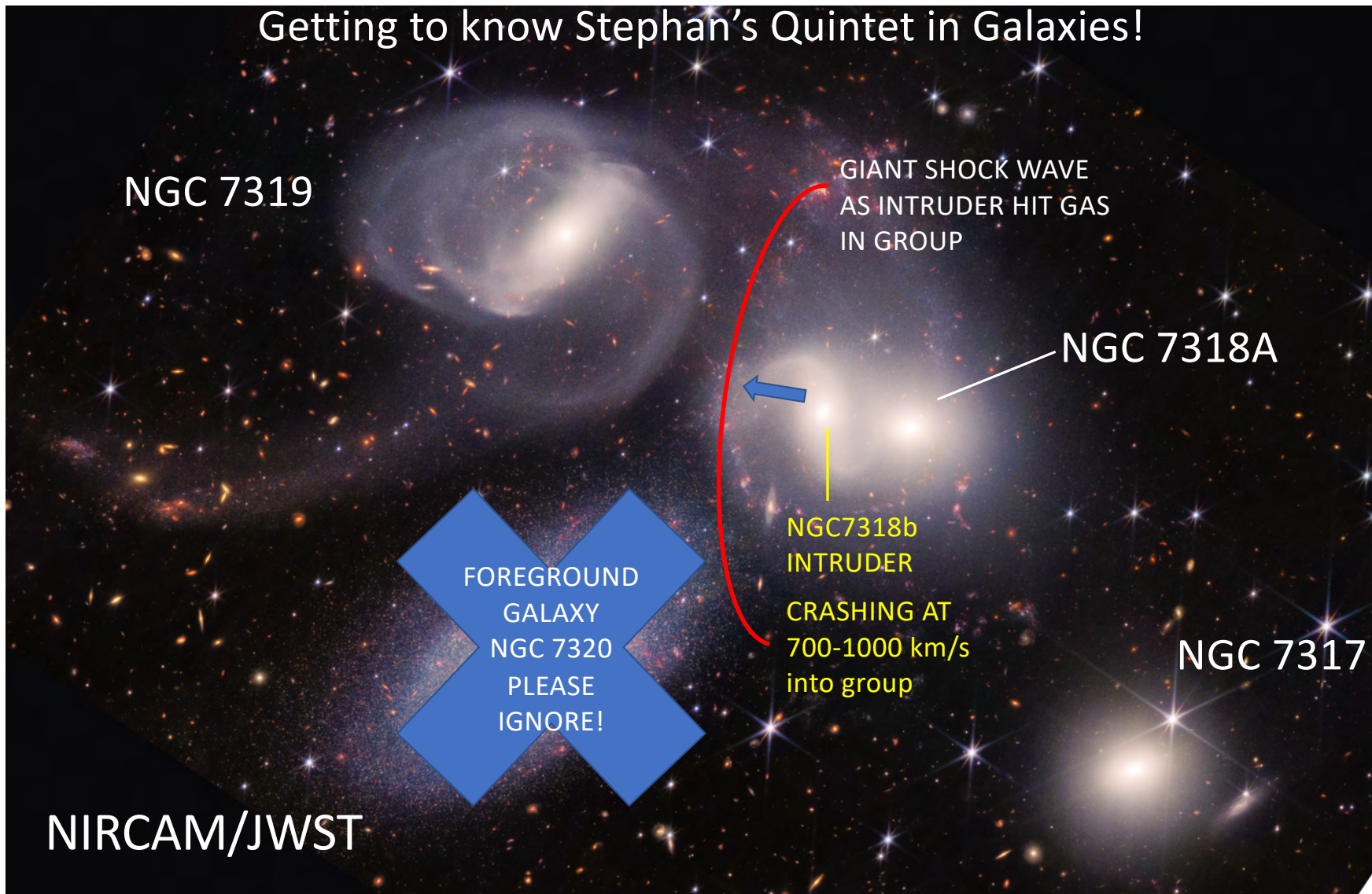
NGC7318b
INTRUDER

CRASHING AT
700-1000 km/s
into group

NGC 7317

FOREGROUND
GALAXY
NGC 7320
PLEASE
IGNORE!

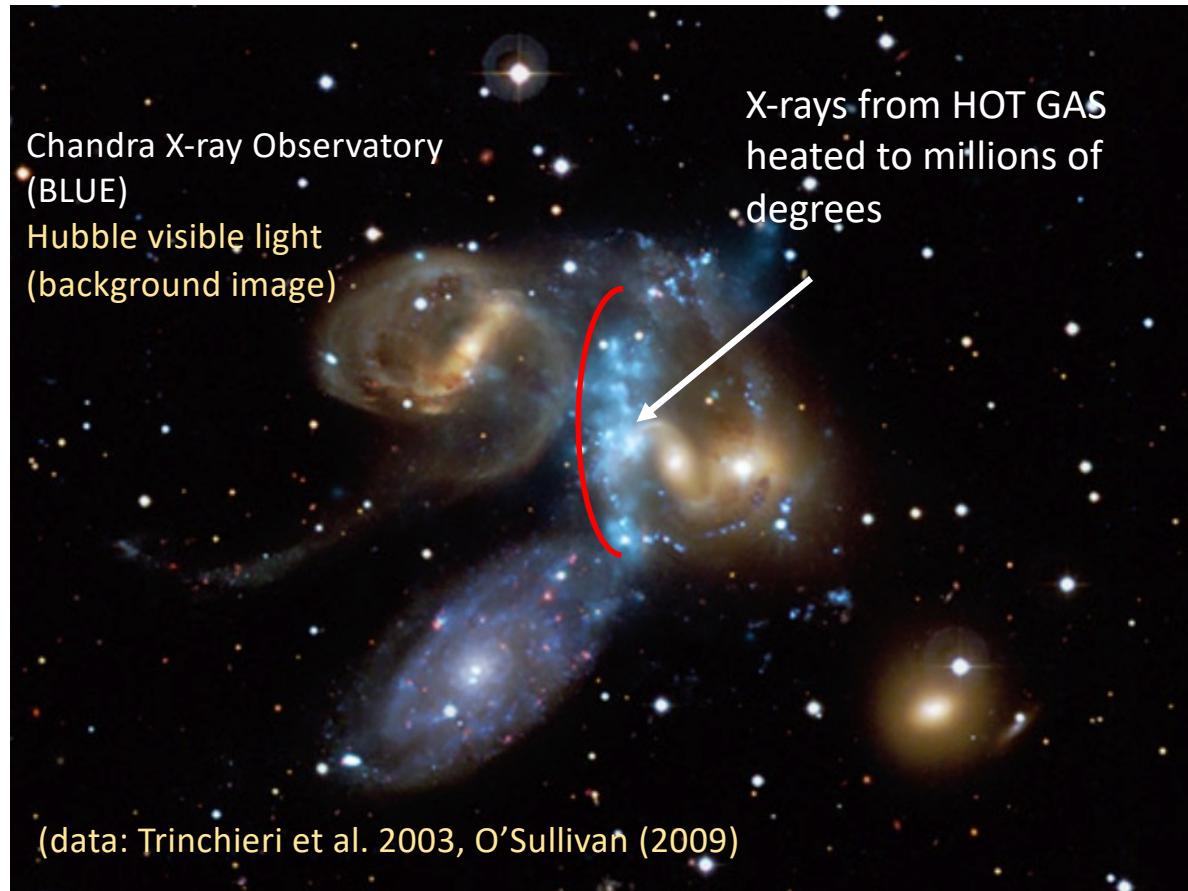
NIRCAM/JWST



A SHOCK WAVE IS PRODUCED AHEAD OF AN OBJECT TRAVELING FASTER THAN THE SPEED OF SOUND IN A GASEOUS MEDIUM

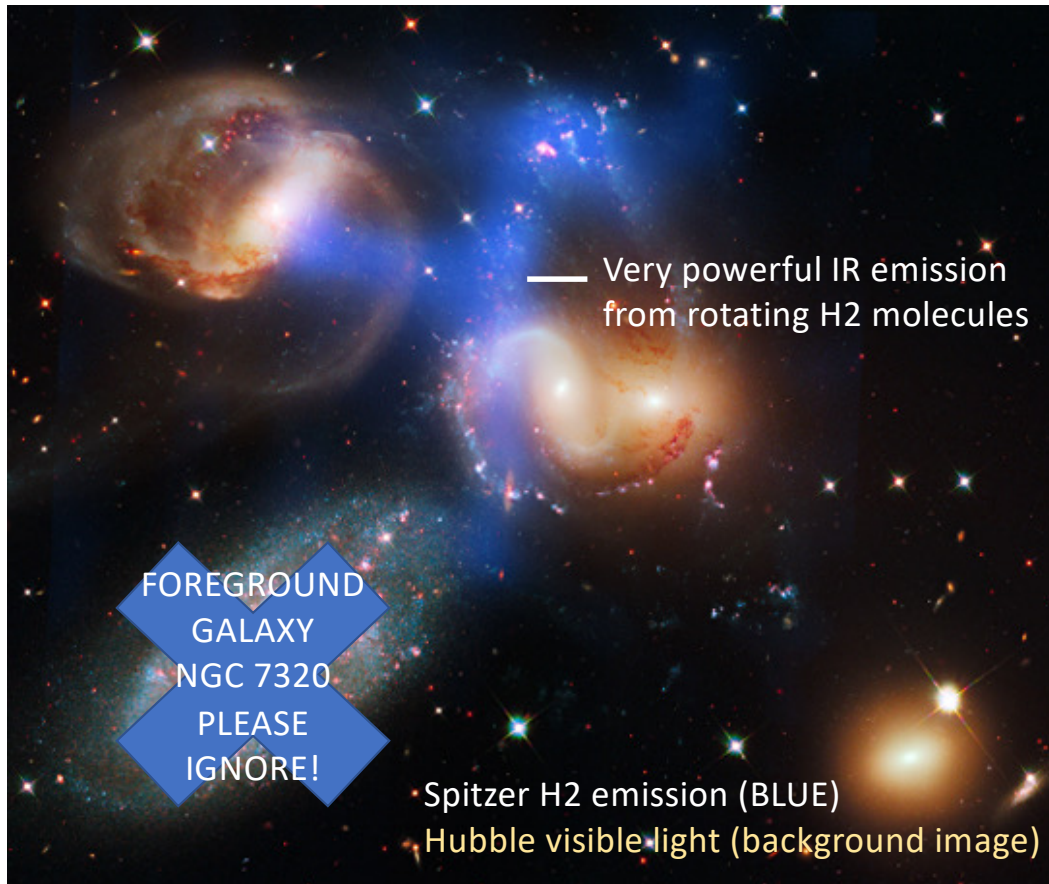
In our case the “object” is the INTRUDER GALAXY and the “gaseous medium” is gas in the intergalactic medium of the group

THERE IS PREVIOUS EVIDENCE OF THE SHOCK FROM CHANDRA X-RAY OBSERVATIONS



This early X-ray result is
CONSISTENT
WITH HIGH SPEED
SHOCK WAVE HEATING
GAS IN ITS WAKE

In 2006 NASA's *Spitzer Space Telescope* discovered a remarkable fact:
We found lots of fragile H₂ molecules radiating in the shock!



H₂ molecules would not normally survive shock waves traveling faster than **30-50 km/s**

HOW IS THIS RECONCILED WITH 1000 km/s shock?

Appleton et al. (2006), Cluver et al. (2010)

Mystery:

This presentation will try to solve the **MYSTERY of why most of the powerful energy flowing out from the shock is from very fragile hydrogen molecules (H-H) which are easily destroyed** by shock waves as slow as 30-50 km/s.

How can they be formed and continue to survive in such a violent environment?

Solution:

Shock wave hits a CLUMPY MEDIUM. **Hot X-ray gas AND DENSE COLD CLUMPS FORM IN WAKE OF SHOCK**

DENSE CLUMPS TAKE THE BRUNT OF THE FAST FLOWING HOT GAS SHATTERING INTO CLOUDLETS

THE CLOUDLETS ARE THE SOURCE OF THE MOLECULAR HYDROGEN EMISSION AS THEY SLOWLY JOIN THE VIOLENT FLOW BEHIND THE SHOCK

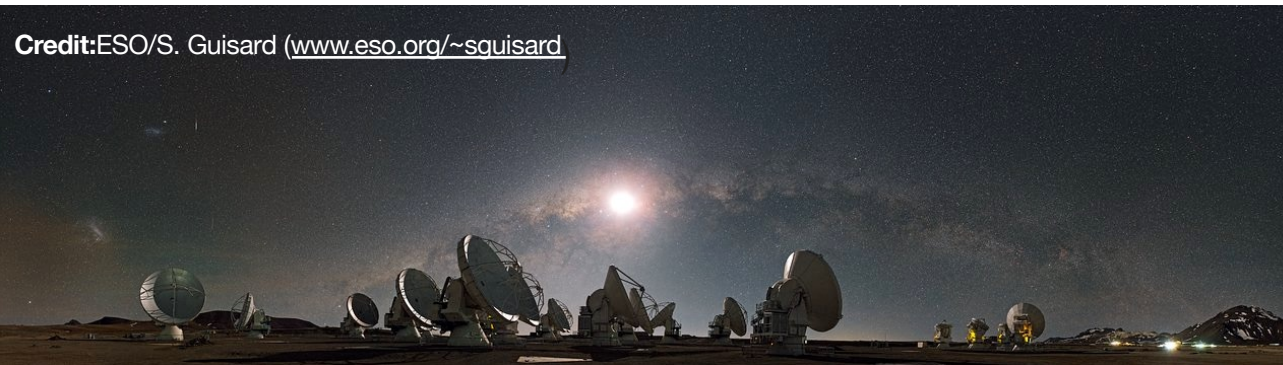
TO SOLVE THE MYSTERY: WE ZOOM IN ON

Early Release Observation (ERO) Images from JWST and new ALMA observations

James Web Space Telescope (JWST): can detect with **AMAZING CLARITY**

- THE SAME **WARM H₂ MOLECULES** that *Spitzer* detected with MIRI instrument
- **IONIZED HYDROGEN** gas heated to 10000 degrees (K) or more

ATACAMA LARGE MILLIMETER ARRAY (ALMA): -sensitive to Carbon-Monoxide (CO 2-1 transition) molecules which traces the **VERY COLD H₂ molecules**

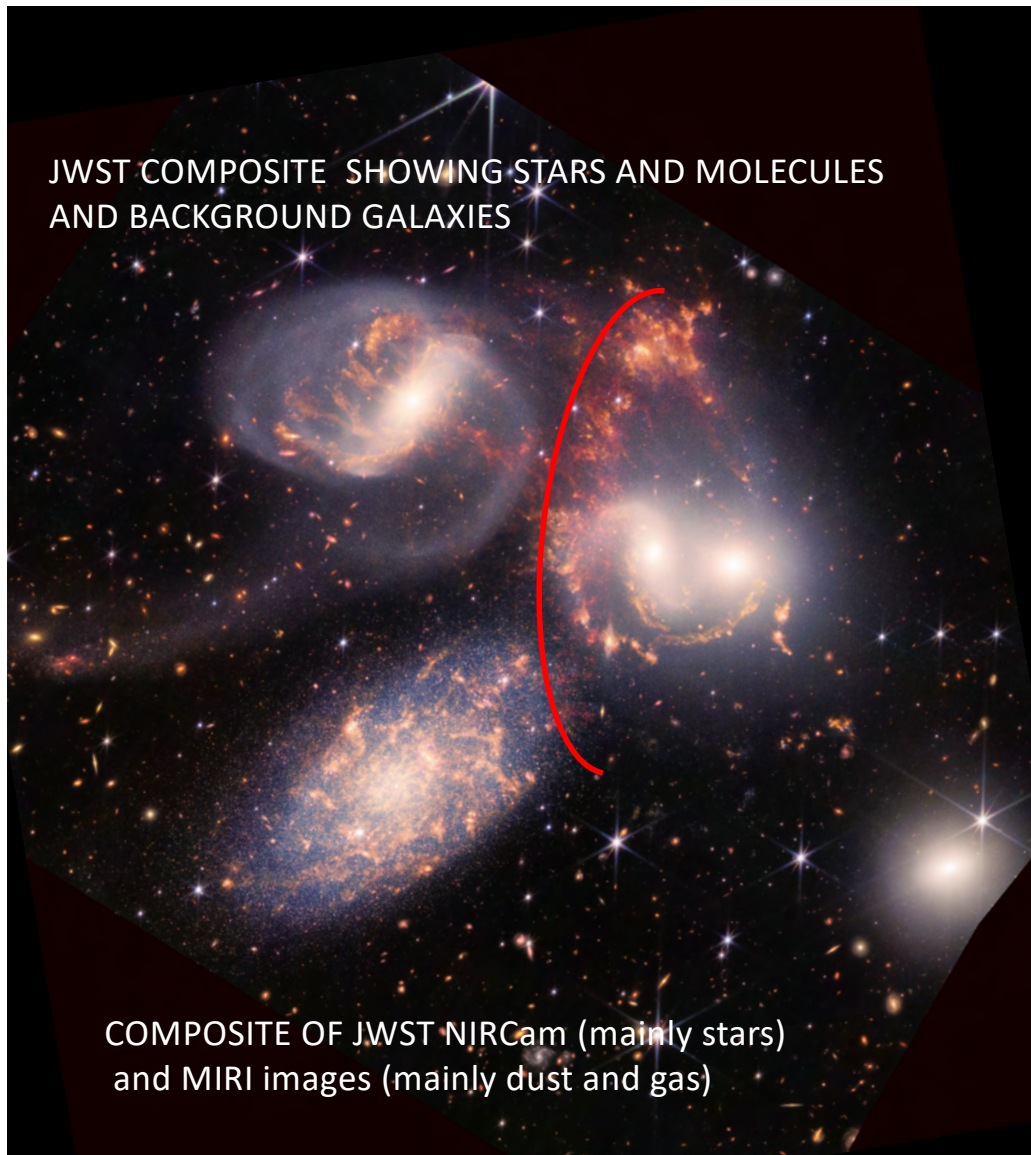


ALMA and OUR MILKY WAY GALAXY



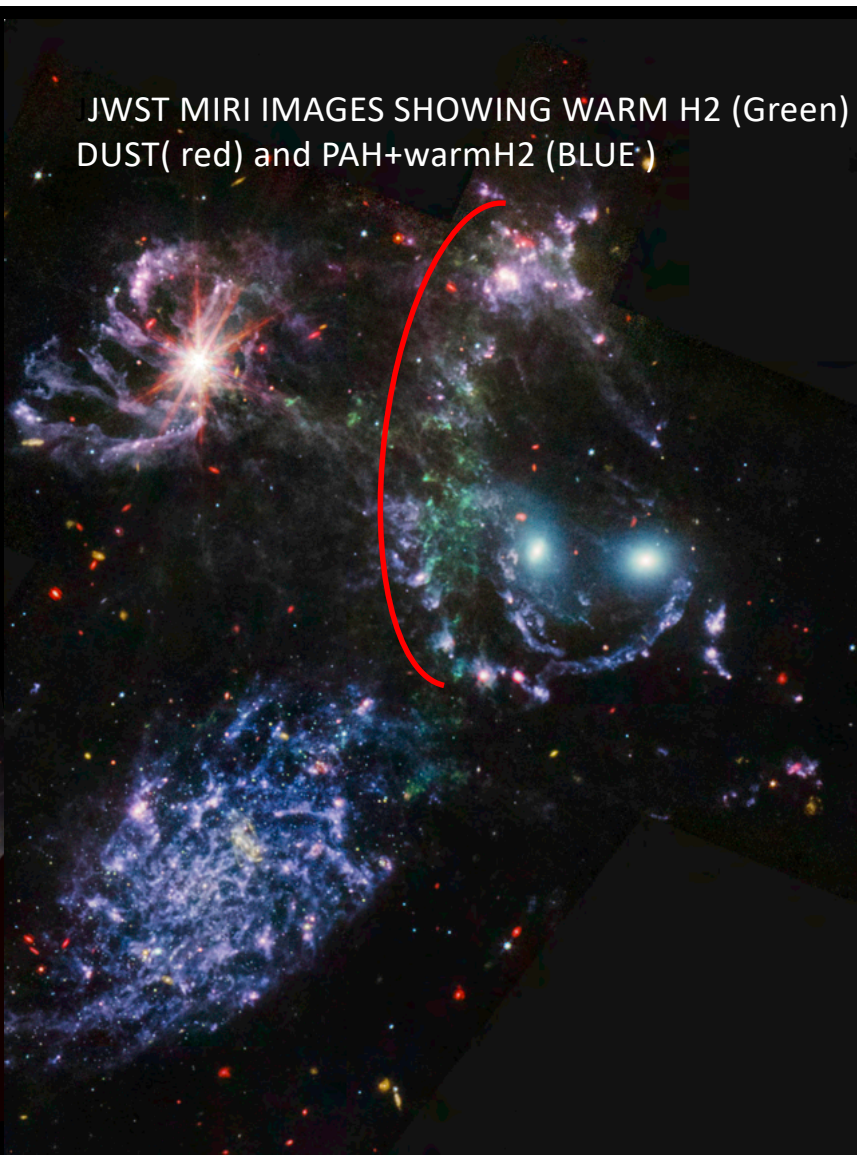
James Web Space Telescope
and humans

JWST COMPOSITE SHOWING STARS AND MOLECULES
AND BACKGROUND GALAXIES



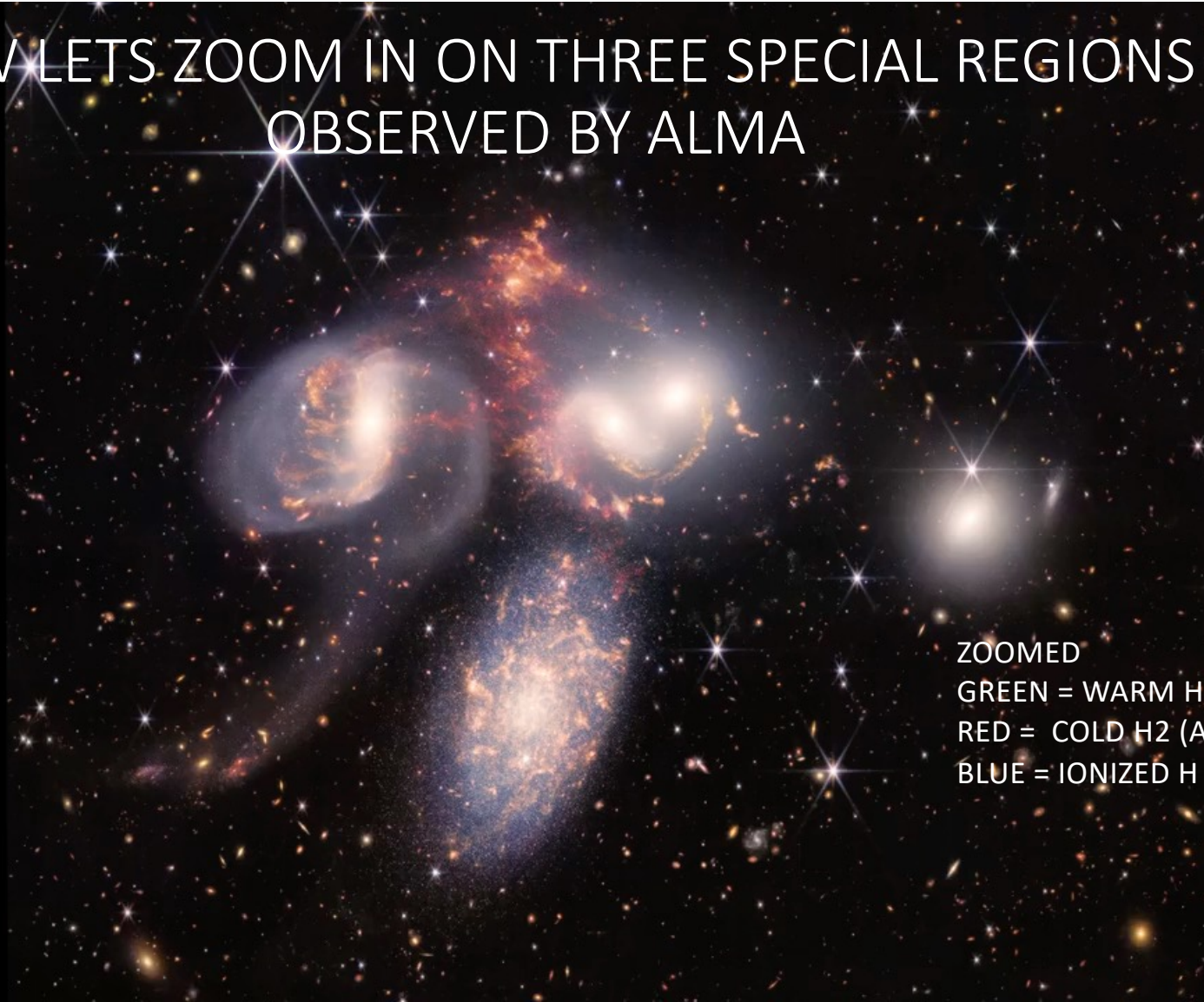
COMPOSITE OF JWST NIRCам (mainly stars)
and MIRI images (mainly dust and gas)

JWST MIRI IMAGES SHOWING WARM H₂ (Green)
DUST (red) and PAH+warmH₂ (BLUE)

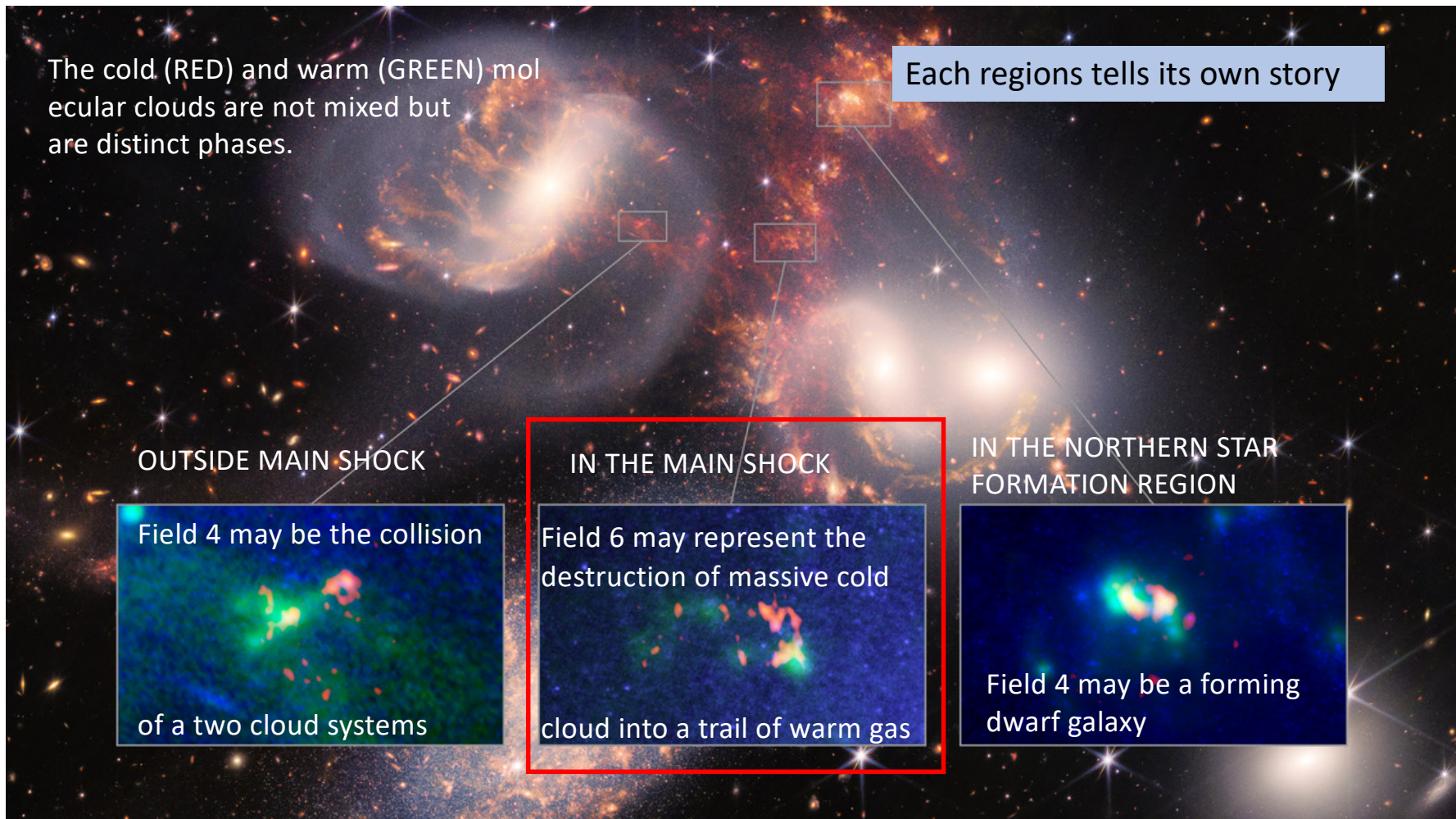


NOW LETS ZOOM IN ON THREE SPECIAL REGIONS
OBSERVED BY ALMA

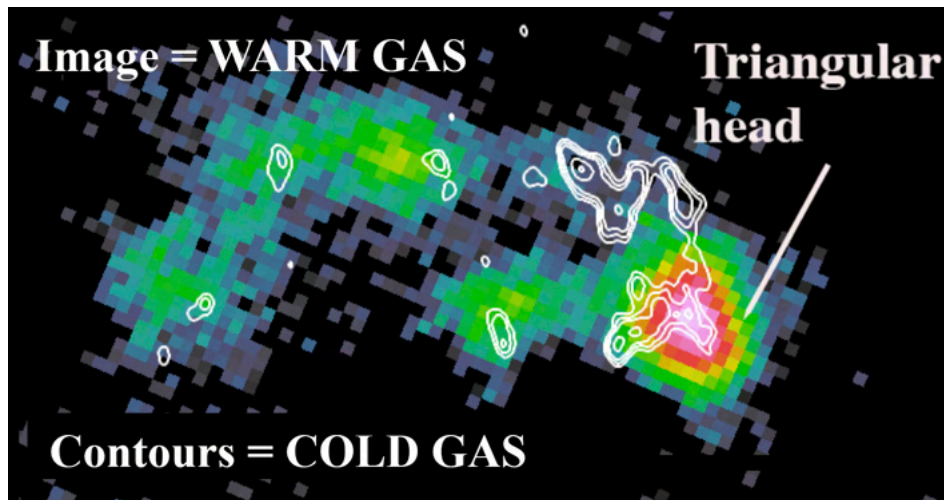
ZOOMED
GREEN = WARM H₂ (JWST)
RED = COLD H₂ (ALMA)
BLUE = IONIZED H + Stars (JWST)



WHAT CAN WE LEARN FROM THE ZOOM IN ON THE PHASES OF THE (WARM, COLD AND IONIZED) GAS?



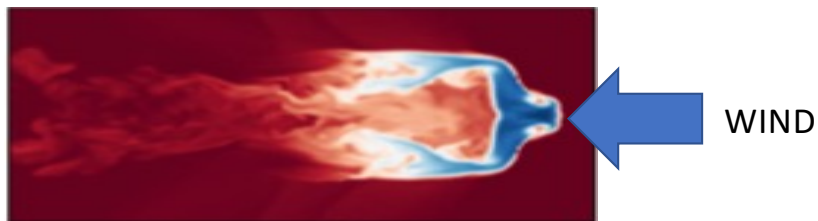
Lets concentrate on the region in the **MAIN SHOCK** where a massive cloud is being destroyed



The **HEAD IS A DENSE SHELL** of **COLD H₂** **SURROUNDED BY WARM H₂** AND A **TAIL OF WARM GAS**

The ALMA data tells us the **COLD GAS IS QUITE TURBULENT** IN THE HEAD AND PARTS OF THE TAIL (Kinematics)

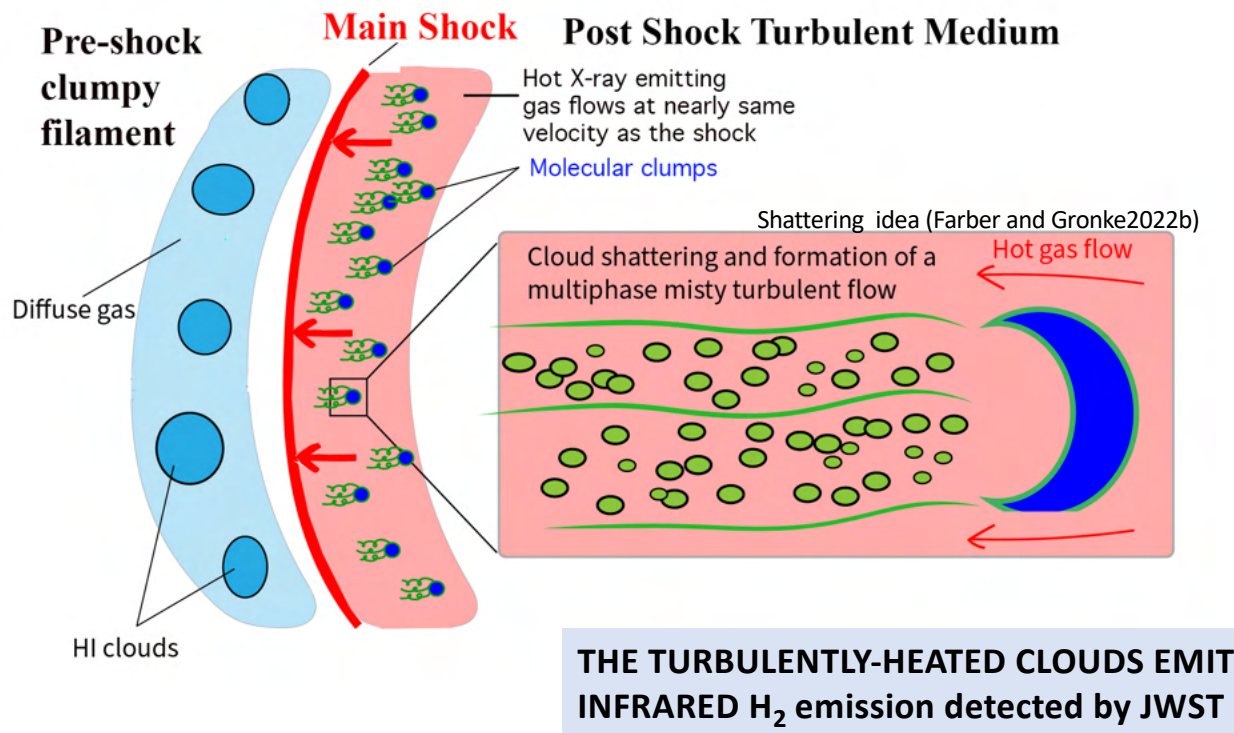
THE **GAS MOTIONS** APPEARS TO **STREAM AWAY FROM THE HEAD**



One of a series of models of break-up of massive cloud by fast wind (Farber and Gronke 2022a)

Structure is reminiscent of what happens when a dense cloud encounters a fast **WIND** of hot gas

A "toy" model to explain the abundance of "warm" H₂ in the shock-wave



- 1) FAST SHOCK WAVE overtake "clumpy" tidal filament
- 2) HOT GAS AND DENSE cold clumps form
- 3) the violent hot gas flow begins to shatter the cloud into tiny cloudlets
- 4) the cloudlets INITIALLY ARE SHIELDED FROM THE FULL IMPACT OF THE FLOW but they get **dragged SLOWLY into the hot flow** and start to turbulently mix

Mystery Partially Solved

The inter-galactic medium of Stephan's Quintet is not uniform but is complex mix of warm, cold molecular gas and ionized gas: All three ALMA-study regions have different warm and cold structures:

ONE OF THE REGIONS (Field 6) provides a clue to the **MYSTERY OF WHY THE MAIN SHOCK GLOWS SO BRIGHTLY IN THE INFRARED GLOW** from **FRAGILE WARM MOLECULES**

Dense cold clouds (observed by ALMA) are formed behind the shock. These cold clouds are exposed to the full violence of the flow of hot gas (**CHANDRA X-ray emitting**) created there, causing them to begin to shatter into tiny cloudlets. Because the cloudlets are partially protected by the larger cold clouds, **they are more gently** drawn into the fast flows behind the shock. They are **slowly accelerated, buffeted, and turbulently heated**, creating a **foggy tail of warm IR radiating H₂ gas (JWST)** behind the dense cold clouds. *Future spectroscopic observations with JWST and more extensive ALMA data will test this picture by allowing us to measure the motions in the warm H₂ gas tails.*

You can view the full scientific paper on the
astrophysics pre-print server

Paper will appear tomorrow (Tues Jan 10 2023 at 1pm GMT)

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