ANADIPLOSIS*:

*ANAlysis of Dispersal Indicators in Planet-fOrming circumStellar dISks***

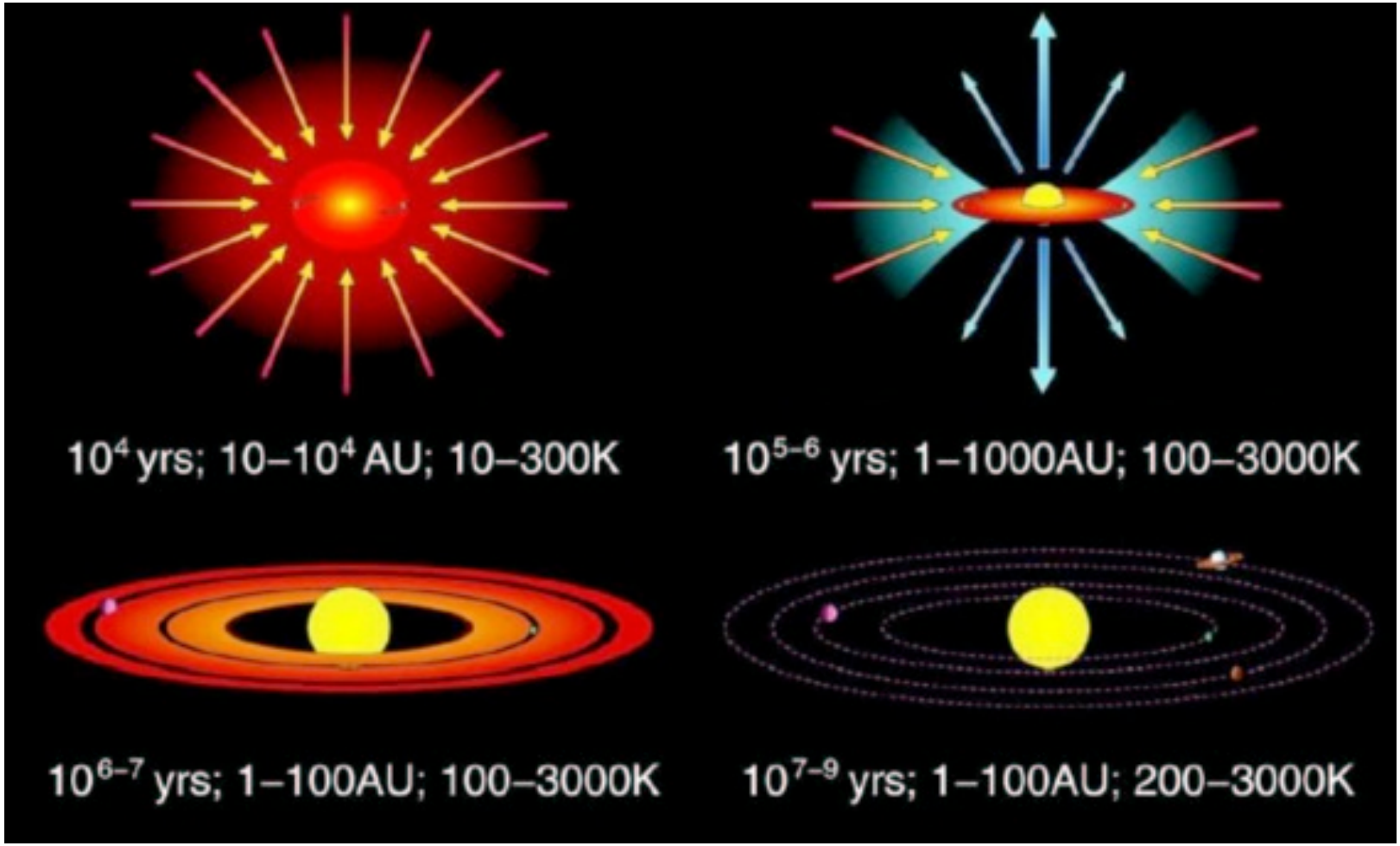
Elisabetta Rigliaco (INAF – OAPD)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 664931

*"Once you change your philosophy, you change your thought pattern. Once you change your thought pattern, you change your attitude. Once you change your attitude, it changes your behavior pattern and then you go on into some action."—Malcolm X

**"Disks form planets, the same planets that hide the life we are all looking for." —E. Rigliaco

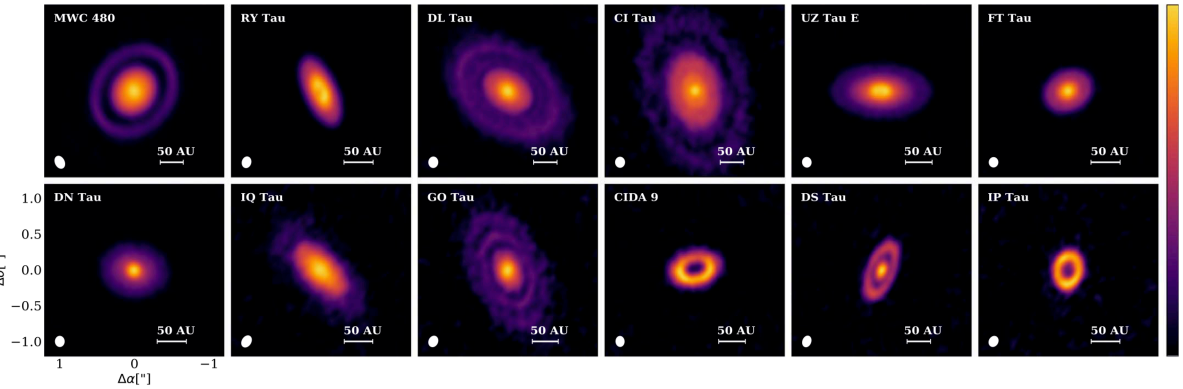
General Context: star formation and circumstellar disks

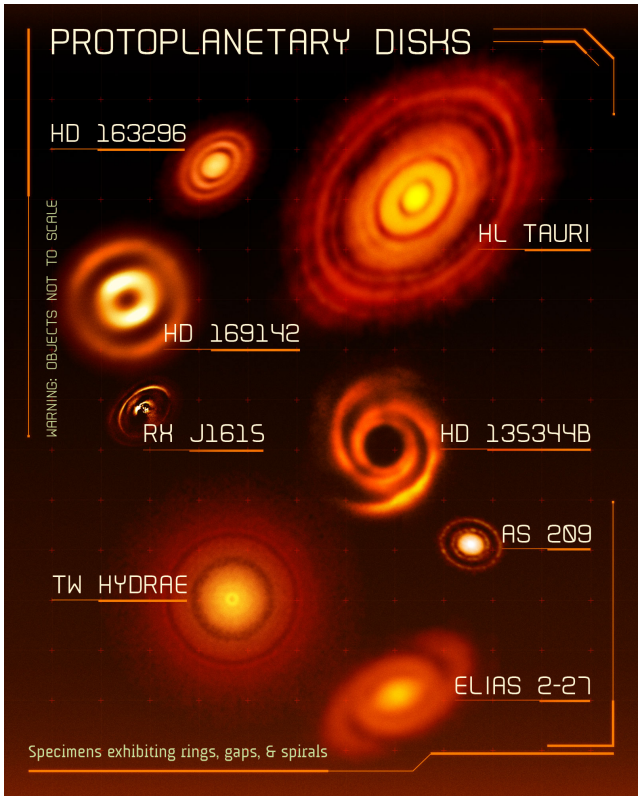


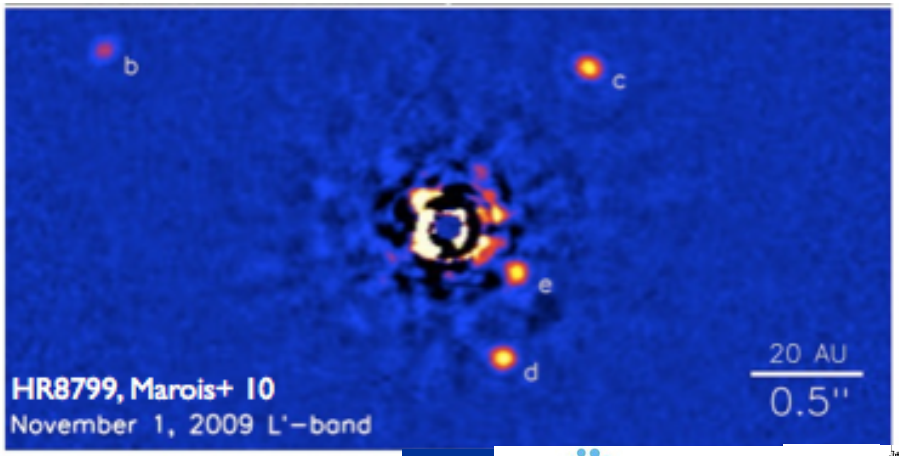
Circumstellar disks are the natal environment of planets

How Does a Disk Disperse?

Long,…,Rigliaco et al. 2018

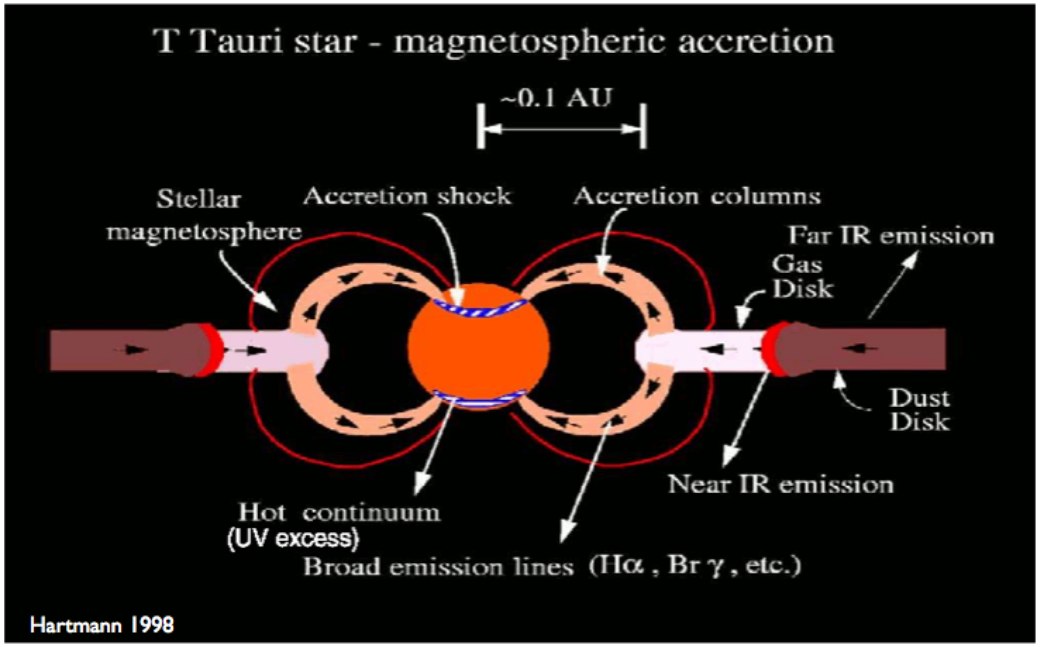






Disk Dispersal Mechanisms

Magnetospheric accretion: active throughout the disk lifetime (e.g., Alcala',…,Rigliaco et al. 2017) affecting mainly the inner disk



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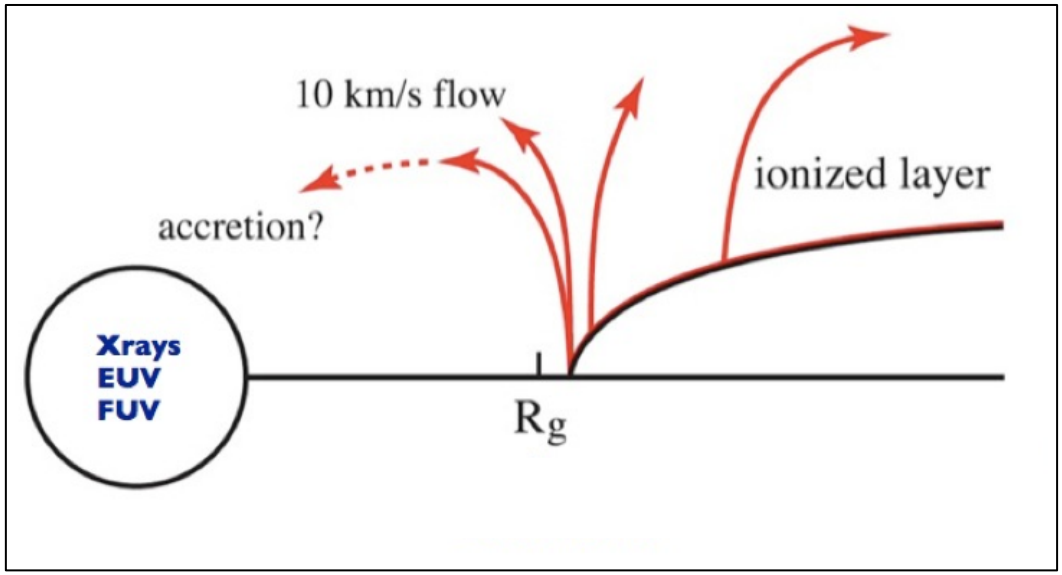

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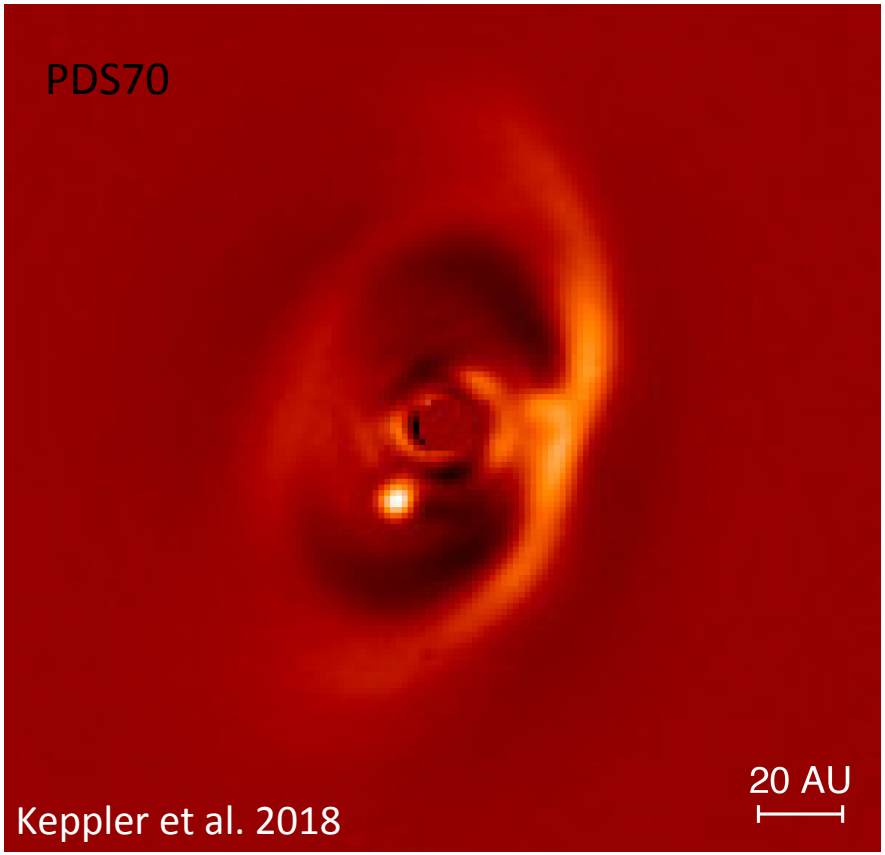
Planet formation: only a small fraction of the disk mass ends up in planets (e.g., Wright et al. 2011, Mayor et al. 2013)



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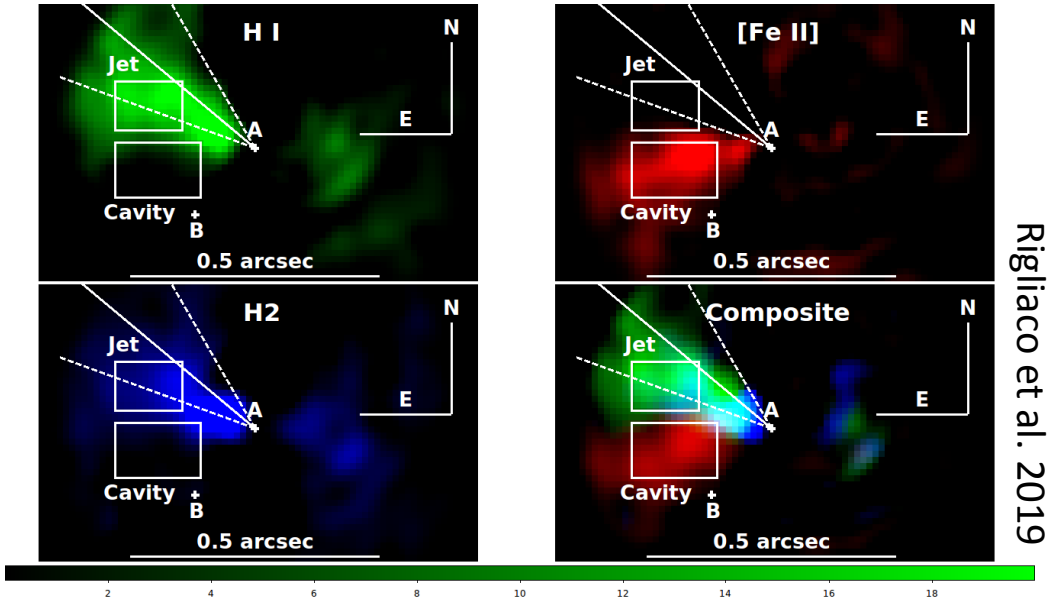
Jets and stellar winds: mainly efficient in the early stages of star formation (e.g., Rigliaco et al. 2019; Giannini,…,Rigliaco et al. 2019)

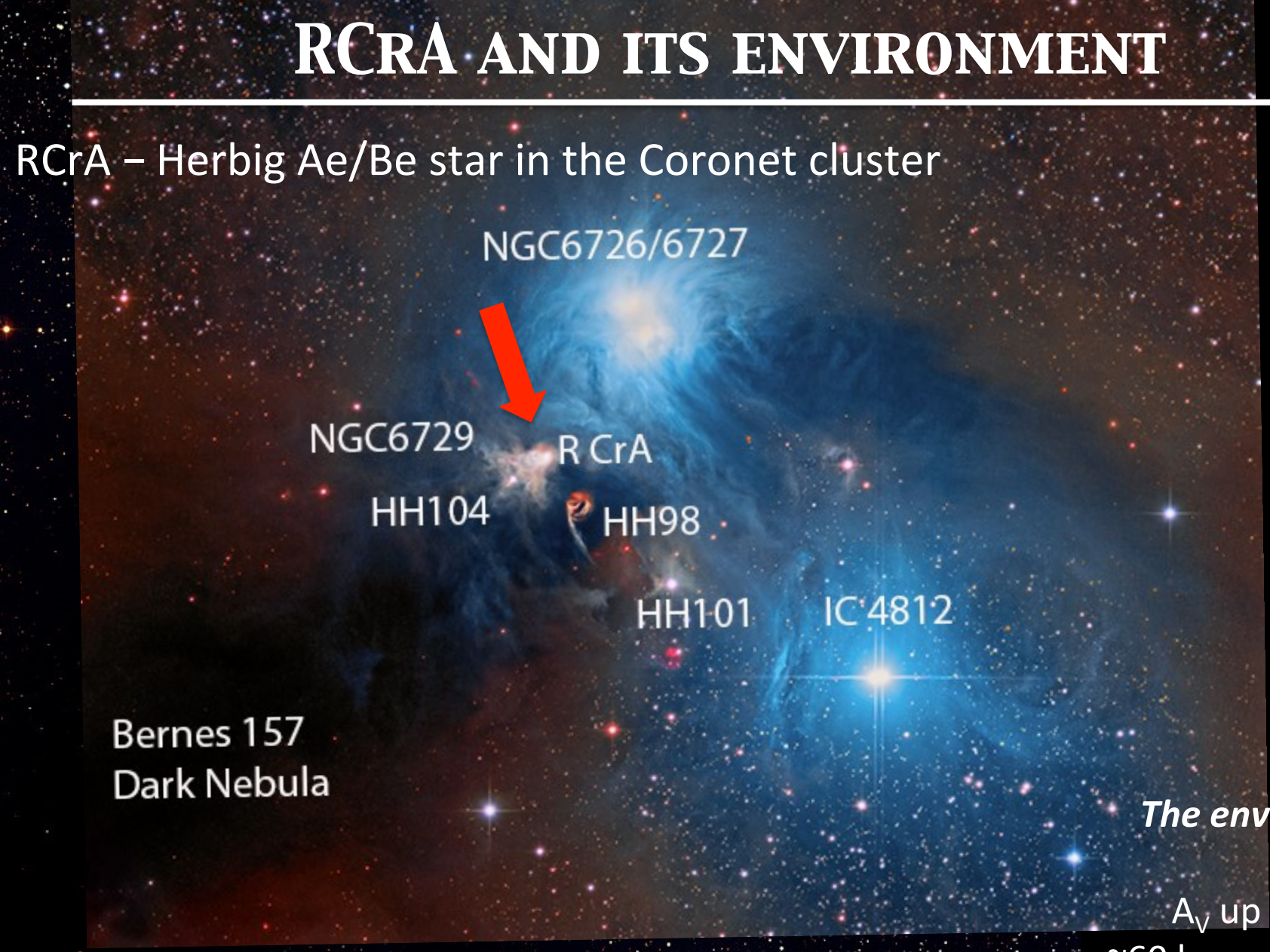
RCrA



Rigliaco et al. 2019

RCrA and its environment

RCrA – Herbig Ae/Be star in the Coronet cluster



R Coronae Australis Complex (MPI/ESO 2.2-m + WFI)

ESO PR Photo 25a/00 (6 October 2000)

The environment:

A_V up to 45 mag

~60 known optically detected members

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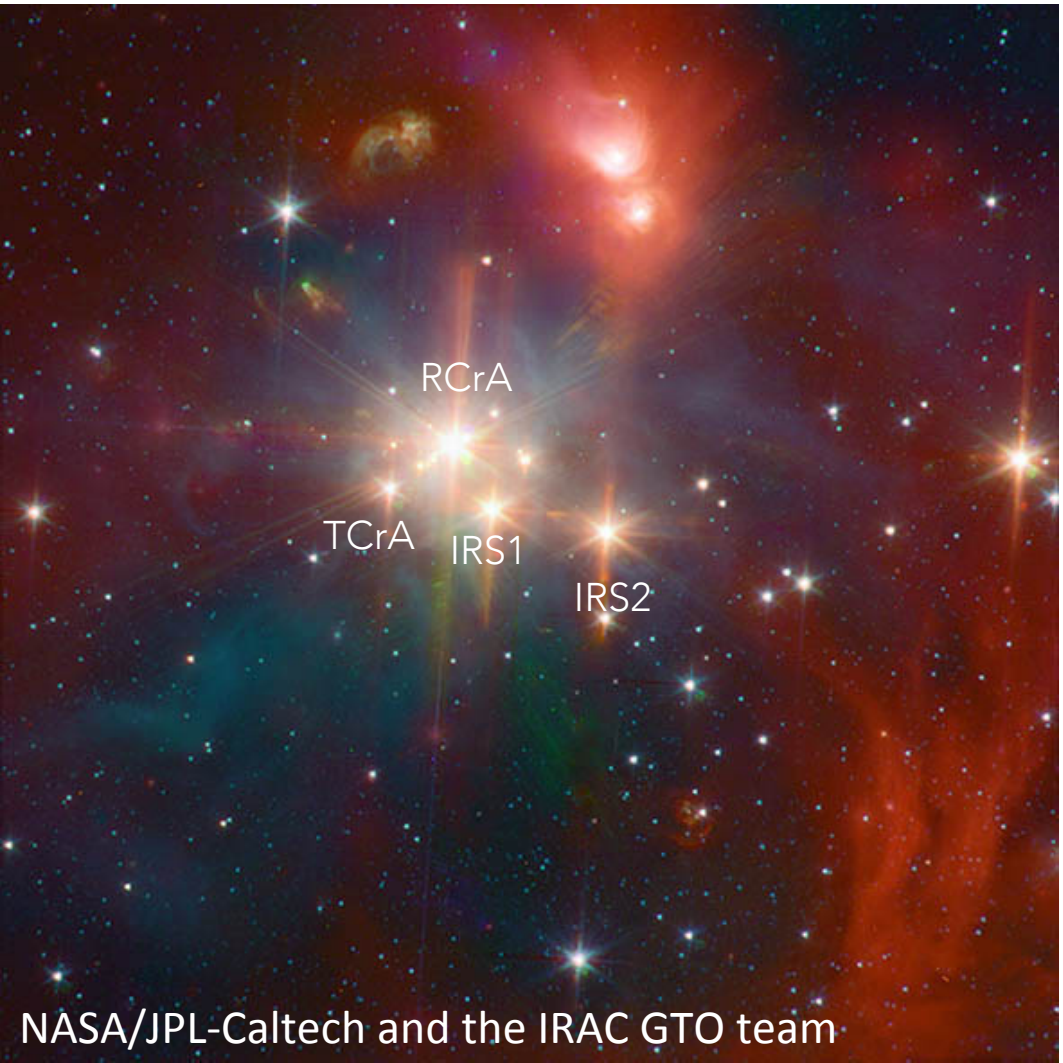


The star:

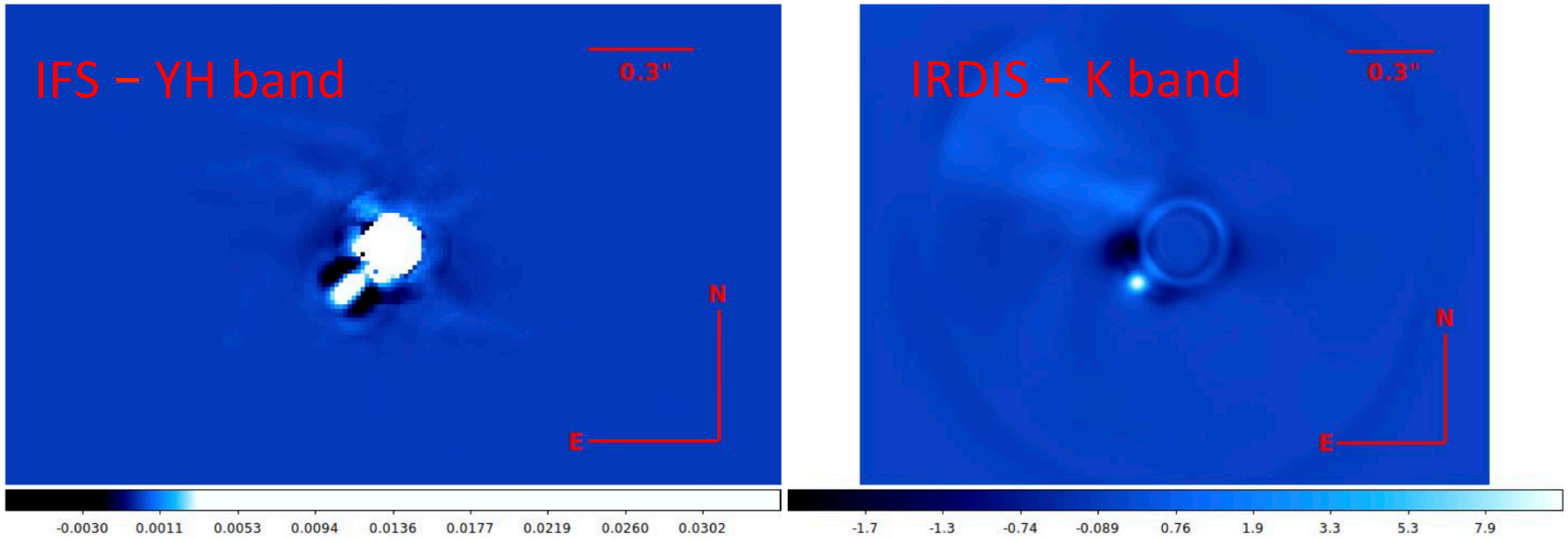
SpTy: B5-F5
Distance ~ 154 +/- 4 pc
Age ~ 1 Myr

Why is it interesting?

Variable
Embedded in natal environment
Has a companion
Shows signatures of outflow

RCrA as observed with SPHERE

extreme AO system and coronagraphic facility at VLT



Mesa,...,Rigliaco et al. 2019

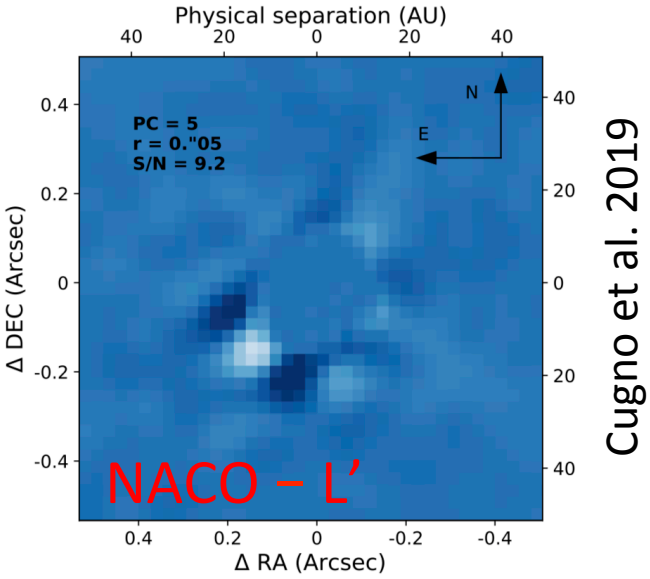
M-type companion at 0.156" (~25au)

0.30 < mass < 0.55 M_{sun}

orbital eccentricity *e*=0.4

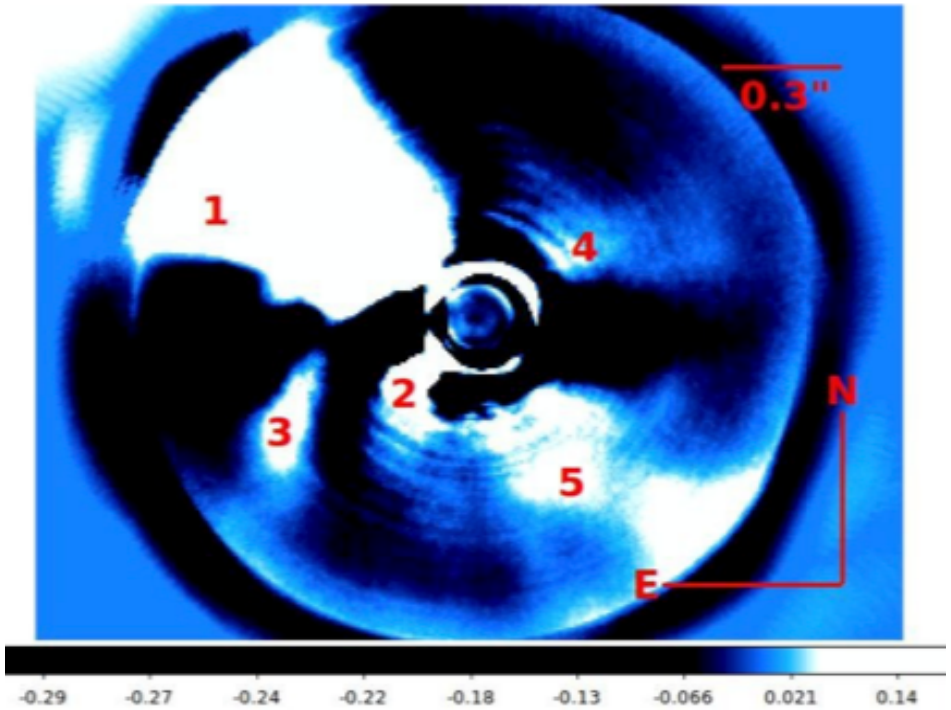
semi-major axis = 27au

orbit inclination~ 70 deg



Cugno et al. 2019

RCrA: SPHERE DATA



Mesa et al. 2019

Identified Features:

1: extended structure

2: M-type ~0.5 M_{sun} companion at ~20AU (confirmed by Cugno et al. 2019)

3,4: External disk (?)

5: Counter-extended structure (fainter)

RCrA: THE NATURE OF THE VARIABILITY

Light curve due to a close binary surrounded by a circumbinary dusty disk

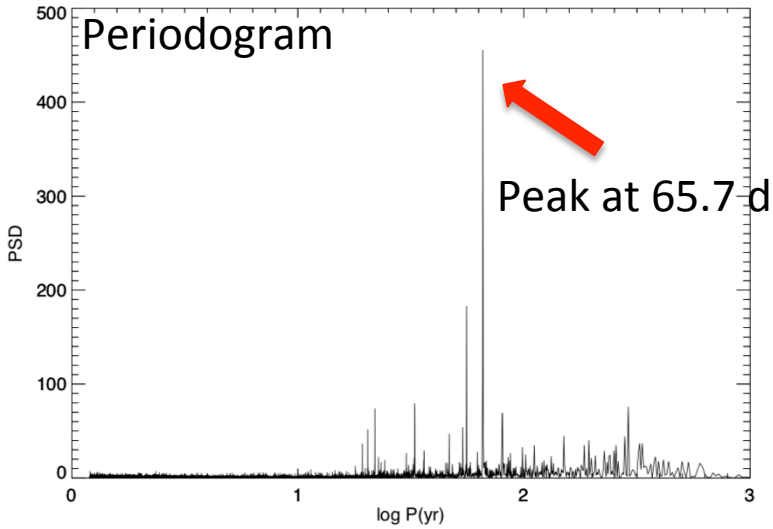
M_A = 3.02 +/- 0.43 M_{sun}
M_B = 2.32 +/- 0.35 M_{sun}

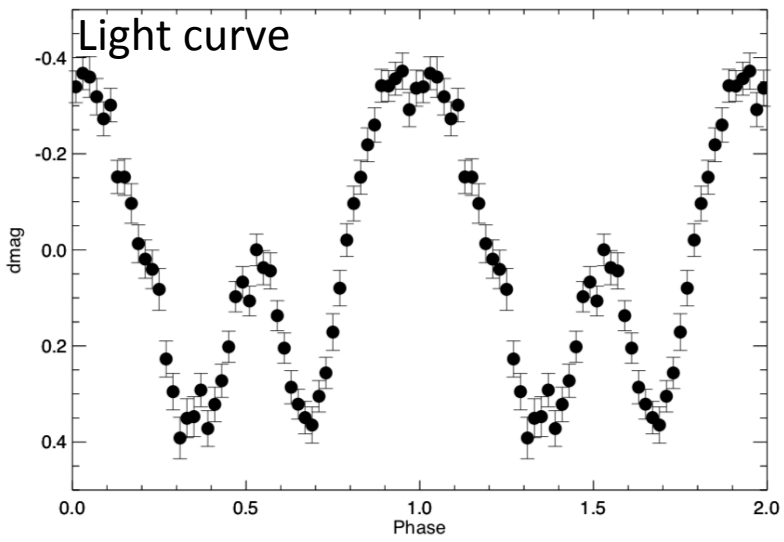
M_{TOT} = 5.34 +/- 0.8 M_{sun}

semi-major axis = 0.56 au

A_V = 5.47 mag (from spectroscopic data)

RCrA is thus a triple system

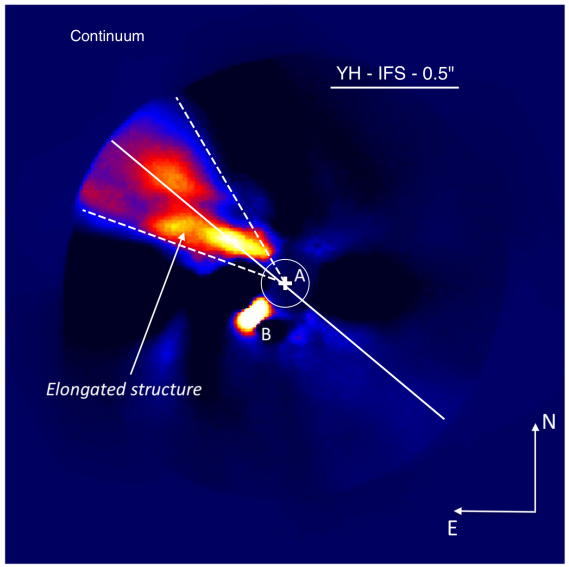




Sissa,...,Rigliaco et al. 2019

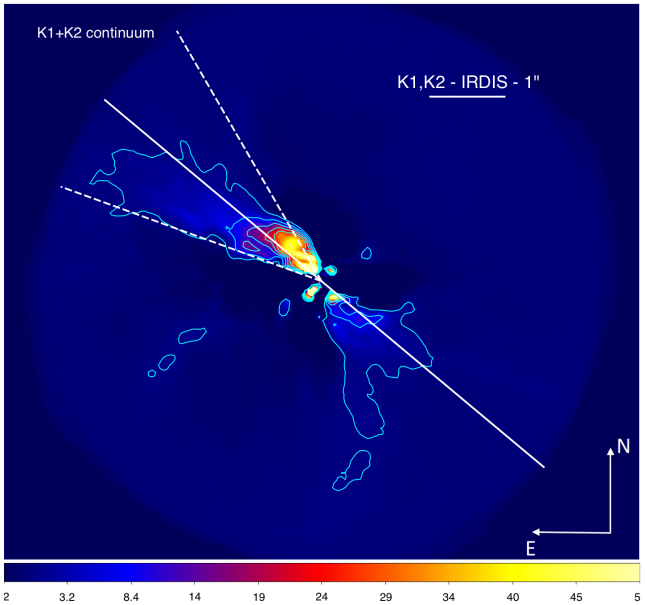
Combining HR and Diffraction Limited IFS

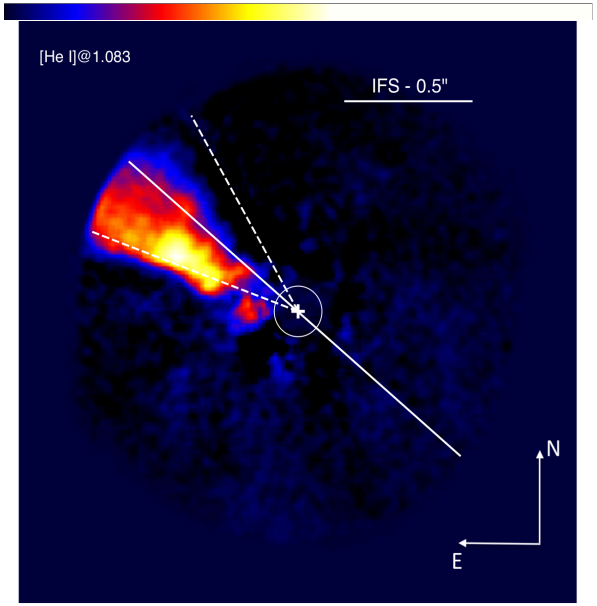
SPHERE data: continuum versus line emission



PA = 50 deg
aperture: 30-70 deg
extends up to 2.6” in IRDIS

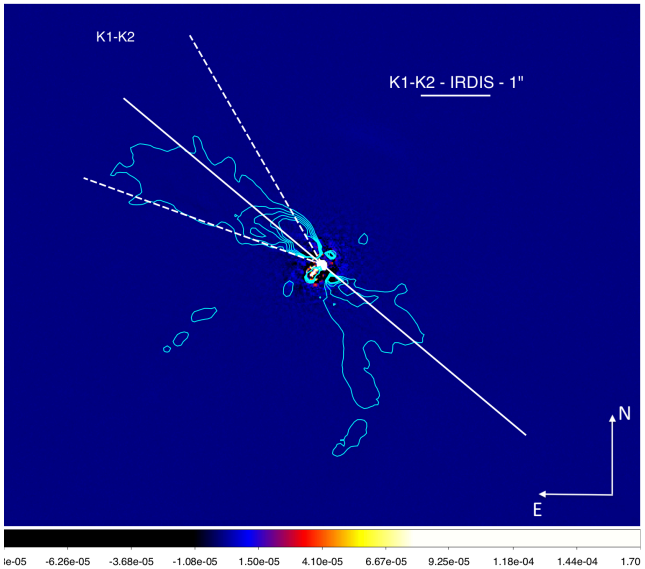
discontinuous continuum emission





HeI@1.083µm appears misaligned wrt cont. emission (PA~65 deg)

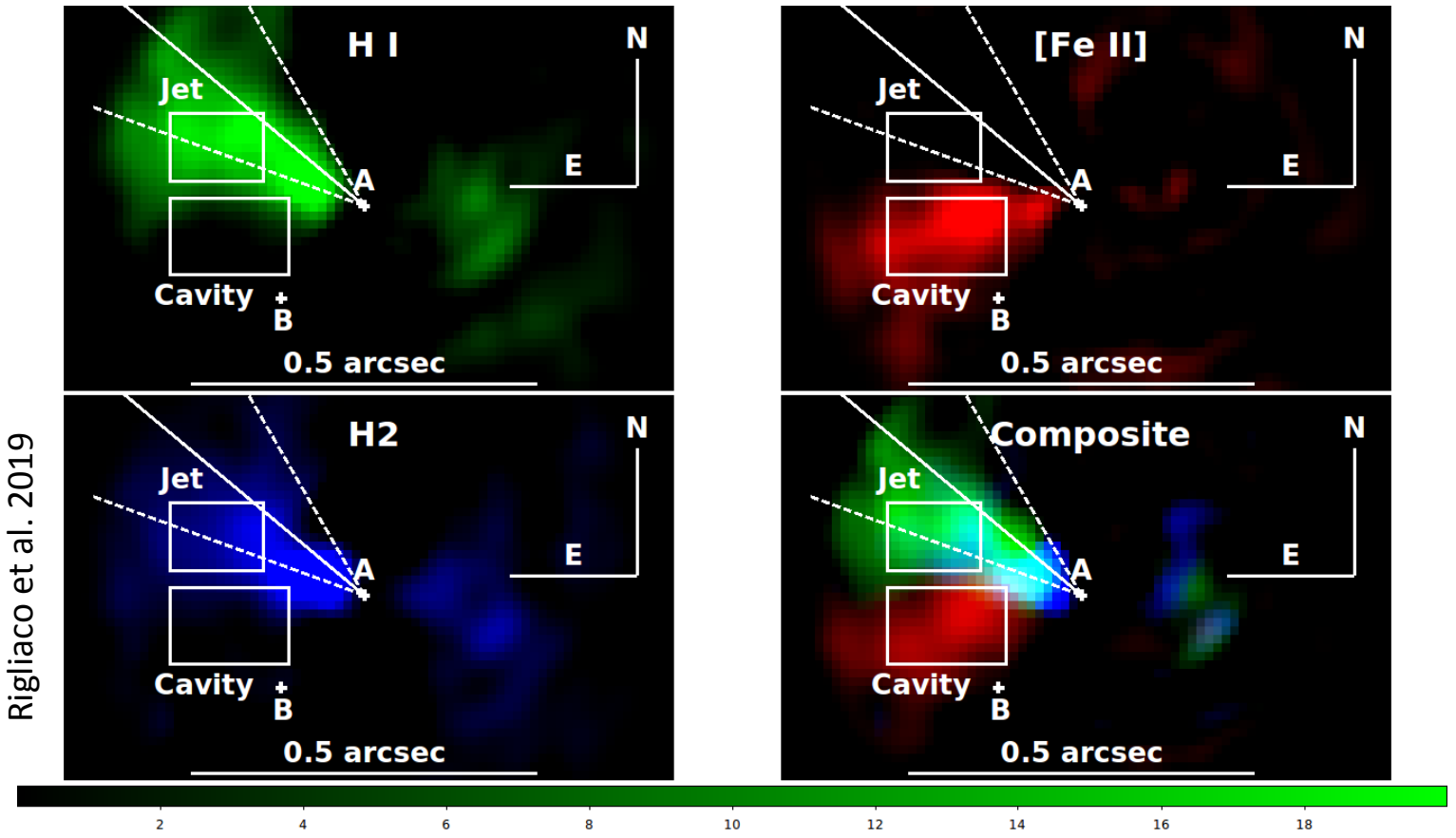
No H_2 lines detected in K1-K2



Rigliaco et al. 2019

Combining HR and Diffraction Limited IFS

SINFONI data λ1.45-1.85μm, R=3000 -- line emission

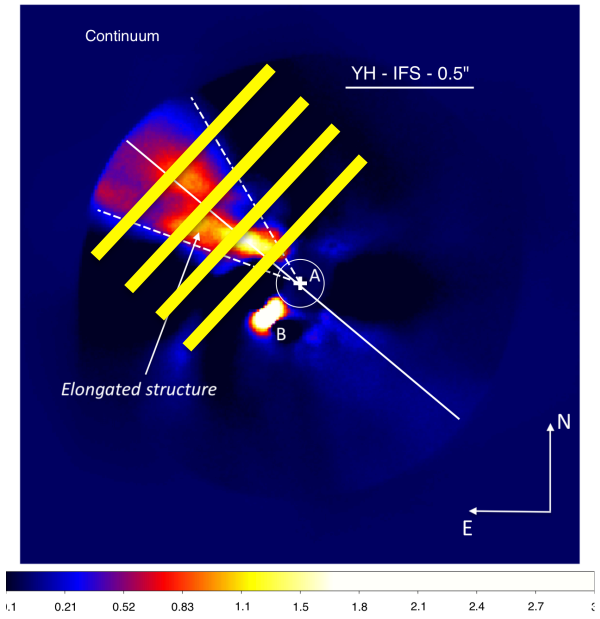


Rigliaco et al. 2019

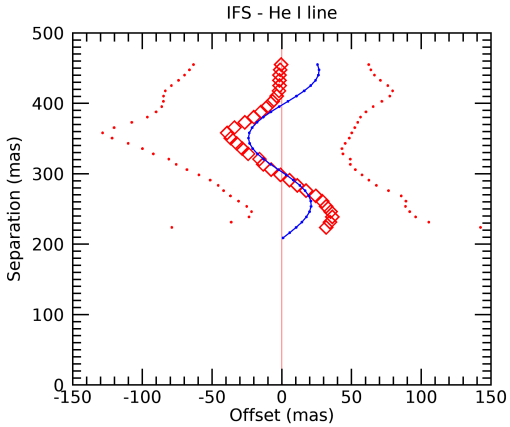
Gas lines do not share the same PA as the continuum emission

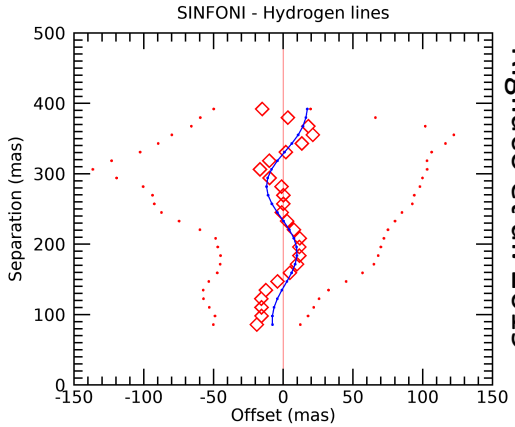
Hydrogen lines appear emitted along the “jet” direction
[FeII] lines appear emitted along the “cavity” direction
H2 lines appear emitted in a region close-by the central stars

WIGGLING OF THE JET

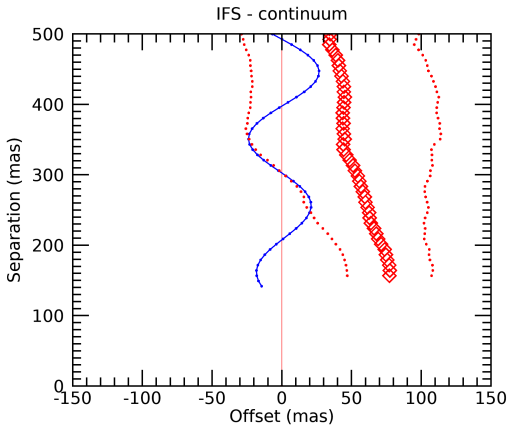


We consider set of continuous slices orthogonal to the axis and in each slice we fit the pixel distribution with a Gaussian function → we obtain profile peak position as a function of the distance from the star





Rigliaco et al. 2019



HeI and H lines have a wiggling pattern consistent with the rotation period of the central binary, as it is produced by the orbital motion of the jet around the binary system.

Continuum emission does not show a wiggling pattern.

Blue line: fit of the rotation period of the binary central star (66 days)

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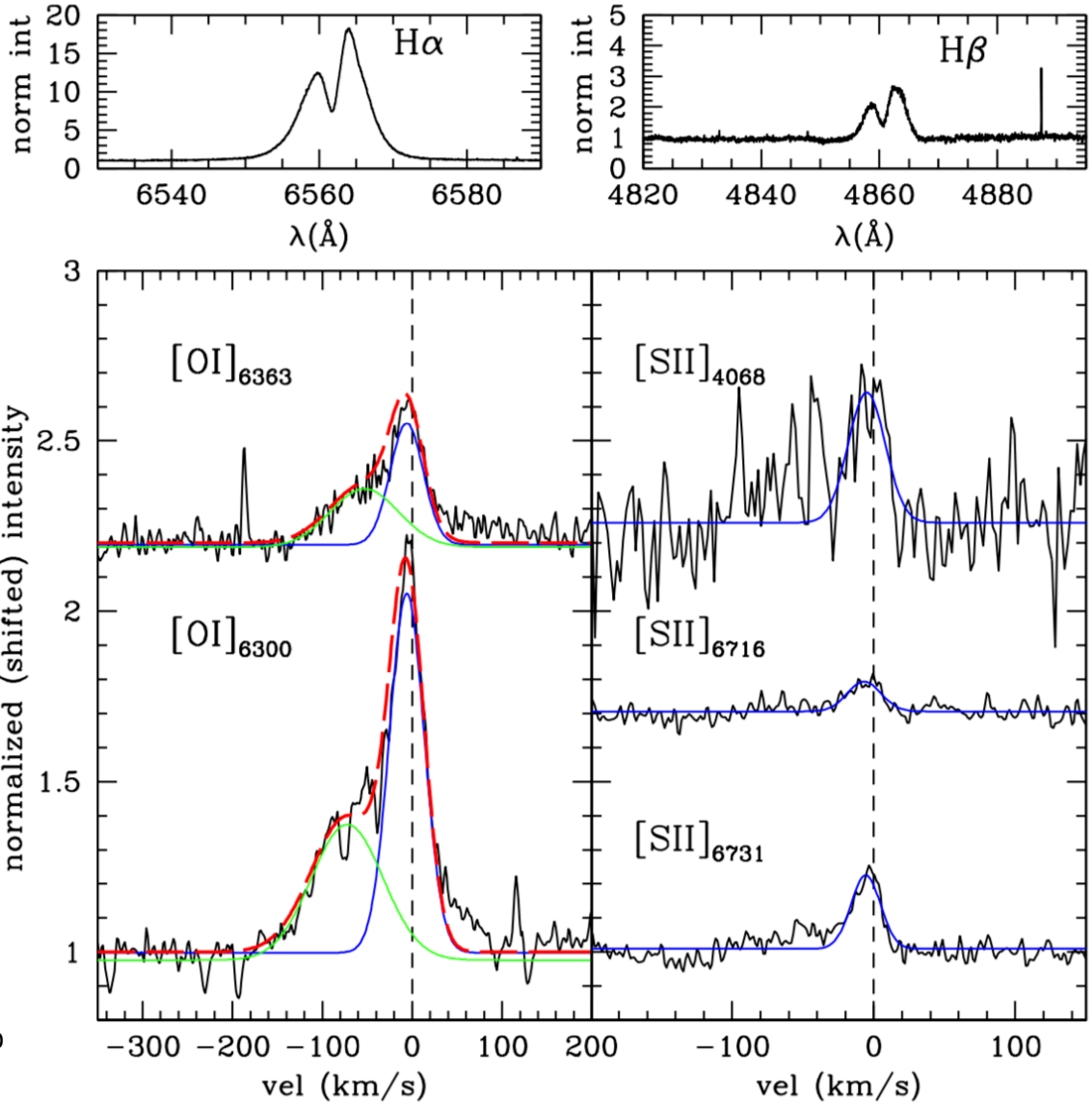
Astronomy Fellowships in Italy

Combining HR and Diffraction Limited IFS



Rigliaco et al. 2019

Physical properties of the gas from permitted and forbidden optical lines:

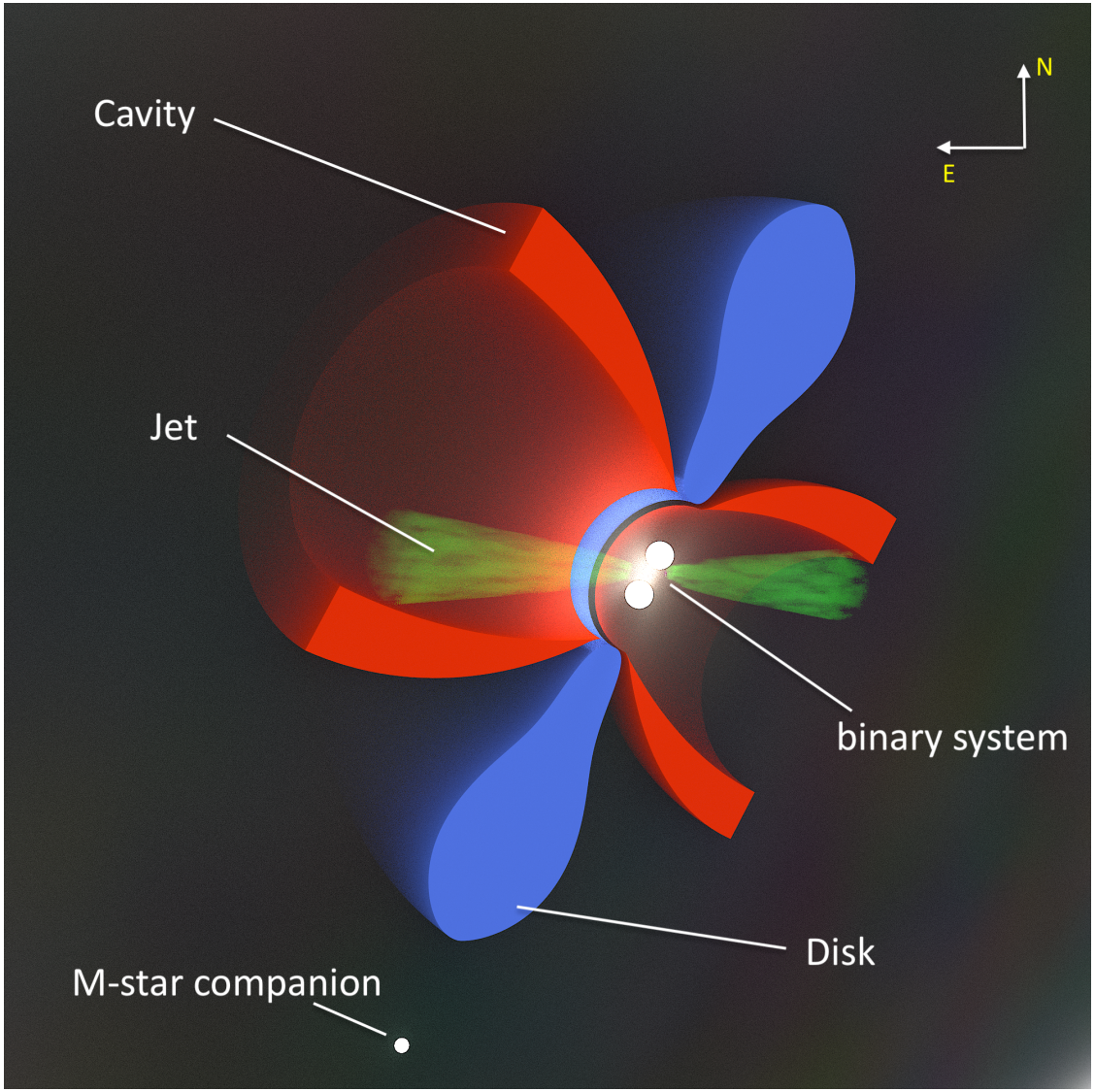
From [SII]6716/6731 line ratio:
$n_e \sim 7.0 \times 10^3$ cm^{-3}
$T_e \sim 10{,}000$ K

From Hα and Hβ lines:
$M_{acc} \sim 3.3 \times 10^{-6}$ M_{sun}/yr

From [OI]6300-HVC line:
$M_{loss} \sim 2.8 \times 10^{-7}$ M_{sun}/yr

$M_{acc}/M_{loss} \sim 0.08$
typical of TTSs with prominent jets

RCrA PROPOSED MODEL



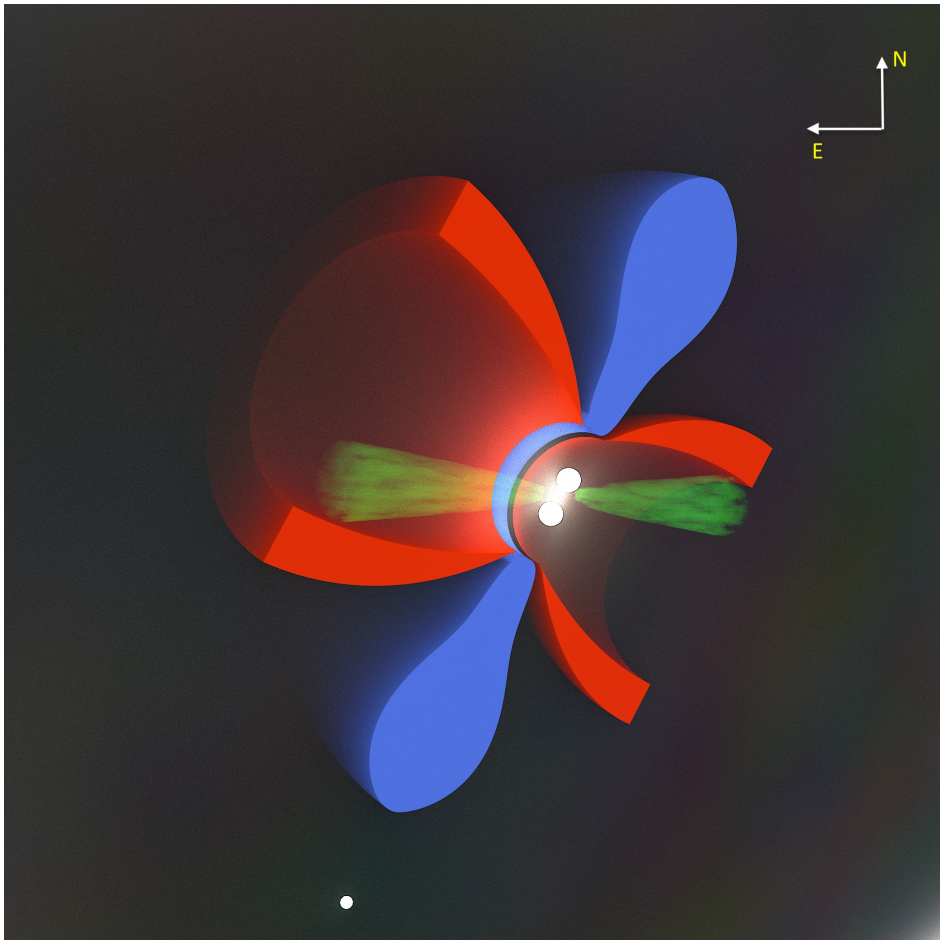
Complementary detailed analysis of IRDIS, IFS, SINFONI and FEROS data provide a picture of the environment around RCrA.

The extended structure is composed by 2 elemenets:

1- a **CAVITY** carved out into the circumstellar environment

2- a **GASEOUS JET** flowing inside the cavity

RCrA proposed model: CAVITY and JET



The scattered light observed in IFS and IRDIS images shows the **CAVITY WALLS**.

The dust on the cavity walls is illuminated by the central binary and scatters light toward us.

The emission lines ([OI] in their HVC, HeI, Hydrogen) trace the gaseous component of the elongated structure, which is associated with a **JET**.

The [FeII] and LVC of [OI], [SII] are more likely associate with a slower moving **DISK WIND.**

H_2 lines might instead form in the shock area close to the star.

RCrA proposed model: cavity and jet

RCrA represents an ideal target to study jets around intermediate mass Herbig stars:

- close-by object
- binary system (actually triple system)
- it hosts jet, disk and companion

It helps our understanding of the accretion mechanisms around these still poorly investigated objects.

It is the first case where the binarity of the system can be directly associated with the wiggling of the jet.

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Besides the ANADIPLOSIS Science Project:

Side Activities:

- Outreach:
  - Media INAF interview
  - Invited speaker public event “Ad Alta Voce”
  - Invited speaker at “Pint of Science” public event
- Supervision of a PhD student
- Referee for Astronomical Journals
- Having a baby girl
- SOC member

The future:

- Applying for tenure track/permanent position
- Investigating new research path using new generation instruments
- Being a key person in the Italian community when talking about disk dispersal mechanisms

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ANADIPLOSIS: *ANAlysis of Dispersal Indicators in Planet-fOrming circumStellar dISks*

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How did the AstroFIt2 Fellowship impact on me?

Work perspective:

- Conducting independent research
- Managing my money for traveling
- Initiate collaboration independently
- Time management

Personal perspective:

- Self consciousness:
  - awareness of my unique skills
  - communication skills
  - broader-view of how my research activity impacts on other fields
- Networking:
  - Presenting yourself as an independent researcher
- Managerial skills:
  - Managing your time/collaboration/money

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