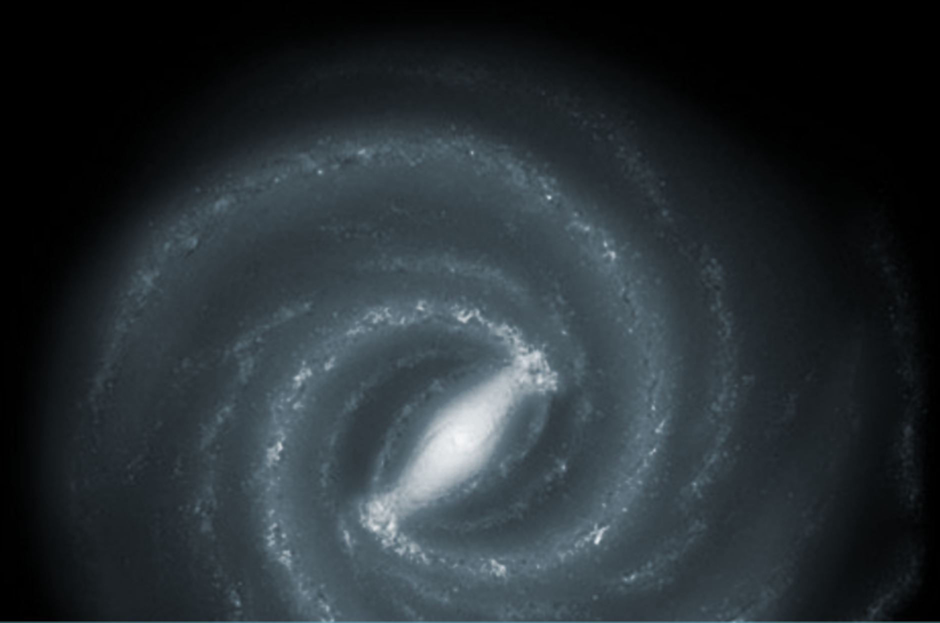
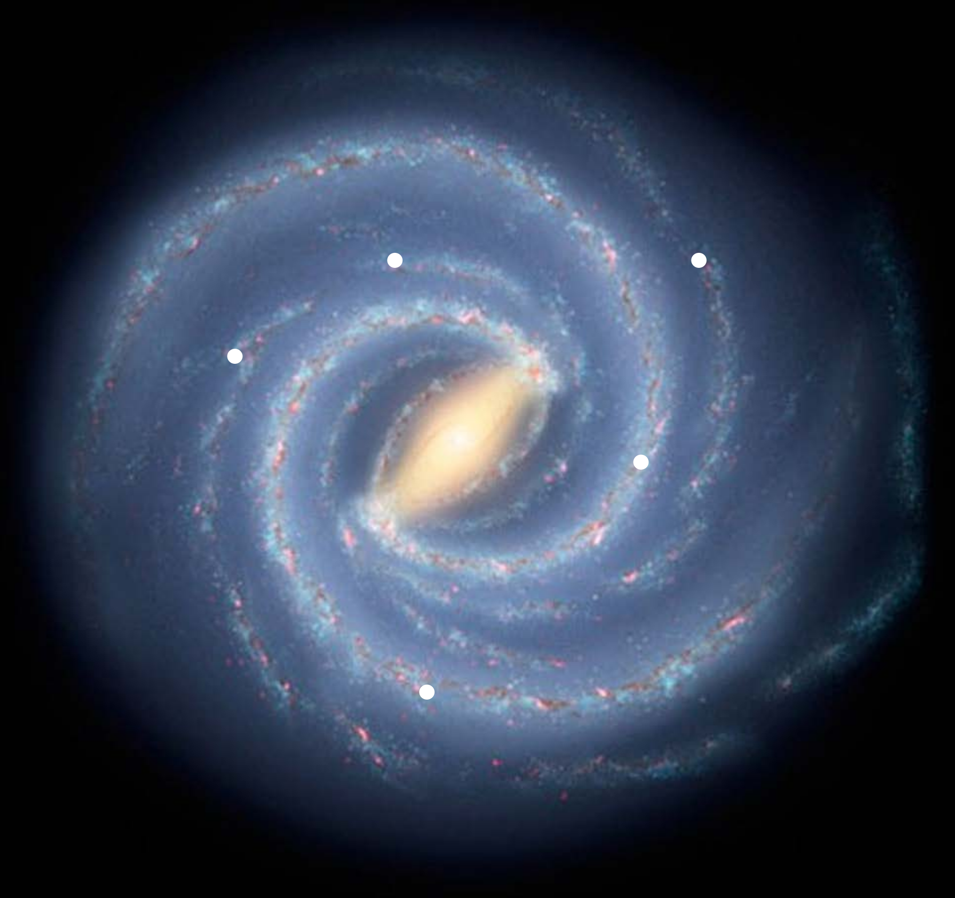
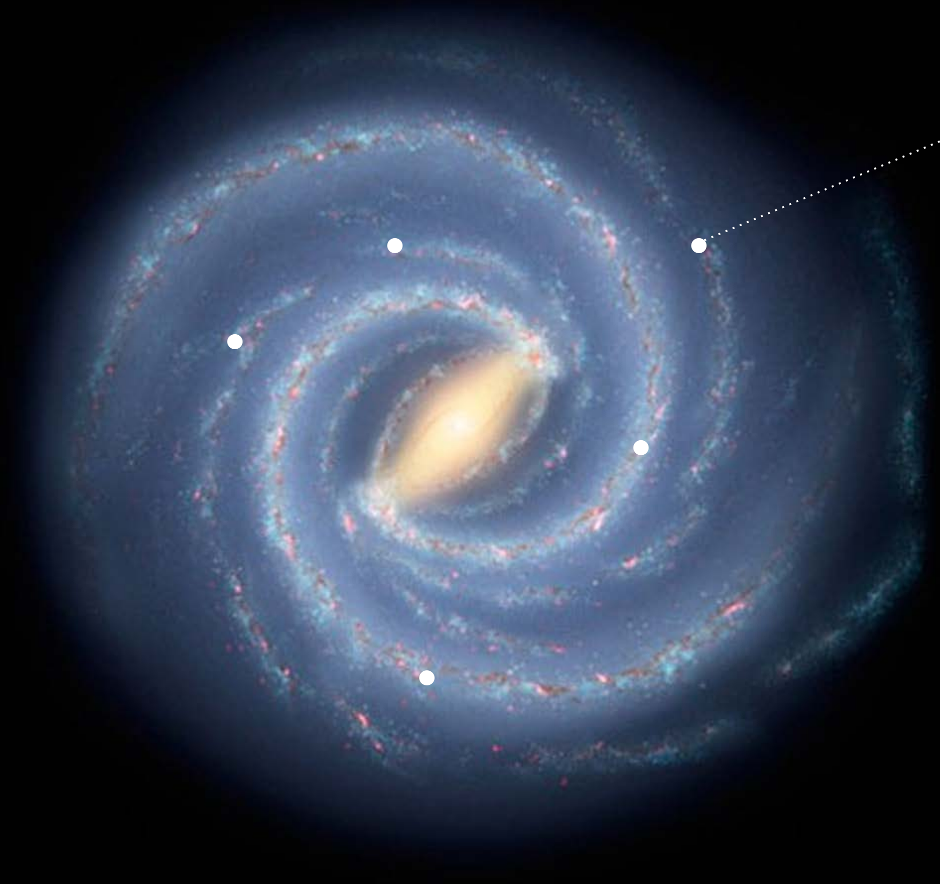


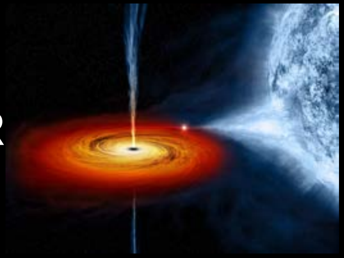
OBJETS STELLAIRES, QUASI-STELLAIRES ET LEUR ENVIRONNEMENT

STELLAR, QUASI-STELLAR OBJECTS, AND THEIR ENVIRONMENT

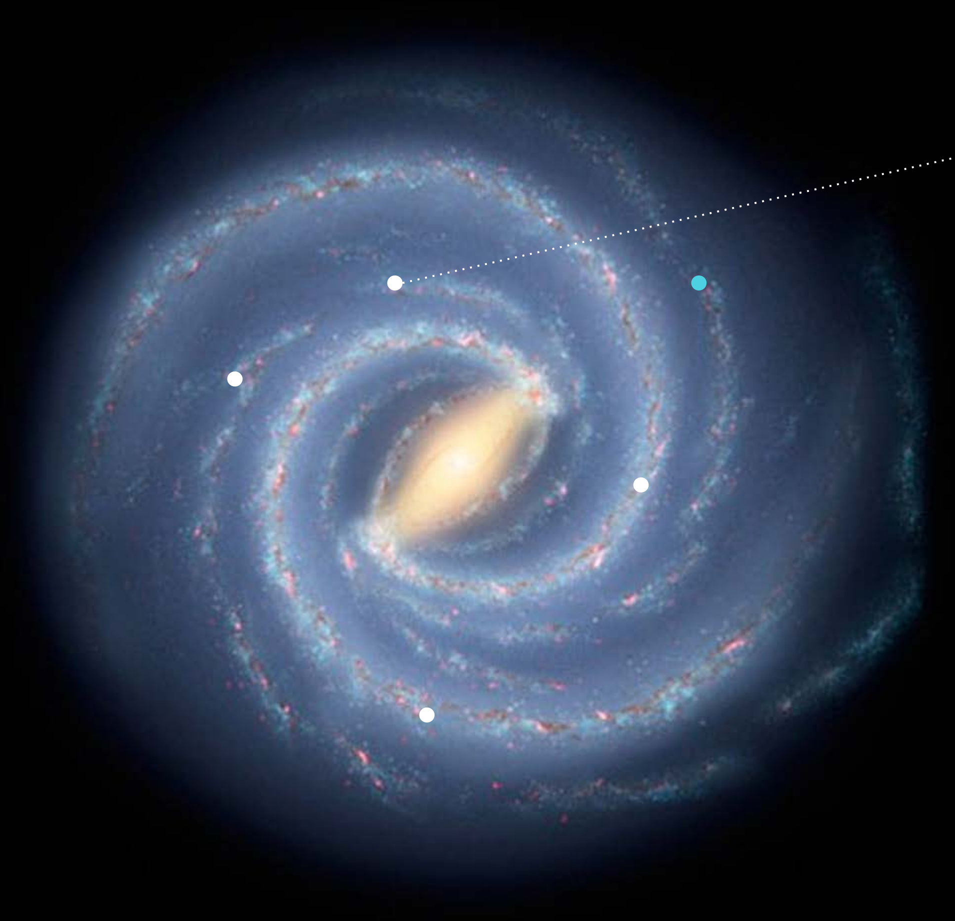




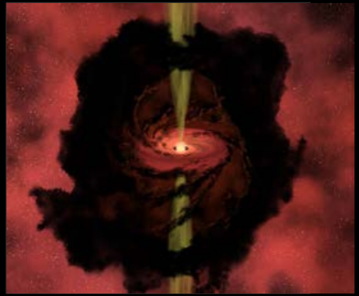
BLACK HOLE MICROQUASAR



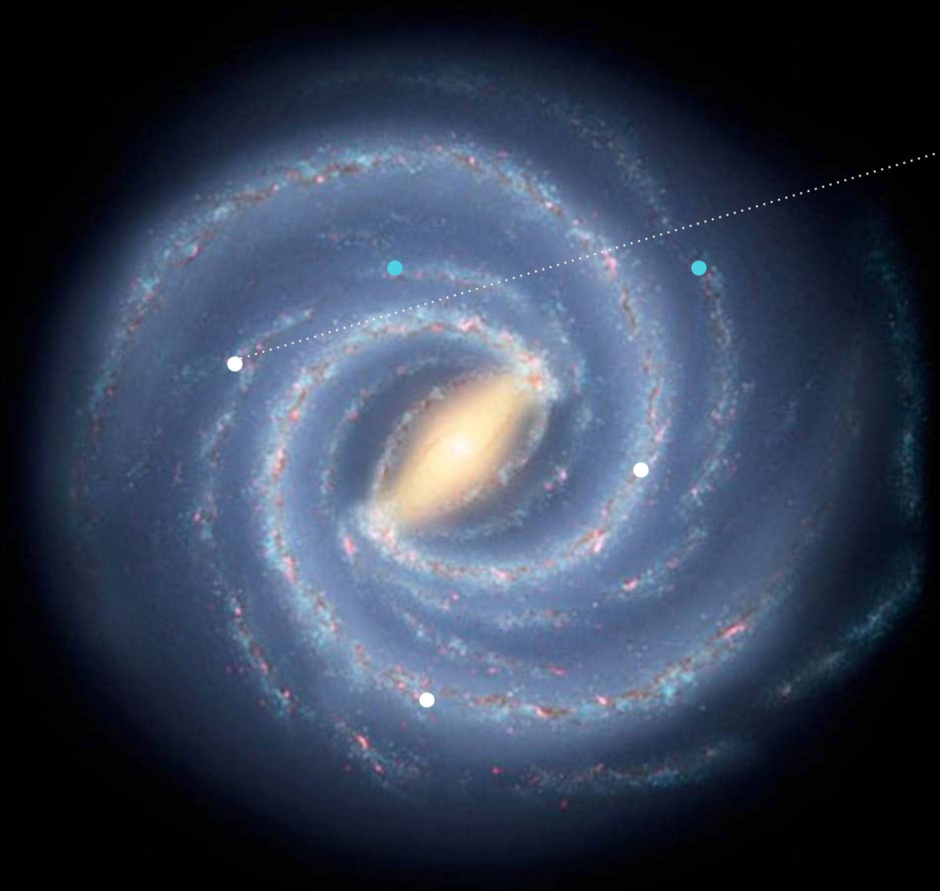
- SIZE | few kilometers
- AGE | End of life
- WAVELENGTH | X-ray Disk emission; Radio Jet
- ASPECT | Accretion disk and jets



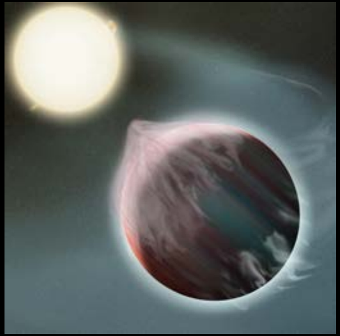
MASSIVE PROTOSTAR



- SIZE | 10^{8-13} km
- AGE | ~100 kyr
- WAVELENGTH | Infrared
  Dust thermal emission
- ASPECT |
  Something very dusty
  + outflows

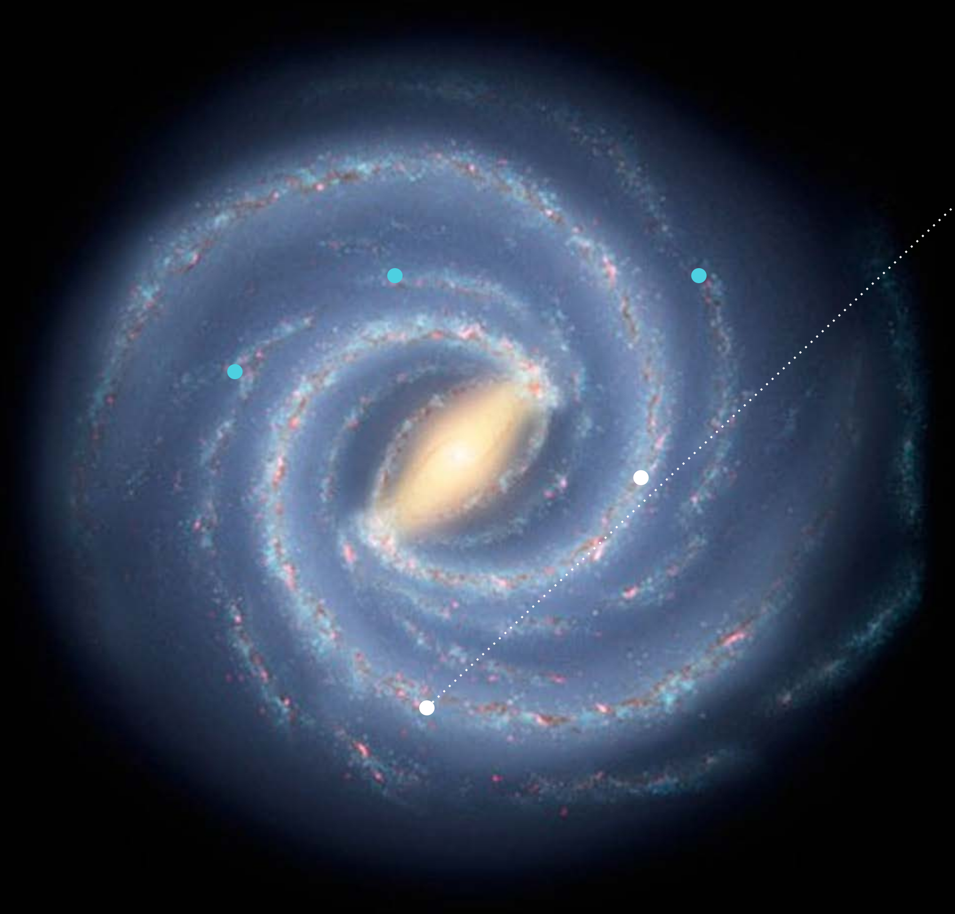


HOST LOW-MASS STAR

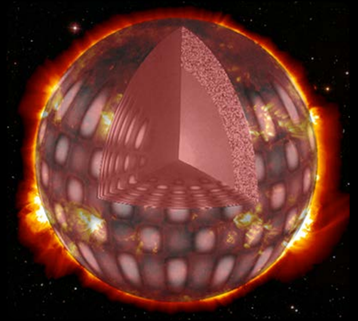


- SIZE | 10^8-10^9 km (~ R_{Sun})
- AGE | 100 Myr → 10 Gyr
- WAVELENGTH | Visible-Near infrared
- ASPECT |

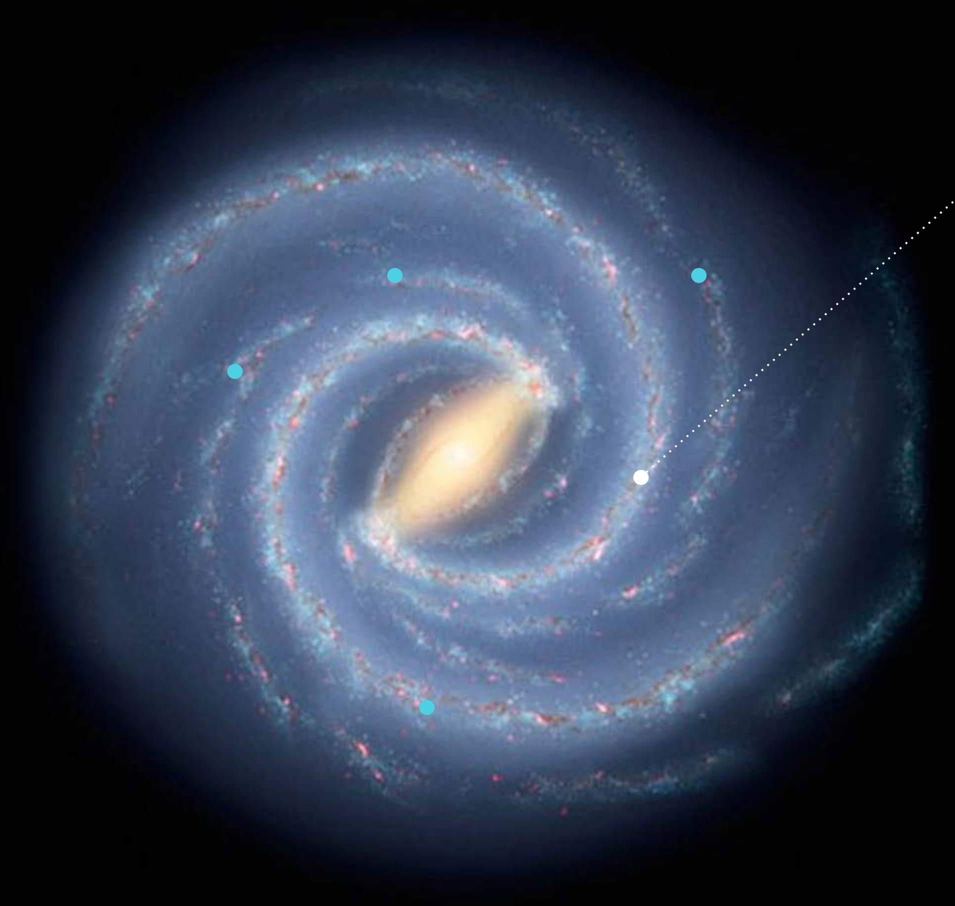
M-dwarf → the Sun
Closeby companion



RED GIANT



- SIZE | 10^6 - 10^8 km
- AGE | 5 - 10 Gy
- WAVELENGTH | Visible
- ASPECT | Big sun

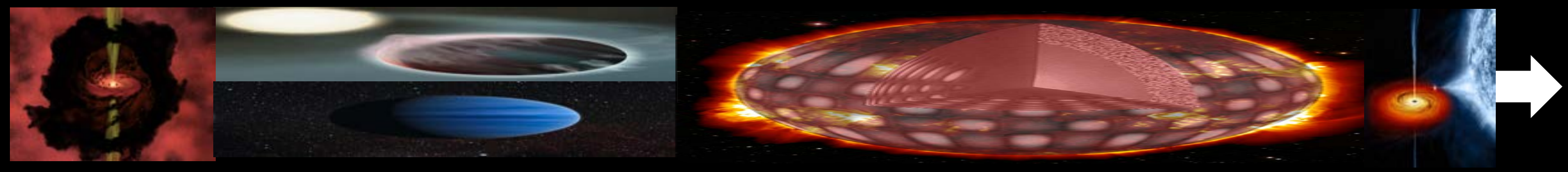


EXOPLANET

- SIZE | 10^3 - 10^4 km
- AGE | 2 Gy
- WAVELENGTH | Thermal-Infrared
- ASPECT | Planet
  Gas or rocky sphere
  Not very hot

INTRODUCTION YOUR CHOICE NOW!

A



B

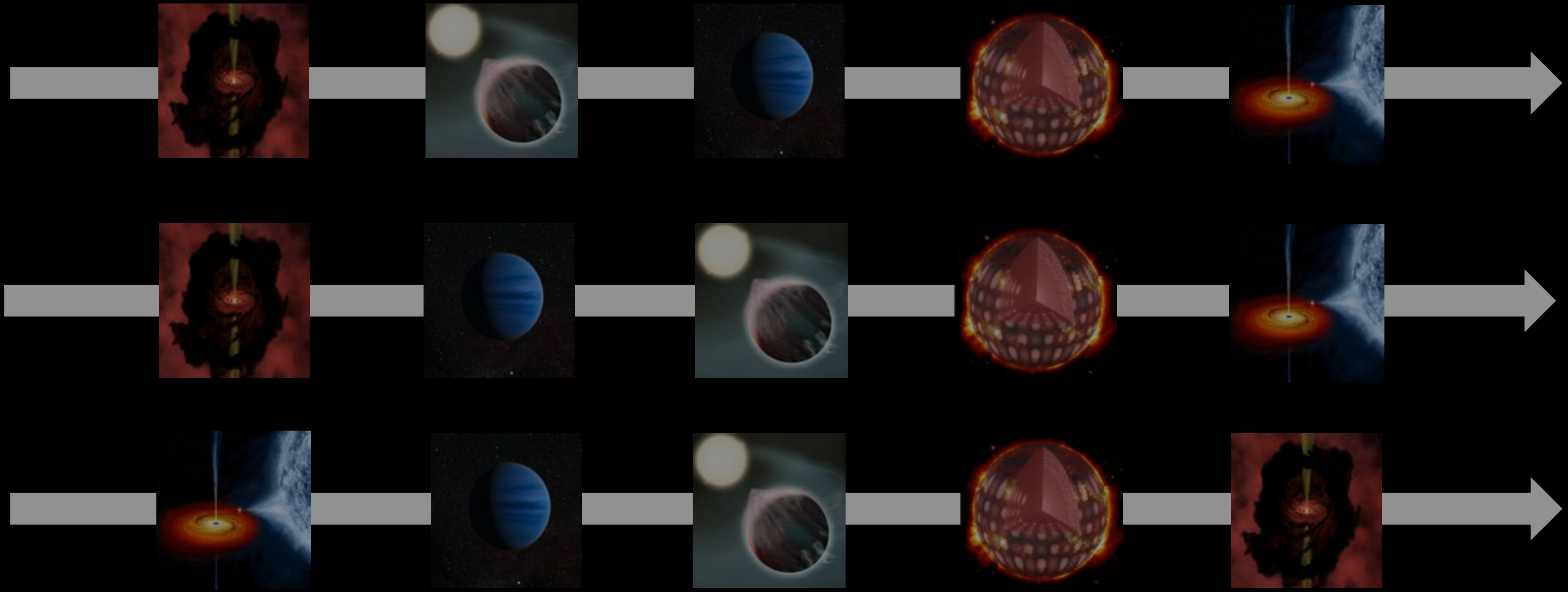
C

D

A

B

C



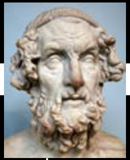
HISTORY !

D

INTRODUCTION HISTORY !

D |

1300 BC
| Ramses
| Egypt
| He’s a code now



800 BC
| Homère
| Greece
| First mention of Tidal effects

1571
| Kepler
| Germany
| Telescope

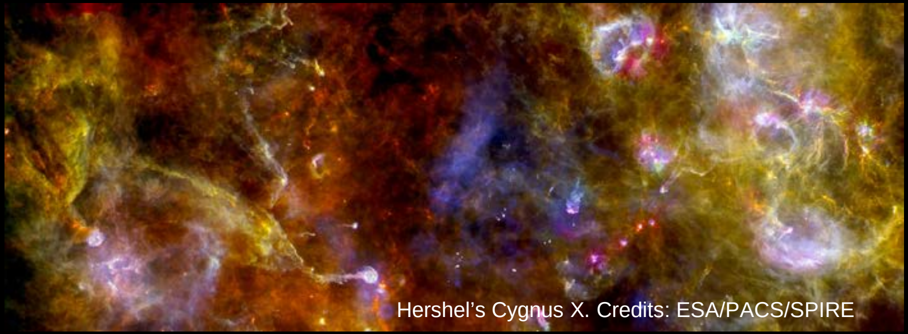
1686
| Leibniz
| Germany
| Publication of the basics of integral

1967
| James E. Webb
| USA
| Former NASA Administrator
Now a great telescope

STUDY OF MASSIVE STAR FORMATION

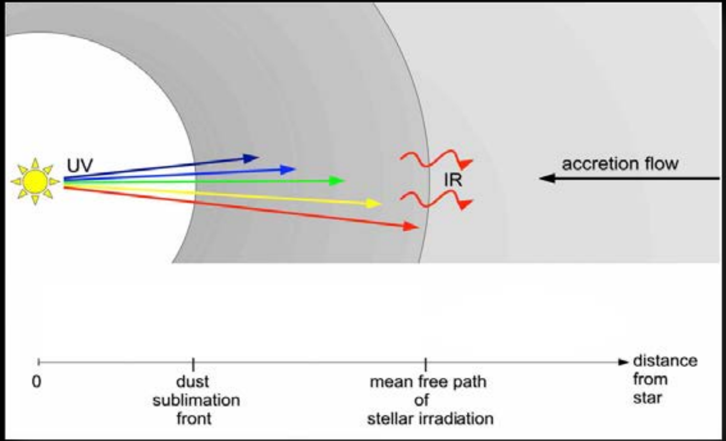
WHO

- ME | Raphaël Mignon-Risse
- ADVISOR | Matthias González
- LABORATORY | DAp/LMPA


Hershel's Cygnus X. Credits: ESA/PACS/SPIRE

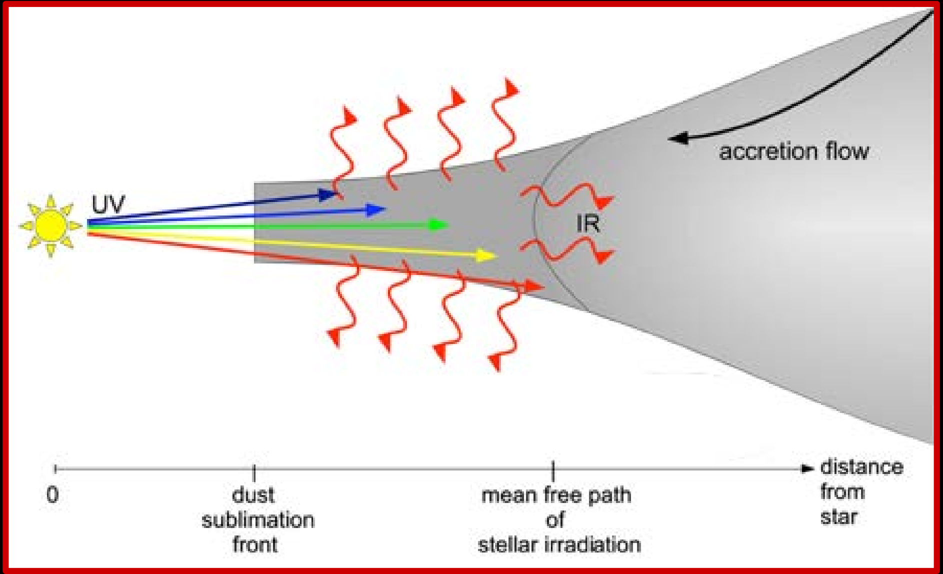
WANTED

- WHAT | >10 solar masses
- TYPE | GAS
- REASON | Radiative Pressure



Credits: Kuiper+10

$$F_{rad} > F_g \,?$$

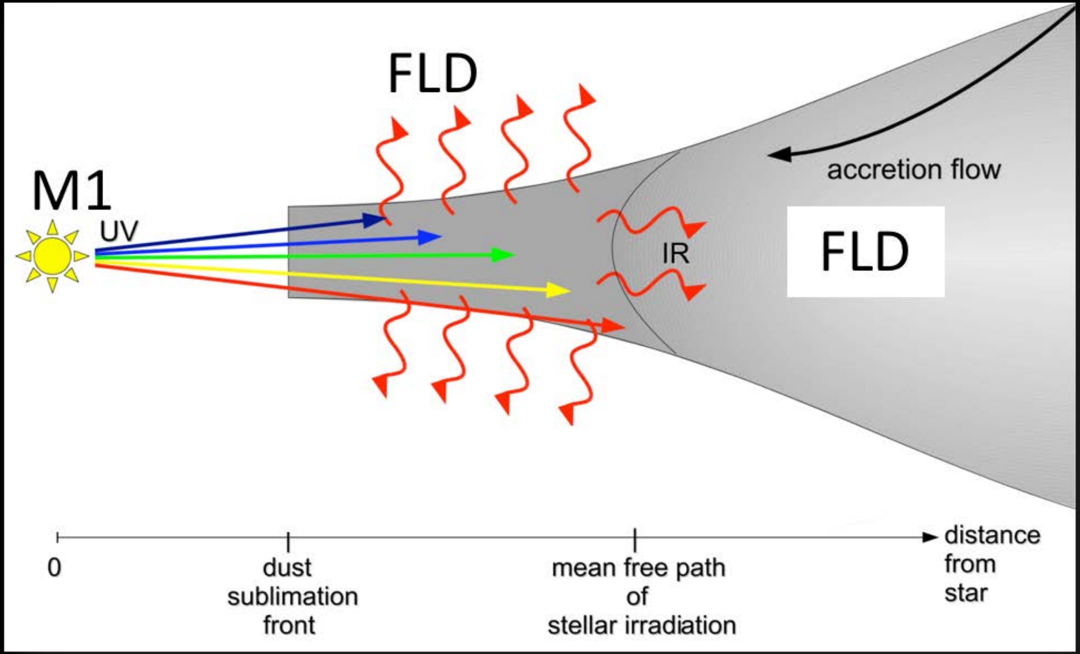


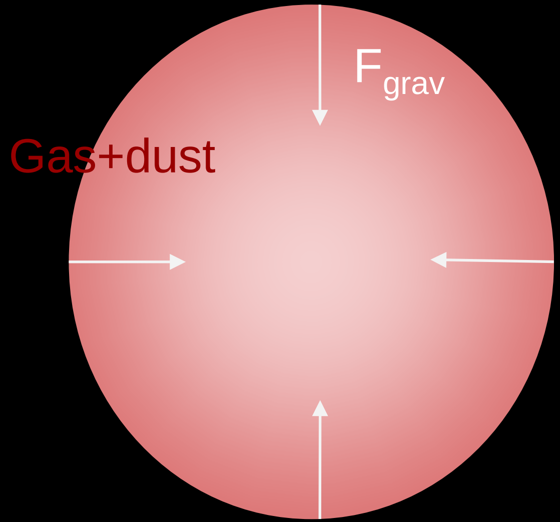
- 1D
  Spherical accretion
  Maximal mass : **40 $M_\odot$**

- 2D and 3D
  Disk accretion
  Maximal mass : **130 $M_\odot$**

- Flux-Limited Diffusion (FLD)
  Opaque medium
  Star-formation simulations

- M1 : RAMSES-RT
  Transparent medium
  Cosmological simulations





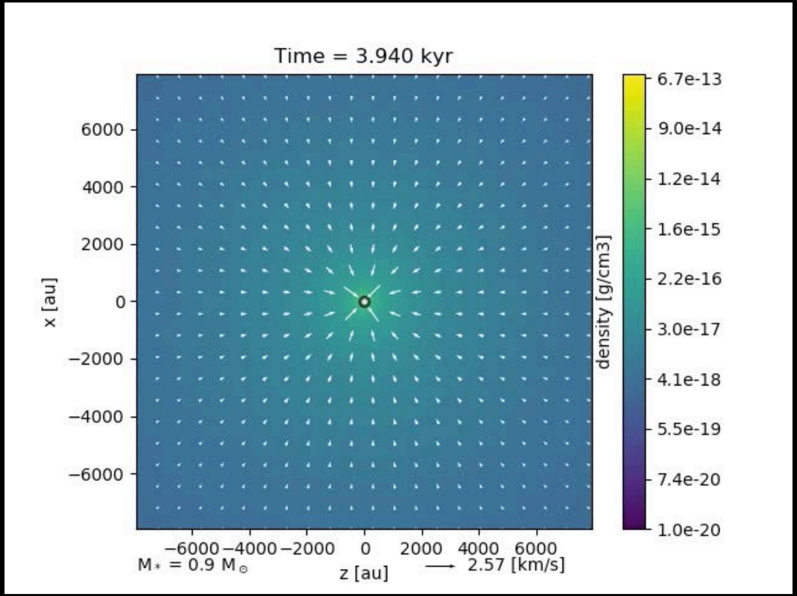
30AU = 

- Initial conditions
  - Mass: 150$M_\odot$, radius 40000 AU (10^{15}m)
  - Density profile $\rho(r) \propto 1/r^{1.5}$
  - Solid-body rotation
  - Resolution 20 AU = box/4000
    => adaptive mesh refinement

- 3D RAMSES code including:
  - Hydrodynamics
  - Radiative Transfer
  - Sink particles

30AU = 

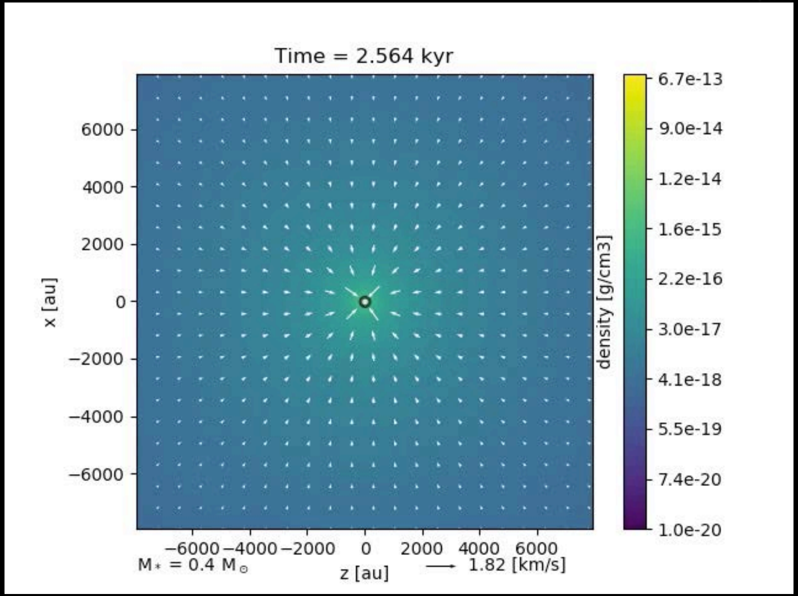
Flux-Limited Diffusion



- $M = 23.3\ M_\odot$

  Polar outflows launched for $M > 15\ M_\odot$

Hybrid



- $M = 17.6\ M_\odot$

  Polar outflows launched for $M > 12\ M_\odot$

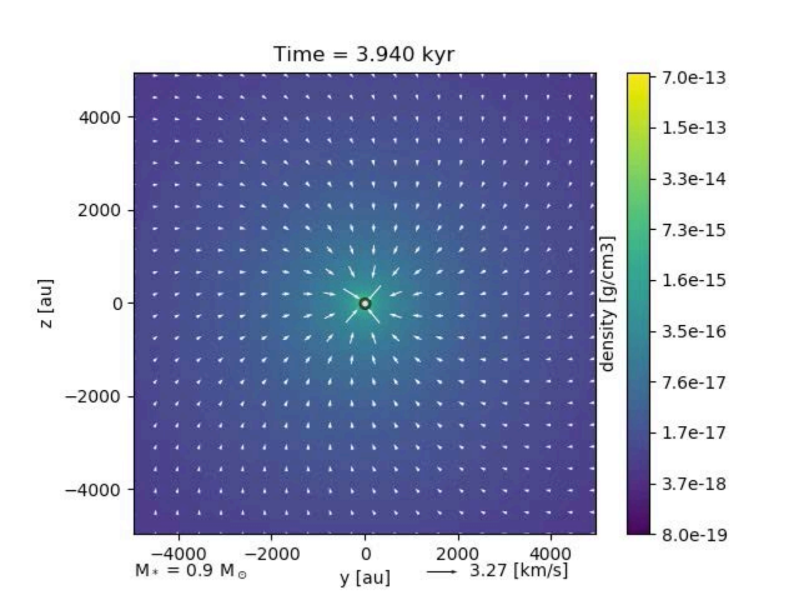
Larger radiative cavities (+50%)

Less massive star

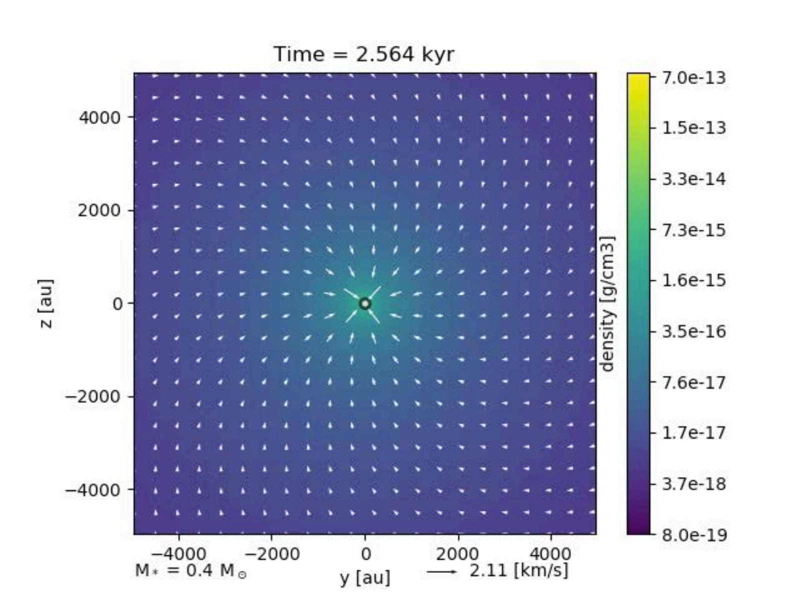
COLLAPSE OF A PRESTELLAR CORE : DISK MORPHOLOGIES

30AU = 

Flux-Limited Diffusion



Hybrid



➔ Multiplicity : 1 main star

➔ Disk $M_{disk} \sim 18\ M_\odot$

$R_{disk} \sim 700$ AU

➔ Accretion episodes

Similar disk properties

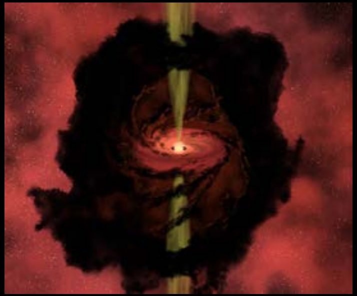
Consistent with previous studies

CONCLUSIONS AND PERSPECTIVES TOWARD MASSIVE STAR FORMATION

- Implementation of the Hybrid method
  - Valid in transparent and opaque media

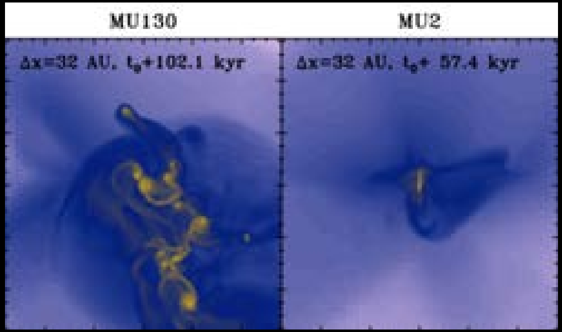
- Hybrid Radiative Transfer in a collapse simulation *(Mignon-Risse et al. in prep)*
  - ★ Stronger radiative outflows (+50% in extent)
  - ★ Less massive star
  - ★ Accretion rate and disk size consistent with previous studies

- Collapse with Non-Ideal Magneto-HydroDynamics *(Commerçon+11, González et al., in prep)*



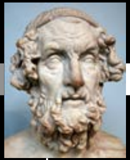
Magnetic and/or radiative outflows ?

Fragmentation Multiplicity ?



TIMELINE HISTORY !

D |



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| Publication of the basics of integral

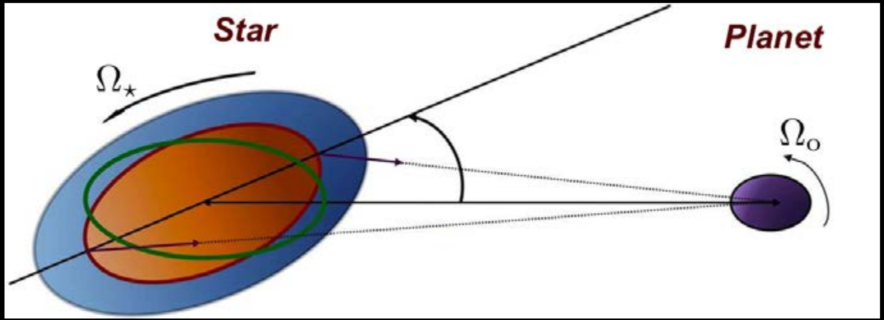
1967
| James E. Webb
| USA
| Former NASA Administrator
Now a great telescope

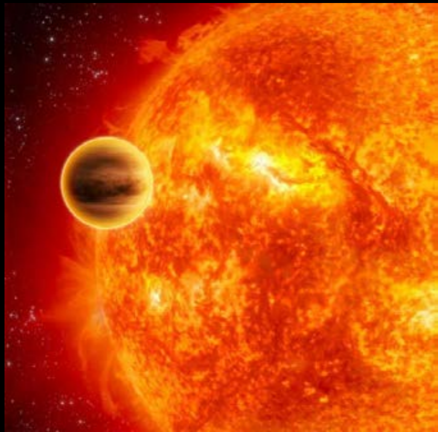
WHO

- ME | Aurélie Astoul
- ADVISOR | Stéphane Mathis
- LABORATORY | DAp/LDE3

WANTED

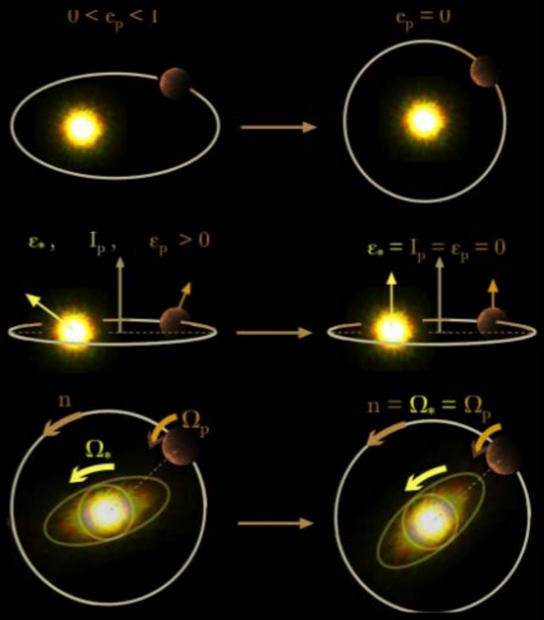
- WHAT | Tidal interactions
- TYPE | Hot-Jupiter systems
- WHY | Understand the formation of tight exoplanetary systems

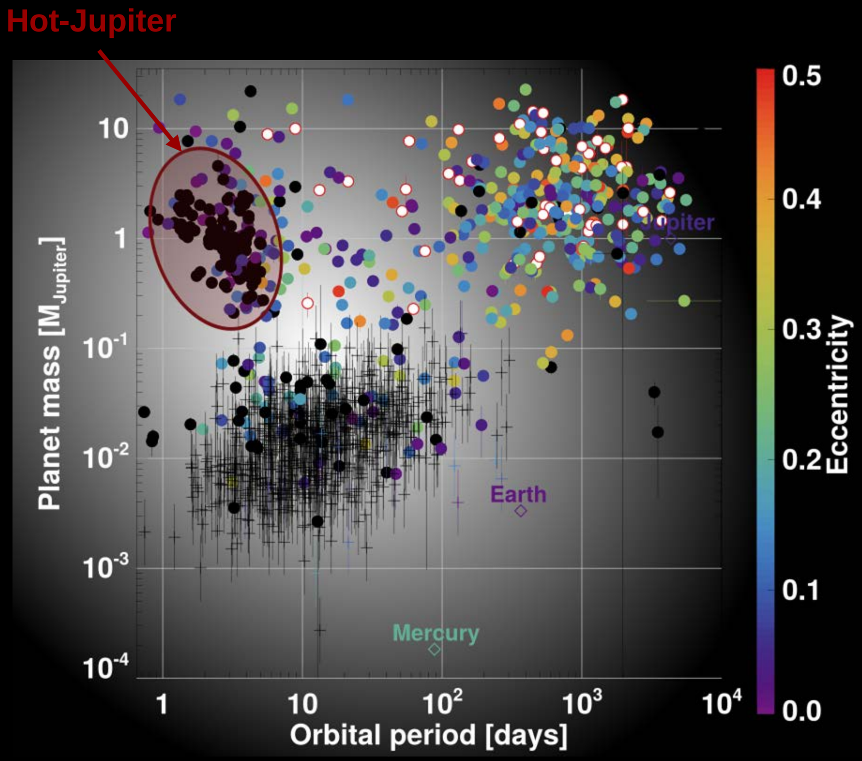




- many close-in star-planet systems ↠ tidal interactions are important

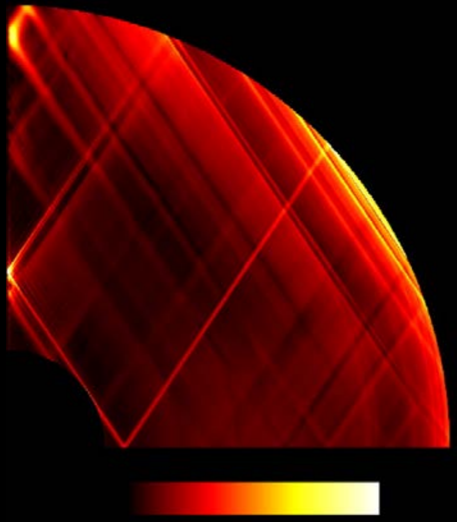
↪ Long term effects on the orbital architectures and on the stellar/planetary rotations:





STATE OF THE ART

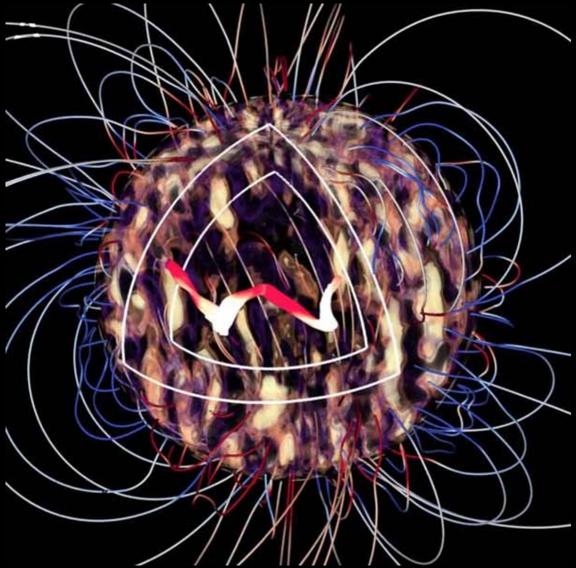
Simulation of tidally-excited waves in a stellar convective envelope



Ogilvie & Lin 2004

DOES STELLAR MAGNETISM IMPACT TIDAL WAVES?

Modelisation of a stellar magnetic structure

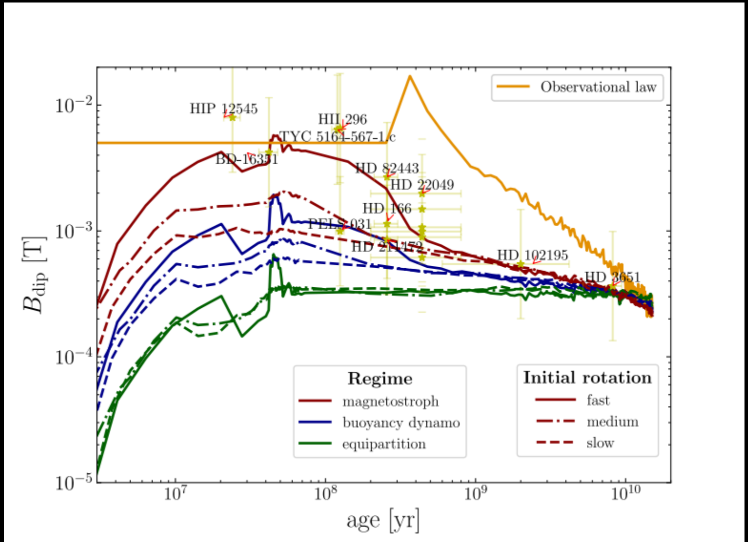


Strugarek+ 2017

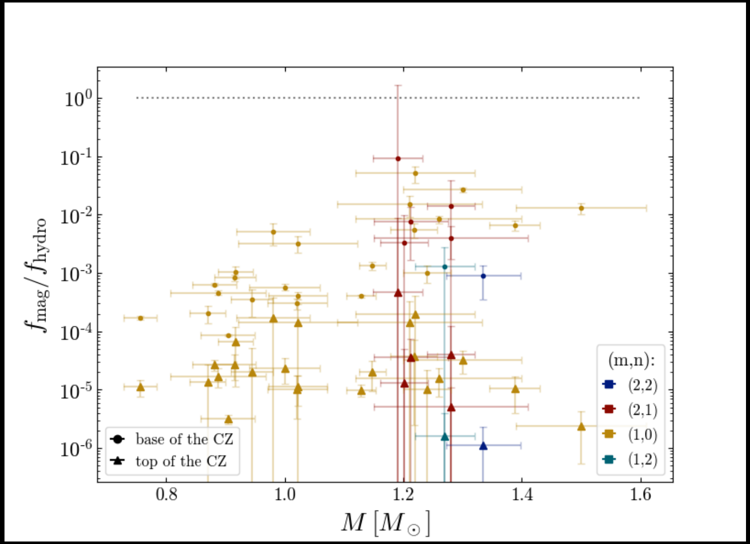
1) The effect of stellar magnetic fields on tidal excitation:

$$\underbrace{\rho(\partial_t \mathbf{u} + 2\boldsymbol{\Omega} \times \mathbf{u}) + \boldsymbol{\nabla} p - \rho\nu\Delta\mathbf{u} - \mathbf{F}_{\mathrm{L}}}_{\text{Wave-like part}} = \underbrace{f_{\mathrm{hydro}} + f_{\mathrm{mag}}}_{\text{Tidal forcings}}$$

⋆ Simple scaling laws to estimate a mean magnetic field



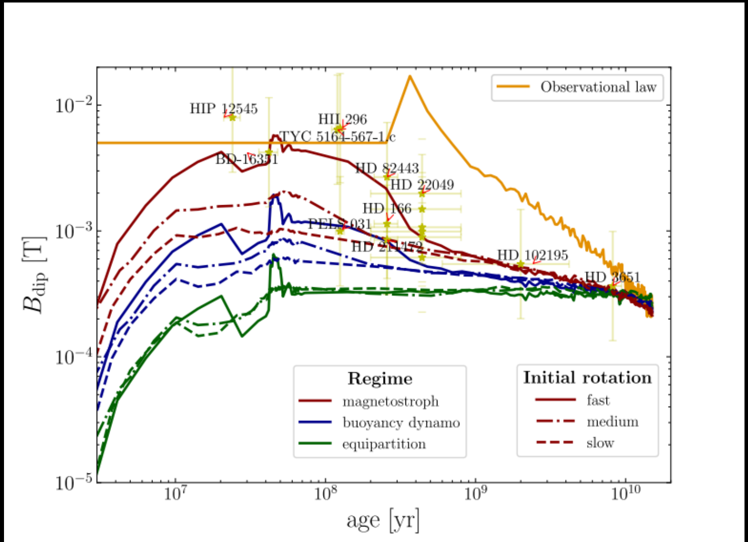
⋆ The contribution of magnetism to tidal forcing



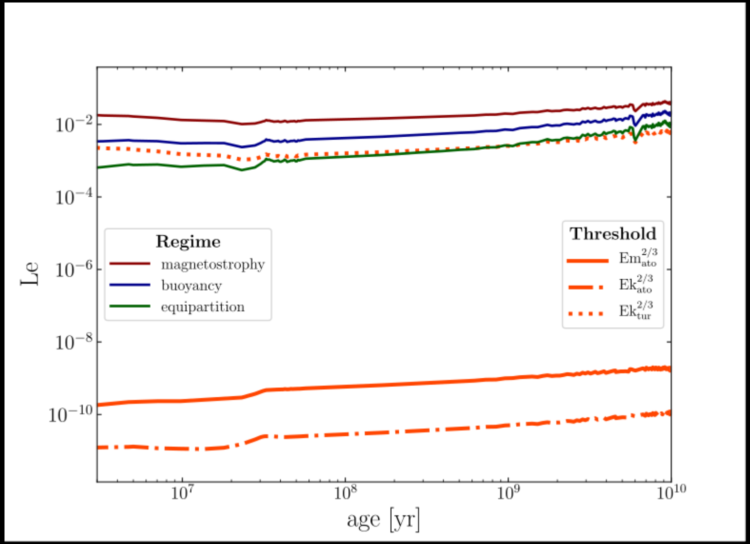
2) The effect of stellar magnetic fields on tidal propagation and dissipation:

$$\begin{cases} \rho(\partial_t \mathbf{u} + 2\boldsymbol{\Omega} \times \mathbf{u}) + \boldsymbol{\nabla} p - \rho\nu\Delta\mathbf{u} - \mathbf{F_L} = f_{\text{hydro}} \\ \partial_t \mathbf{b} = \boldsymbol{\nabla} \times (\mathbf{u} \times \mathbf{B}) + \eta\boldsymbol{\Delta}\mathbf{b} \end{cases}$$

⋆ Simple scaling laws to estimate a mean magnetic field



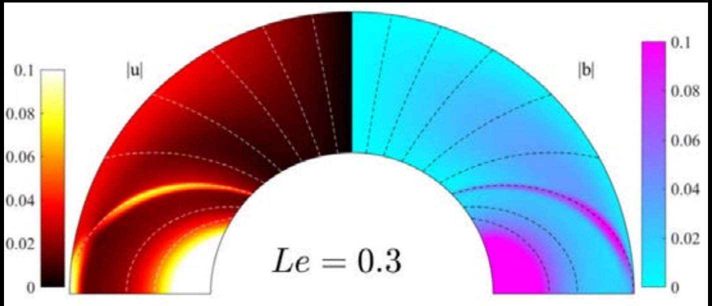
⋆ The contribution of magnetism to tidal dissipation



⊖ Large-scale magnetic field have a limited impact on the forcing of tidal waves in the convective zone of low-mass stars.

✔ Magnetism has a strong influence on the inertial tidal waves propagation and dissipation.

⇢ MHD treatment of tidal waves



Lin & Ogilvie 2018

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D

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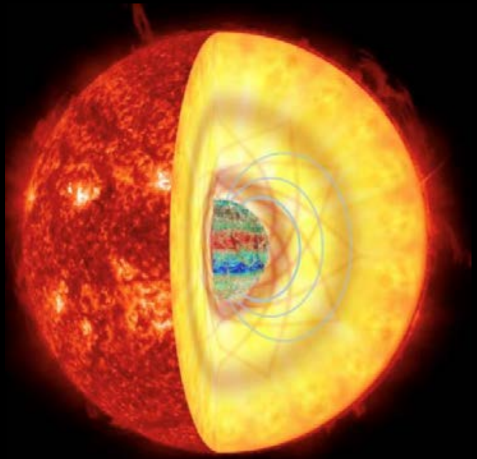
1967
| James E. Webb
| USA
| Former NASA Administrator
Now a great telescope

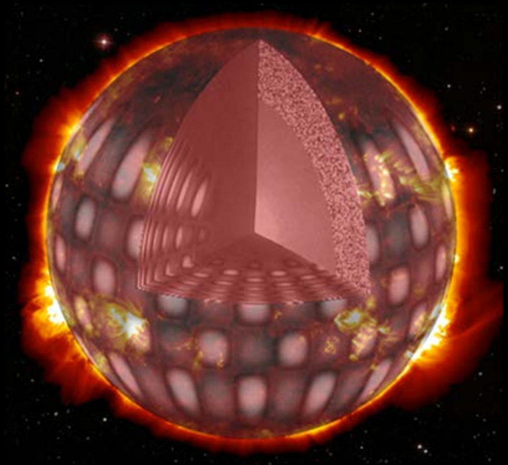
WHO

- ME | Lisa Bugnet
- ADVISOR | Rafael A. García
- LABORATORY | DAp/LDE3

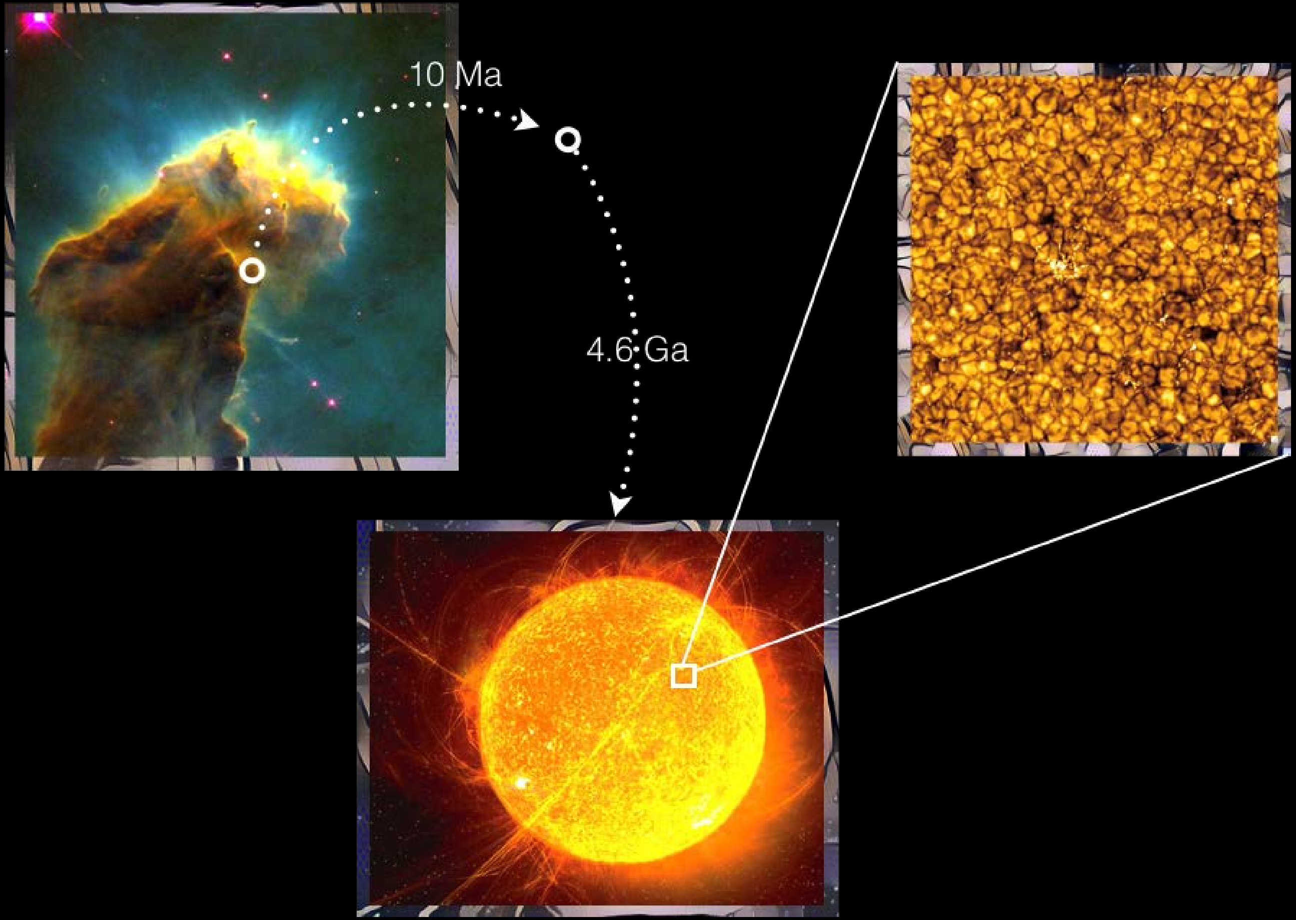
WANTED

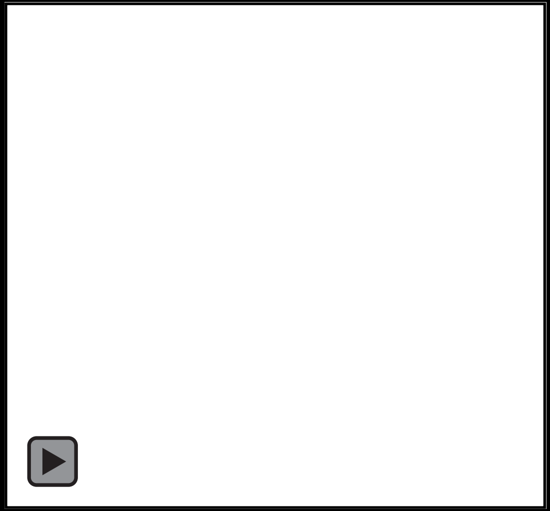
- WHAT | A SOUND WAVE
- TYPE | *KEPLER* DATA: Fourier spectrums
- PROBLEM| Which internal process is responsible for the lake of oscillation in some red giants ?





ASTEROSEISMOLOGY TO UNDERSTAND STARS DYNAMICS





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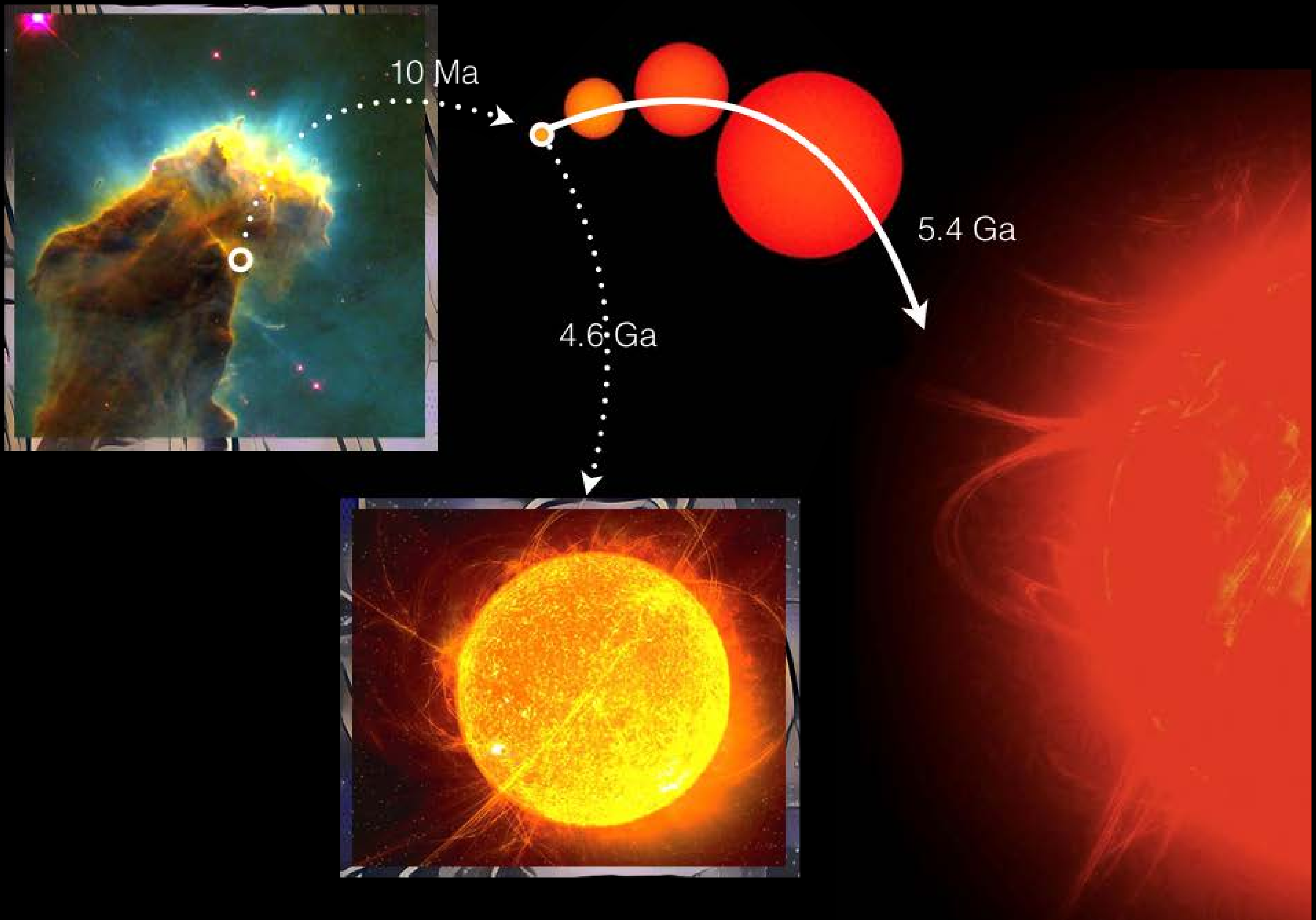


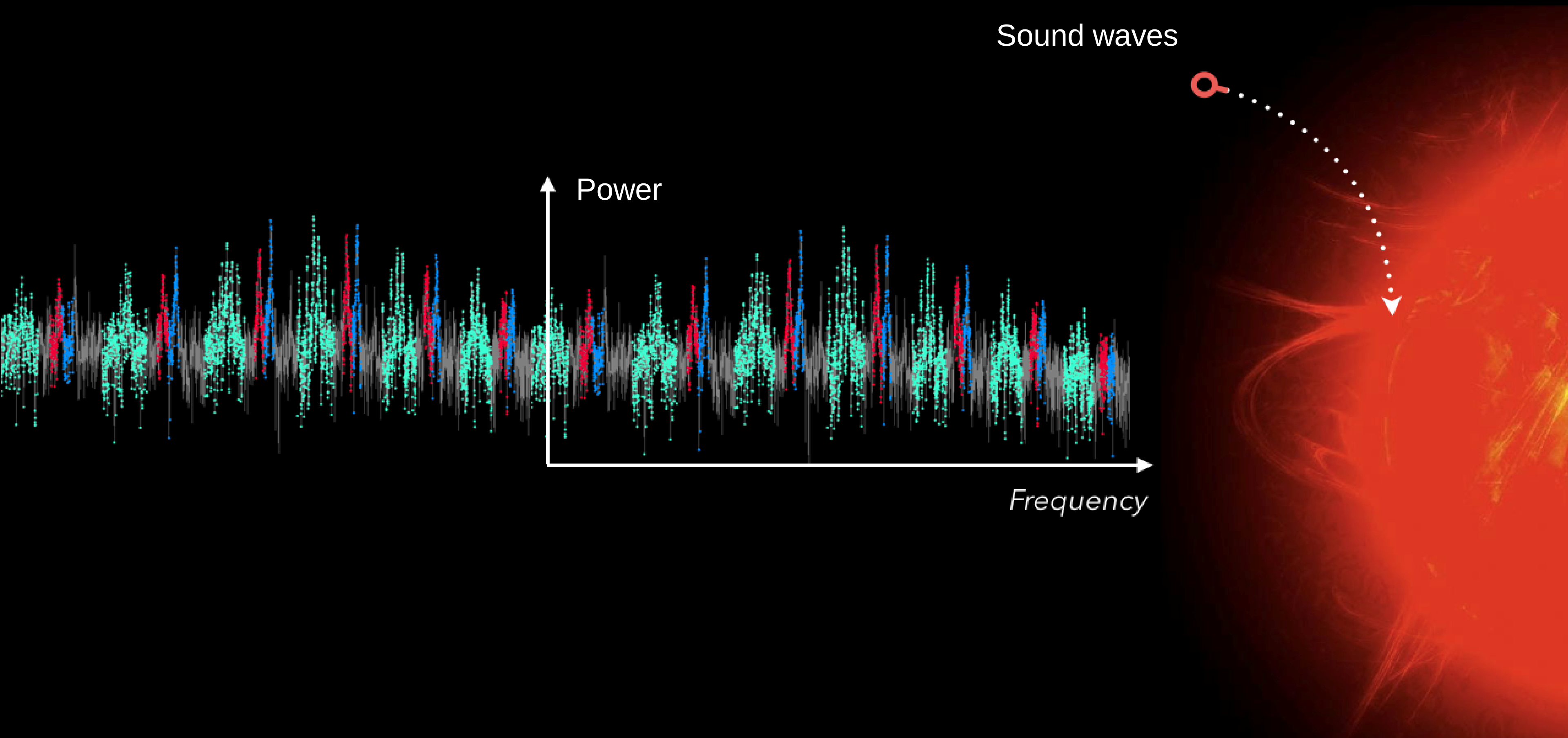
Classification of ~200,000 stars observed by *Kepler* with machine learning algorithms
[Bugnet et al. 2019]

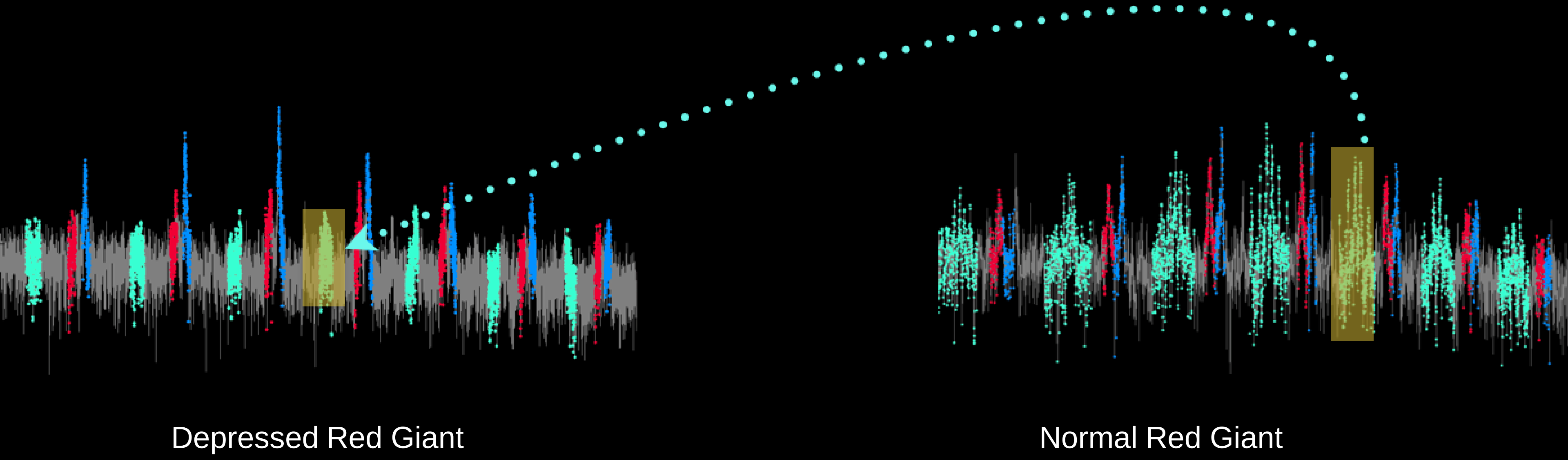
+

Characterisation of red giants
[Bugnet et al. 2018]

~ 30,000 red giants to be studied

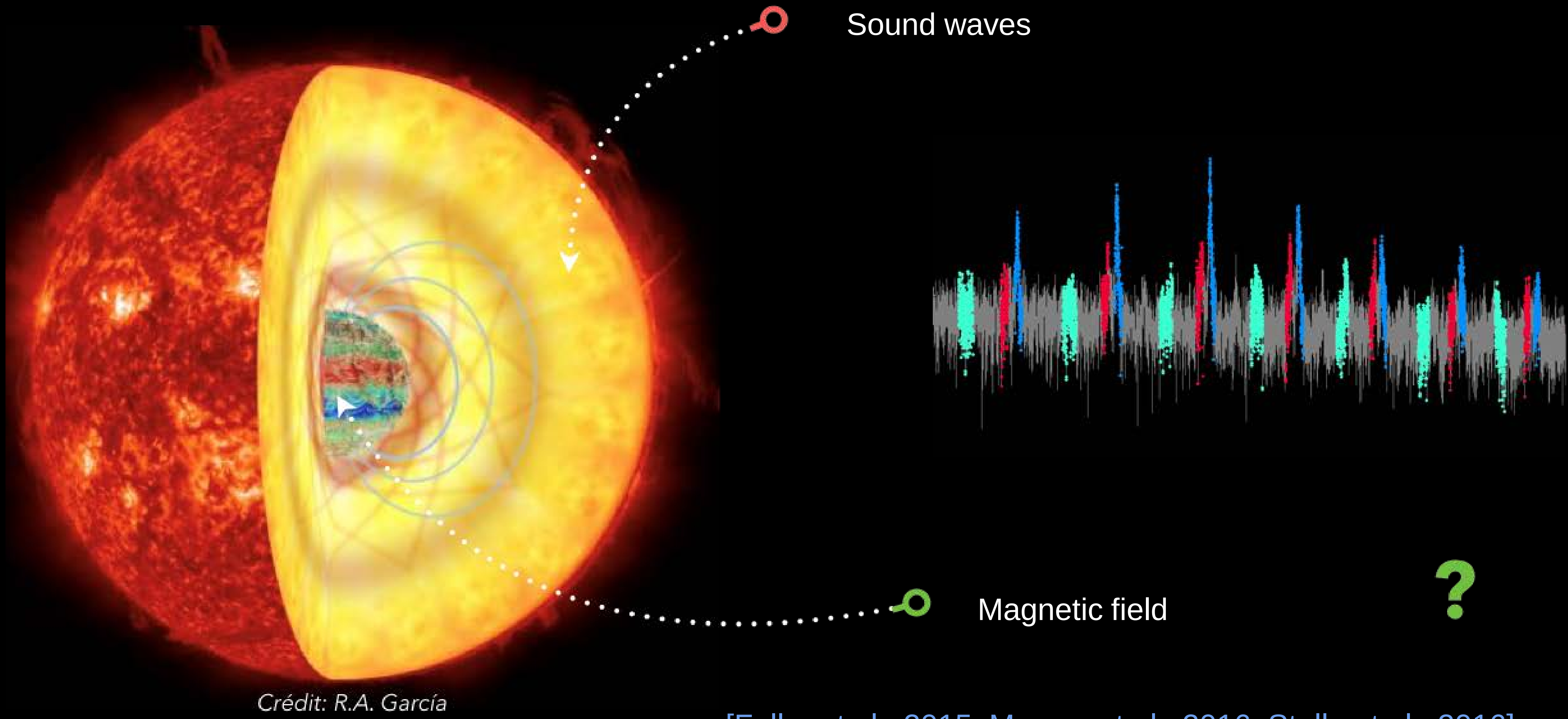
ASTEROSEISMOLOGY TO UNDERSTAND STARS DYNAMICS





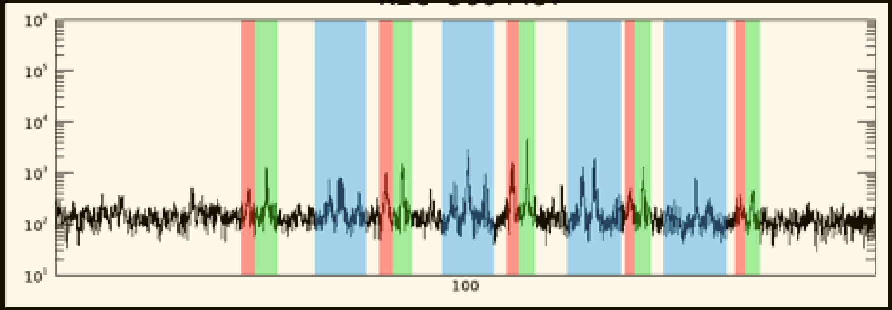
Quel est le phénomène à l'origine de la non-détection des modes d'oscillation de certaines géantes rouges ?

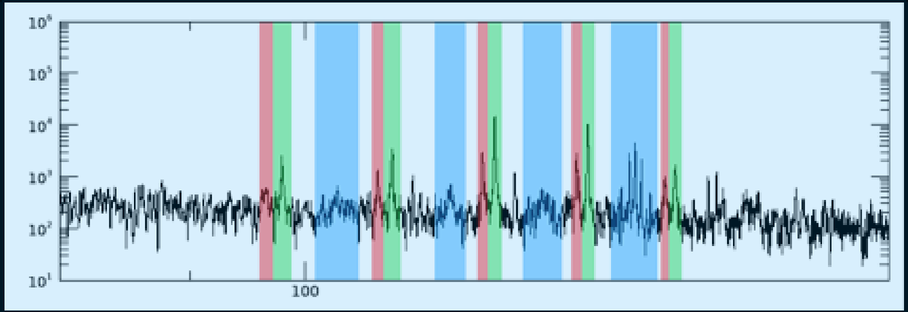
ASTEROSEISMOLOGY TO UNDERSTAND STARS DYNAMICS

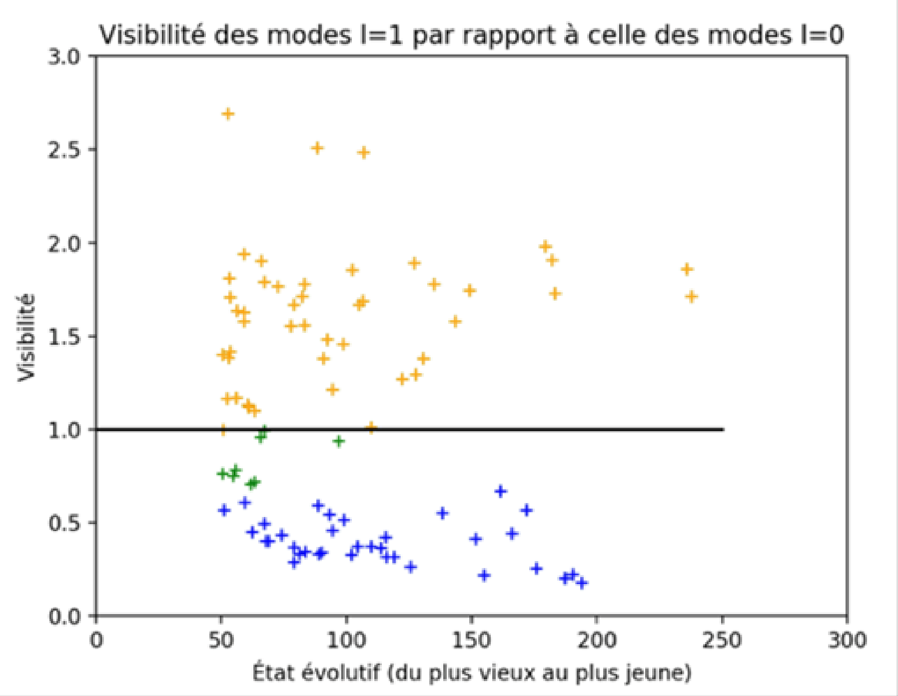


[Fuller et al., 2015, Mosser et al., 2016, Stello et al., 2016]

ASTEROSEISMOLOGY TO UNDERSTAND STARS DYNAMICS

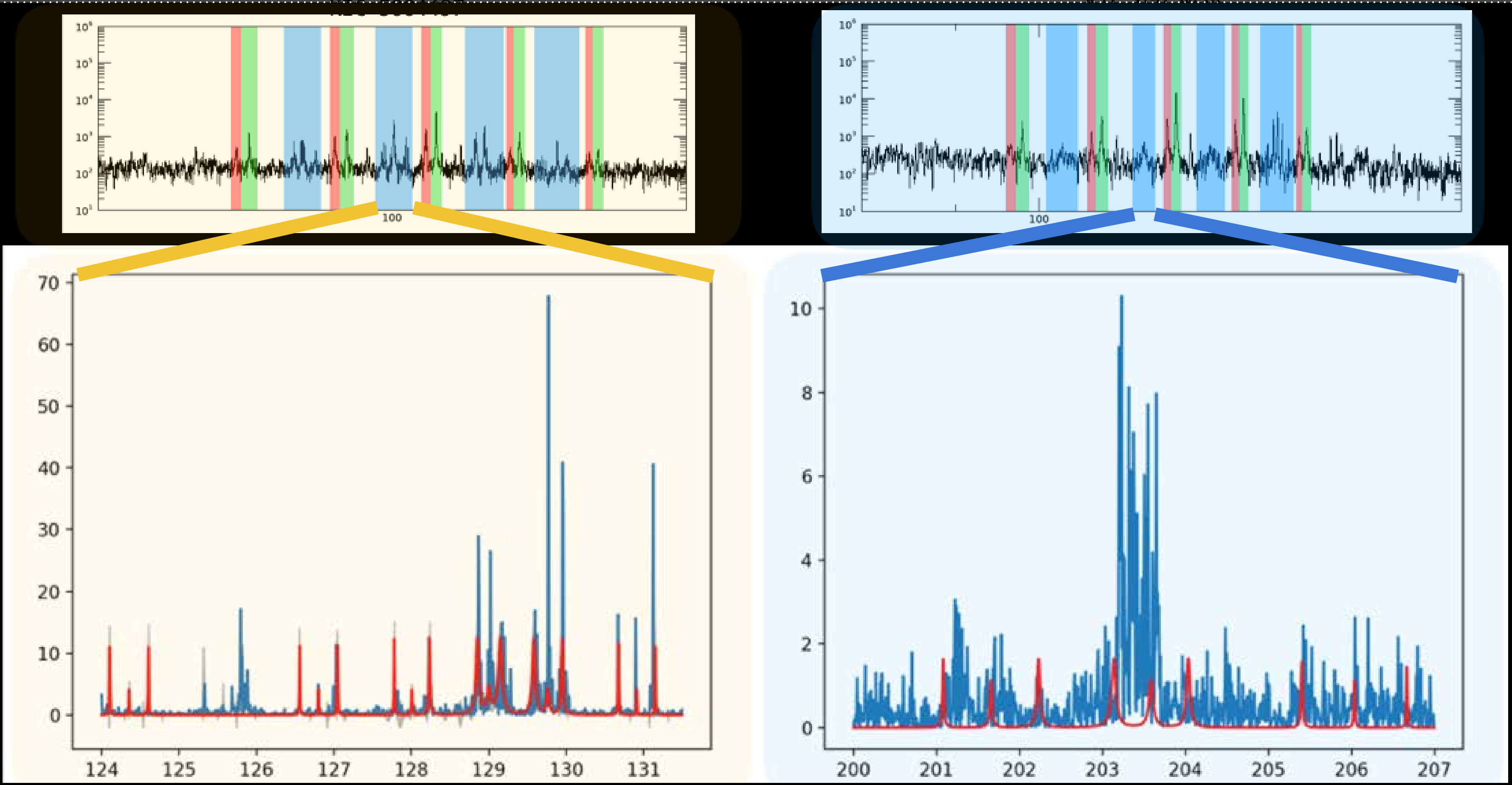






[method from Stello et al., 2016]

ASTEROSEISMOLOGY TO UNDERSTAND STARS DYNAMICS



- CONCLUSIONS |
  MACHINE LEARNING to detect red giants observed by *Kepler:* **DONE**
  Detection of depressed red giants: **DONE** (with the help of Arthur Le Saux)

- PERSPECTIVES |
  Theoretical model of oscillation frequencies in presence of a strong internal magnetic field
  Bayesian fitting of the new model on real data

- FUTURE MISSIONS | TESS NASA 2018, PLATO M2 ESA 2024

Where does the magnetic field come from ? Dynamo ? Fossil field ?

Where does it go ? magnetised white dwarfs…

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1967
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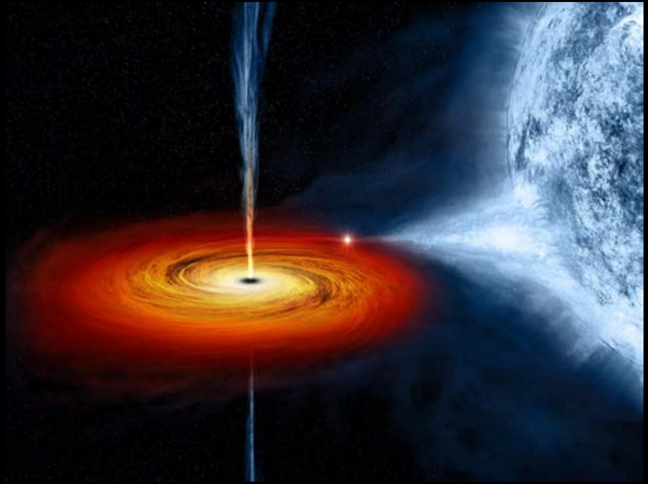
Now a great telescope

WHO

- ME | Floriane CANGEMI
- ADVISOR | Jérôme Rodriguez
- LABORATORY | DAp/LEPCHE

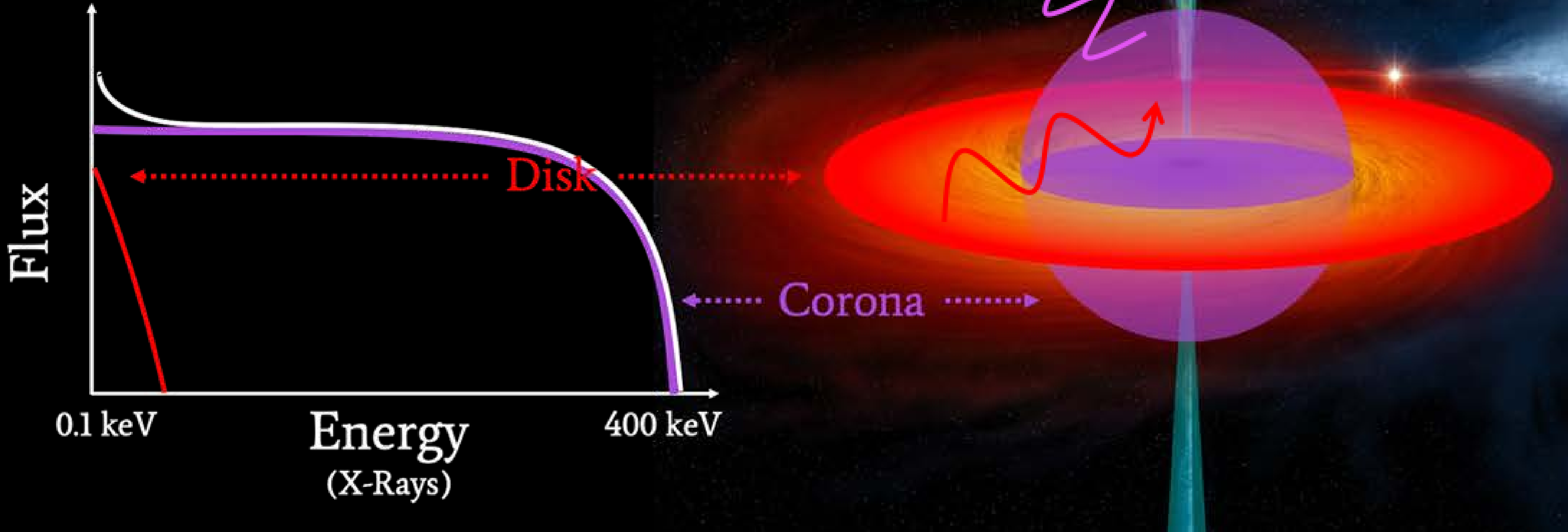


WANTED

- WHAT | black hole microquasars
- TYPE | observations X (INTEGRAL)
- PROBLEM | Physics of accretion-ejection?

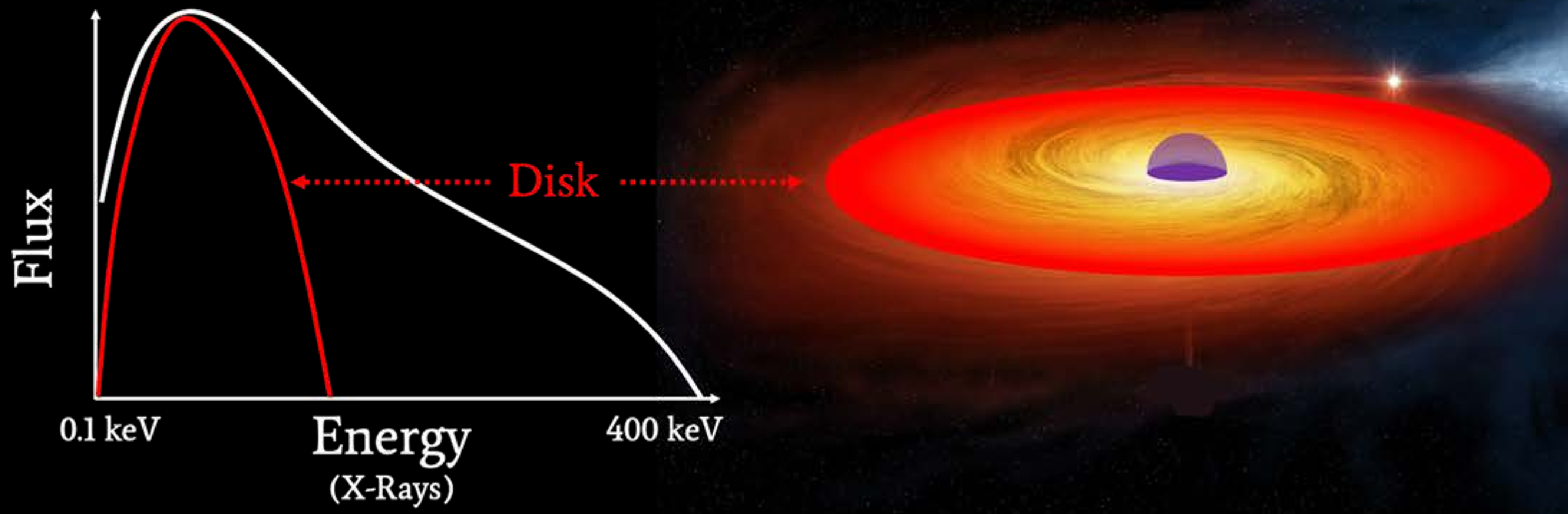
The Hard State

- Corona emission (Inverse Compton)
- Presence of radio jets
- Cold disk (0.1 keV)

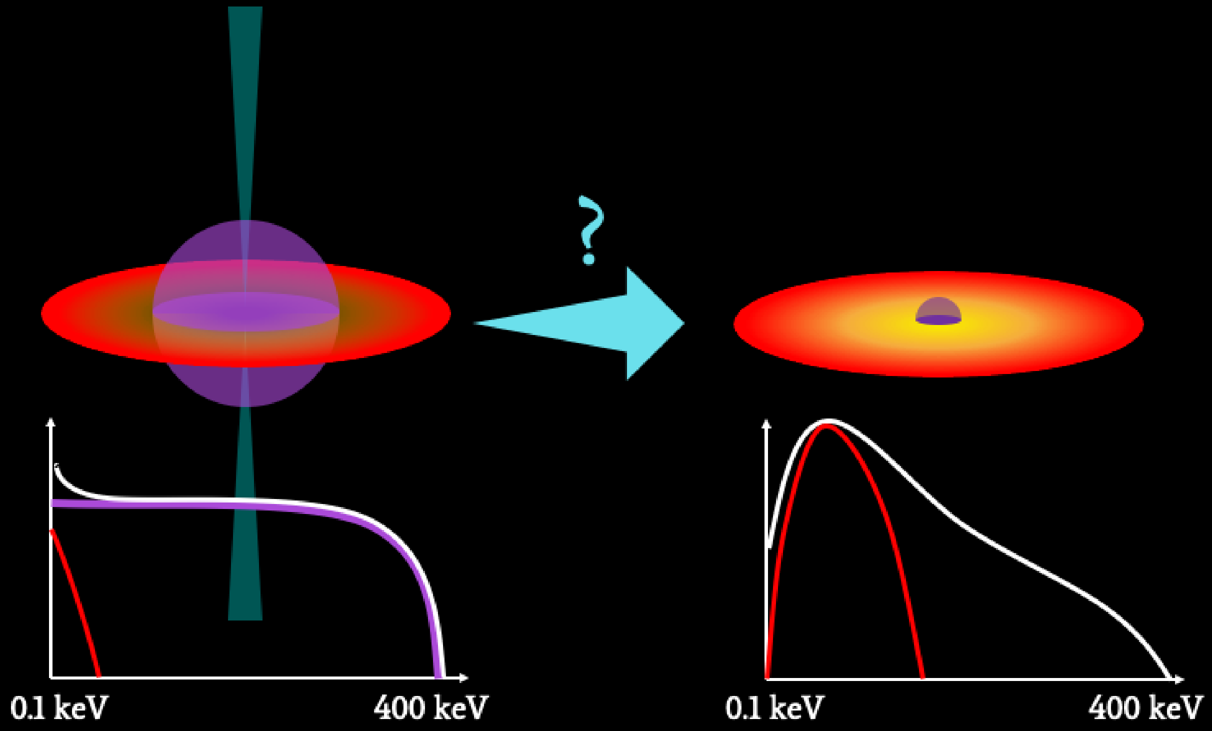


BLACK HOLE SPECTRAL STATES

The Soft State
- No jets
- Hotter disk (1 keV)



Behavior of the various components?



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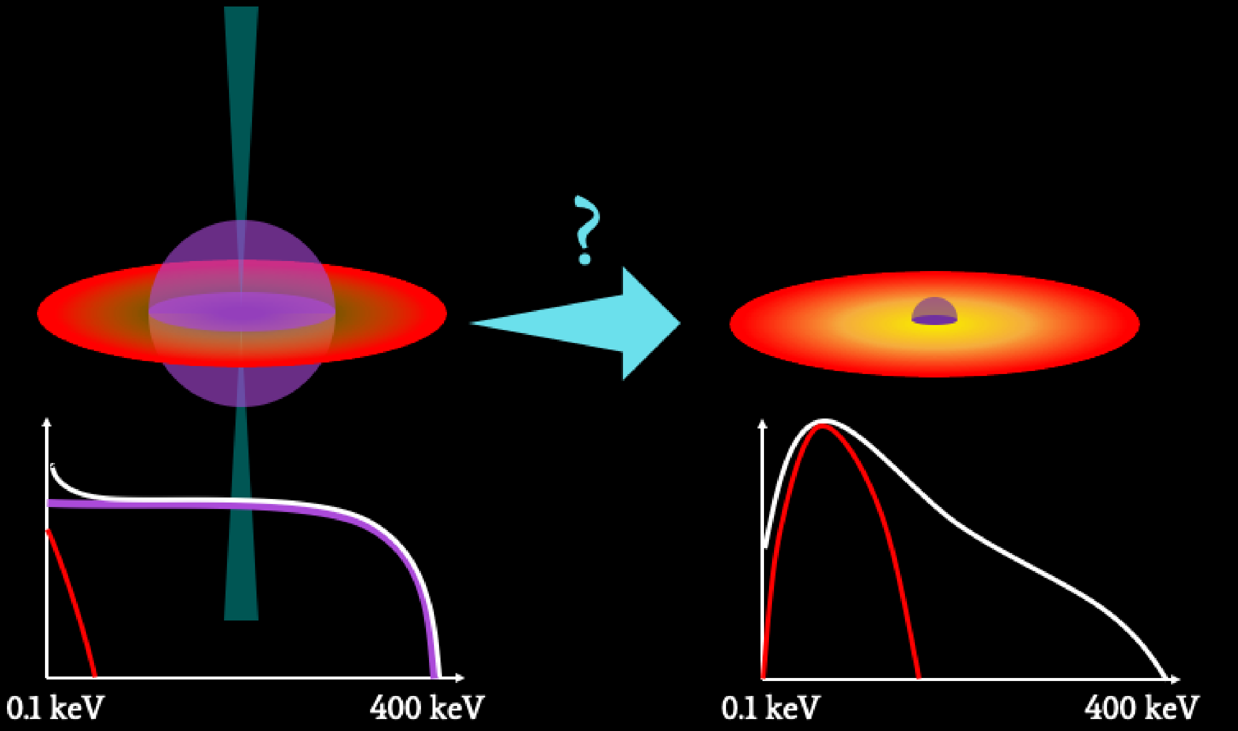
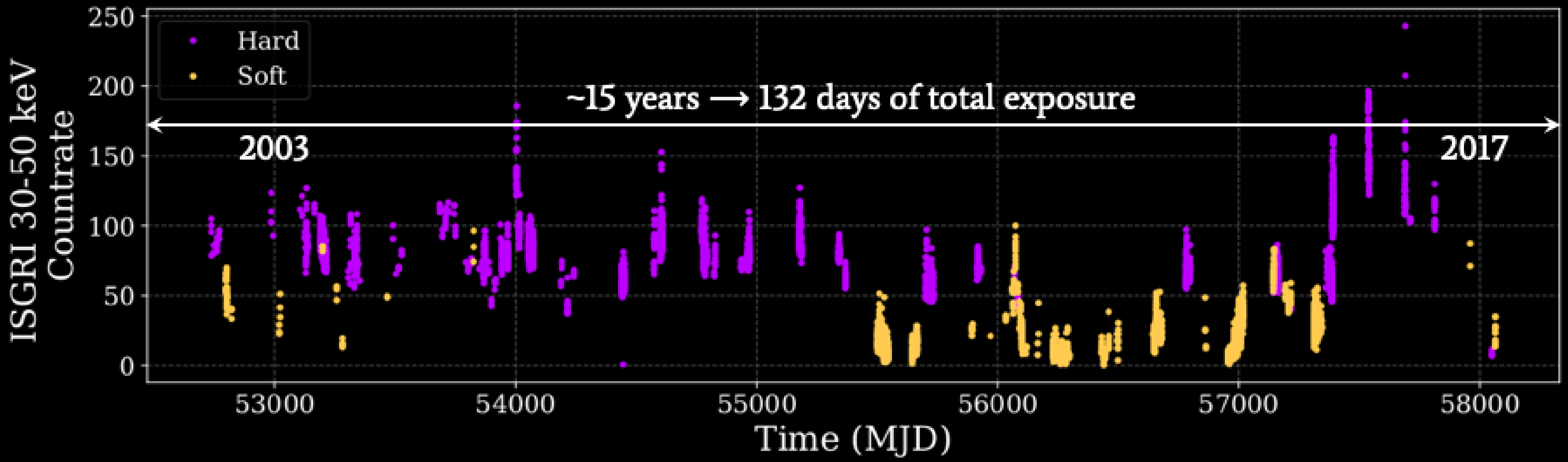


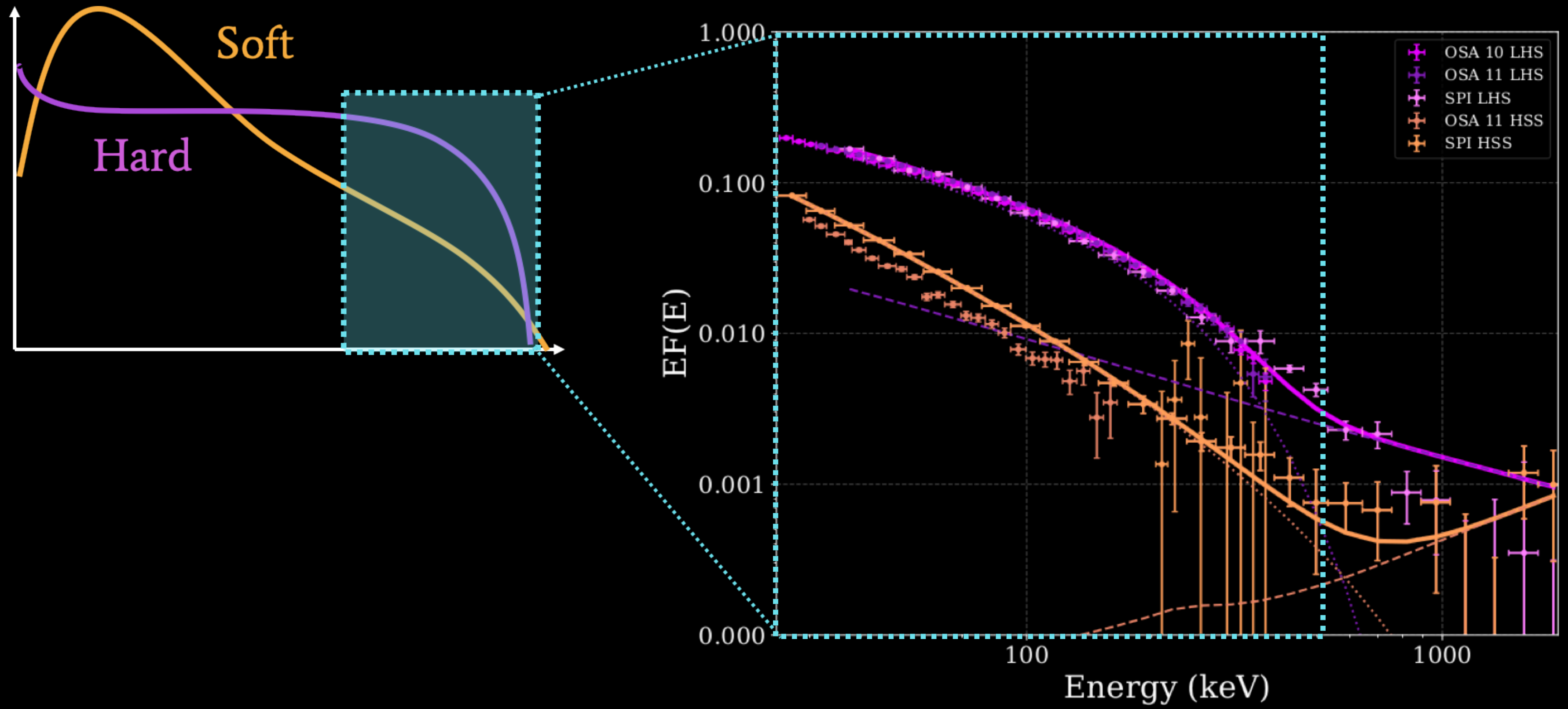
- What is the physics responsible of the transition?
- Where do the jets come from? And what are their links with the accretion disk?

CYGNUS X-1 WITH INTEGRAL

CYGNUS X-1 WITH INTEGRAL



ANOTHER SPECTRAL COMPONENT?



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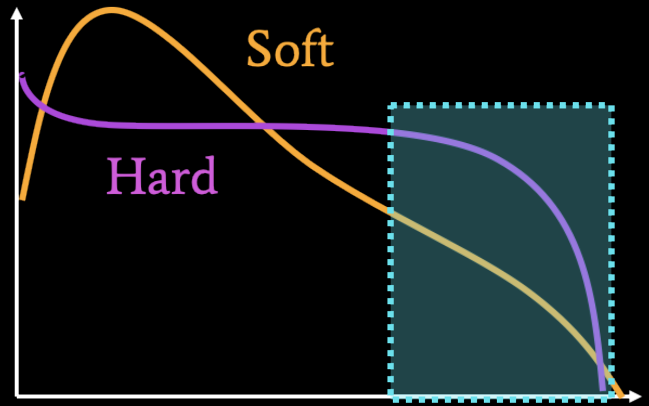

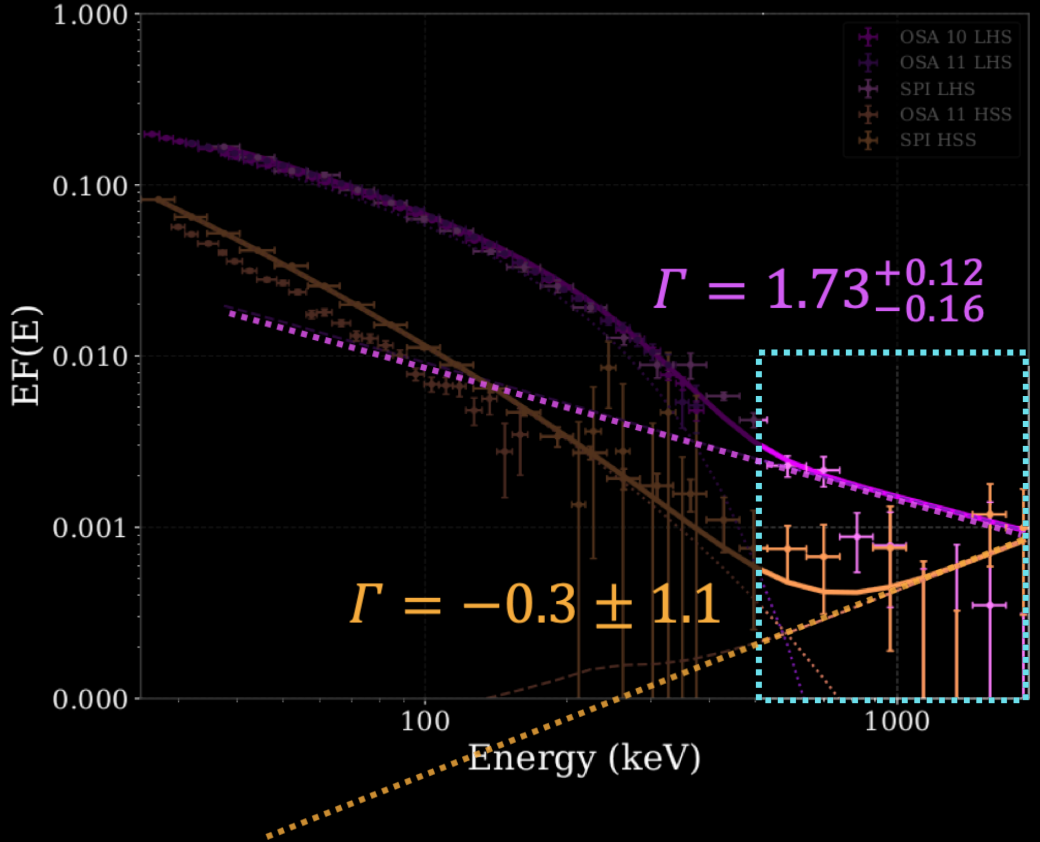

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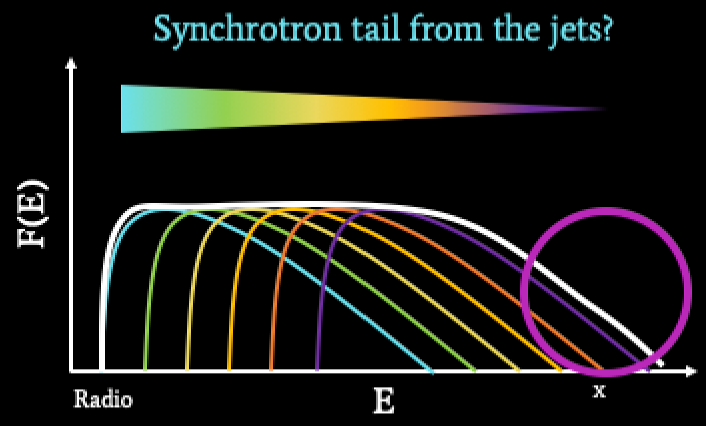
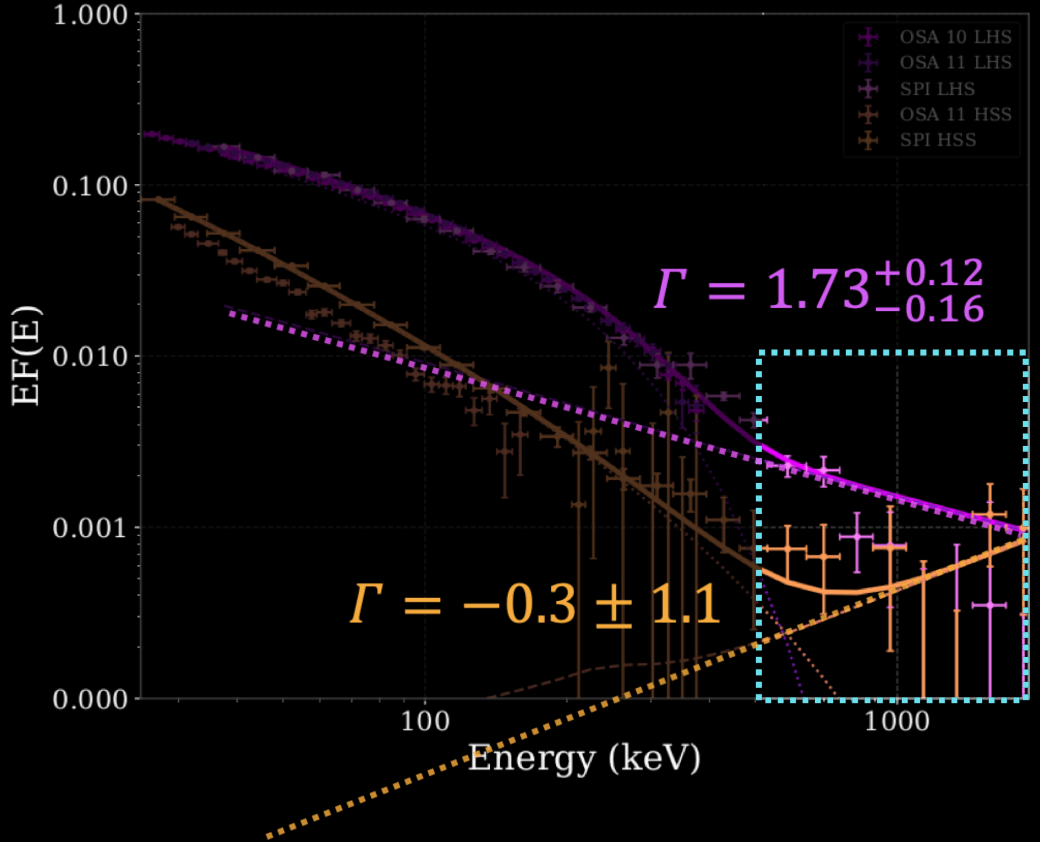
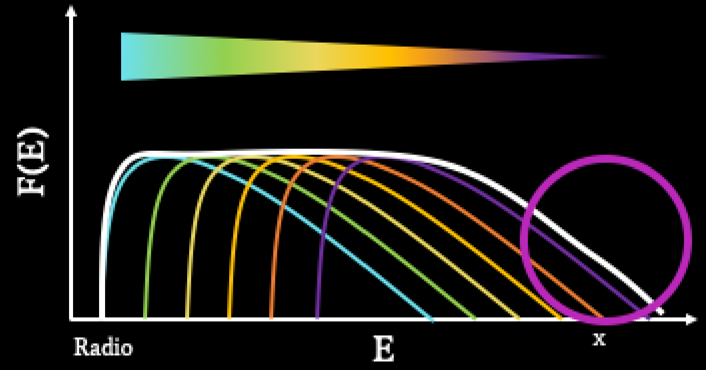


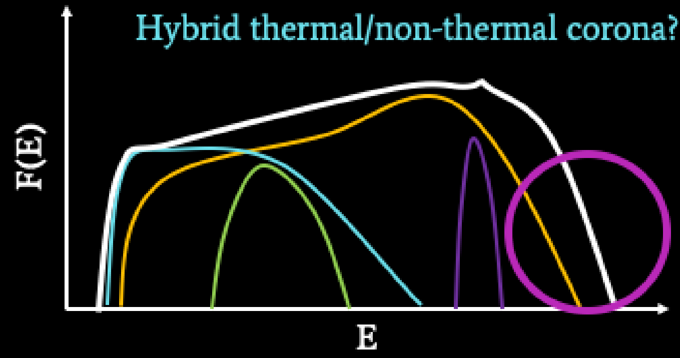


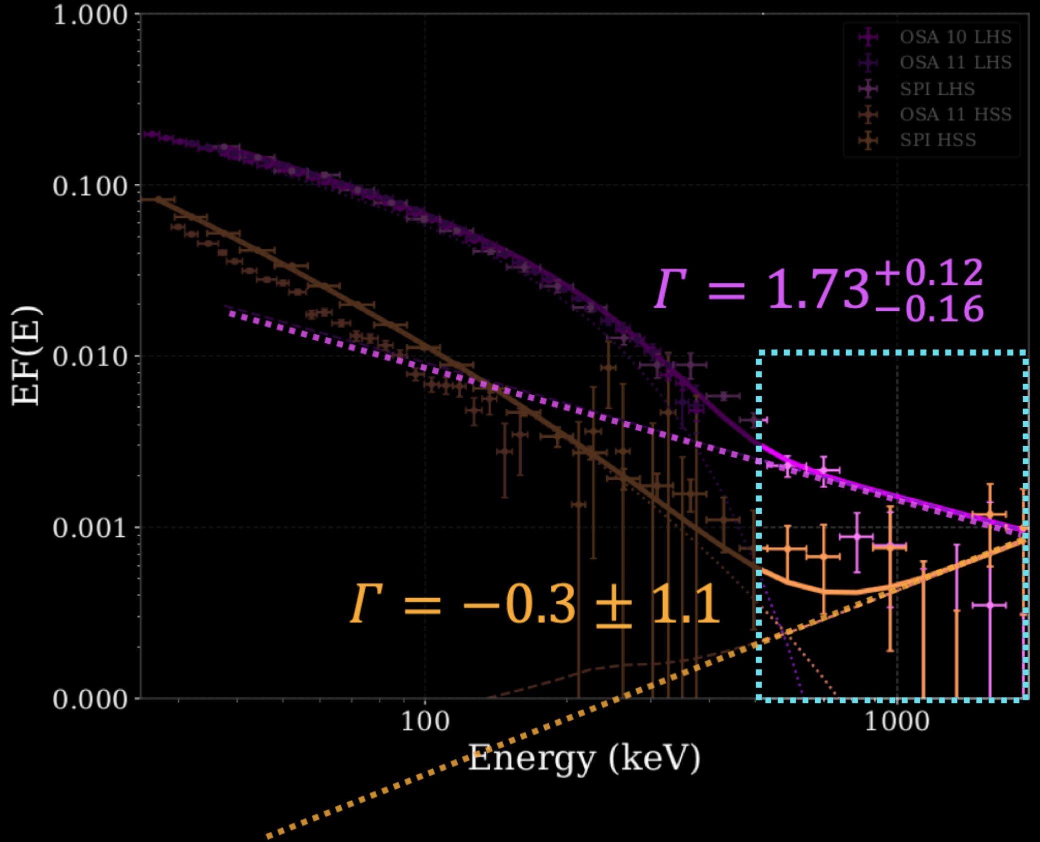
ANOTHER SPECTRAL COMPONENT?

Synchrotron tail from the jets?



Hybrid thermal/non-thermal corona?





CONCLUSION AND PERSPECTIVES TO UNDERSTAND EVOLUTION OF BLACK HOLE MICROQUASARS

- SPECTRAL STATES STUDY |

  High-energy tails detected in both states in the black hole microquasar Cygnus X-1

- ORIGIN? |

  Polarisation studies reveals scenario compatible with jets origin in the hard state, only upper limits in the soft state

  Testing hybrid thermal/non-thermal corona models => ongoing

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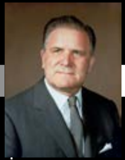
- ACCRETION-EJECTION MECANISM IN THE UNIVERSE |

  Jets feedback on stellar formation

TIMELINE HISTORY !

D |



1300 BC
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| Kepler
| Germany
| Telescope

1686
| Leibniz
| Germany
| Publication of the basics of integral

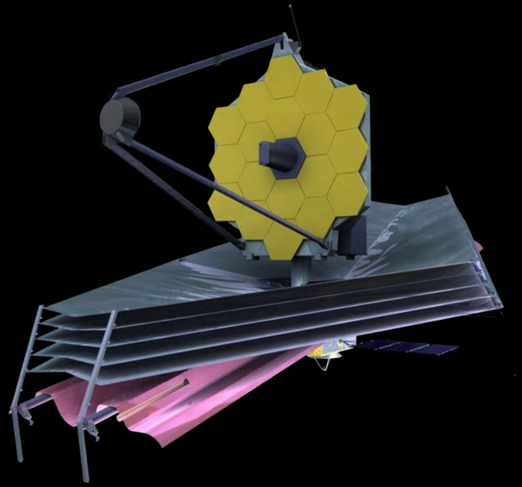
1967
| James E. Webb
| USA
| Former NASA Administrator
Now a great telescope

WHO

- ME | Marine Martin-Lagarde
- ADVISOR | Pierre-Olivier Lagage
- LABORATORY | DAp/LDE3

WANTED

- WHAT | JWST
- TYPE | Telescope
- WHY | Not launched yet



- I SIMULATE IMAGES IN INFRARED THAT THE JAMES WEBB SPACE TELESCOPE WILL SEND AND THAT WILL ALLOW US TO CHARACTERIZE EXOPLANETS ATMOSPHERE.

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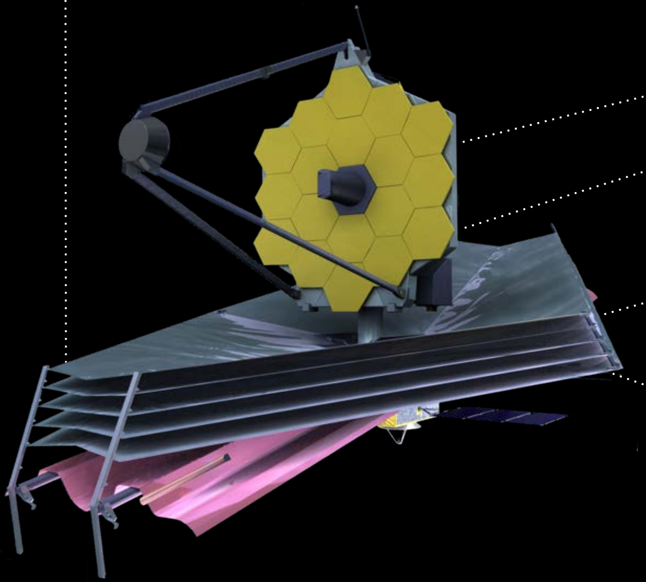


DIAMETER | 6.5 m

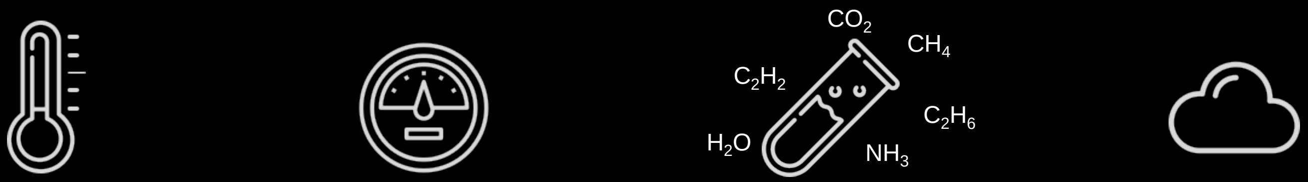
SPECTROMETER | 3 - 11 um

| $\frac{\Delta\lambda}{\lambda}$ =100

LAUNCH | March 2021

OBSERVATIONS | Transit Spectroscopy

I SIMULATE IMAGES IN INFRARED THAT THE JAMES WEBB SPACE TELESCOPE WILL SEND AND THAT WILL ALLOW US TO CHARACTERIZE EXOPLANETS ATMOSPHERE.



TEMPERATURE PRESSURE COMPOSITION CLOUDS

EXOPLANETS ATMOSPHERES - JWST MISSION PREPARATION WHY ?

TELESCOPE IMAGES

→

REDUCTION

→

TREATMENT / INTERPRETATION

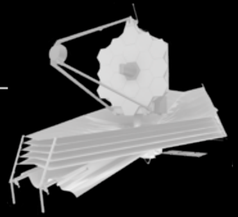
TELESCOPE IMAGES

REDUCTION

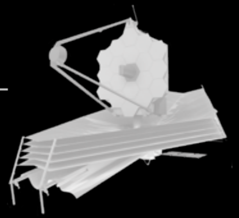
TREATMENT / INTERPRETATION

EXOPLANETS ATMOSPHERES - JWST MISSION PREPARATION WHY ?

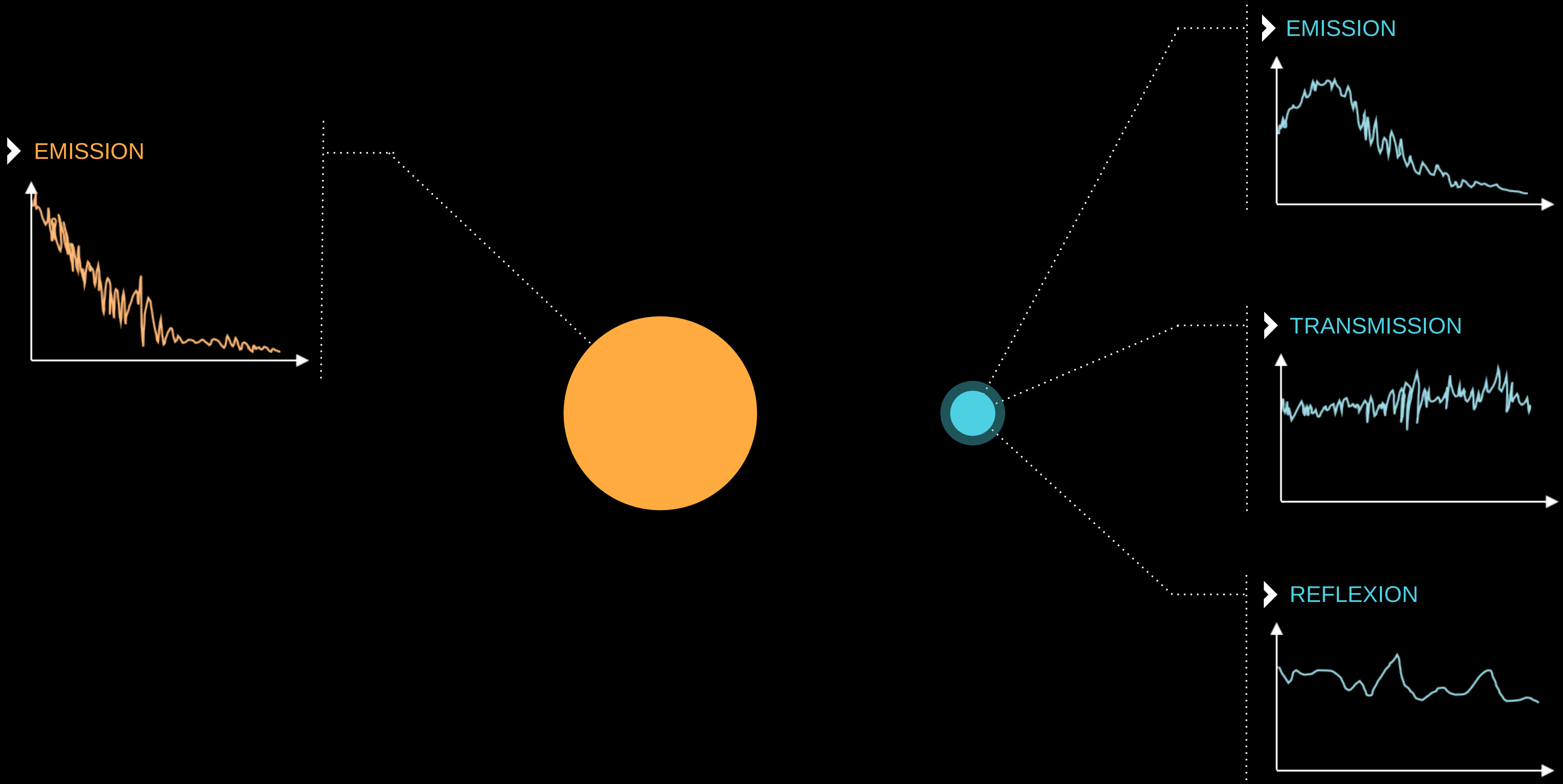
SIMULATED IMAGES



SIMULATED IMAGES

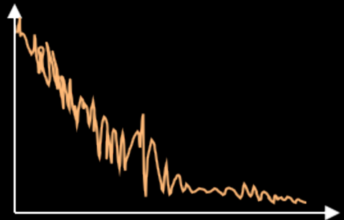


EXOPLANETS ATMOSPHERES - JWST MISSION PREPARATION MODELLING

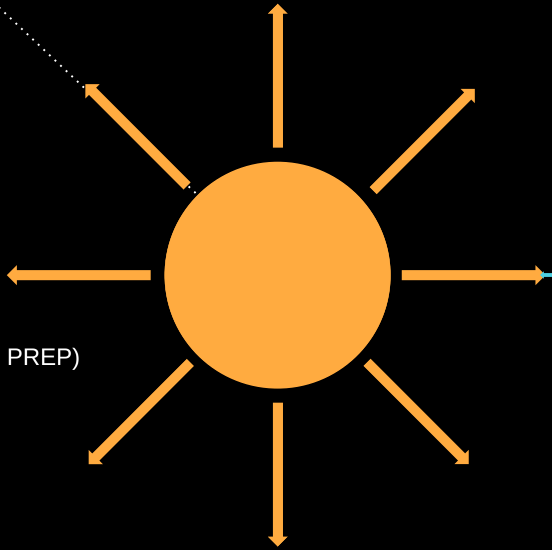


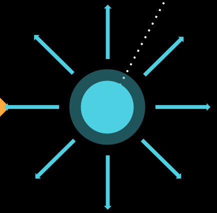
EXOPLANETS ATMOSPHERES - JWST MISSION PREPARATION MODELLING

EMISSION

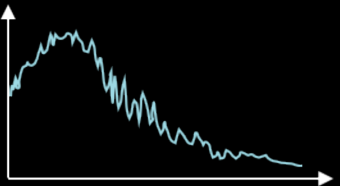


MODEL :
PHOENIX (ALLARD ET AL. 2003-2017)
LIMB-DARKENING (MORELLO ET AL. IN PREP)



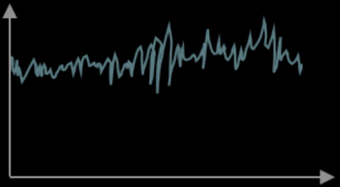


EMISSION

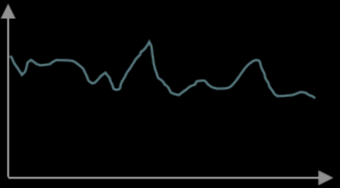


: MODEL
COLLABORATION L.A.B. (BORDEAUX)

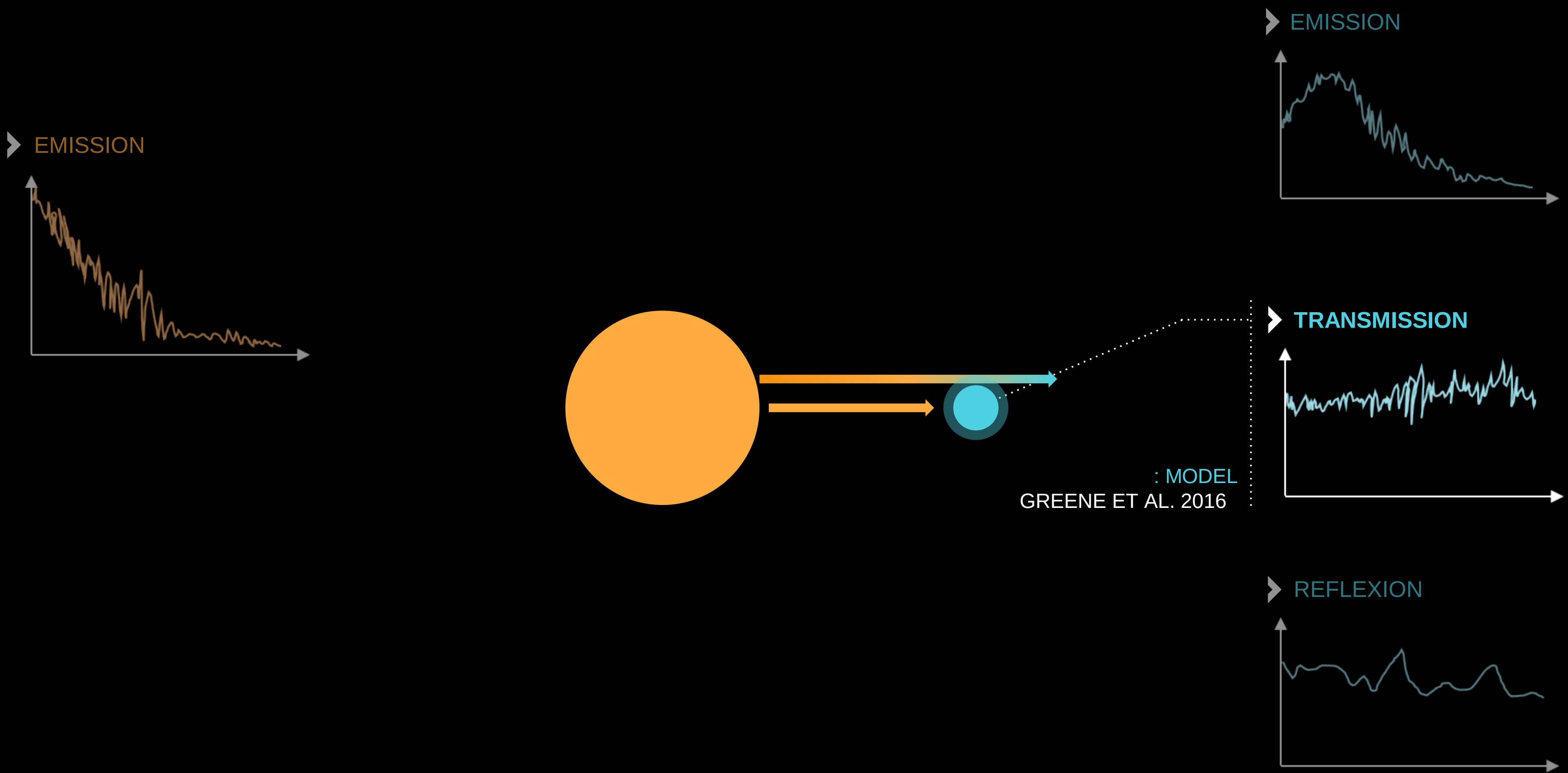
TRANSMISSION



REFLEXION



EXOPLANETS ATMOSPHERES - JWST MISSION PREPARATION MODELLING



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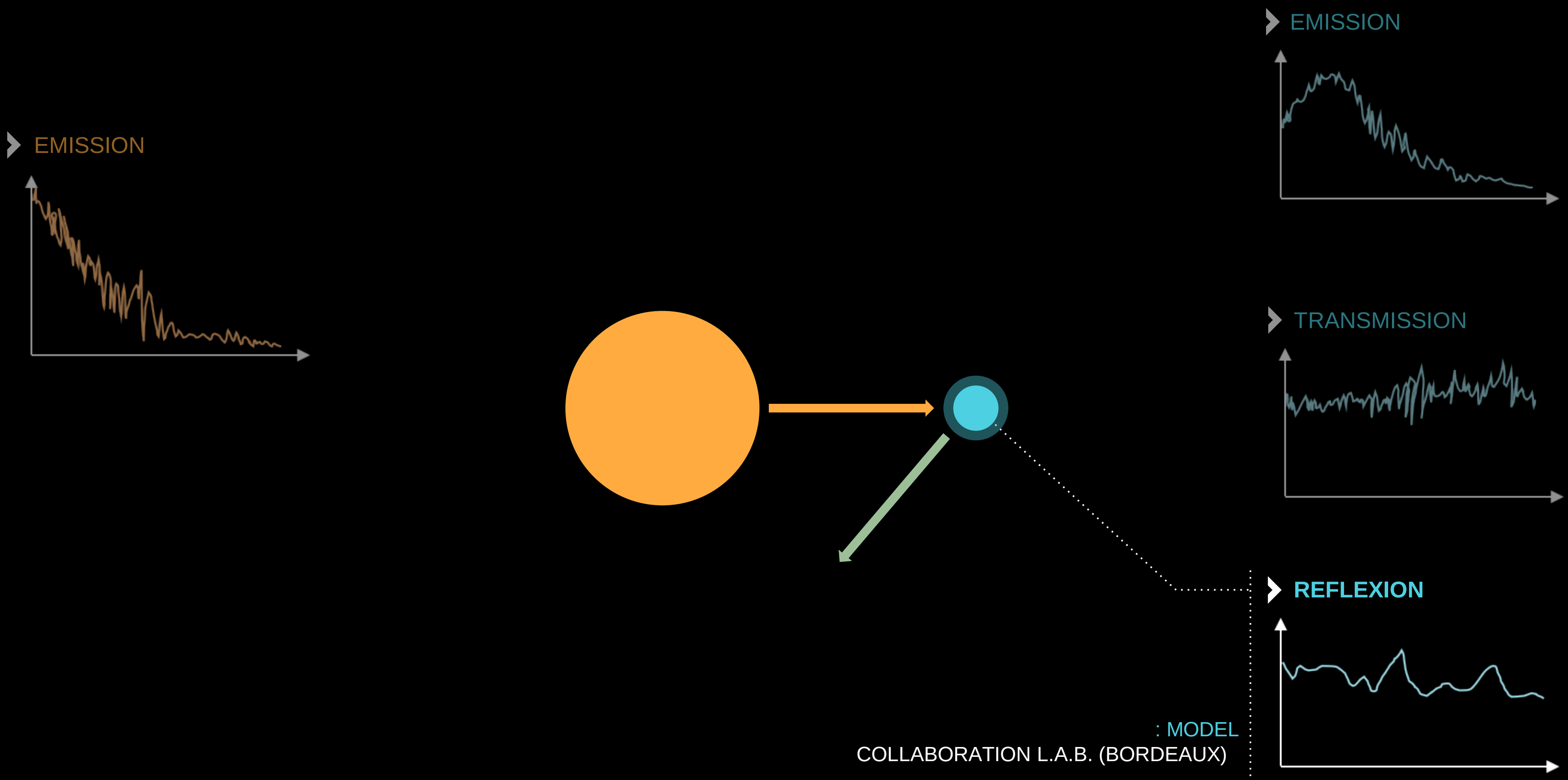
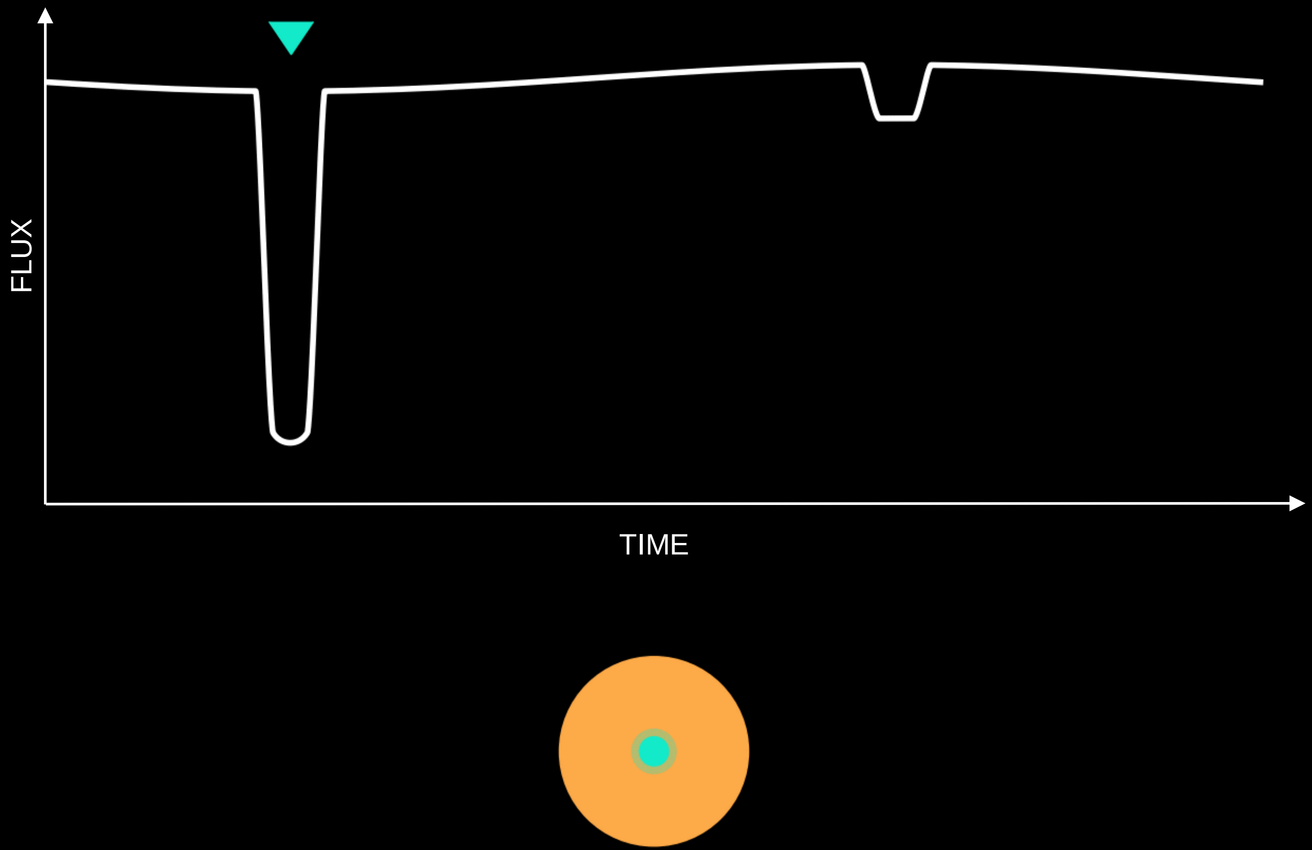
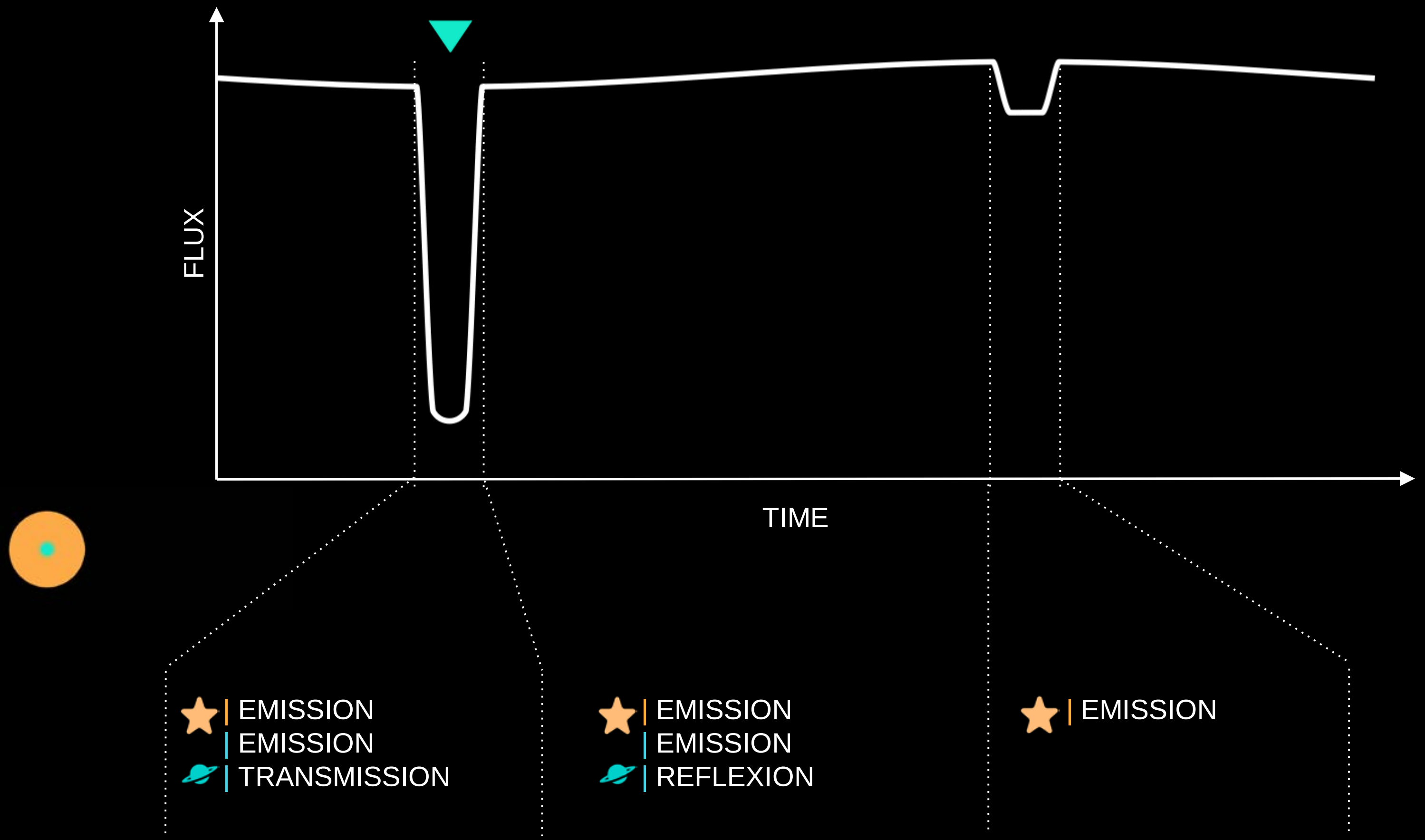
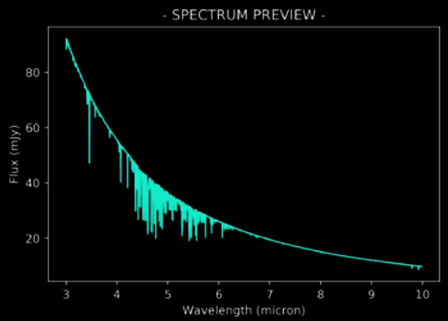


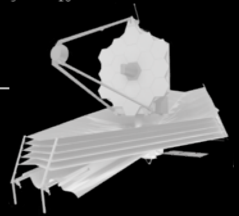

FLUX
TIME

EXOPLANETS ATMOSPHERES - JWST MISSION PREPARATION LIGHTCURVE



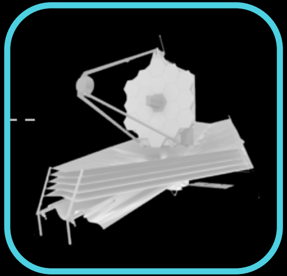


SIMULATED IMAGES



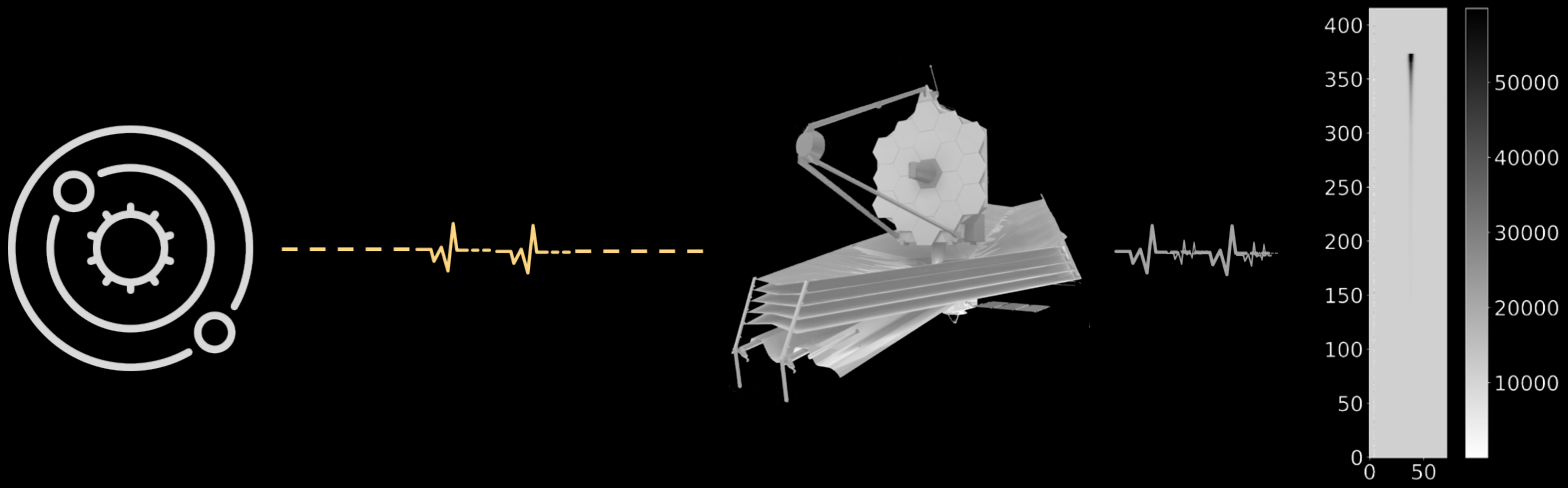
EXOPLANETS ATMOSPHERES - JWST MISSION PREPARATION WHY ?

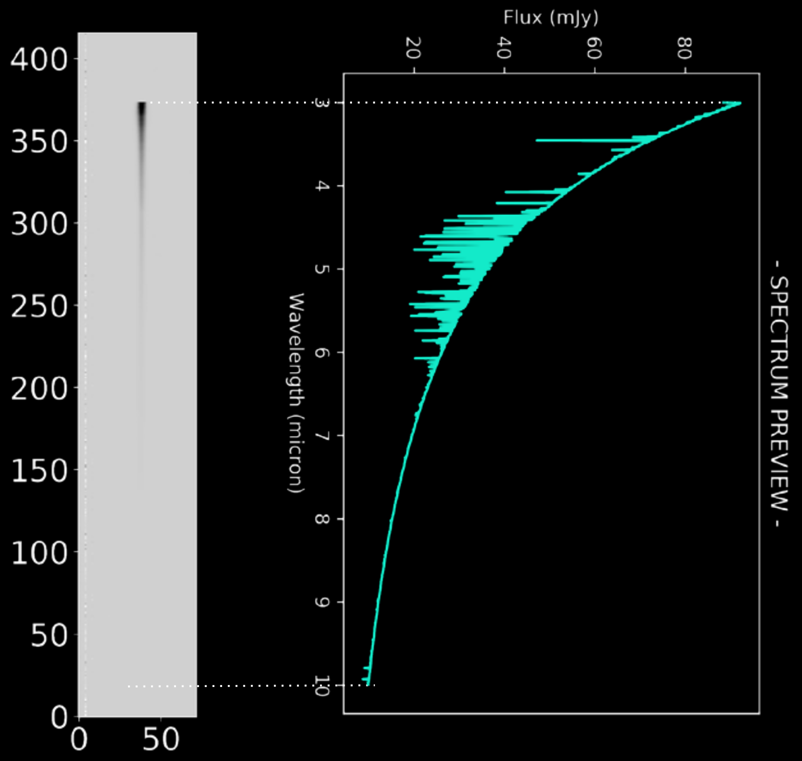
SIMULATED IMAGES

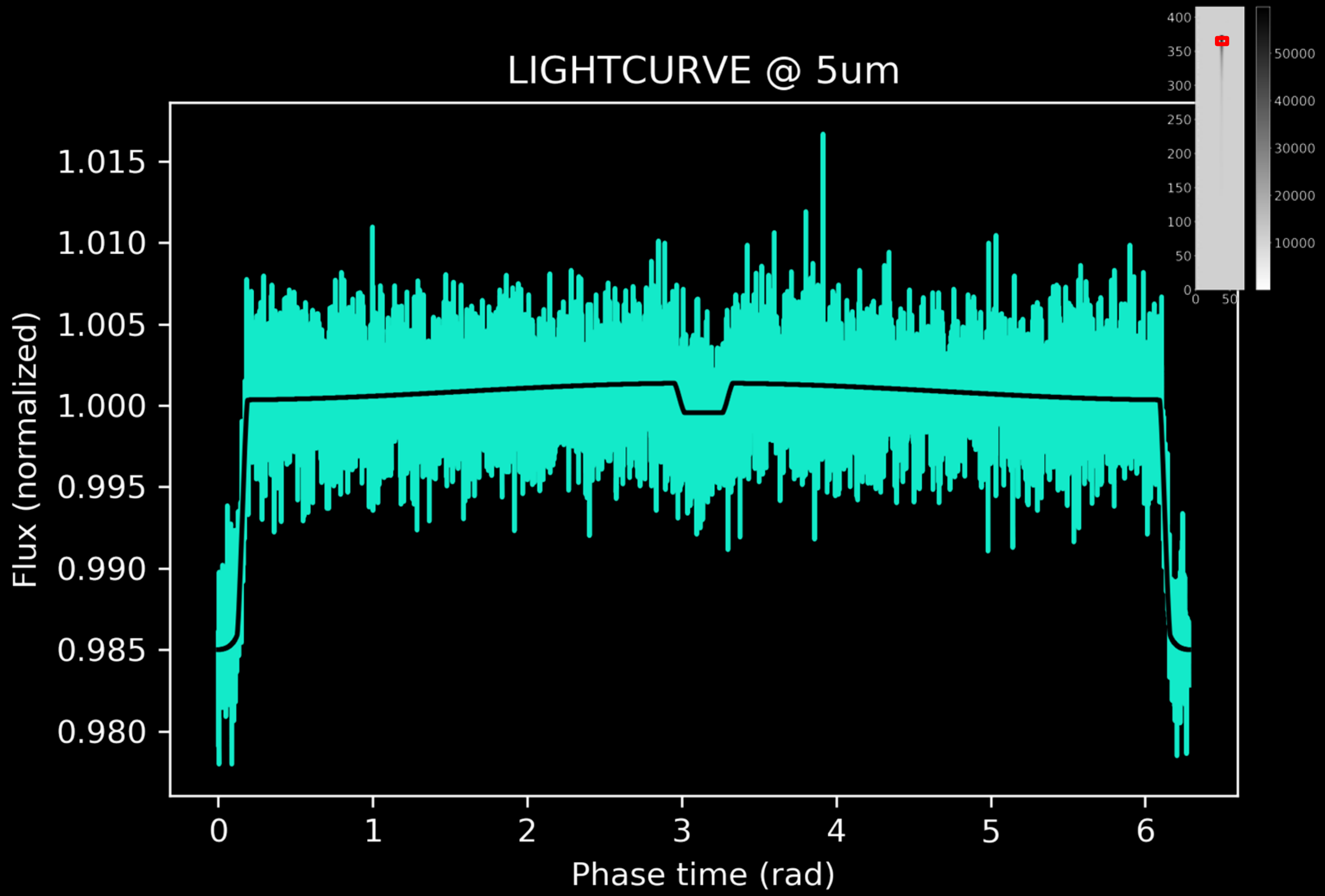


MIRI CONSORTIUM
(Incl. CEA)

EXOPLANETS ATMOSPHERES - JWST MISSION PREPARATION SYNTHETIC IMAGES




400
350
300
250
200
150
100
50
0
0
50
Flux (mJy)
20
40
60
80
3
4
5
6
7
8
9
10
Wavelength (micron)
- SPECTRUM PREVIEW -


LIGHTCURVE @ 5um
Flux (normalized)
1.015
1.010
1.005
1.000
0.995
0.990
0.985
0.980
0
1
2
3
4
5
6
Phase time (rad)
400
350
300
250
200
150
100
50
0
0
50
50000
40000
30000
20000
10000

| Exoplanet transit spectroscopy
| Preparation of the next telescope mission
| Training the astrophysicists to analyse the data

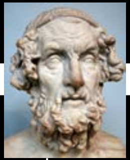
- Creation of synthetic images

| Reintroduction of drifts in the simulations
| Test of hypothesis accuracy

- Getting it more realistic !

CONCLUSION

D |



1300 BC
| Ramses
| Egypt
| He’s a code now

800 BC
| Homère
| Greece
| First mention of Tidal effects

1571
| Kepler
| Germany
| Telescope

1686
| Leibniz
| Germany
| Publication of the basics of integral

1967
| James E. Webb
| USA
| Former NASA Administrator
Now a great telescope

CHRONOLOGY

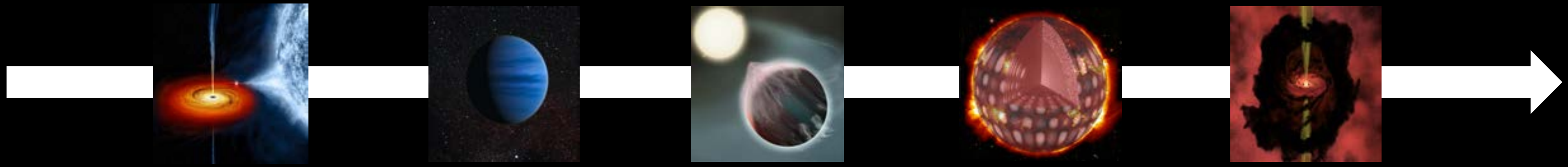
A

WAVELENGTH RANGE

B

SIZE OF THE OBJECTS

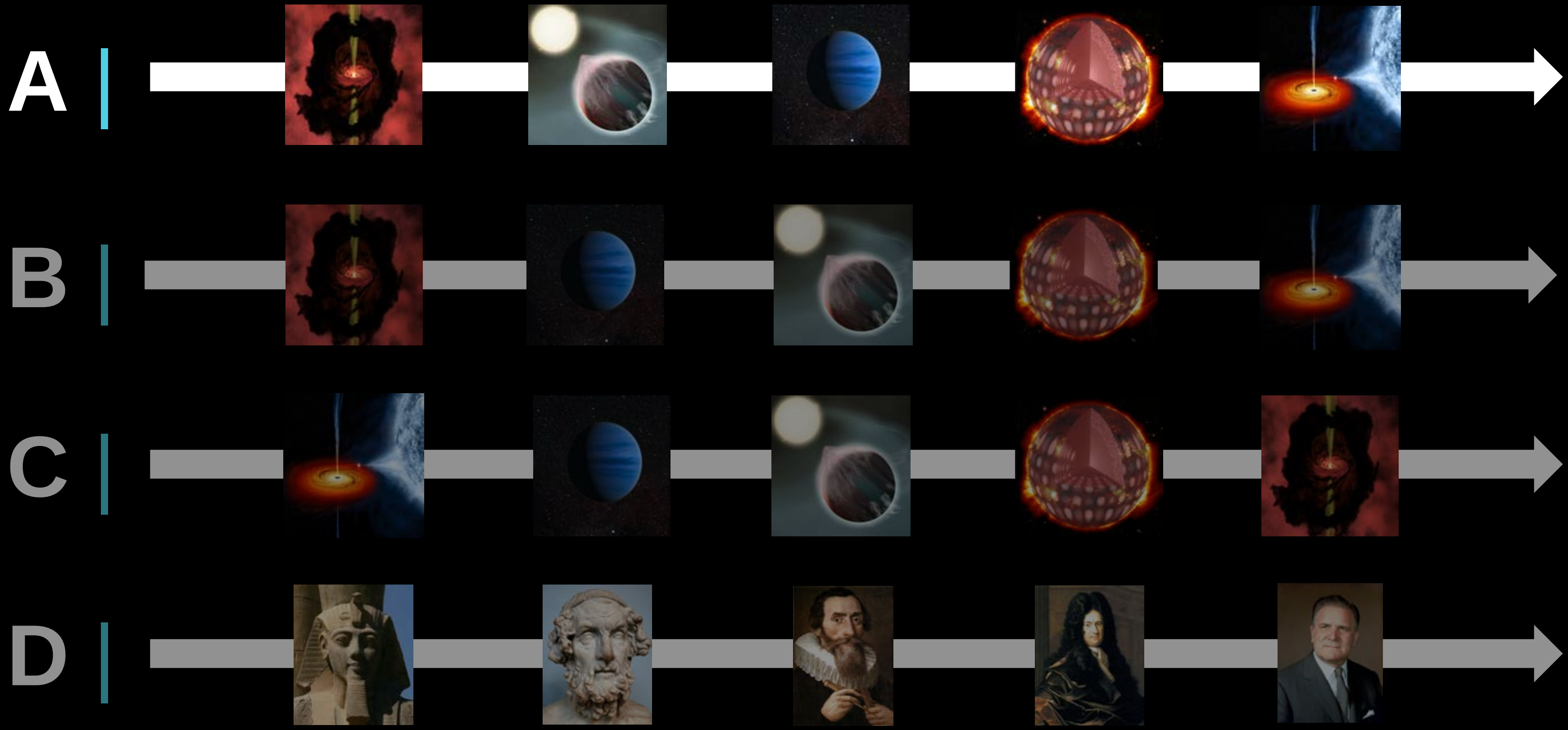
C



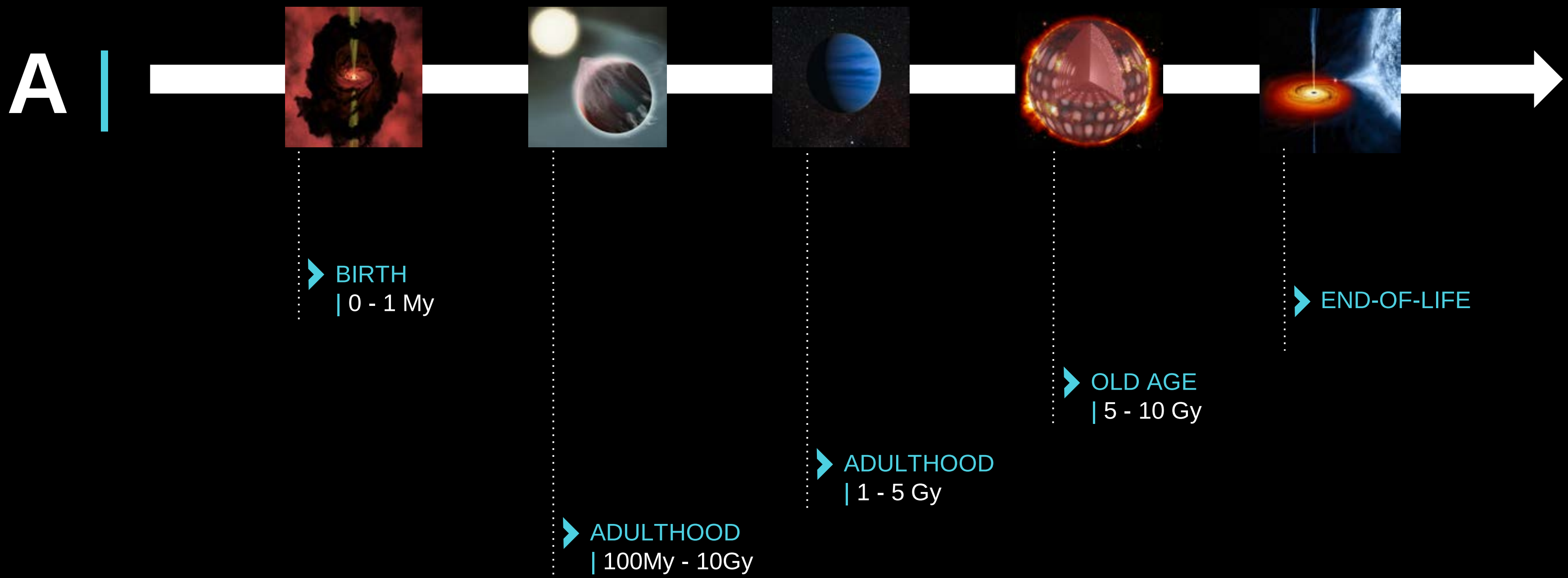
HISTORY !

D

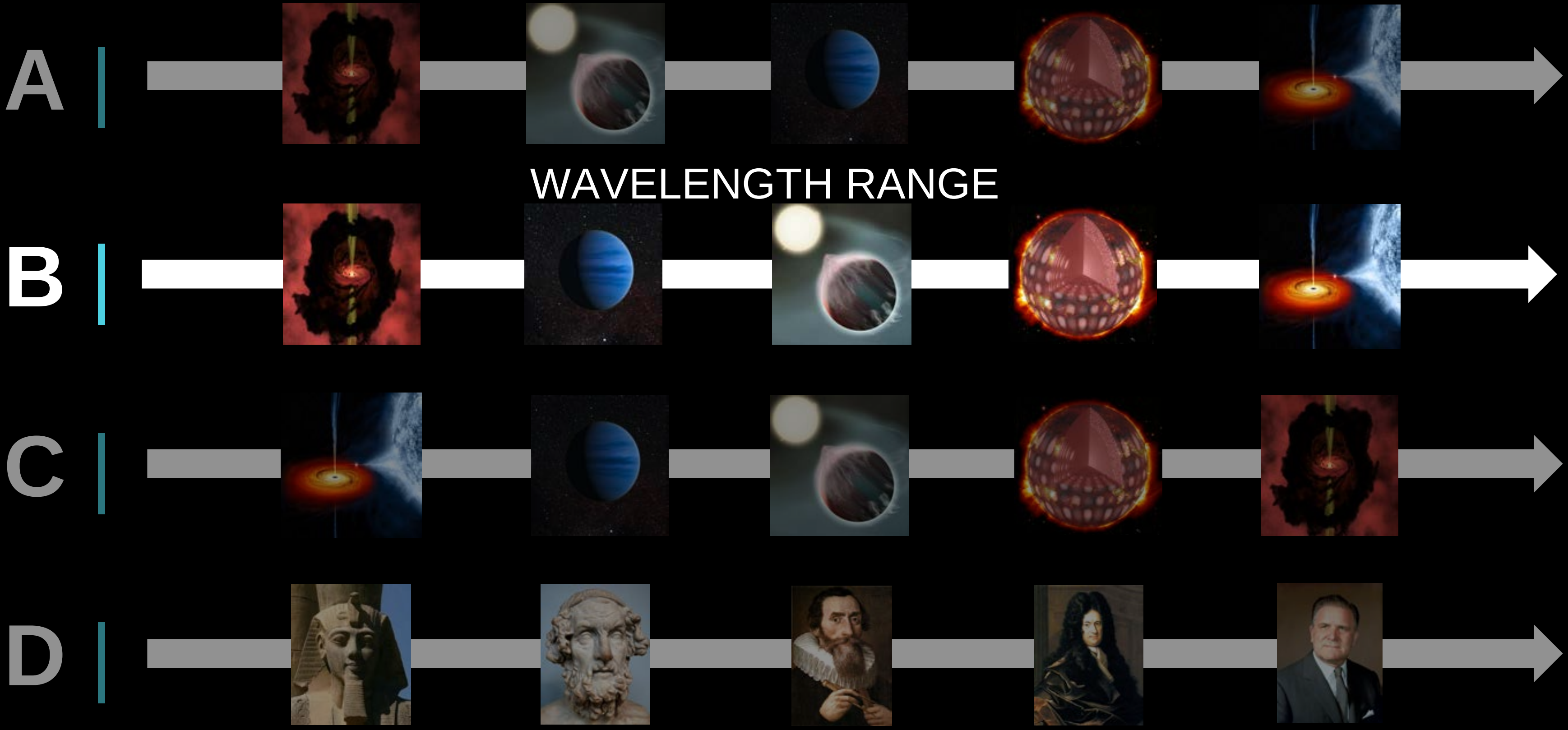
CHRONOLOGY



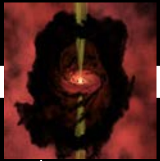
TIMELINE CHRONOLOGY



INTRODUCTION YOUR CHOICE NOW!

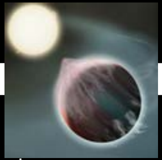


B |

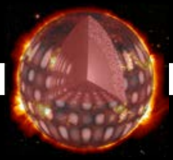


Thermal - IR
| 10^{-4} m

M-IR
| $3x10^{-6}$ to 10^{-5} m



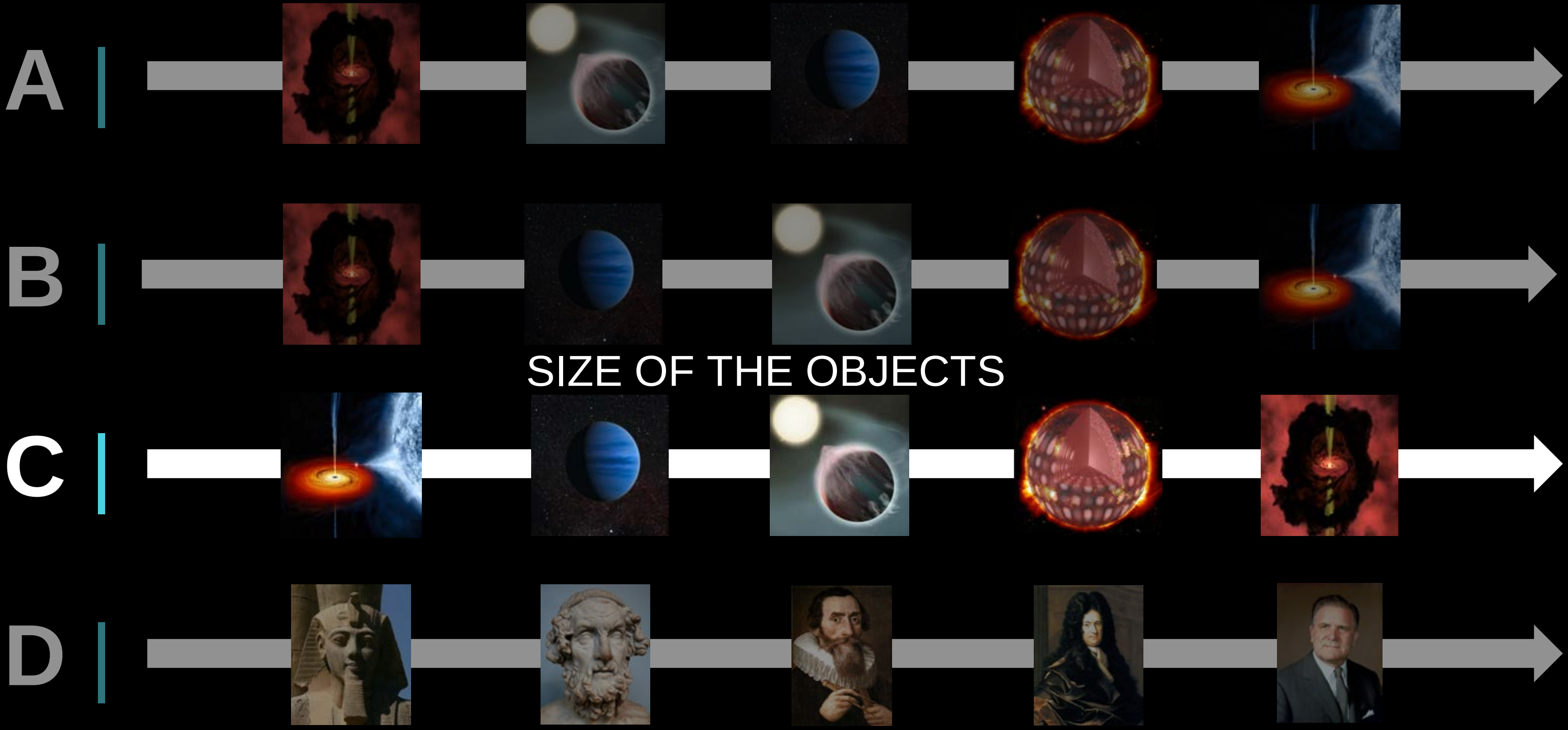
Vis/N-IR
| 10^{-5} to 10^{-7} m



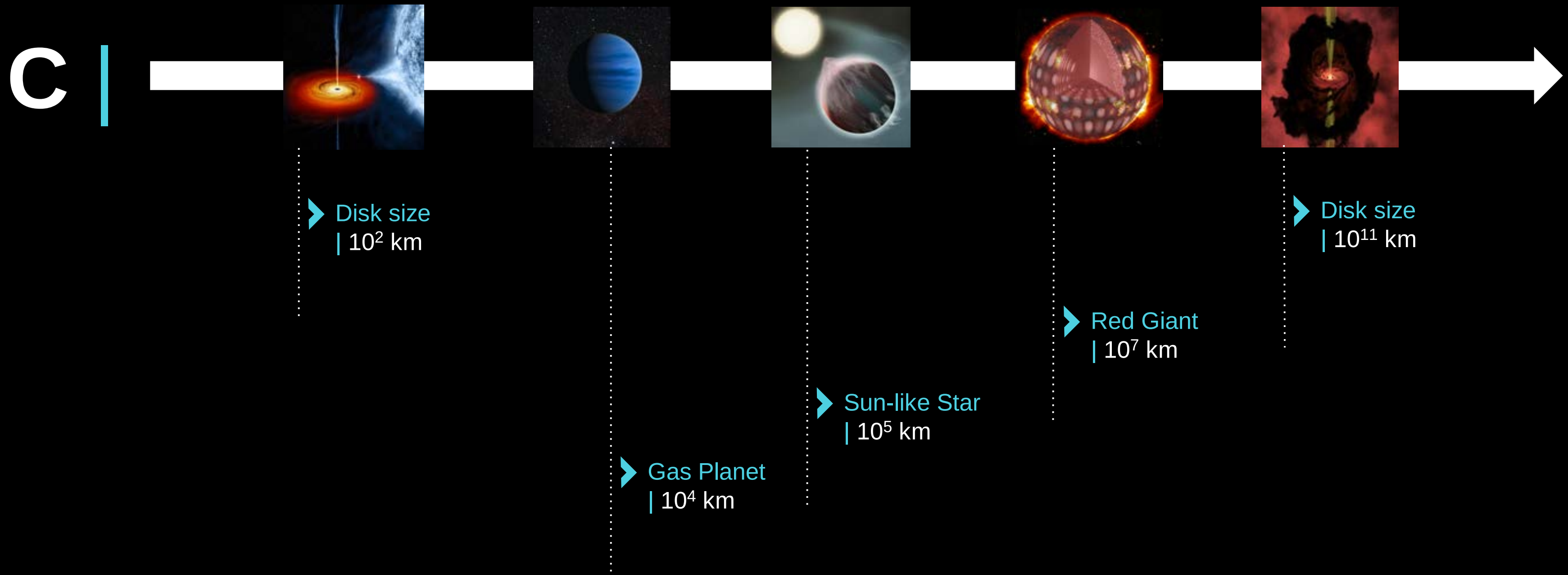
Vis
| 10^{-7} m

X-Gamma
| 10^{-10}- 10^{-13} m

INTRODUCTION YOUR CHOICE NOW!



INTRODUCTION SIZE OF THE OBJECTS



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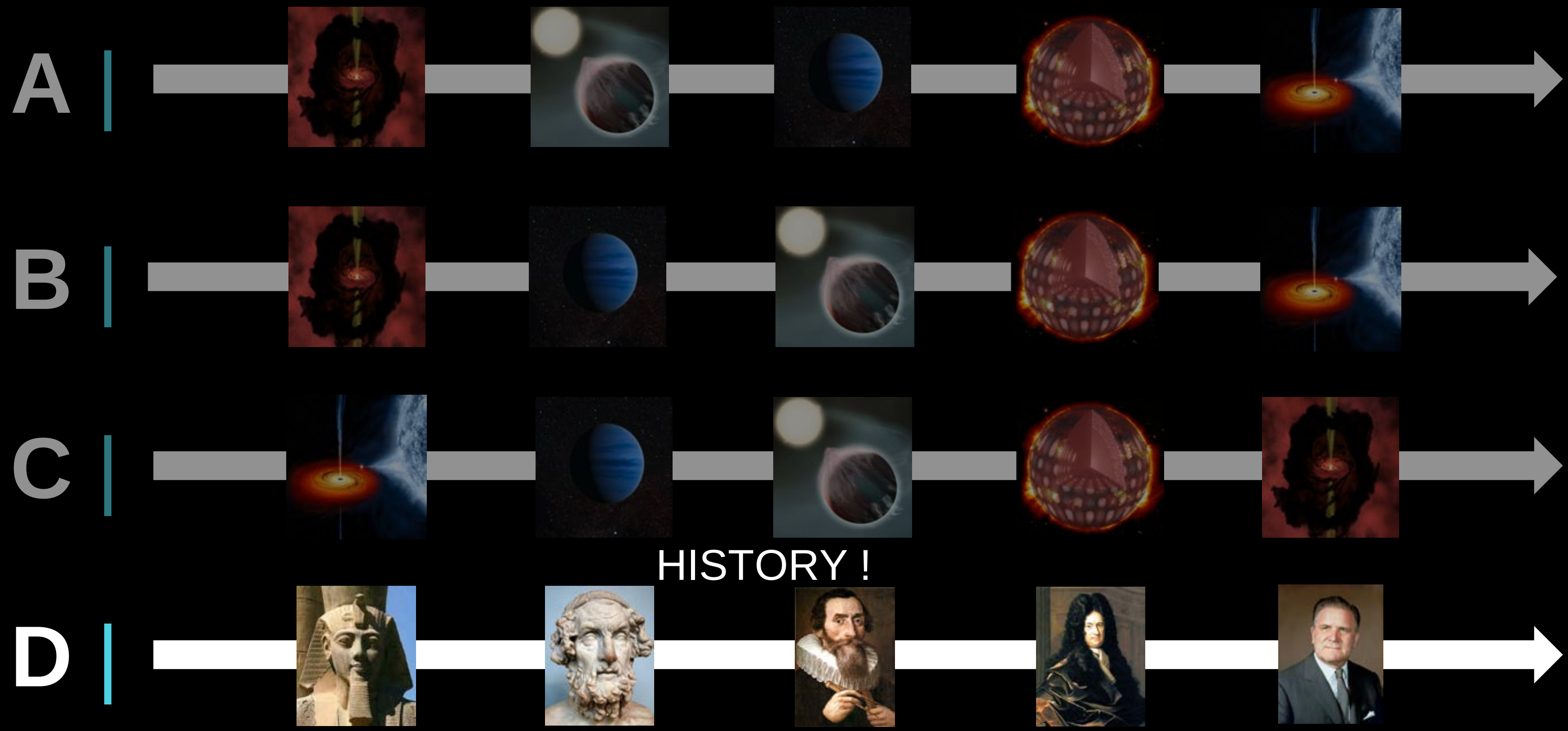
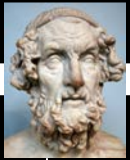


INTRODUCTION HISTORY !

D |



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