



Recycling the Sun

From dying stars to life on Earth

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University of Leeds

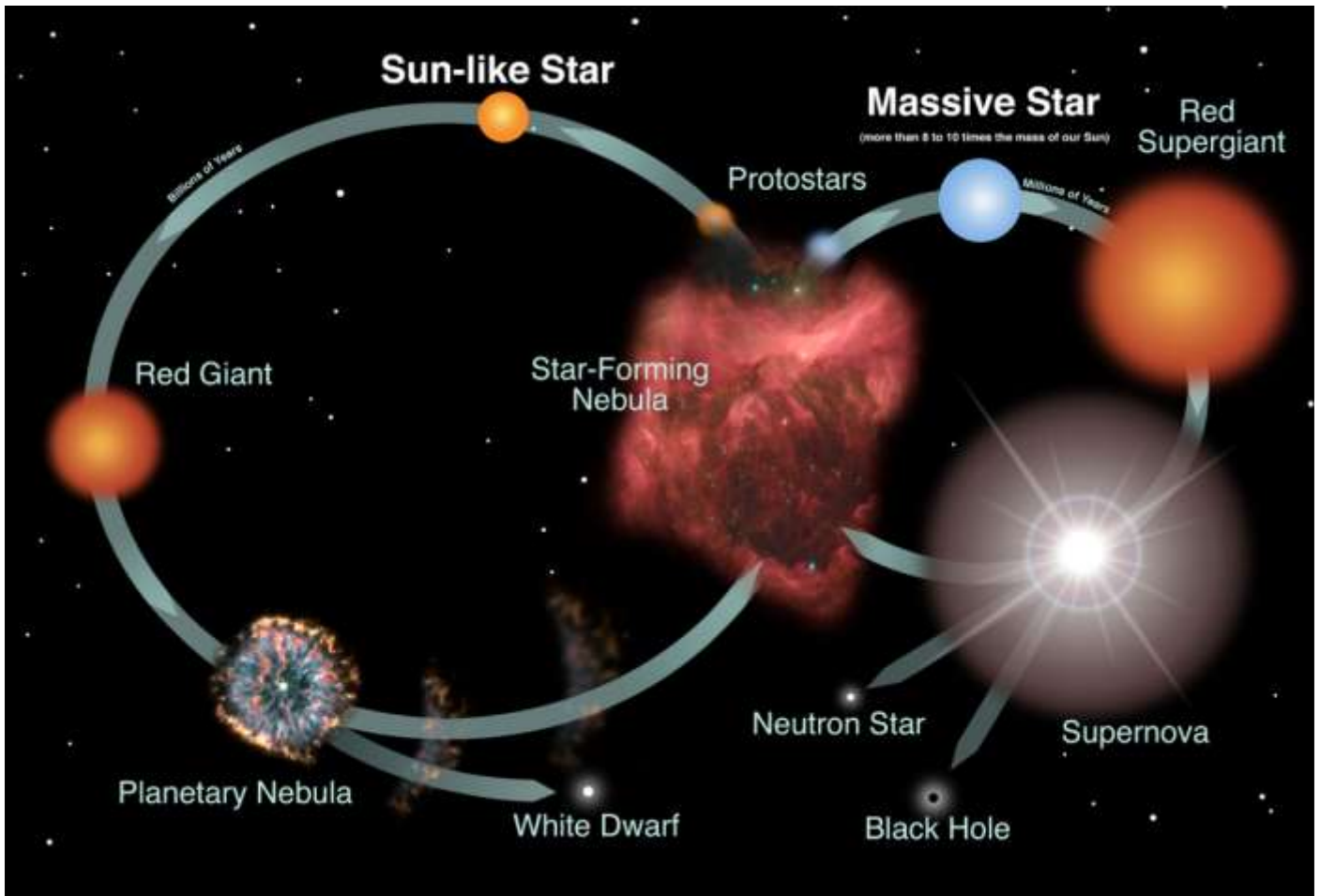
Headingley Café Scientifique - 13/02/2023

MARIE CURIE ACTIONS



UNIVERSITY OF LEEDS





What is a star?

Nuclear fusion
 $4\text{ H} \rightarrow \text{He}$

Gravity

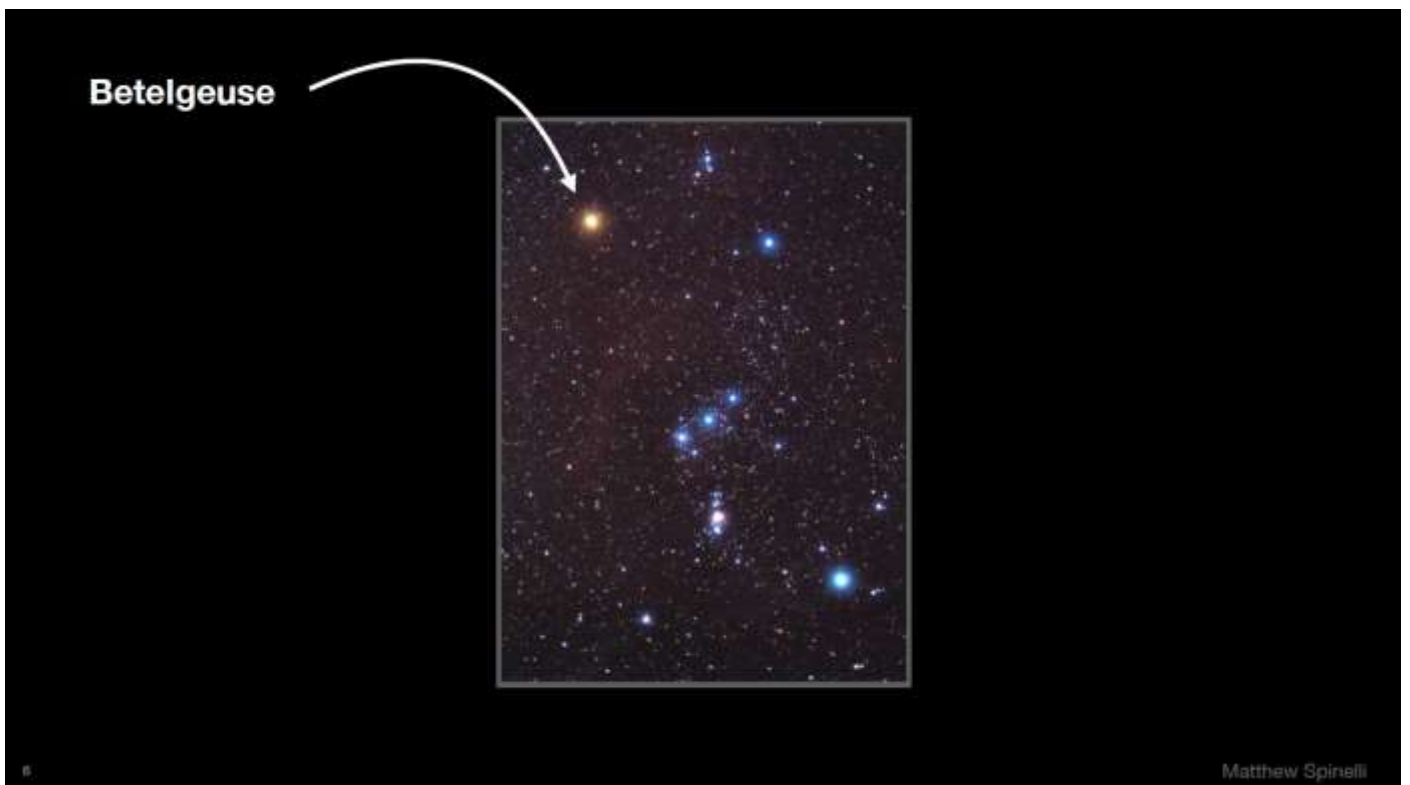
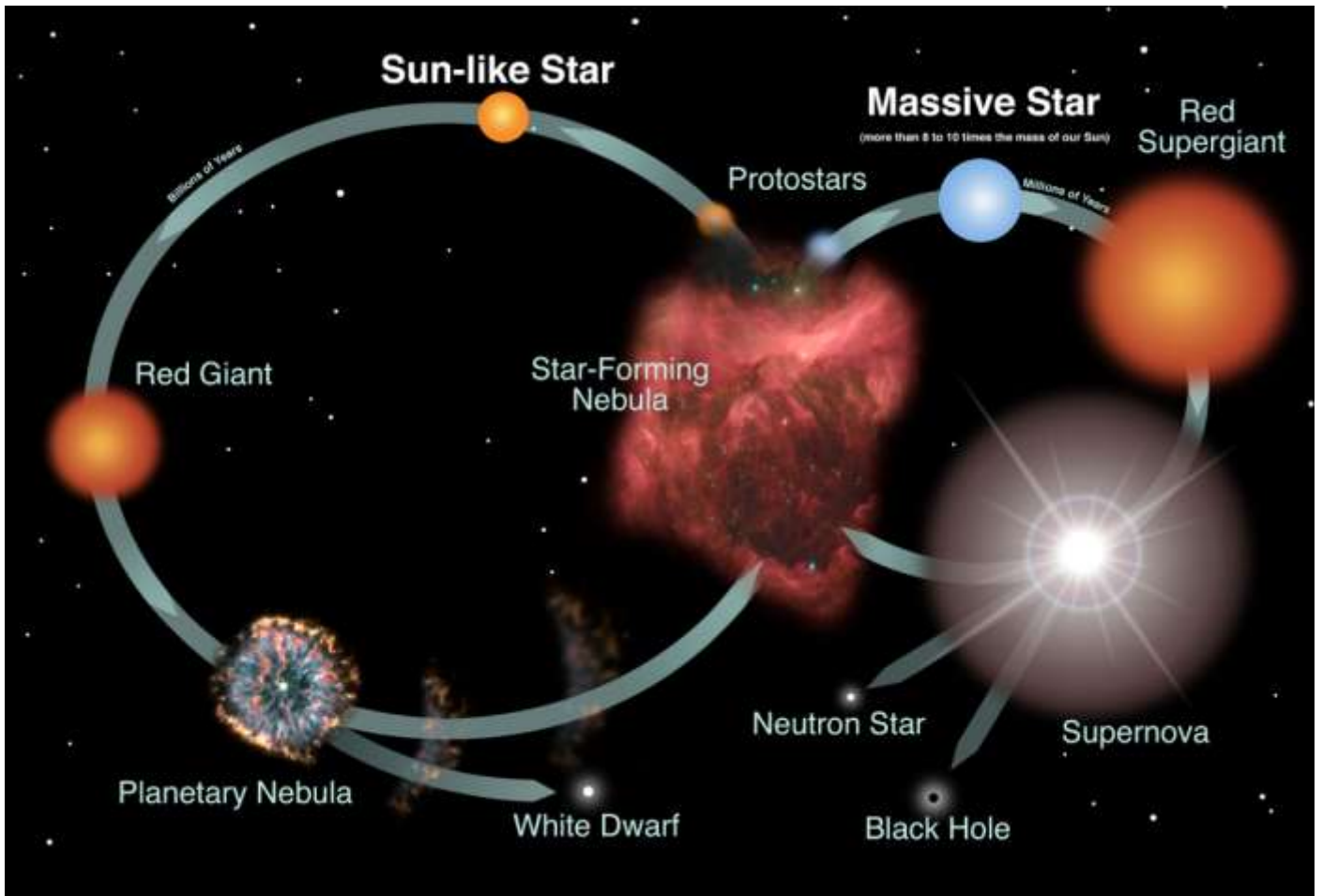
Thermal pressure

Solar core:
15 million K
265 billion bar

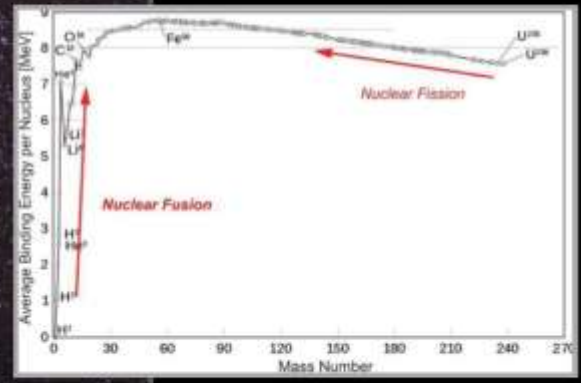
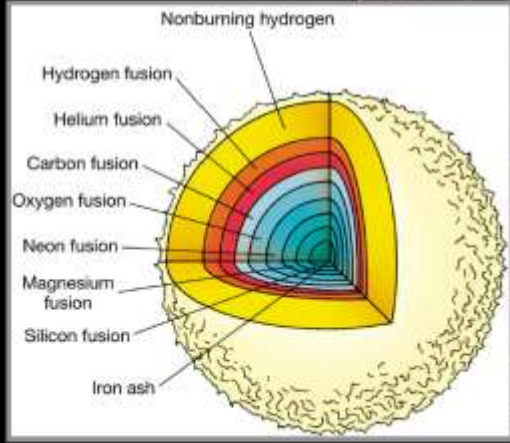
2006/12/13 20:19

ITER Organisation

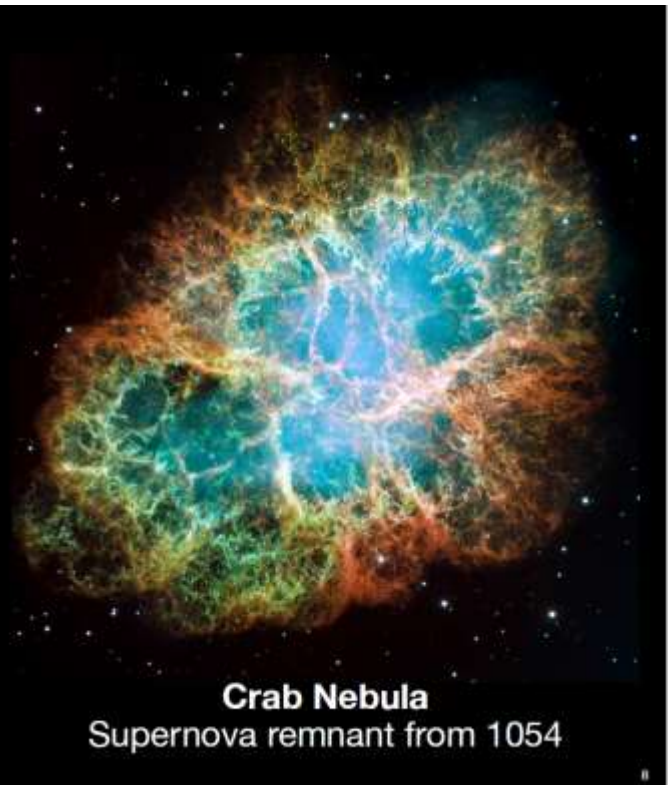
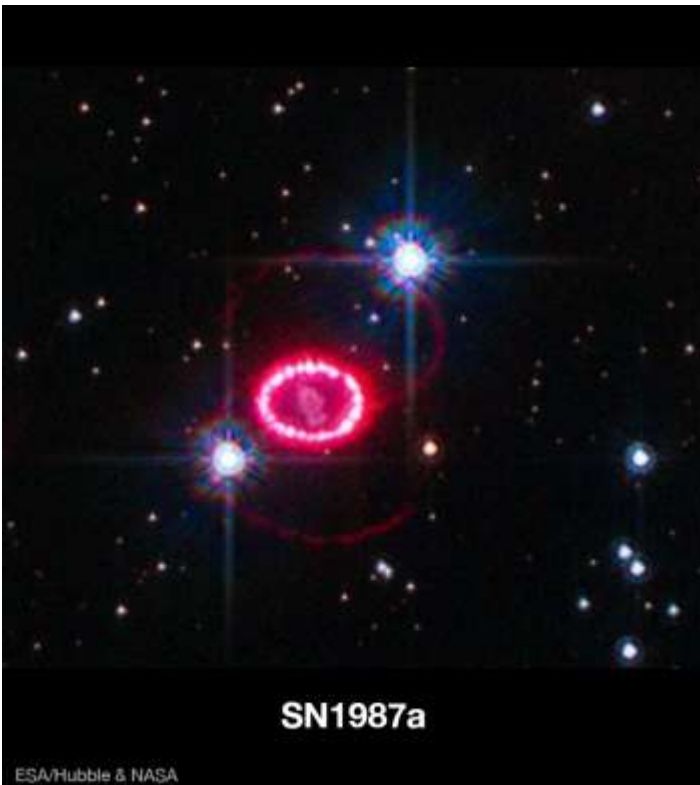
SOHO image of storm on Sun, 13 December 2006
False colour image of UV
Credit: SOHO ESA



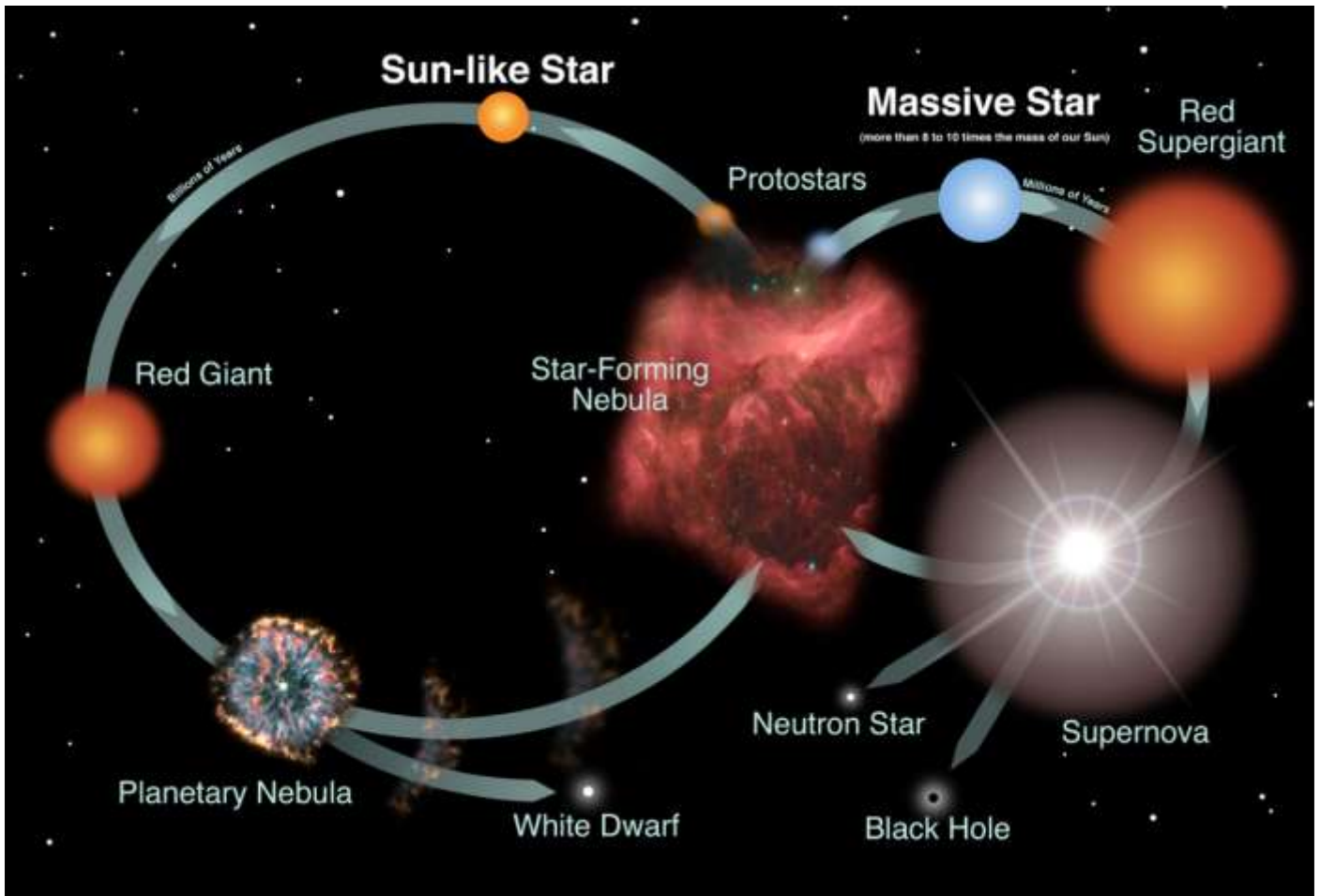
Betelgeuse



Matthew Spinelli



ESA/Hubble & NASA



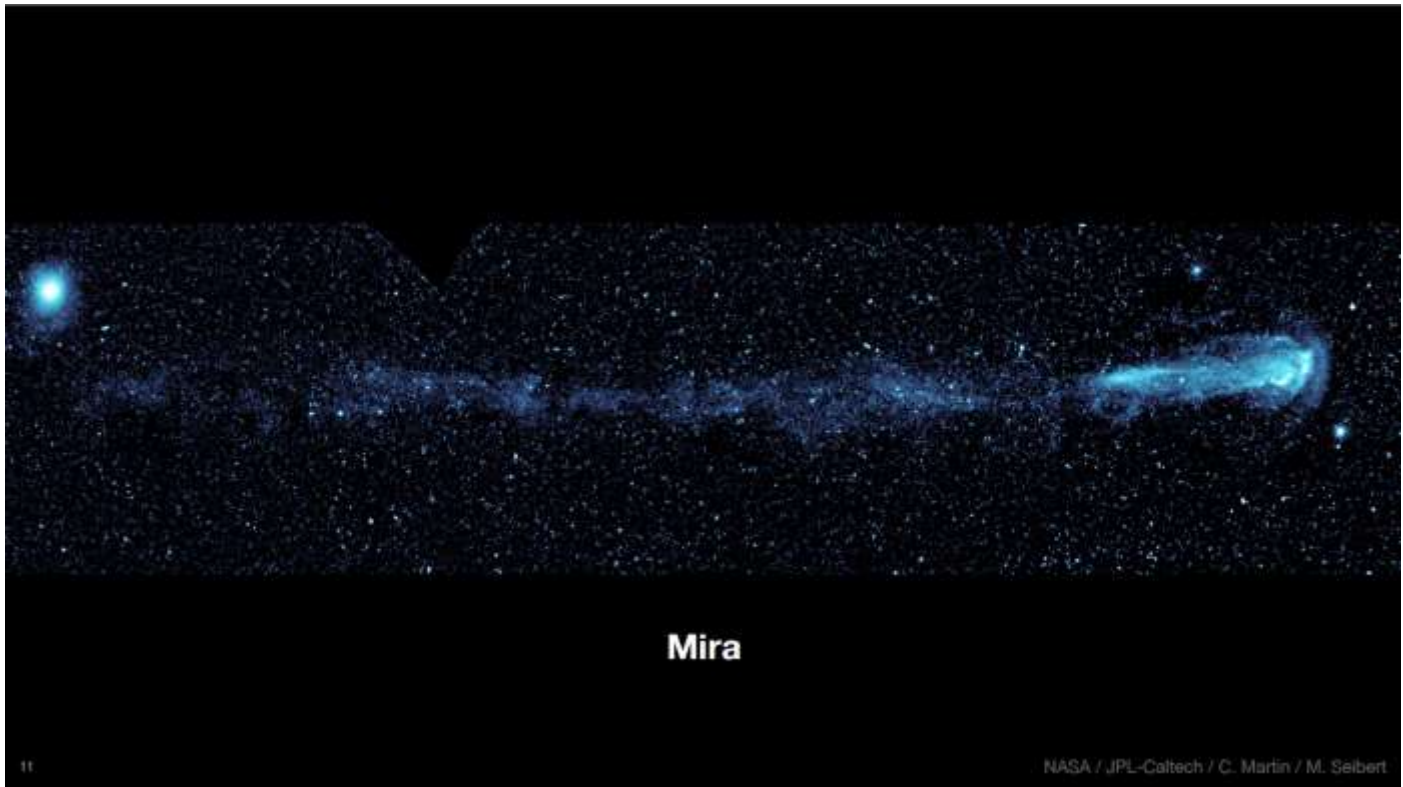
IRC+10216

- Asymptotic giant branch (AGB) stars
- Mass loss via a stellar outflow
- Pulsations → dust formation

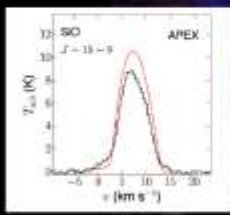
→ **Chemical enrichment of the ISM**

- 80% of gas
- 35% of total dust (Tielens 2005)
- ~70% of newly formed stellar dust (Zhukovska & Henning 2013)

Jessberger 2001
Gail & Sedlmeyer 2013
ESA/Hubble, NASA, Toshiya Ueta (University of Denver), Hyosun Kim (KASI)



Mira



Close-by companions → wide companions

EDE/disk
M low

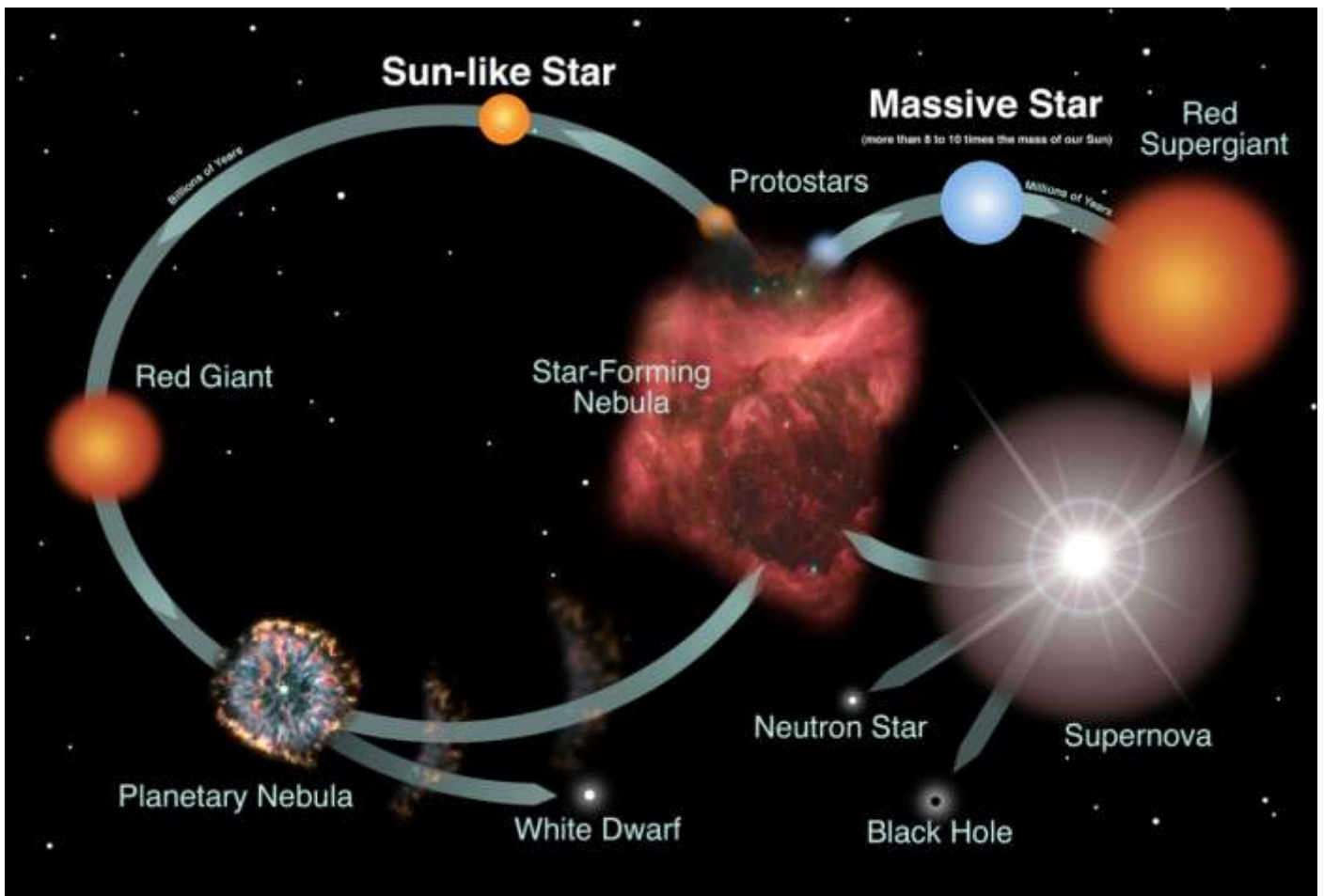
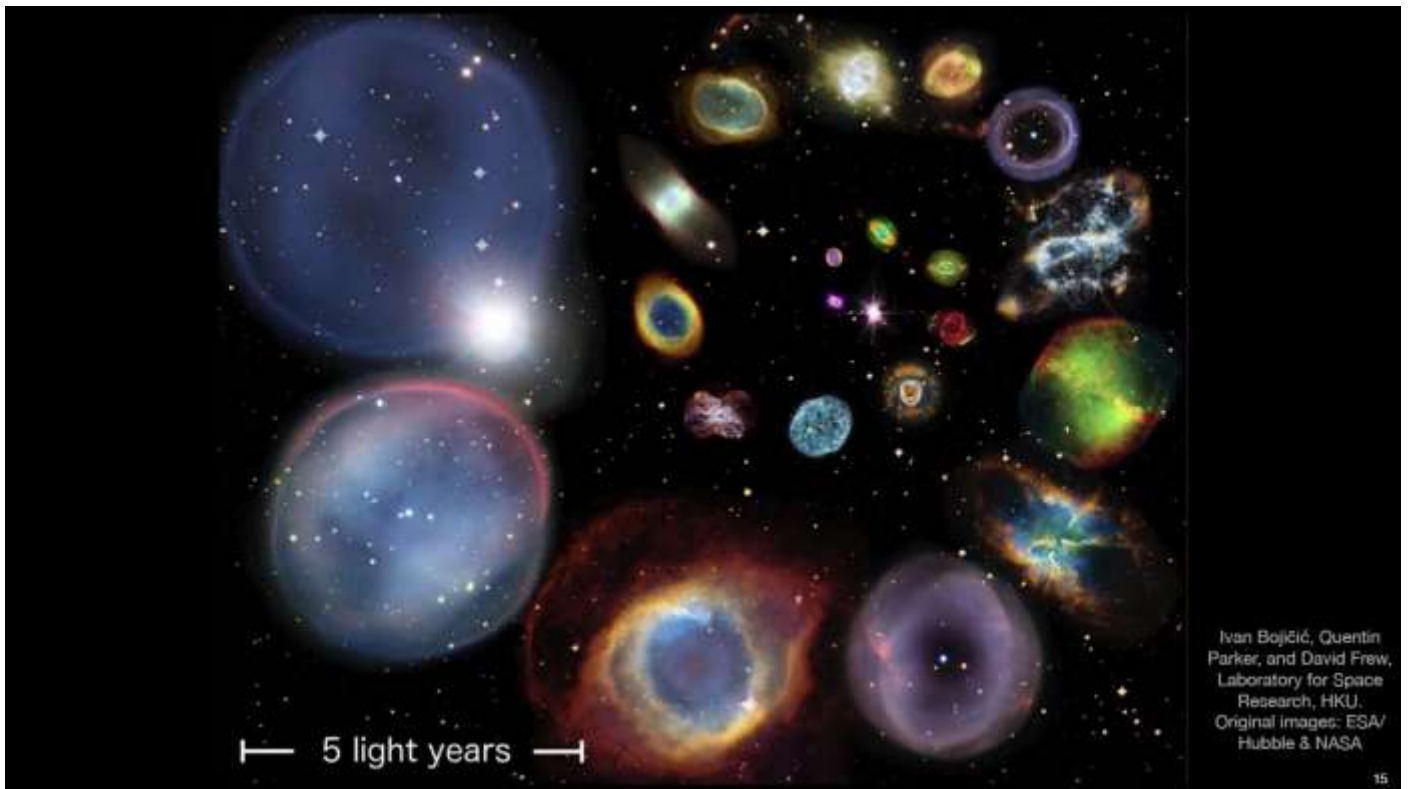
Bipolar
M medium

Spiral
M high







ESO/NRAO/NAOJ
Decin et al. 2020

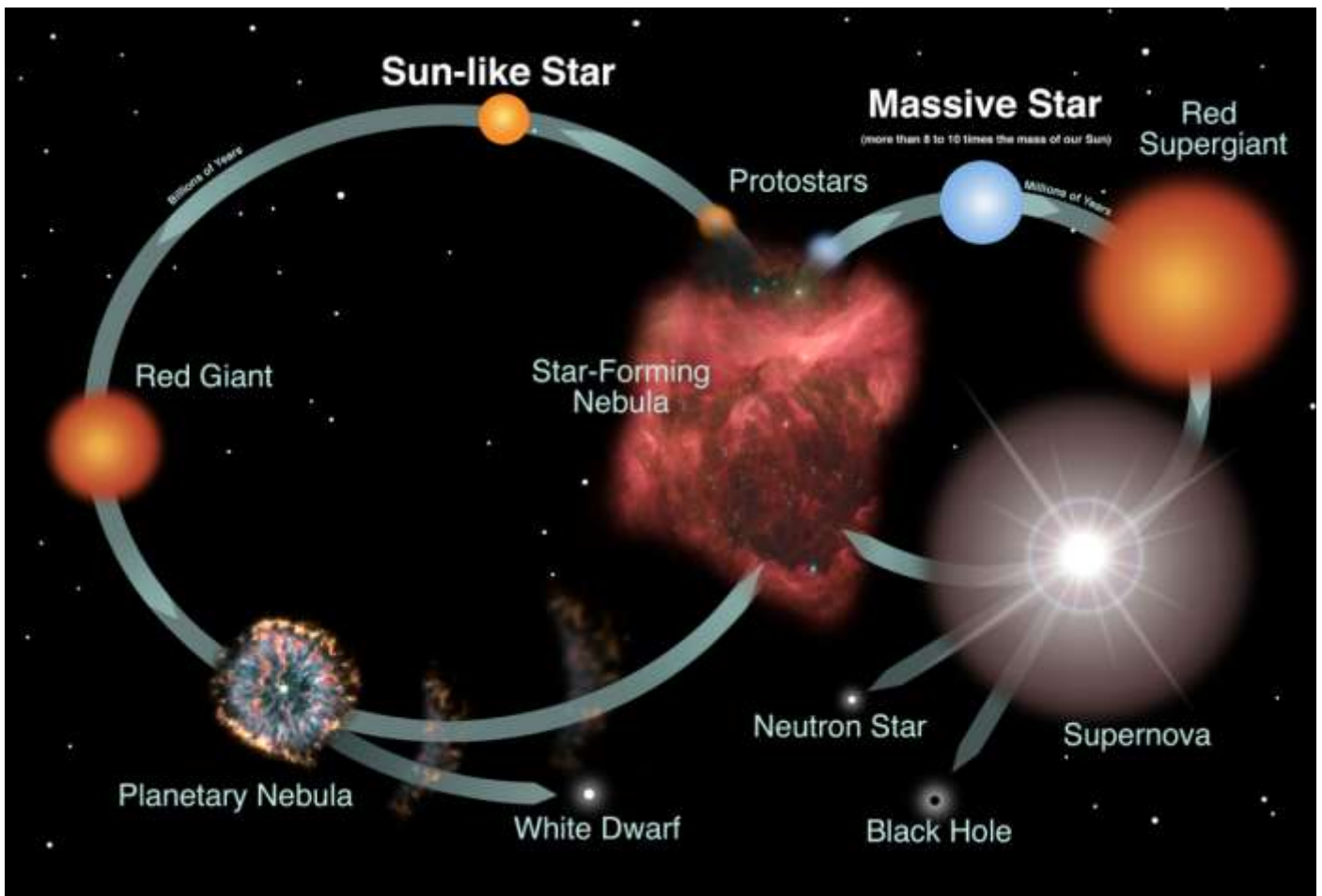
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The Origin of the Solar System Elements

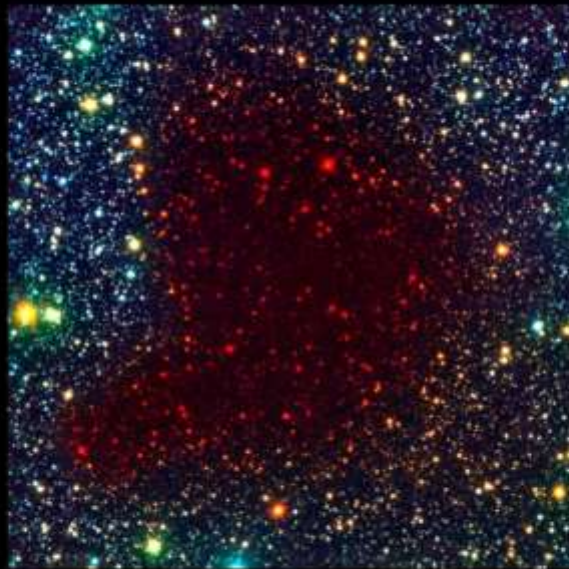
1 H	big bang fusion 										cosmic ray fission 						2 He															
3 Li	4 Be	merging neutron stars 										exploding massive stars 						5 B	6 C	7 N	8 O	9 F	10 Ne									
11 Na	12 Mg	dying low mass stars 										exploding white dwarfs 						13 Al	14 Si	15 P	16 S	17 Cl	18 Ar									
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr															
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe															
55 Cs	56 Ba	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn																
87 Fr	88 Ra																															
																	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
																	89 Ac	90 Th	91 Pa	92 U												

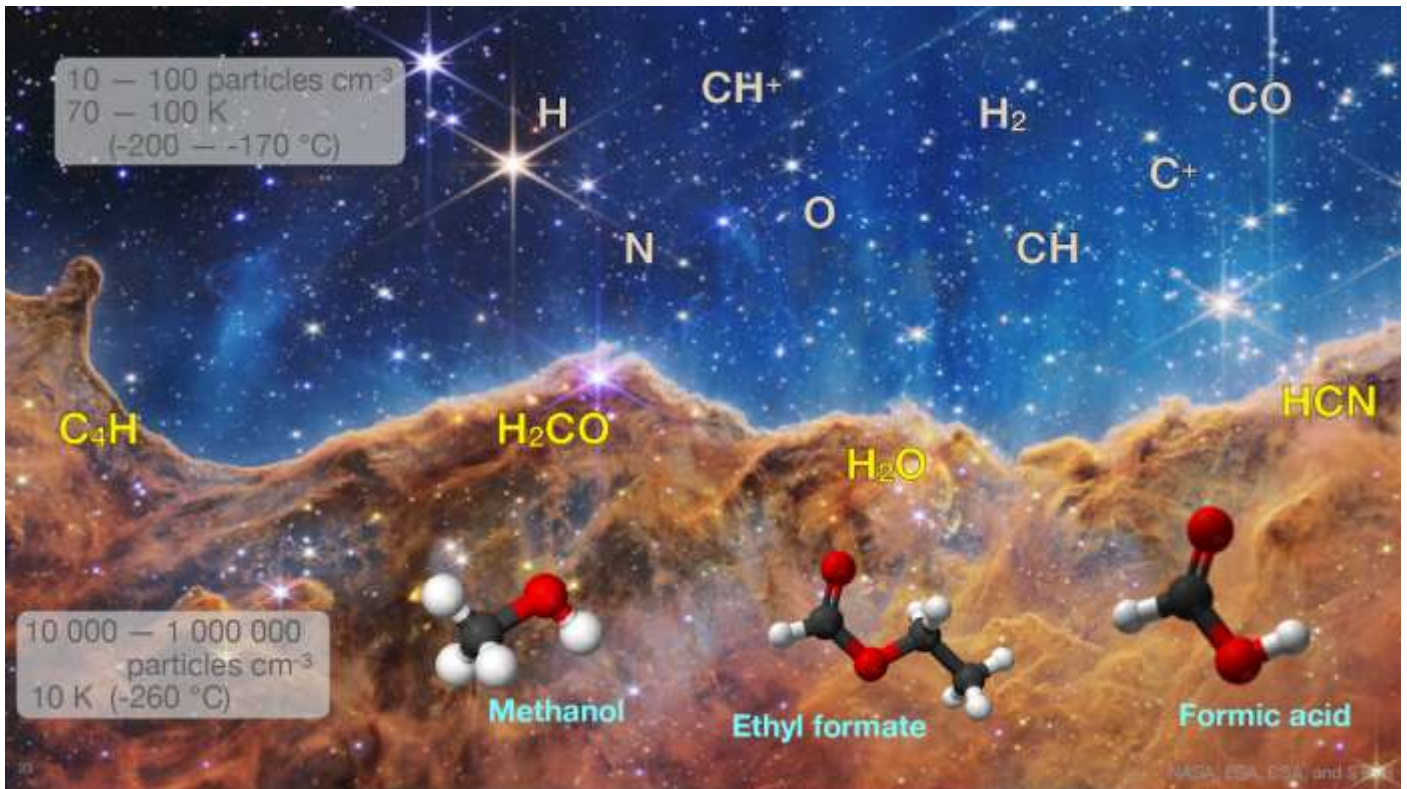


Barnard 68



Barnard 68





The formation of complex organic molecules on interstellar dust particles

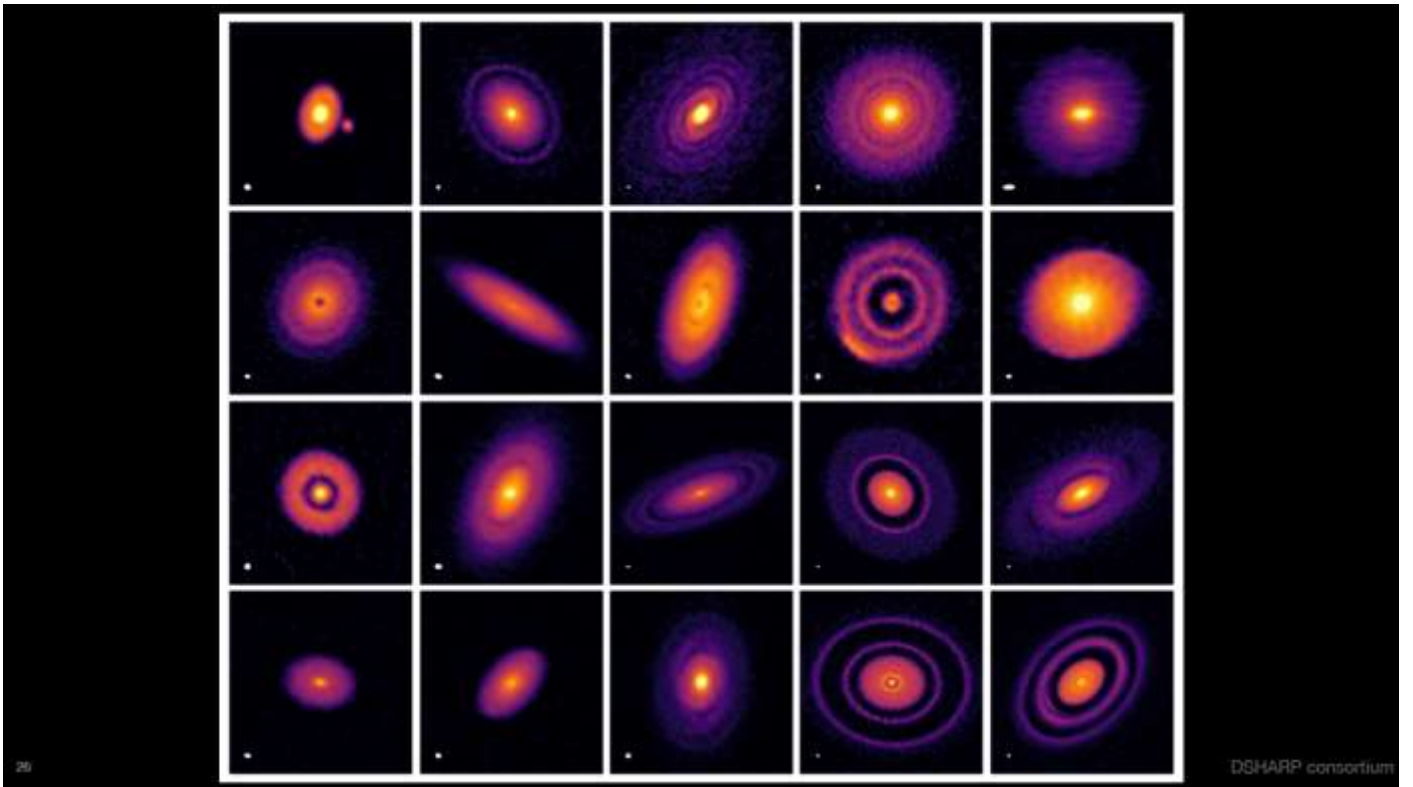
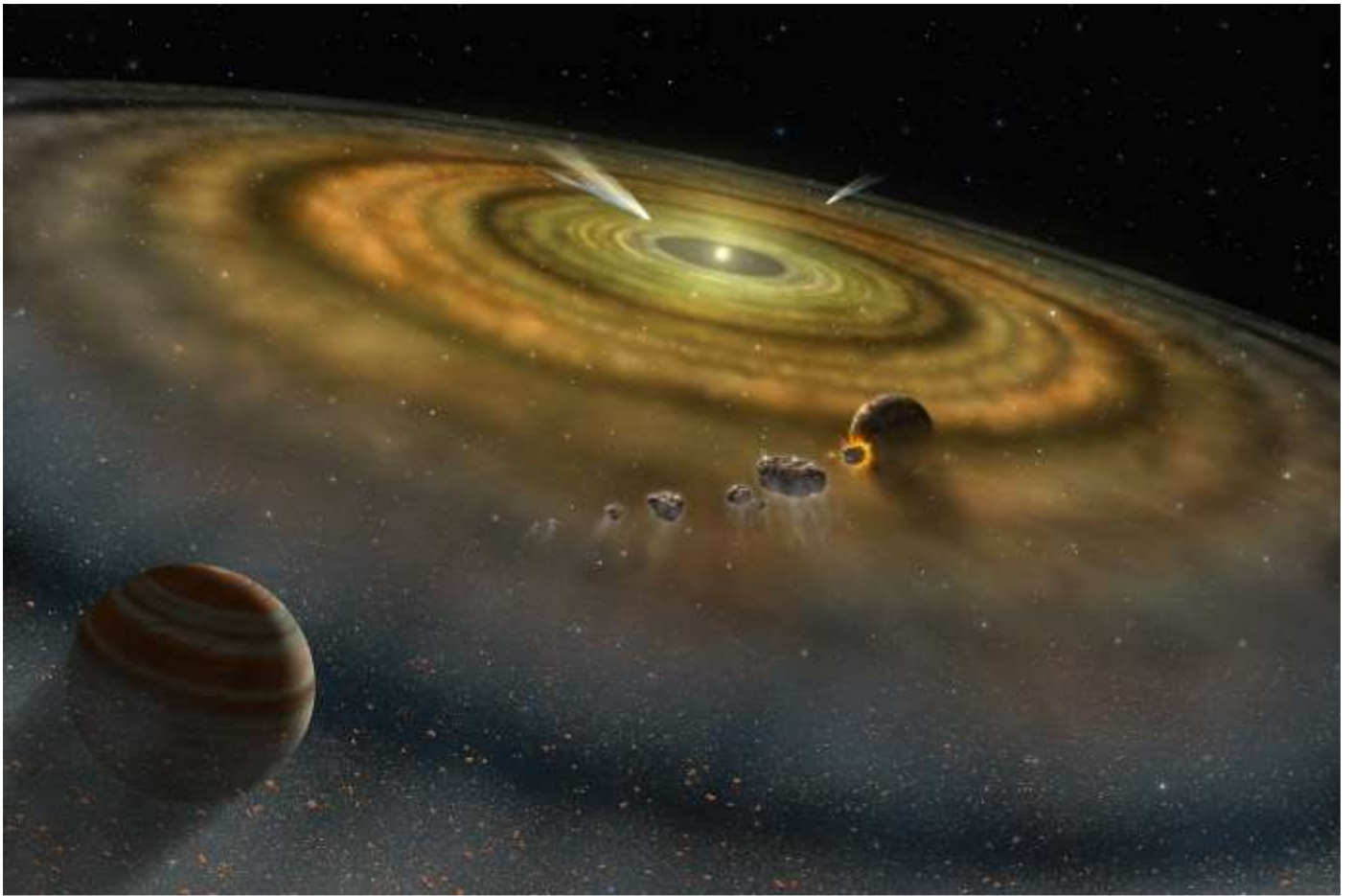
Prof. Ewine F. van Dishoeck

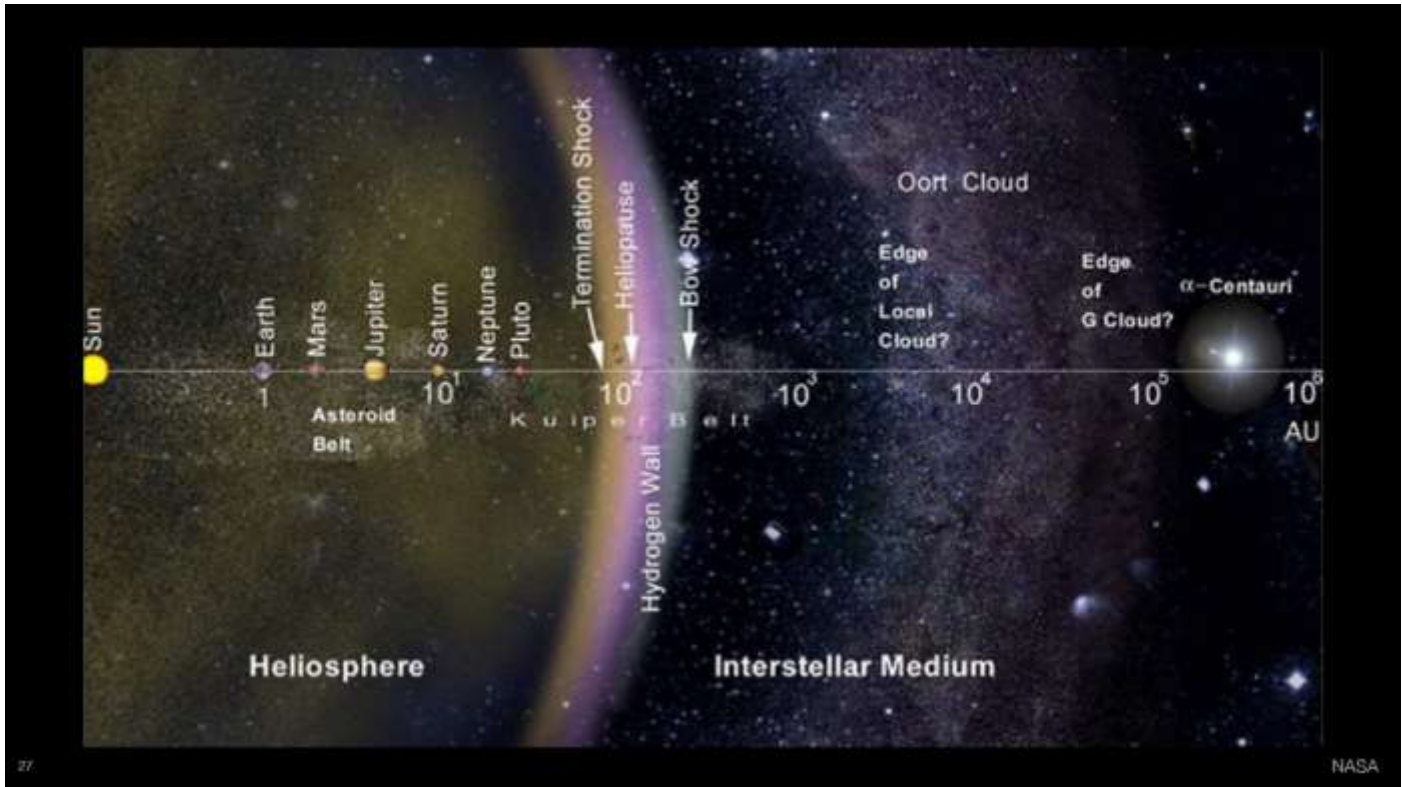


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→ THE COMETARY ZOO: GASES DETECTED BY ROSETTA



THE LONG CARBON

CHAINS

Methane
Ethane
Propane
Butane
Pentane
Hexane
Heptane



THE AROMATIC RING COMPOUNDS

Benzene
Toluene
Xylene
Benzoic acid
Naphtalene



THE KING OF THE ZOO

Glycine (amino acid)



THE "MANURE SMELL" MOLECULES

Ammonia
Methylamine
Ethylamine



THE "POISONOUS" MOLECULES

Acetylene
Hydrogen cyanide
Acetonitrile
Formaldehyde



THE ALCOHOLS

Methanol
Ethanol
Propanol
Butanol
Pentanol



THE VOLATILES

Nitrogen
Oxygen
Hydrogen peroxide
Carbon monoxide
Carbon dioxide



THE "SMELLY" MOLECULES

Hydrogensulphide
Carbonylsulphide
Sulphur monoxide
Sulphur dioxide
Carbon disulphide



THE "SMELLY AND COLOURFUL"

Sulphur
Disulphur
Trisulphur
Tetrasulphur
Methanethiole
Ethanethiol
Thioformaldehyde



THE TREASURES WITH A HARD CRUST

Sodium
Potassium
Silicon
Magnesium



THE "SALTY" BEASTS

Hydrogen fluoride
Hydrogen chloride
Hydrogen bromide
Phosphorus
Chloromethane



THE BEAUTIFUL AND SOLITARY

Argon
Krypton
Xenon



THE "EXOTIC" MOLECULES

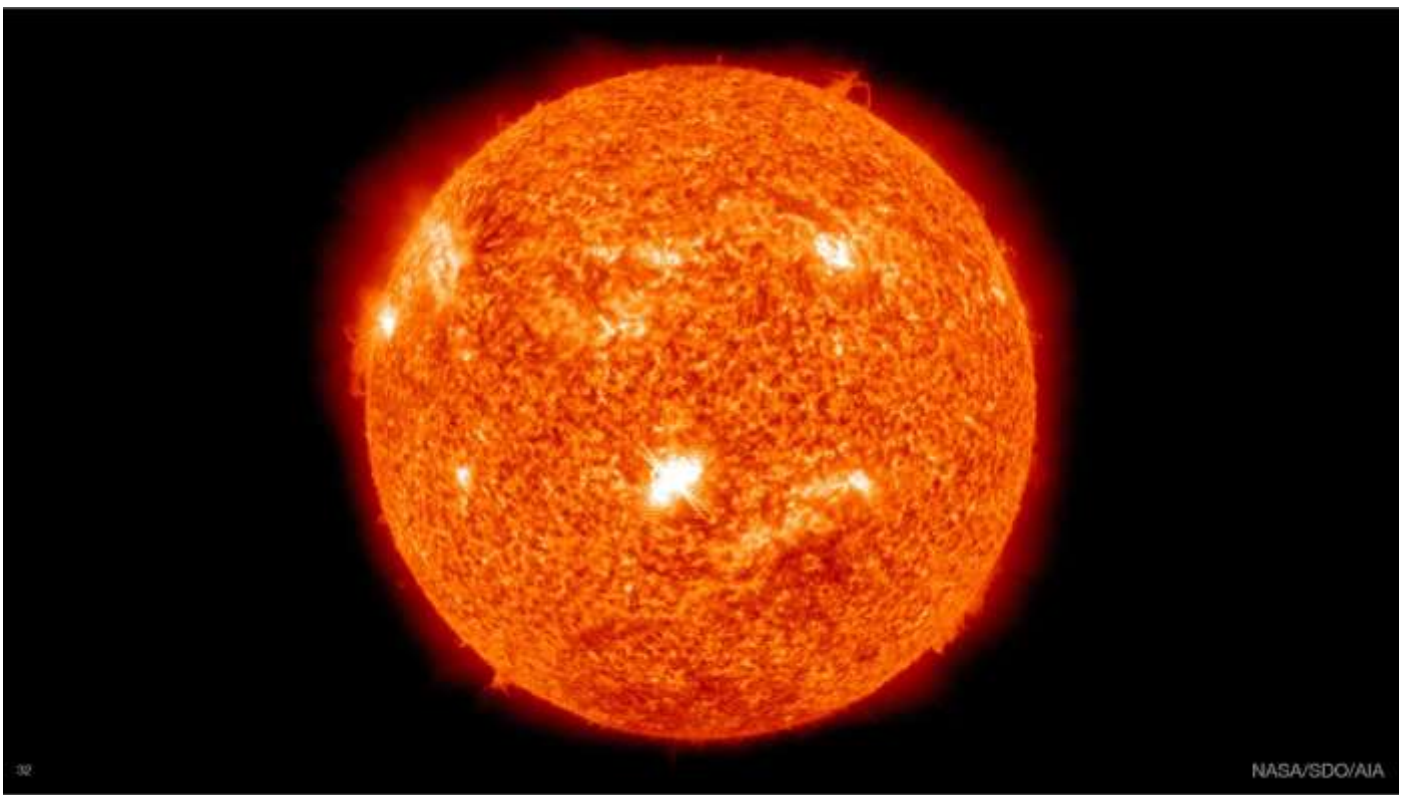
Formic acid
Acetic acid
Acetaldehyde
Ethylenglycol
Propylenglycol
Butanamide



THE MOLECULE IN DISGUISE

Cyanogen





L₂ Puppis



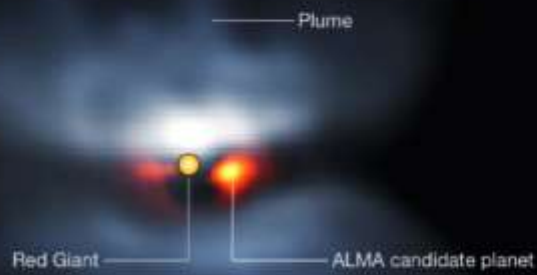
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ESO/Brunier
ESO/Kervella

L₂ Puppis



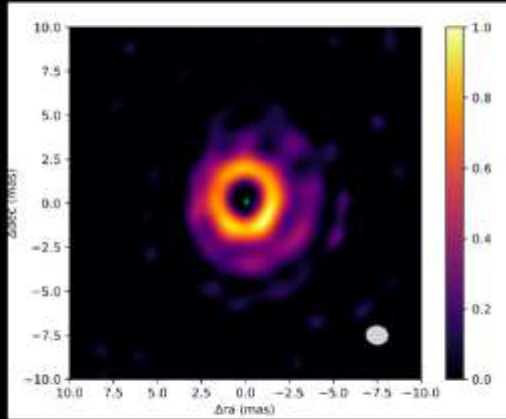
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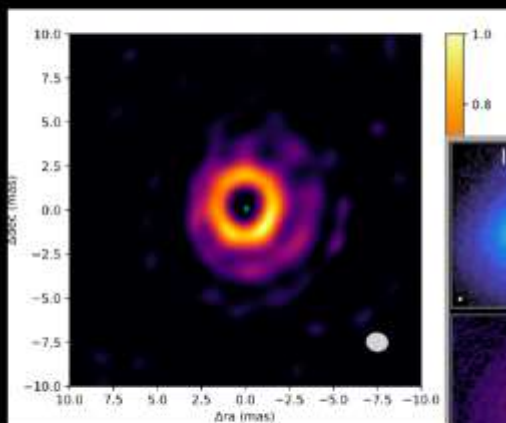
5 AU

0.1"

ESO/NRAO/NAOJ
ESO/Brunier
ESO/Kervella

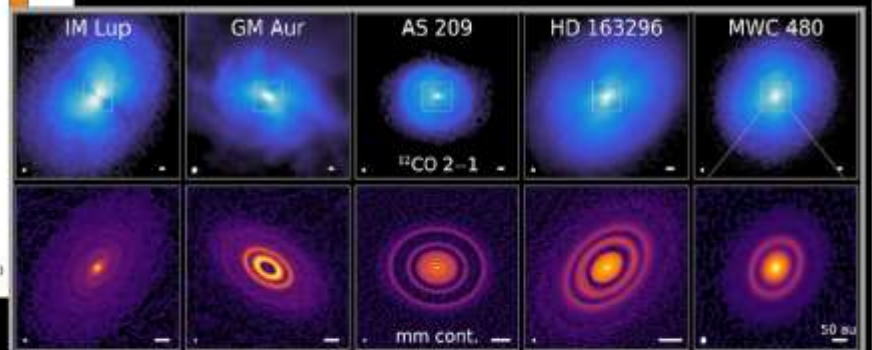


HD101584
Image reconstruction



HD101584
Image reconstruction

Protoplanetary disks

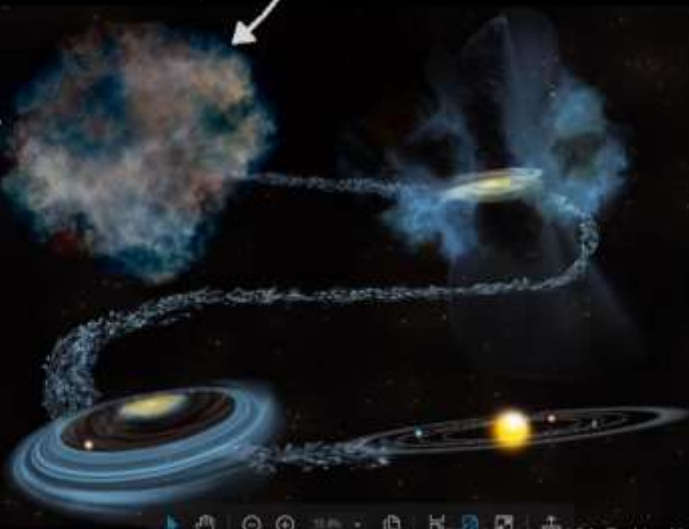




Mira



IRC +10216



Bill Saxton - NRAO-NST

