NEBULÆ'S LIGHT

STELLAR NURSERIES REVEALED BY JWST

Katie Carolan

SPACEtalks on August 27, 2024 @ 2pm

Black Rock Observatory, Burning Man



✨ Star Lady ✨
← TO TELESCOPE

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INSPIRED BY OUR COSMIC PERSPECTIVE

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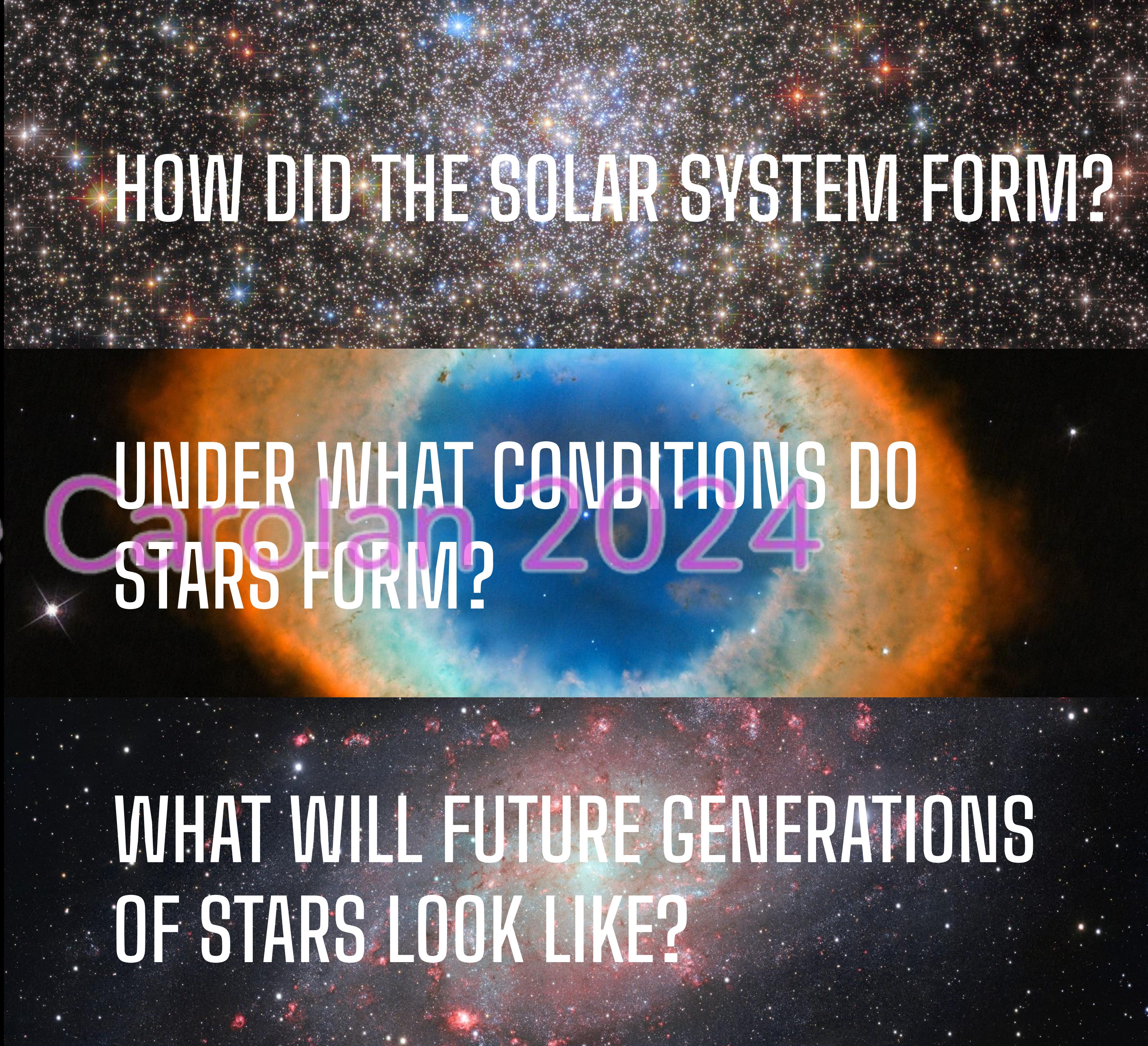
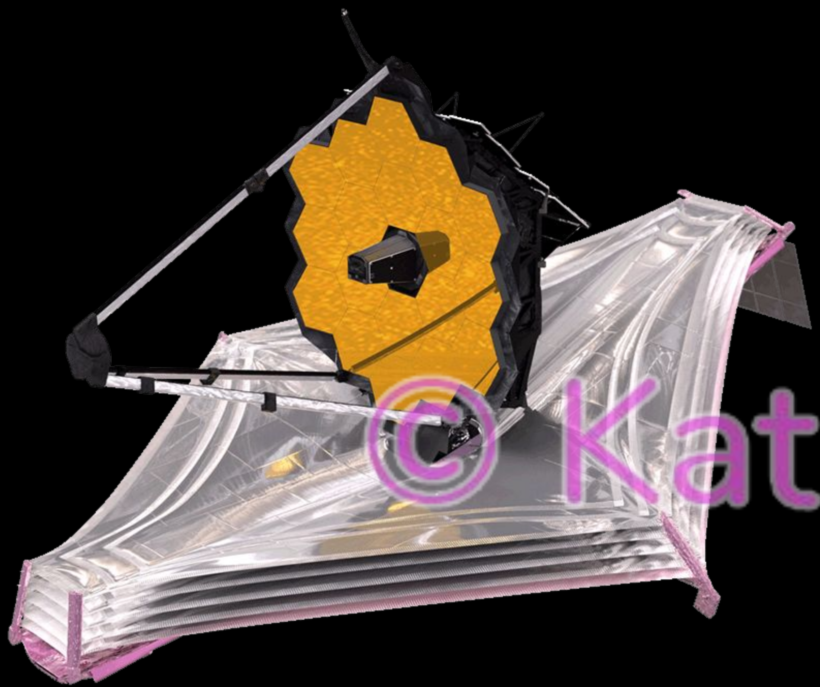


1.

SPACE TELESCOPES!

Beloved Infrared Space Telescopes



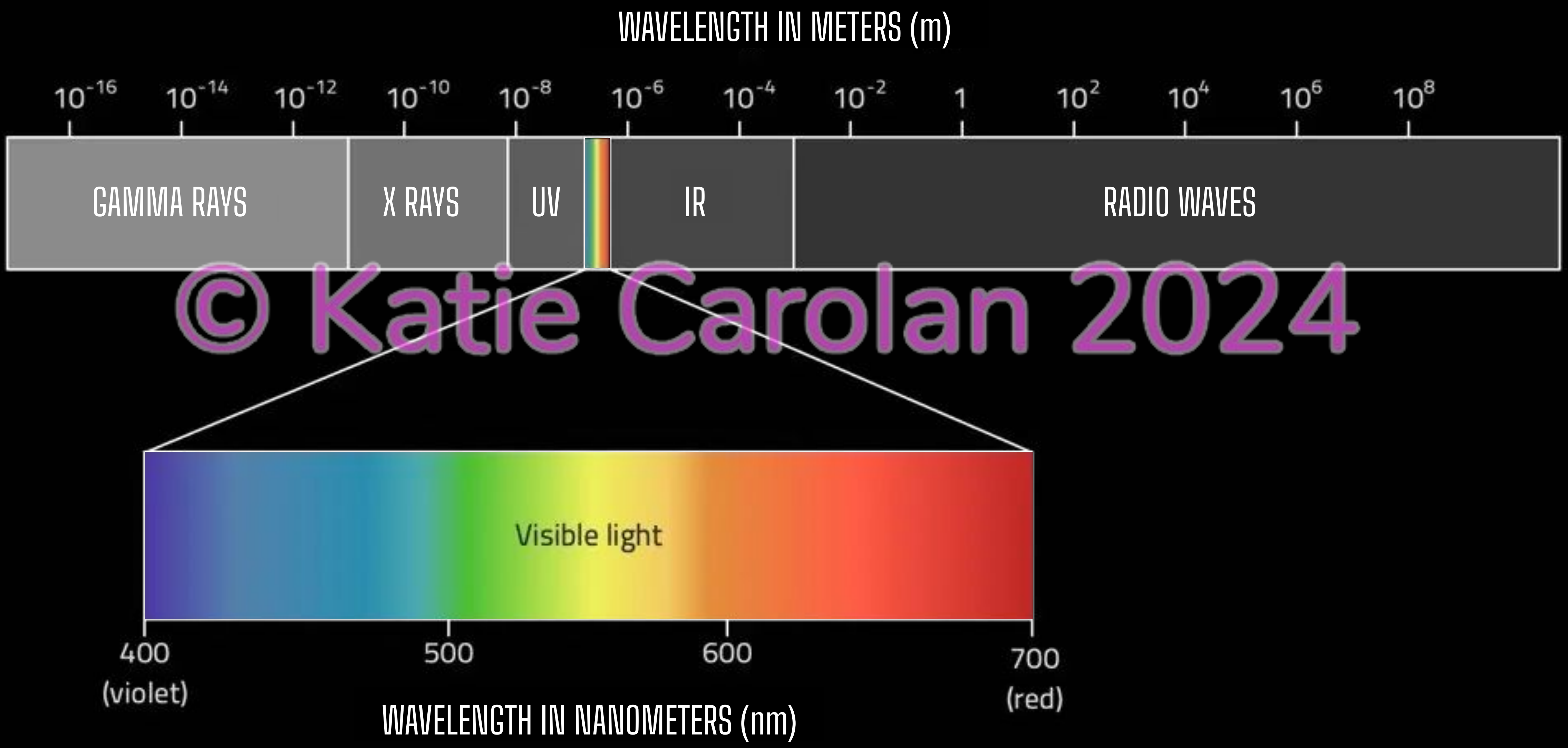
Webb
Near, Mid-Infrared

Hubble
Ultraviolet, Optical, Near-Infrared

Spitzer
Mid, Far-Infrared

Herschel
Far-Infrared, Submillimetre

The Electromagnetic Spectrum



OUR WINDOW TO THE UNIVERSE

The Milky Way surveyed in all wavelengths.

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JWST
HUBBLE

JWST

SPITZER


JWST
SPITZER

II.

AN INTRO TO STAR FORMATION

AN INFANT STAR GROWS:

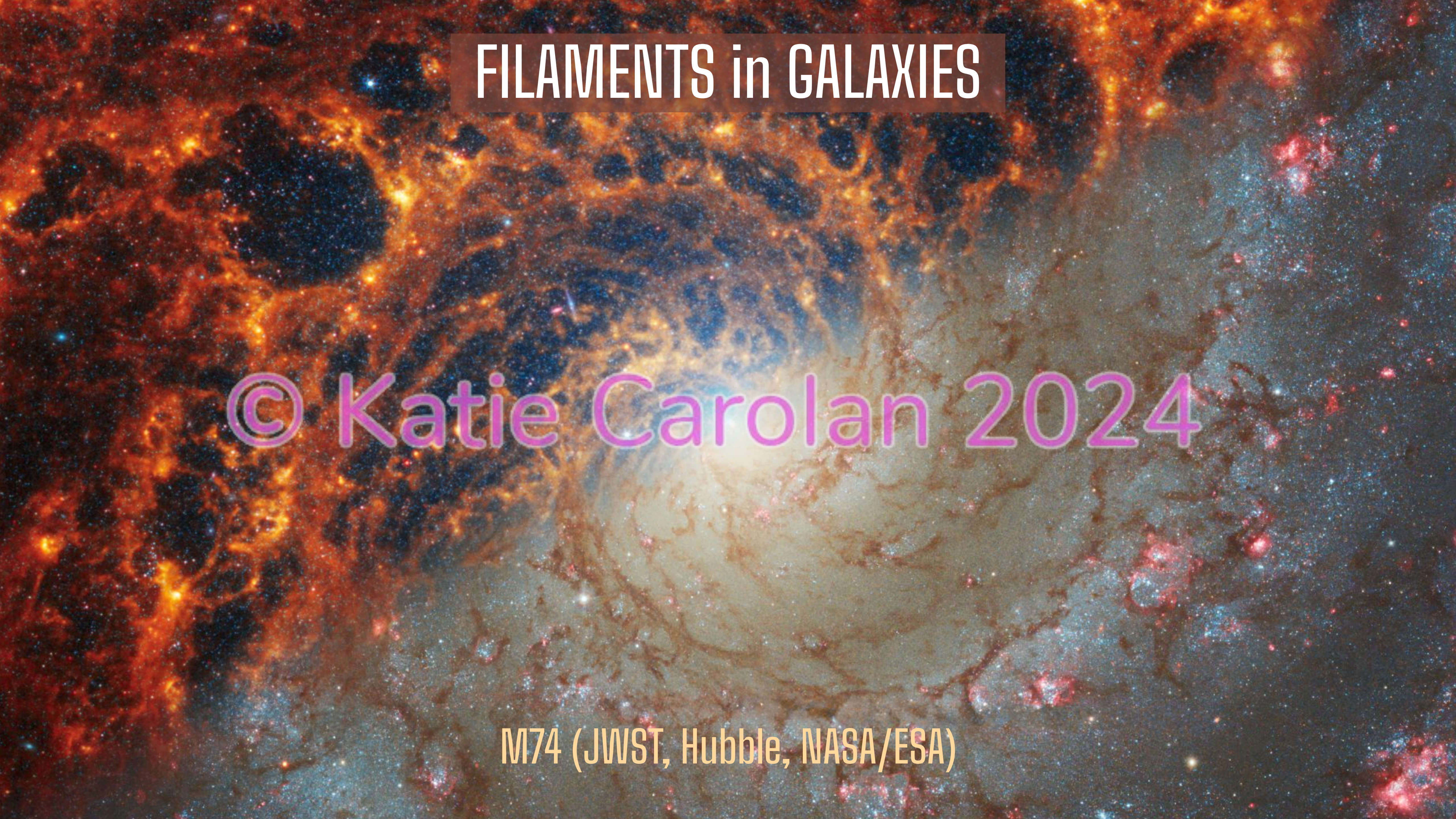
cold gas falls into the this growing protostar. most gas makes it to the core, although some gets blasted away in outflows

NASA

III.

NEBAULÆ STRUCTURE

FILAMENTS in GALAXIES

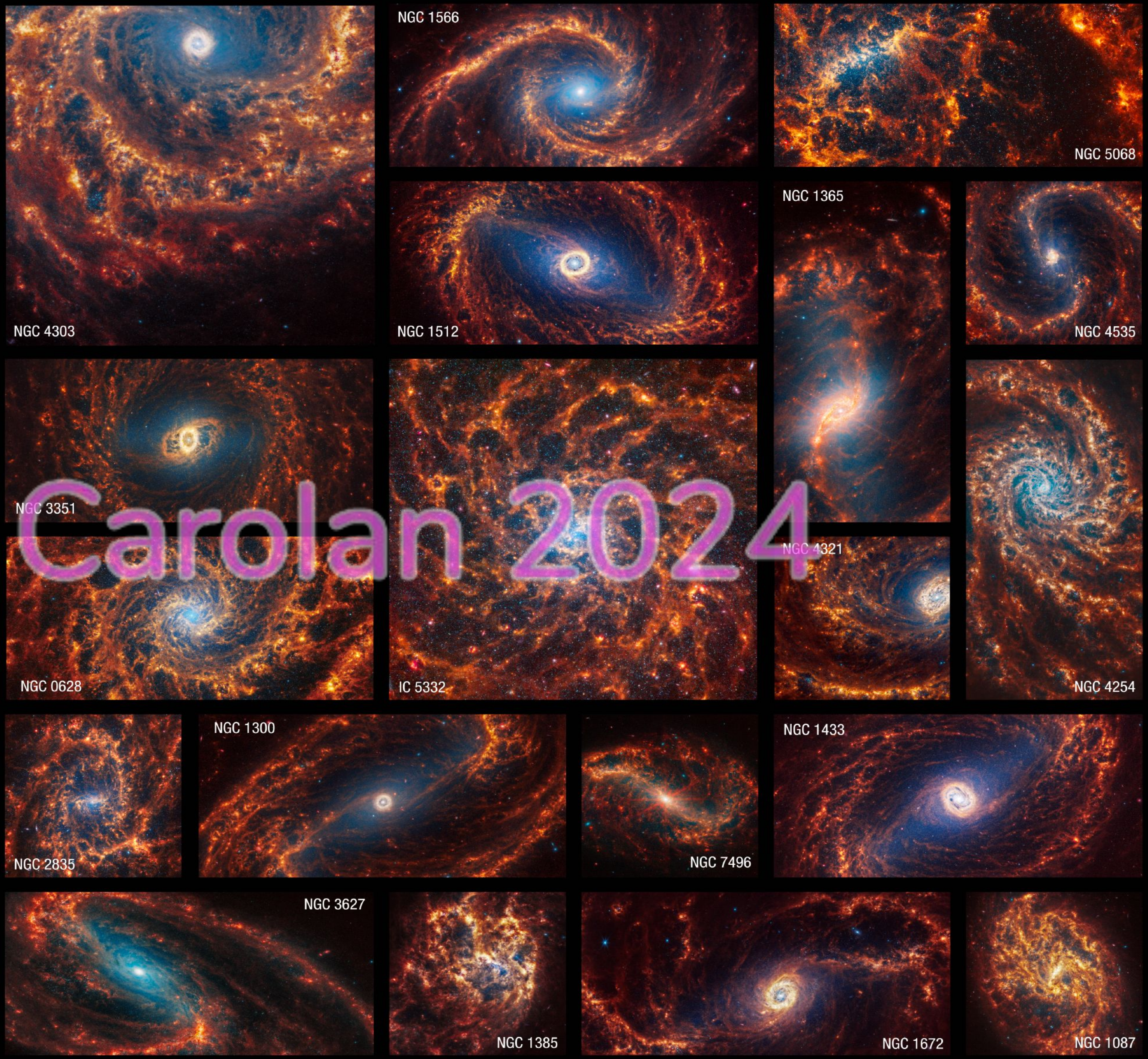


M74 (JWST, Hubble, NASA/ESA)

M74 (JWST, NASA/ESA)

FILAMENTS in GALAXIES:

survey showing how filamentous spiral galaxies are



PHANGS Galaxies (JWST)

FILAMENTS in NEBULÆ

W3, W4, W5 (Herschel Space Observatory, ESA)

FILAMENTS in NEBULÆ

Taurus (Herschel Space Observatory, ESA)

FILAMENTS in NEBULÆ

Rho Ophiuchi (Herschel Space Observatory, ESA)

FILAMENTS in NEBULÆ:

a closer look at the heart of this active star-forming region

Rho Ophiuchi (JWST)

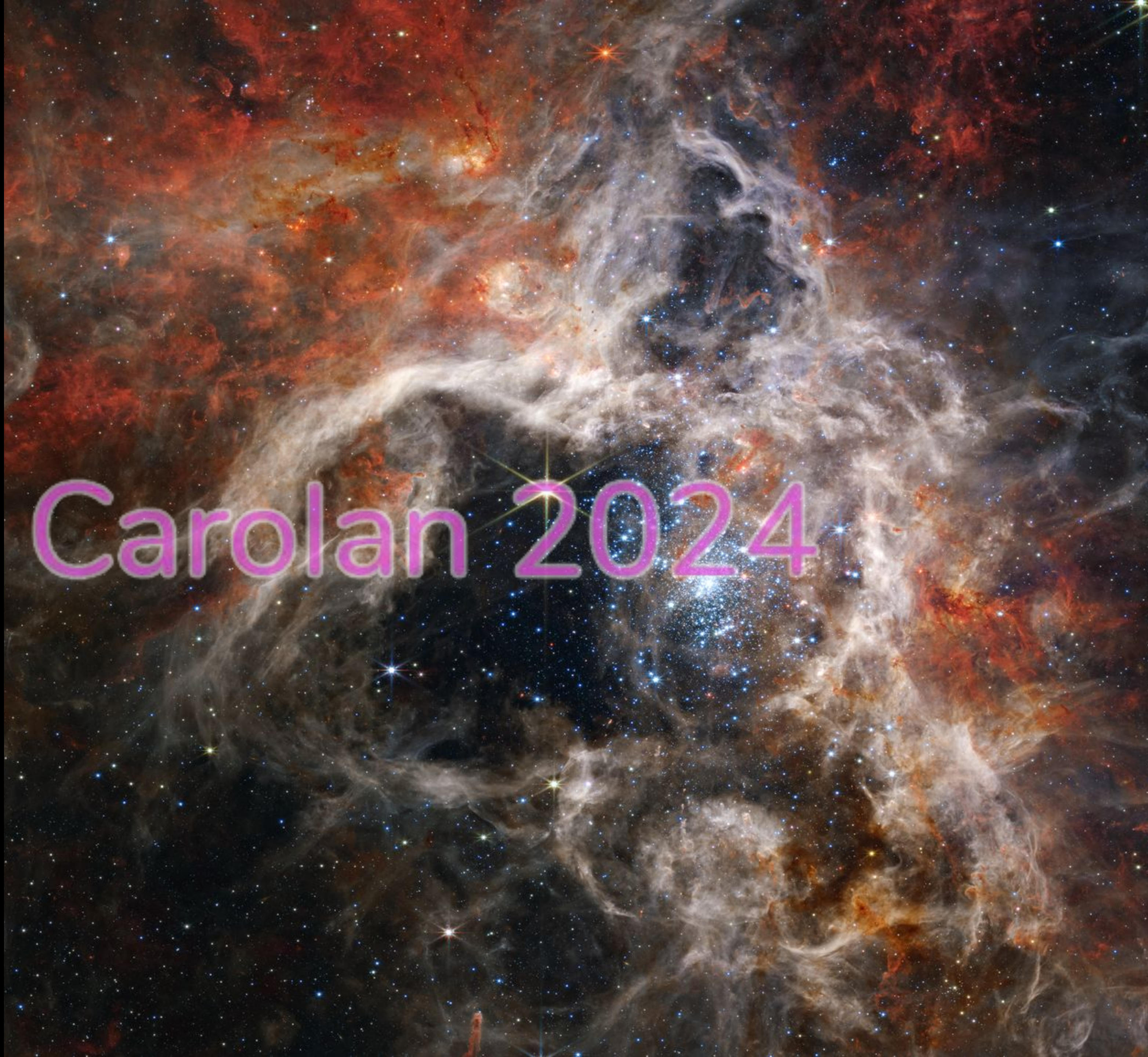
FILAMENTS in NEBULÆ:

cold, dense filaments are the perfect place for baby stars to start forming

NGC 346 (JWST)

FILAMENTS in NEBULÆ:

the Tarantula Nebula is the largest, brightest star forming region in the Local Group



NGC 2070 (JWST)

PROTOSTARS & THEIR OUTFLOWS:

huge outflows of gas that didn’t make it to the core

L1527 in TAURUS (JWST)

PROTOSTARS & THEIR OUTFLOWS:

invisible protostar shrouded in dust

HH 211 (JWST)

PROTOSTARS & THEIR OUTFLOWS:

star ignites and reveals itself!

HH 46/47 (JWST)

IV.

ALIGNED OUTFLOWS IN SERPENS

ALIGNED OUTFLOWS in SERPENS

Serpens Main (JWST)

ALIGNED OUTFLOWS in SERPENS

ALIGNED POLARIZATION in SERPENS

Serpens Main (JWST)

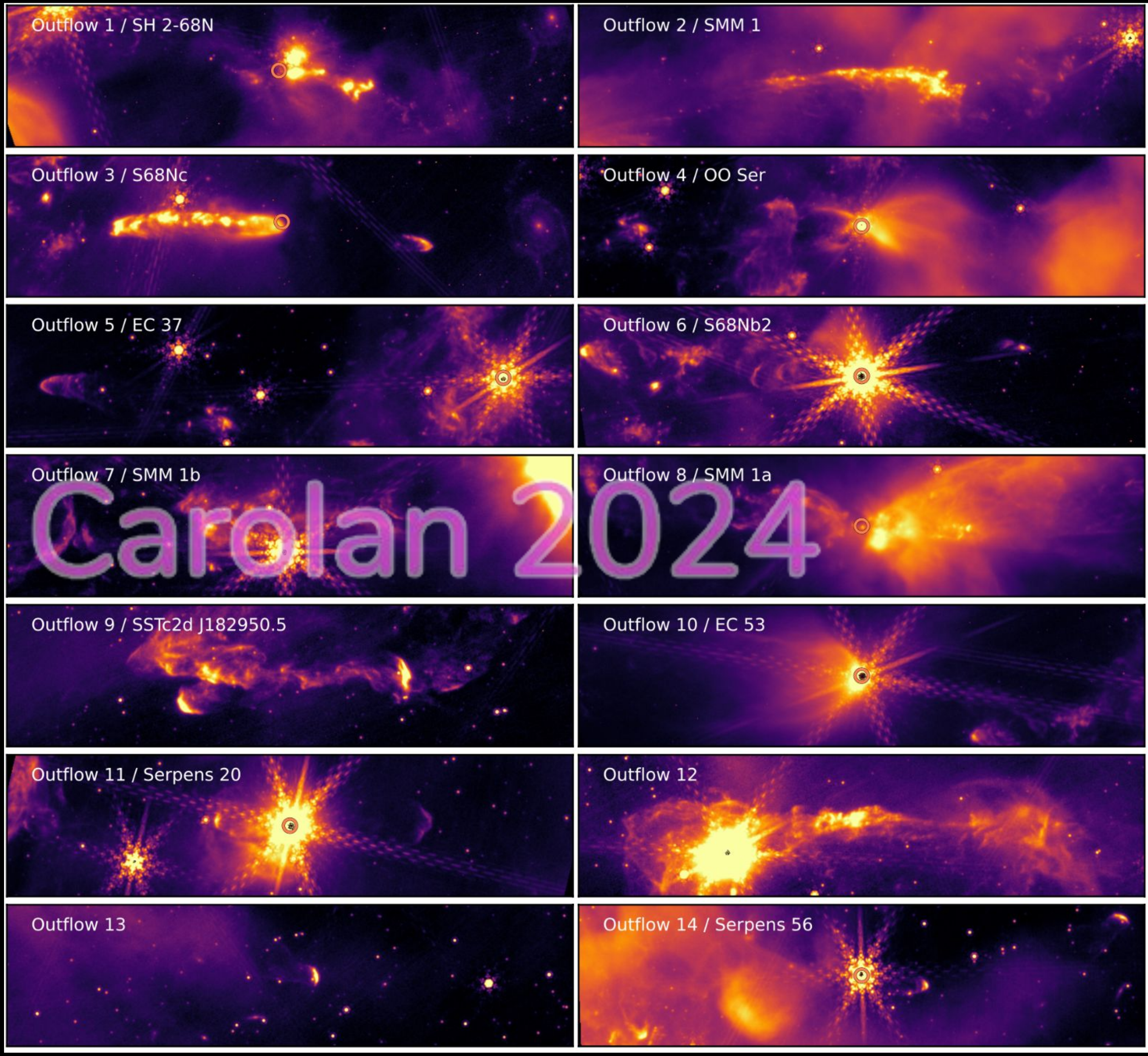
V.

WHAT SCIENCE REALLY LOOKS LIKE

IS THIS THE SCIENCE?

Why are (almost) all the protostellar outflows aligned in Serpens Main?

(Green et al., June 2024)



DATA GETS EXTRACTED FROM PRETTY PICTURES

Why are (almost) all the protostellar outflows aligned in Serpens Main? (Green et al., June 2024)

Table 2. Average position angle and uncertainty, and likely driving source for each outflow in this work. RA/Dec are given for the central/driving source coordinates. Pol. is the dust polarization angle as measured in the HAWC+ Band E (216 μm archival data (see text).

ID	RA	Dec	PA	Length	Length Ratio[a]	Pol.[b]	Conf.	Driving Source Cand.
	degree	degree	degree	arcsec		degree		
1	277.45017	1.27892	141.2 ± 9.3	0.39	1.12	119.0 ± 3.5	A	SMM 9 (SH 2-68N)
2	277.45025	1.26917	129.6 ± 3.5	0.59	1.11	110.5 ± 3.1	B	SMM 1 (S7)
3	277.45296	1.28233	112.0 ± 2.1	0.91	1.23	118.5 ± 4.6	A	S68Nc[c]
4	277.45471	1.27225	108.3 ± 21.4	0.9-2.8	1.18	110.8 ± 3.5	A	OO Ser
5	277.45521	1.275431	115.6 ± 2.5	1.4	1.06	109.3 ± 11.1	A	EC37 (V370 Ser)
6	277.45663	1.28506	151.6 ± 2.7	1.3	–	259.2 ± 5.2	A	S68Nb2
7	277.45704	1.24914	158.8 ± 6.9	0.51-1.7	–	166.0 ± 4.5	A	SMM 1b
8	277.45742	1.25581	135.2 ± 6.2	1.5-5.1	1.03	131.3 ± 4.5	A	SMM 1a
9	277.45946	1.23919	135.6 ± 9.2	0.89-1.4	1.04	179.8 ± 5.3	A	SSTc2d J182950.5+01141
10	277.46321	1.27800	138.9 ± 5.2	1.7	–	116.1 ± 9.8	A	EC 53
11	277.46742	1.26347	83.4 ± 0.6	1.3	1.29	265.1 ± 6.7	A	Serp 20
12	277.46833	1.25169	132.7 ± 6.4	1.2	1.02	106.6 ± 4.1	A	No identification
13	277.47400	1.22158	123.2 ± 15.8	0.59	5.56	161.7 ± 6.2	B	No identification
14	277.47996	1.22283	68.1 ± 5.0	0.63	–	177.3 ± 6.2	A	Serpens 56
15	277.49504	1.24622	156.3 ± 11.9	0.33	–	240.1 ± 6.3	B	No identification
16	277.49642	1.23522	160.8 ± 0.7	1.4	1.32	239.1 ± 5.1	A	SMM 3
17	277.49646	1.21064	2.7 ± 4.8	1.2	–	228.9 ± 3.7	A	Serpens 9
18	277.50167	1.19583	76.1 ± 2.0	1.1	1.02	259.0 ± 6.6	B	SMM 11
19	277.50296	1.21603	130.4 ± 9.1	1.7	–	266.9 ± 4.3	C	Ser-emb 4E
20	277.51067	1.24542	216.8 ± 10.1	1.7	–	197.3 ± 13.2	A	2MASS J18300491+0114393
21	277.48688	1.24633	134.0 ± 5	–	–	177.3 ± 5.1	A	[EC92] 82
22	277.50621	1.25431	140.4 ± 5	–	–	241.0 ± 39.5	A	Shd 2

[a] The ratio of the lengths of two outflow lobes. This is only available for bipolar morphologies.

[b] The position angle of the polarization vector.

[c] The driving source position (S68Nc) presented here is the center of the central knot, as indicated in Figures 2 and 3.

DATA GETS PLOTTED

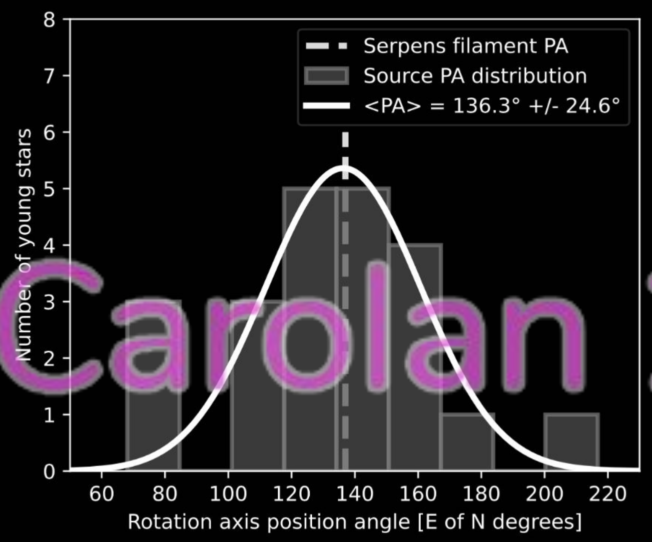


Figure 5. Distribution of measured average position angles for all 22 sources, clustering around the filament PA = 139°. The black curve is a Gaussian fit to the distribution with parameters (mean and standard deviation) given in the legend.

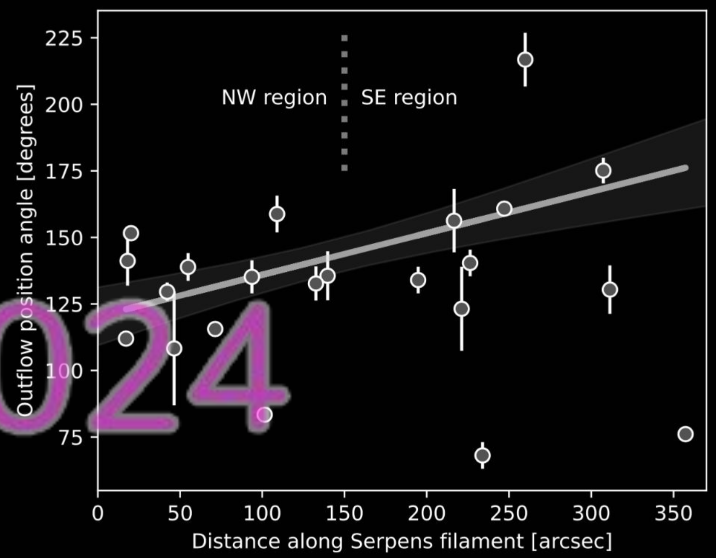


Figure 6. PA as a function of position along the filament. The PAs of the NW region are more correlated than the SW region. The line is the best linear fit after removing three outliers with the highest and lowest measured PA. The shaded region shows the 99% confidence level of the fit.

Why are (almost) all the protostellar outflows aligned in Serpens Main?

(Green et al., June 2024)

CONCLUSIONS ARE DRAWN

Why are (almost) all the protostellar outflows aligned in Serpens Main? (Green et al., June 2024)

- NIRCam/F480M is particularly well-suited to detect outflows because it contains molecular, atomic, and ionic tracers that all emit strongly in protostellar outflows/jets. The result is a mixed morphological catalog with a high detection rate.
- 12 outflows were identified in the northwestern filament/region, while 8 outflows were identified in the southeastern filament/region. Additionally, two prominent disk shadows were confirmed in the central region.
- The axes of the 12 outflows in the NW region are inconsistent with random orientations and align with the filament direction from NW to SE. Additionally, the position angle of jets/outflows from the 2 identified disk shadows align with the filament axis. We estimate ~0.005% probability of the the observed alignments if sampled from a uniform distribution in position angle.
- The position angles of the outflows align with SOFIA/HAWC+ 214 μm dust polarization vectors measured locally around each driving source. However, the disk shadows do not align with their local magnetic fields. This broad alignment does not apply in the SE region. Few of the 8 identified outflows in this region align with the filament axis, or with the dust polarization vector.
- The density of outflows detected in this catalog (~ 66 outflows per pc2) is higher than other low mass star forming regions (e.g., NGC 1333), and ten times greater than observed by JWST/NIRCam in Carina (NGC 3324).

ALIGNED OUTFLOWS in SERPENS

Serpens Main (JWST)

✨💖⭐

THANK YOU FOR YOUR ATTENTION!

QUESTIONS?

Design by Pamela Moidel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