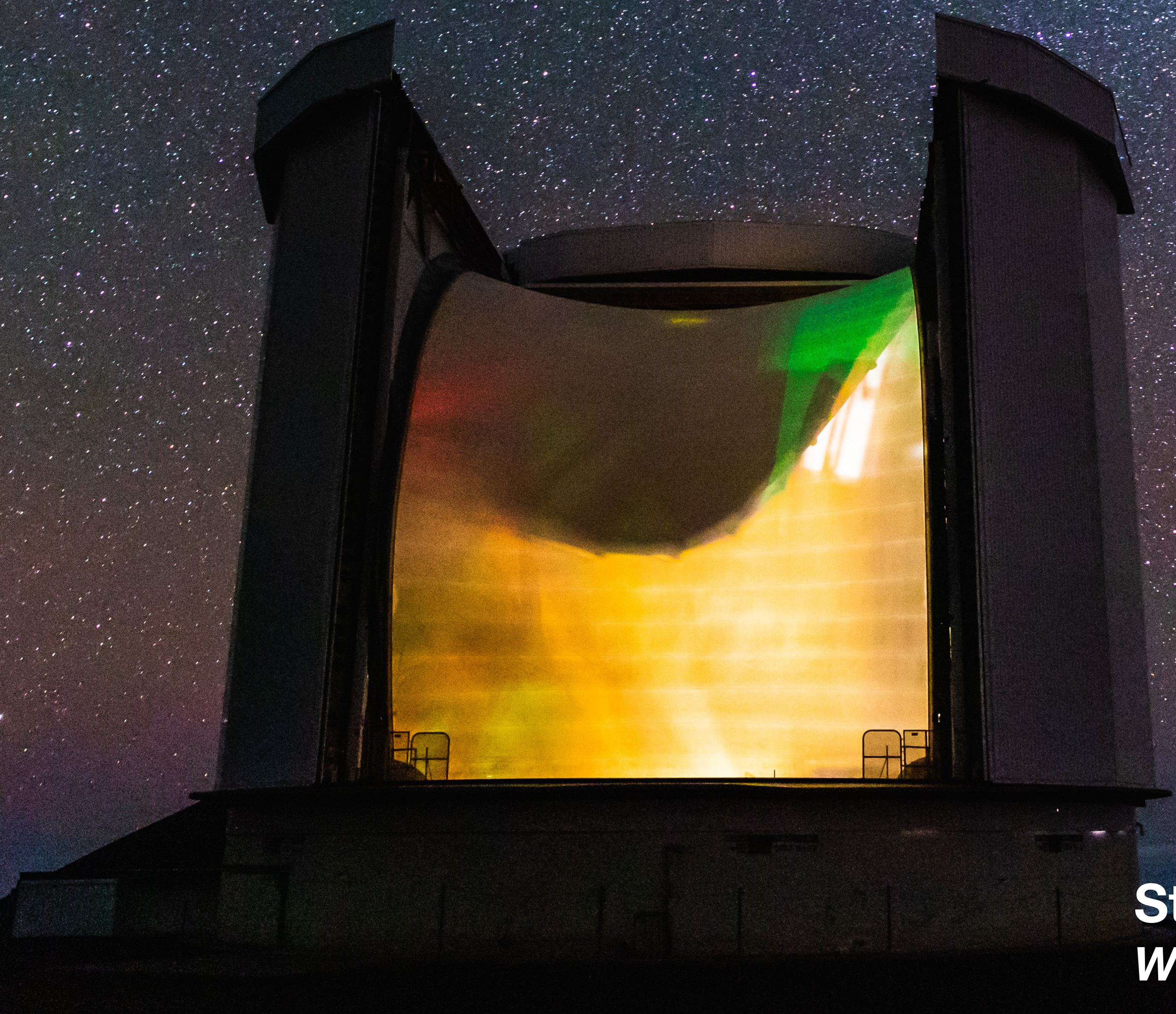
JCMT Science

Results and Resources



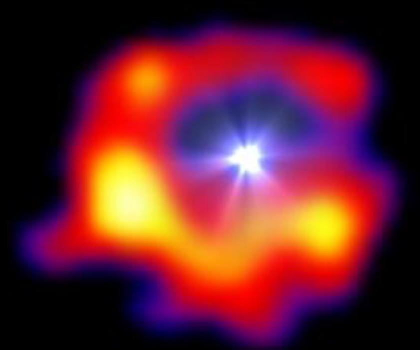
Steve Mairs - December 1, 2020
With thanks to Mark Rawlings

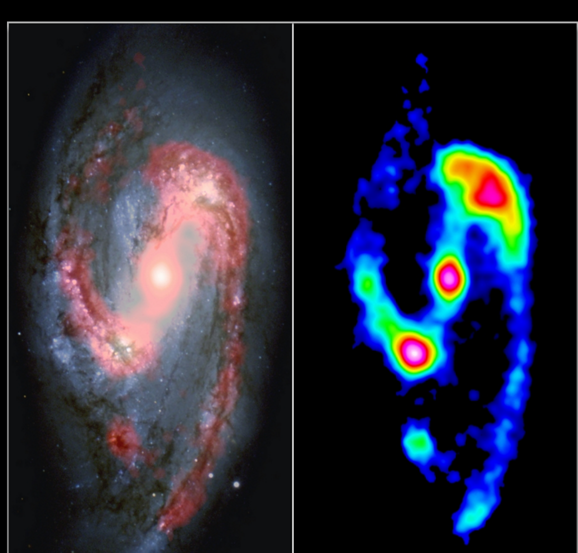

Overview
★ PI & Urgent queues
- Recent Results
★ Large Programs
- Recent Results
★ The Event Horizon Telescope
★ JCMT Data Archive

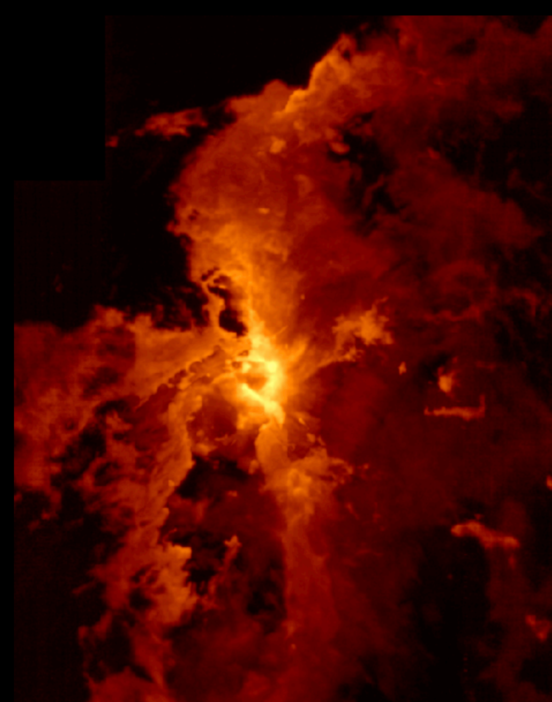
What does the JCMT do?

Submillimetre light is ideal for observing
Dust and gas related to the formation of stars

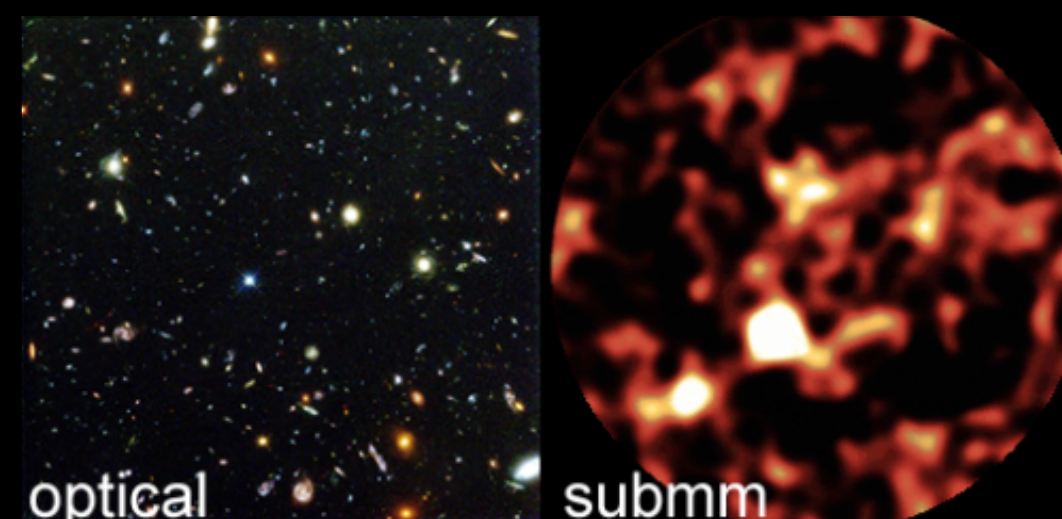
Both Near…

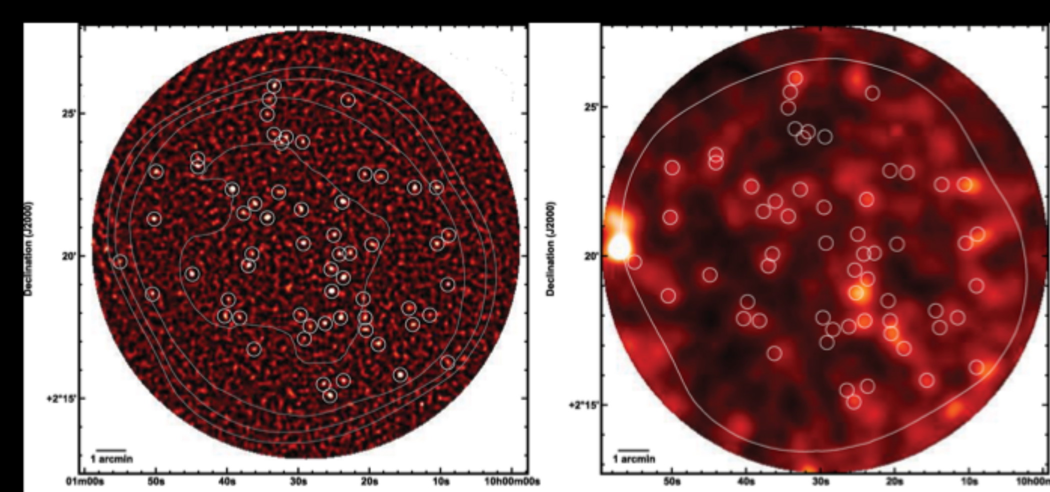






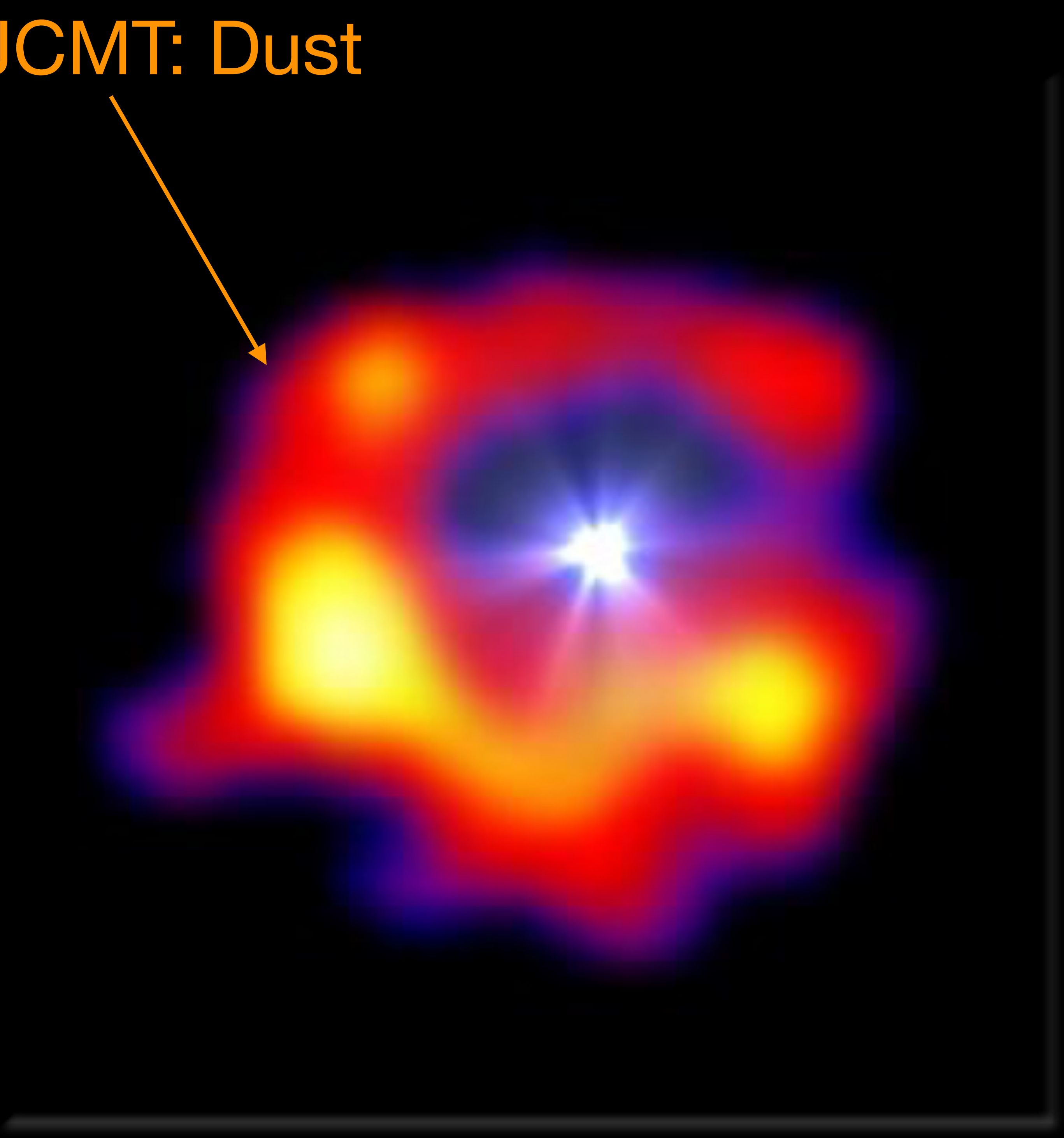
…And Far





JCMT/SCUBA image of ring of dust particles around the nearby star Epsilon Eridani. This star is similar to the Sun, with the dust eventually going on to form a planetary system.

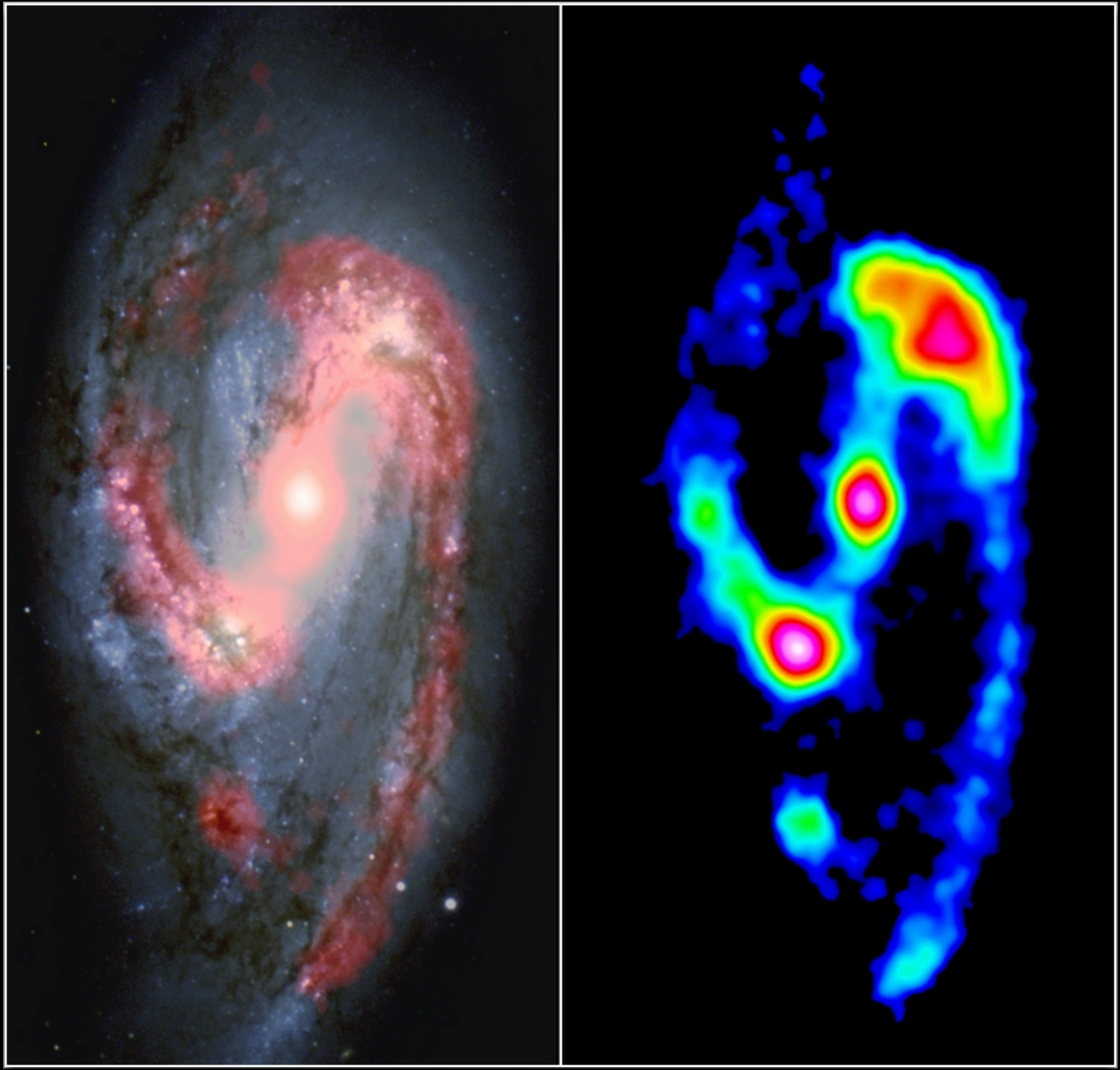
Credit: Greaves et al.



M66 at 850μm (red) and visible light (white background).

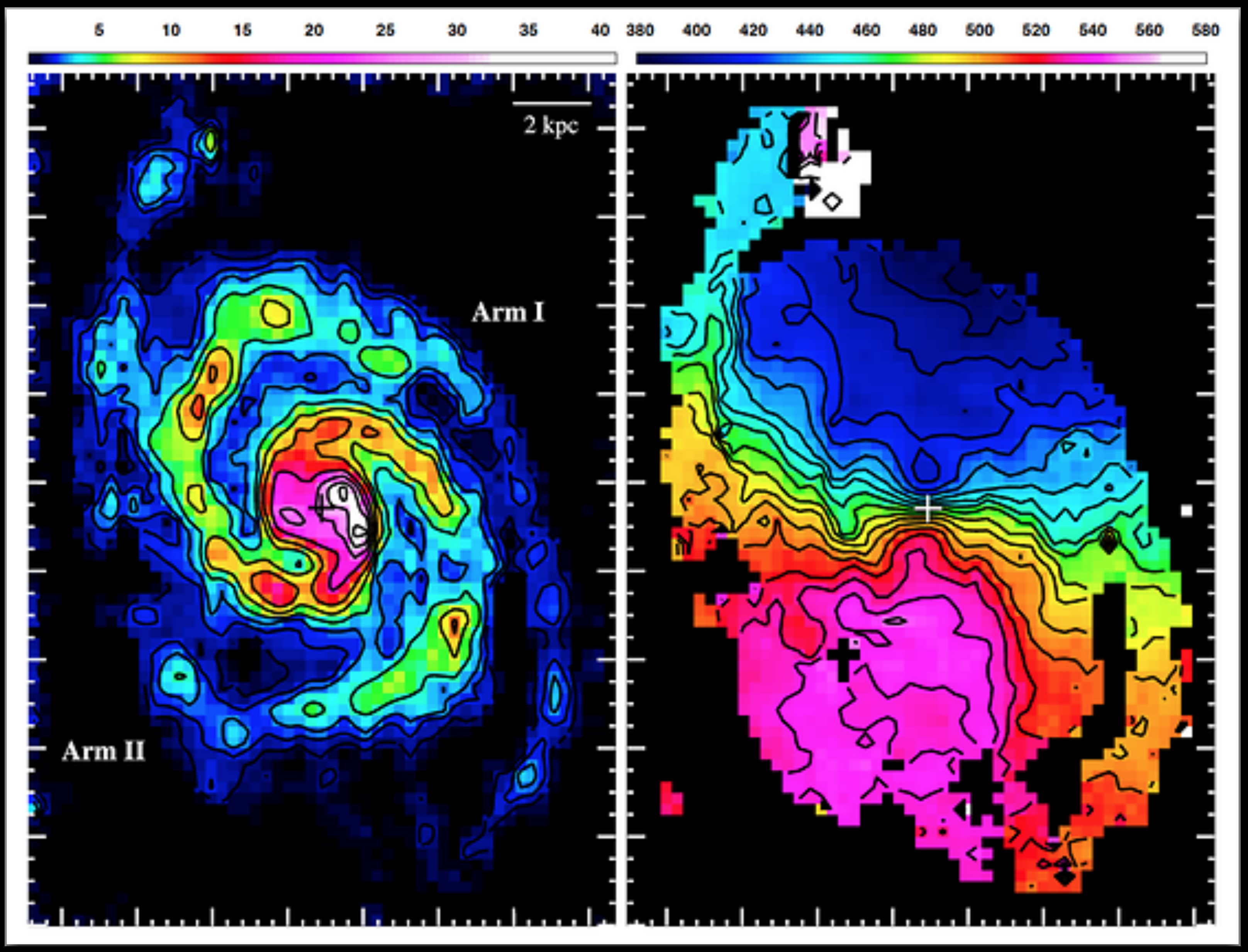
Regions of cold dust that appear as dark streaks in the white image glow brightly in the red image.

Right-hand panel: The SCUBA-2 image at 850 μm seen on its own.



Credit: VLT/ESO, JAC, G. Bendo

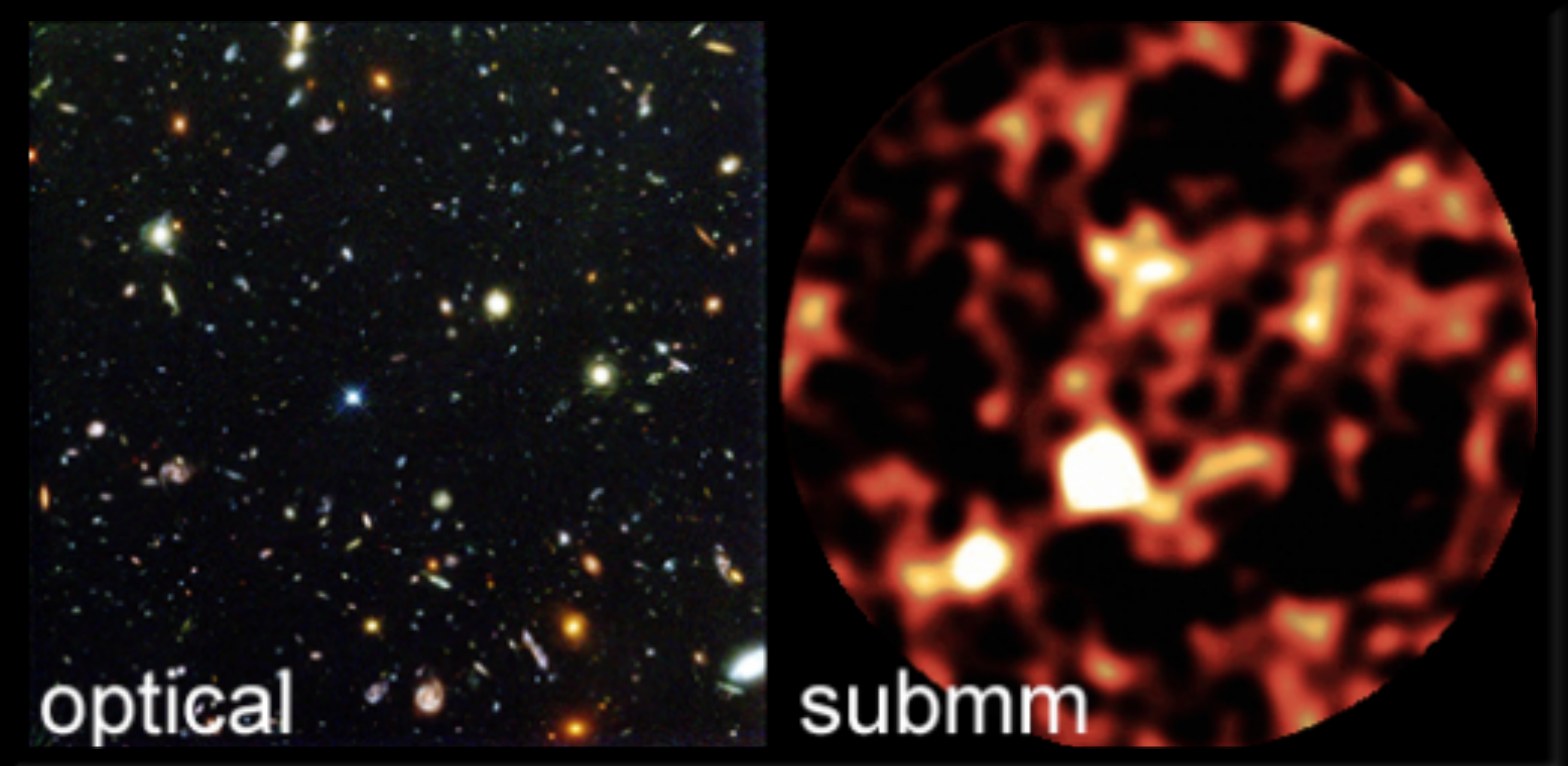
Molecular Line Strength and Galaxy Kinematics



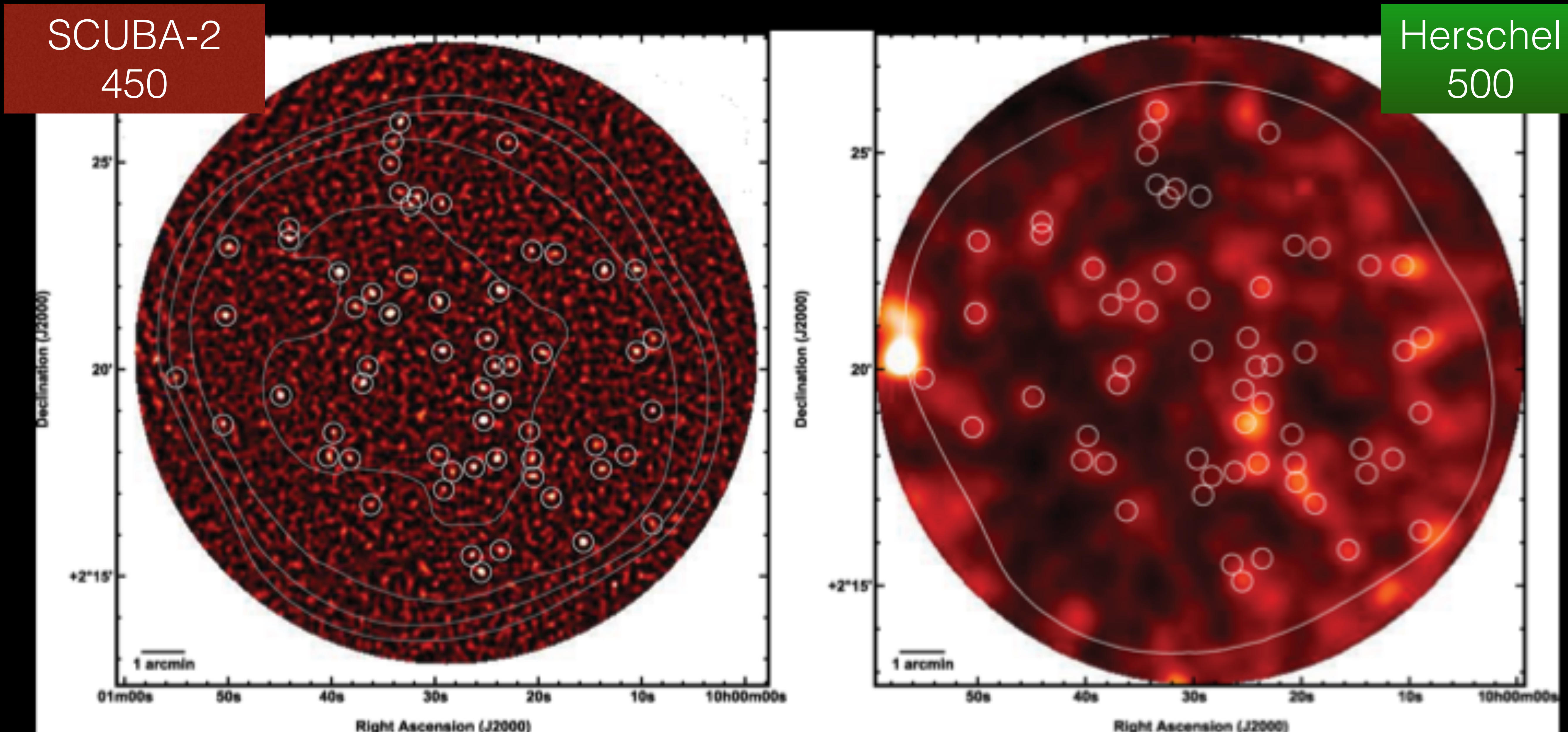
M51 – CO 3-2 map by Vlahakis et al 2013 HARP (16-receptors)

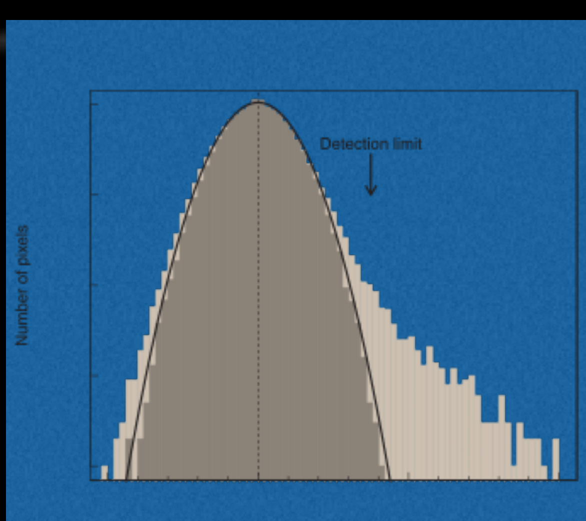
SCUBA Finds First Galaxies

- Groundbreaking JCMT result was when we looked at the Hubble Deep Field with world's first submillimeter camera (it had 91 pixels!) at 850 μm (0.8cm)
- Paper has over 1000 citations because of that blob
- This is a galaxy - in fact there are many in this picture - some of earliest ever formed in our universe



SCUBA-2: Cosmology Legacy Survey Blank Field





140 arcmin² HST-Candles Blank Field, observed to 1.3 mJy at 450 μm.
60 SMGs identified with > 3.75σ -> directly resolve 16±7 percent of CIB.
Statistical stacking of 24μm emitters recovers an additional ~40 percent.
Average redshift of emitters is estimated to be <z> = 1.3.

Credit: Geach et al. 2013

SCUBA-2 and Herschel

Complementary facilities:

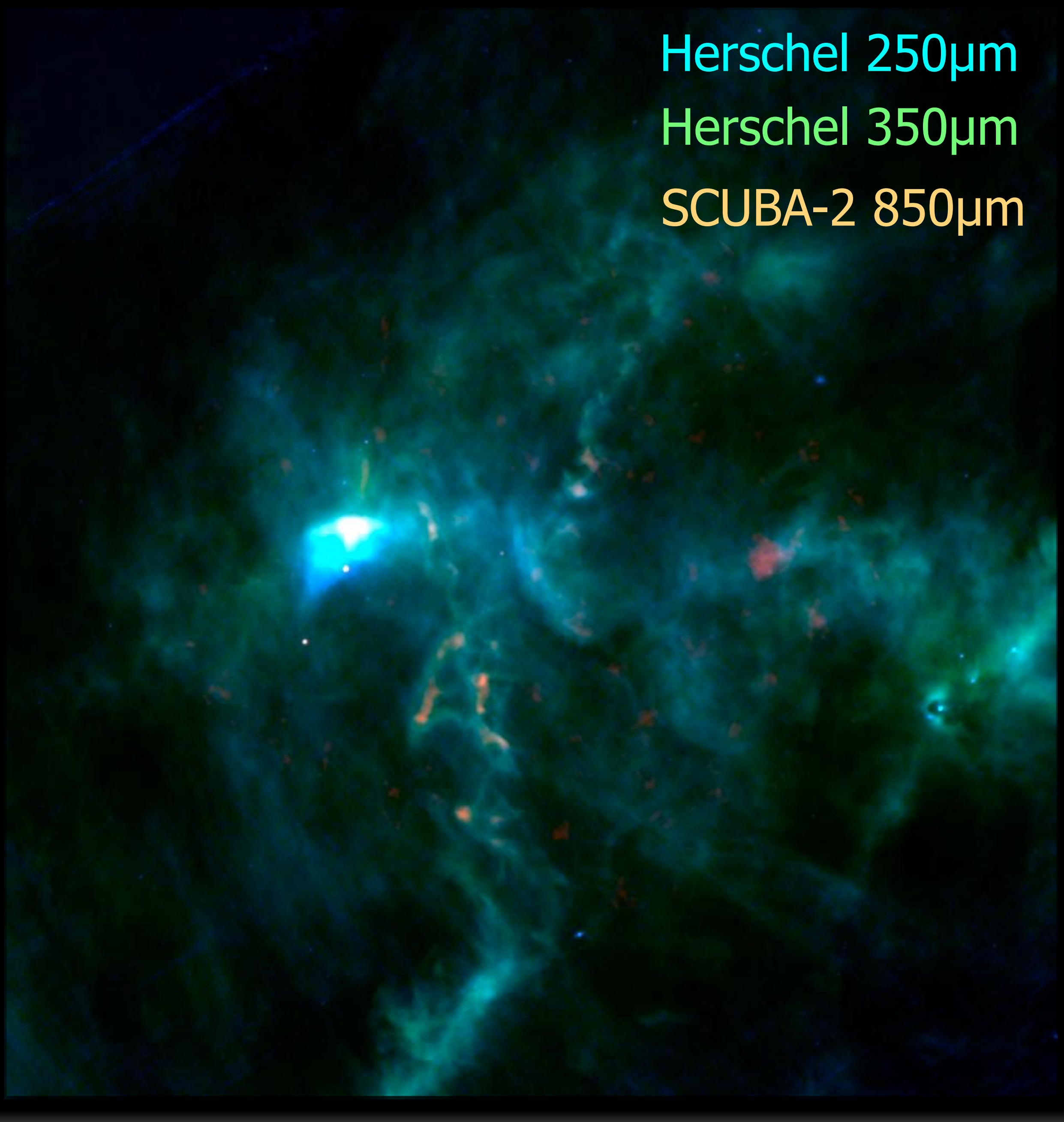
JCMT offers higher angular resolution

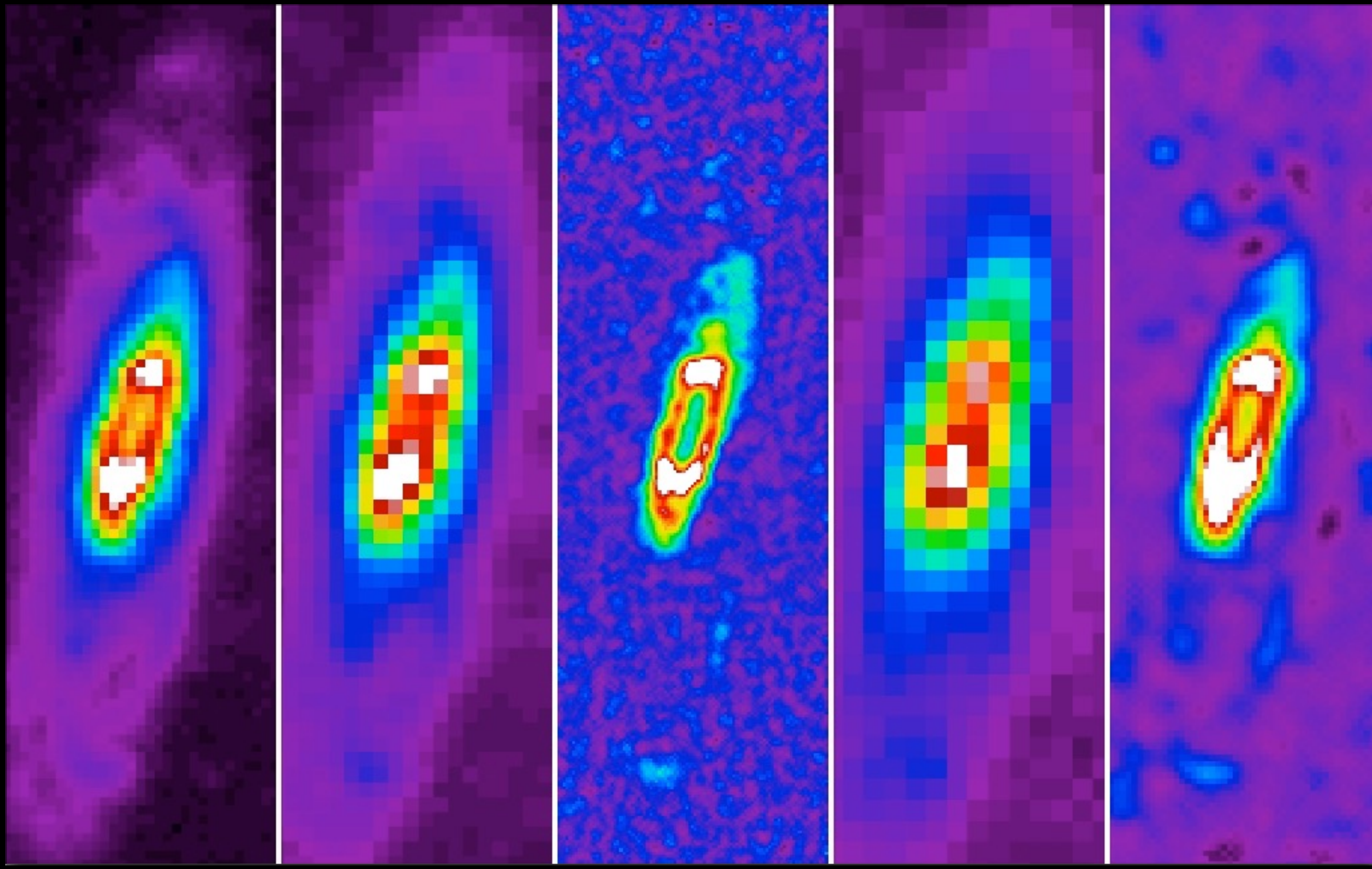
SCUBA-2 offers longer-wavelength data over comparable area

Extragalactic: sample different redshift ranges

Galactic: sample different core temperatures

Galactic: break degeneracy between dust temperature and emissivity



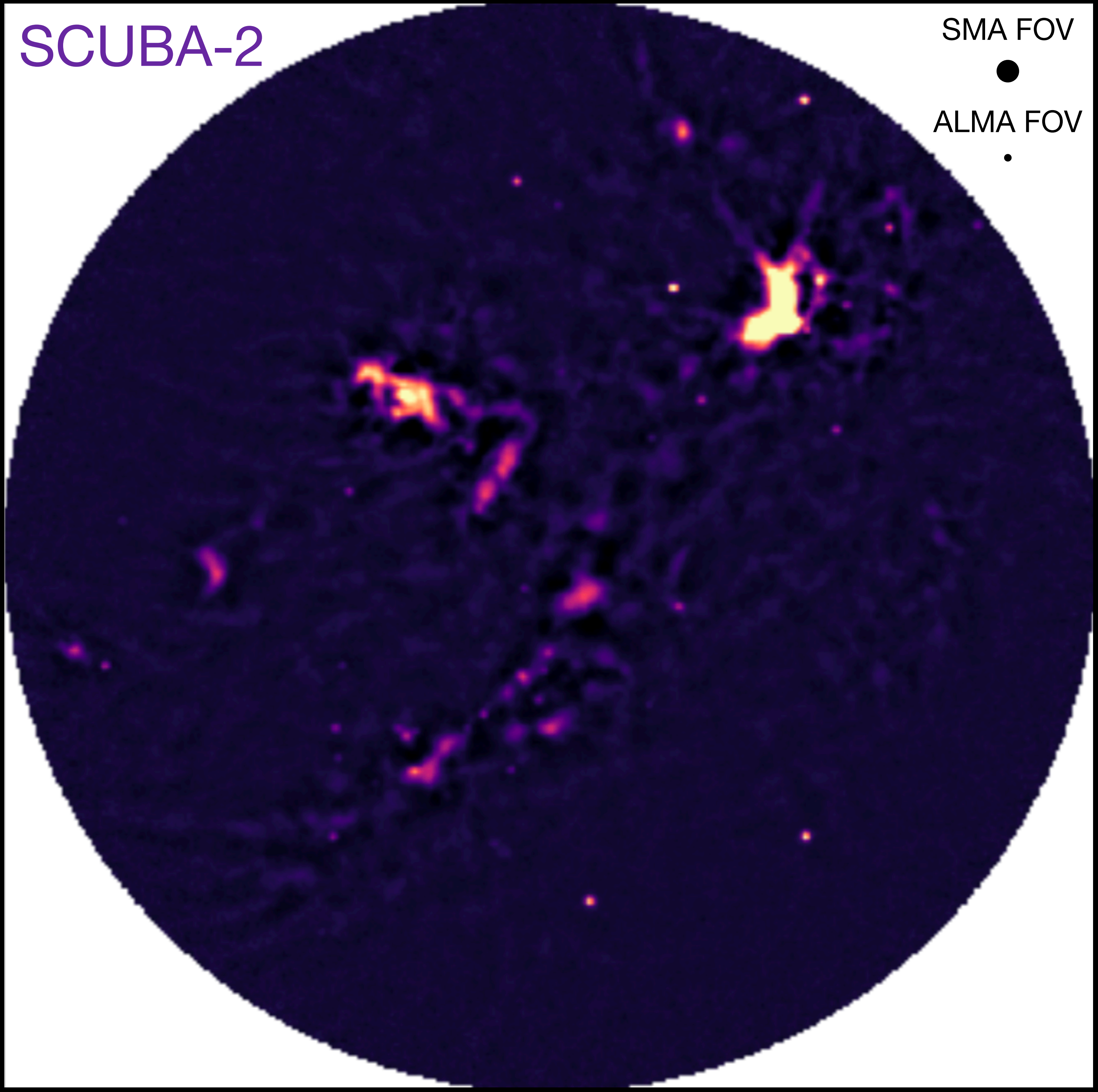


250µm	350µm	450µm	500µm	850µm

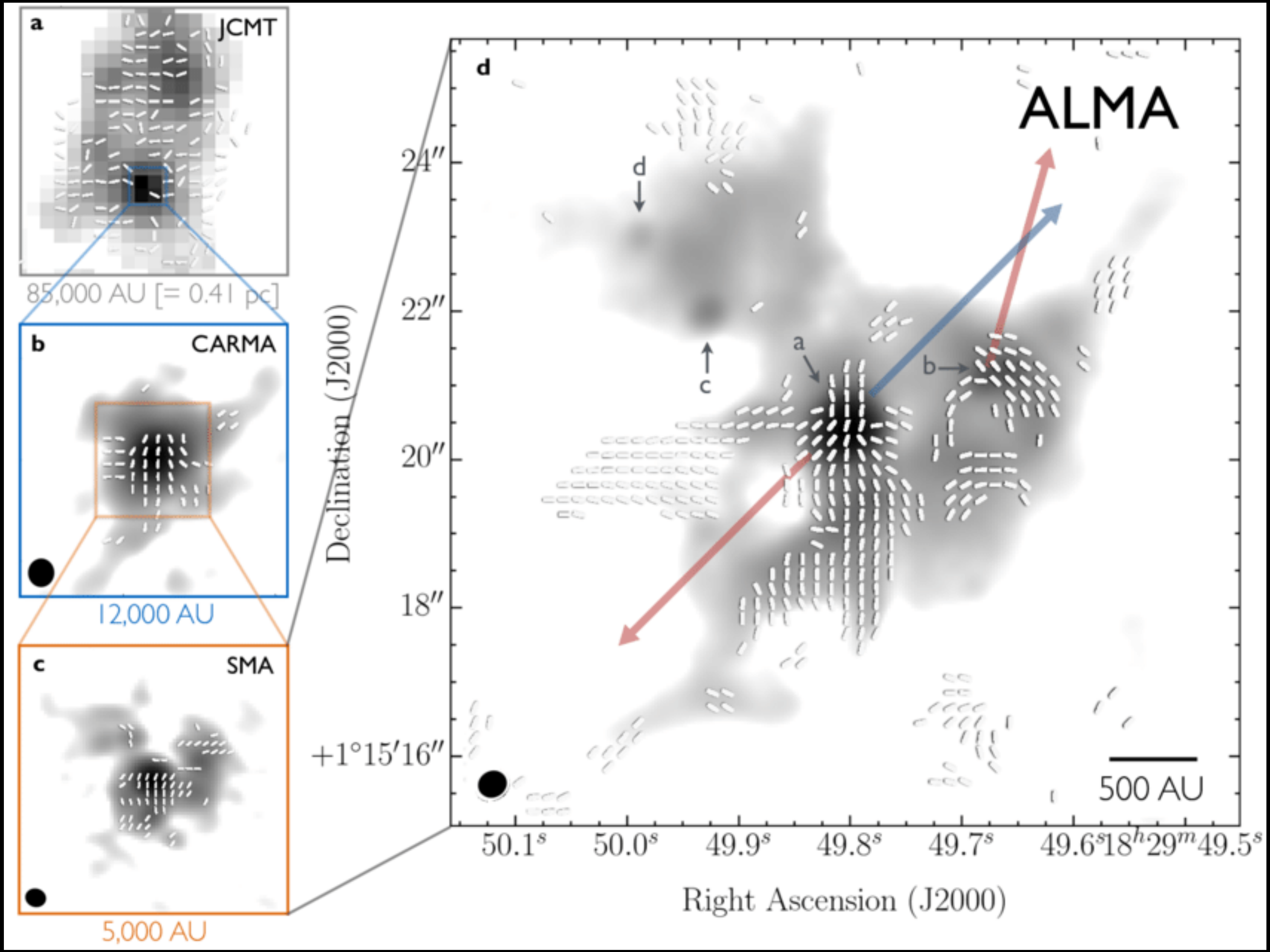
NGC 7331: Spiral galaxy that lies about 50 million light years away in Pegasus. SCUBA-2 data show details of central dust ring

Credit: Joint Astronomy Centre, Herschel KINGFISH consortium

JCMT and SMA/ALMA



JCMT and SMA/ALMA



Overview

- ★ PI & Urgent queues
  - Recent Results
- ★ Large Programs
  - Recent Results
- ★ The Event Horizon Telescope
- ★ JCMT Data Archive

PI Queue

★ Call for Proposals issued **every 6 months** for “normal sized” projects (< 200 h, but typically ~ 3 — 50 hours) to be run during following semester

- ⋆ Current semester: **20B** (1st August 2020 — 31st Jan 2021)

★ Proposals competitively assessed by Time Allocation Committee (TAC)

★ Successful projects run via “PI queue”: Best project based on TAC priority and current weather is observed

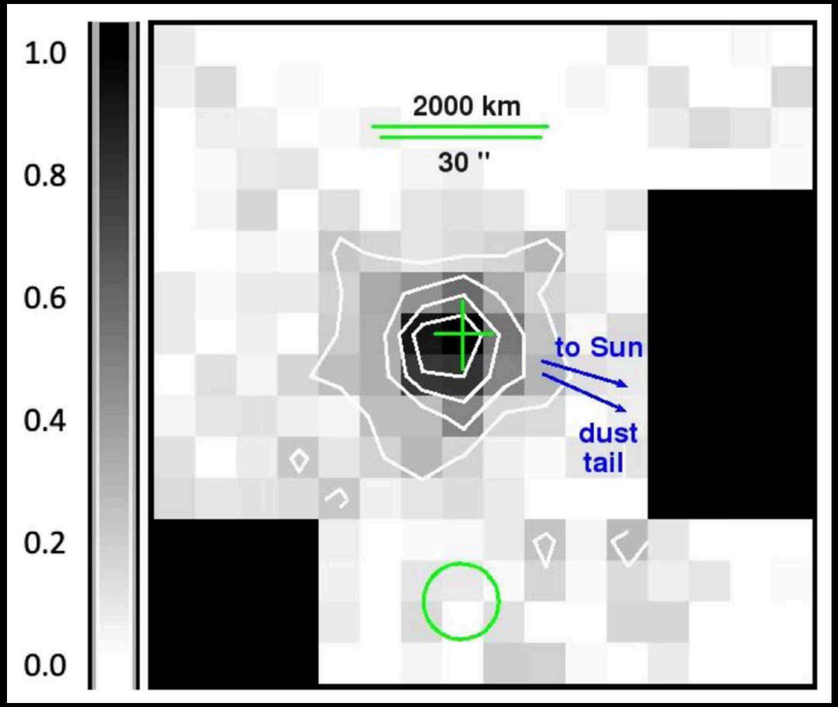
★ Also: Urgent queue always open for submissions for **current semester**

https://proposals.eaobservatory.org

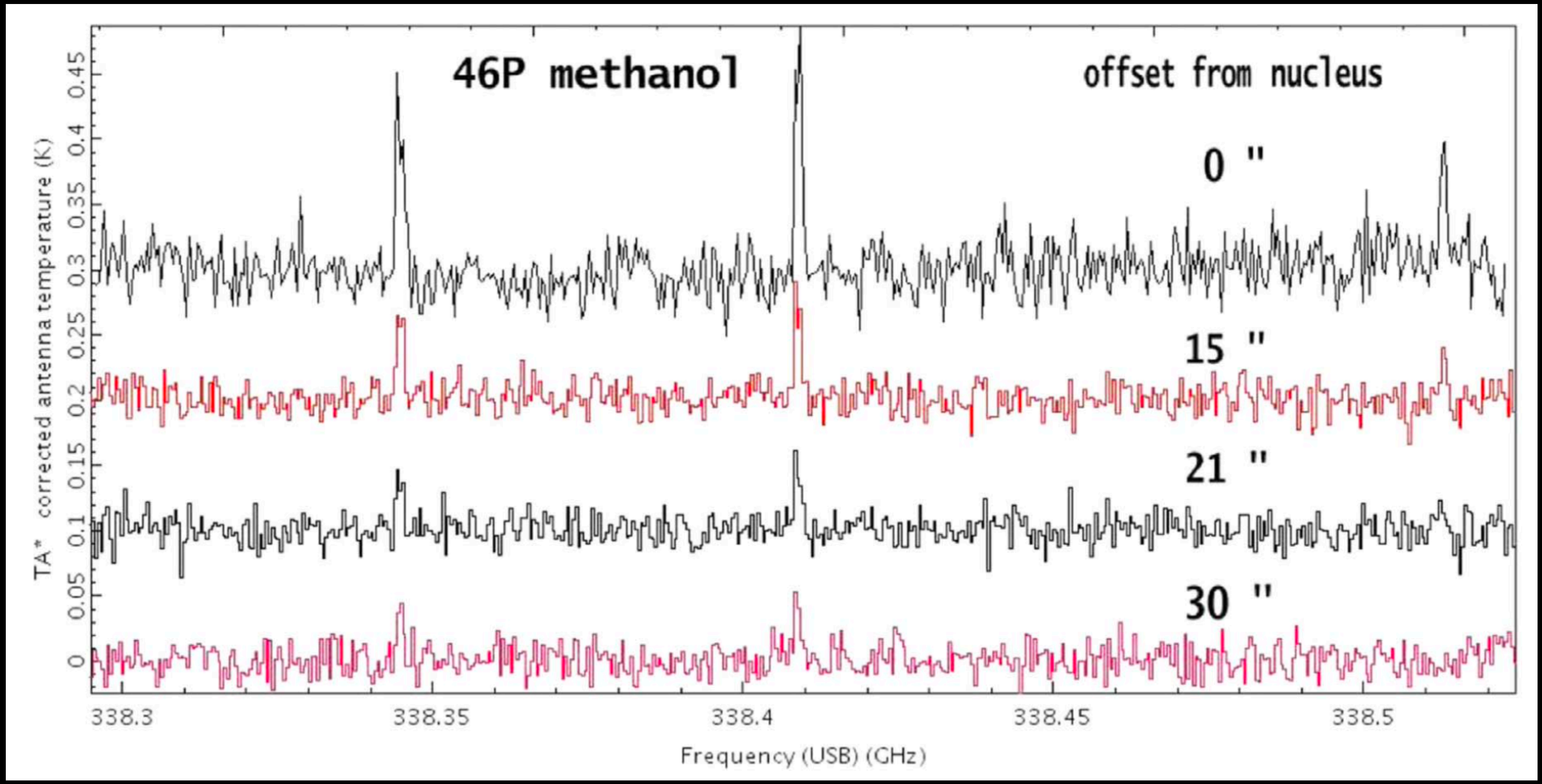
Spectral and Continuum Imaging of Hyperactive Comet 46P/Wirtanen

Coulson, Liu et al. The Astronomical Journal, 160:182. 2020

Goal: Take an inventory of the molecules in the coma and observe distributions to monitor evolution throughout 1 week



Integrated intensity map of HCN (J = 4 – 3) This HARP image serves as a proxy for the activity level of the comet.



Results

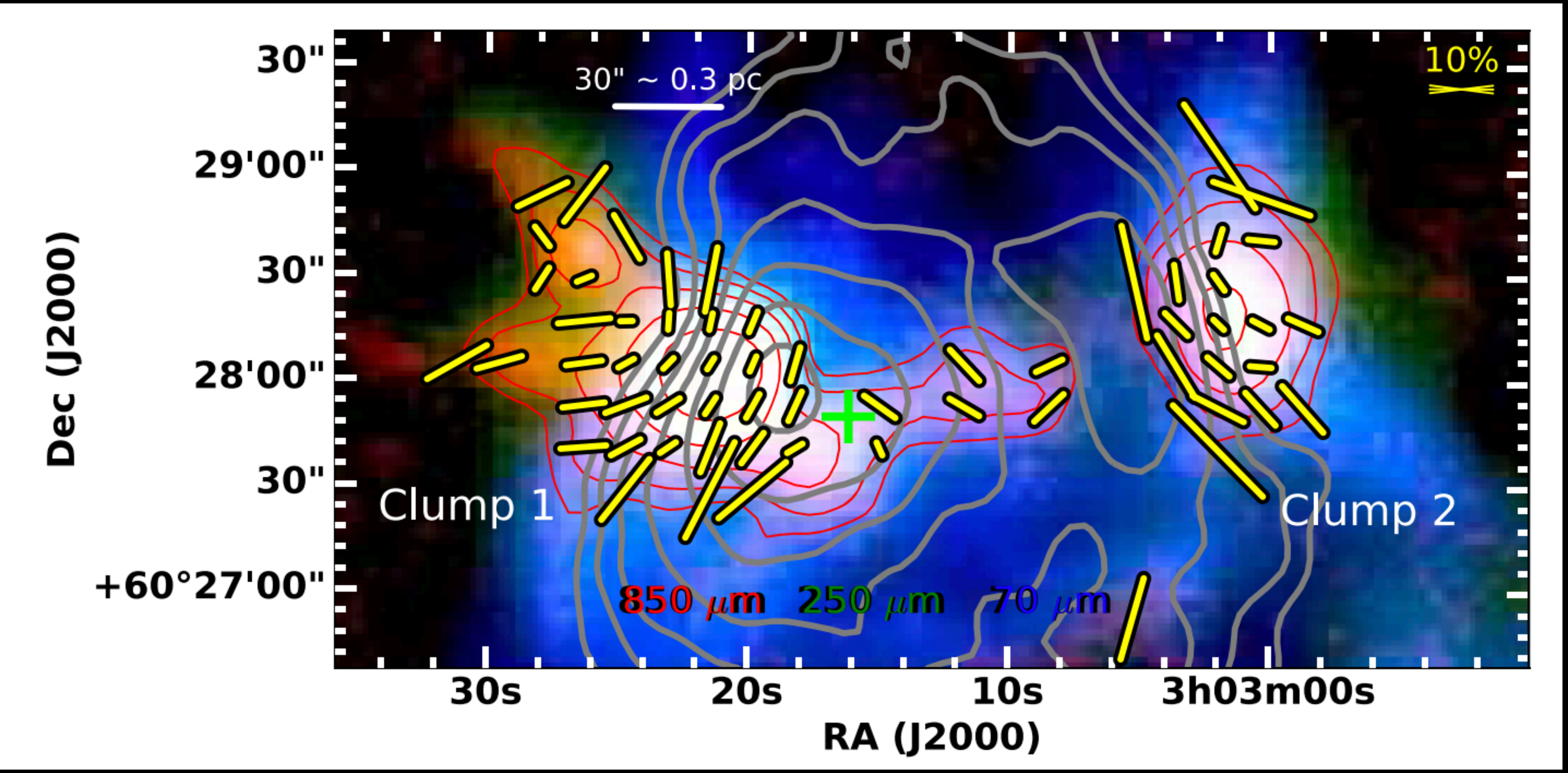
★Confirmed the existence of a population of particles exuding methanol in the coma

★Saw evidence of 1 mm-sized dust particles survive for ~10^5 s and found HCN depletion over ~few hundred km

Magnetic Fields at the Waist of Bipolar HII Regions

Chakali, et al. The Astrophysical Journal, 897:1. 2020

Goal: Study the interplay of HII feedback and magnetic fields in areas of dense ISM material



Vector map showing B-field orientations overlaid on the color composite of JCMT/SCUBAPOL2 850 μm Stokes I, Herschel SPIRE/250 μm, and Herschel PACS/70 μm. Red contours correspond to the JCMT/SCUBAPOL2 850 μm Stokes I map. Gray contours correspond to the VLA/21 cm continuum emission and represent the distribution of the ionized medium of the H II region

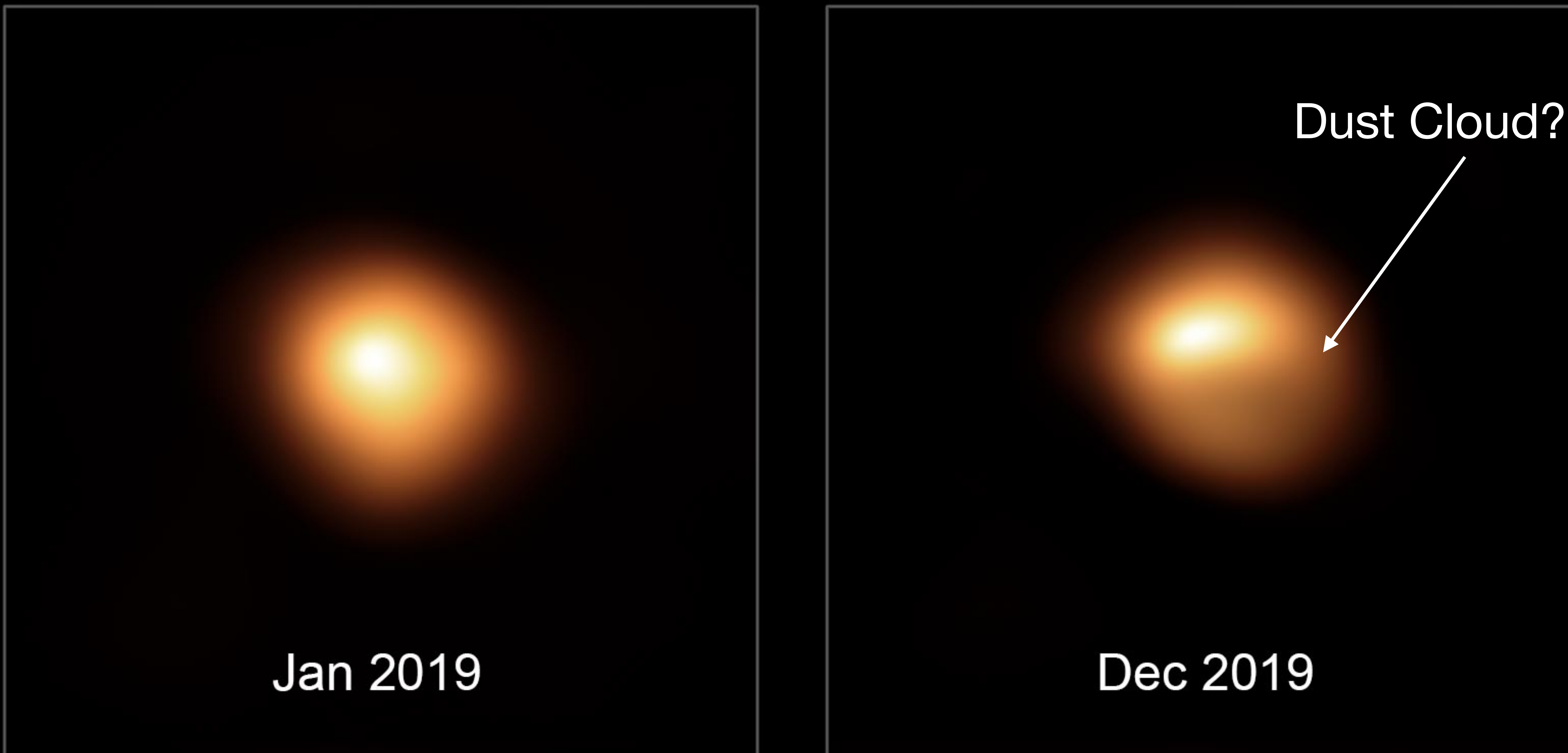
Results

★ B fields are compressed and bent by the expanding ionization fronts from the H II region. Enhances B-field and injects turbulence.

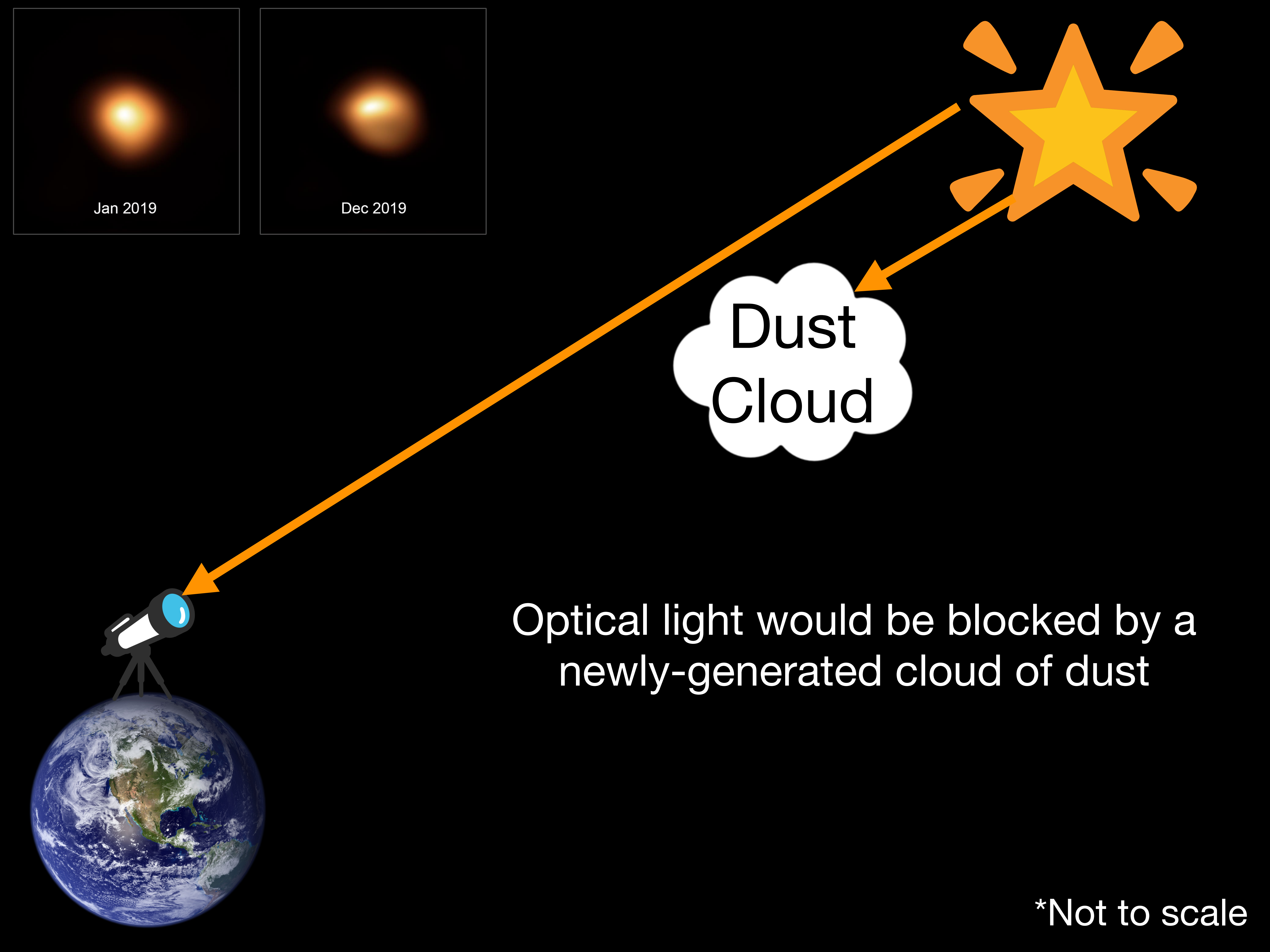
★ The combined contribution from thermal energy, turbulence, and B fields can not counteract the gravity in clump 1 but can in clump 2

The Abnormal Dimming of Betelgeuse

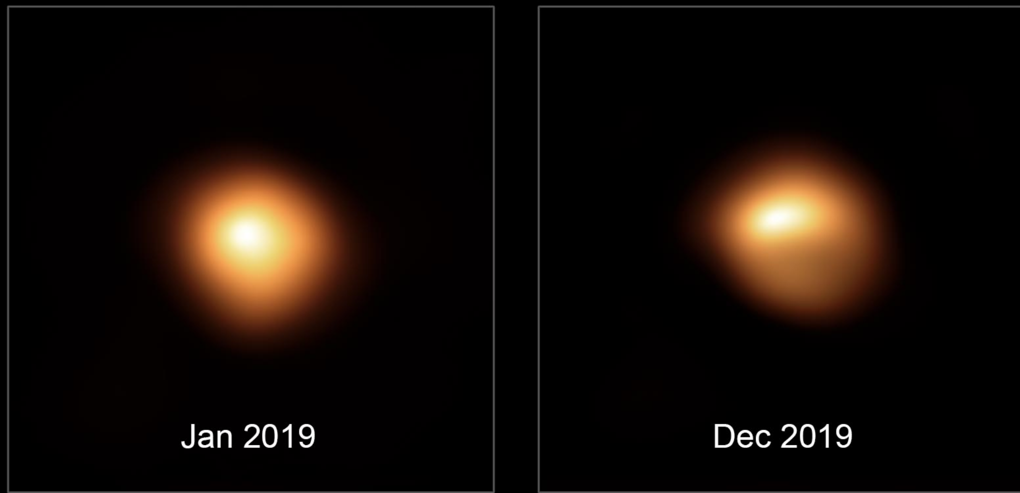
Dharmawardena, Mairs et al. The Astrophysical Journal Letters, 897:1. 2020



Credit: ELT



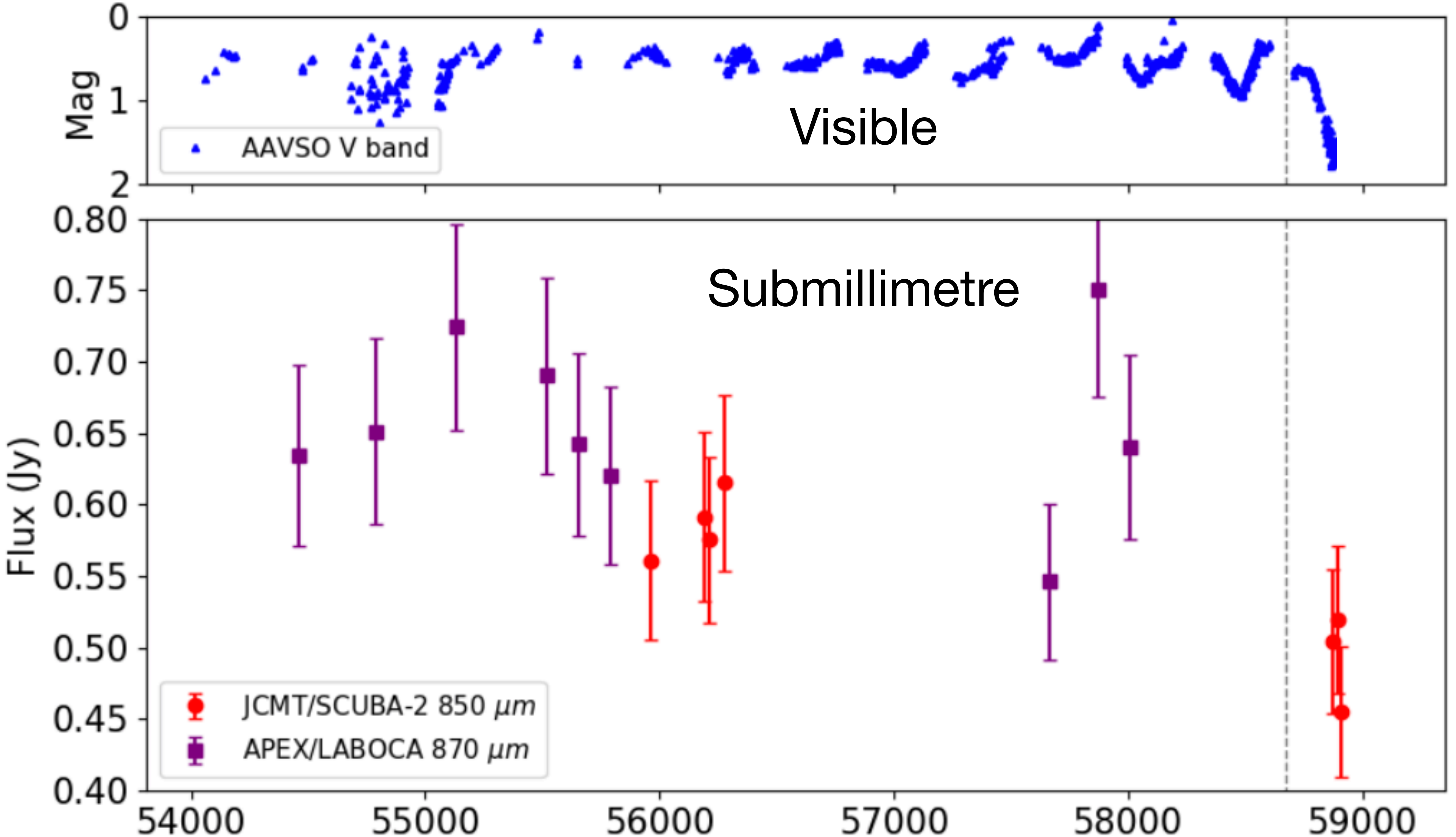
Jan 2019
Dec 2019
Dust Cloud
Optical light would be blocked by a newly-generated cloud of dust
*Not to scale



But submillimetre data would either:

1. See right through the thin cloud
2. Obtain a **brighter** signal due to the dust

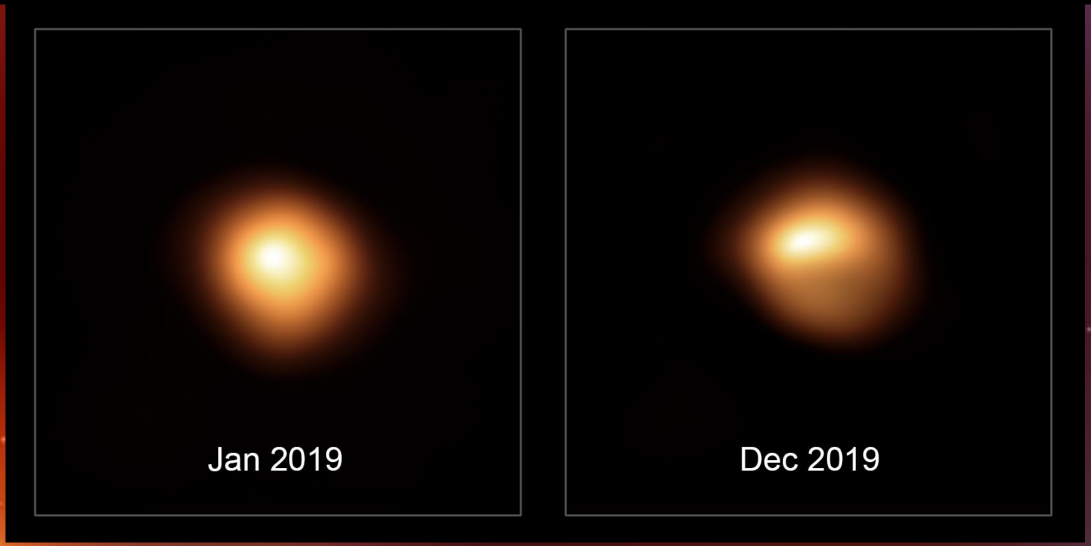
*Not to scale



Visible
Submillimetre
Mag
AAVSO V band
Flux (Jy)
JCMT/SCUBA-2 850 μm
APEX/LABOCA 870 μm
0
1
2
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
54000
55000
56000
57000
58000
59000

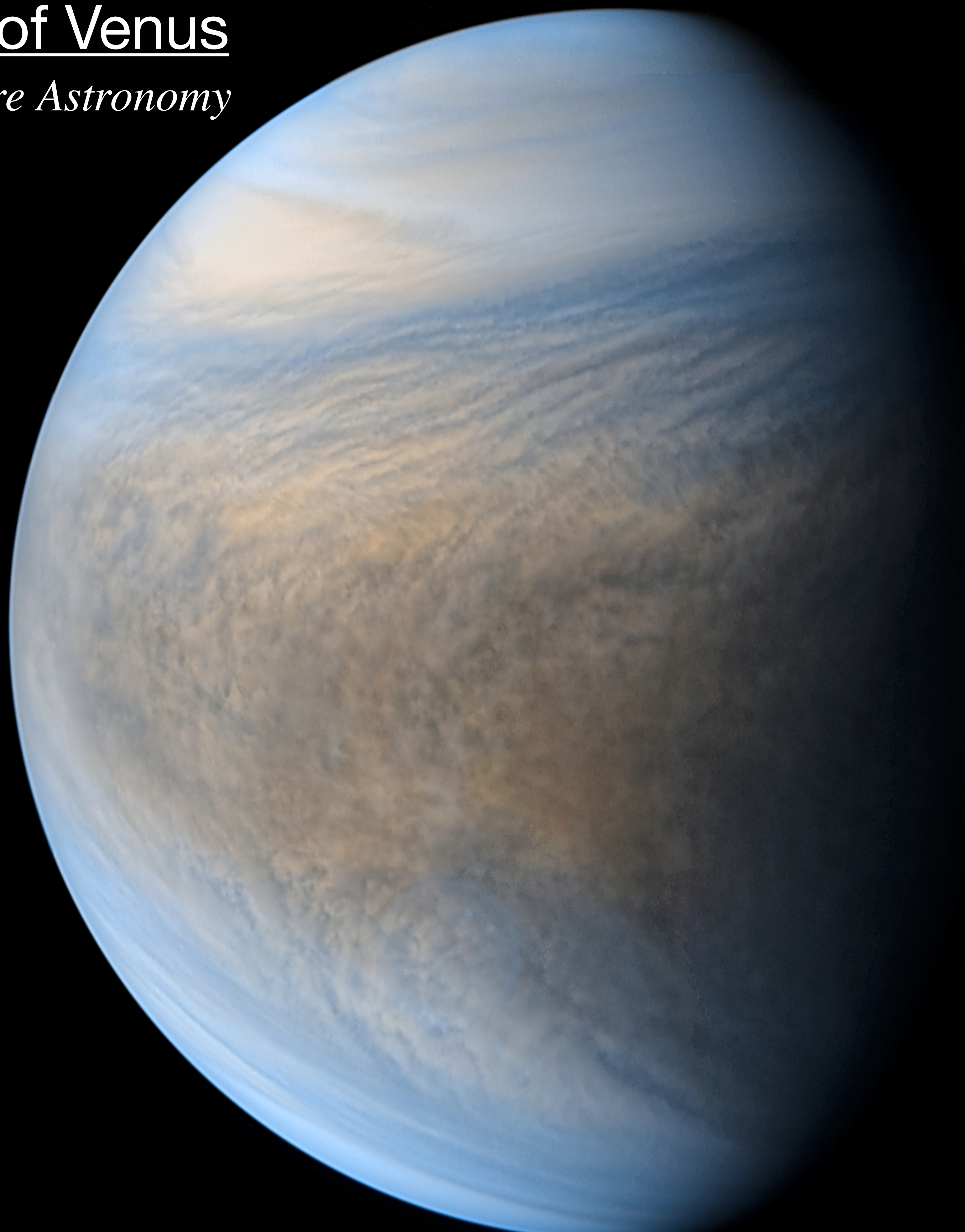
Star Spots!

Dr. Thavisha Dharmawardena



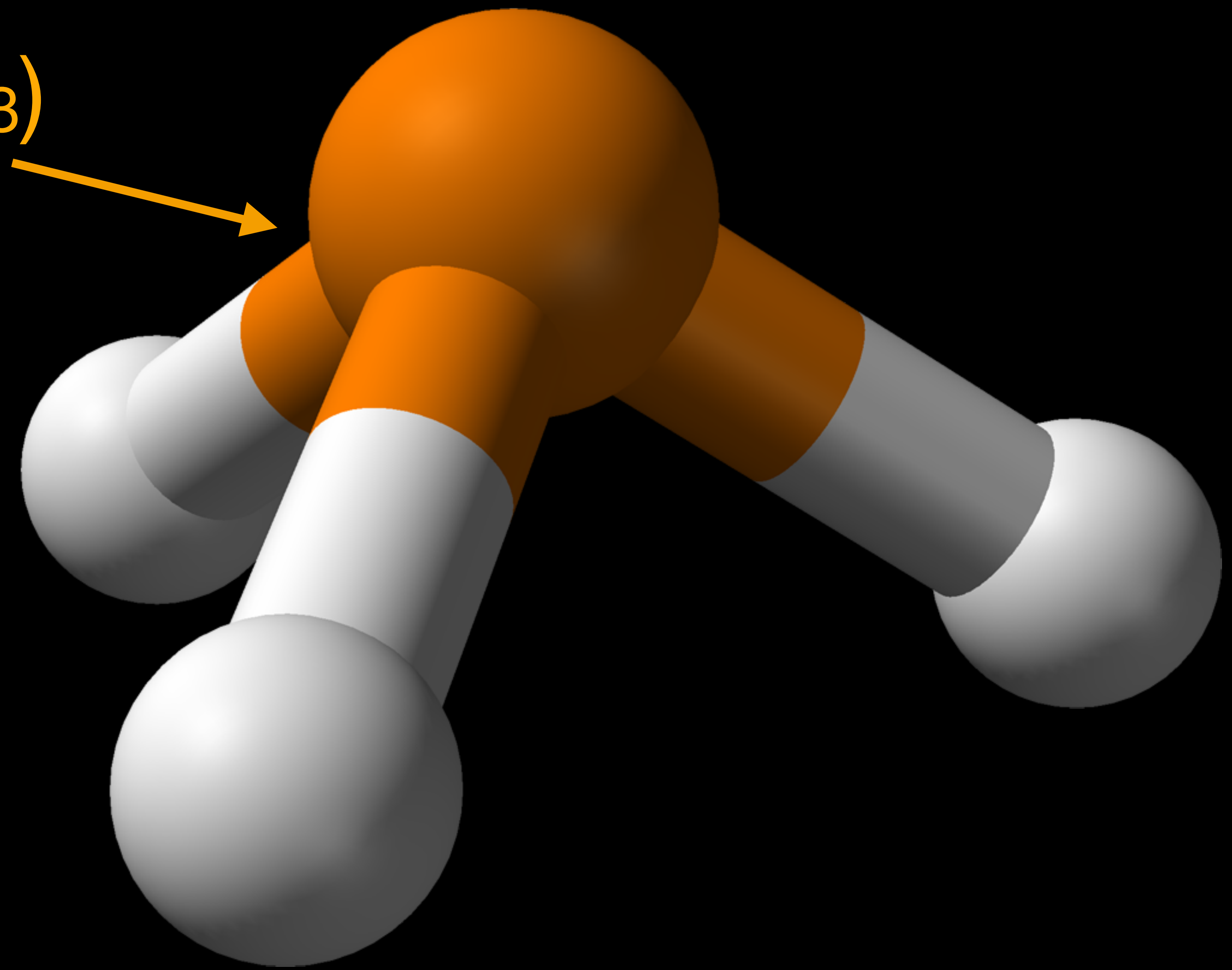
Phosphine Gas in the Cloud Decks of Venus

Greaves, et al. Nature Astronomy



JAXA/ISAS/DARTS/Damia Bouic

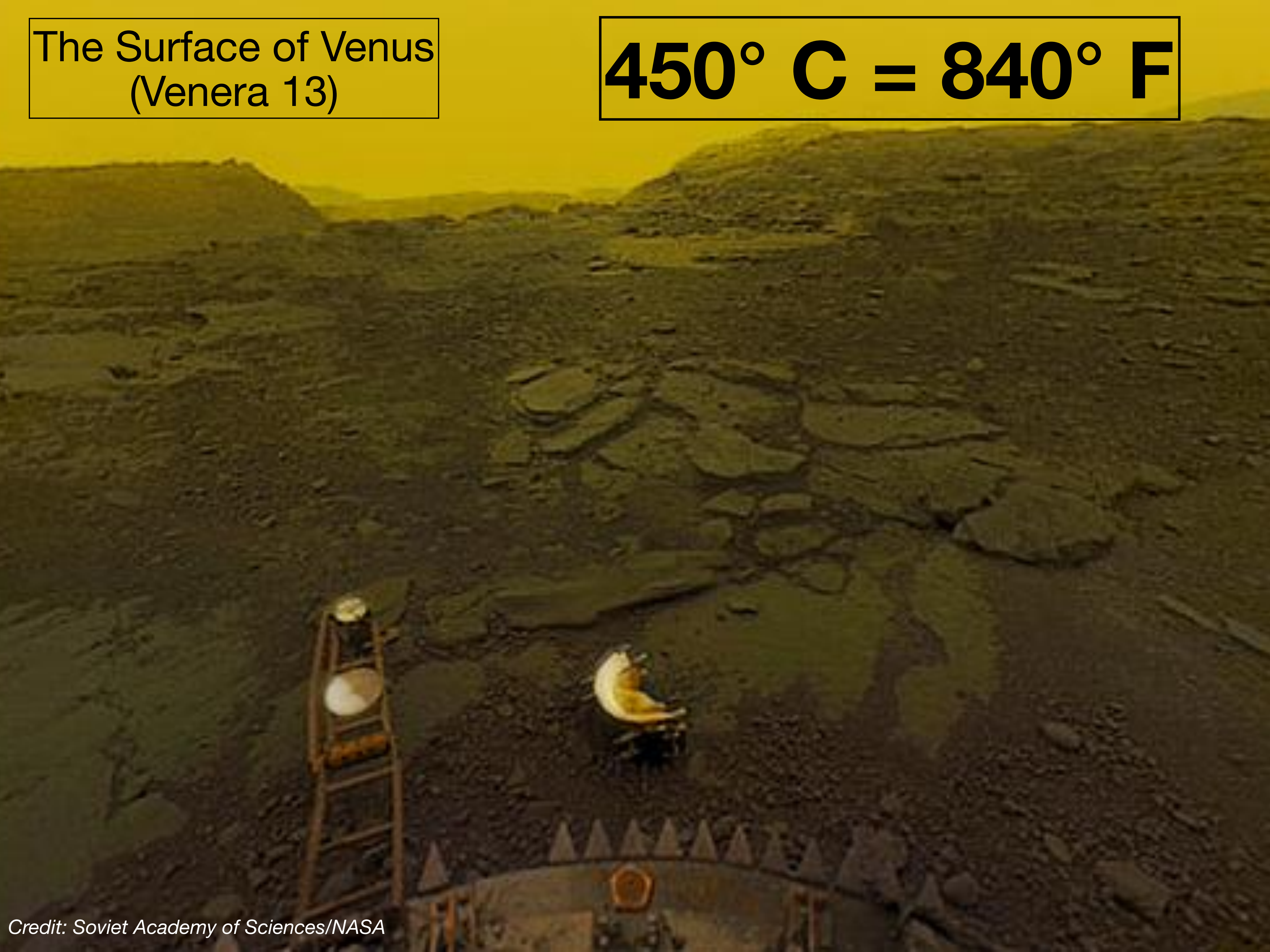
“Phosphine” (PH_3)



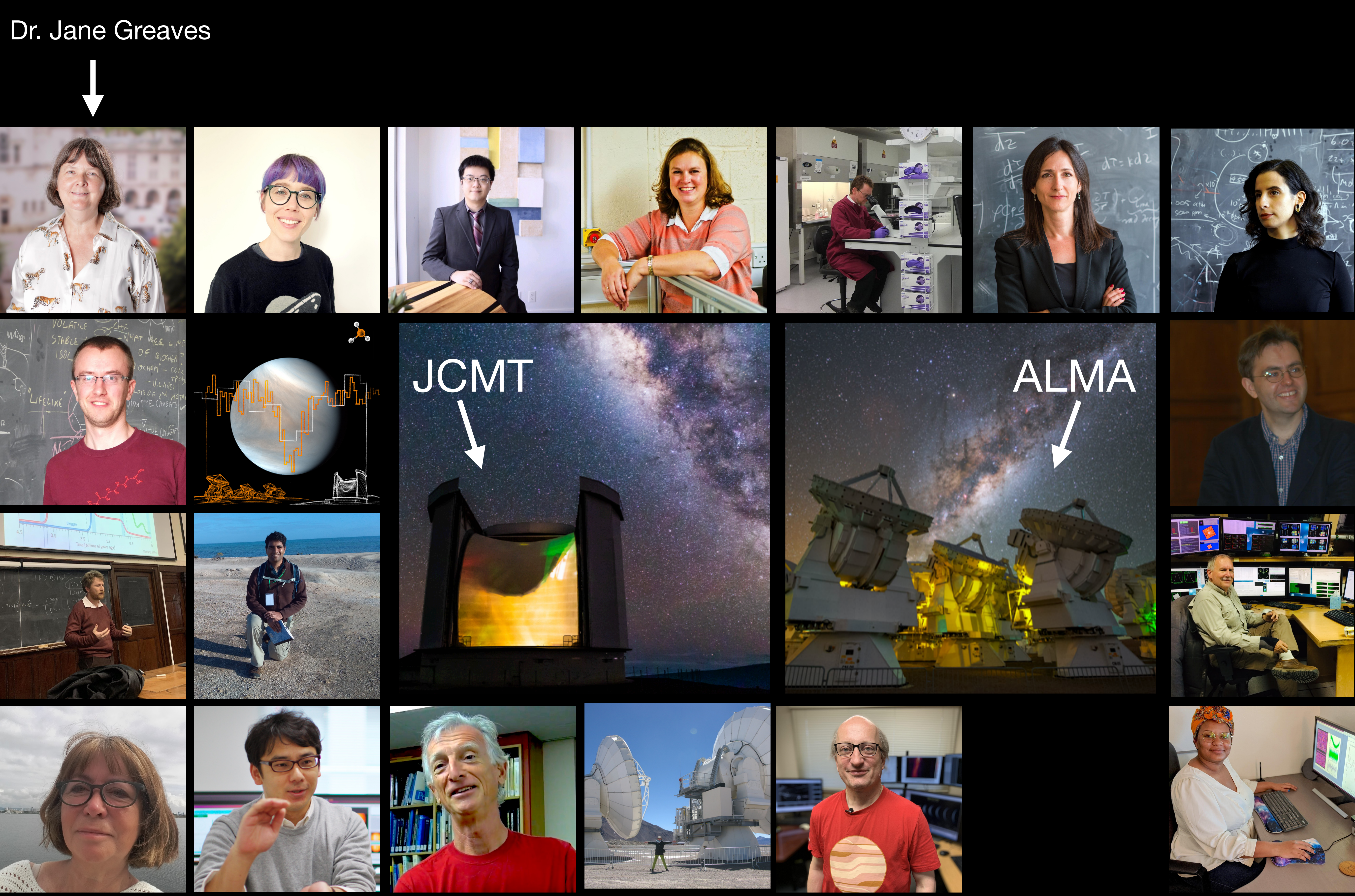
Biomarker:
Molecules that may indicate the presence of life.

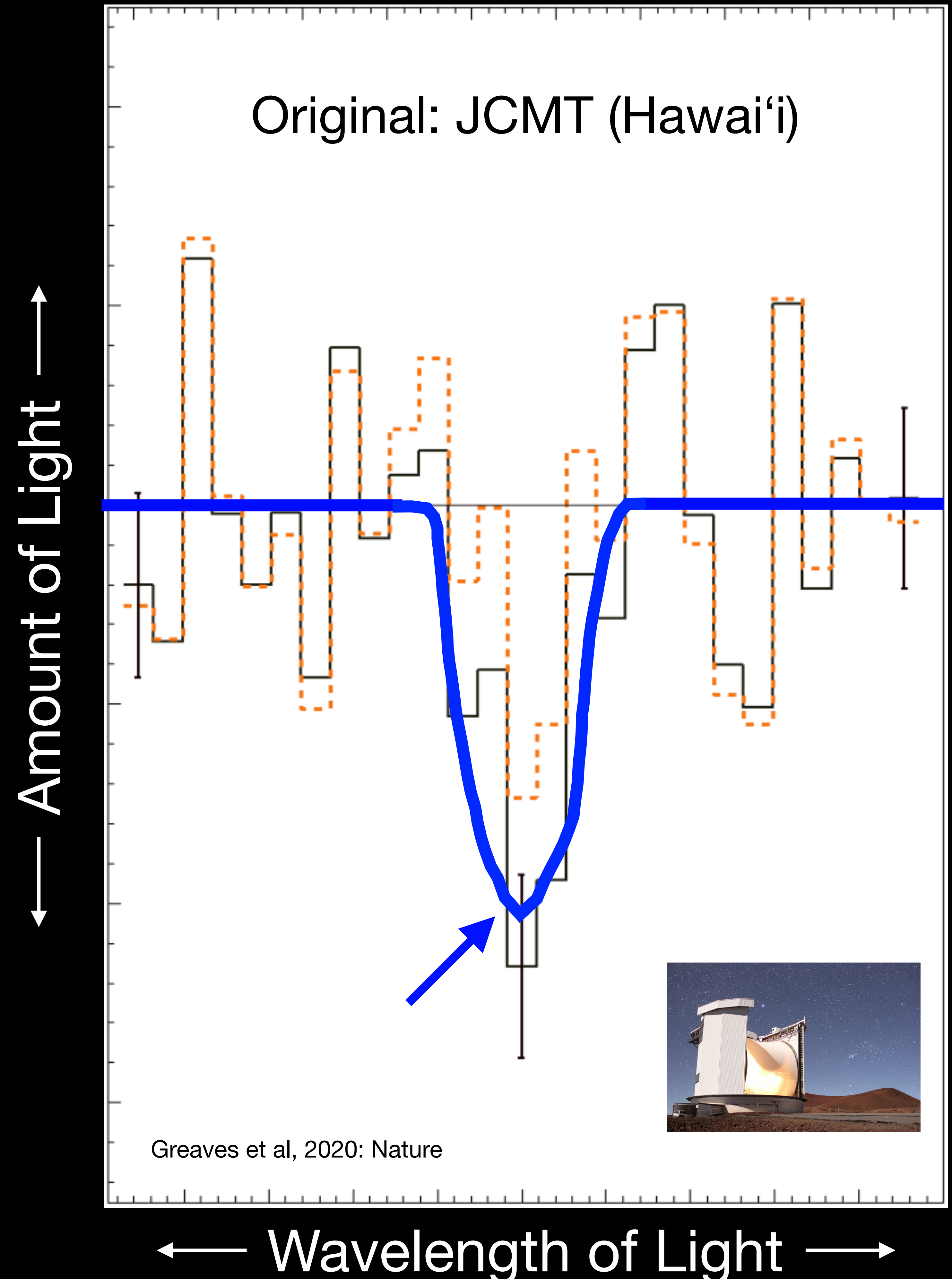
The Surface of Venus
(Venera 13)

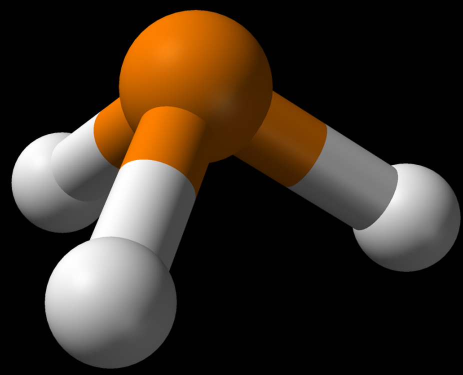
450° C = 840° F



Credit: Soviet Academy of Sciences/NASA

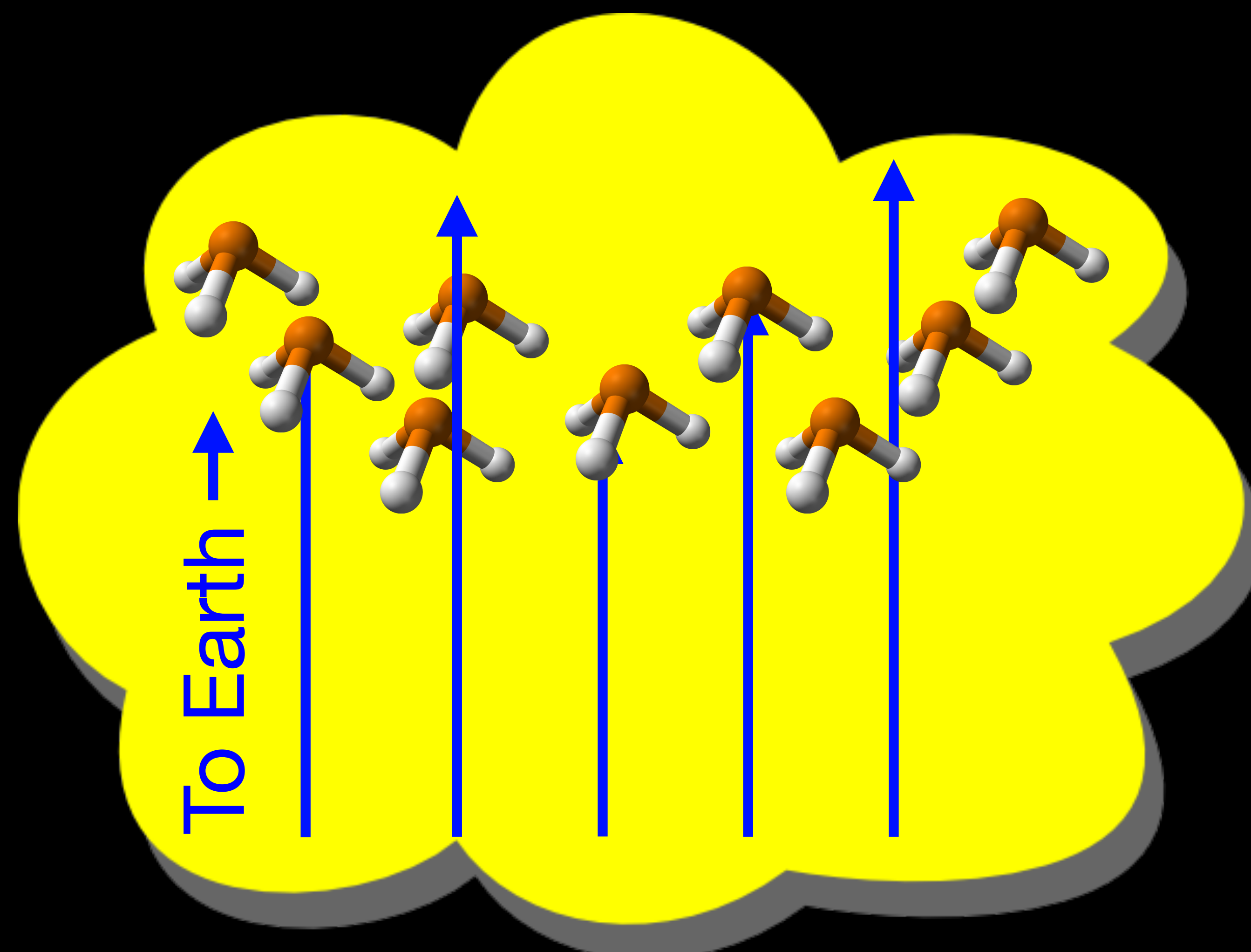

Dr. Jane Greaves
JCMT
ALMA


Original: JCMT (Hawai‘i)
Amount of Light
Wavelength of Light
Greaves et al, 2020: Nature

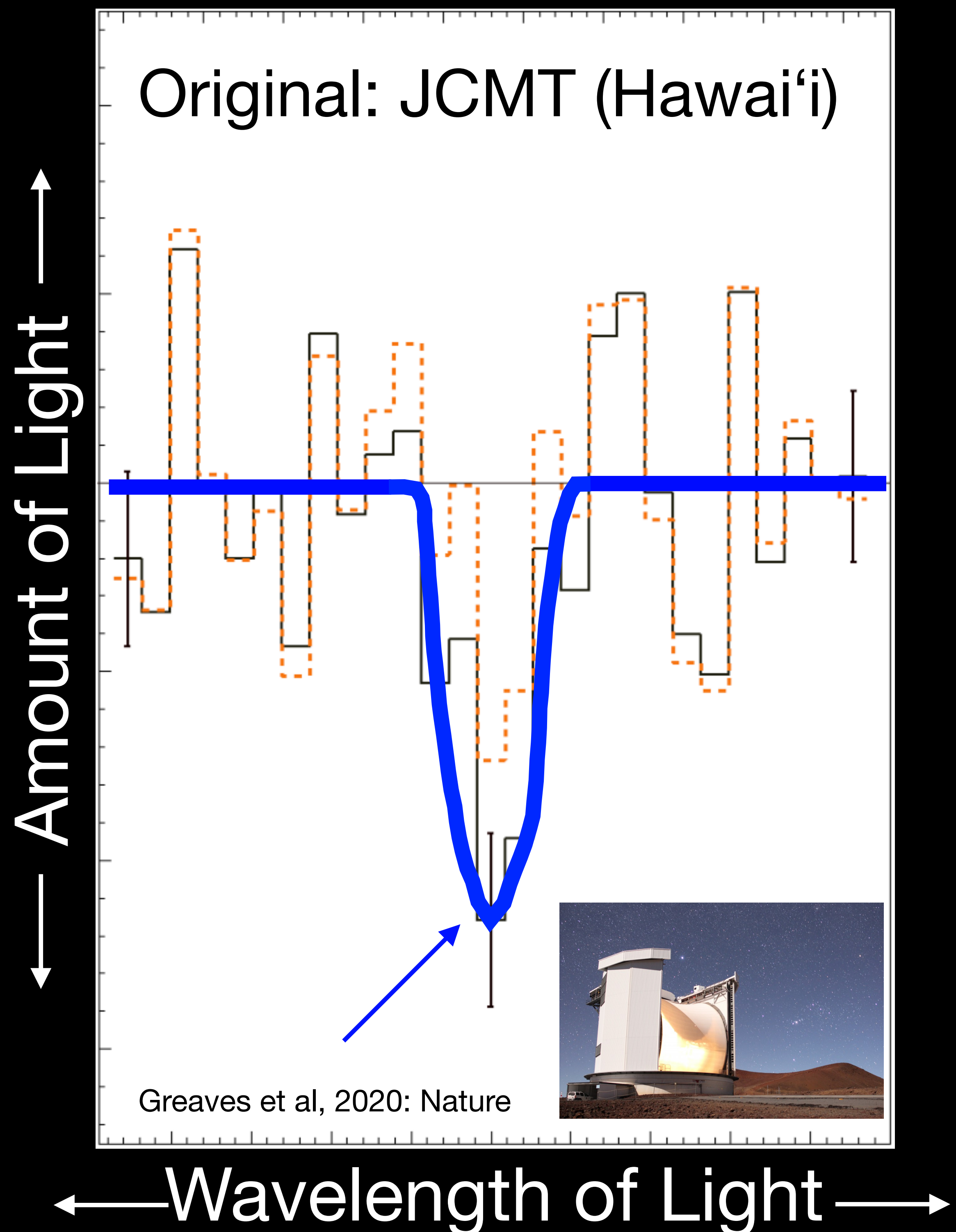


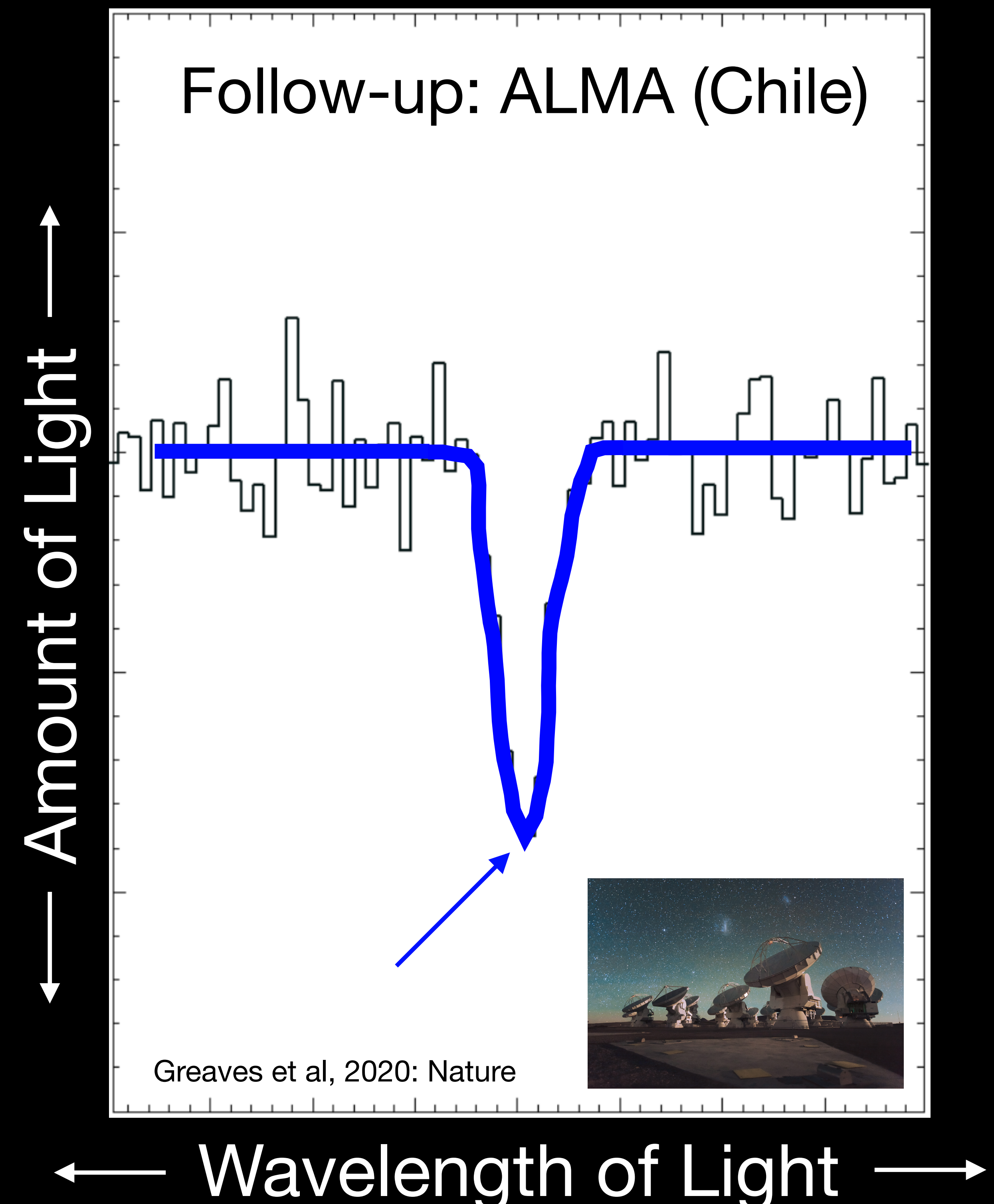
“Phosphine” (PH_3)

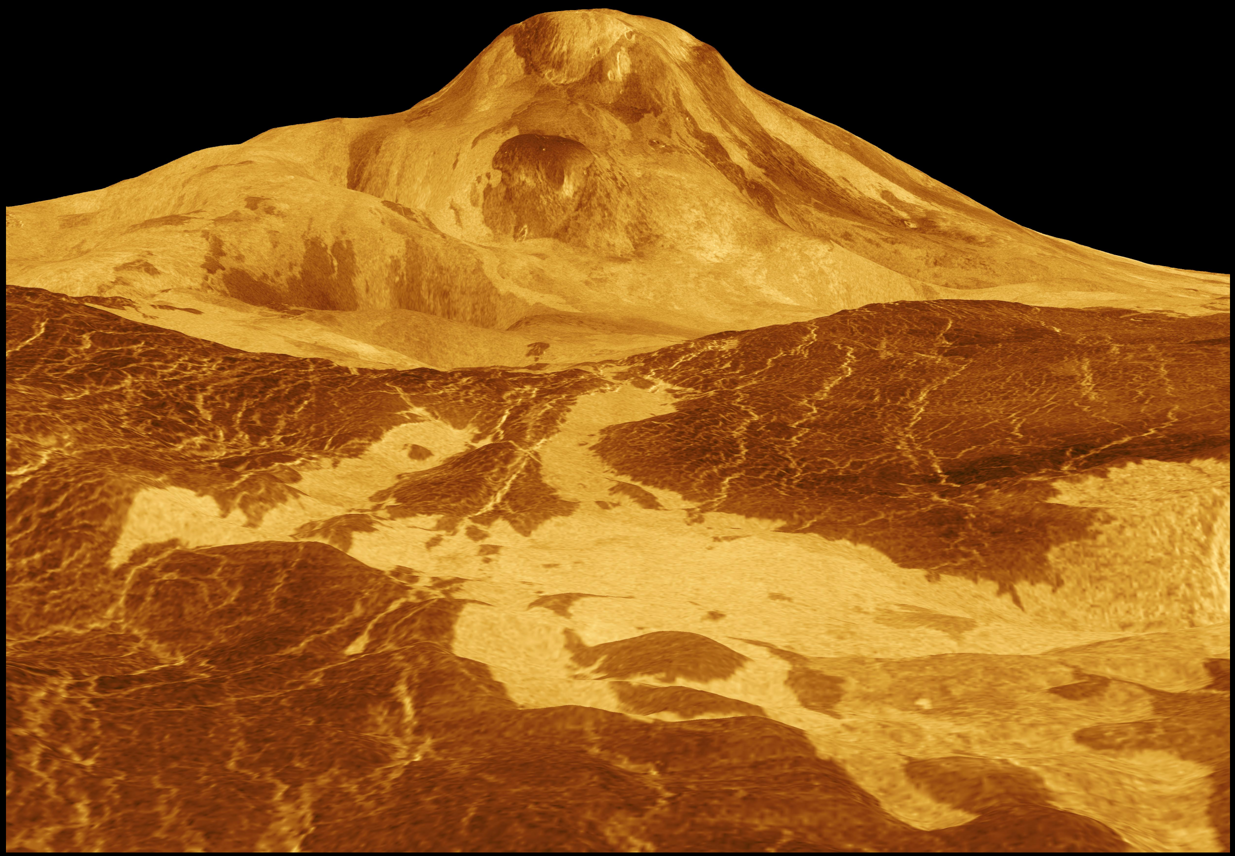
30° C

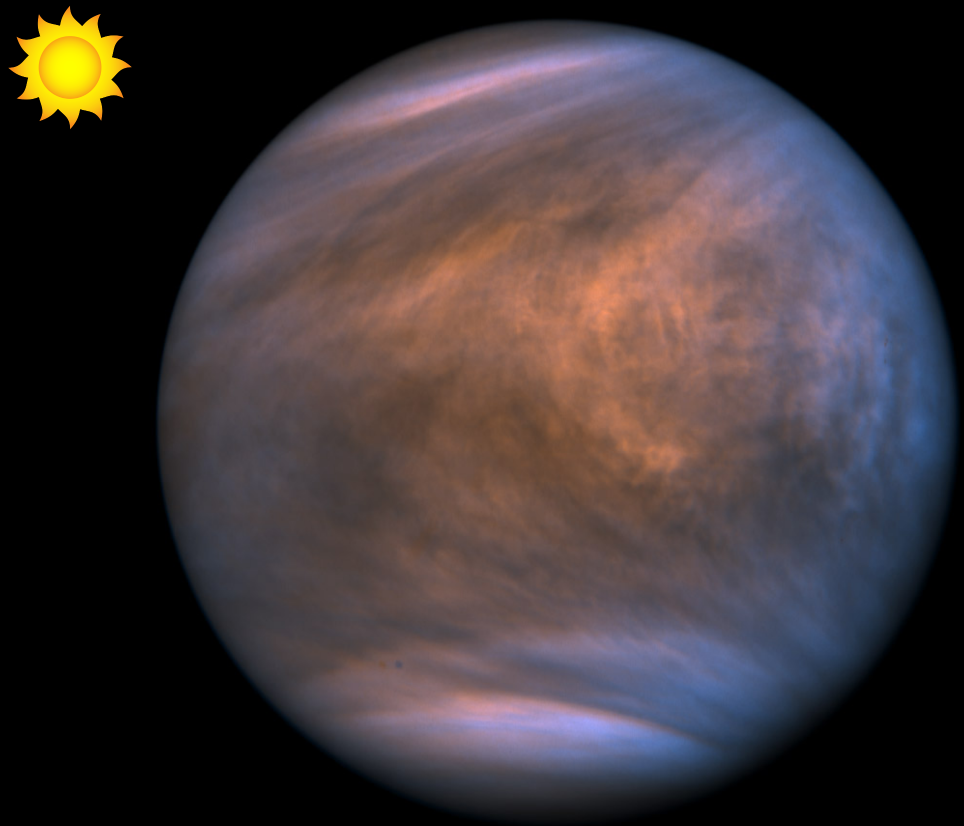


Venus


Original: JCMT (Hawai‘i)
Amount of Light
Greaves et al, 2020: Nature
Wavelength of Light


Follow-up: ALMA (Chile)
Amount of Light
Greaves et al, 2020: Nature
Wavelength of Light






Volcanoes

+ Lightning

+ Minerals

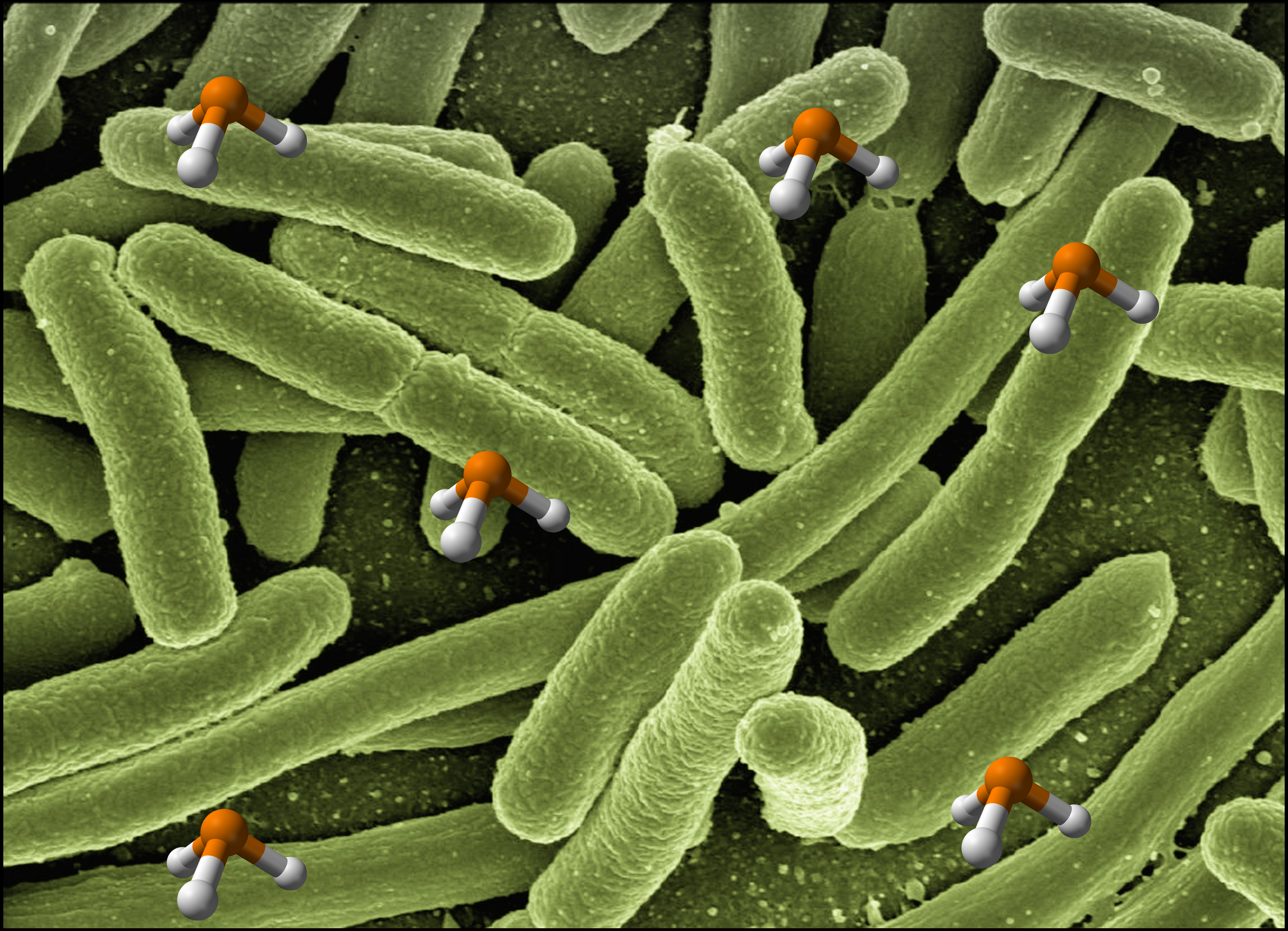
+ Photochemistry

+ Meteorites

+ …

=

0.01% of the observed amount of phosphine



Phosphorous (P) + Hydrogen (H) → Phosphine (PH3)

Microbes (tiny living organisms)
similar to those on Earth

\+ Nothing

=

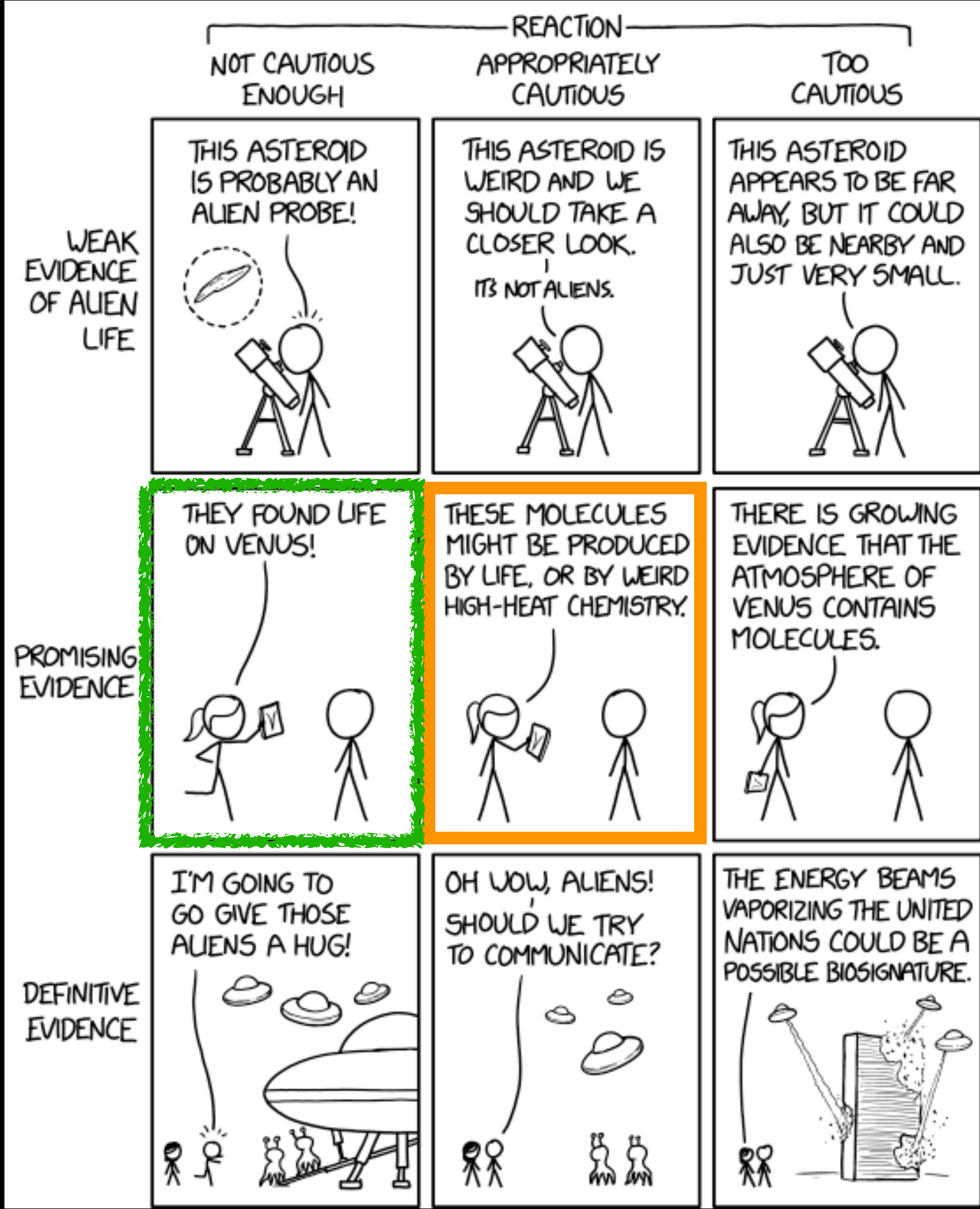
10x **the observed amount of phosphine**

Authors

JCMT

Media

Press



XKCD

Overview

- ★ PI & Urgent queues
  - Recent Results
- ★ Large Programs
  - Recent Results
- ★ The Event Horizon Telescope
- ★ JCMT Data Archive

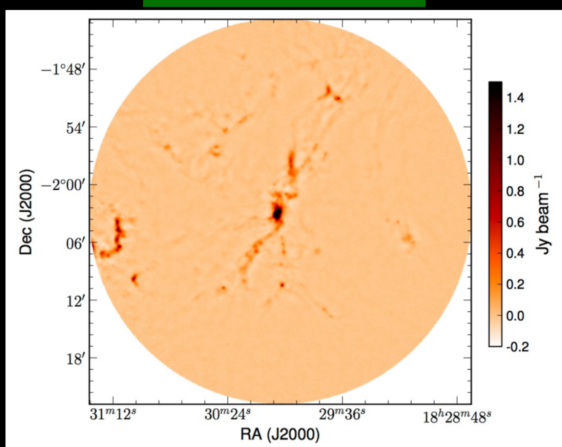
Large Program Queue

- ★ The JCMT spends 50% of its available science time on JCMT Large Programs.
- ★ Typically require significant (>200 hours) amounts of time over multiple semesters to address important scientific questions.
- ★ Proposals competitively assessed by Time Allocation Committee (TAC)
- ★ Enrolment open to: EAO regions (CN, JP, KR, TW), partner institutions (CA, UK), and observer status regions (Vietnam, Thailand, Malaysia, Indonesia). Open enrolment for semester 20A has ended.
- ★ Successful projects run via "LAP queue": Best project based on TAC priority and current weather is observed

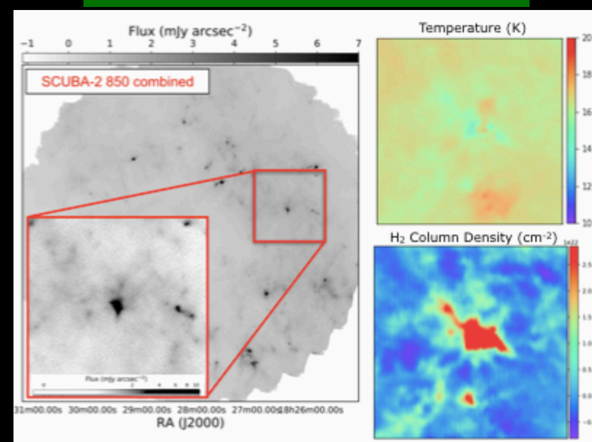
https://www.eaobservatory.org/jcmt/science/large-programs/

Large Programs:
Star Formation and Evolution in the Milky Way

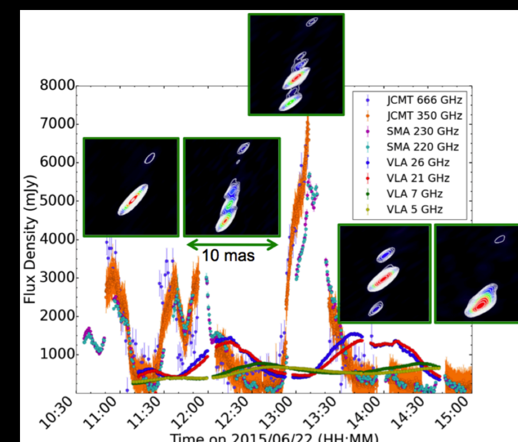
Transient



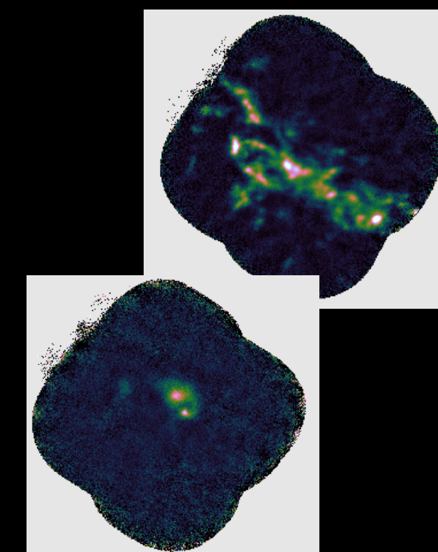
ALOHA-IRDCs



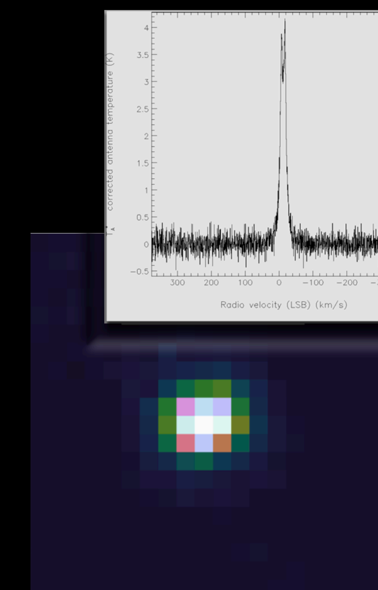
PITCH-BLACK



SCOPE

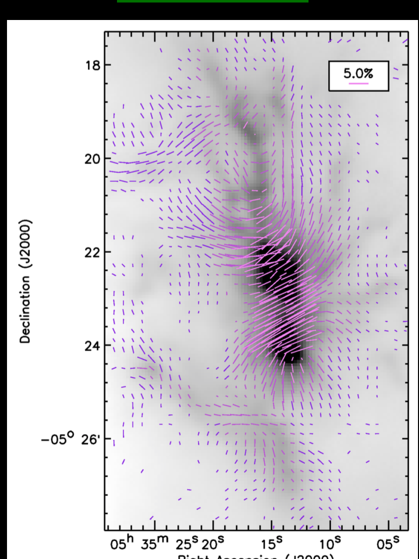


NESS

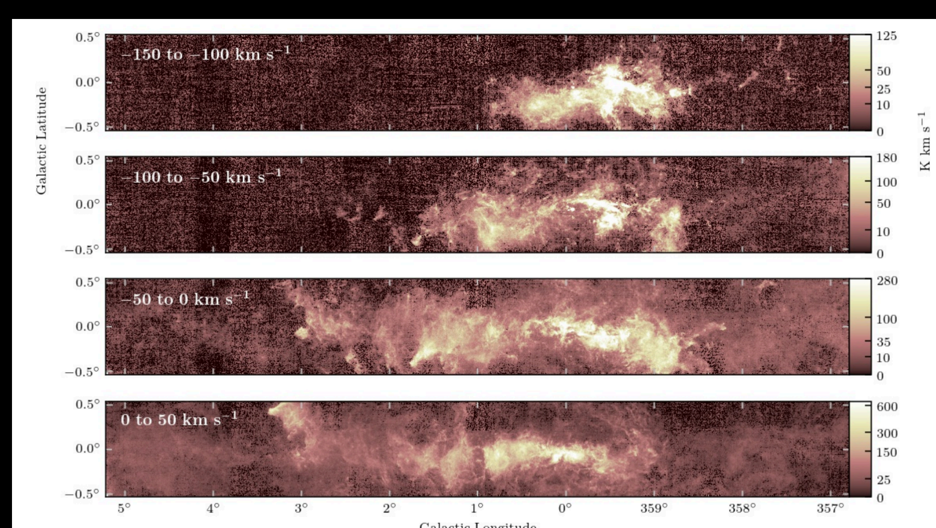


https://www.eaobservatory.org/jcmt/science/large-programs/

Bistro



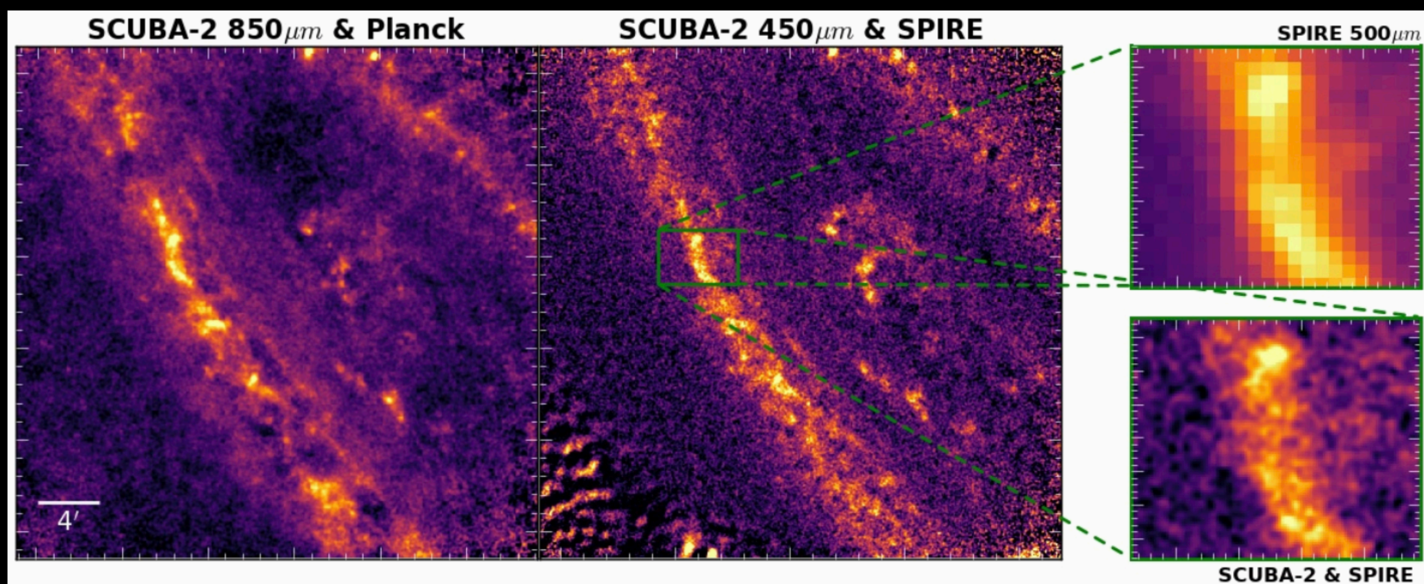
CHIMPS2



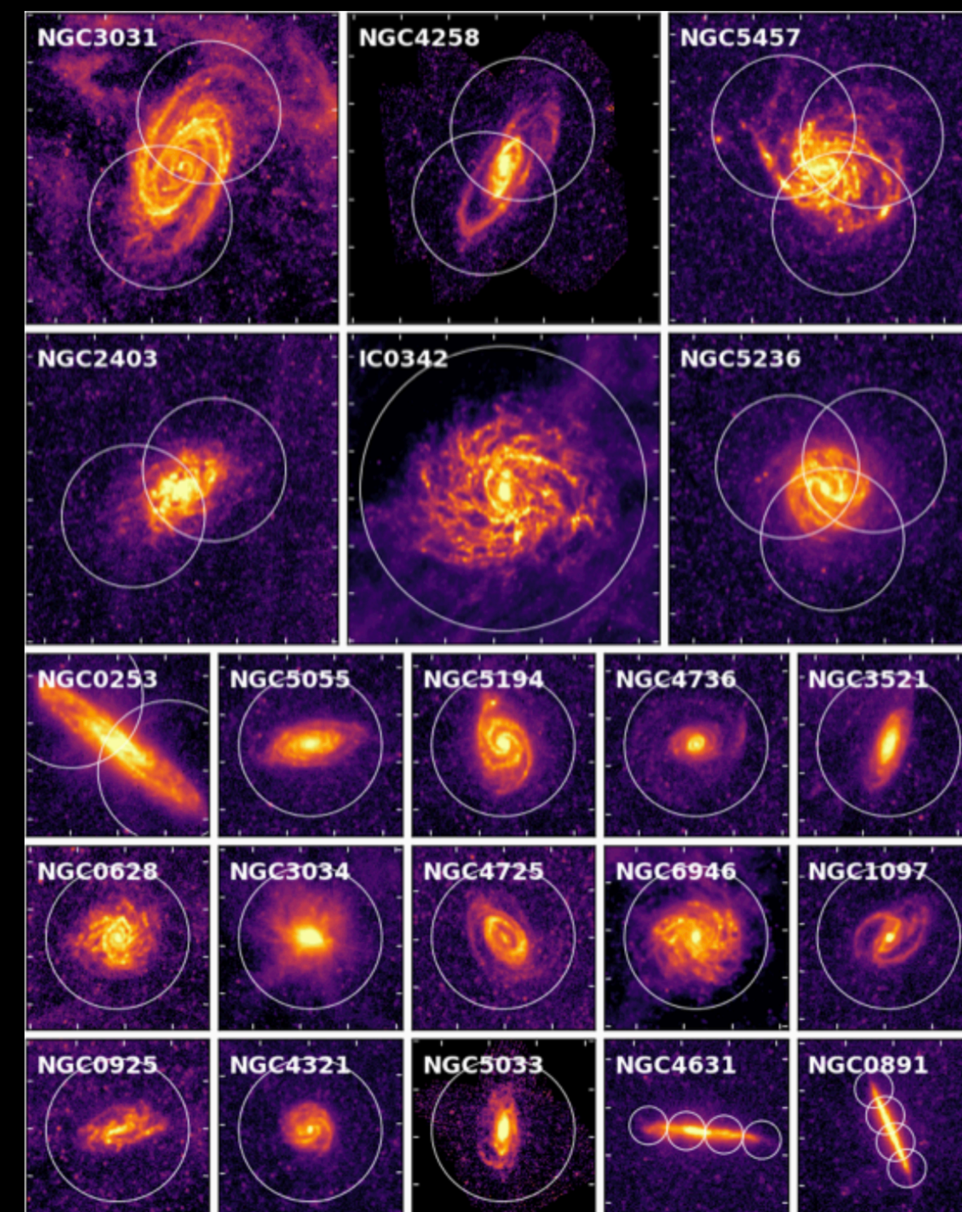
SPACE

Large Programs: Nearby Galaxy Surveys

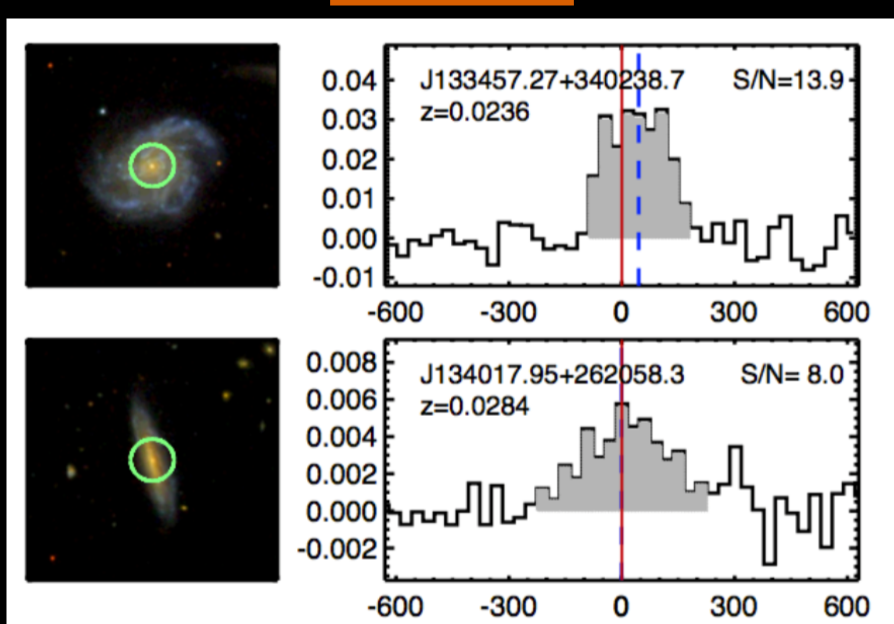
HASHTAG



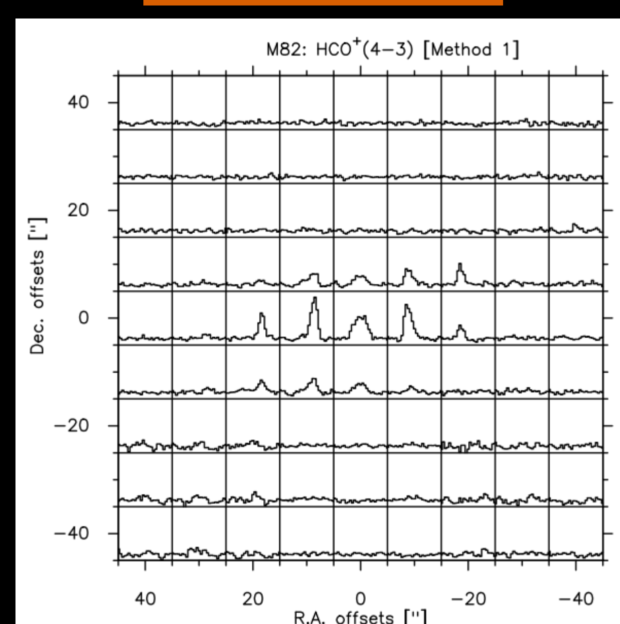
DOWSING



JINGLE



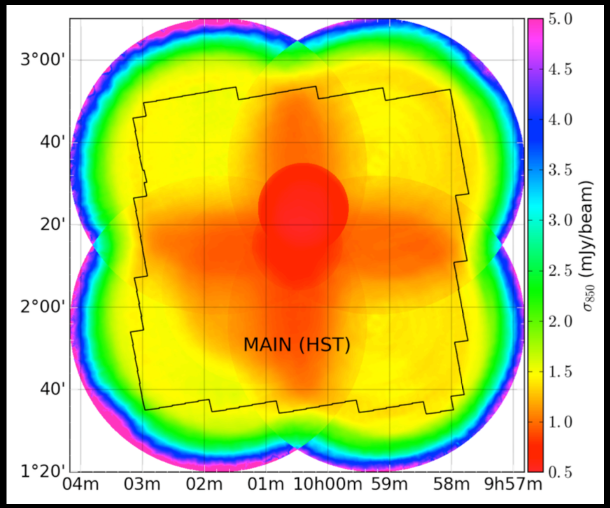
MALATANG



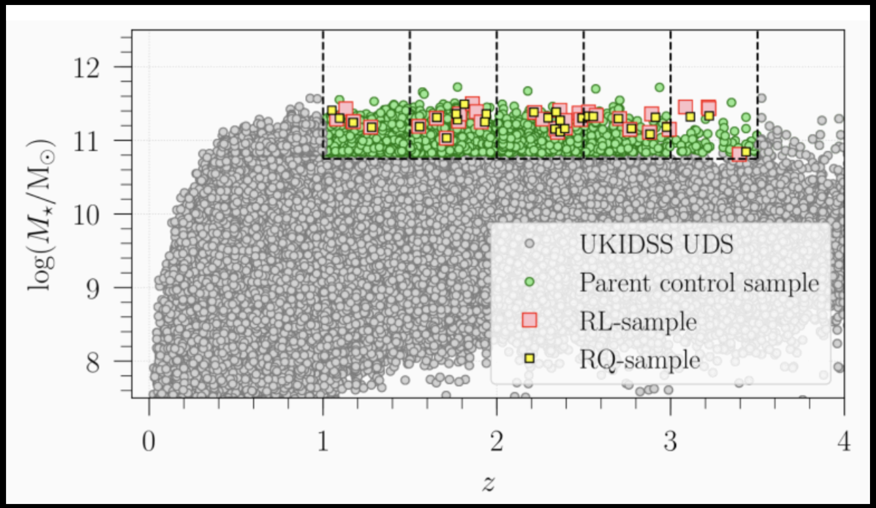
https://www.eaobservatory.org/jcmt/science/large-programs/

Large Programs: Submillimetre Galaxy Studies

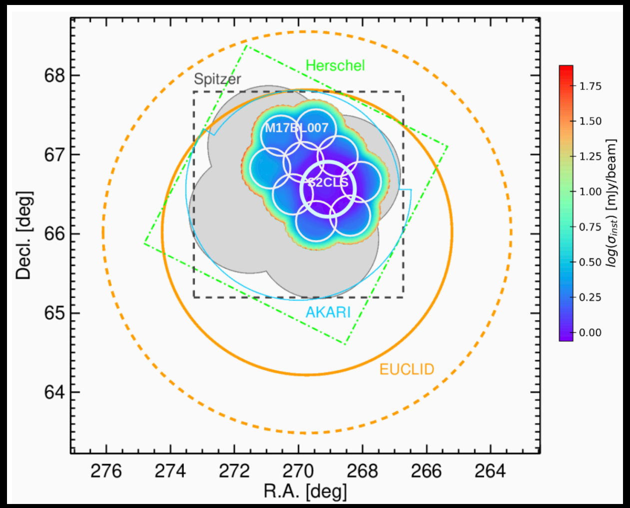
S2COSMOS



RAGERS

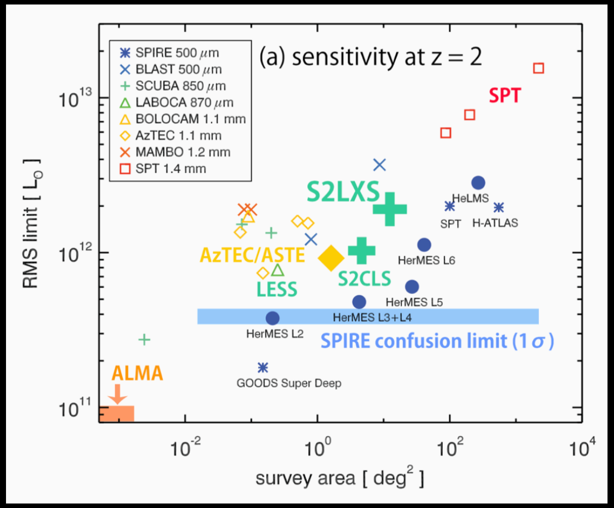


NEP

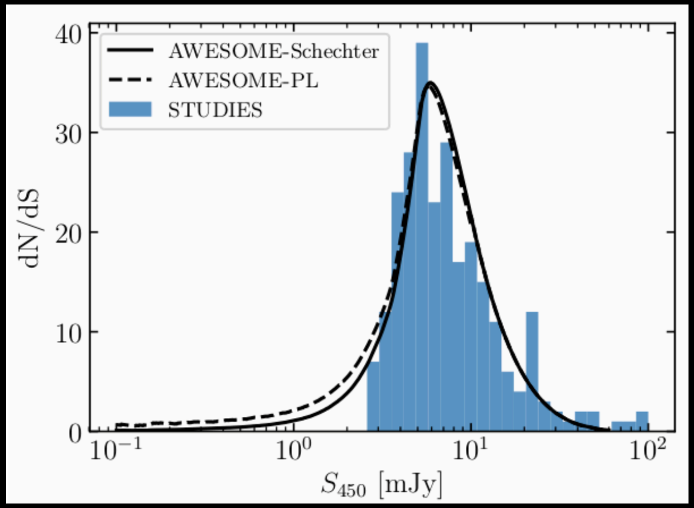


https://www.eaobservatory.org/jcmt/science/large-programs/

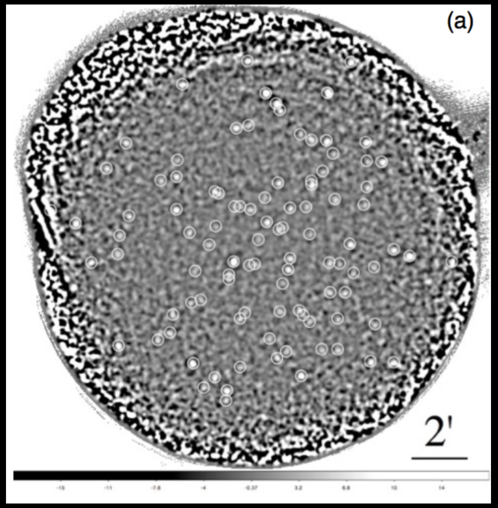
S2LXS



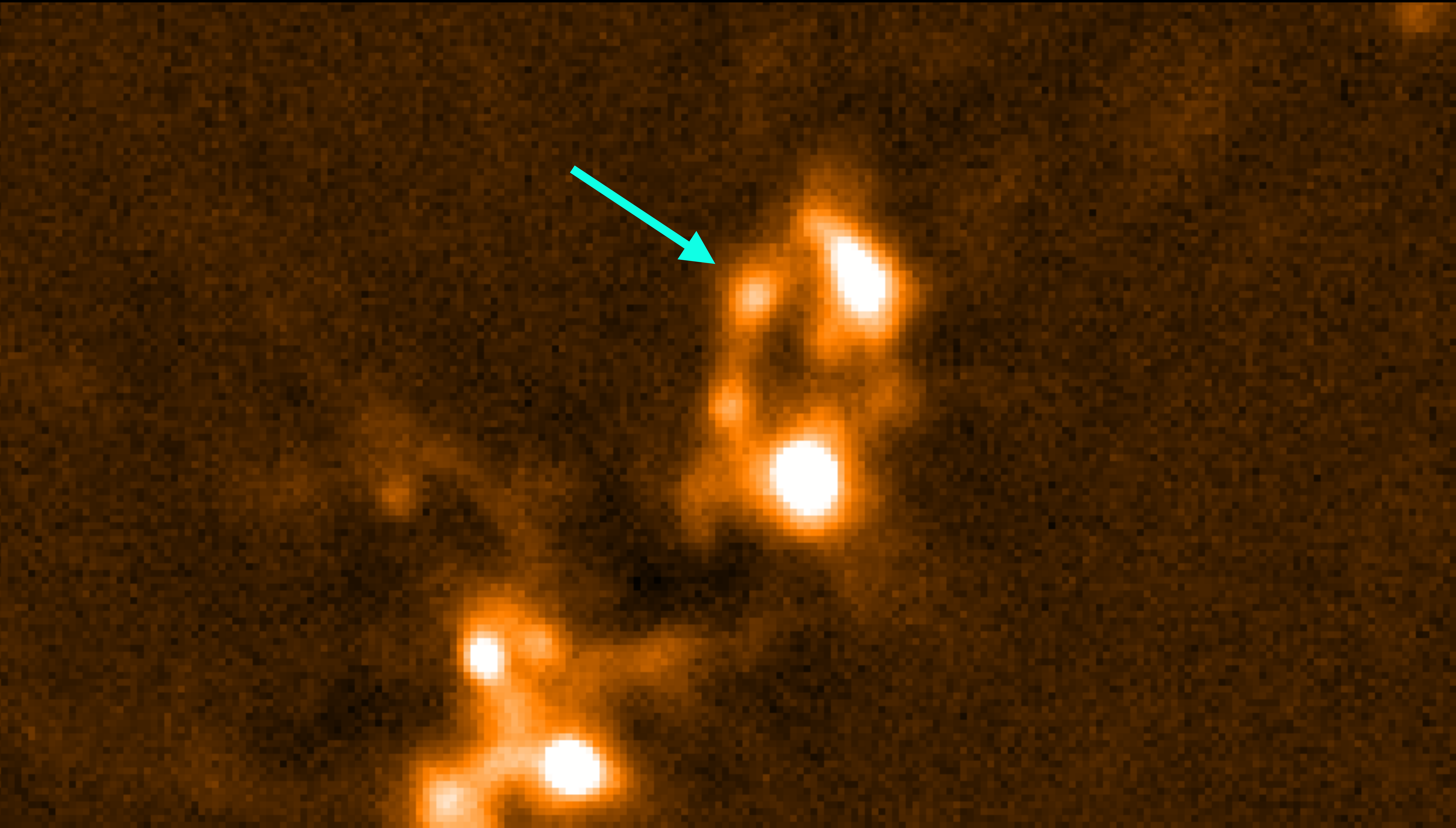
AWESOME

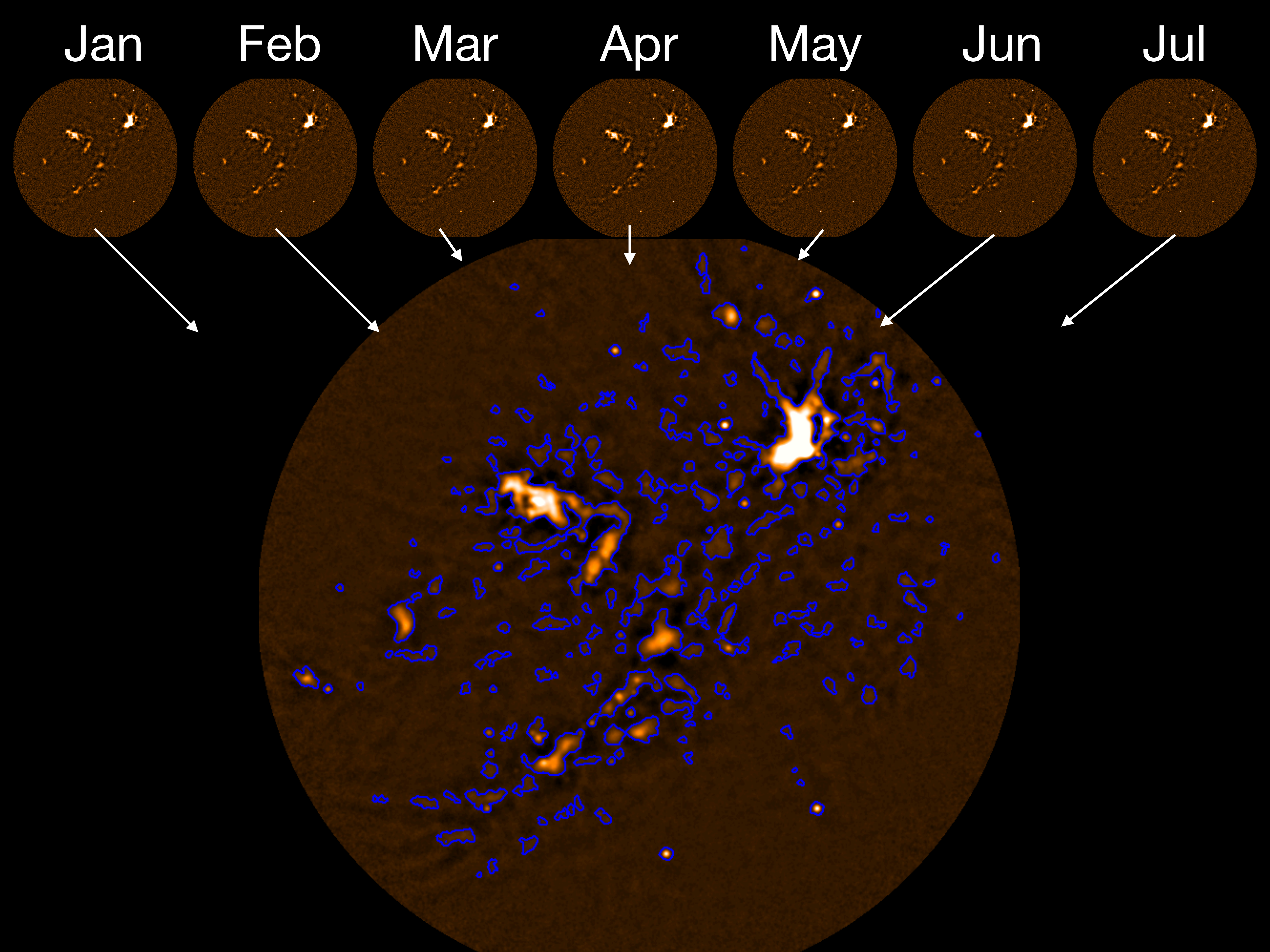


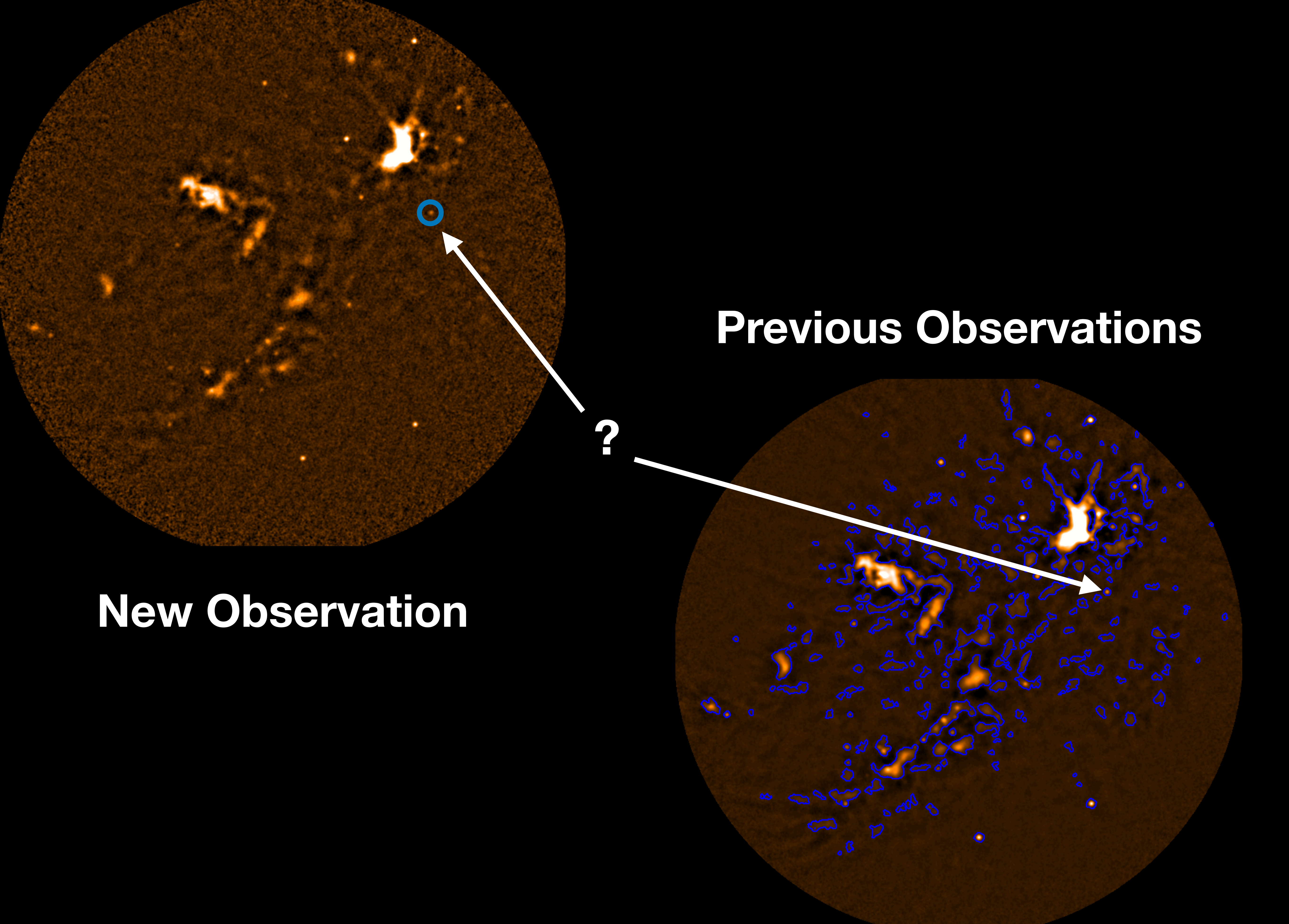
STUDIES



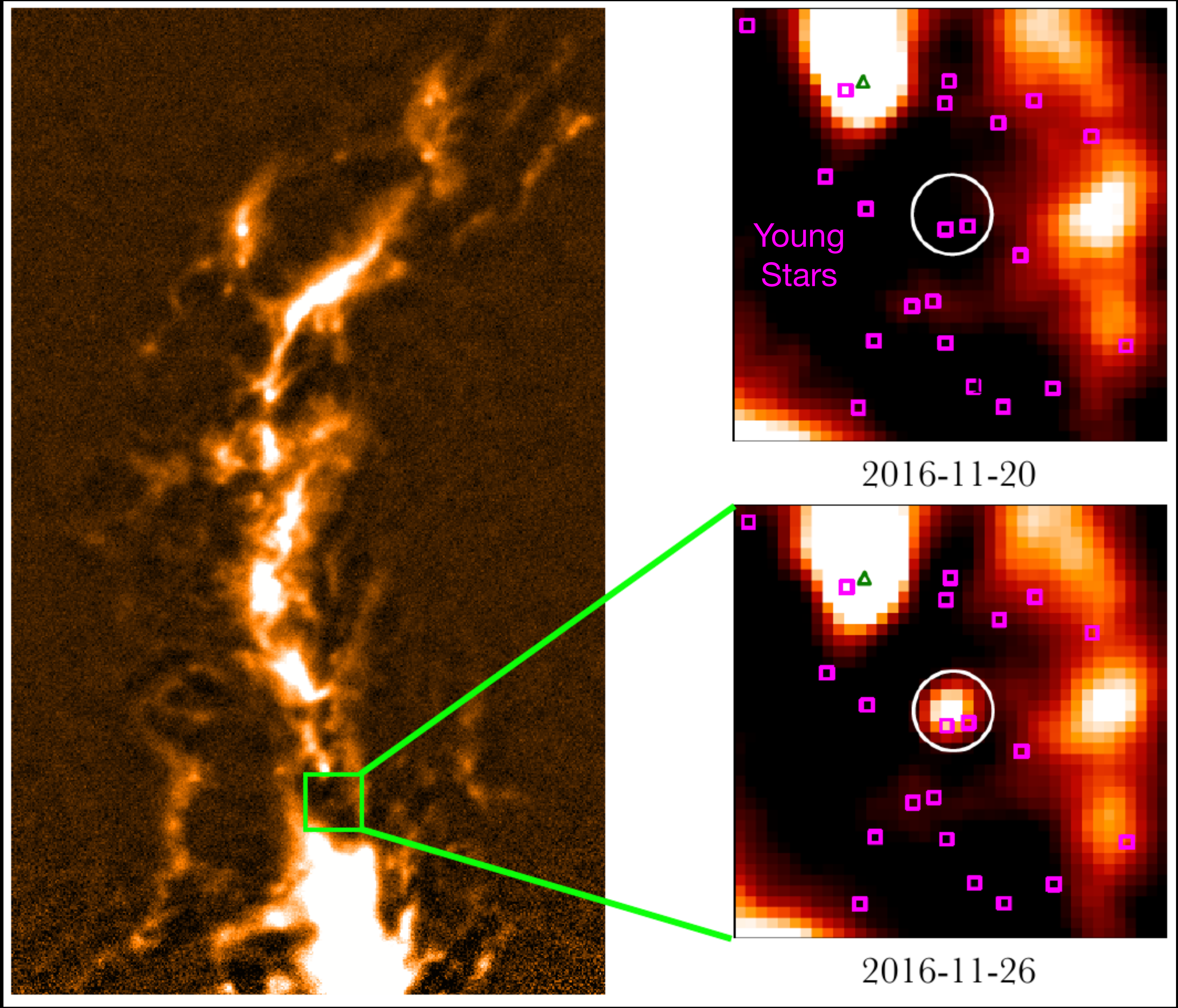
The JCMT Transient Survey:
How do young stars grow?

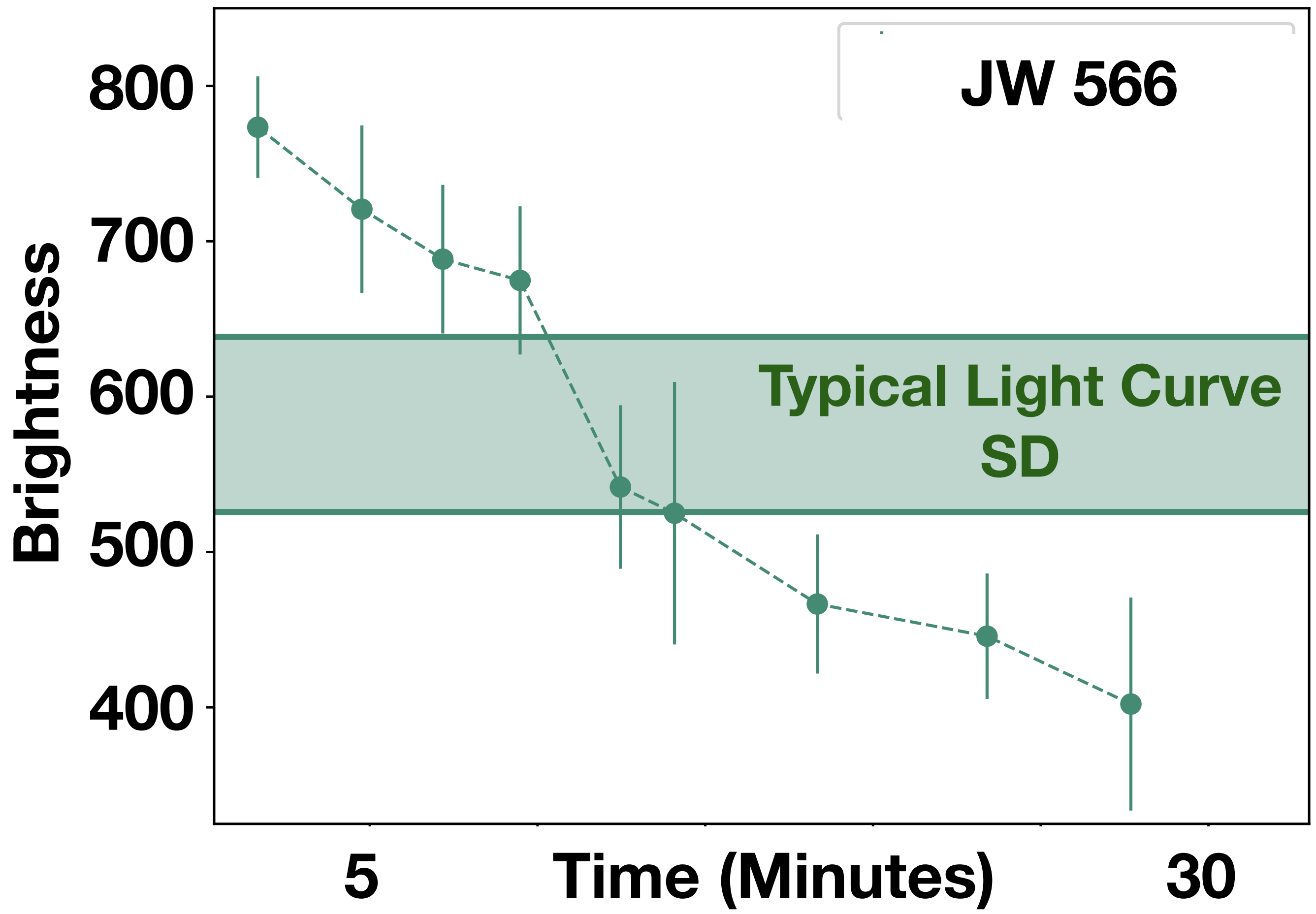



Jan
Feb
Mar
Apr
May
Jun
Jul



Previous Observations
?
New Observation


Young
Stars
2016-11-20
2016-11-26



The decline of the flare was tracked over 30 minutes!

(Mairs et al 2018, ApJ 871:72)

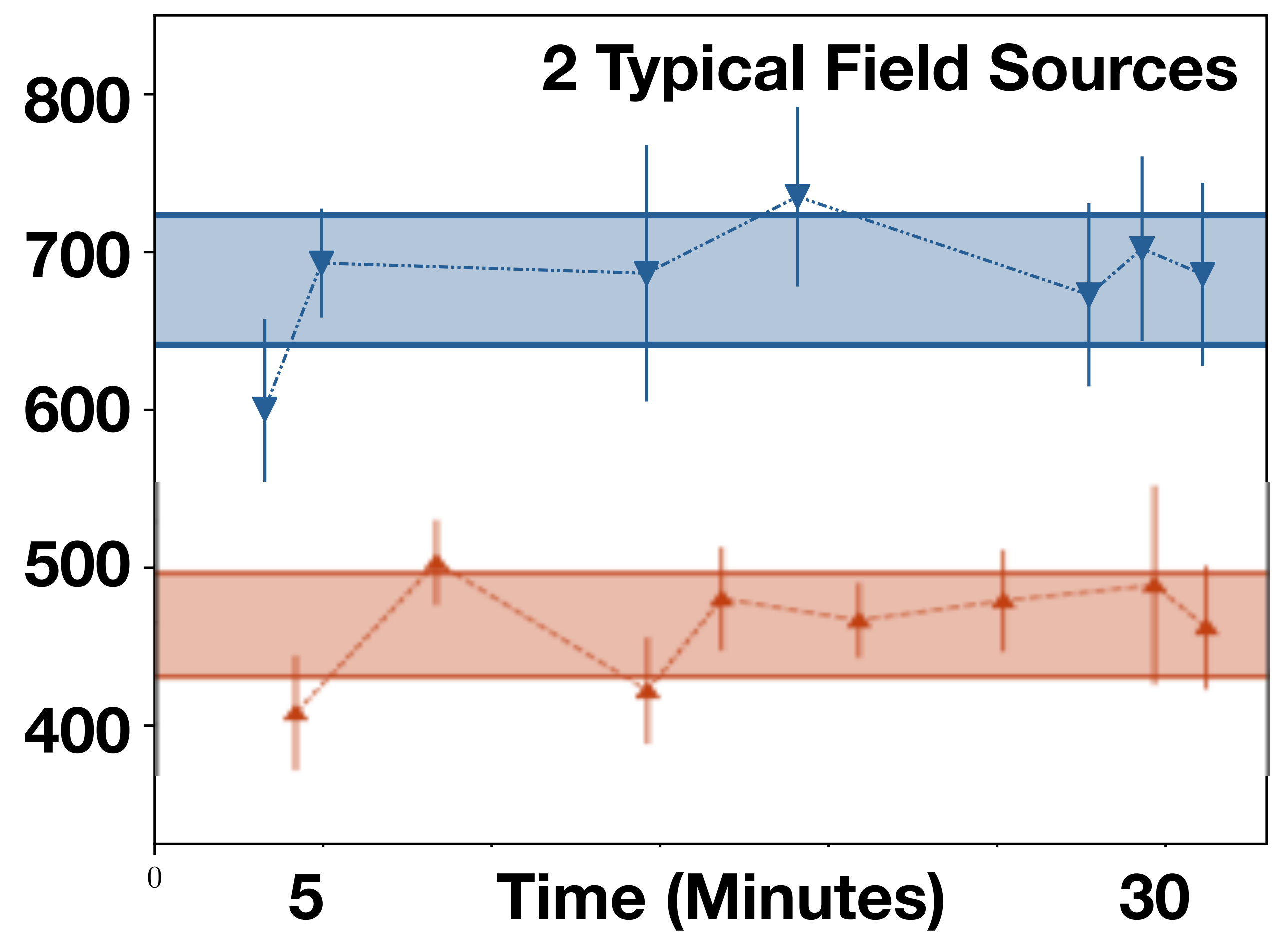
Scientists Find Stellar Flare 10 Billion Times More Powerful Than Those on the Sun

By: Julie Freydlin | February 21, 2019

365

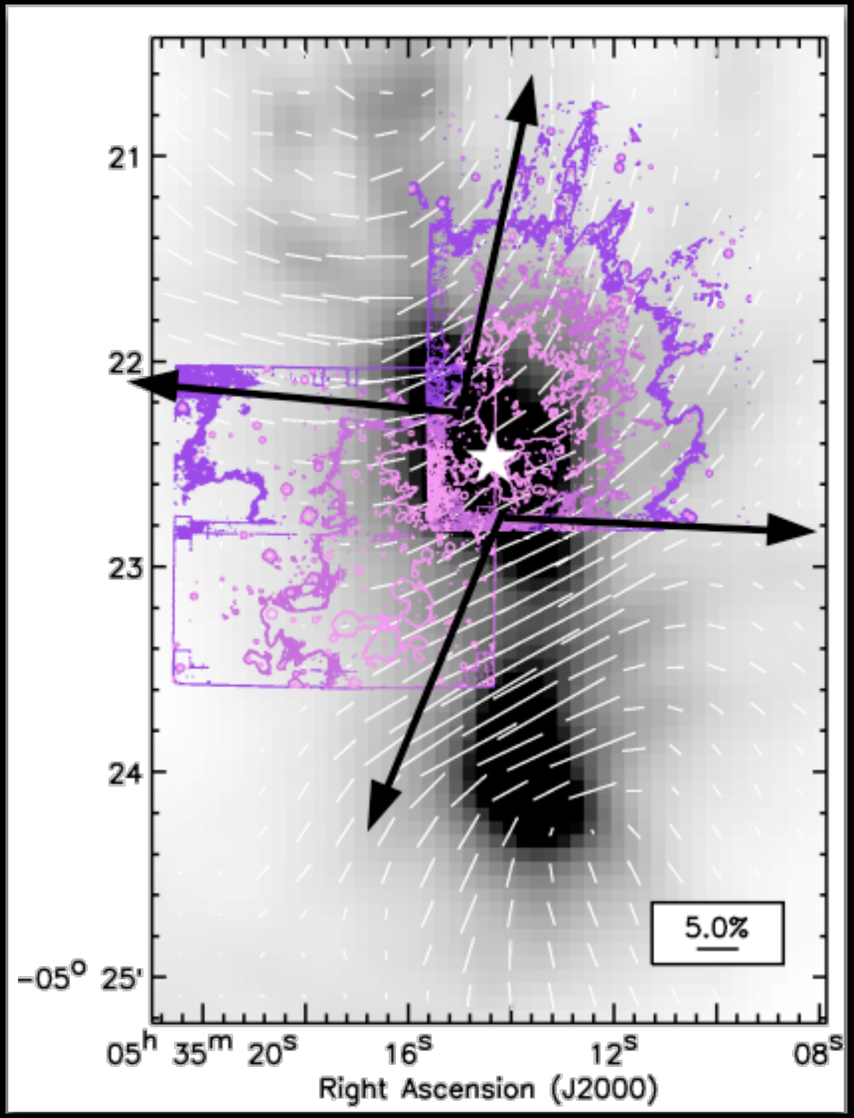
Scientists have caught a powerful flare of submillimeter-wavelength radiation from a young star in the Orion Nebula.

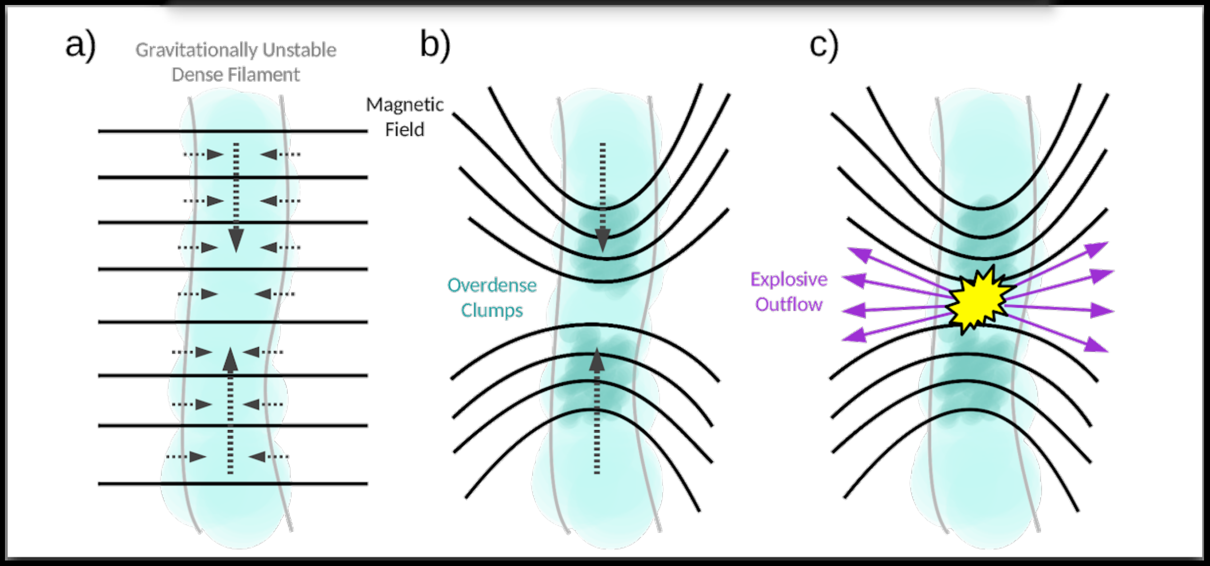
A research team using the James Clerk Maxwell Telescope (JCMT) has discovered the first stellar flare at submillimeter wavelengths — one that is 10 billion times more powerful than flares from our Sun. This finding, published January 20th in *The Astrophysical Journal*, can help scientists better understand the processes by which

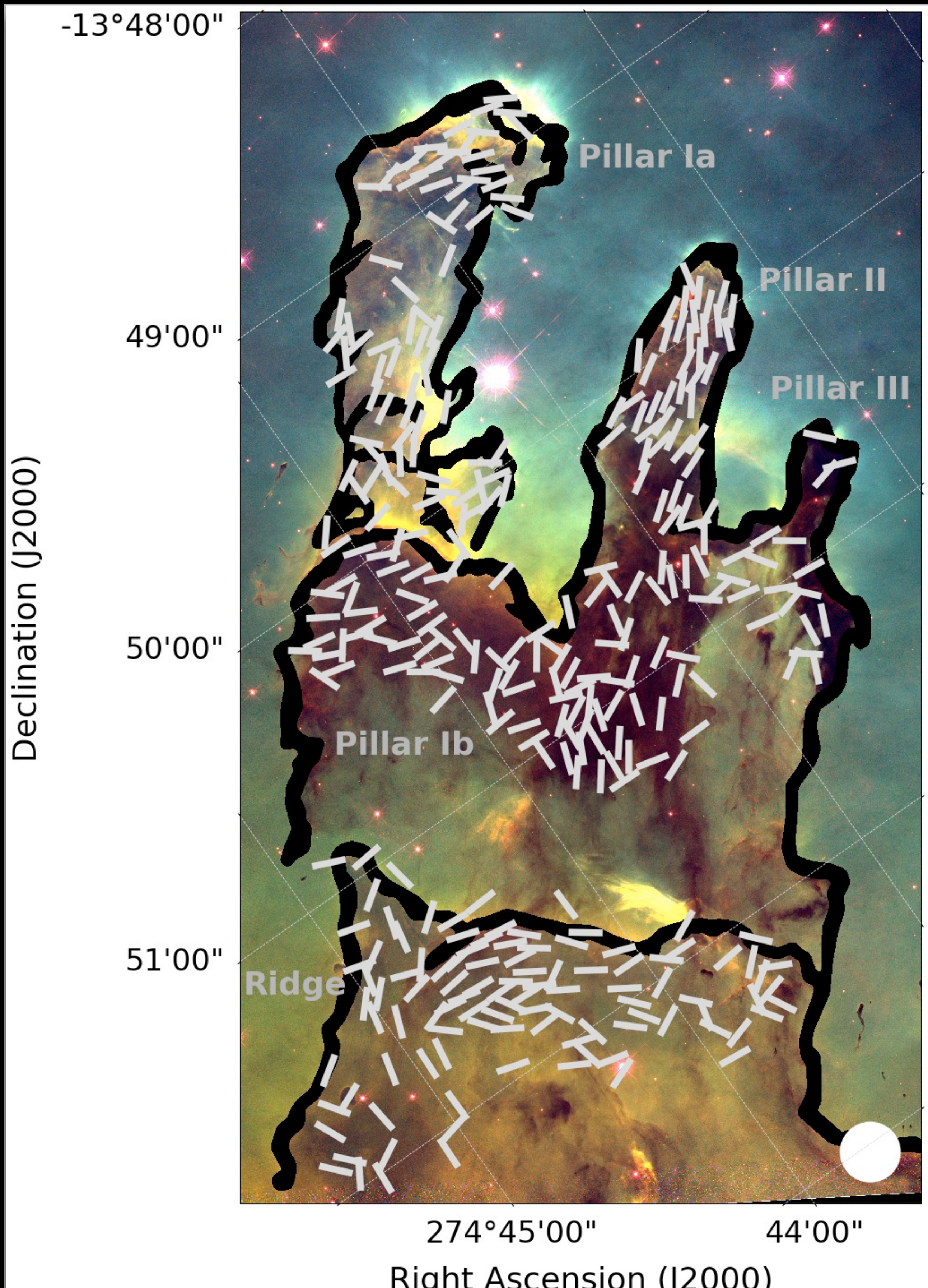


BISTRO - Science Highlights

- Chandrasekhar-Fermi Method (Pattle et al. 2017)
- The results suggest:
  - Magnetic field strength & gravitational force between outflows in approximate balance
  - ‘Hourglass’ magnetic field shape may have been produced by gravitational interaction. Magnetic field may have been compressed until equilibrium was reached
  - On large scales, orientation of BN/KL outflow has, been determined by magnetic field







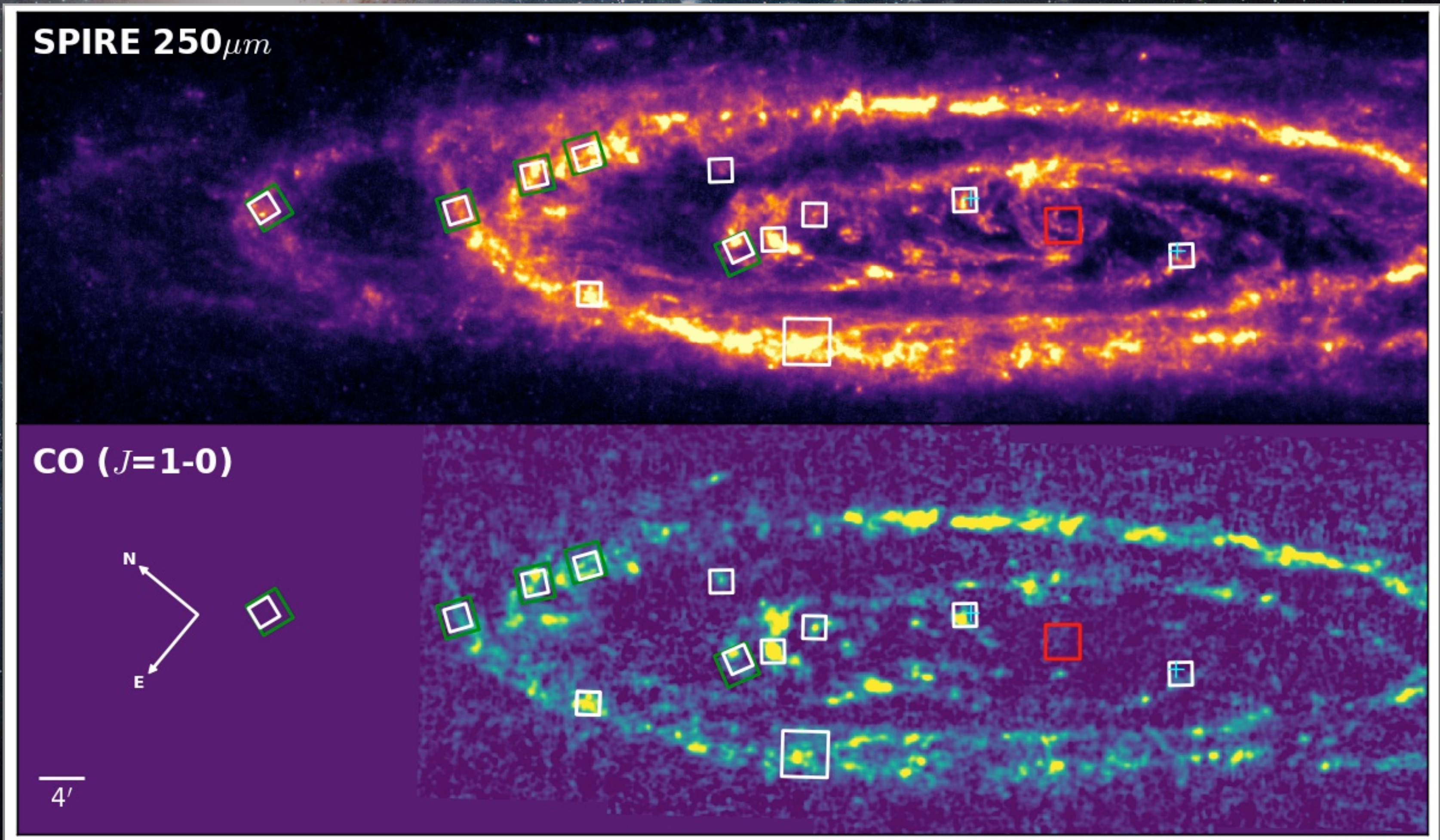
Pattle, K. et al. (2018)

BISTRO: Pillars of Creation

- Magnetic field runs along the length of the pillars, at significantly different angle from field in surrounding ionized plasma
- Intermediate magnetic field strength for region of space which is forming stars

HASHTAG

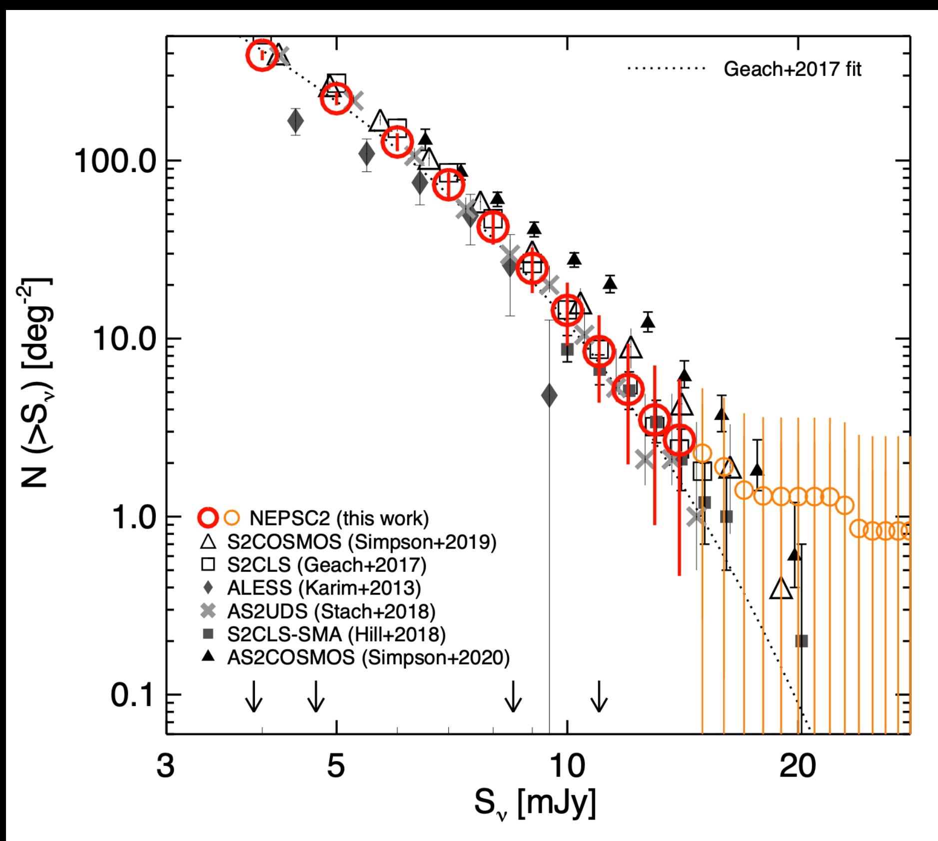
- Mapping **whole of Andromeda Galaxy (M31)** with SCUBA-2
- Also, selected regions with HARP
- Will tell us about:
  - Physics of dust
  - Interstellar Medium (ISM)
  - Star formation

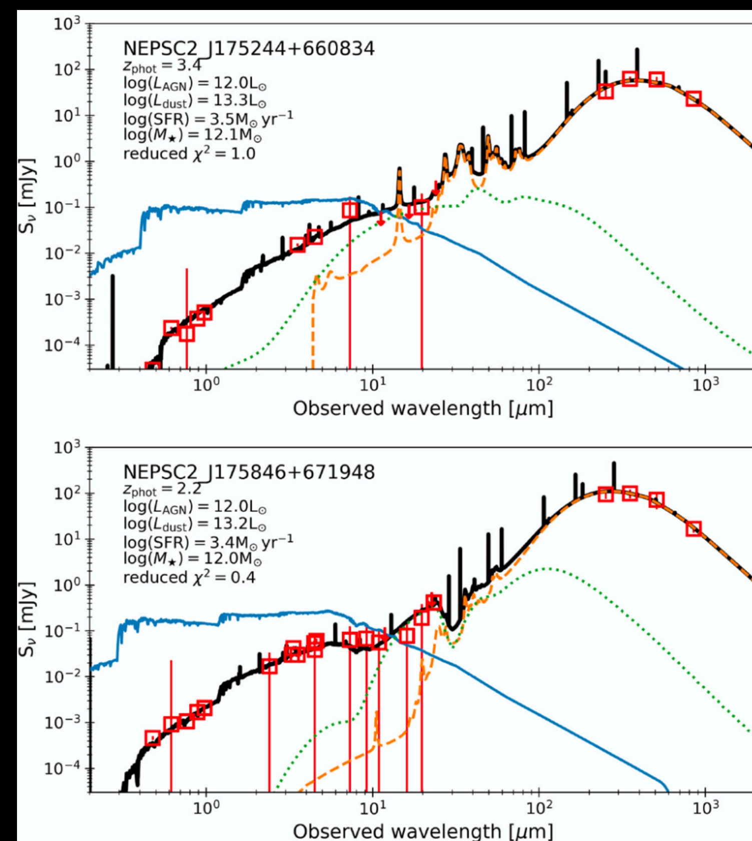


The North Ecliptic Pole SCUBA-2 survey: 850-µm map and catalogue over 2 deg^2

Shim, et al. MNRAS, 498:4, 5065–5079. 2020

Goal: Produce deep (1-2.3 mJy) new map of North Ecliptic Pole Region and analyse sources catalogued





Left: Cumulative number counts of 850 µm sources in the 2 deg^2 around the NEP. Arrows mark the 50% and 80% completeness limits for regions with σ = 1 mJy and σ = 2.3 mJy.

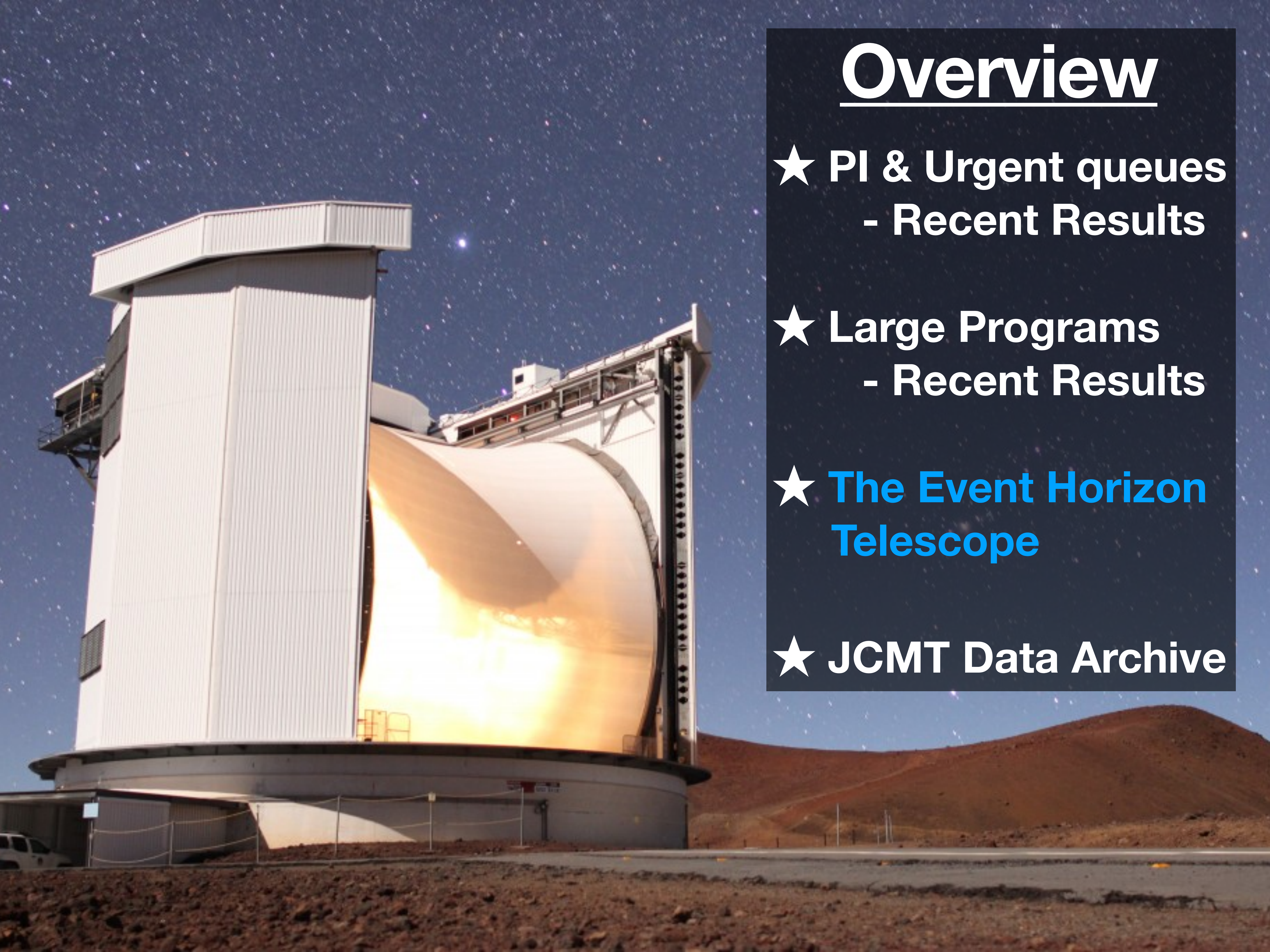
Right: SEDs of two of the brightest sources from optical to submm wavelengths. Arrows represent 3σ upper limits and overplotted lines represent the best-fitting models

Results

★ Data have extended the submm coverage by a factor of ~4 compared to previous surveys

★ Source counts at 850 µm are compared with other surveys.

★ Valuable long-wave information for mid-IR AKARI sources



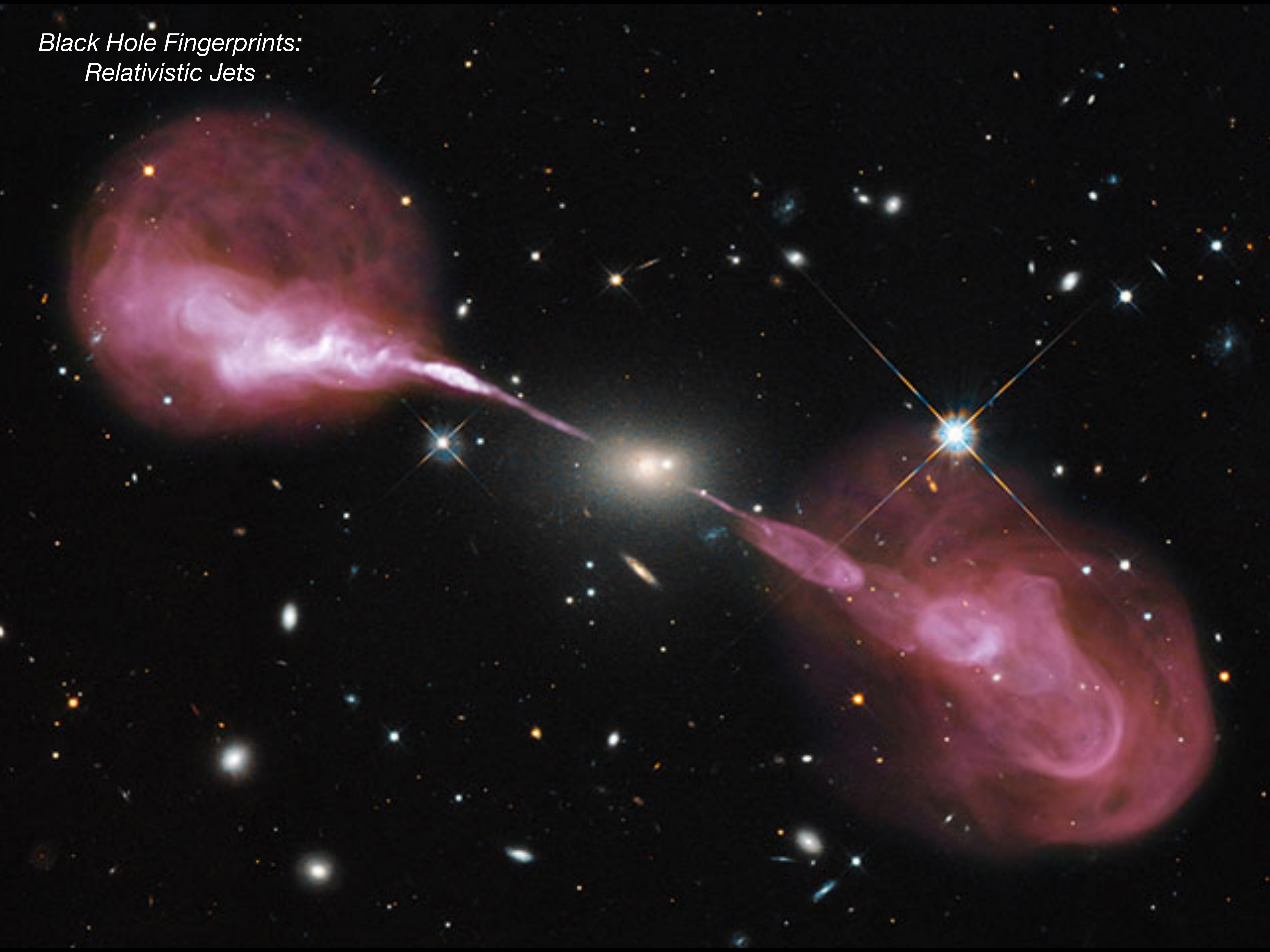
Overview

★ PI & Urgent queues
- Recent Results

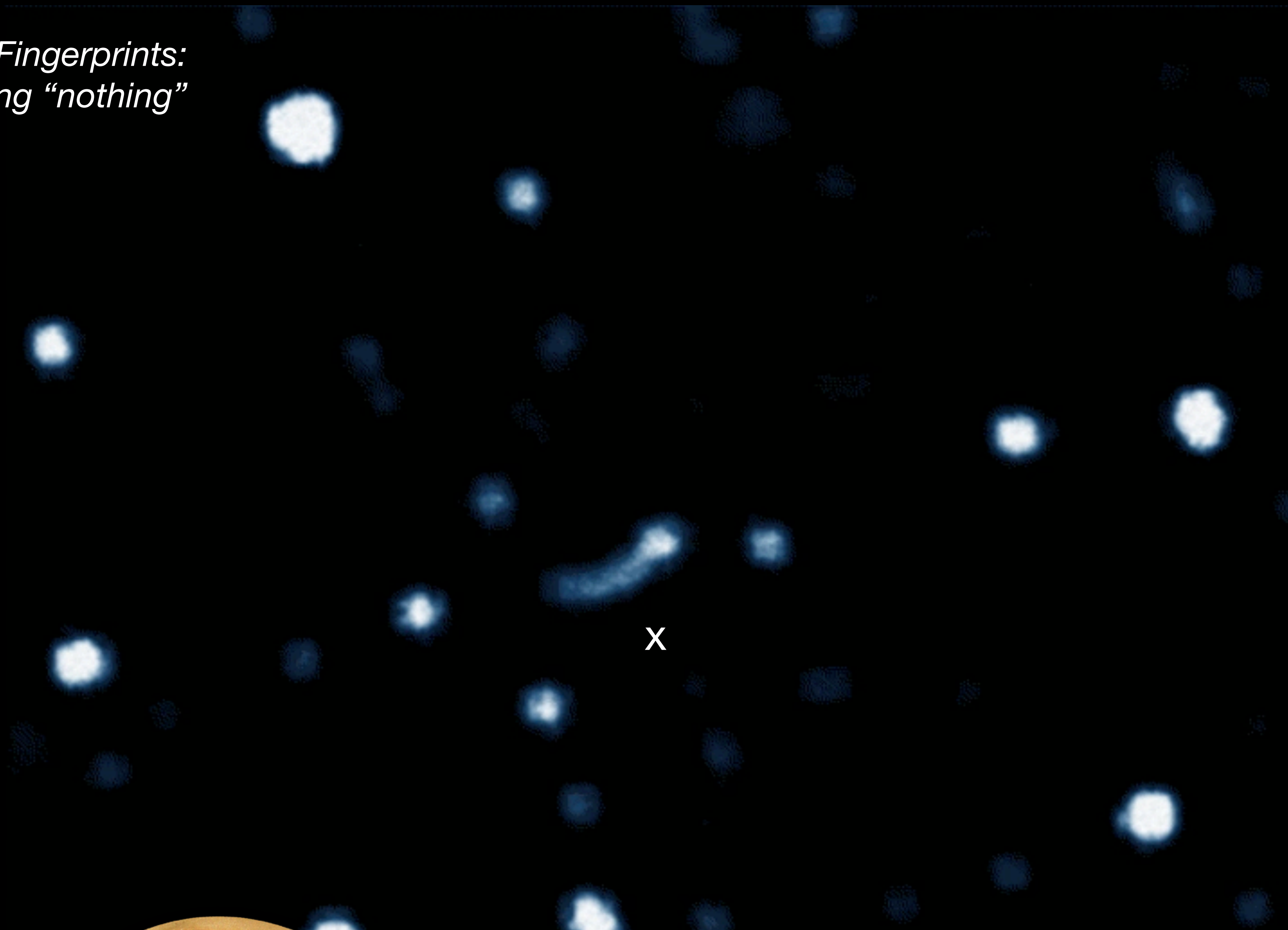
★ Large Programs
- Recent Results

★ The Event Horizon Telescope

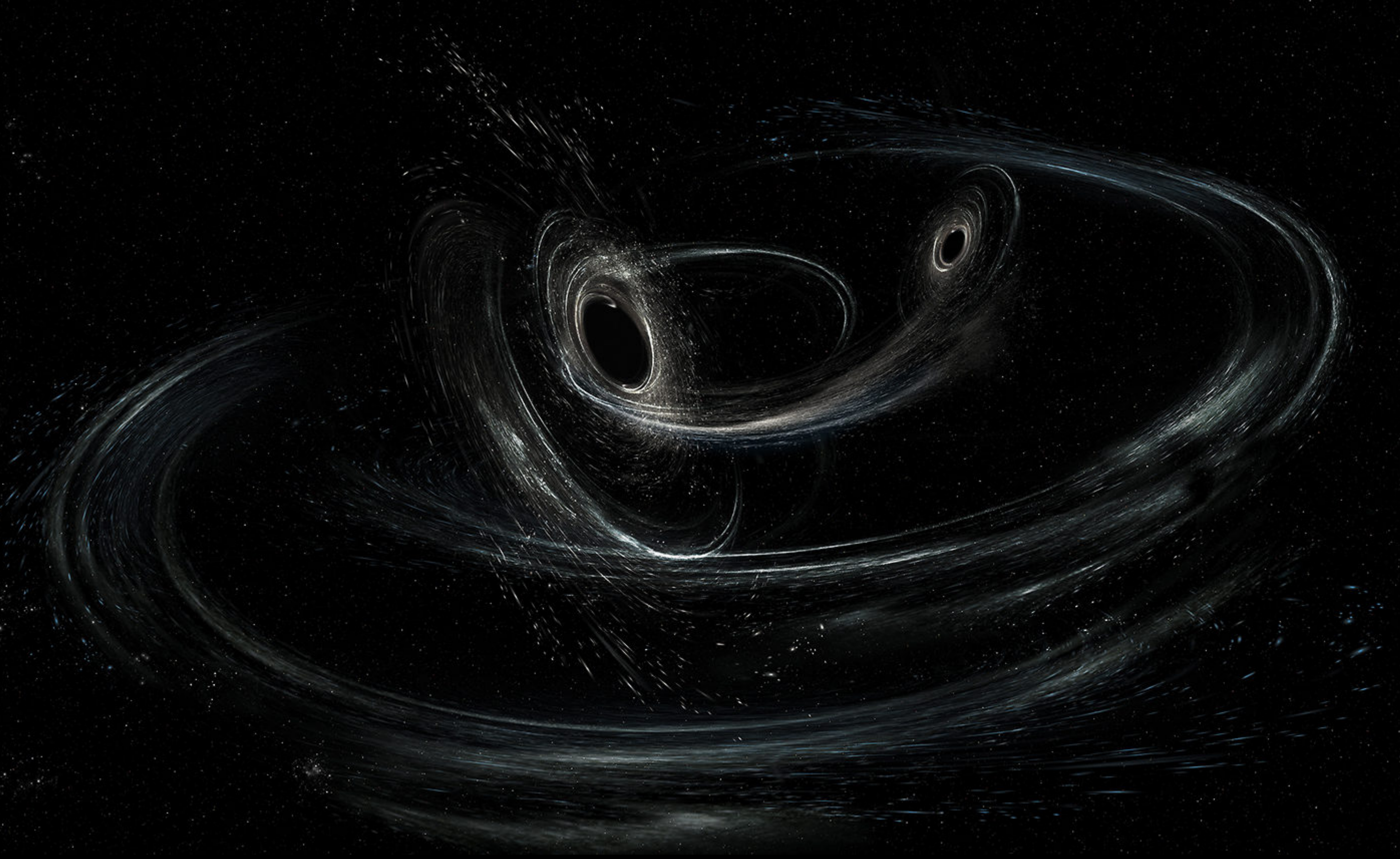
★ JCMT Data Archive


Black Hole Fingerprints:
Relativistic Jets

Black Hole Fingerprints:
Stars Orbiting "nothing"



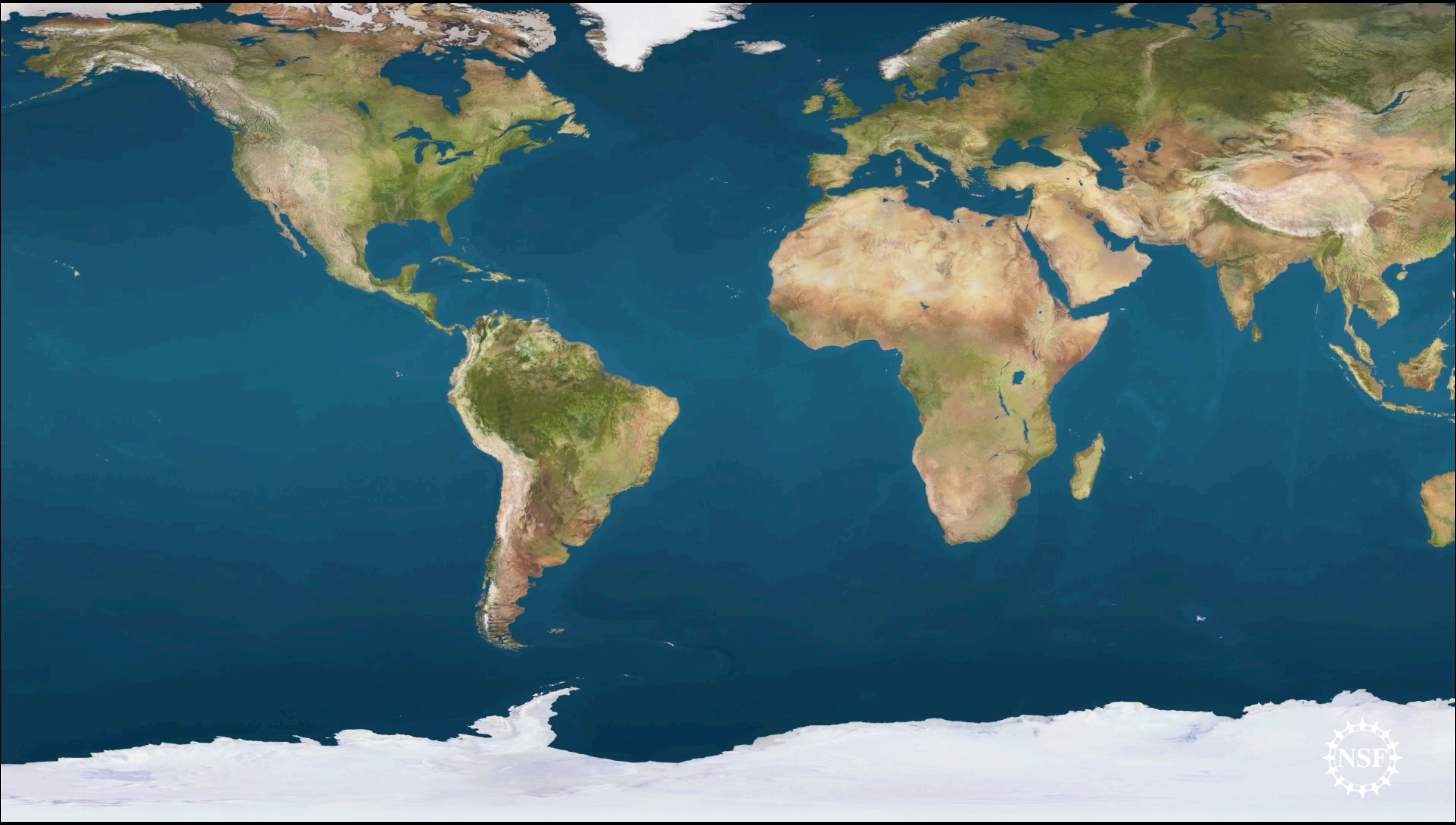
Black Hole Fingerprints: Gravitational Waves



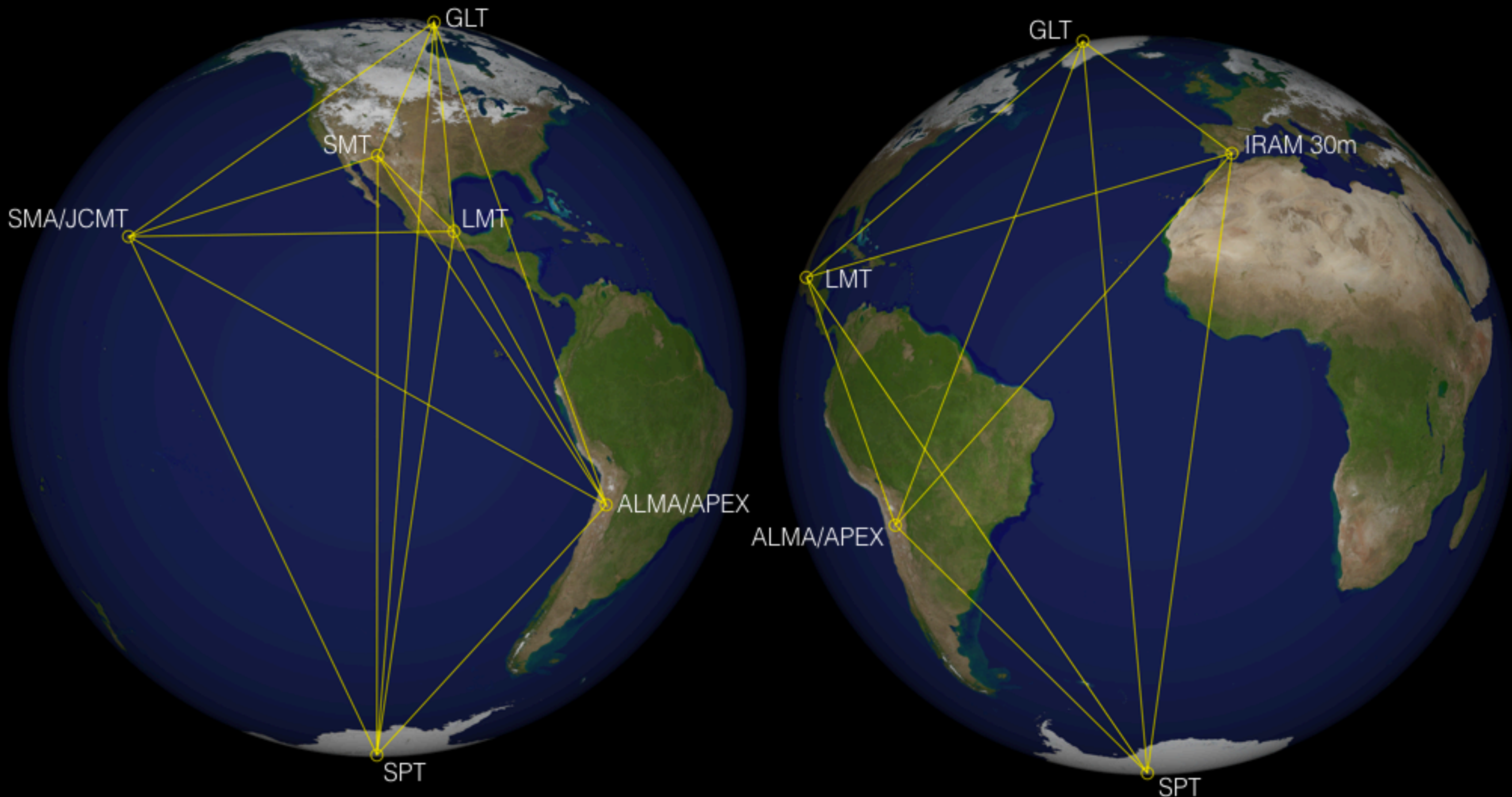
To observe a black hole directly….

…Telescope Diameter = ~13,000 km


But we don't need the whole mirror!
D
Martin Ryle and Antony Hewish won a Nobel Prize for developing:
Interferometry


NSF

Event Horizon Telescope



Event Horizon Telescope

A massive project with many people involved!

The Event Horizon Telescope Collaboration,
Kazunori Akiyama[1,2,3,4], Antxon Alberdi[5], Walter Alef[6], Keiichi Asada[7], Rebecca Azulay[8,9,6], Anne-Kathrin Baczko[6], David Ball[10], Mislav Baloković[4,11], John Barrett[2], Dan Bintley[12], Lindy Blackburn[4,11], Wilfred Boland[13], Katherine L. Bouman[4,11,14], Geoffrey C. Bower[15], Michael Bremer[16], Christiaan D. Brinkerink[17], Roger Brissenden[4,11], Silke Britzen[6], Avery E. Broderick[18,19,20], Dominique Broguiere[16], Thomas Bronzwaer[17], Do-Young Byun[21,22], John E. Carlstrom[23,24,25,26], Andrew Chael[4,11], Chi-kwan Chan[10,27], Shami Chatterjee[28], Koushik Chatterjee[29], Ming-Tang Chen[15], Yongjun Chen (陈永军)[30,31], Ilje Cho[21,22], Pierre Christian[10,11], John E. Conway[32], James M. Cordes[28], Geoffrey B. Crew[2], Yuzhu Cui[33,34], Jordy Davelaar[17], Mariafelicia De Laurentis[35,36,37], Roger Deane[38,39], Jessica Dempsey[12], Gregory Desvignes[6], Jason Dexter[40], Sheperd S. Doeleman[4,11], Ralph P. Eatough[6], Heino Falcke[17], Vincent L. 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Koch[7], Shoko Koyama[7], Michael Kramer[6], Carsten Kramer[16], Thomas P. Krichbaum[6], Cheng-Yu Kuo[60], Tod R. Lauer[61], Sang-Sung Lee[21], Yan-Rong Li (李彦荣)[62], Zhiyuan Li (李志远)[63,64], Michael Lindqvist[32], Kuo Liu[6], Elisabetta Liuzzo[65], Wen-Ping Lo[7,66], Andrei P. Lobanov[6], Laurent Loinard[67,68], Colin Lonsdale[2], Ru-Sen Lu (路如森)[30,6], Nicholas R. MacDonald[6], Jirong Mao (毛基荣)[69,70,71], Sera Markoff[29,72], Daniel P. Marrone[10], Alan P. Marscher[56], Iván Martí-Vidal[32,73], Satoki Matsushita[7], Lynn D. Matthews[2], Lia Medeiros[10,74], Karl M. Menten[6], Yosuke Mizuno[36], Izumi Mizuno[12], James M. Moran[4,11], Kotaro Moriyama[33,2], Monika Moscibrodzka[17], Cornelia Müller[6,17], Hiroshi Nagai[3,34], Neil M. Nagar[75], Masanori Nakamura[7], Ramesh Narayan[4,11], Gopal Narayanan[76], Iniyan Natarajan[39], Roberto Neri[16], Chunchong Ni[19,20], Aristeidis Noutsos[6], Hiroki Okino[33,77], Héctor Olivares[36], Gisela N. 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Chuter[12], Rodrigo Córdova Rosado[4,11], Iain M. Coulson[12], Thomas M. Crawford[24,25], Joseph Crowley[108], John David[84], Mark Derome[2], Matthew Dexter[109], Sven Dornbusch[6], Kevin A. Dudevoir[2,144], Sergio A. Dzib[6], Andreas Eckart[6,110], Chris Eckert[2], Neal R. Erickson[76], Wendeline B. Everett[111], Aaron Faber[112], Joseph R. Farah[4,11,113], Vernon Fath[76], Thomas W. Folkers[10], David C. Forbes[10], Robert Freund[10], Arturo I. Gómez-Ruiz[105,106], David M. Gale[105], Feng Gao[30,40], Gertie Geertsema[114], David A. Graham[6], Christopher H. Greer[10], Ronald Grosslein[76], Frédéric Gueth[16], Daryl Haggard[115,116,117], Nils W. Halverson[118], Chih-Chiang Han[7], Kuo-Chang Han[107], Jinchi Hao[107], Yutaka Hasegawa[7], Jason W. Henning[23,119], Antonio Hernández-Gómez[67,120], Rubén Herrero-Illana[121], Stefan Heyminck[6], Akihiko Hirota[3,7], James Hoge[12], Yau-De Huang[7], C. M. Violette Impellizzeri[7,1], Homin Jiang[7], Atish Kamble[4,11], Ryan Keisler[25], Kimihiro Kimura[7], Yusuke Kono[3], Derek Kubo[122], John Kuroda[12], Richard Lacasse[102], Robert A. Laing[123], Erik M. Leitch[23], Chao-Te Li[7], Lupin C.-C. Lin[7,124], Ching-Tang Liu[107], Kuan-Yu Liu[7], Li-Ming Lu[107], Ralph G. Marson[125], Pierre L. Martin-Cocher[7], Kyle D. Massingill[10], Callie Matulonis[12], Martin P. McColl[10], Stephen R. McWhirter[2], Hugo Messias[121,126], Zheng Meyer-Zhao[7,127], Daniel Michalik[128,129], Alfredo Montaña[105,106], William Montgomerie[12], Matias Mora-Klein[102], Dirk Muders[6], Andrew Nadolski[46], Santiago Navarro[84], Joseph Neilsen[103], Chi H. Nguyen[10,130], Hiroaki Nishioka[7], Timothy Norton[11], Michael A. Nowak[131], George Nystrom[15], Hideo Ogawa[132], Peter Oshiro[15], Tomoaki Oyama[133], Harriet Parsons[12], Scott N. Paine[11], Juan Peñalver[84], Neil M. Phillips[121,126], Michael Poirier[2], Nicolas Pradel[7], Rurik A. Primiani[134], Philippe A. Raffin[15], Alexandra S. Rahlin[23,135], George Reiland[10], Christopher Risacher[16], Ignacio Ruiz[84], Alejandro F. Sáez-Madaín[102,126], Remi Sassella[16], Pim Schellart[17,136], Paul Shaw[7], Kevin M. Silva[12], Hotaka Shiokawa[11], David R. Smith[137,138], William Snow[15], Kamal Souccar[76], Don Sousa[2], T. K. Sridharan[11], Ranjani Srinivasan[15], William Stahm[12], Anthony A. Stark[11], Kyle Story[139], Sjoerd T. Timmer[17], Laura Vertatschitsch[11,134], Craig Walther[12], Ta-Shun Wei[7], Nathan Whitehorn[140], Alan R. Whitney[2], David P. Woody[141], Jan G. A. Wouterloot[12], Melvin Wright[142], Paul Yamaguchi[11], Chen-Yu Yu[7], Milagros Zeballos[105,143], Shuo Zhang[104], and Lucy Ziurys[10]

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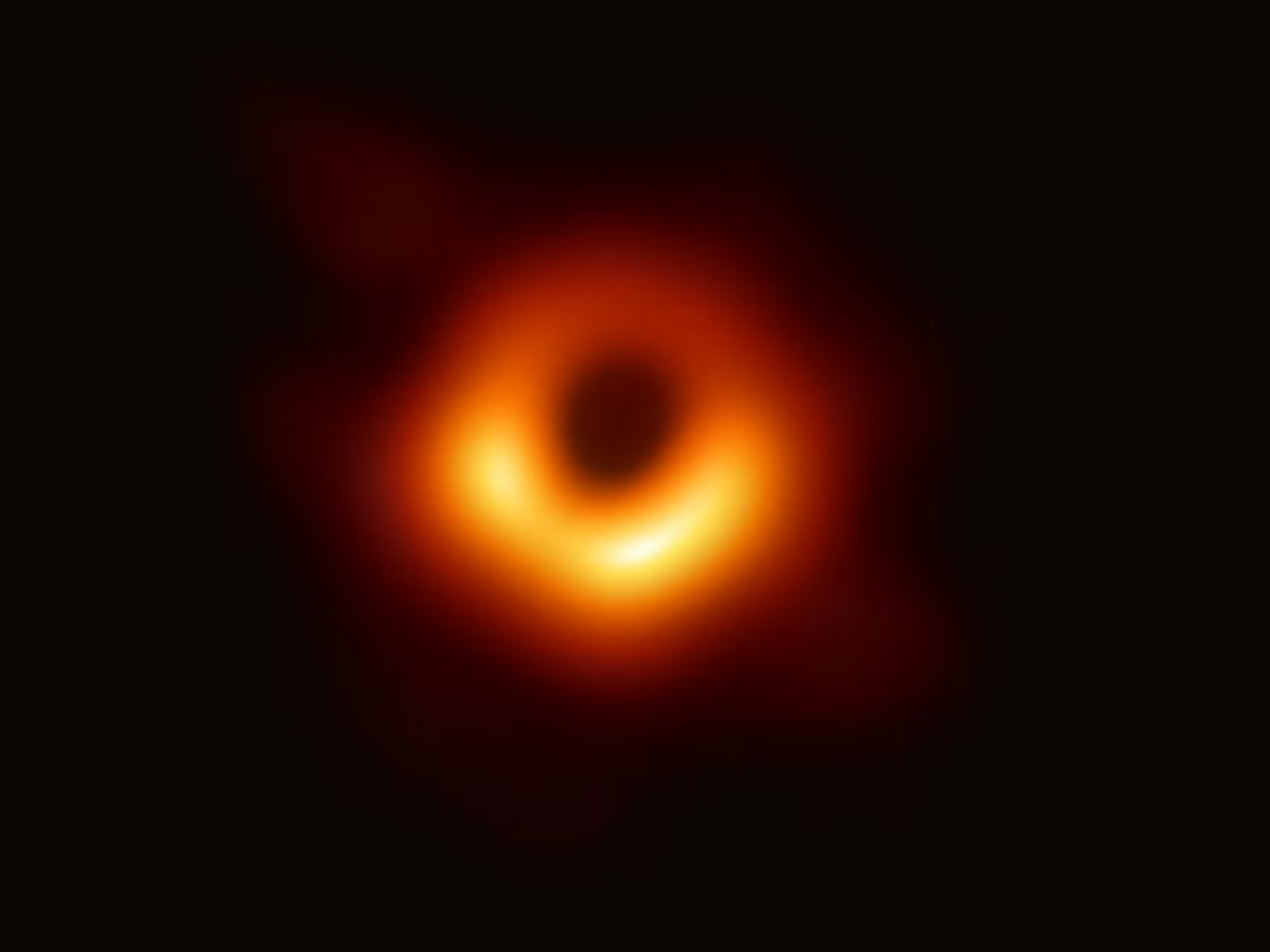
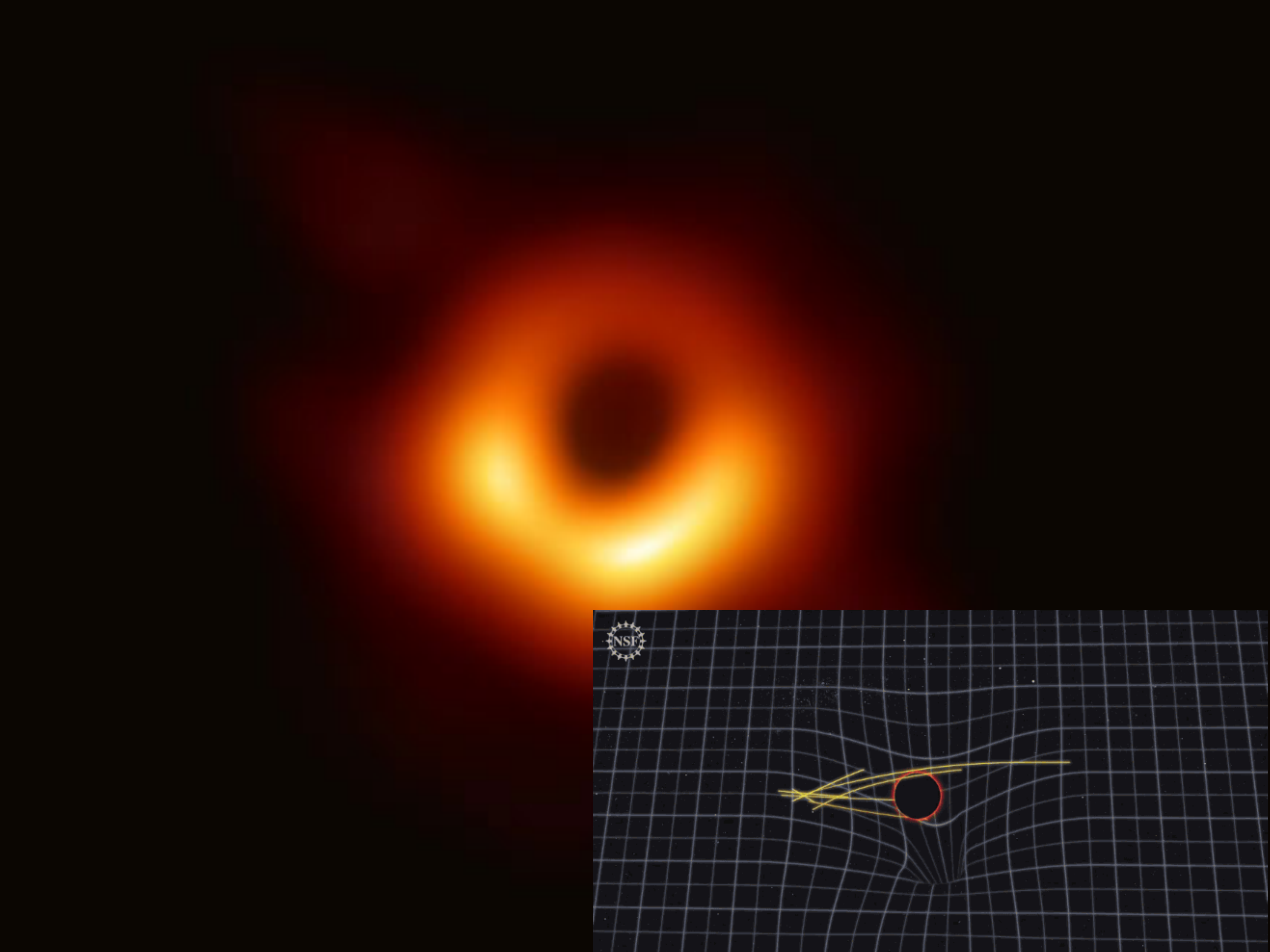
Outreach: Mislav Baloković, Eduardo Ros, Fumie Tazaki





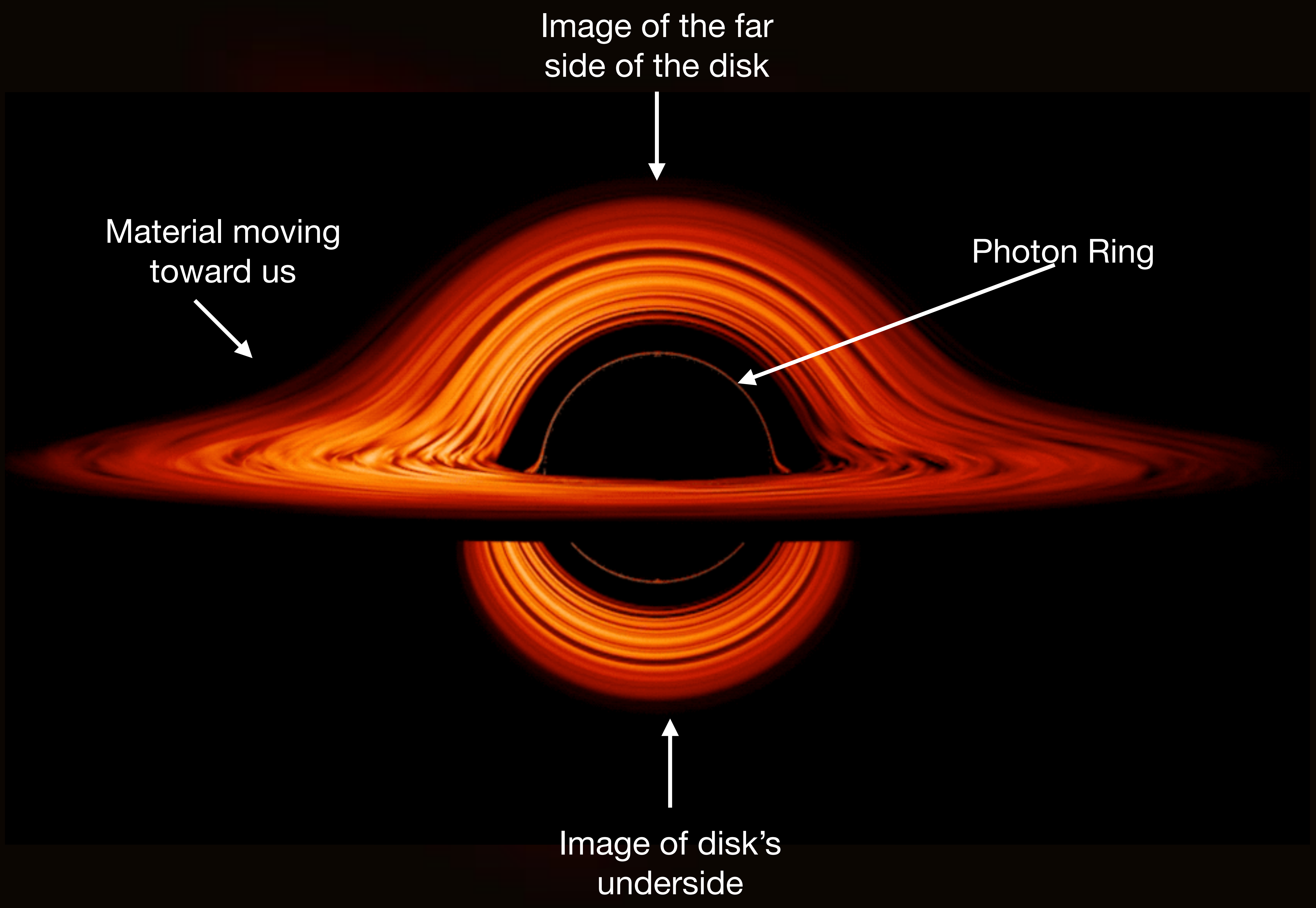
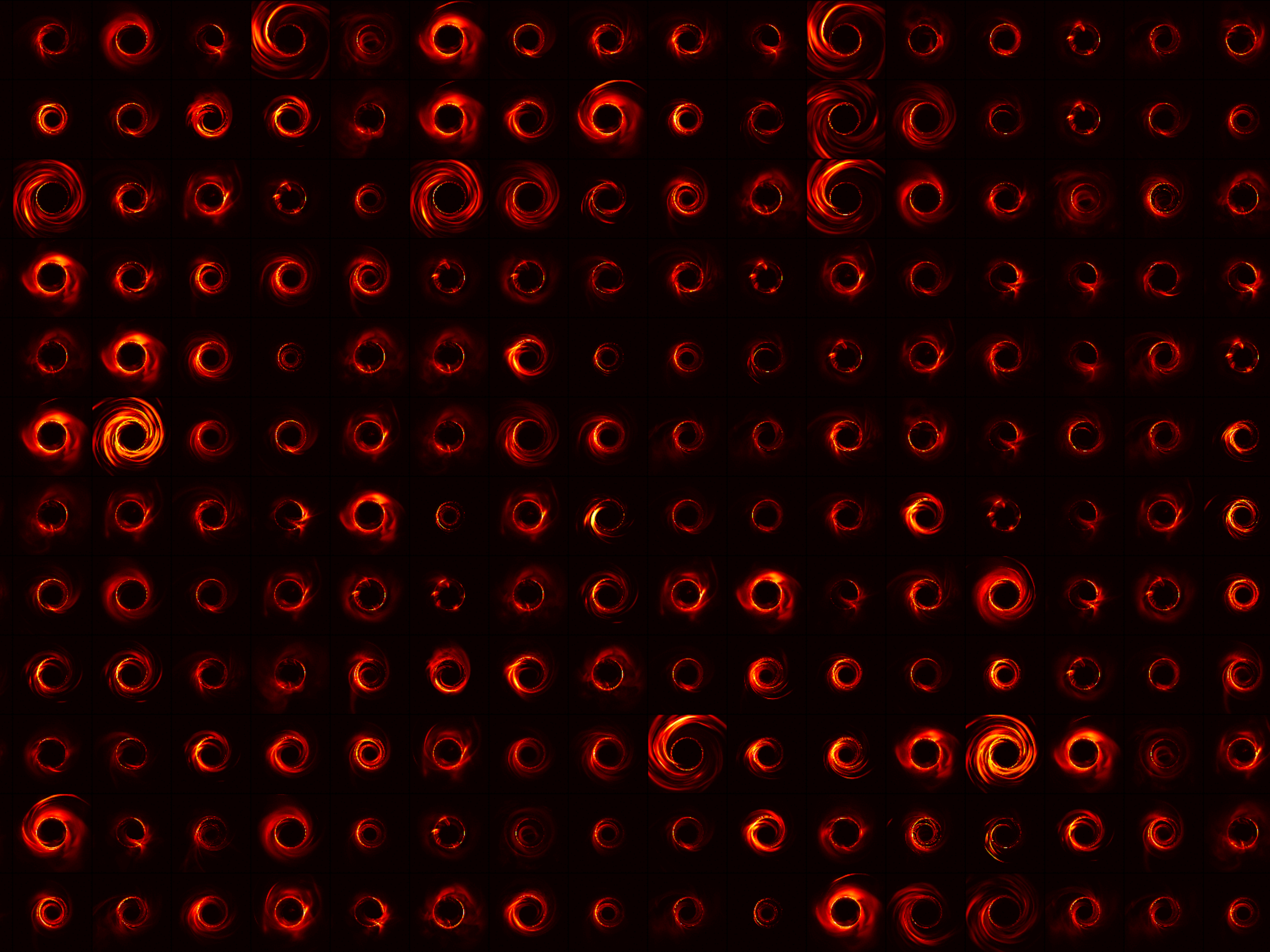
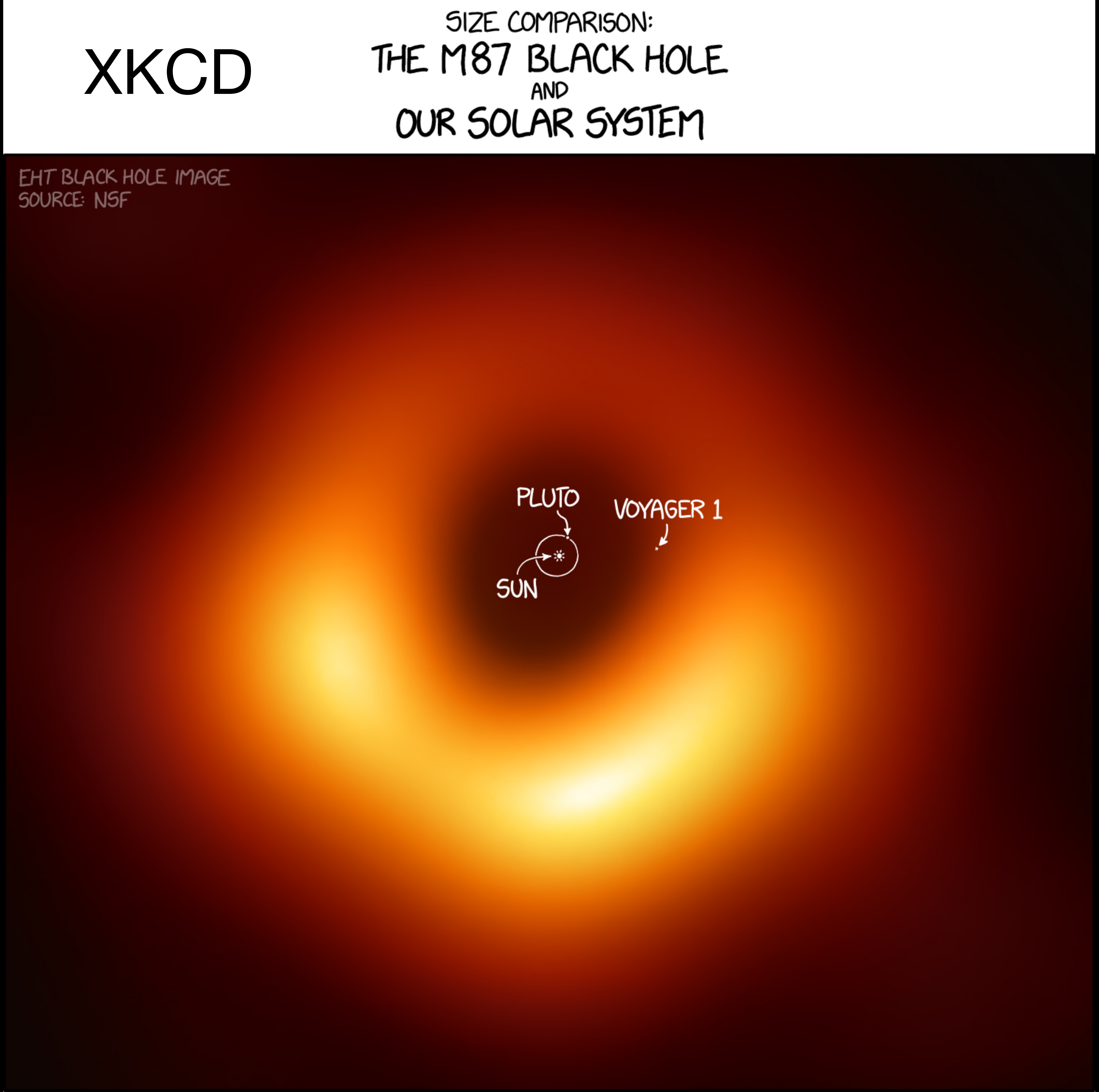
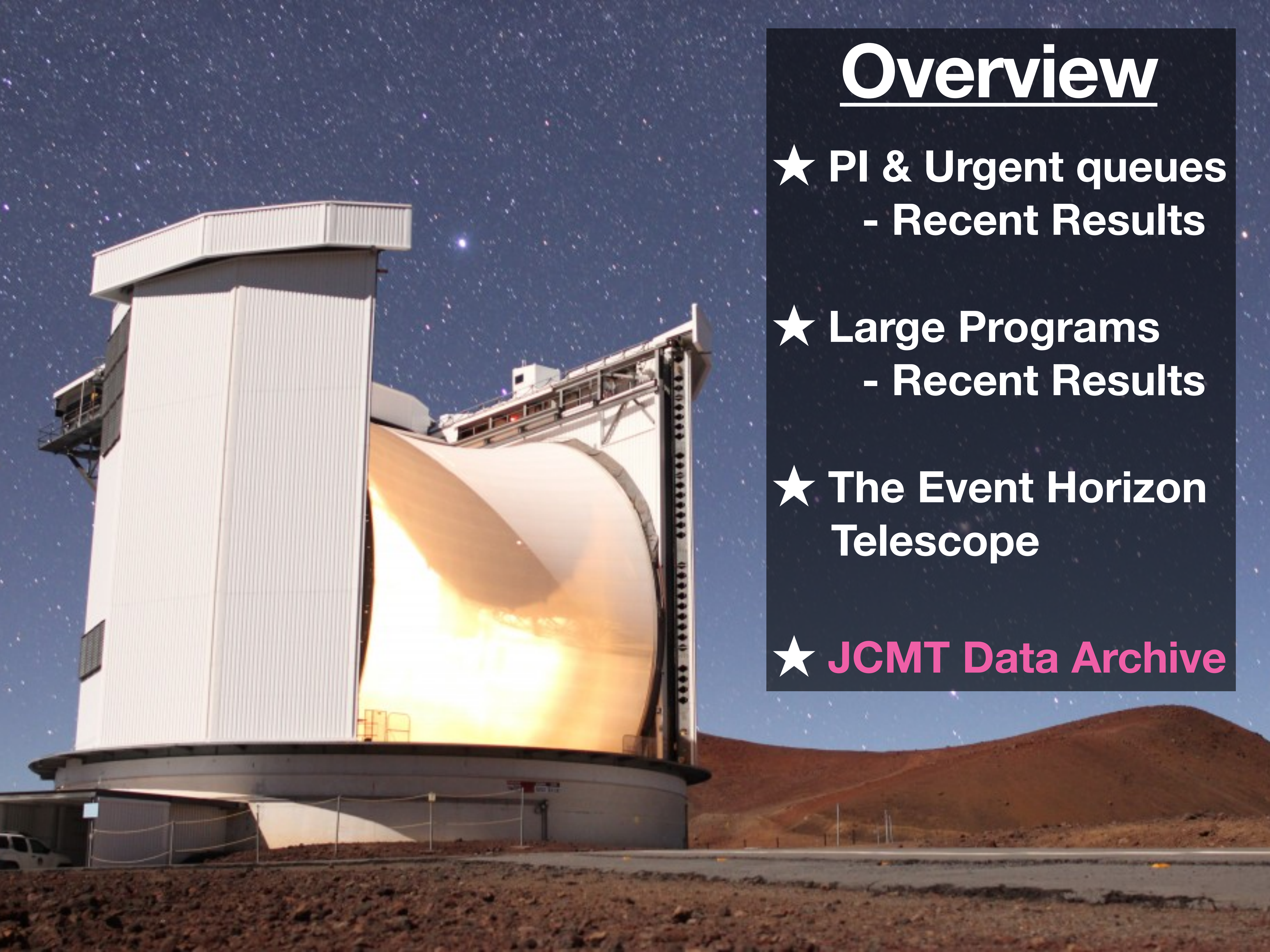


Image of the far side of the disk
Material moving toward us
Photon Ring
Image of disk’s underside



XKCD


SIZE COMPARISON:
THE M87 BLACK HOLE
AND
OUR SOLAR SYSTEM
EHT BLACK HOLE IMAGE
SOURCE: NSF
PLUTO
VOYAGER 1
SUN

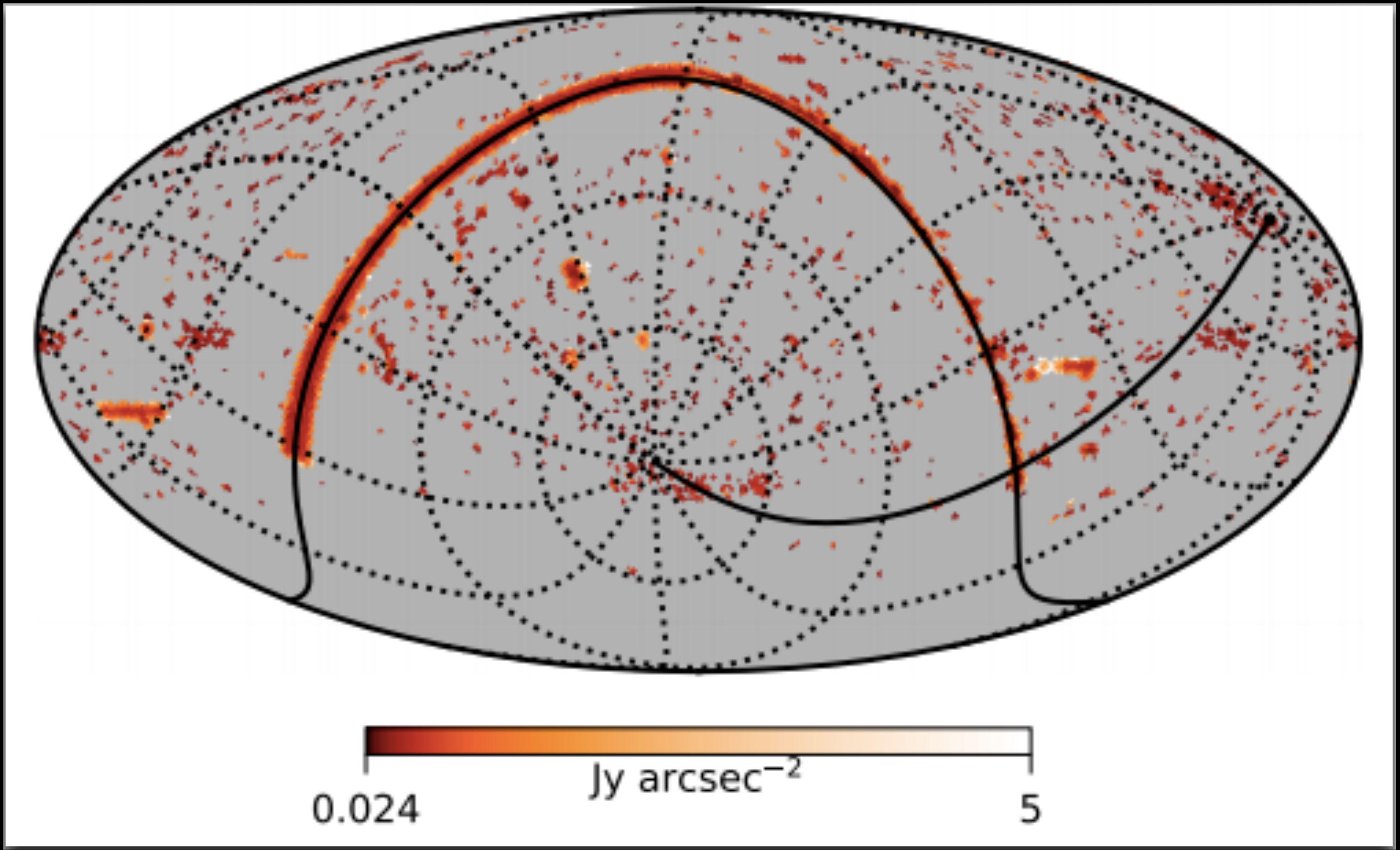

Overview
★ PI & Urgent queues
- Recent Results
★ Large Programs
- Recent Results
★ The Event Horizon Telescope
★ JCMT Data Archive

Data Archive Power

THE JCMT LEGACY RELEASE 2: SCUBA-2 850μm CO-ADDS AND CATALOGS

Sarah F. Graves[1,2], Graham S. Bell[1], David S. Berry[1], Iain M. Coulson[1], Malcolm J. Currie[3,7], Jessica T. Dempsey[1], Per Friberg[1], Tim Jenness[4], Doug Johnstone[5,6,7], Harriet A. L. Parsons[1], Mark G. Rawlings[1], Holly S. Thomas[7], and Jan G. A. Wouterloot[1]

- SCUBA legacy catalogue continues to produce highest number of JCMT papers
- Especially for non-experts, key to high impact is easily accessible, calibrated, trusted data
- New JCMT legacy releases intended to continue this trend

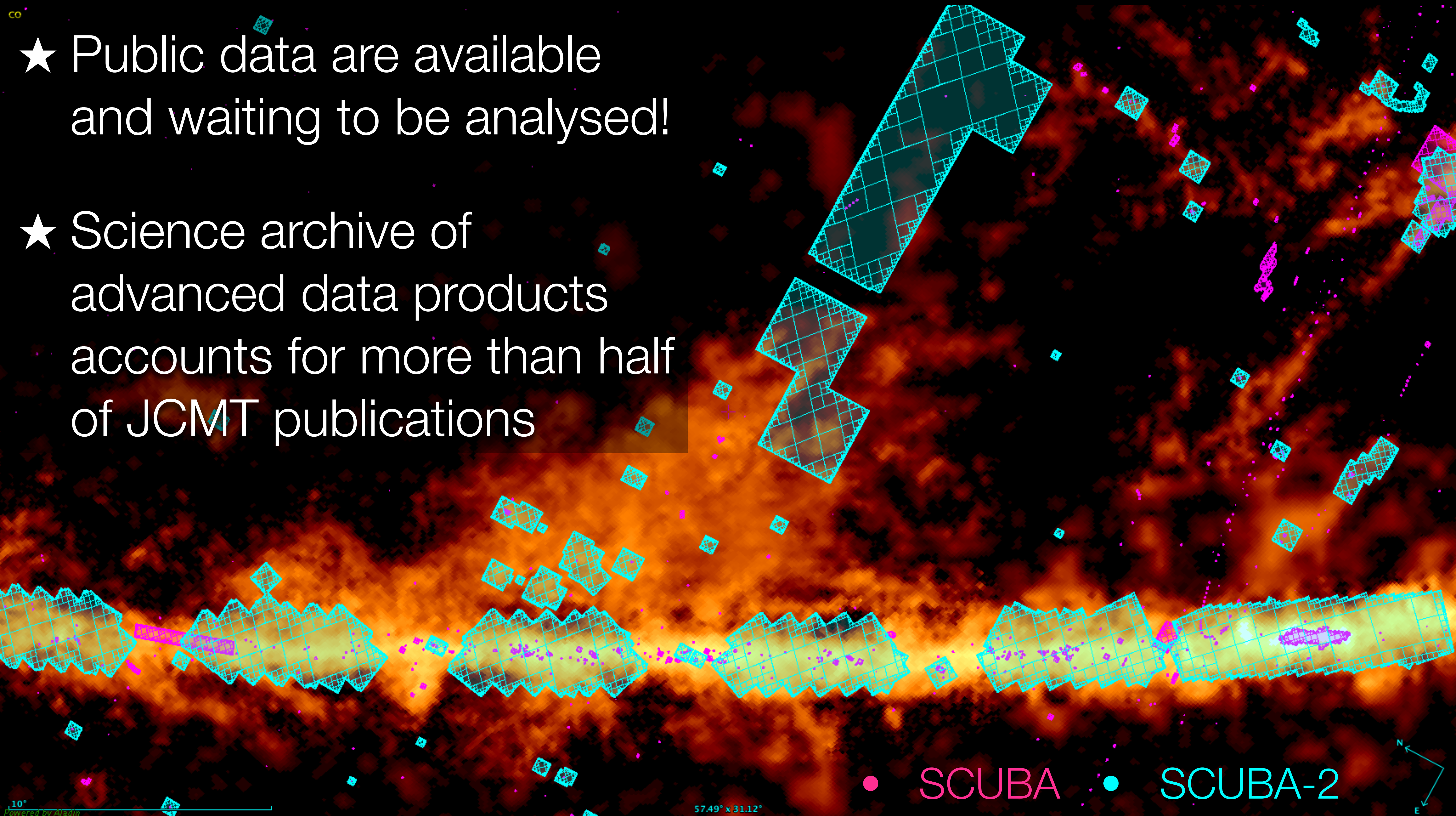


JCMT Science Archive

http://www.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/en/jcmt/

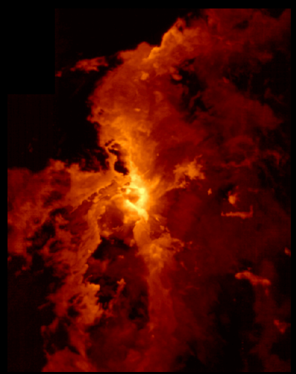
★ Public data are available and waiting to be analysed!

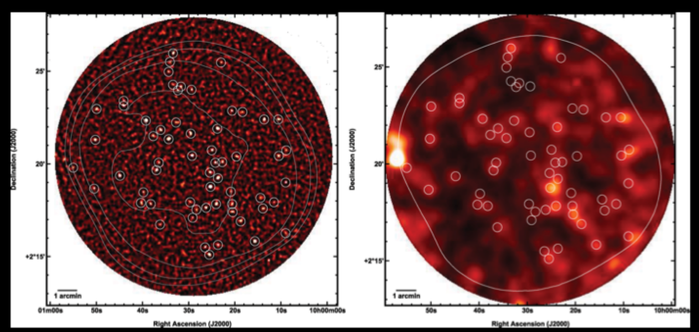
★ Science archive of advanced data products accounts for more than half of JCMT publications



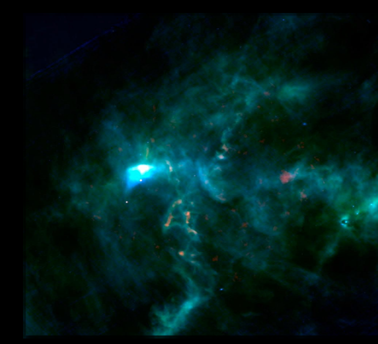
Summary

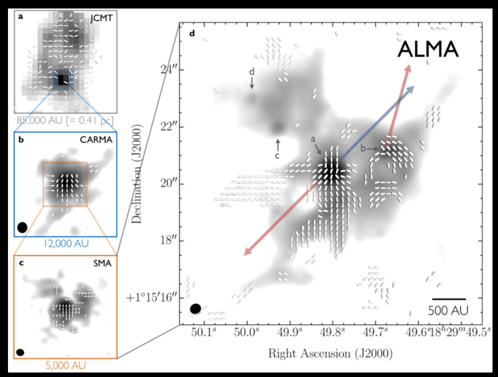
★ JCMT observes gas and dust both near and far!



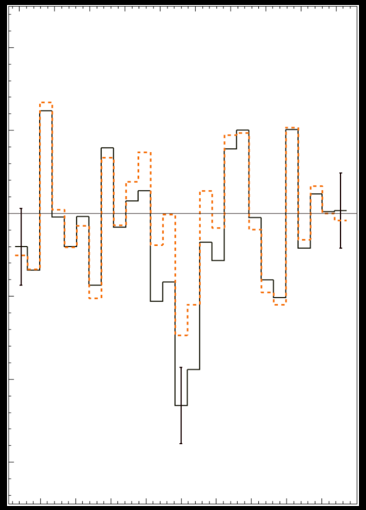


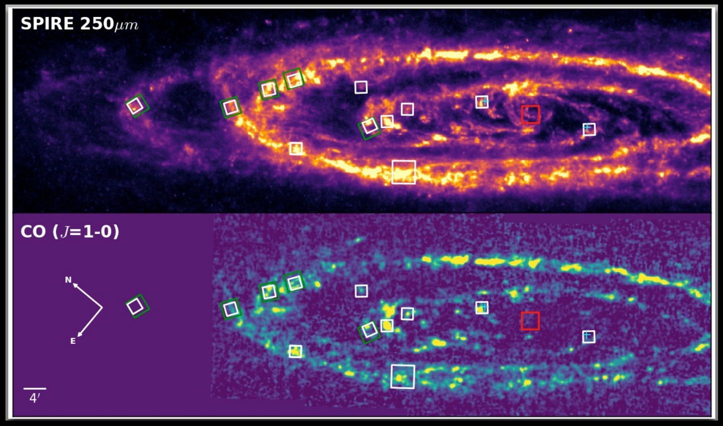
★ Very complementary to satellite/interferometry data



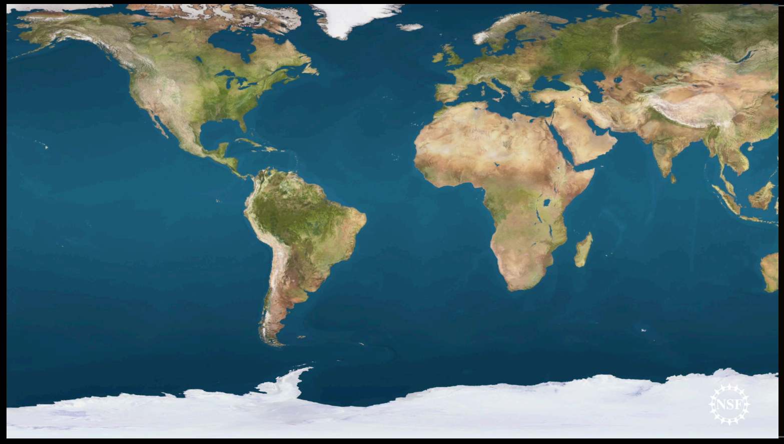


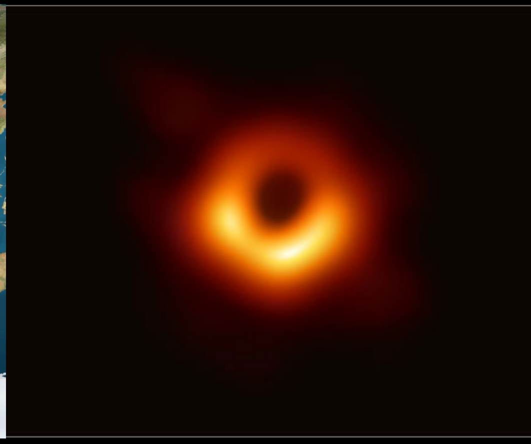
★ 50% PI queue and 50% LAP queue - lots of science!





★ Essential piece of the Event Horizon Telescope - black holes!





★ Public data are available!

http://www.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/en/jcmt/