Evolution of matter from the interstellar medium to exoplanets with the JWST

Modeling of protoplanetary disks

Robert Brauer (DAp/IAS)

CSNSM: C. Engrand, J. Duprat, M. Godard, L. Delauche, L. Delbecq, D. Le Du, J. Bourcois, C. Baumier, C. Bachelet, F. Fortuna, B. Augé, E. Charron, B. Guerin, J. Roja

IAS: A. Abergel, A. Aleon, R. Brunetto, E. Habart, A. Jones, M. Olivier, L. Verstraete, N. Ysard, Z. Djouadi, O. Mivumbi, K. Dassas, C. Cossou, R. Brauer, T. Bouteraon, Z. Dionnet, T. Schirmer, R. Maupin, R. Urso

ISMO: E. Dartois

IPNO: M. Chabot, G. Martinet, S.Bouneau, N. De Sereville, F. Hamache

DAp/AIM: P. Bouchet, D. Dicken, S. Fromang, P.-O. Lagage, E. Pantin, A. Coulais, R. Gastaud, R. Brauer, G. Morello, M. Martin-Lagarde

Maison de la Simulation: P. Tremblin

PhD and post-doc since Sept. 2016

P2IO
Physique des 2 Infinis et des Origines

Evolution of interstellar dust

Visible (ESO/S. Brunier)

Everywhere
Optical ⇒ Infrared

Planck HFI (thermal dust)

Key actor of matter evolution at **all angular scales**

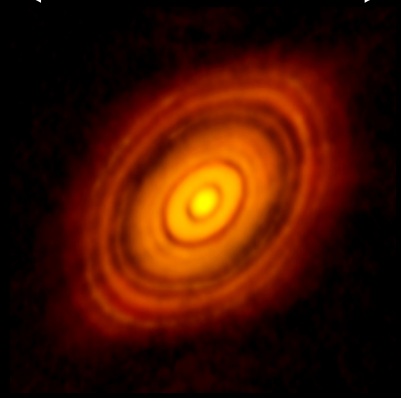
~ 50 kpc

Herschel, FIR, M31

NRAO, visible in Orion

HST visible, M16

~ 280 AU



ALMA 1 mm, HL Tau

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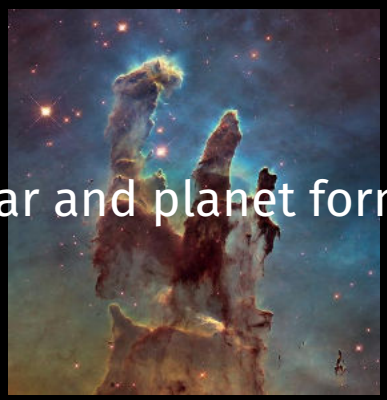

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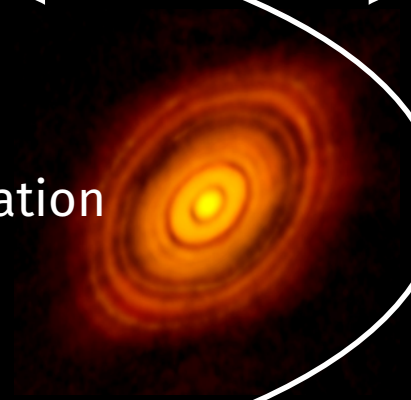

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Star and planet formation

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JWST Herschel Planck

Ke es

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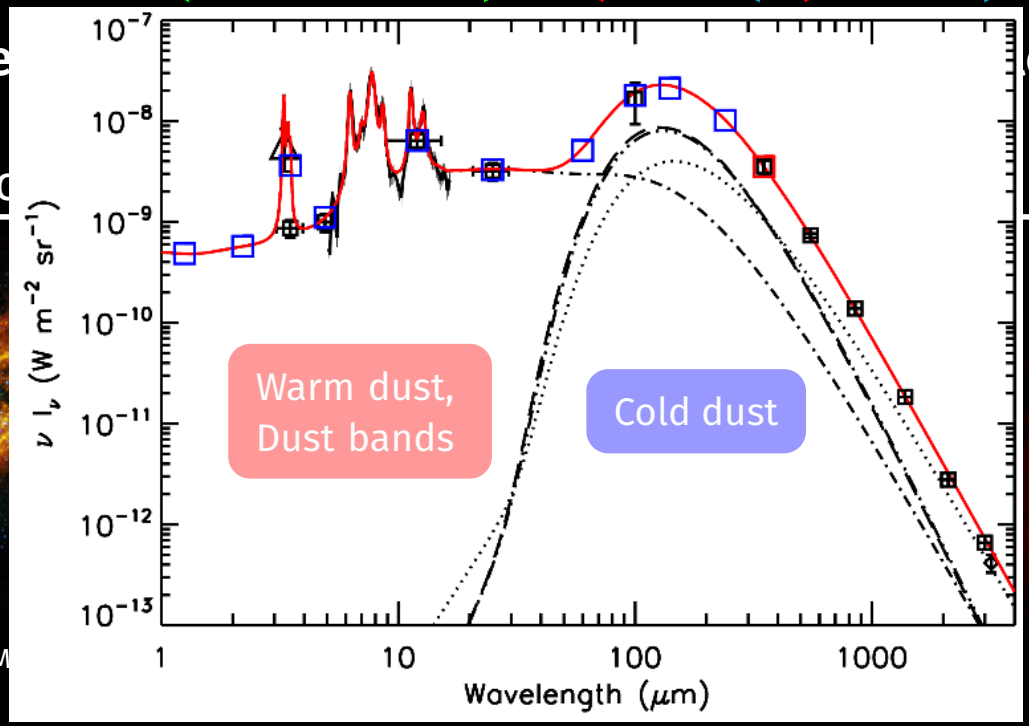
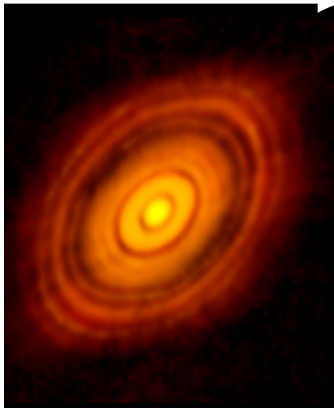


Jones et al. 2013 + DUSTEM



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The JWST: successor of the HST
A 6.5 meter infrared telescope in space

Optimized in the IR
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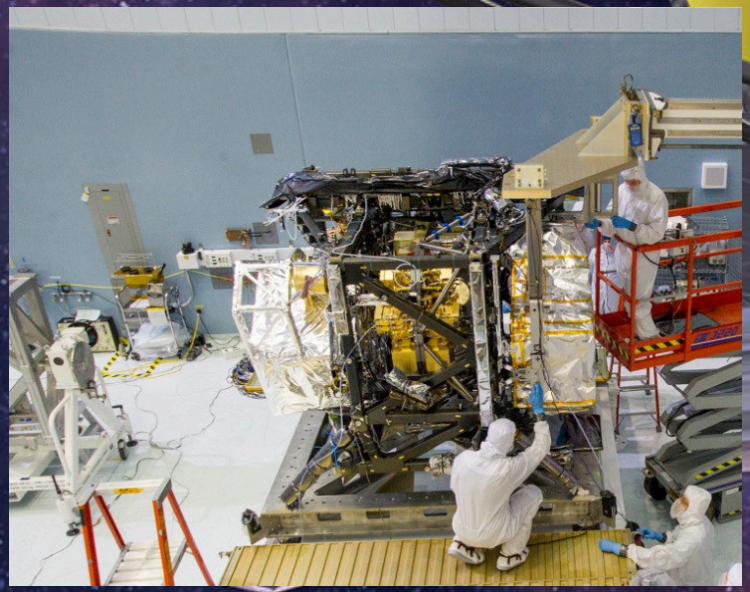

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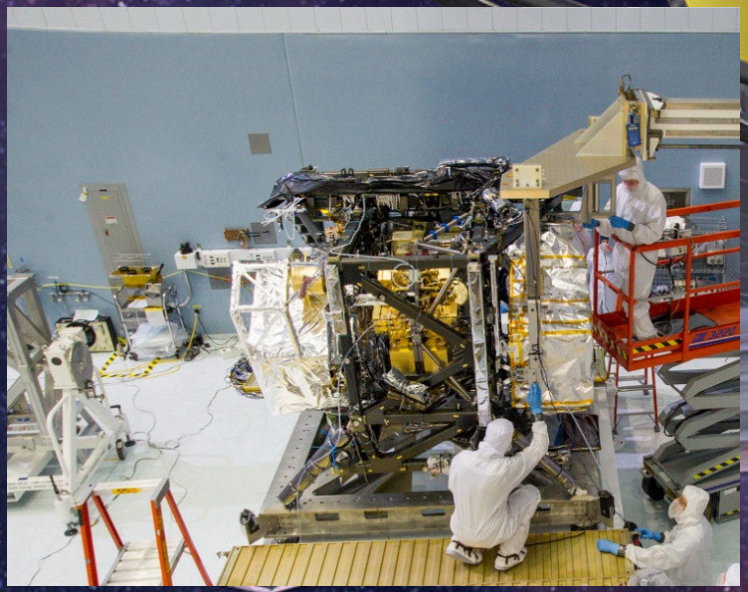
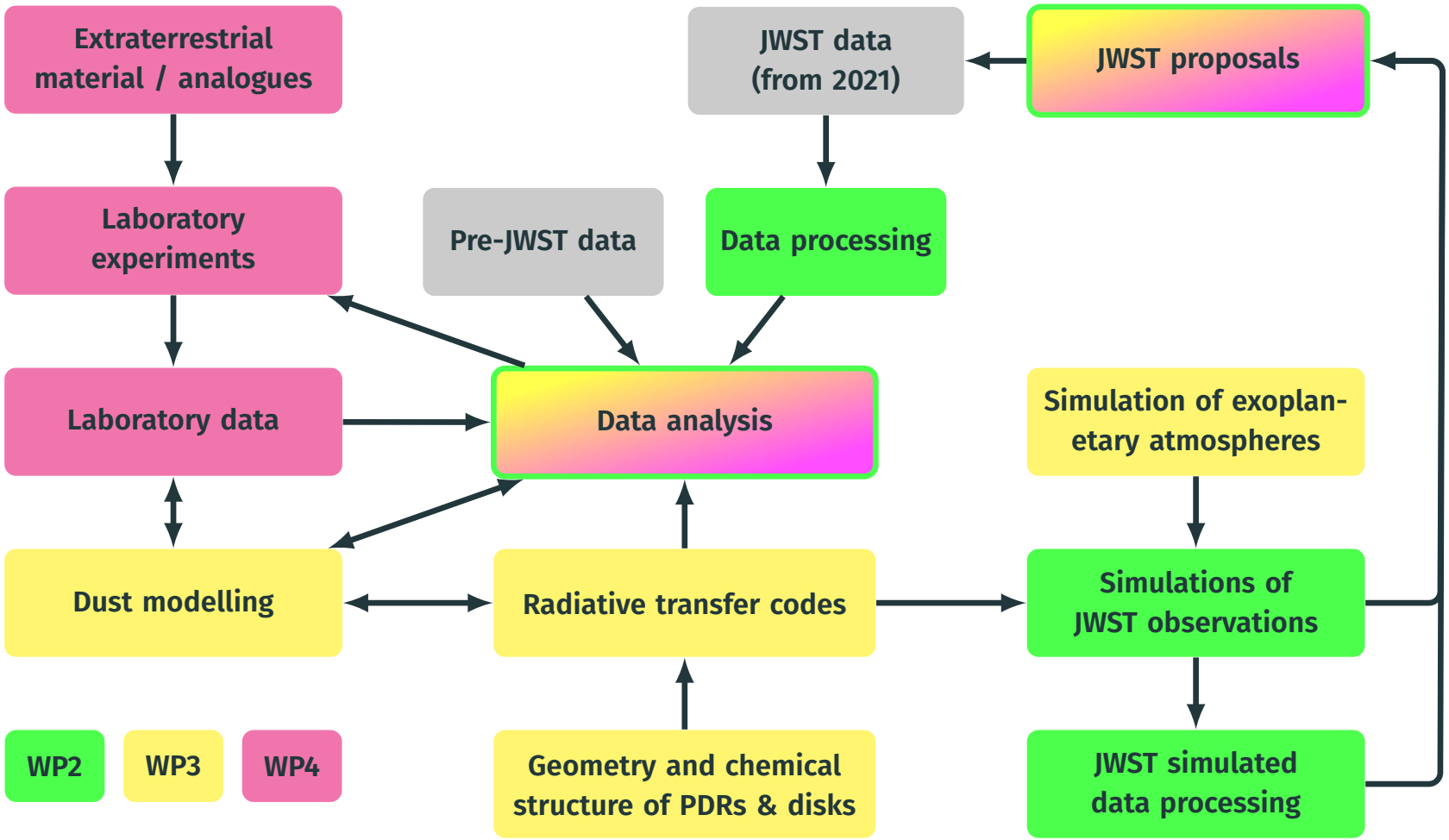
Four scientific themes:
- First light and the reionisation
- Assembly of galaxies
- Birth of stars and proto-planetary systems
- Planetary systems and the origin of life



Overview of work packages



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Prior to launch (2016-2020)

- Participation to the French Center of Expertise for MIRI
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Strongly involed in several observing programs

- Eearly Released Science programs
- Guaranteed Time Observations (GTO)
- Open Time Observations (Cycle 1 call in 2019)

WP3: Modelisation & Simulations (ongoing work)

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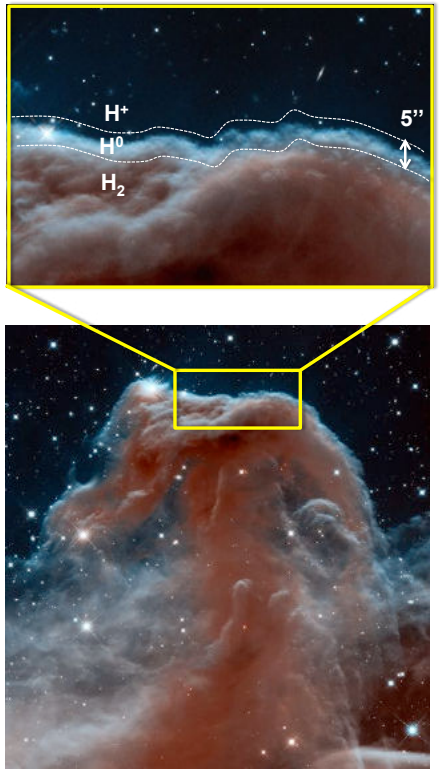
Photodissociation Regions (PDRs) and Disks

- New charge model for dust grains
- Optical properties of large aggregates
- Laboratory-based silicate optical properties (collaboration with IRAP/Toulouse)
- Dust and radiative transfer models to analyse pre-JWST data (RT codes: MCRT, MCFOST, POLARIS)
- Nano carbon dust emission in protoplanetary disks (VLT IR spectroscopy data)
- Dust evolution in PDRs (Spitzer, Herschel, and HST data)



Horsehead nebula

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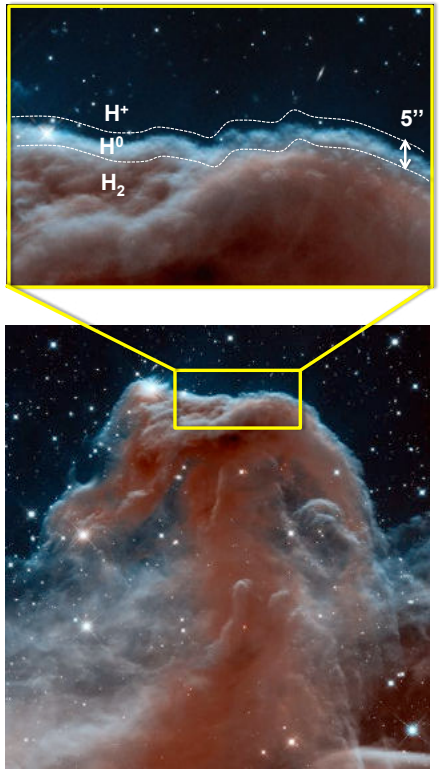
Exoplanet atmospheres

- Effect of composition variations
- Influence of the convection



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- Measurements at Soleil and at UMET Lille $\Rightarrow$ N/C, C/Si and O/Si ratios
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Evolution of chemistry in the ISM and Solar System

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- High- (GANIL, GSI, ...) and low- (SIDONIE, ARAMIS) energy ion irradiation

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Mineral matter

- Sample preparation (new microscope for micromanipulation)
- Multi-technique analysis of refractory inclusions from primitive meteorites (micro-IR, TEM, nano-SIMS)
- IR hyperspectral imaging of meteorites and dust from sample return missions

PhD students and post-doc

4 two year post-doc (2 in the initial project)

- E. Charron - Cometary matter (CSNSM, P2IO)
- R. Brauer - Disks (DAp/AIM & IAS, P2IO)
- G. Morello - Exoplanets (DAP/AIM, P2IO)
- R. Urso - Laboratory experiments (IAS1)

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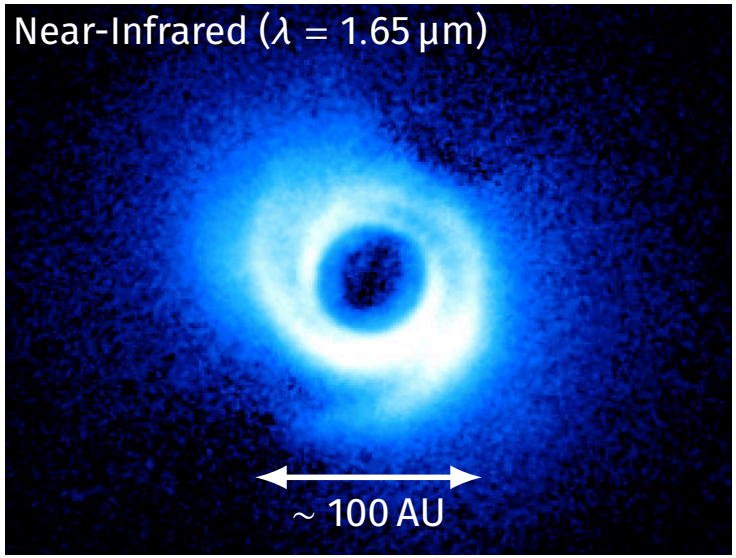
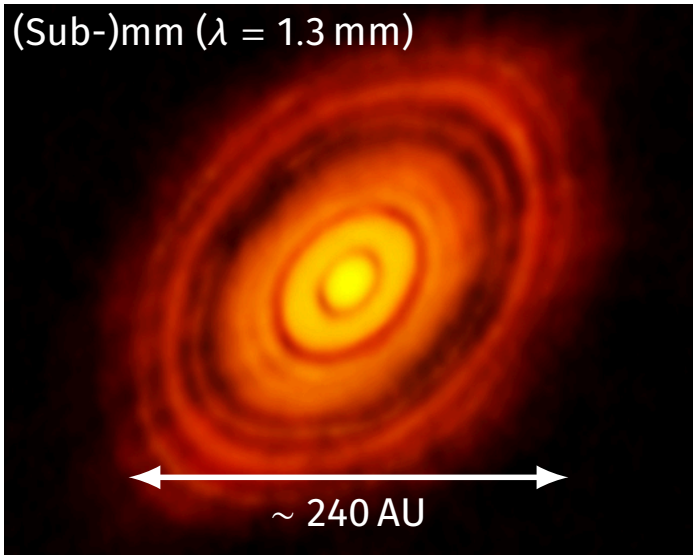


SAO 206462 (Credit: NAOJ/Subaru)
(with coronograph)



HL Tau (Credit: ESO/ALMA)

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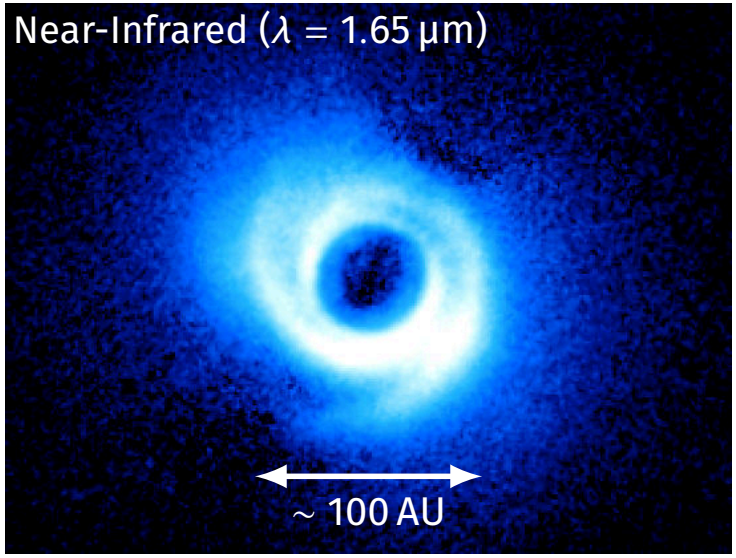

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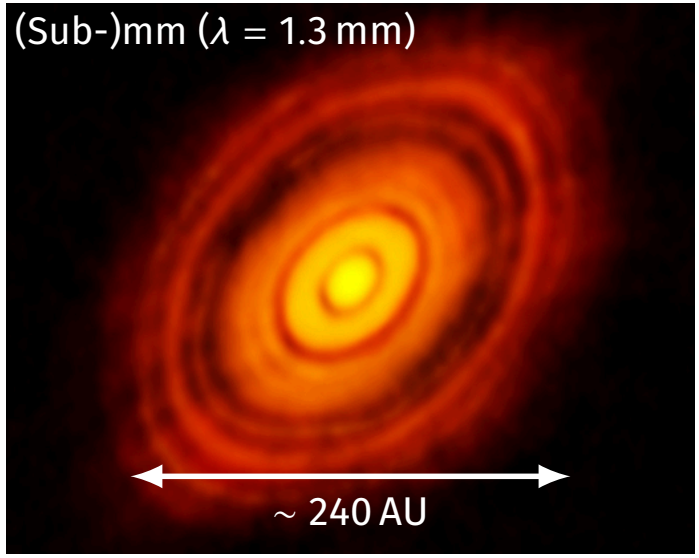

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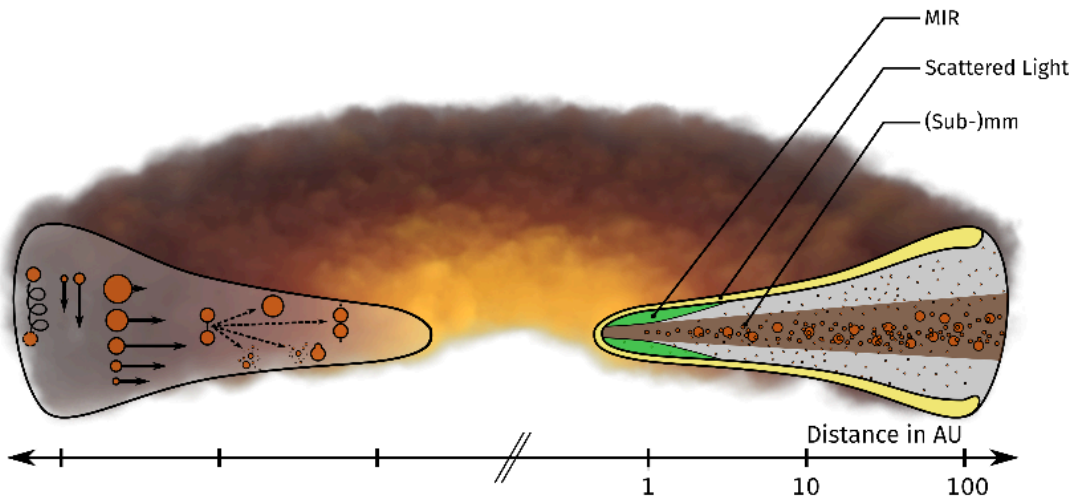

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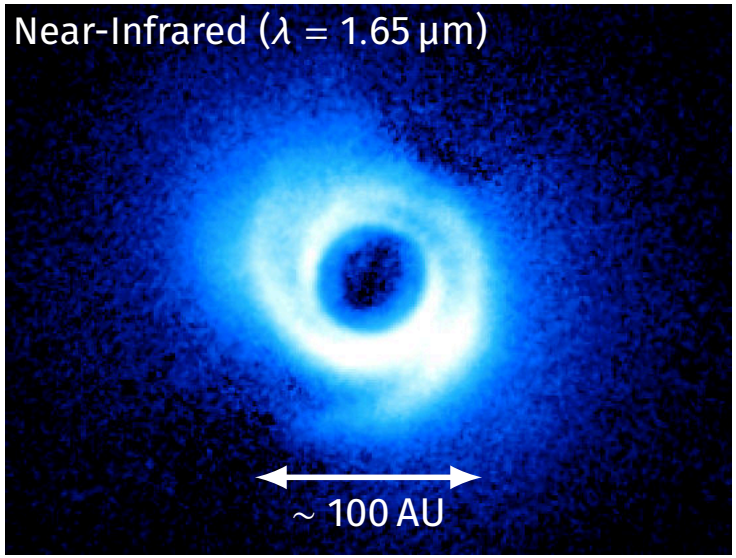

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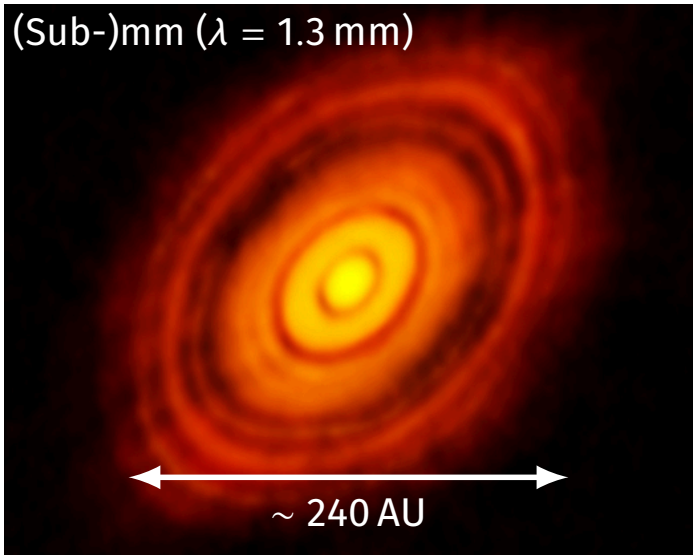
JWST



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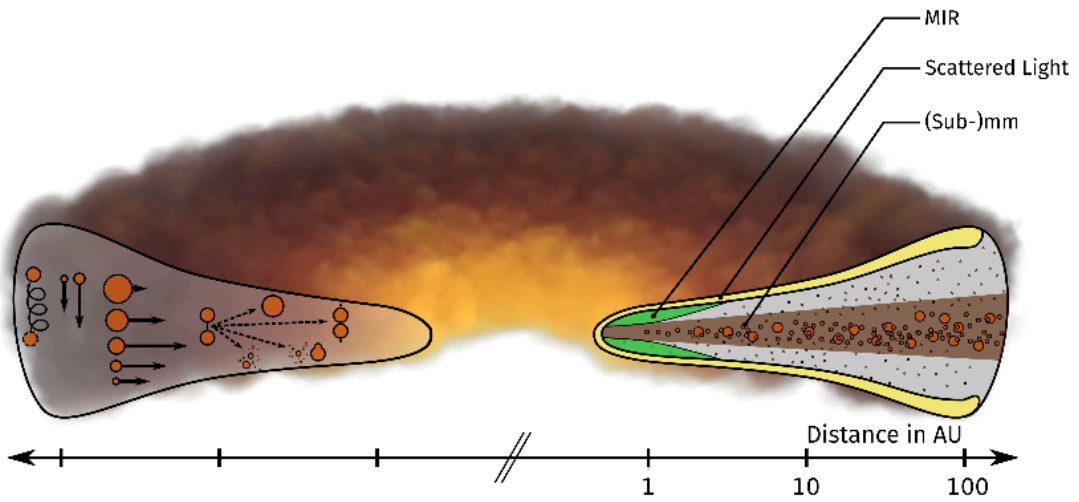

Radiative transfer simulations of protoplanetary disks

- Derive constraints from existing observations
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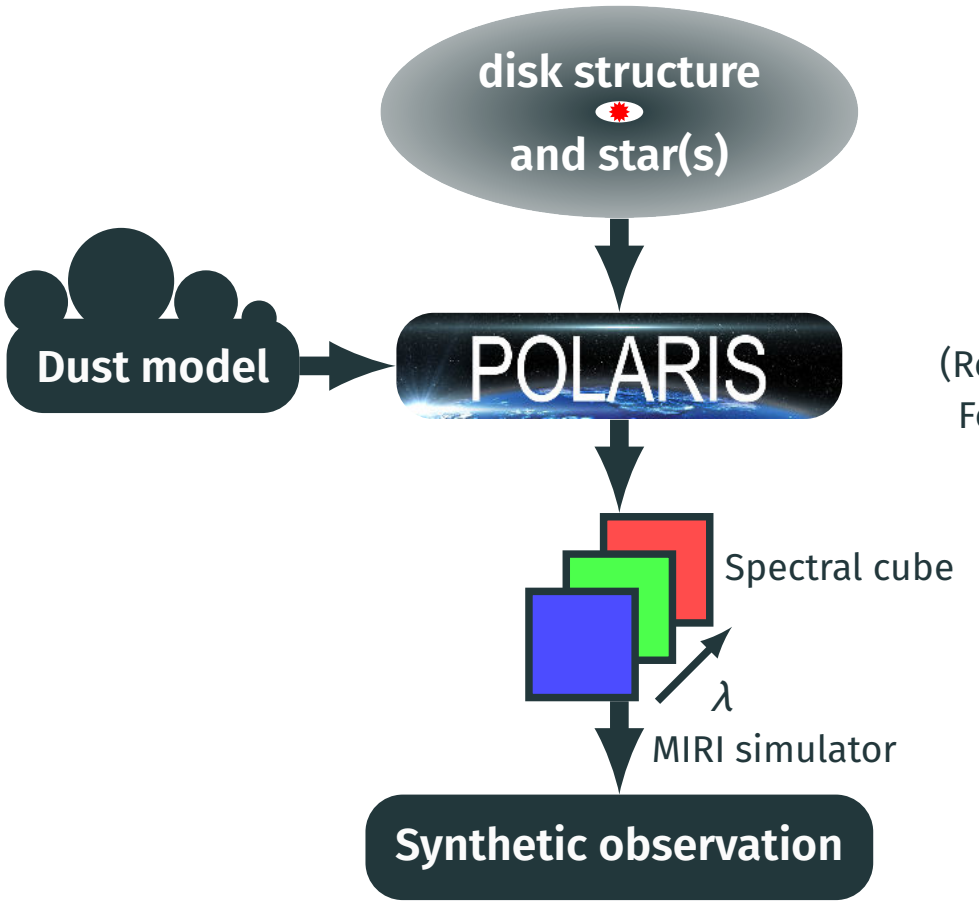
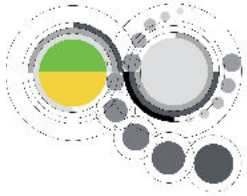


POLArized RadIation Simulator
(Reissl et al. 2016, Brauer et al. 2017)
For disks ⇒ (Brauer et al. in prep.)



THEMIS

The **H**eterogeneous dust **E**volution **M**odel
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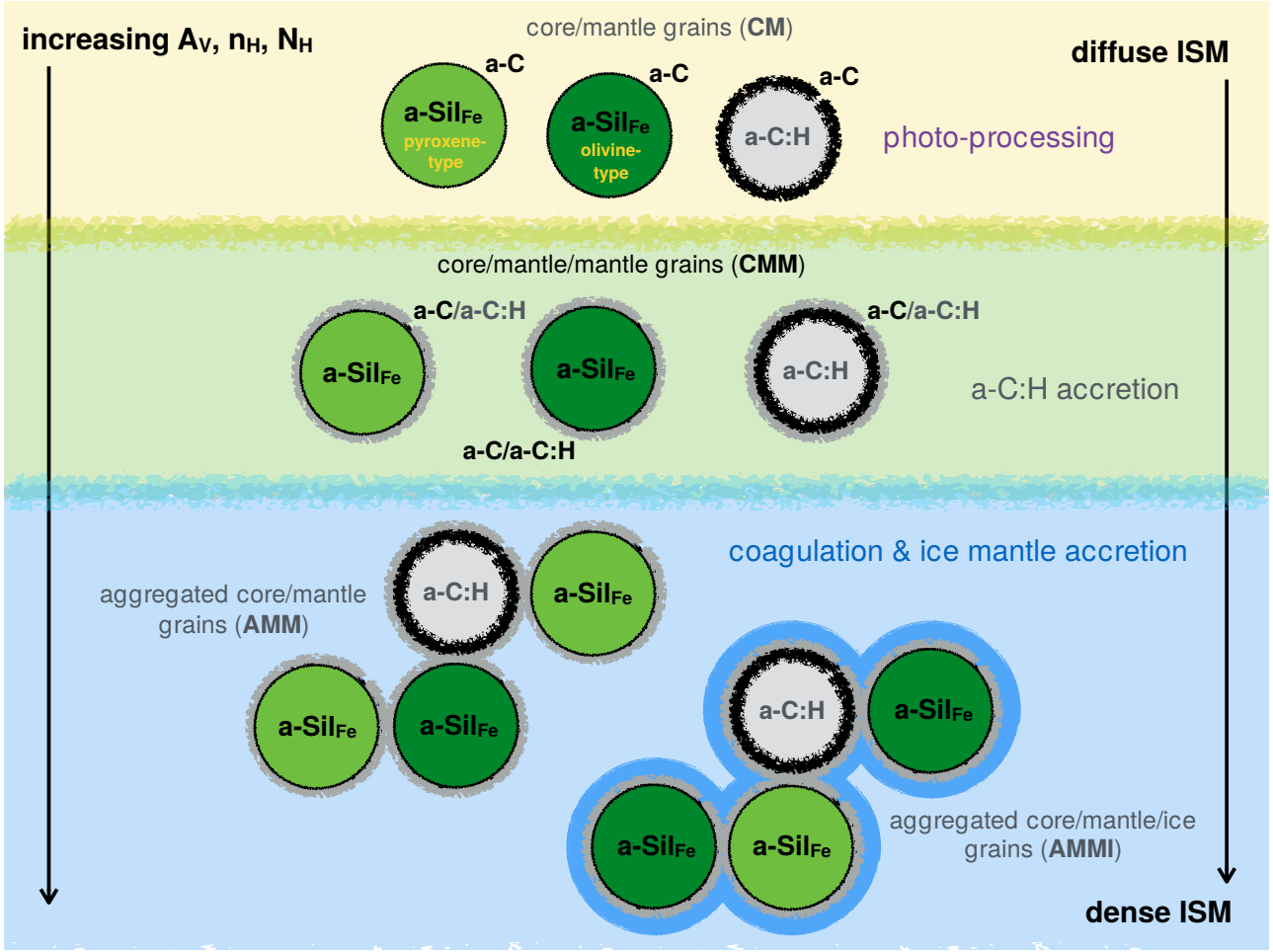

Overview of the THEMIS model (Jones et al. 2017)

THEMIS

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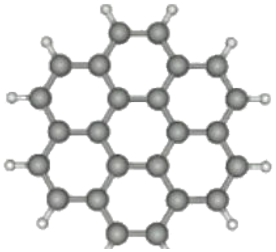
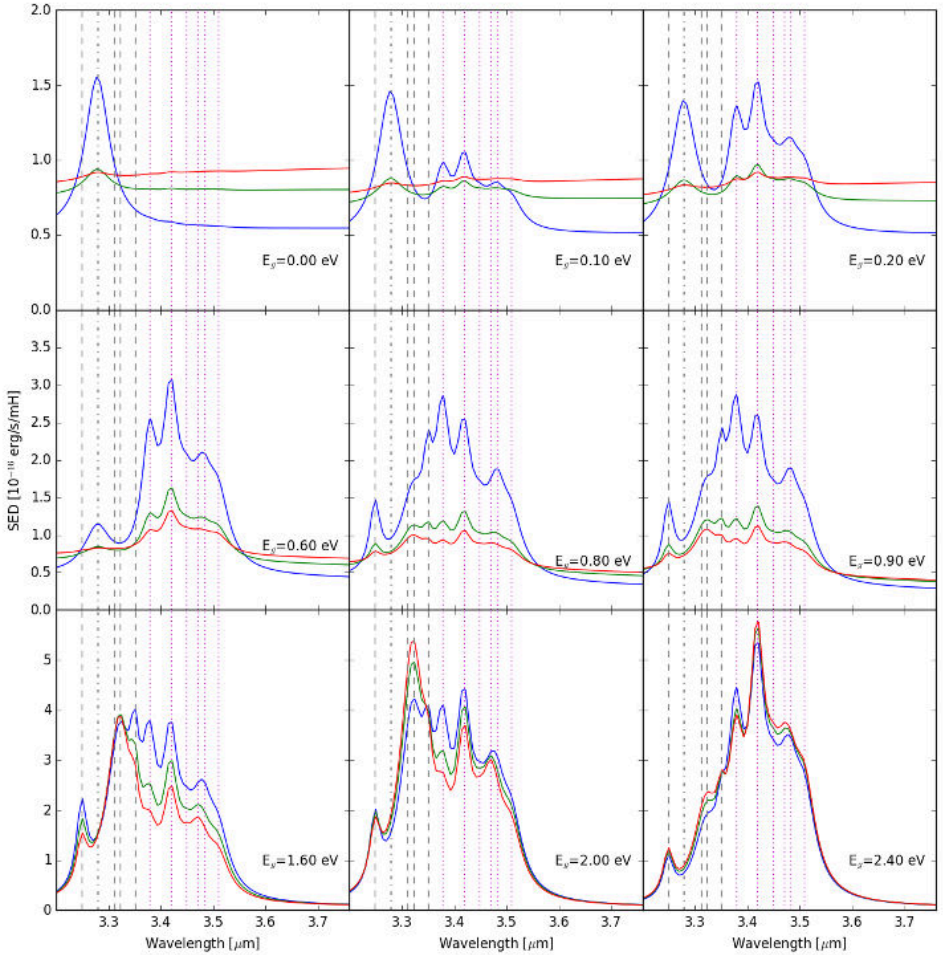
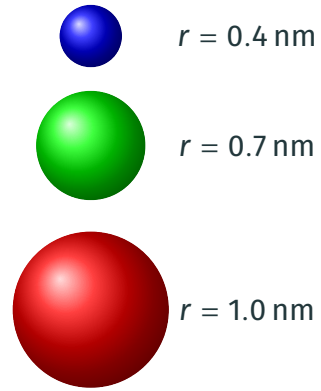
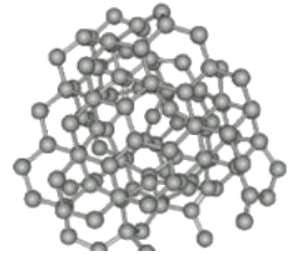
aromatic







aliphatic



Optical properties of carbonaceous grains depending on size and structure
(derived from laboratory data)

Radiative transfer simulations of protoplanetary disks

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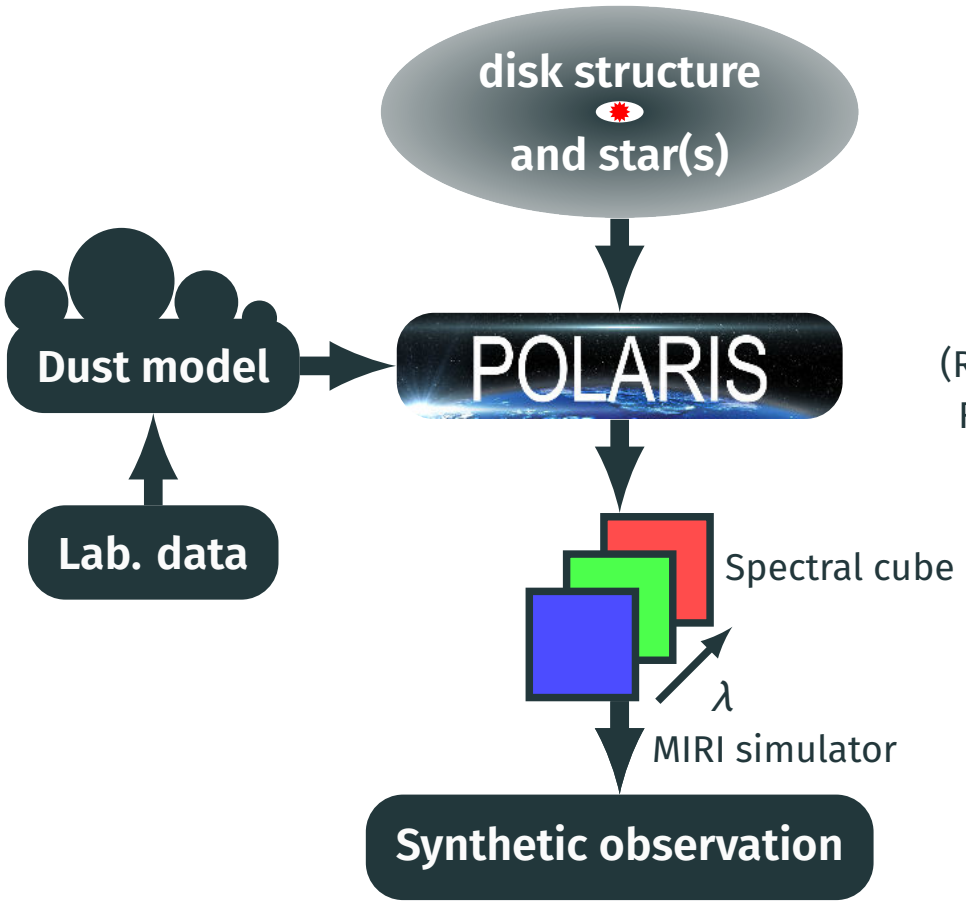
- Derive constraints from existing observations



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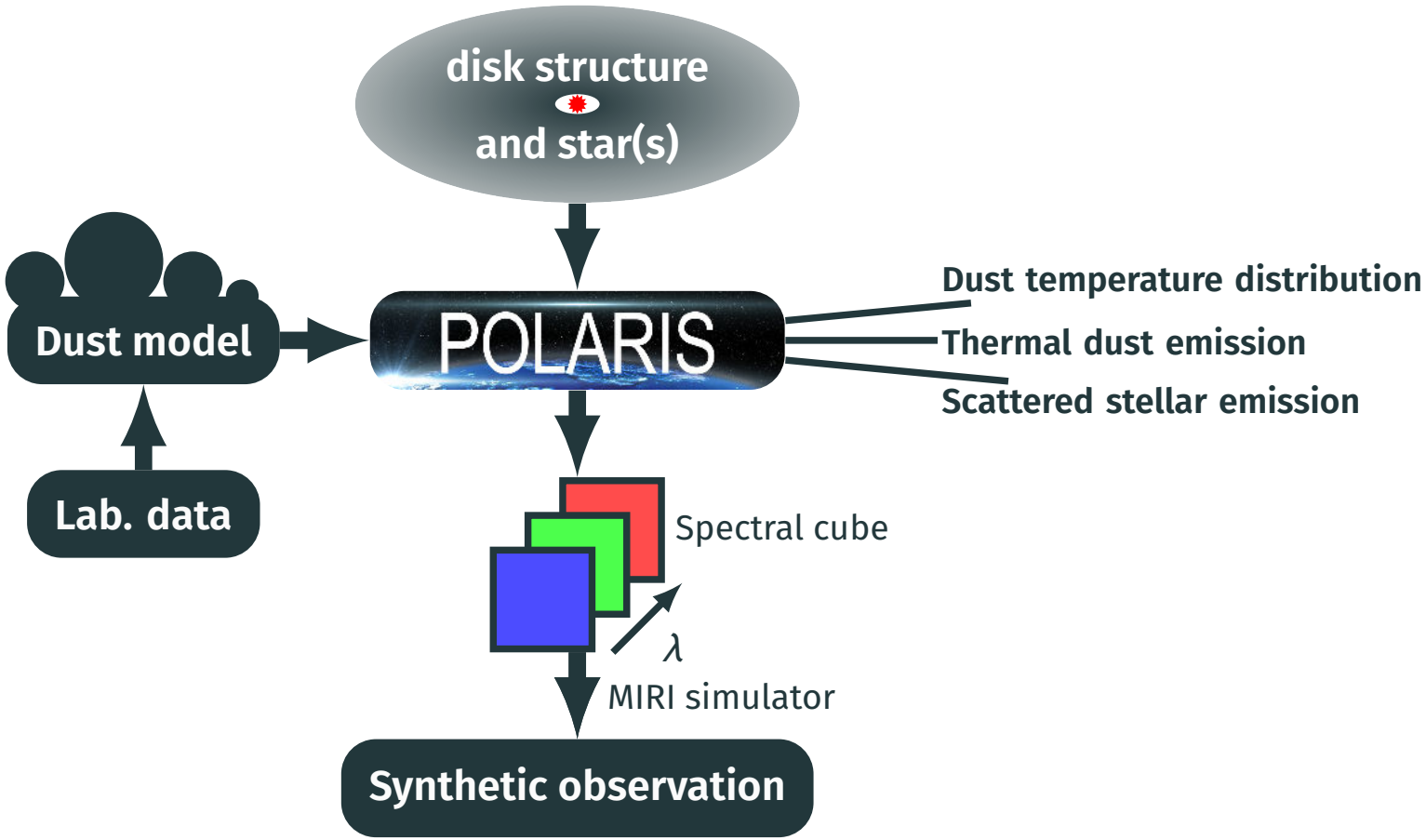

Planet formation in disks around multiple stars

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- **GG Tau A:** Unique system with a large disk around at least 2 stars

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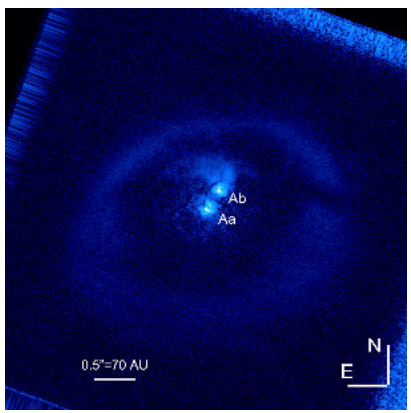
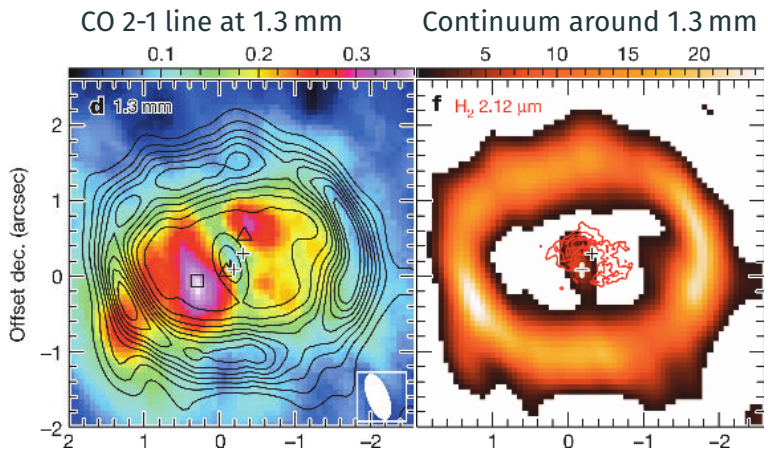


(Yang et al. 2017)



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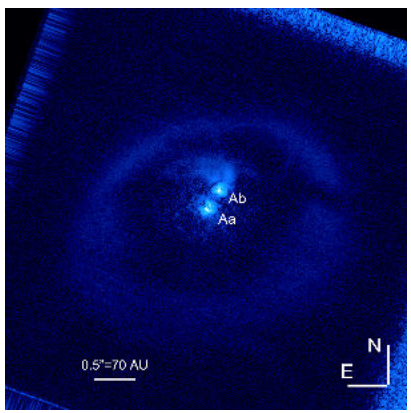

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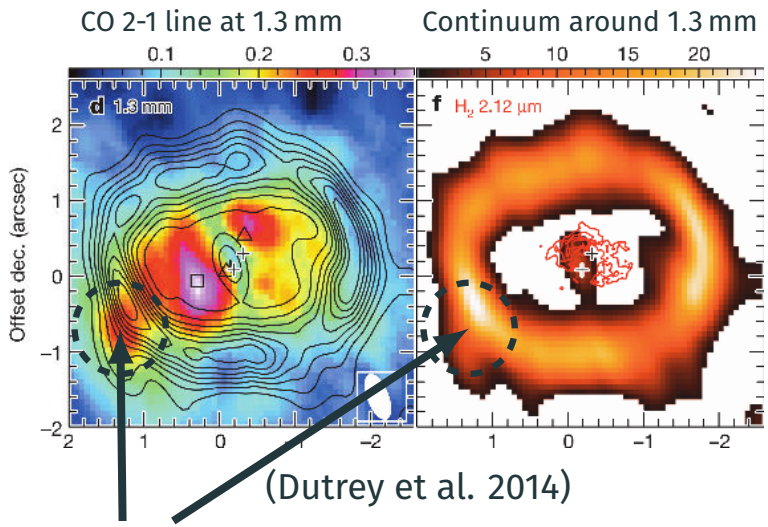

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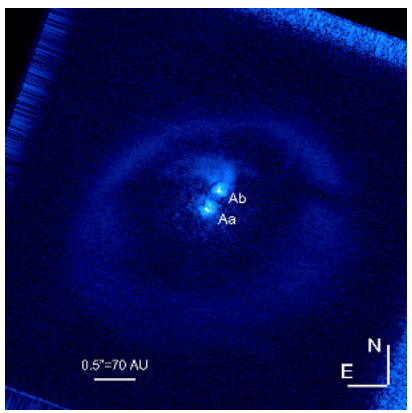

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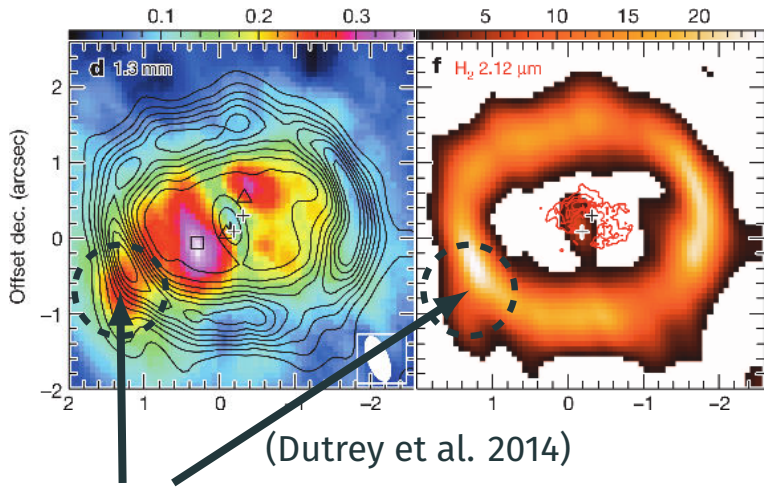
JWST

CO 2-1 line at 1.3 mm | Continuum around 1.3 mm



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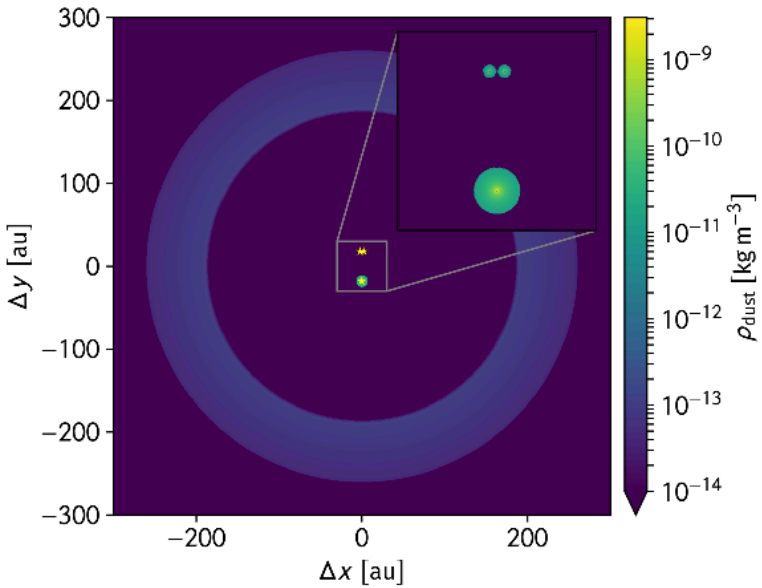

Dust density as a cut through the midplane

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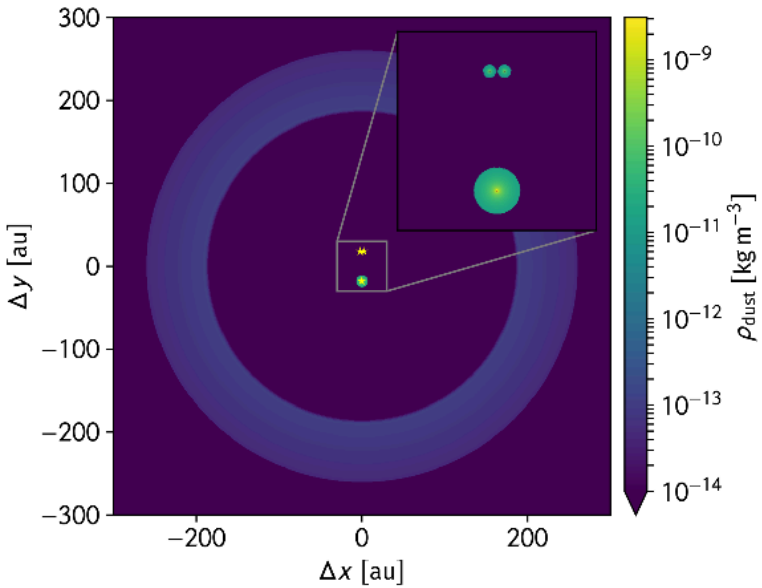
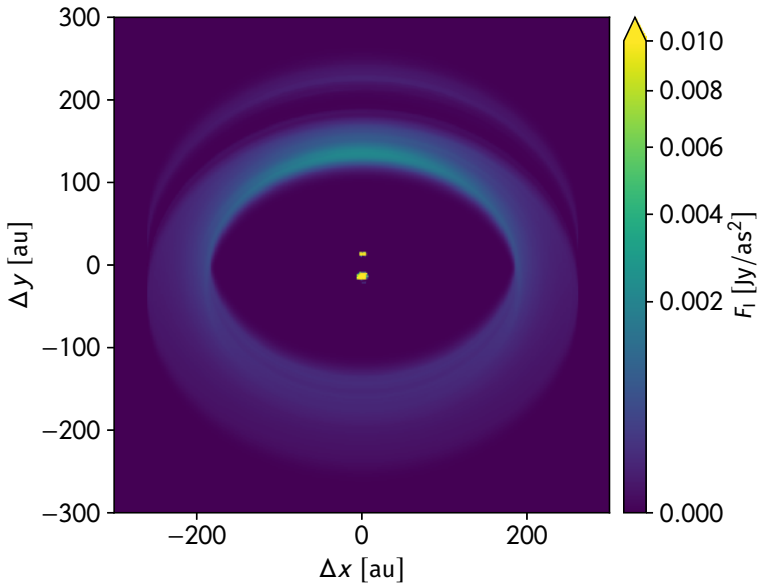


Dust density as a cut through the midplane

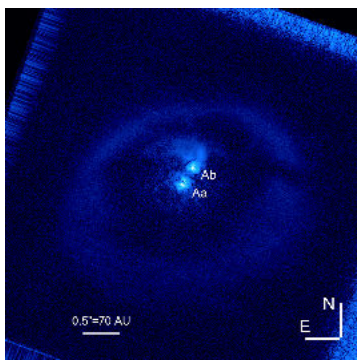


Simulated emission ($\lambda = 7.7\,\mu m$)

Planet formation in disks around multiple stars

- Multiple star systems are very frequent
- **GG Tau A:** Unique system with a large disk around at least 2 stars

Near-Infrared (λ = 1.65 µm)



(Yang et al. 2017)

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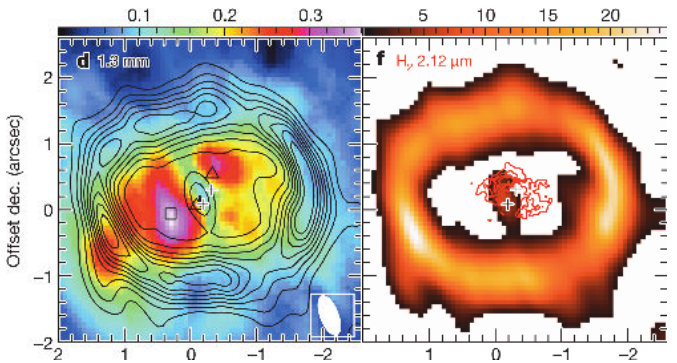
JWST

CO 2-1 line at 1.3 mm Continuum around 1.3 mm



(Dutrey et al. 2014)

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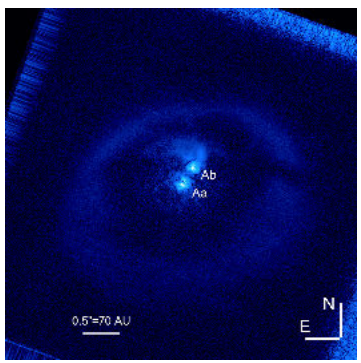

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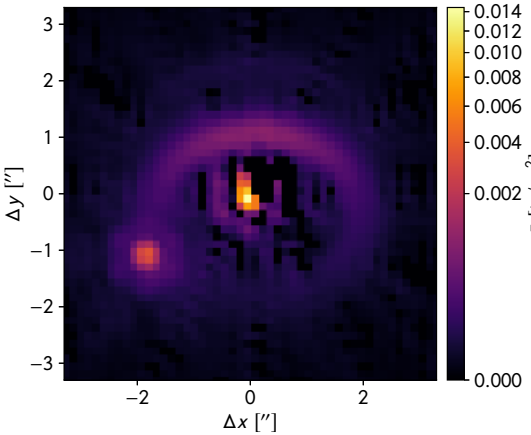
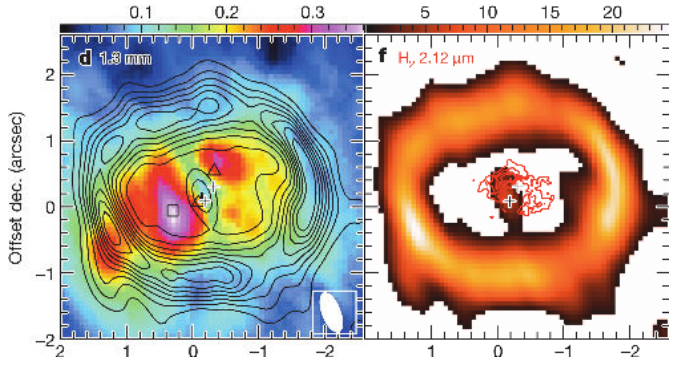
Infrared ($\lambda = 7.7\,\mu m$)



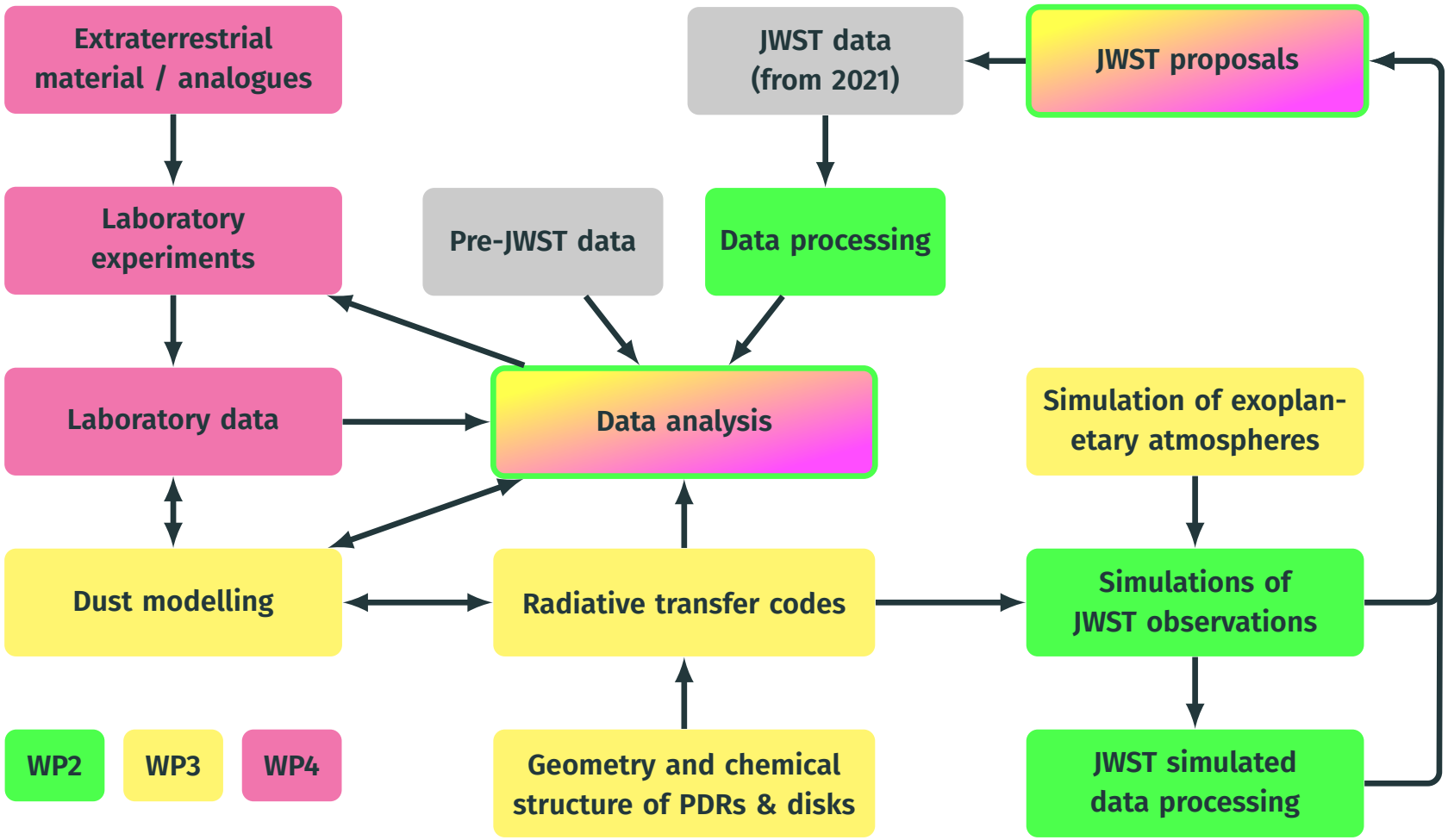
Synthetic observation (MIRI simulator)

CO 2-1 line at 1.3 mm Continuum around 1.3 mm

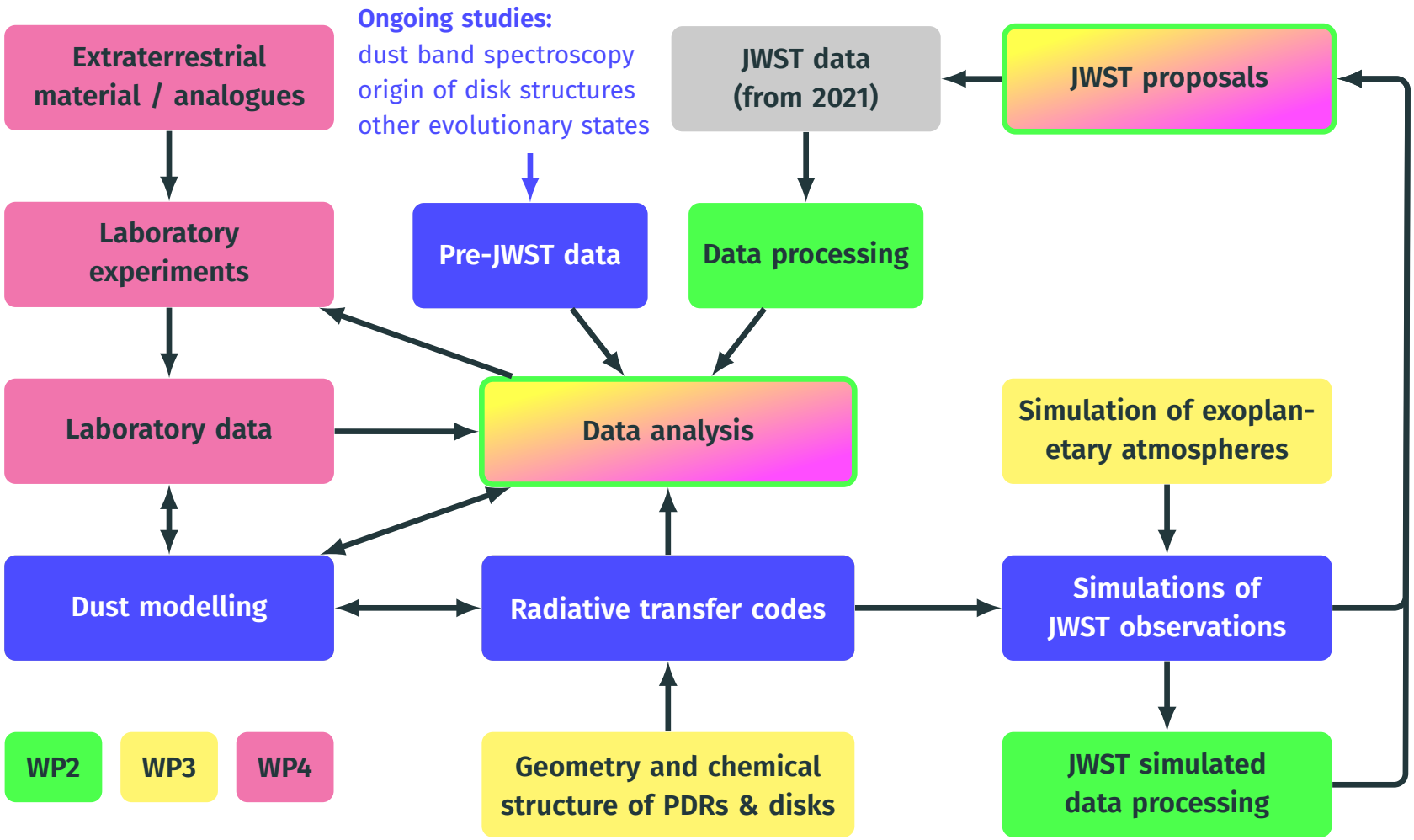


(Dutrey et al. 2014)

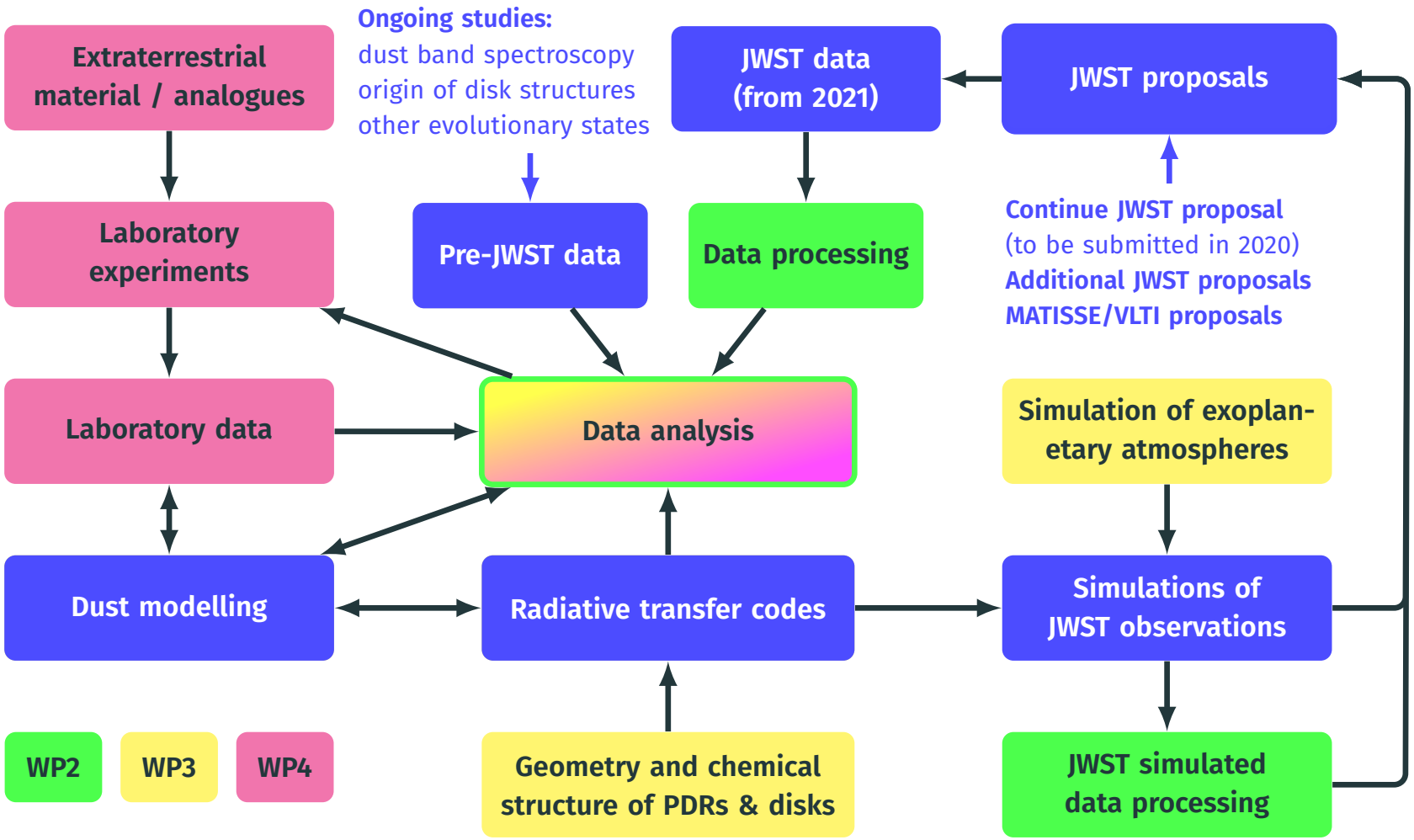
Ongoing work and perspectives



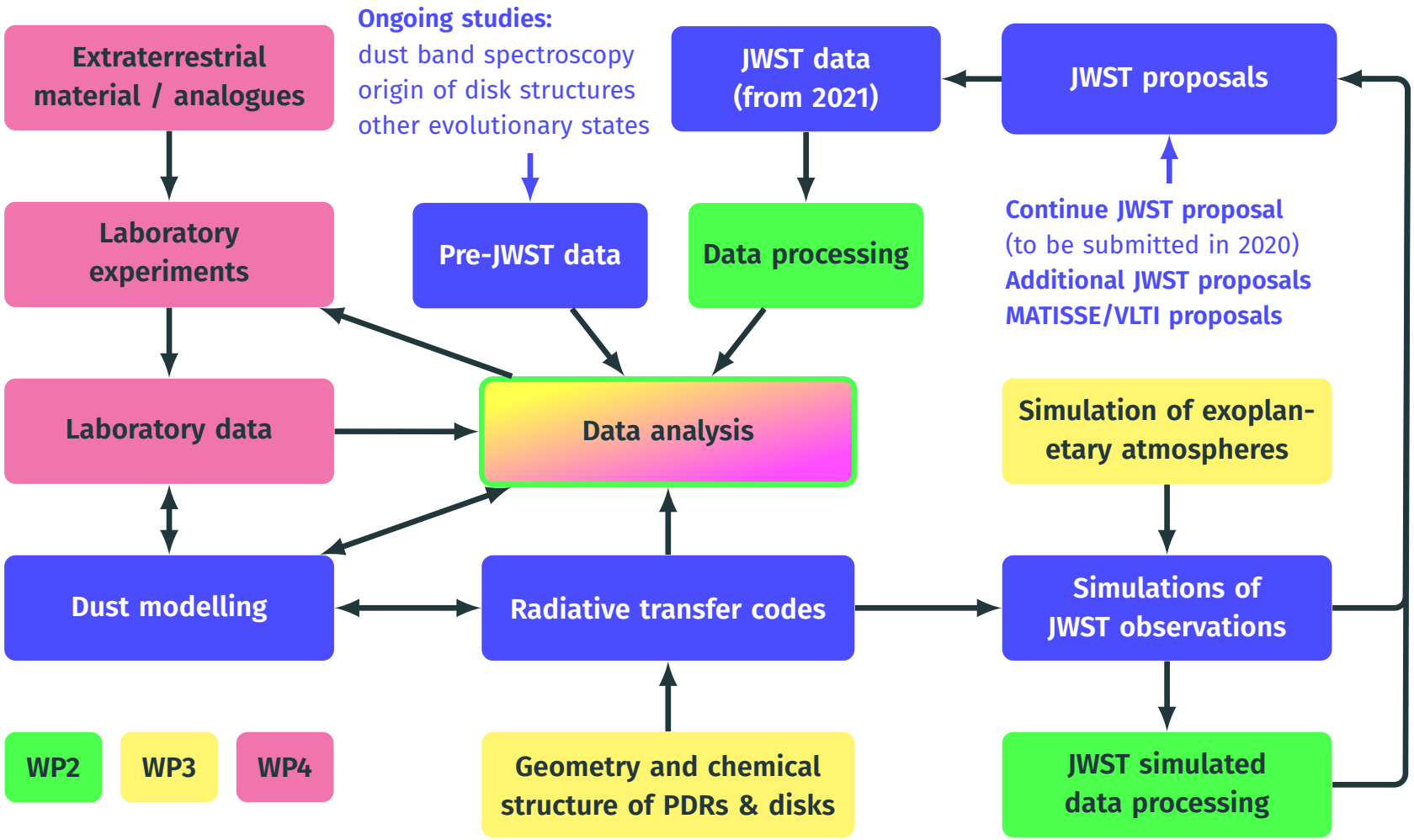
Ongoing work and perspectives



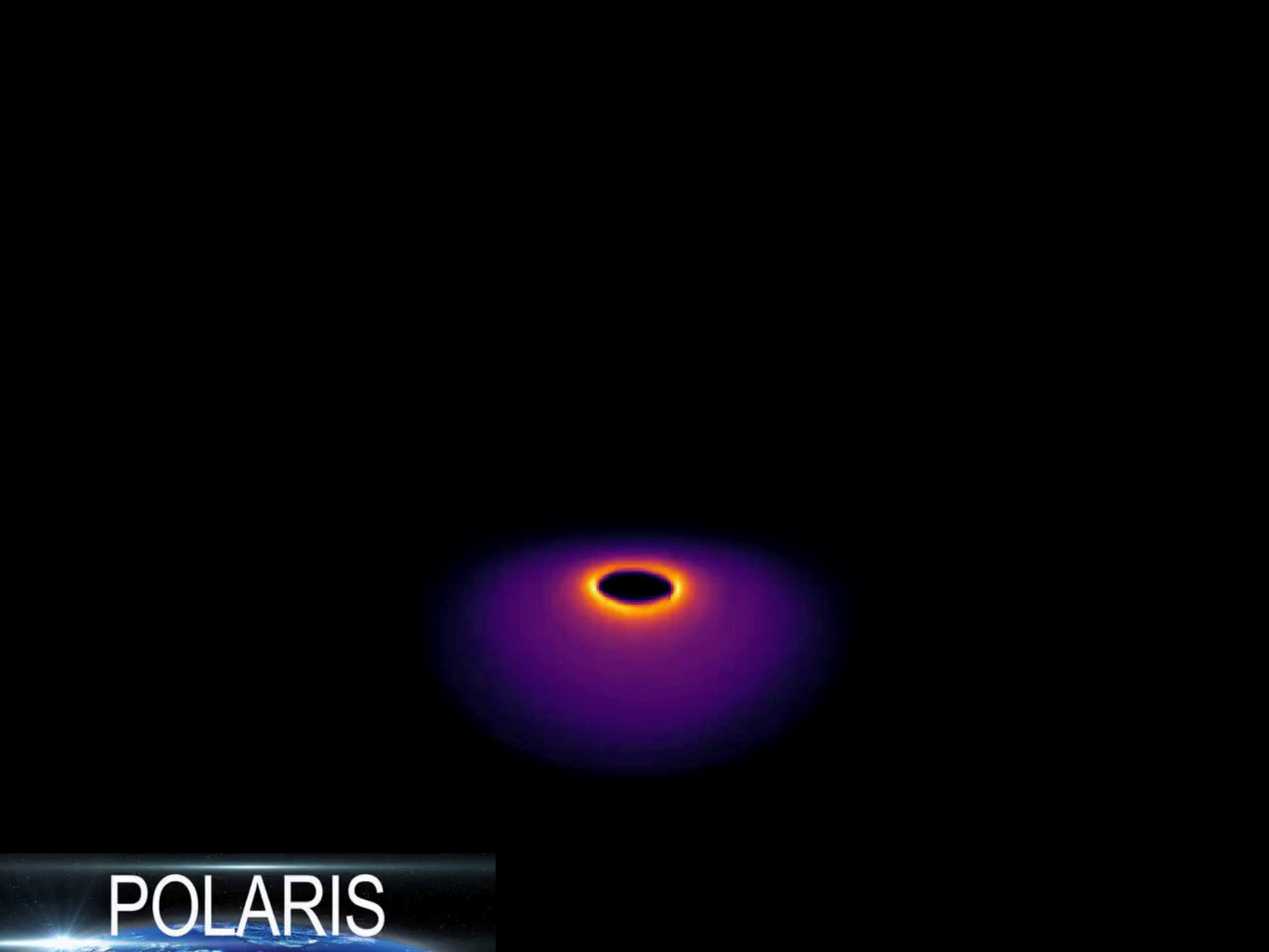
Ongoing work and perspectives



Ongoing work and perspectives



Future perspectives:
Continue to work on star and planet formation
Combine gained expertise/knowledge with new topics


POLARIS