

Mit Hubble durchs Weltall



Bruno Leibundgut
(ESO und TUM)



Hubble Space Telescope - Geschichte

Frühe Pläne

- Erste Ideen für ein "Large Space Telescope" in 1946
- "Scientific Uses of the Large Space Telescope" erscheint 1969
- Erste Design Arbeiten in 1974
- 1. Oktober 1977
Bewilligung durch US Congress



Image credits: Denise Applewhite/Princeton University

OPTICAL TELESCOPE ASSEMBLY

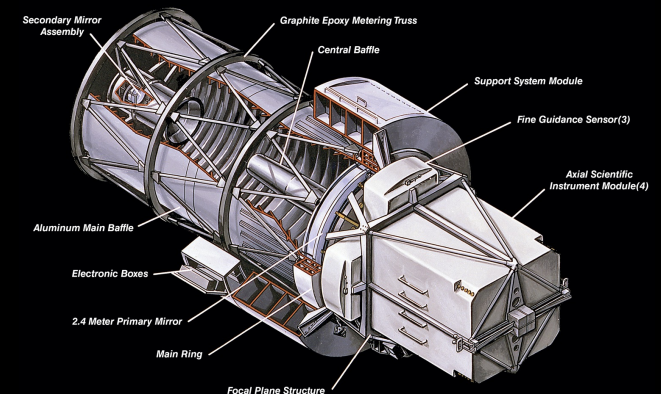


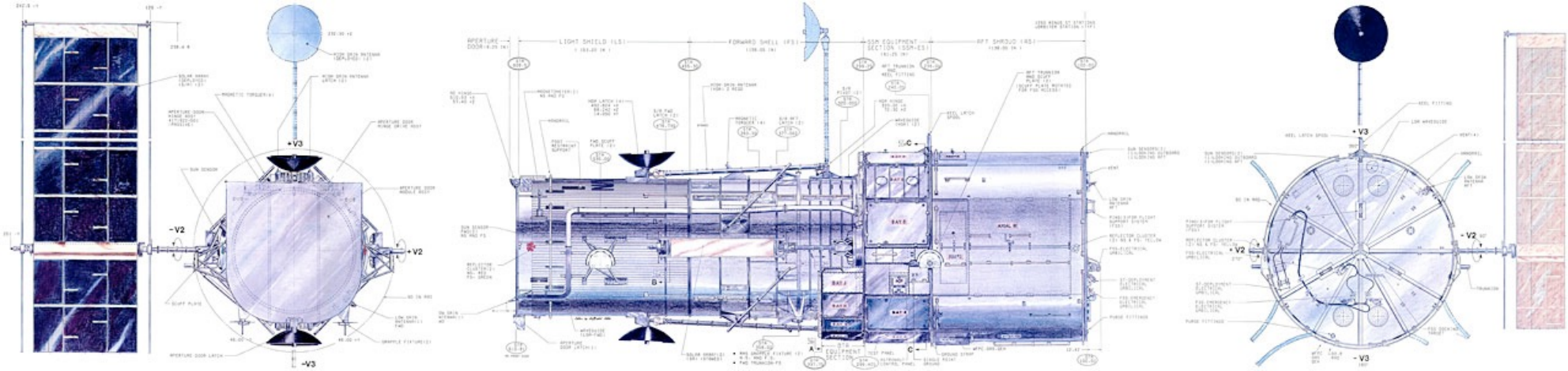
Image credits: NASA/ESA

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Hubble Space Telescope Design

Pläne 1981

Credit: Lockheed Missiles and Space Company (Lockheed Martin).



Hubble Space Telescope - Geschichte

Teleskop Konstruktion

- Dezember 1978 Start der Spiegelproduktion
- Astronauten beginnen mit dem Training in 1979
- Das Teleskop erhält seinen Namen in 1983
- *Challenger* Desaster am 28 Januar 1986

- Start am 24. April 1990



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Image credits: NASA/ESA

Hubble Space Telescope - Geschichte

Früher Betrieb (1990 – 2000)



Hubble Launched

1990



Hubble Deployed



Spherical Aberration Discovered



First Science Paper Submitted



Galaxy Distance Refined Using Supernova

1991



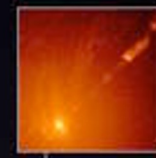
Black Hole Disk Discovered

1992



Servicing Mission 1 Conducted

1993



Supermassive Black Holes Verified

1994



Comet Impact on Jupiter Observed



Star Birth Imaged

1995

Hubble Fakten

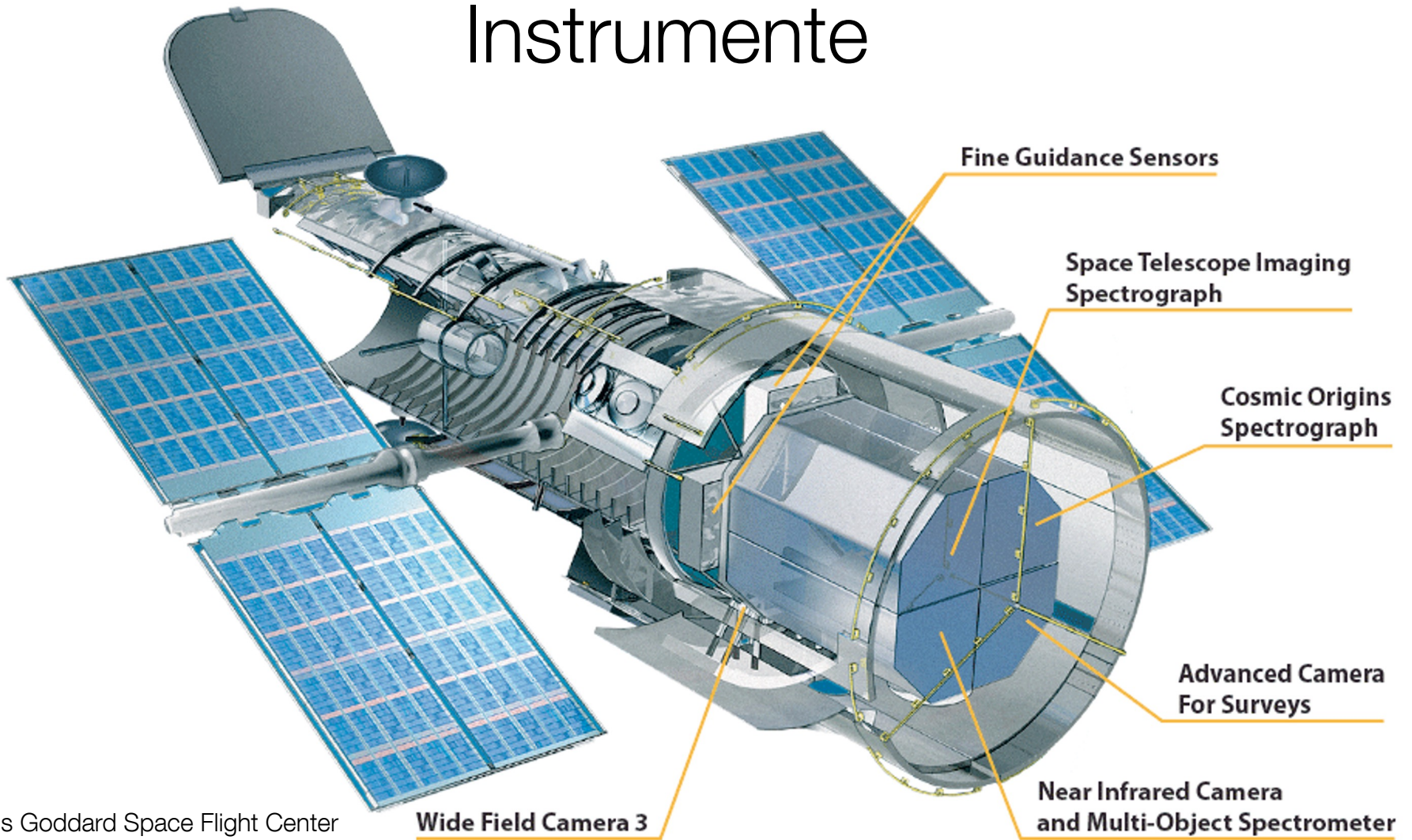
- Länge: 13.3m, Durchmesser: 4.3m
- Umlaufbahn: 535km
- Umlaufzeit: 95 Minuten
- Geschwindigkeit: ca. 27000 km/h
- Gewicht: ca. 12000 kg
- Kosten (insgesamt seit 1977): 16 Mia US\$ (2021)
- Mehr als 19000 wissenschaftliche Publikationen

Credits: NASA

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Instrumente



Credits: NASA's Goddard Space Flight Center

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Servicing Missions

- Servicing Mission 1 (STS-61): Dezember 1993
 - COSTAR, WFPC2, Solar Arrays (**HSP**, **WFPC**)
- Servicing Mission 2 (STS-82): Februar 1997
 - STIS, NICMOS (**FOS**, **GHR**)
- Servicing Mission 3A (STS-103): Dezember 1999
 - Gyroskope, Fine Guidance Sensor
- Servicing Mission 3B (STS-109): Februar 2002
 - ACS (**FOC**)
- Servicing Mission 4 (STS-125): Mai 2009
 - COS, WFC3, ACS and STIS repariert (**COSTAR**)

Bildqualität

M100
Hubble Space Telescope

WFPC1 (1993)

WFPC2 (1994)

WFC3 (2018)

Credit: NASA, ESA, STScI and Judy Schmidt

Woher der Name?



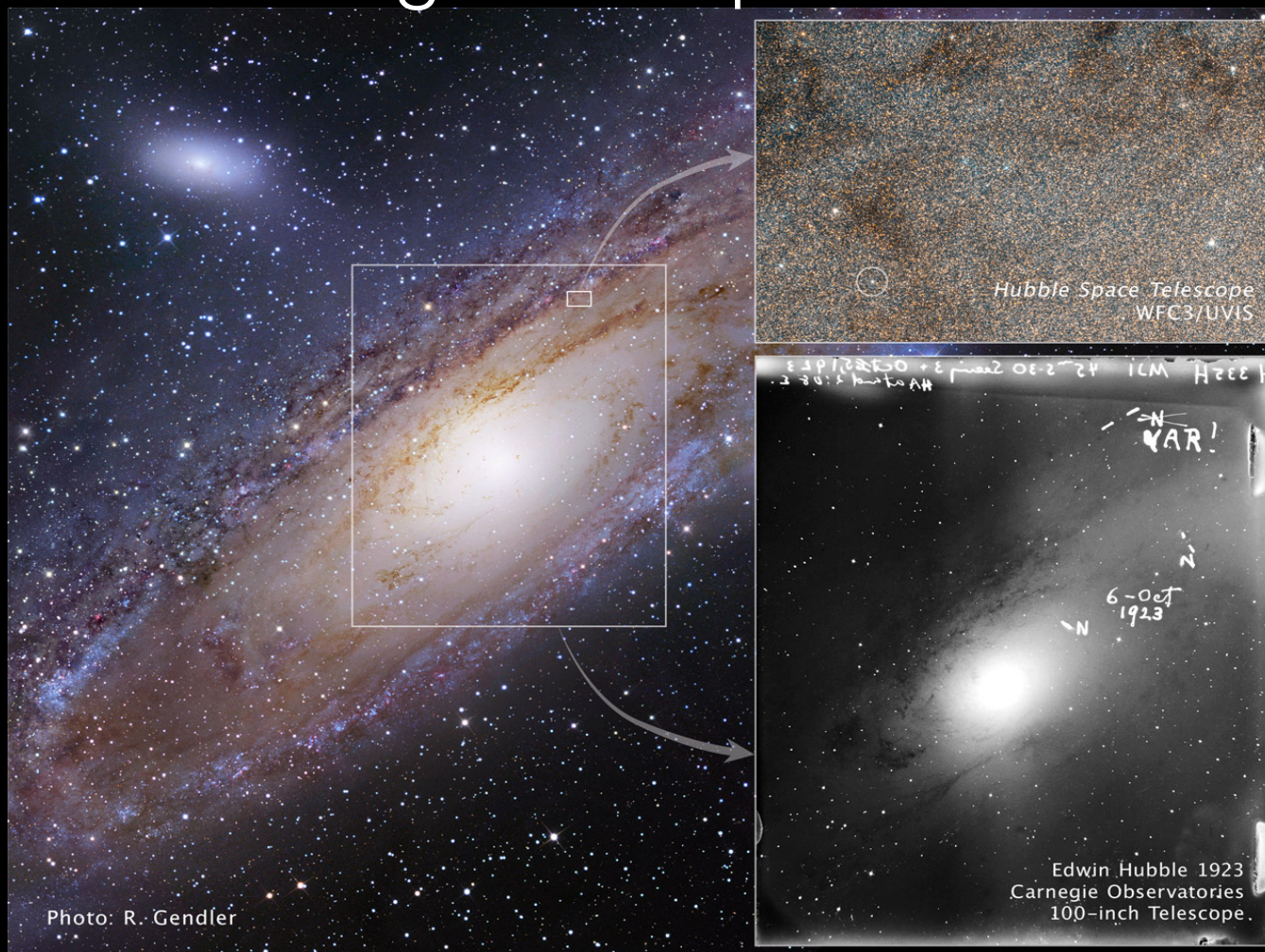
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Image credits: NASA/ESA

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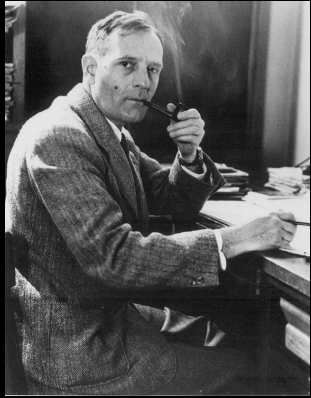


Entdeckung von Cepheiden in Andromeda

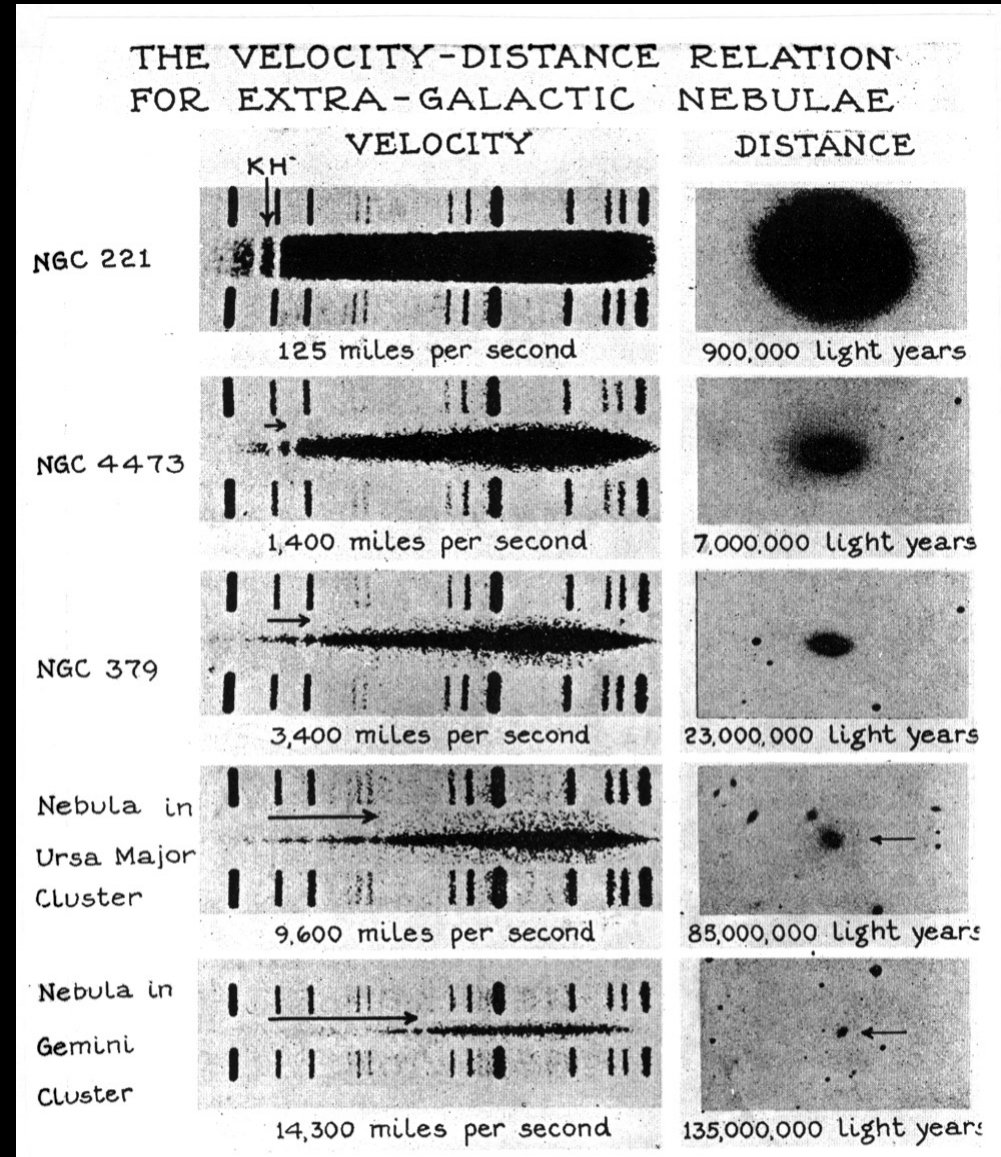


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Die Expansion des Universums



Hubble/Humason 1936

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Das expandierende Universum

Hubbles Hubble-Lemaître Diagramm

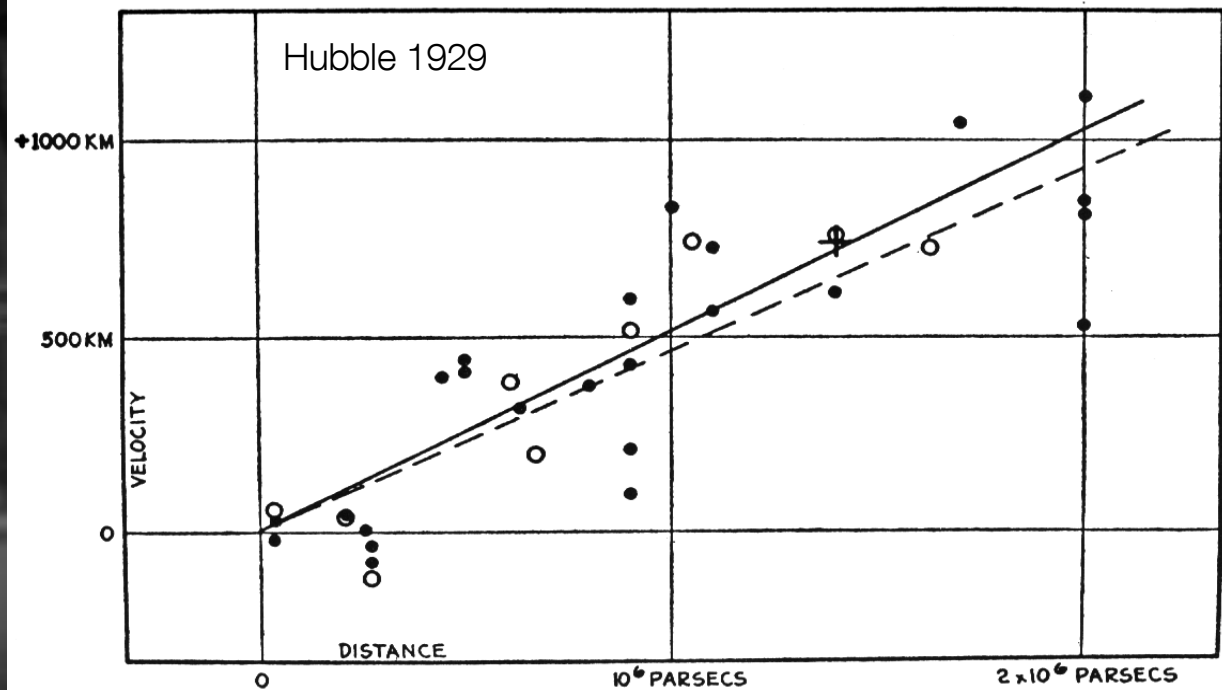


FIG. 9. *The Formulation of the Velocity-Distance Relation.*

Wo ist Hubble?

Satellite Tracker



direction indicated by **Approach**. You should see a slowly moving "star" (weather permitting). The **Departure** entries indicate where the spacecraft will be when it vanishes from sight. Sometimes an appearance or disappearance occurs well up in the sky when the satellite emerges into sunlight or slips into Earth's shadow, respectively.

Hubble Key Projects

- Intergalaktisches Medium und Gas zwischen den Galaxien
 - UV Beobachtungen von Quasar Spektren
- Medium-deep Survey
 - Bilder von verschiedenen Himmelsregionen
- Messung der Hubble Konstante
 - Angepeilte Ungenauigkeit besser als 10%



Gruber Cosmology Prize

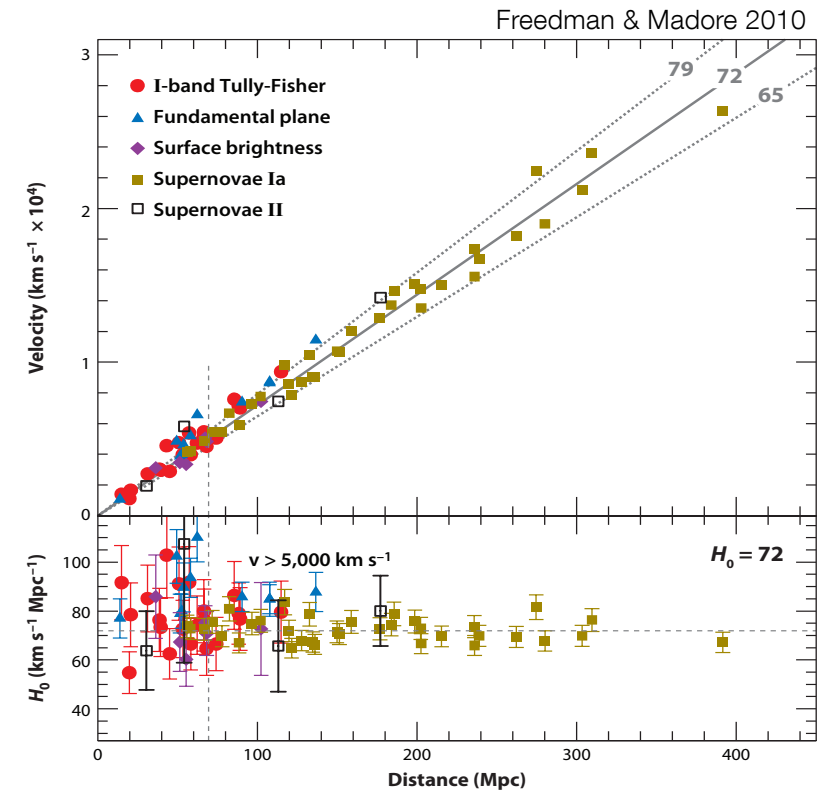
Jeremy Mould
Wendy Freedman
Robert Kennicutt



Hubble Key Project

Bestimmung von verschiedenen
Eichungen in der
Entfernungsleiter

- Galaxien
- Supernovae



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Hubble Resultate



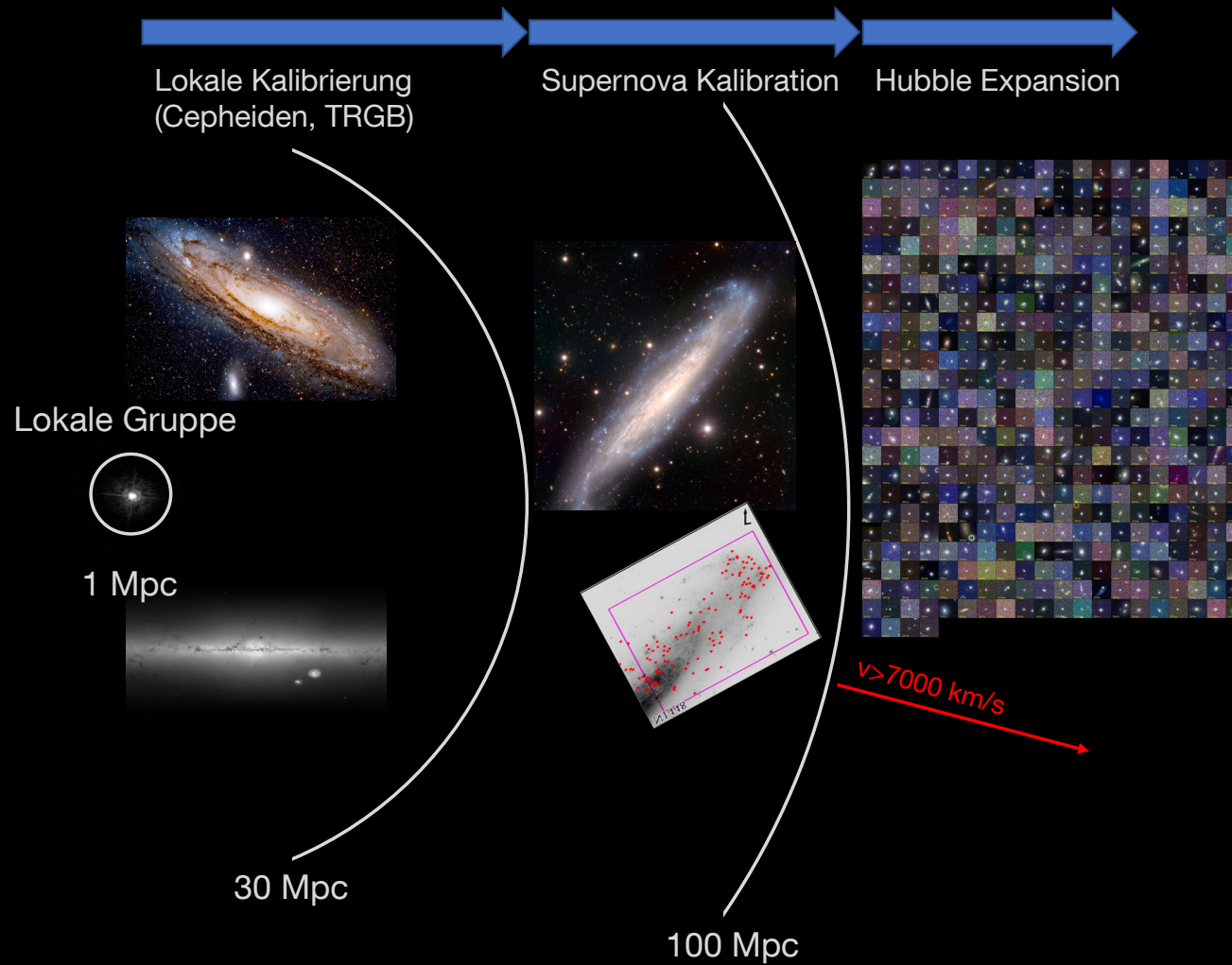
- Hubble Konstante
- Beschleunigte Expansion des Universums
- Galaxienentstehung und -entwicklung/Deep Fields
- Dunkle Materie
- Sonnensystem
- Exoplaneten
- Explodierende Sterne

NASA, ESA, Adam G. Riess (STScI, JHU)

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Die Cepheiden und Supernova Distanzleiter



Cepheiden Sterne

Henrietta Leavitt entdeckt eine Leuchtkraft-Perioden Relation



Wikipedia

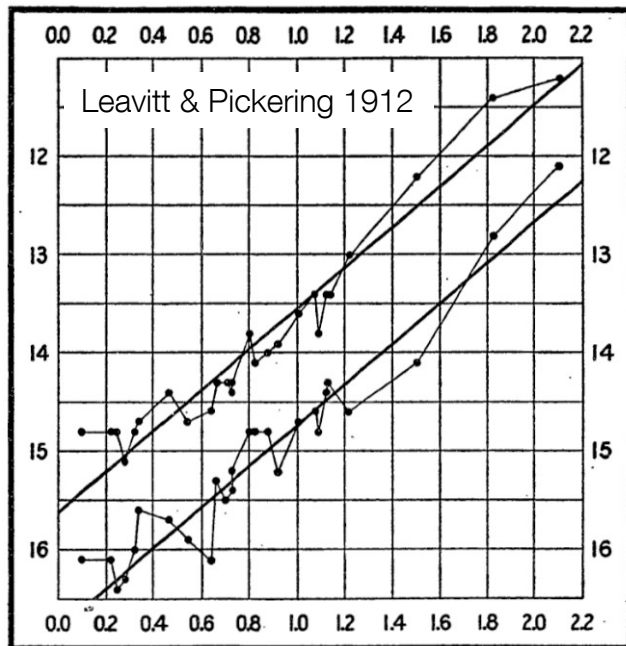
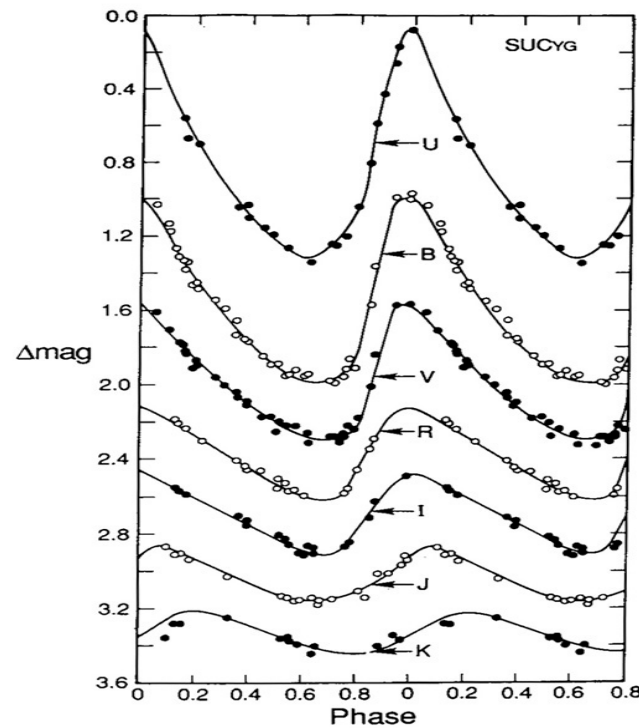


FIG. 2.



Madore & Freedman (1991)

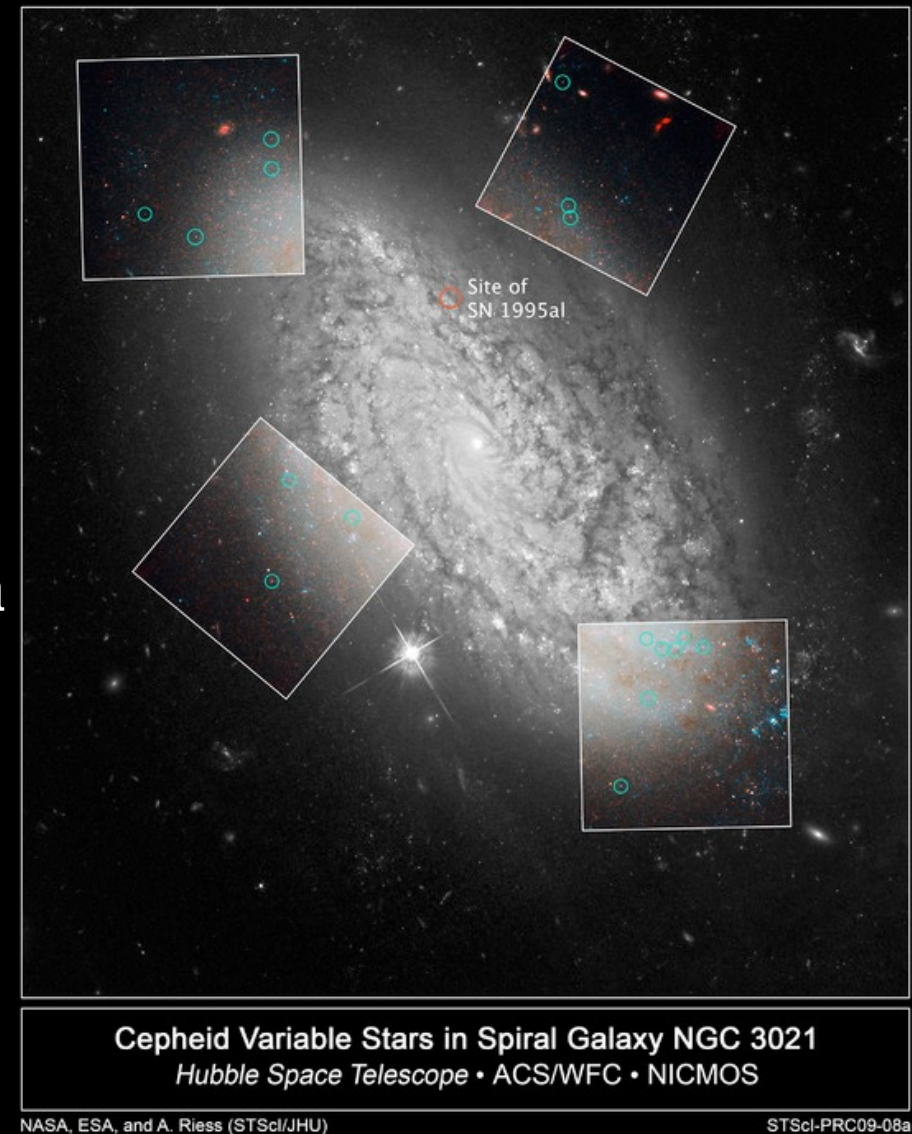


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Cepheiden Sterne

Mehrfache Beobachtung einer Galaxie

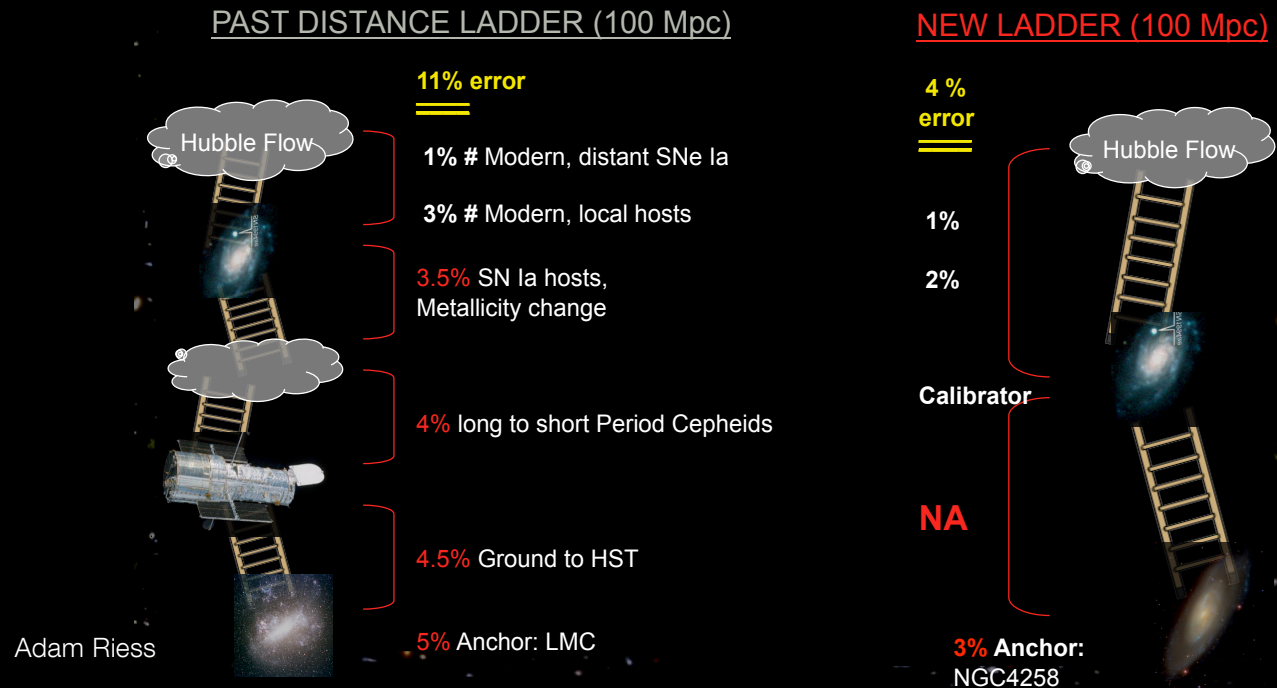
- Cepheiden Lichtkurven
- Entfernung zur Galaxie/Supernova
- Kalibration der Supernova Leuchtkraft





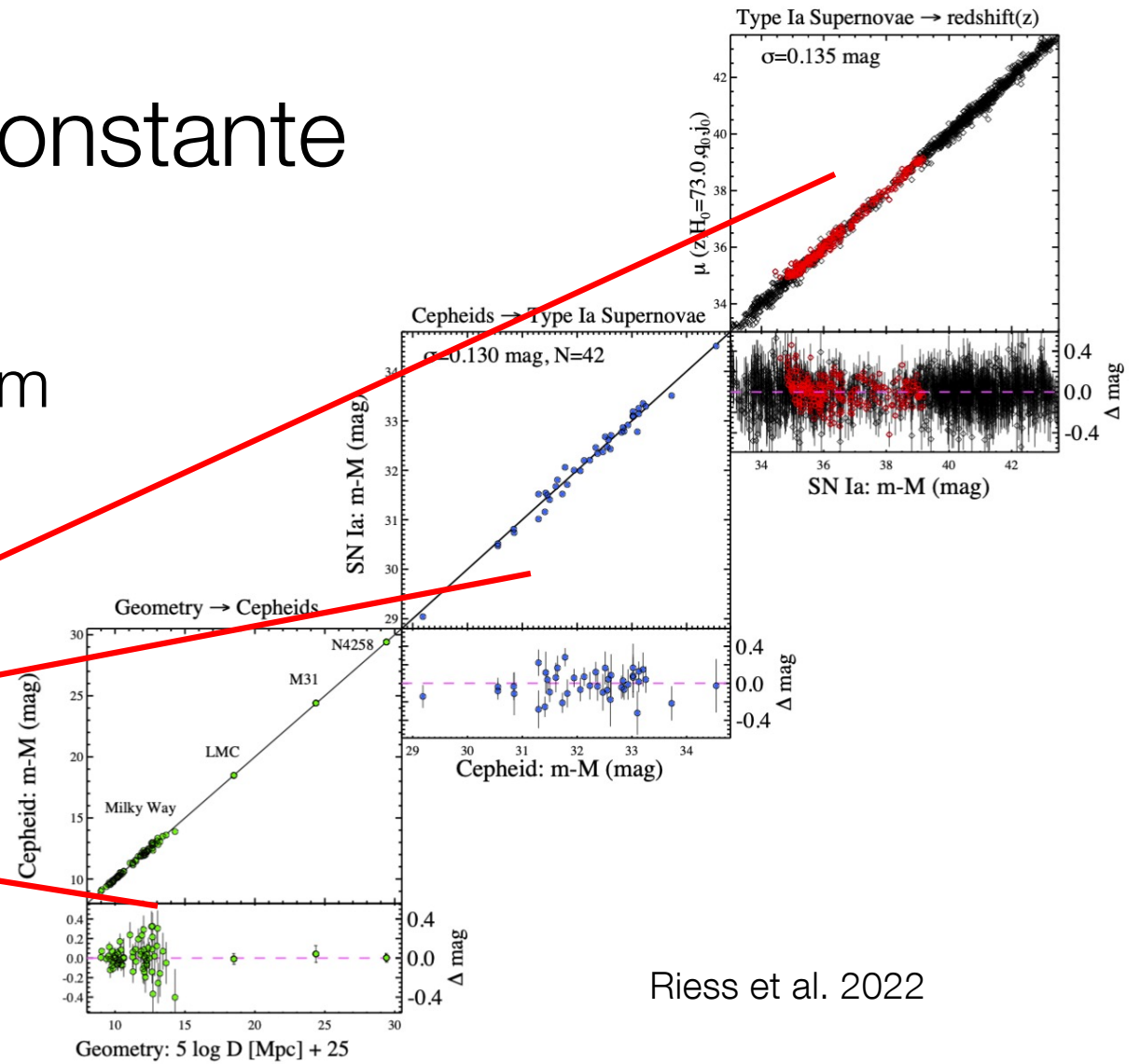
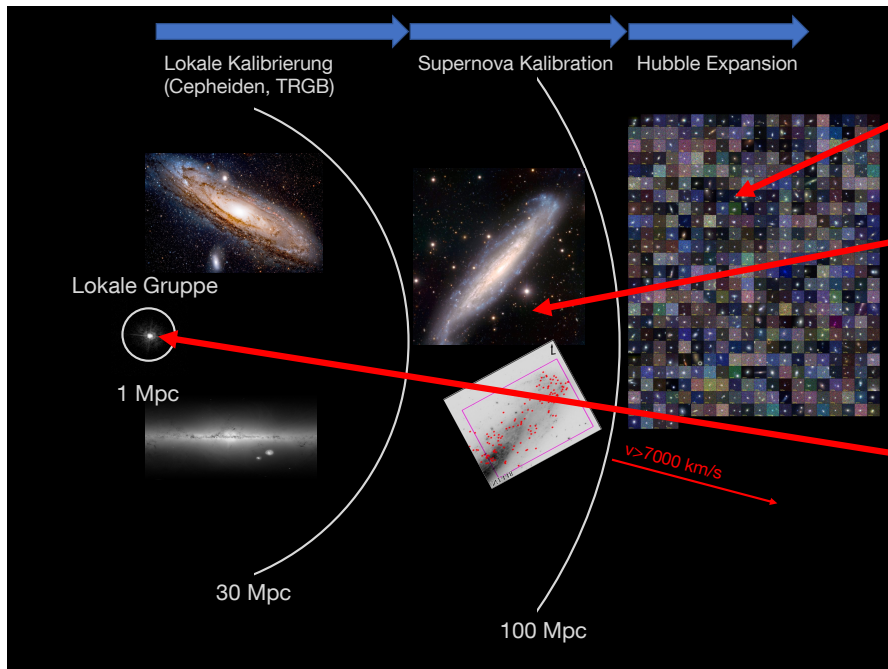
Die Hubble Konstante (Entfernungsleiter)

Eichung der Leuchtkraft von Typ Ia Supernovae am Maximum (*SN Ia @ max*)



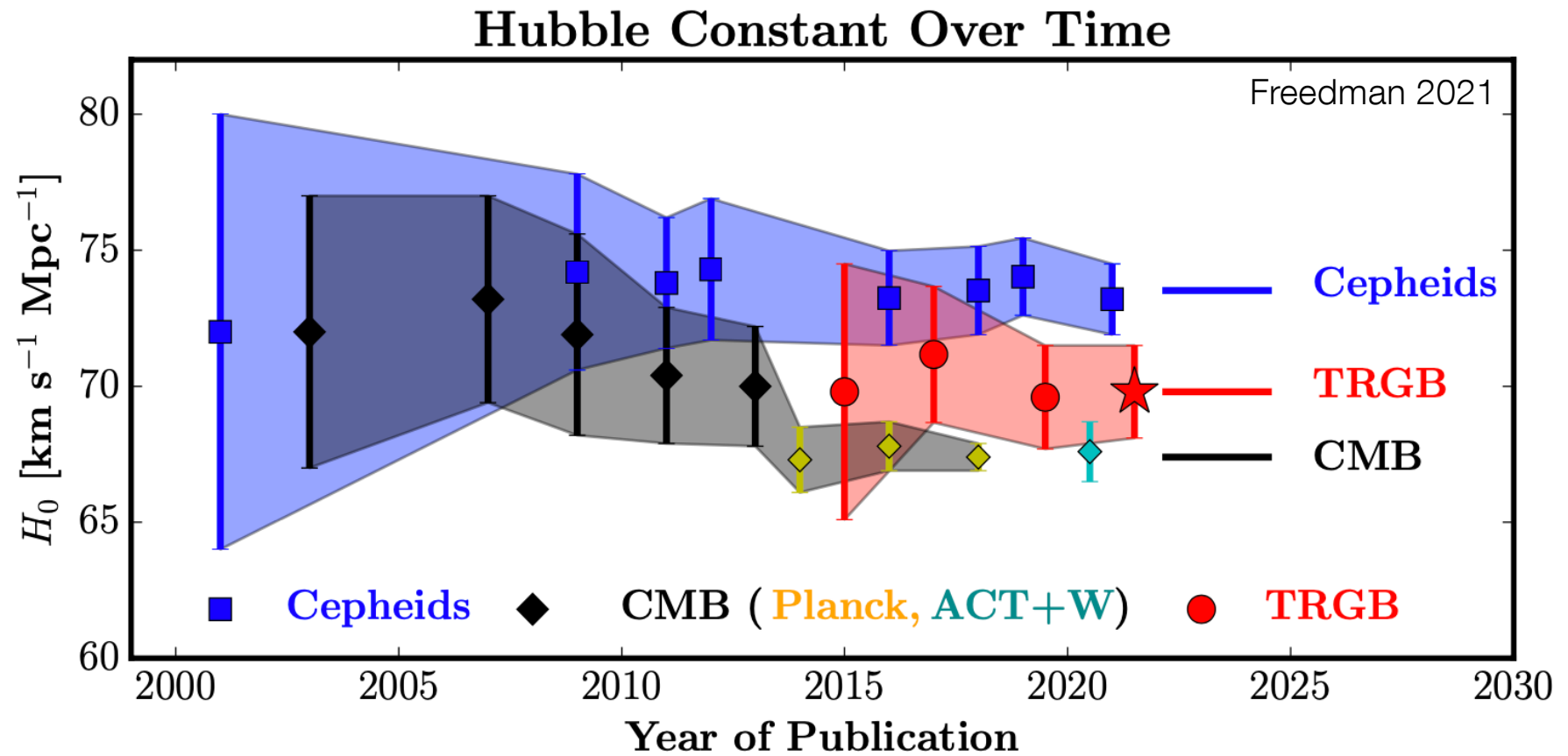
Hubble Konstante

Supernova Ia Hubble-Lemaître diagram



Riess et al. 2022

Ist unser kosmologisches Modell verstanden?

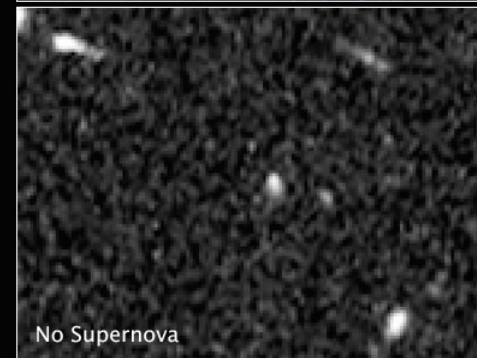
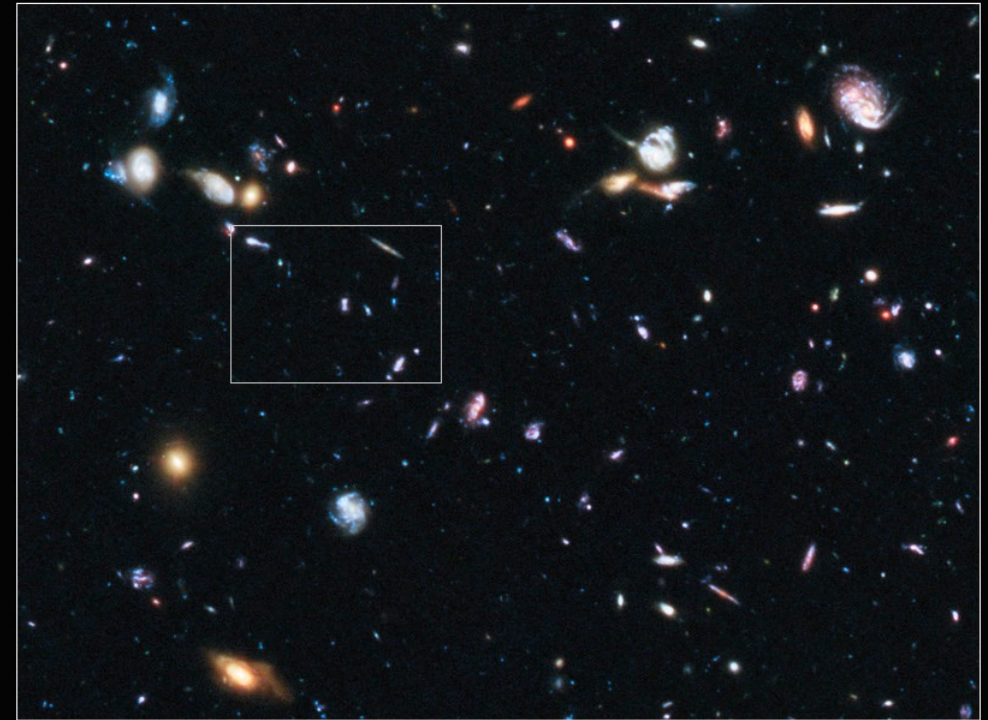


Beschleunigte Expansion

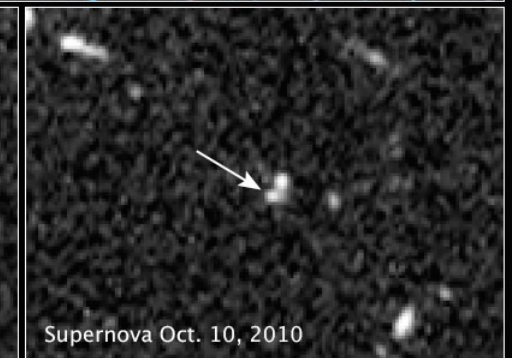
- Entfernte Supernovae erscheinen schwächer als in einem ungebremsten Universum
 - Zusätzliche Komponente in den kosmologischen Modellen benötigt → Dunkle Energie
- Beitrag zu bodenbezogenen Beobachtungen

Supernova Primo in the Hubble Ultra Deep Field

Hubble Space Telescope ■ WFC3 ACS



No Supernova



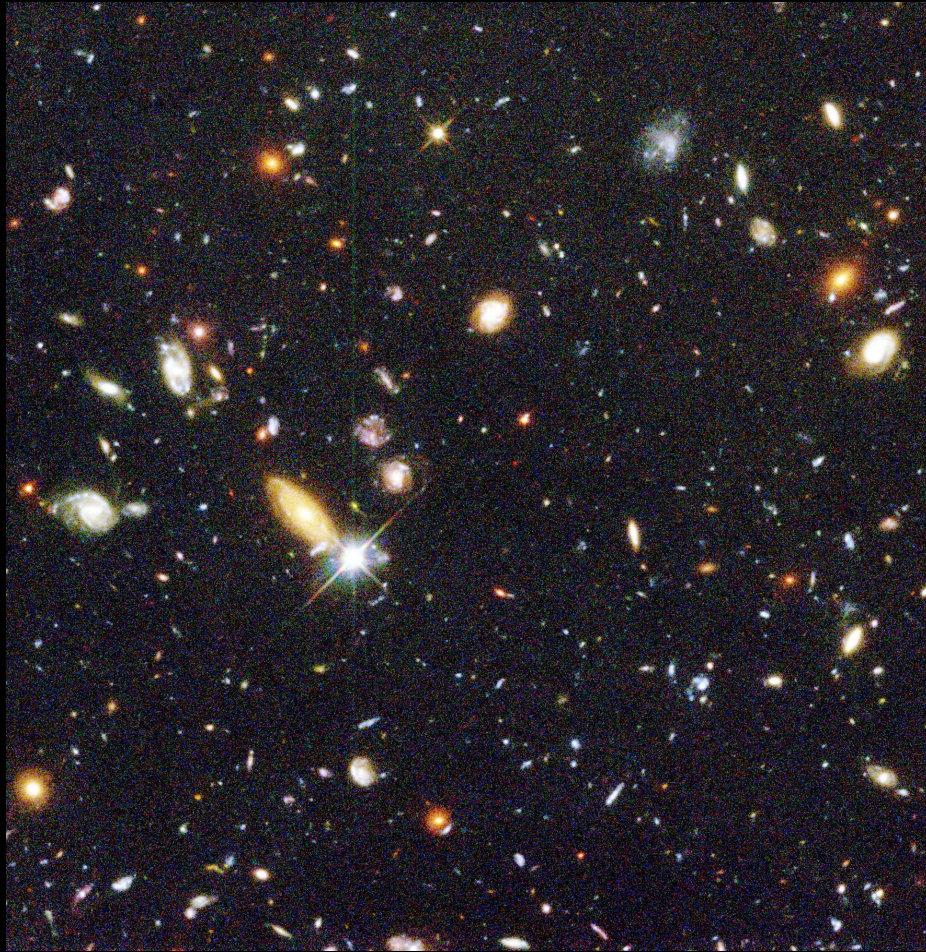
Supernova Oct. 10, 2010

NASA, ESA, A. Riess (STScI and JHU), and S. Rodney (JHU)

STScI-PRC12-05a

Tiefste Bilder des Universums

1996



2004



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Credit: NASA/JPL/STScI Hubble Deep Field Team

Credits: NASA

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Tiefste Bilder des Universums

2012

2022



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Credits: NASA



Credit: NASA, ESA, CSA, and STScI

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Hubble Probes the Early Universe



1990



Ground-based observatories



1995



Hubble Deep Field



2004



Hubble Ultra Deep Field



2010



Hubble Ultra Deep Field-IR



FUTURE



James Webb Space Telescope

Redshift (z):

Time after the Big Bang

Present	1	4	5	6	7	8	10	>20
	6 billion years	1.5 billion years			800 million years		480 million years	200 million years

Credits: NASA

Dunkle Materie



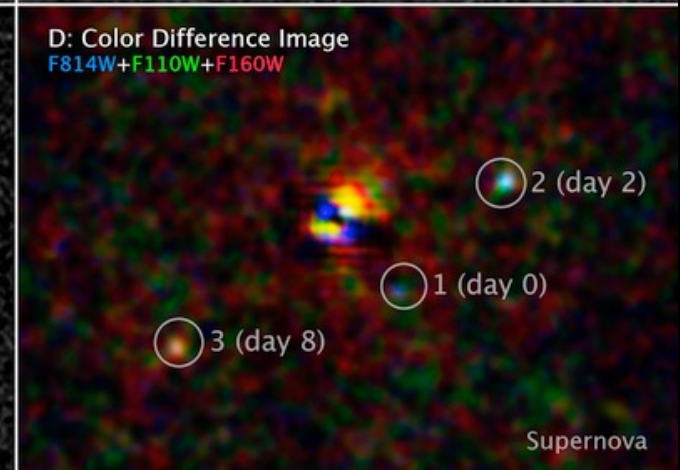
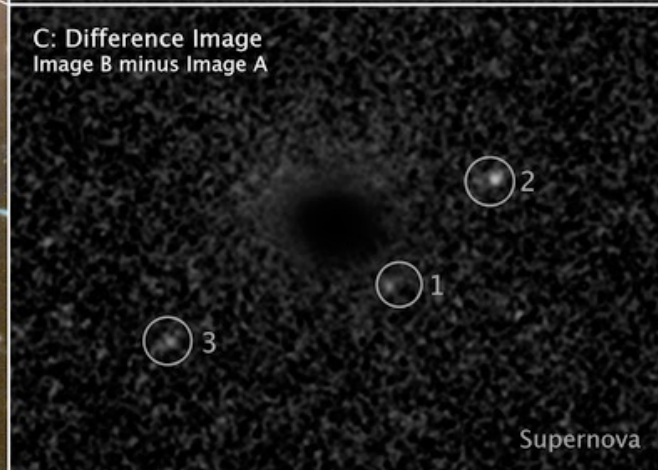
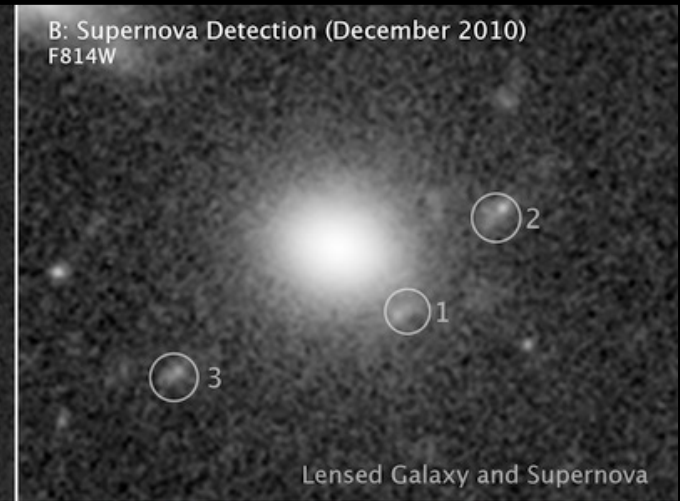
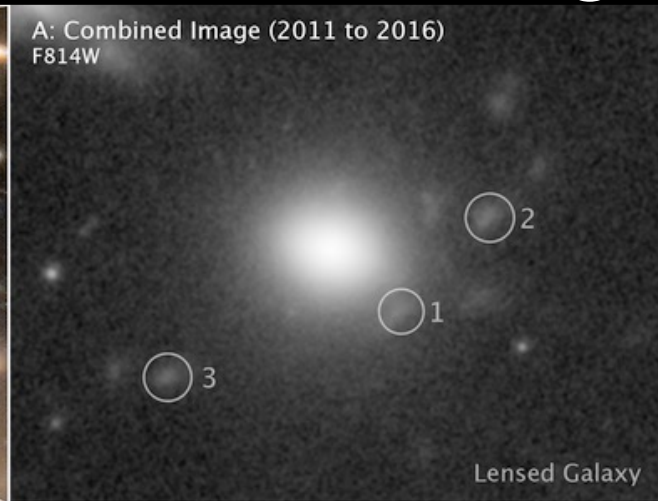
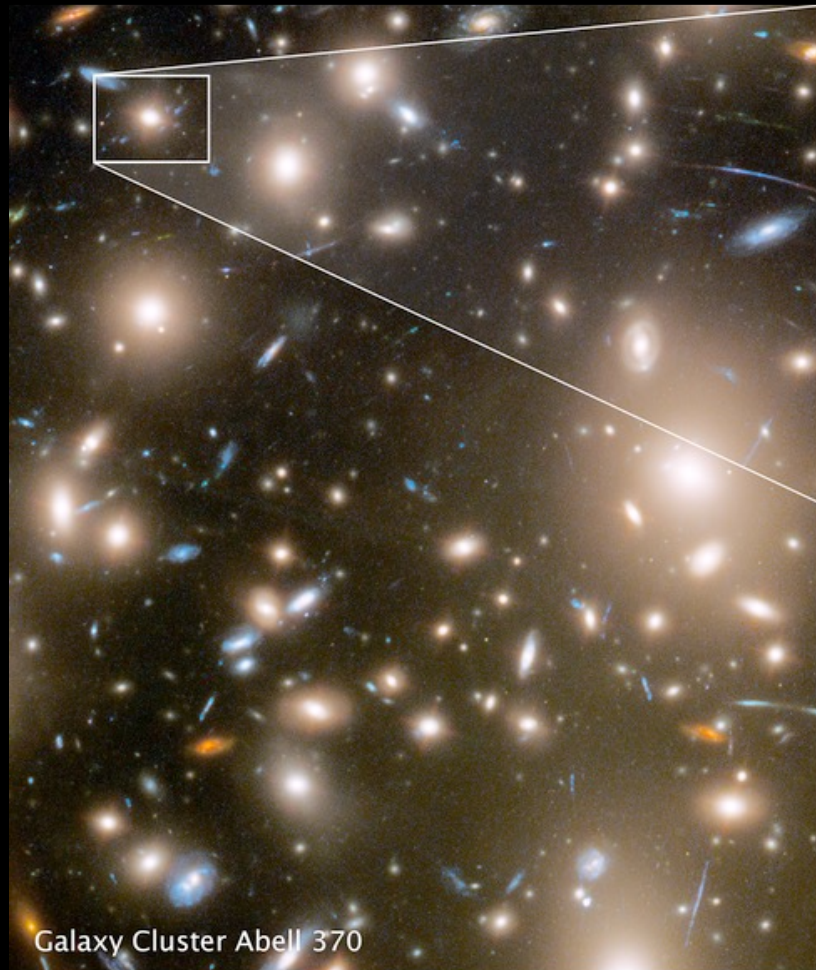
Gravitationslinsen

Credit: NASA, ESA, and Johan
Richard (Caltech, USA)

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Mehrfach Sichtungen

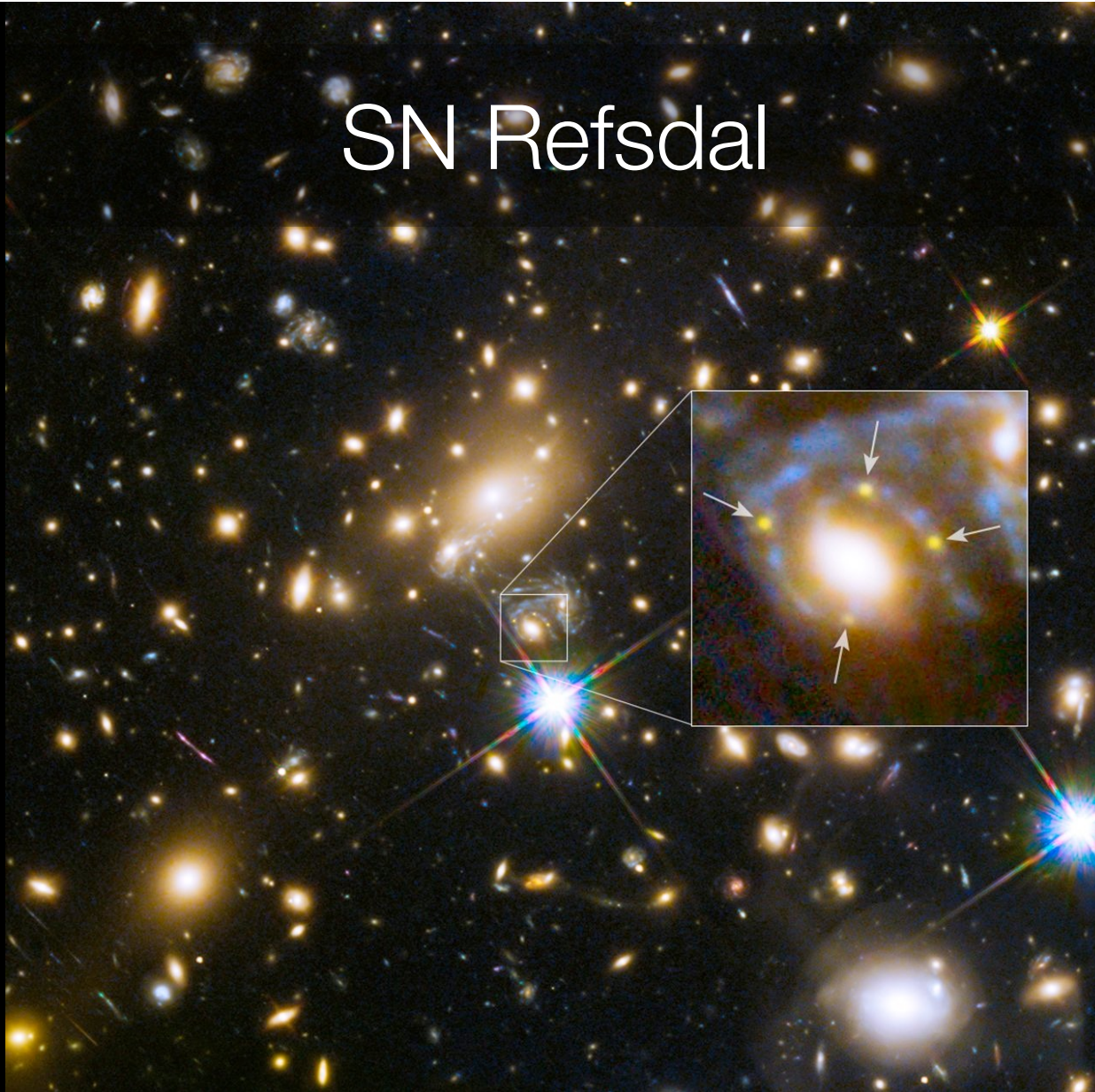


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Credits: NASA, ESA, STScI, Wenlei Chen (UMN), Patrick Kelly (UMN), Hubble Frontier Fields

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SN Refsdal

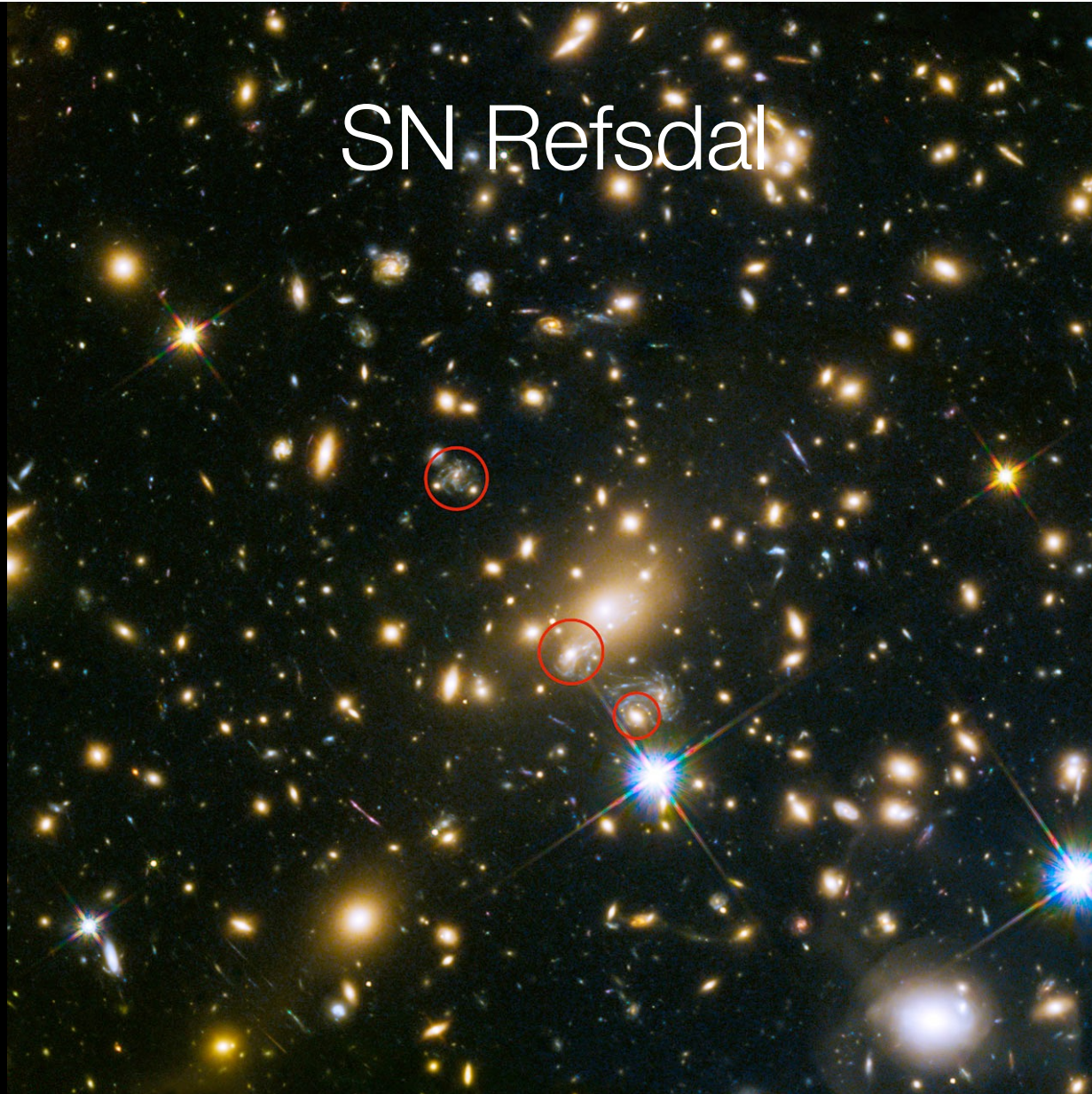


Credit: [NASA](#), [ESA](#), S. Rodney
(John Hopkins University, USA)
and the FrontierSN team

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SN Refsdal



Credit: [NASA & ESA](#) and
P. Kelly (University of California,
Berkeley)

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SN Refsdal



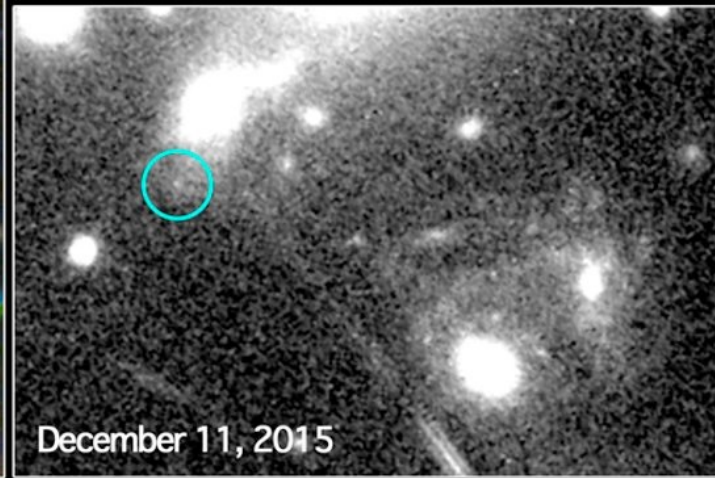
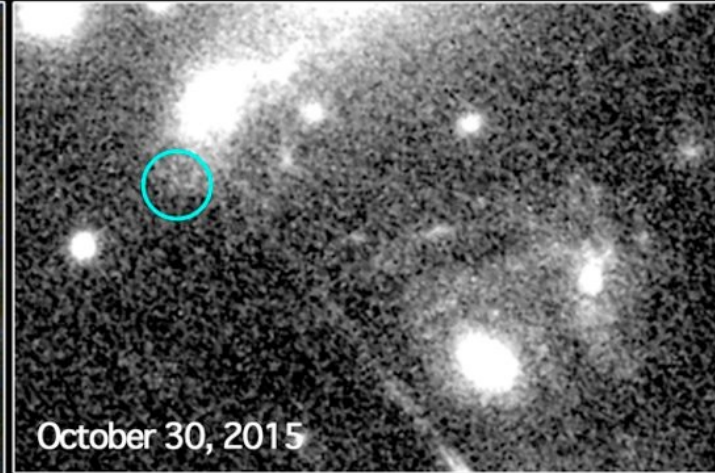
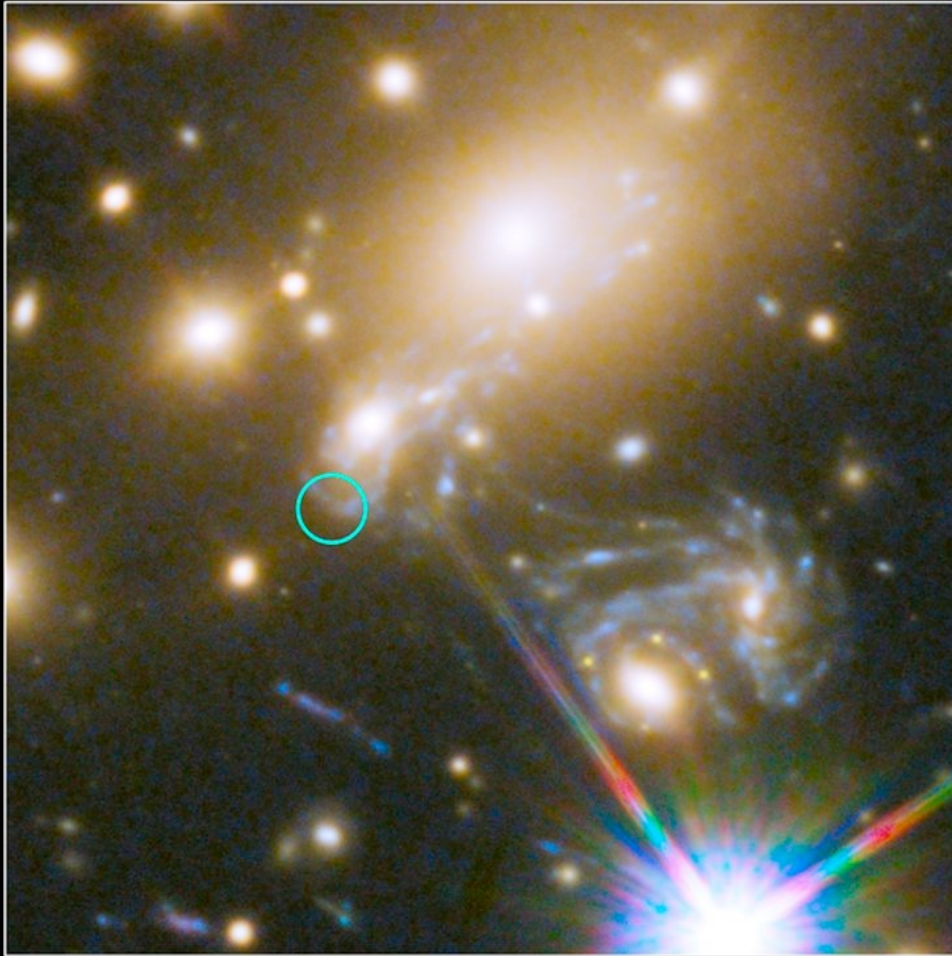
www.spacetelescope.org

Credit: [NASA](#) & [ESA](#)

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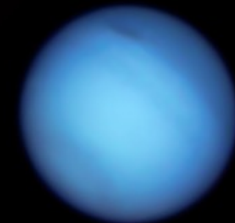
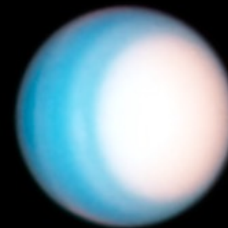
SN Refsdal



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Sonnensystem

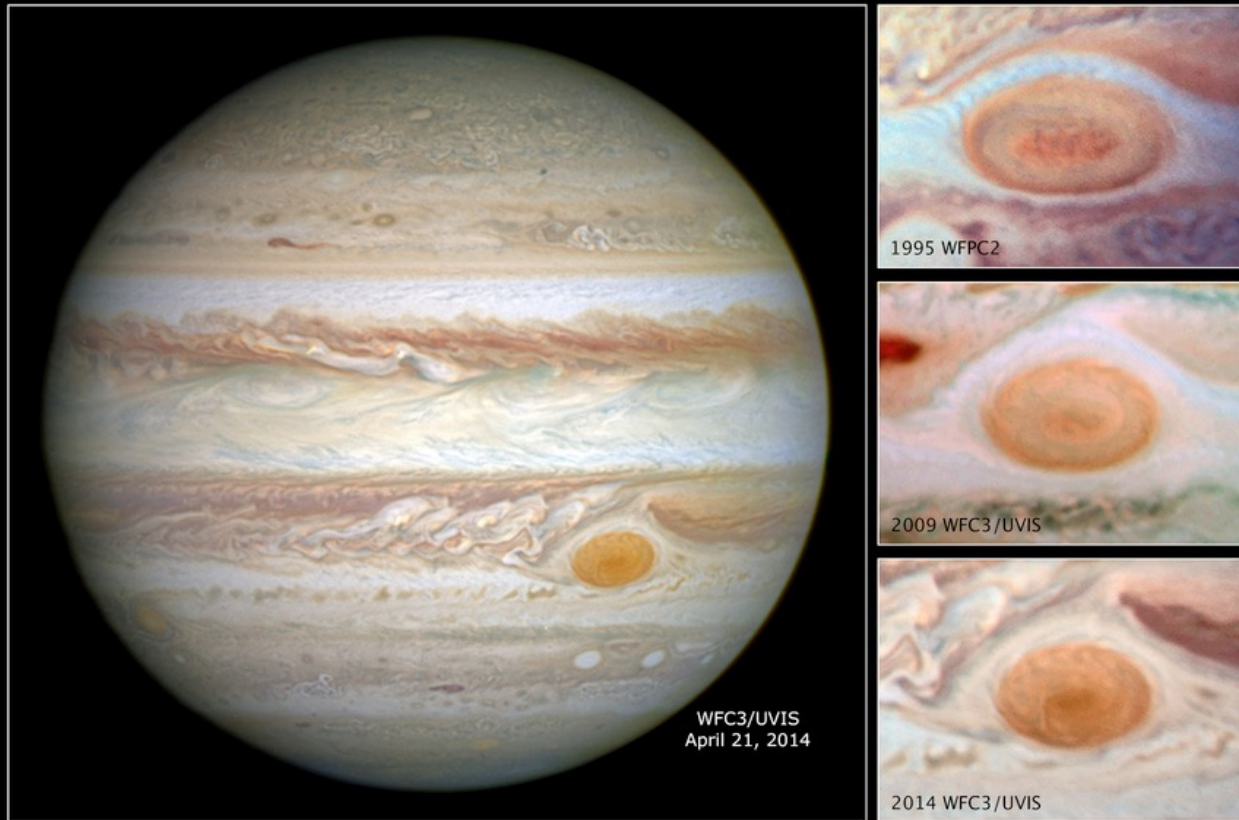


Credits: NASA, ESA, Amy Simon
(NASA-GSFC), Michael H. Wong
(UC Berkeley)

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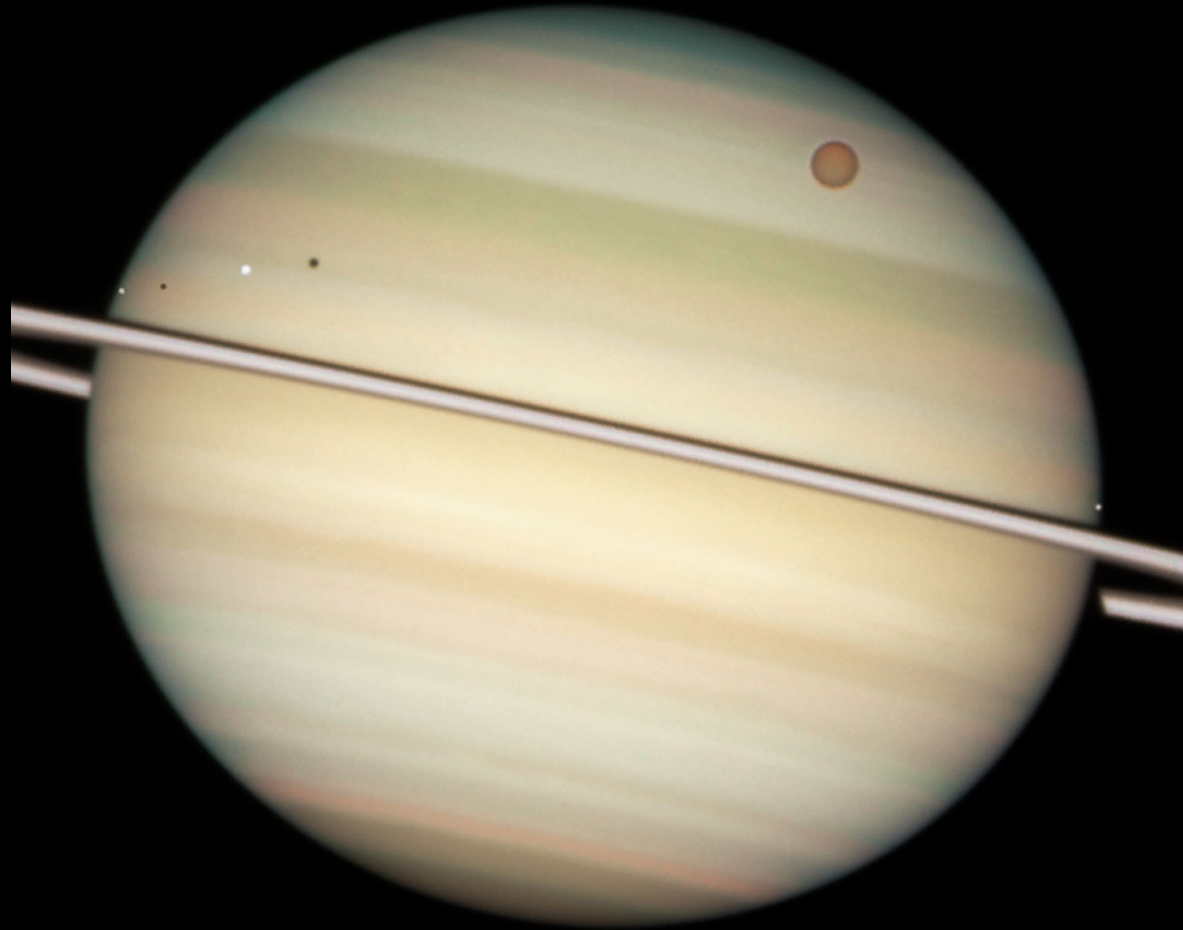
Jupiter



Credit: [NASA](#), [ESA](#), and A. Simon (GSFC)

Jupiter and the Great Red Spot
Hubble Space Telescope WFC3/UVIS WFPC2

Saturn



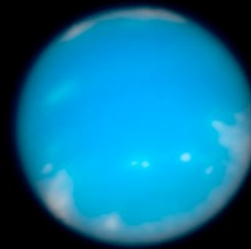
Credit: NASA, ESA and the
Hubble Heritage Team
(STScI/AURA).

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Neptun

Neptune
HST WFC3/UVIS
11656



30,800 mi
49,600 km

F475W *g*
F775W *i*



NASA, ESA, and
M. Showalter (SETI Institute)

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Exoplaneten

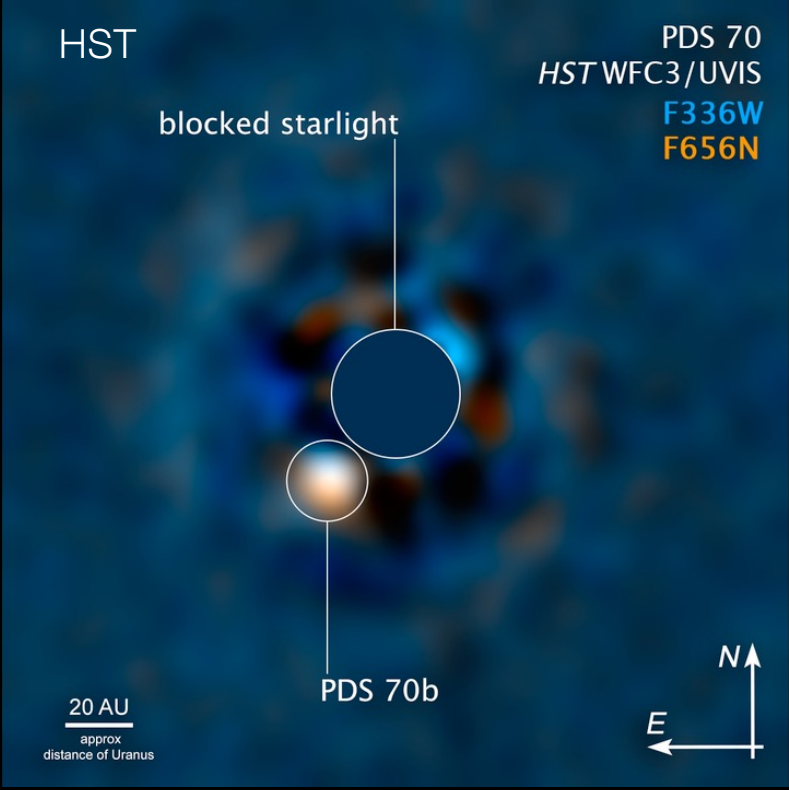
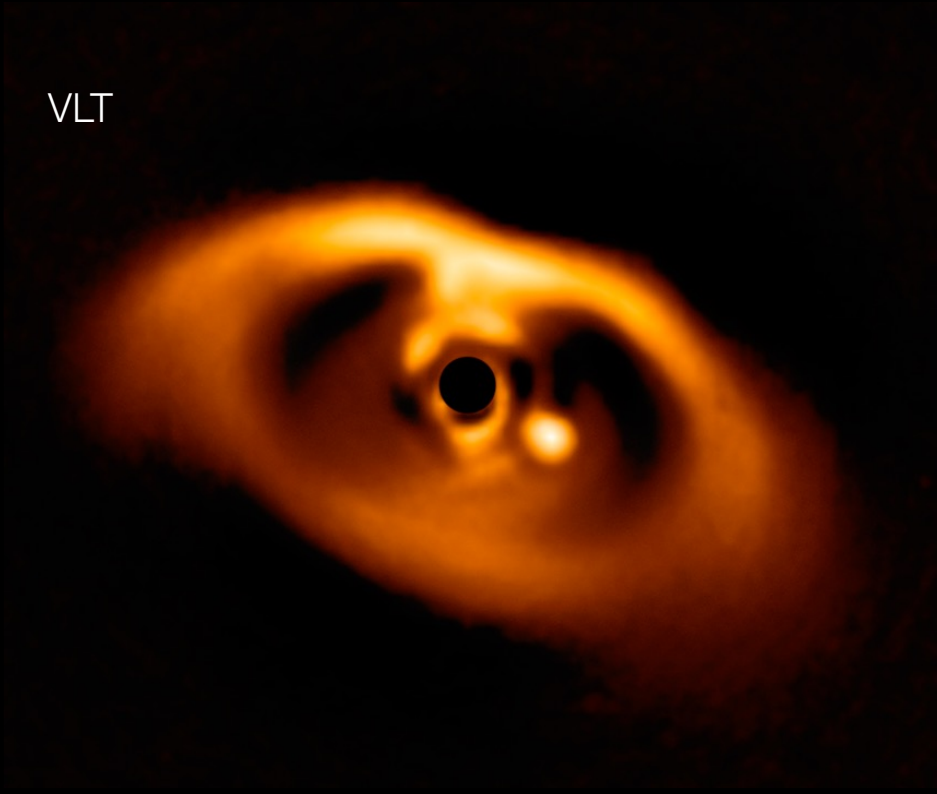


Credits: NASA, ESA, and Leah Hustak (STScI)

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PDS 70



Credit: ESO, VLT, André B. Müller (ESO)

Credit: NASA, ESA, McDonald Observatory–University of Texas, Yifan Zhou (UT)

Explodierende Sterne

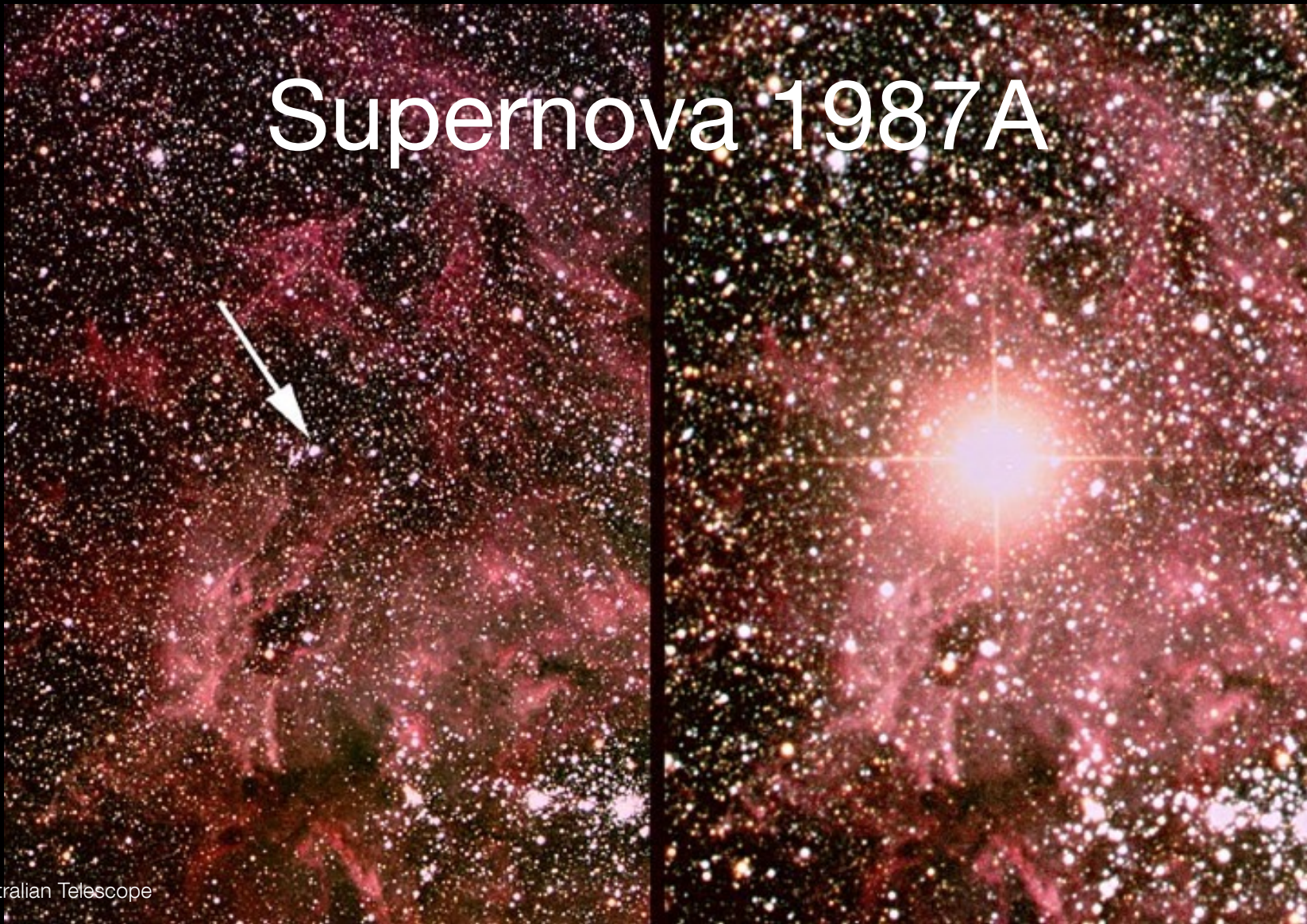


Credit: NASA, ESA and Allison Loll/Jeff Hester (Arizona State University).

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Supernova 1987A



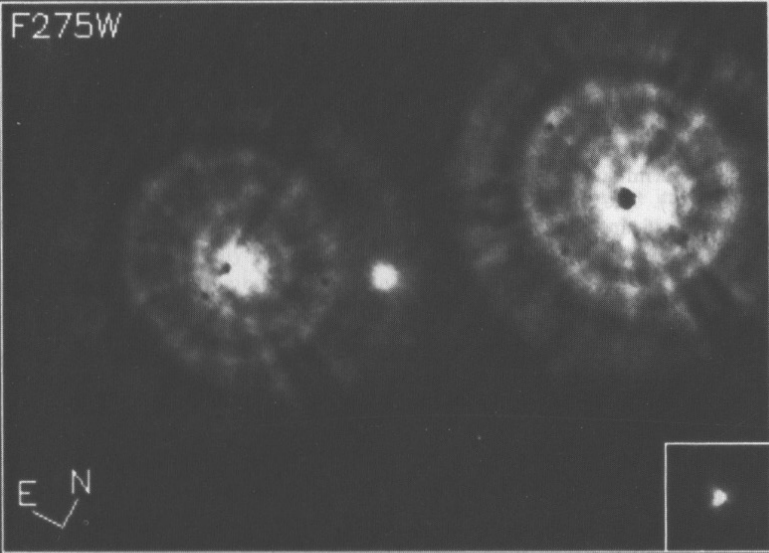
Credit: Anglo-Australian Telescope

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Jakobsen et al. 1991

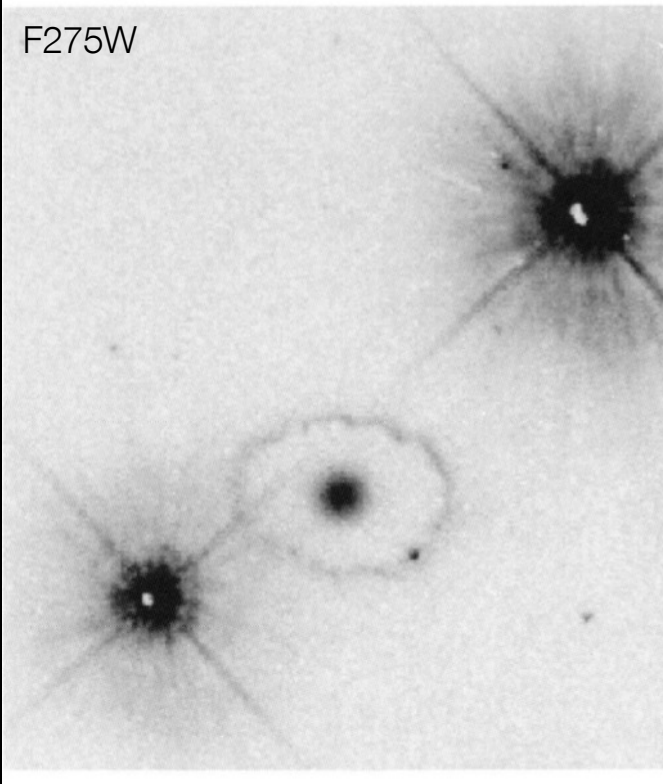
F275W



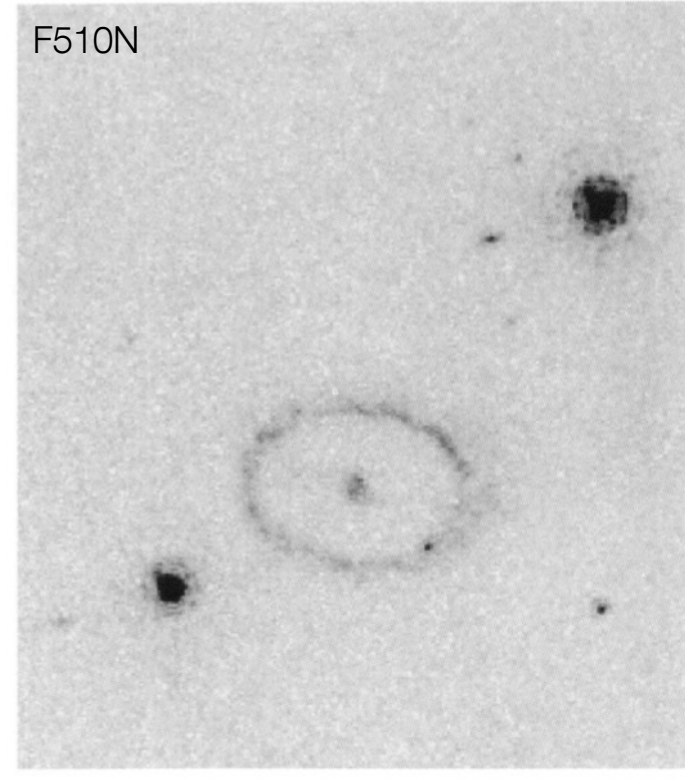
SN 1987A

Jakobsen et al. 1994

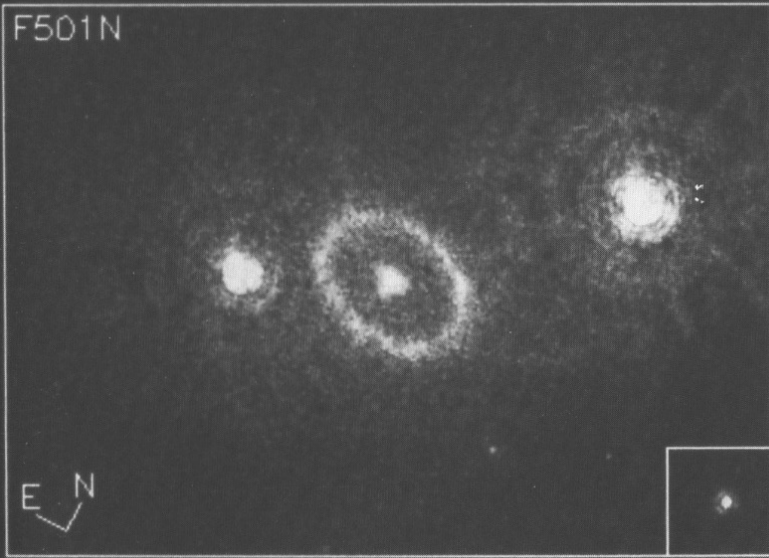
F275W



F510N



F501N

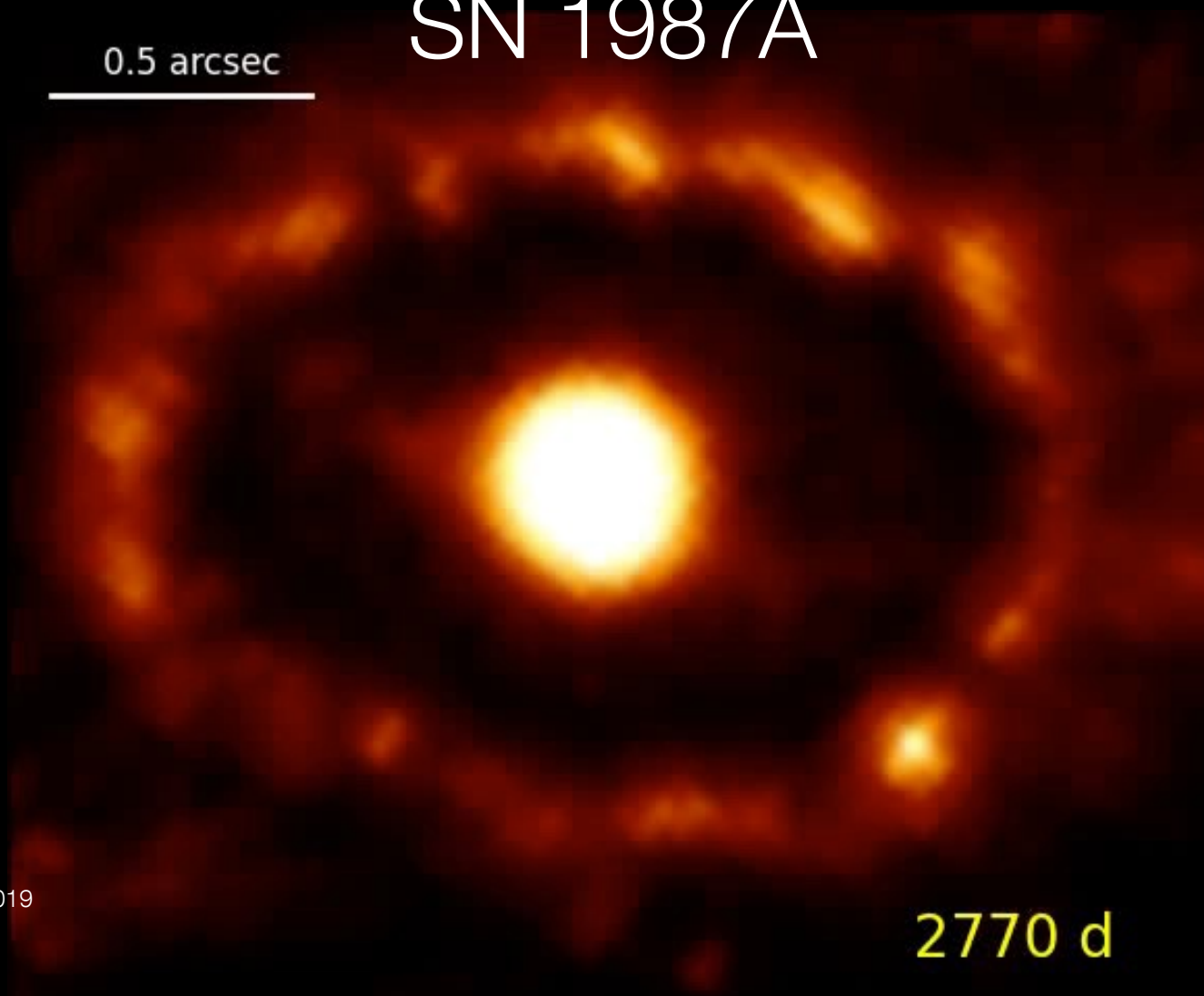


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SN 1987A

0.5 arcsec

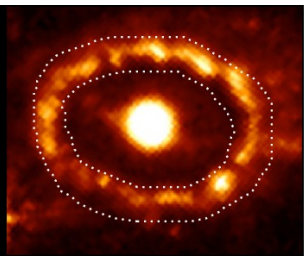


Larsson et al. 2019

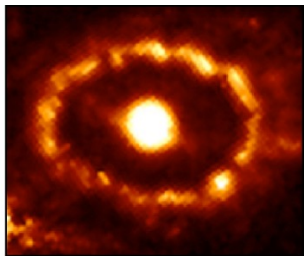
2770 d

6. März 2023

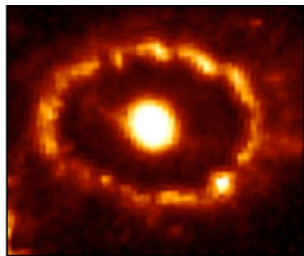
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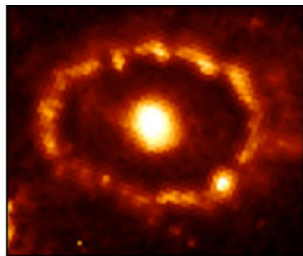
Sep 1994



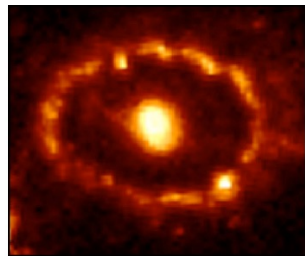
Mar 1995



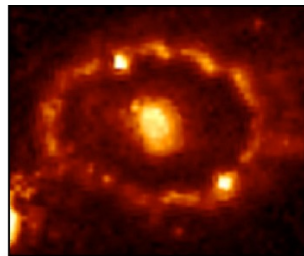
Feb 1996



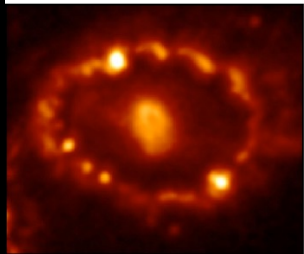
Jul 1997



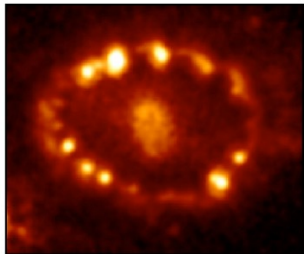
Feb 1998



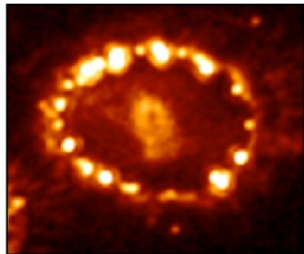
Apr 1999



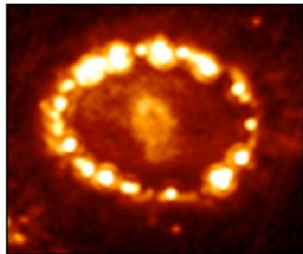
Nov 2000



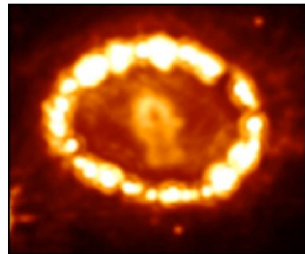
Dec 2001



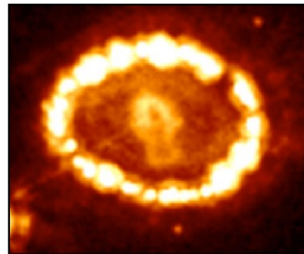
Jan 2003



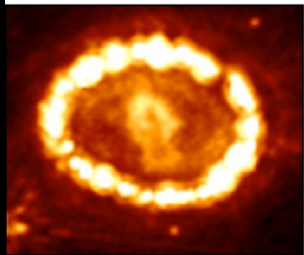
Nov 2003



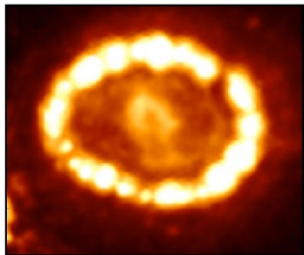
Sep 2005



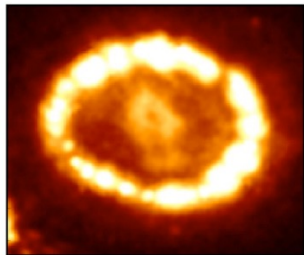
Apr 2006



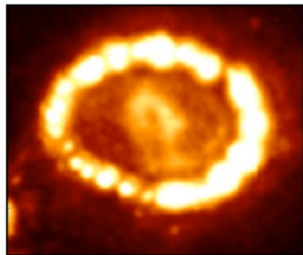
Dec 2006



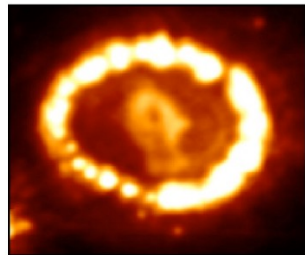
May 2007



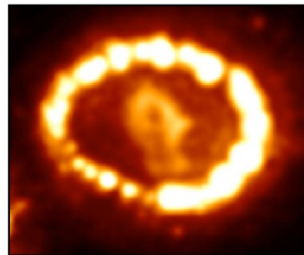
Feb 2008



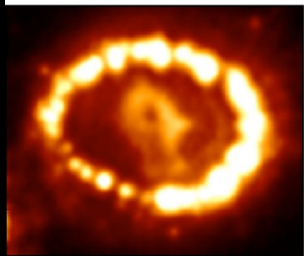
Apr 2009



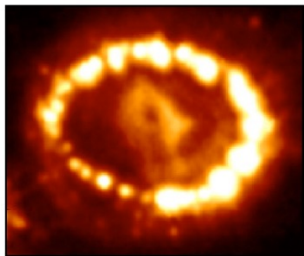
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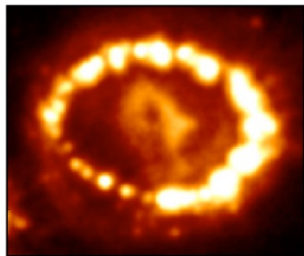
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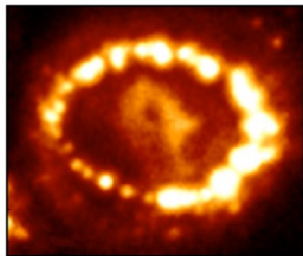
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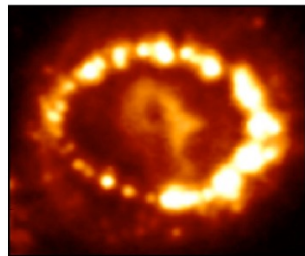
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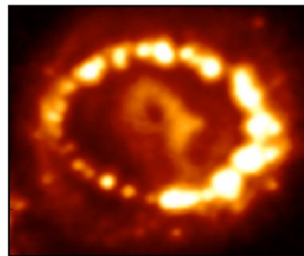
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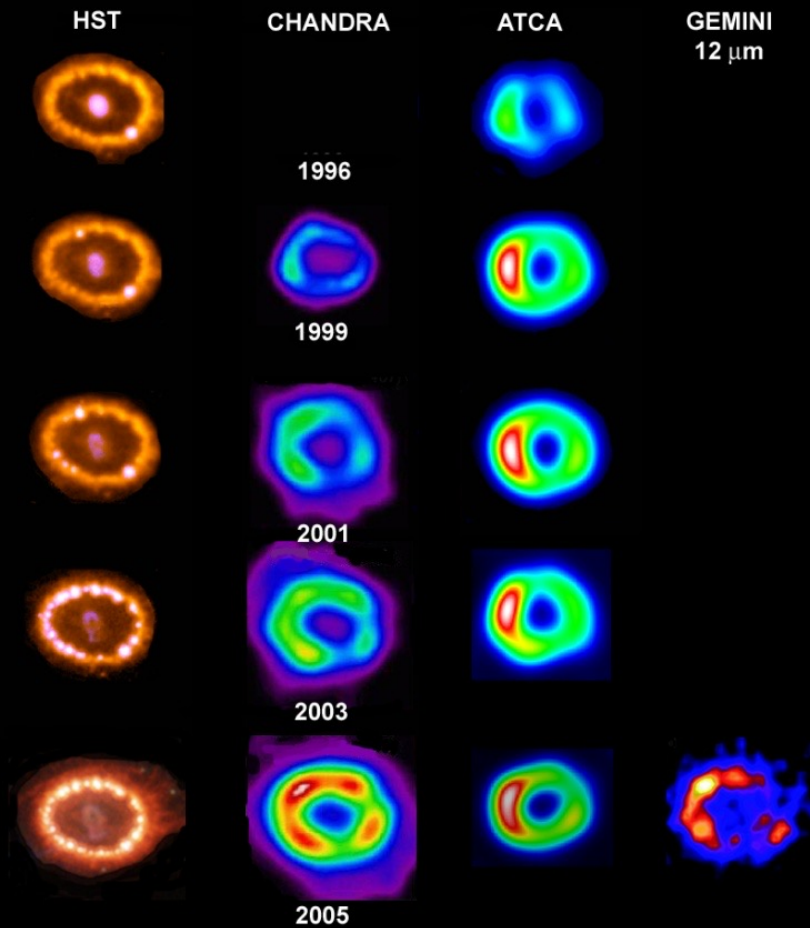


Jul 2018

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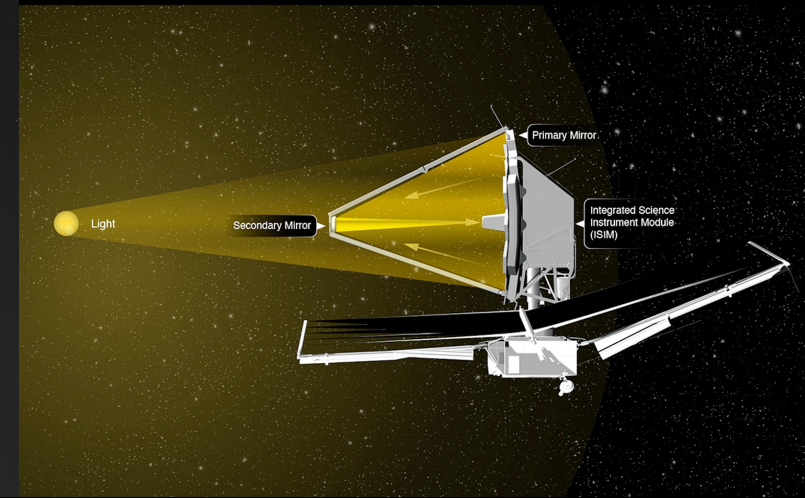
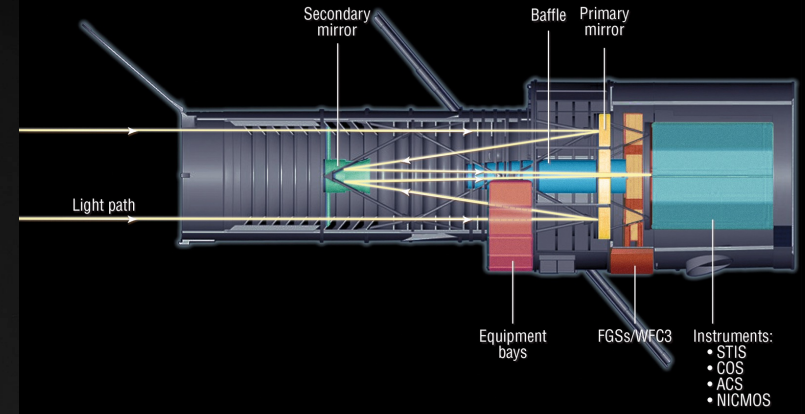
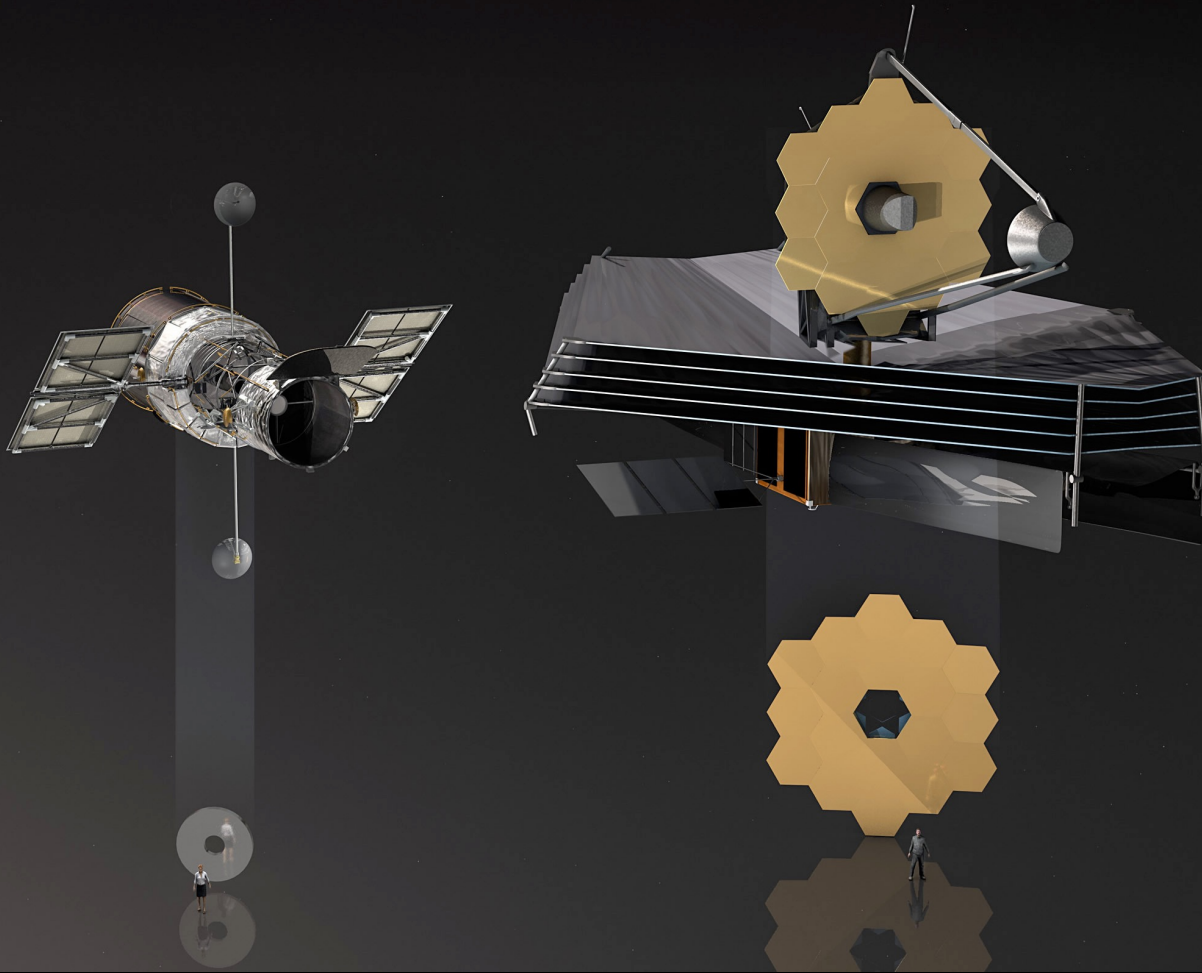
Optical, X-rays and Radio



Park et al
Manchester et al

Credits: NASA-GSFC, STScI

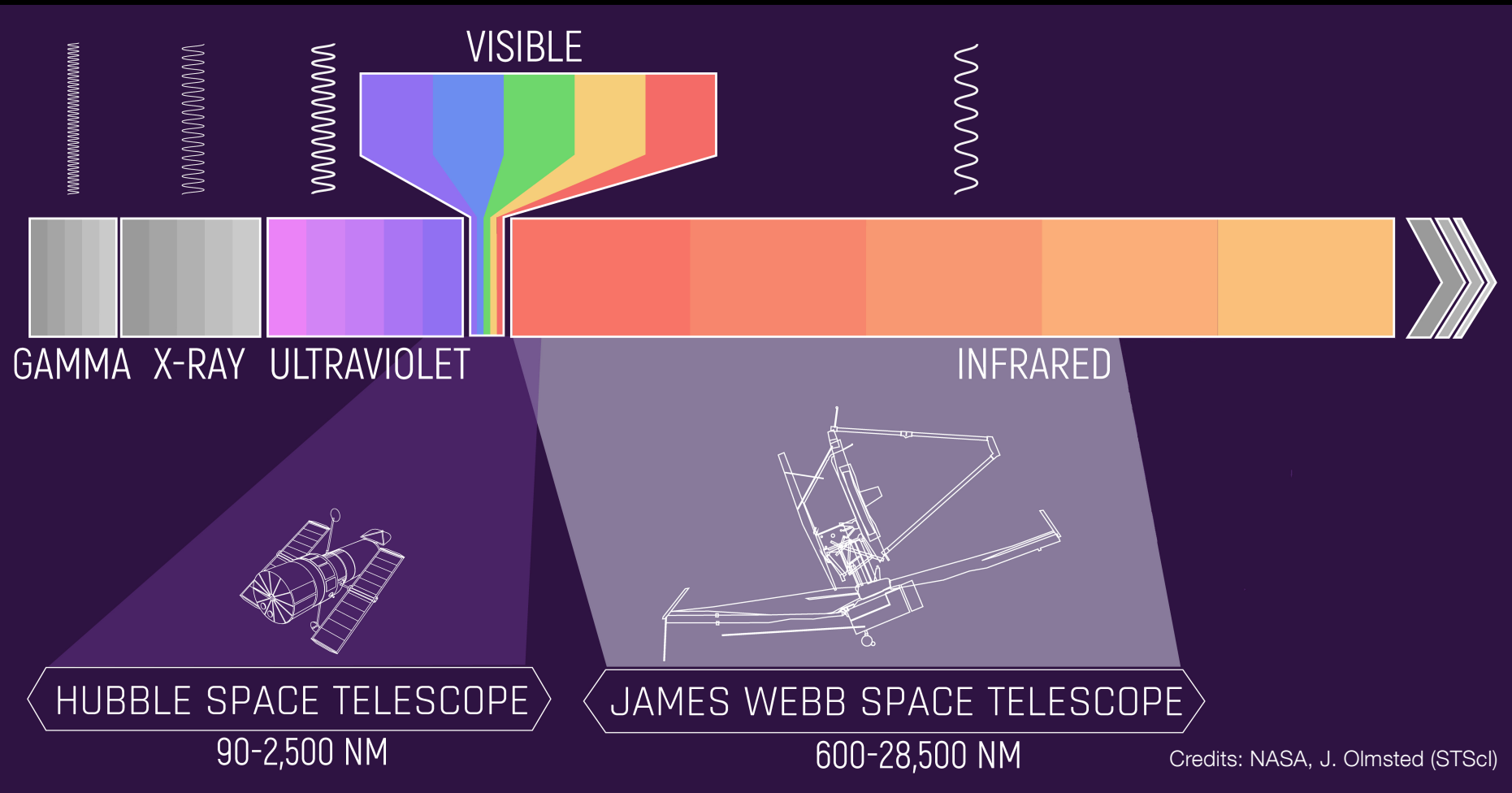
HST und JWST



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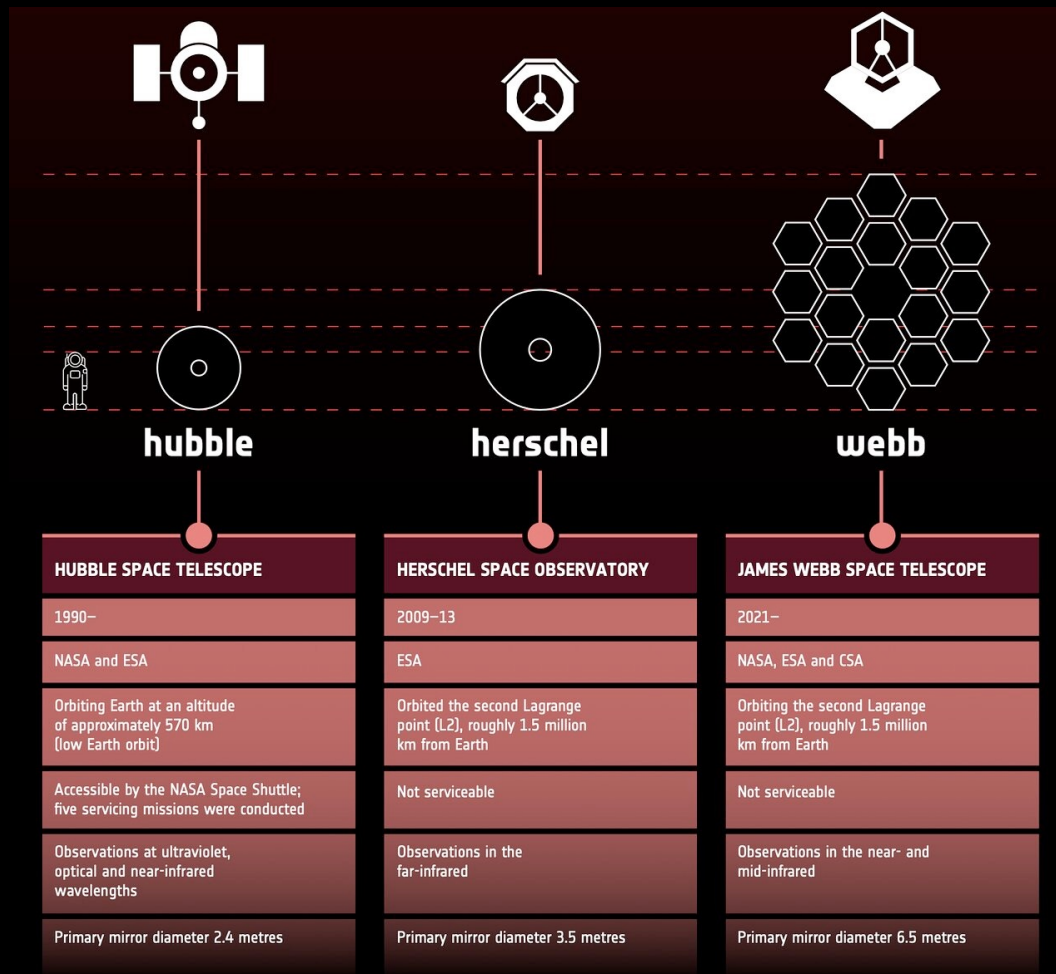
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HST und JWST



Credits: NASA, J. Olmsted (STScI)

HST, Herschel und JWST



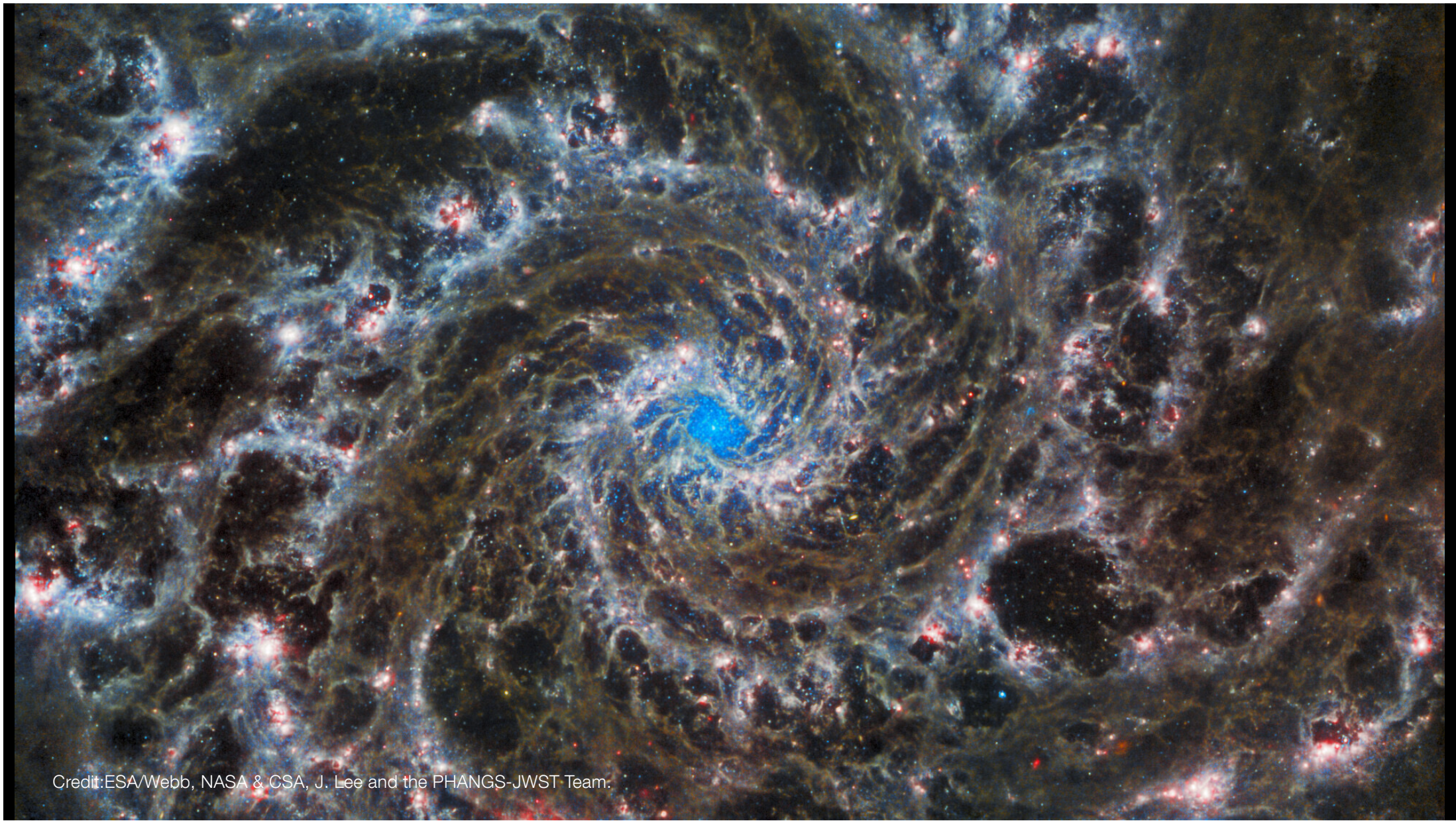
Credit: ESA



Credit: NASA, ESA, and The
Hubble Heritage (STScI/AURA)-
ESA/Hubble Collaboration

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Credit:ESA/Webb, NASA & CSA, J. Lee and the PHANGS-JWST Team.

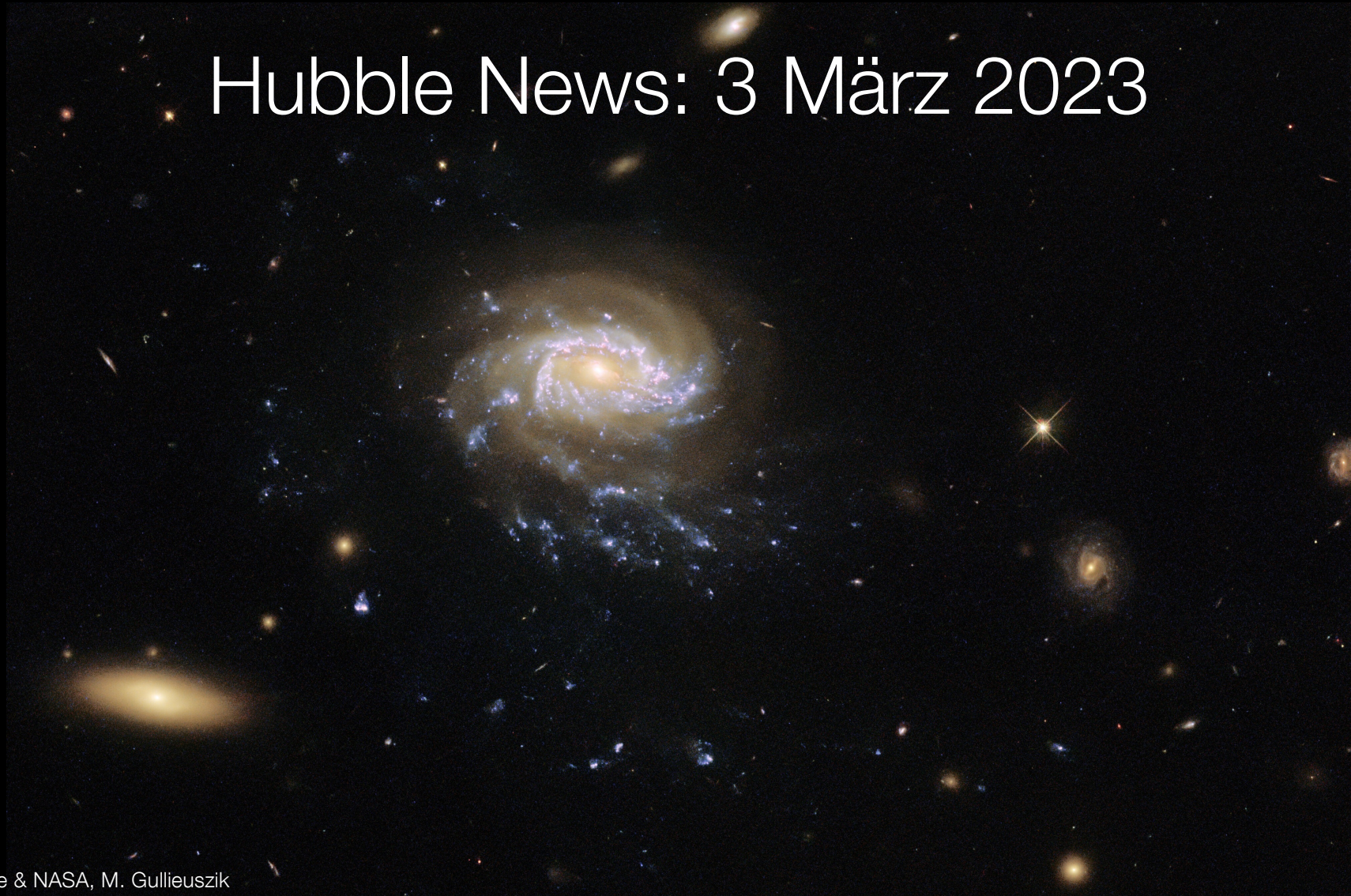
Credit:ESA/Webb, NASA & CSA, J. Lee and the PHANGS-JWST Team; ESA/Hubble & NASA, R. Chandar, N. Bartmann



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Hubble News: 3 März 2023



Credit: ESA/Hubble & NASA, M. Gullieuszik

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Quellen

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- Space Science Institute Webseite <https://www.stsci.edu/hst>
- Öffentliche Webseite STScI <https://hubblesite.org/>
- ESA JWST <https://esawebb.org/>