Revolutionizing our understanding of young stars and protoplanetary disks from the ground and space

Disks and Planets across ESO Facilities - 29/11/22

With:

Carlo F. Manara (ESO)

G. Herczeg (*KIAA*), C. Espaillat (*U. Boston*), N. Calvet (*U. Michigan*),
K. France (*U. Colorado*)

R. Claes, M.L. Aru (ESO), K. Mauco (*UNAM/ESO*)

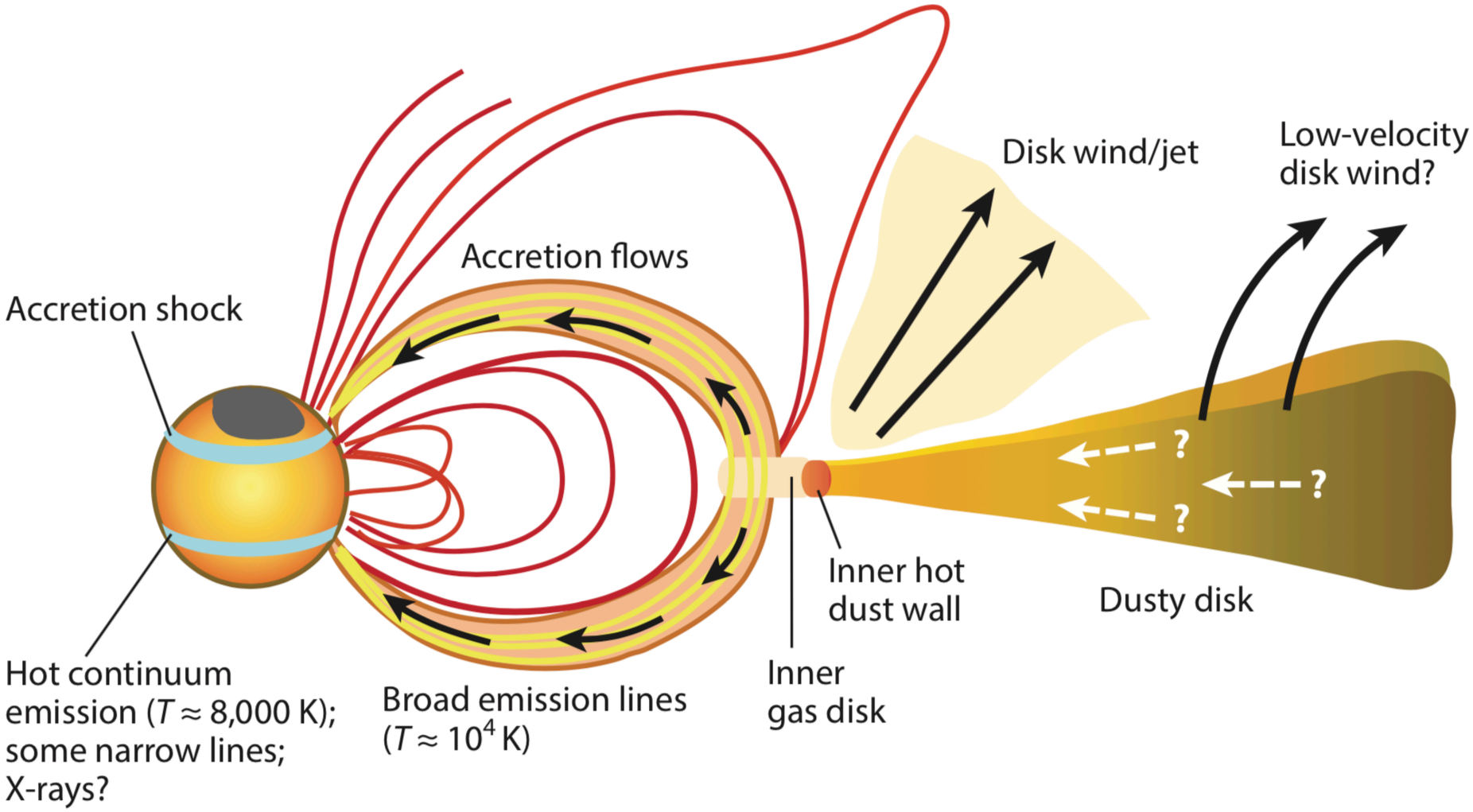
N. Arulanantham, W. Fischer (*STScI*) ,R. Garcia-Lopez (*UCD*),
H. Boffin, M. Petr-Gotzens (*ESO*), T. Thanathibodee, C. Pittman (*U. Boston*),
C. Robinson (*Amherst College*), J. Bouvier (*IPAG*), J.F. Gameiro (*U. Porto*), A. Frasca,
J. Alcala, B. Nisini, S. Antoniucci, M. Gangi (*INAF*), E. Fiorellino (U. Rome)
A. Sicilia-Aguilar (*U. Dundee*), L. Venuti (*NASA*), M. Fang (*P.M.Obs*)
G. Zsidi, A. Kospal, P. Abraham (Konkoli)
ODYSSEUS & PENELLOPE collaborations

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Council. Neither the European Union nor the granting authority can be held responsible for them.

Justyn Campbell-White
ESO/WANDA Postdoc

@justyncw

Magnetospheric accretion onto the star

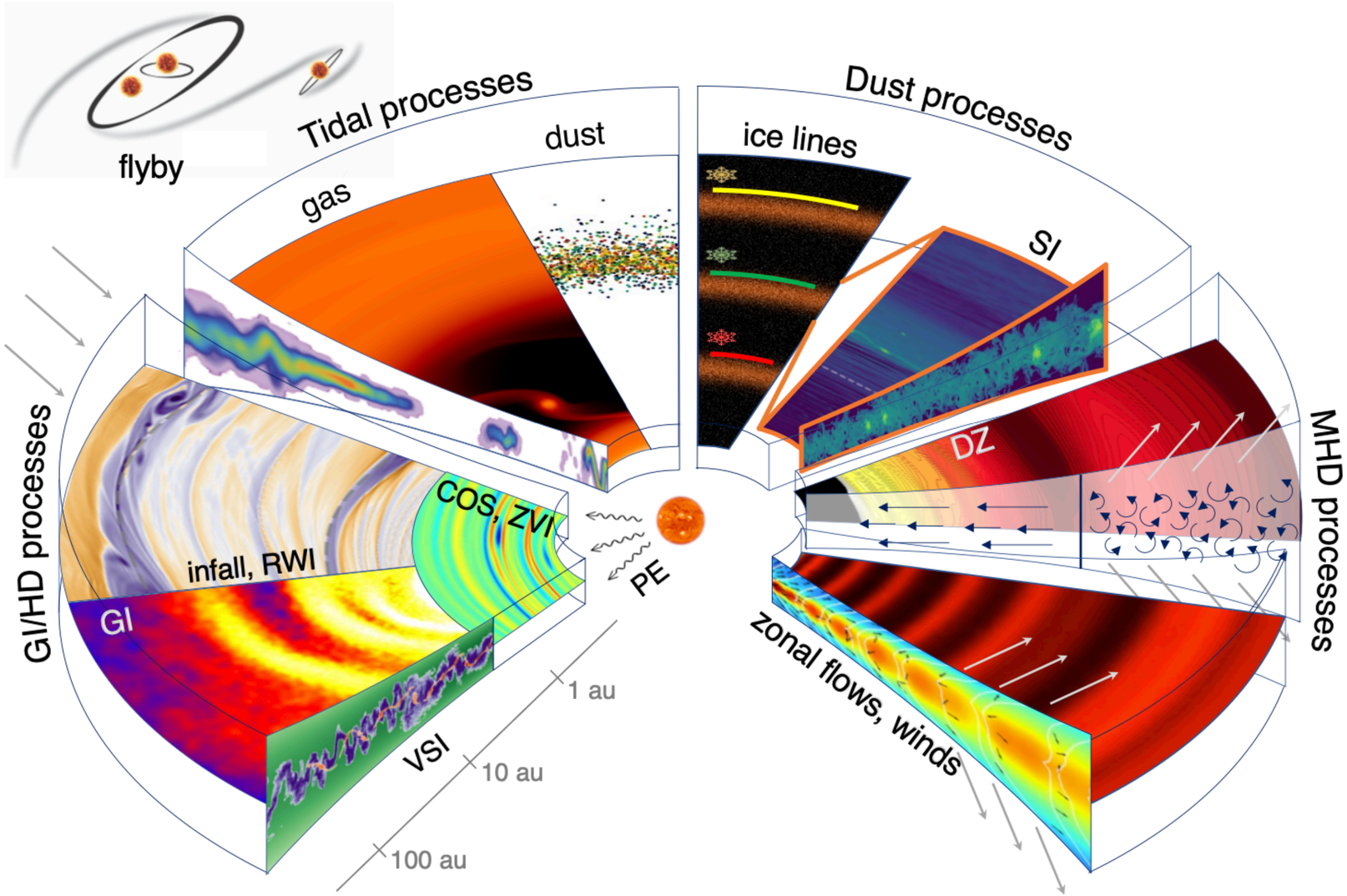


Hartmann, Herczeg and Calvet, 2016, ARAA

Main observables:

- UV-excess
- Emission lines

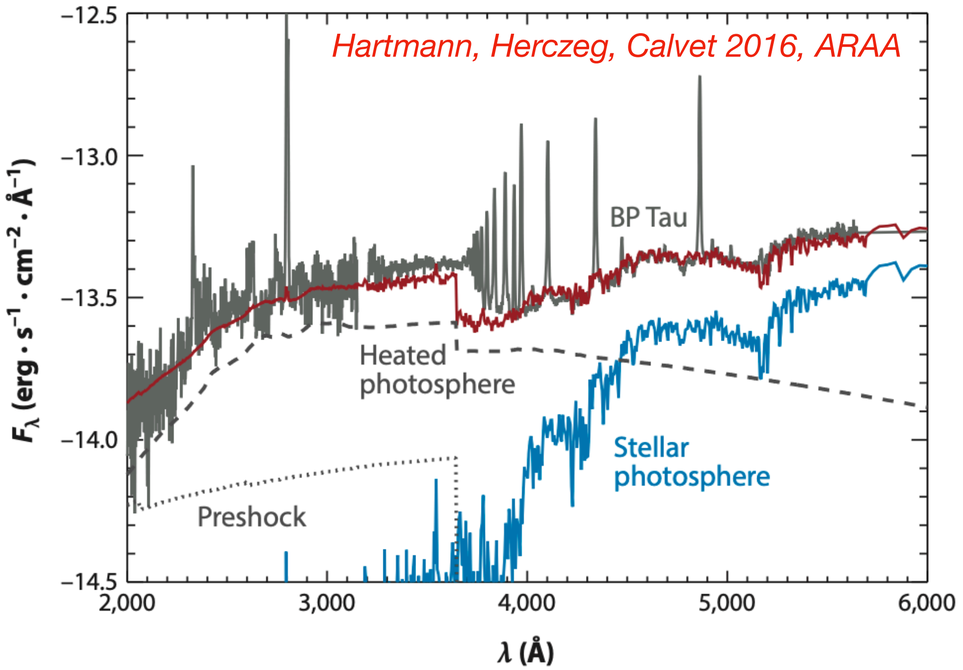
Disk evolution & substructures: key to planet formation?



Bae, Isella, Zhu, Martin, Okuzumi, & Suriano 2022, PPVII chapter

Observing the dynamics (inflow/accretion + outflow/winds) helps us to disentangle the various disk processes

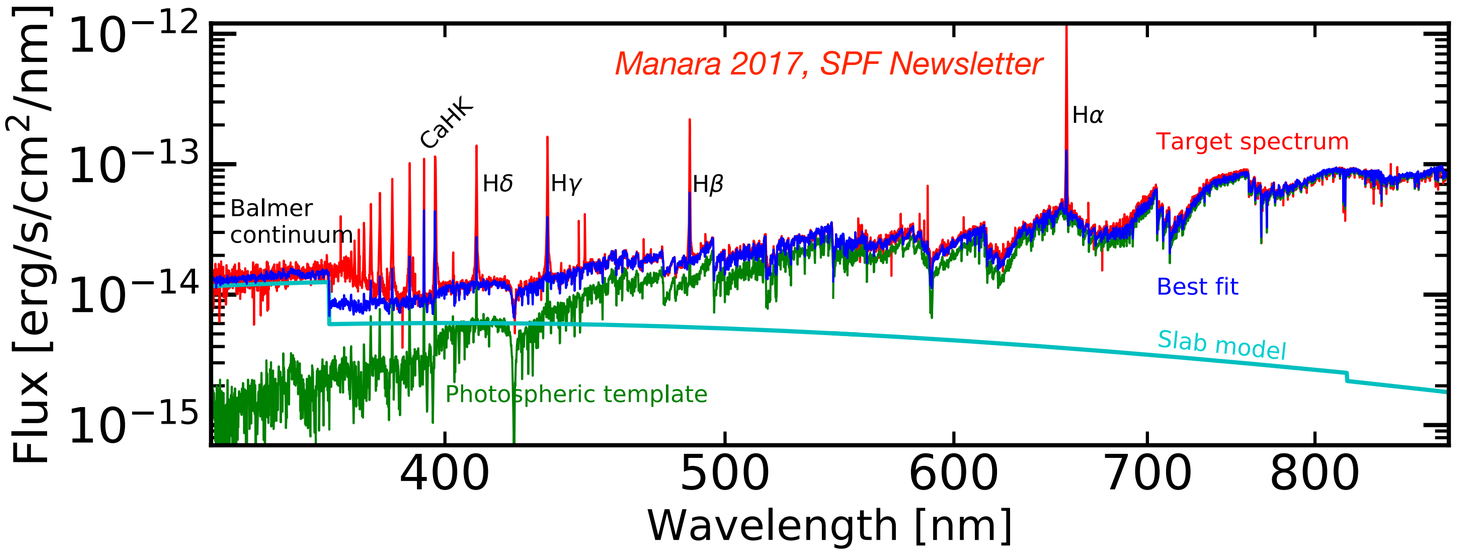
Previous studies of accretion from HST and VLT



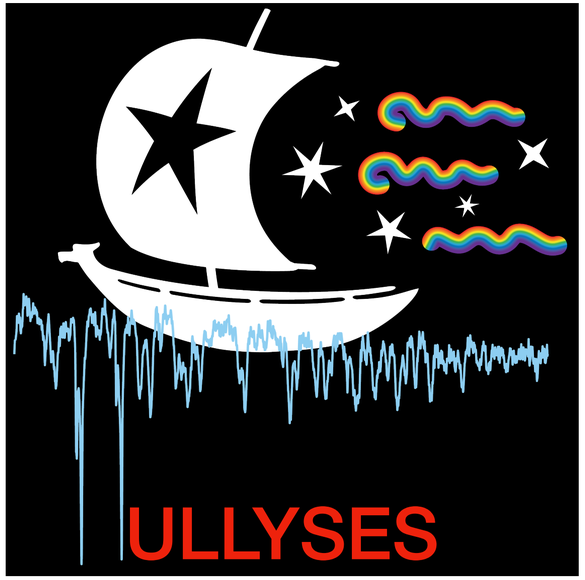
HST gives access to the *most direct* probes of accretion and disk winds

- Modelled with shock models (*e.g., Calvet et al. 2000*)
- Comparatively few observations

- VLT/X-Shooter: large wavelength coverage
- Photospheric templates: Class III YSOs (*Manara et al. 2013a, 2017b*) ➜ SpT, $L_\star$
- Isothermal hydrogen slab model for the accretion shock spectrum ➜ L_{acc}
- Extinction values + reddening law ➜ A_V

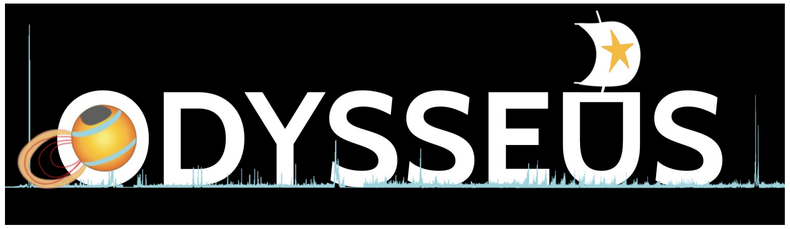


A world-wide collaboration



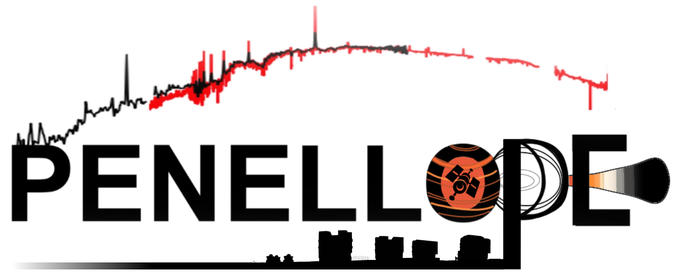
Hubble UV Legacy Library of Young Stars as Essential Standards

500 orbits of HST COS/STIS for low-mass stars (Director's Discretionary program)
PI Roman-Duval



Outflows and Disks around Young Stars: Synergies for the Exploration of Ullyses Spectra

- ~90 astronomers worldwide
- **using the ULLYSES data** to study accretion, outflows, and inner disk composition
- **coordinating complementary data collection** efforts.
- **Lead:** G. Herczeg (KIAA Beijing), C. Espaillat (Boston University)



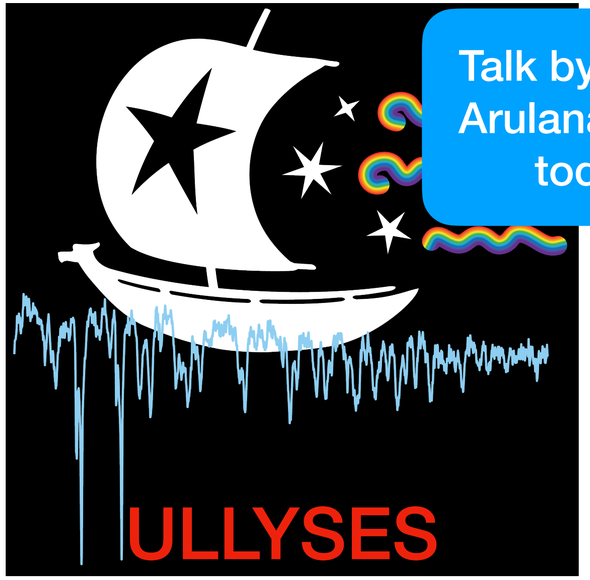
PENELLOPE

Large international team acquiring complementary data with a **~250h Large Program** at the ESO Very Large Telescope (VLT).

PI: C.F. Manara (ESO)
Data public

Several other teams are collecting **photometry**, **high-resolution spectra** and more. Observations are coordinated with **TESS**.

A world-wide collaboration

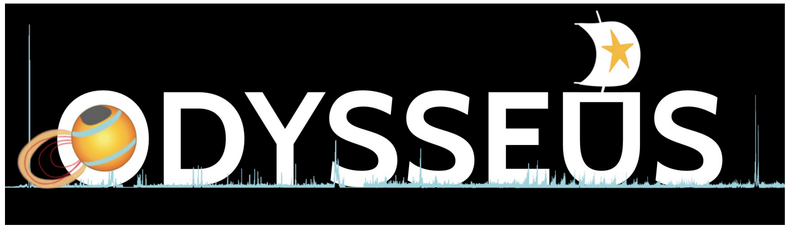


Talk by Nicole Arulanantham today!

Hubble UV Legacy Library of Young Stars as Essential Standards

500 orbits of HST COS/STIS for low-mass stars (Director's Discretionary program)

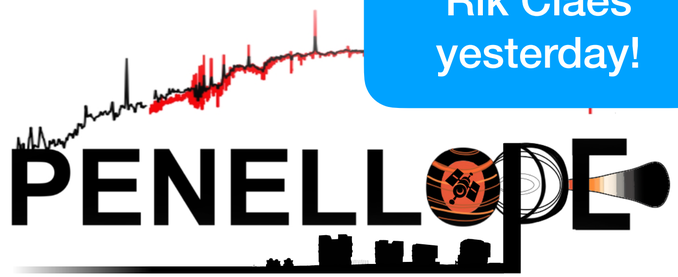
PI Roman-Duval



Outflows and Disks around Young Stars: Synergies for the Exploration of Ullyses Spectra

- ~90 astronomers worldwide
- **using the ULLYSES data** to study accretion, outflows, and inner disk composition
- **coordinating complementary data collection** efforts.
- **Lead:** G. Herczeg (KIAA Beijing), C. Espaillat (Boston University)

Talk by Rik Claes yesterday!



PENELLOPE

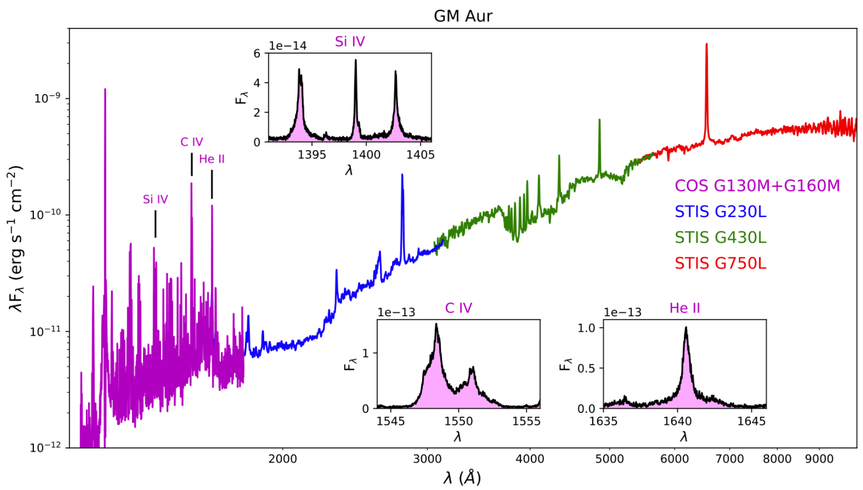
Large international team acquiring complementary data with a **~250h Large Program** at the ESO Very Large Telescope (VLT).

PI: C.F. Manara (ESO)
Data public

Several other teams are collecting **photometry**, **high-resolution spectra** and more. Observations are coordinated with **TESS**.

PROGRAMME STRATEGY: contemporaneous observations

λ~113–180 nm, R~18,000
λ~150–570 nm, R~500
λ~165–315 nm, R~3,000



HST COS/STIS:
NUV/FUV spectra, hot gas lines, Balmer continuum…
Espaillat, Herczeg et al. 2022

λ~300–2500 nm, R~15,000

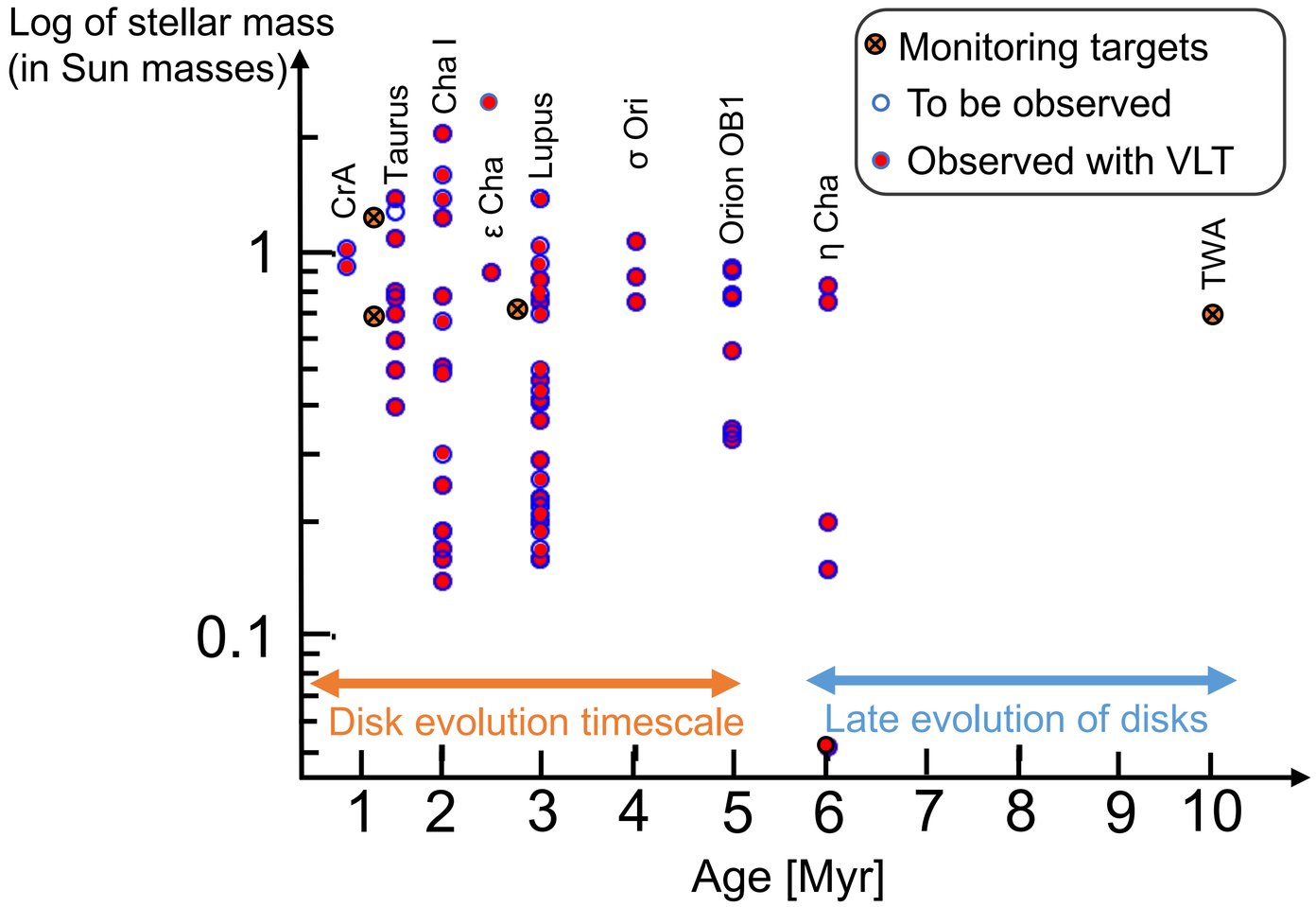
X-Shooter (absolute flux calibrated):
Stellar and accretion properties, extinction, emission lines down to 2.5 micron
Manara et al. 2021

λ~380–788 nm, R~140,000, Δ*v*~2 km/s
Alternative: UVES
λ~330–680 nm, R~70,000, Δ*v*~4 km/s

ESPRESSO/UVES:
Photospheric properties (logg, vsini, RV, veiling…) and line kinematics (with variability) to study accretion and outflows

-1/2 days | **day(s) of the HST observation** | **+1/2 days**

Sample properties

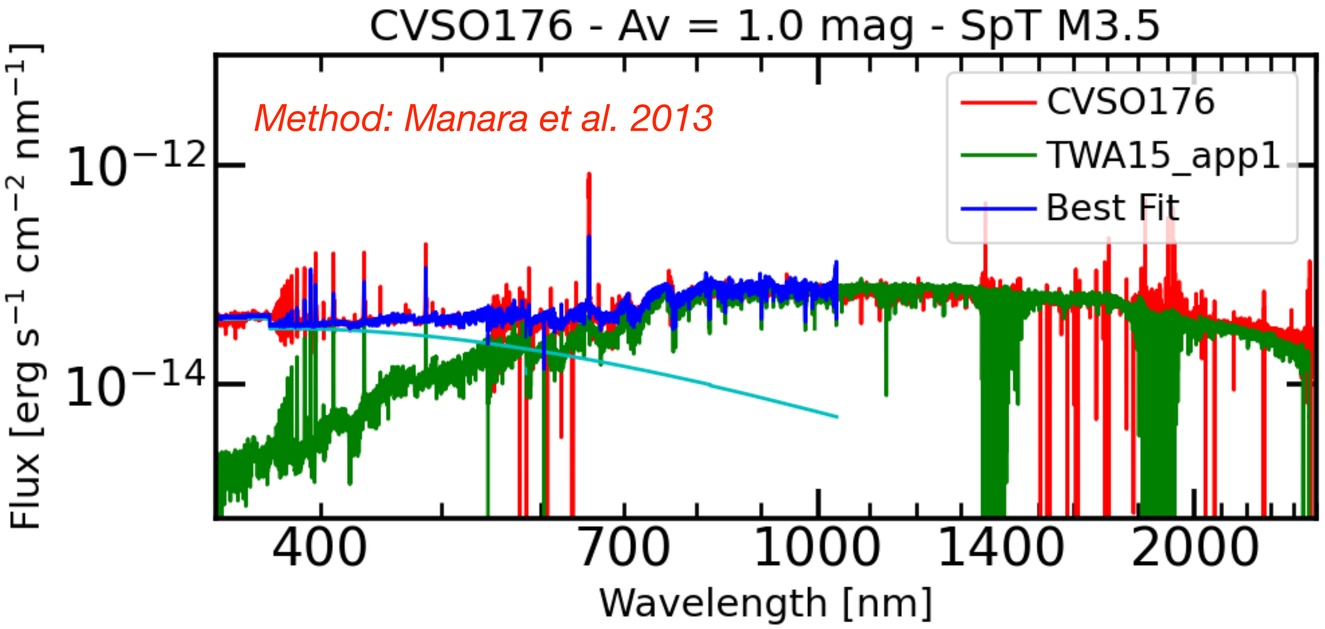


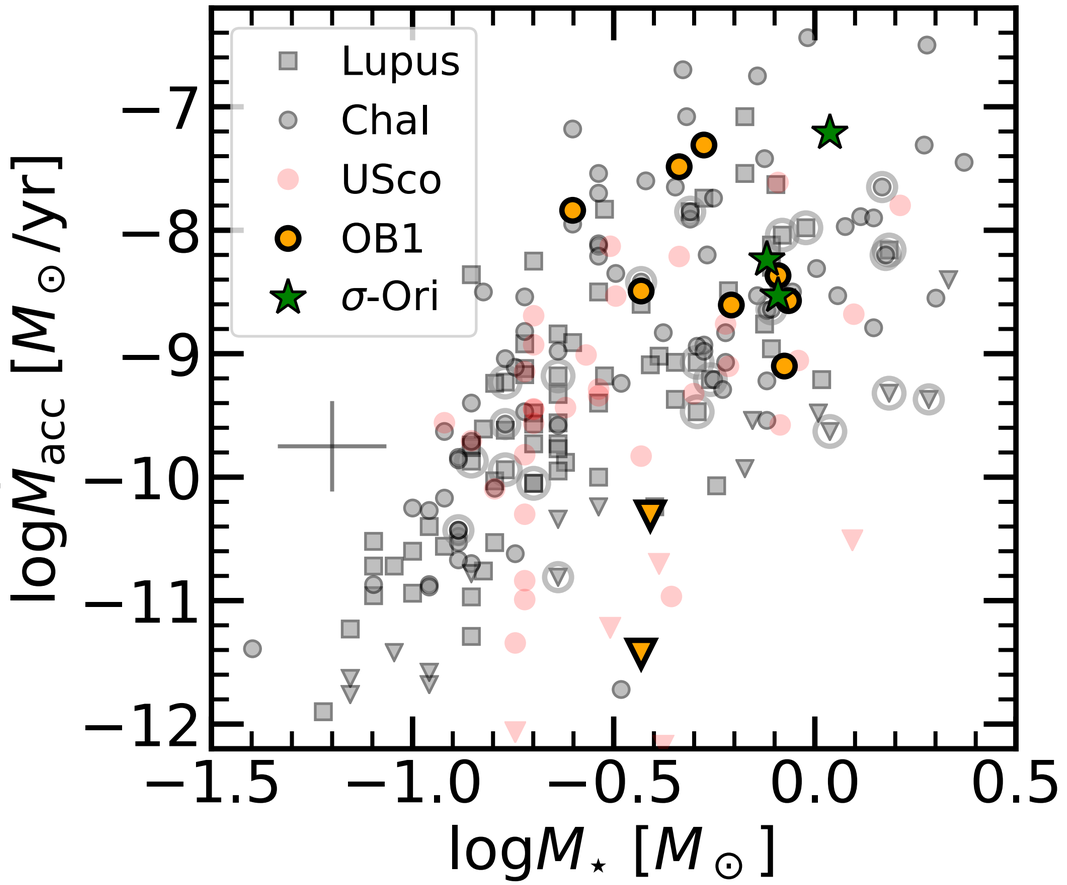
TARGETS FROM HST/ULLYSES

Total ~ 70-80 targets

- Nine nearby star-forming regions
- Ages from ~1 to ~10 Myr
- Masses from ~0.1 to 2 Msun
- Mainly accreting targets
- Different disk types (e.g., transition disks, full disks)
- Four targets monitored for three consecutive rotation periods for two times in two different years

SCIENCE: stellar and accretion properties



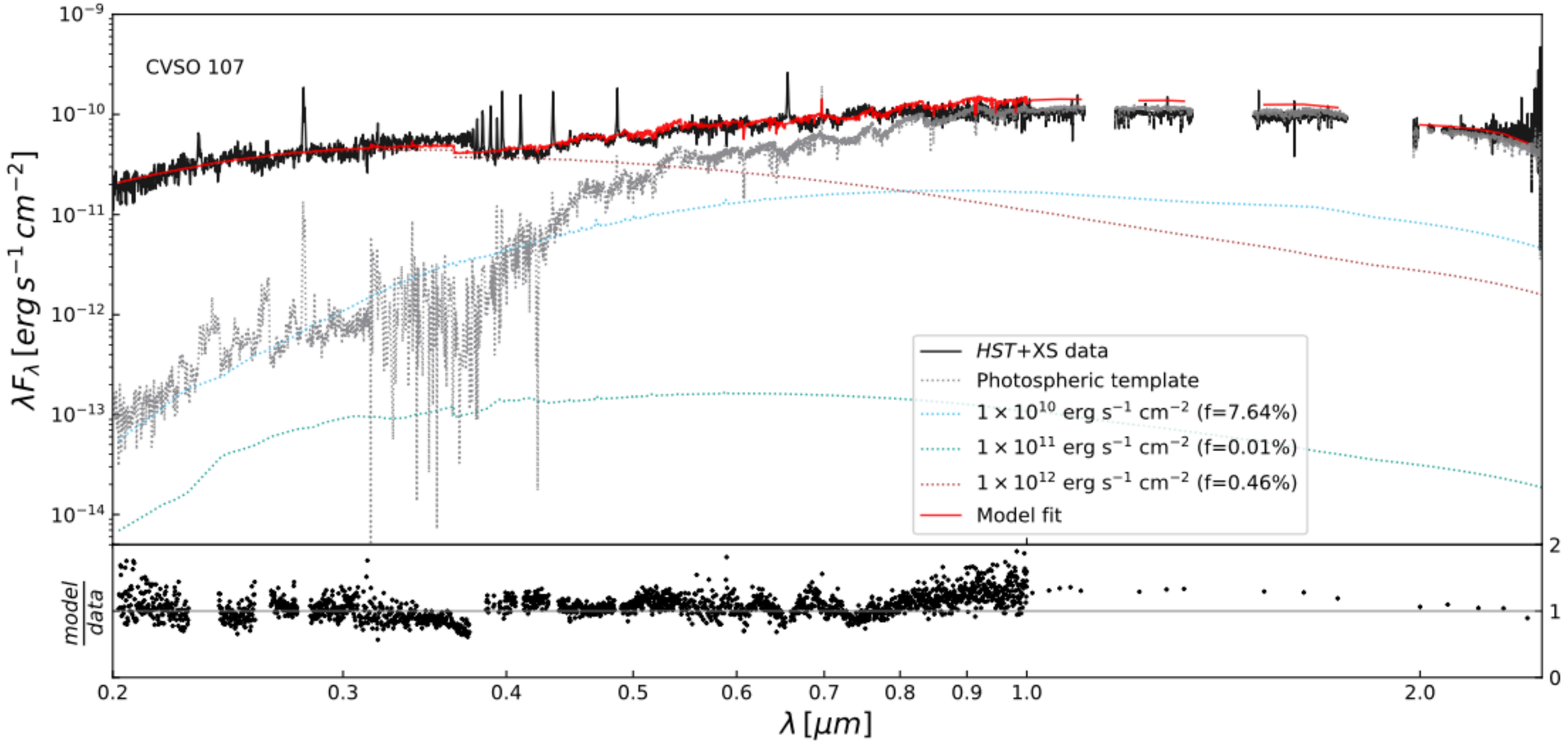


Manara, Frasca and the PENELLOPE team, 2021

Derived mass accretion rates in line with those in other star-forming regions with age ~1 - 5 Myr. Large spread, larger than variability.

Literature Data: *Manara et al. 2016a,2017b,2020*
Alcala et al. 2014,2017

SCIENCE: accretion from the HST side



Pittman, Espaillat, Robinson et al. 2022

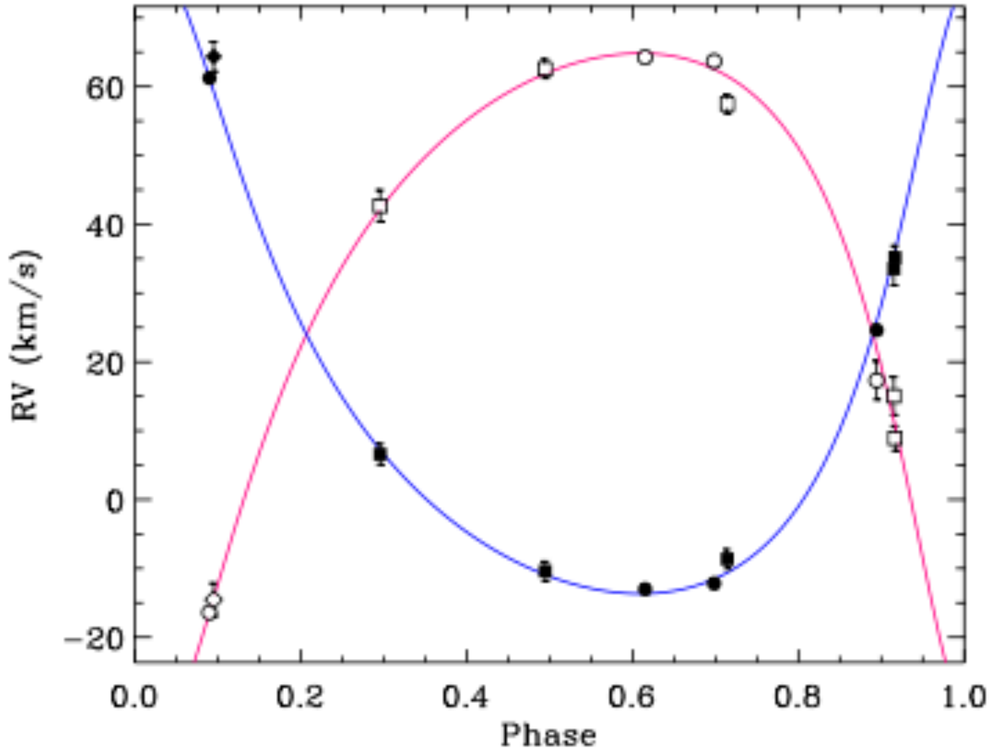
Multiple components are needed to fit the spectrum from UV (HST) to NIR (X-Shooter)

Accretion rates measured with HST are higher by ~3.5 than those measured in the optical.
Currently investigating the effect of the extinction law.

PENELLOPE - Science results

PENELLOPE II. CVSO 104: a pre-main sequence close binary with an optical companion in Ori OB1⋆

A. Frasca[1], H. M. J. Boffin[2], C. F. Manara[2], J. M. Alcalá[3], P. Ábrahám[4,5], E. Covino[3], M. Fang[6], M. Gangi[7], G. J. Herczeg[8], Á. Kóspál[4,5,9], L. Venuti[10], F. M. Walter[11], J. Alonso-Santiago[1], K. Grankin[12], M. Siwak[4], E. Alecian[13], and S. Cabrit[14]

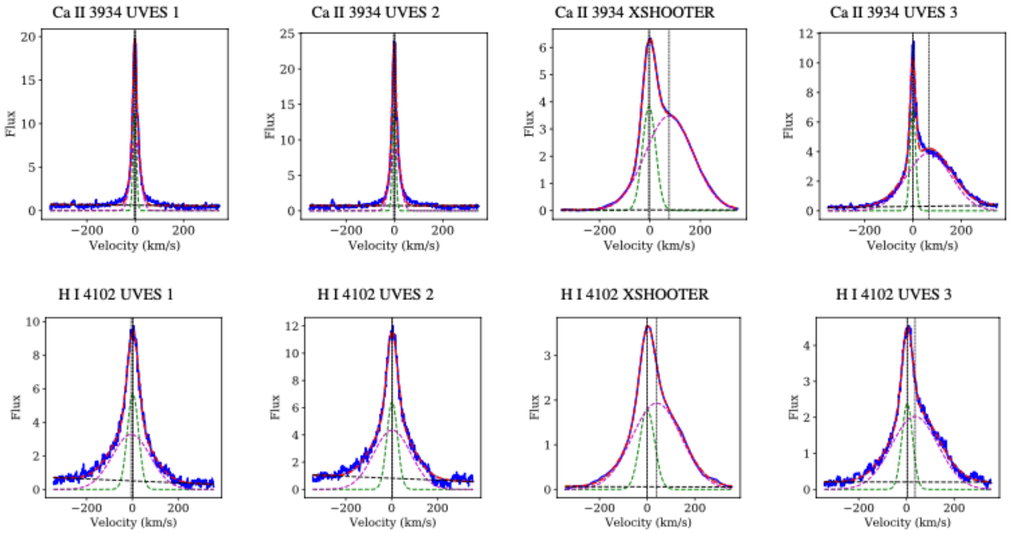


A new spectroscopic binary

- orbital elements of the system
- the stellar parameters of the two components

The STAR-MELT Python package⋆ for emission line analysis of YSOs†

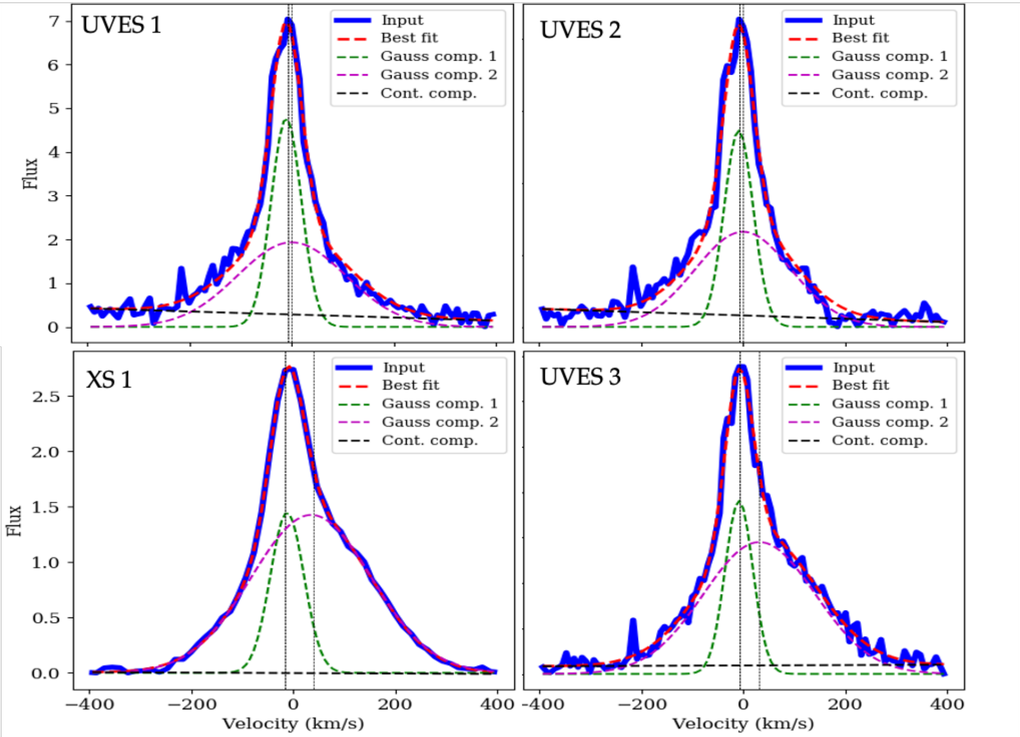
Justyn Campbell-White,[1]‡ Aurora Sicilia-Aguilar,[1] Carlo F. Manara,[2] Soko Matsumura,[1] Min Fang[3], Antonio Frasca,[4] and Veronica Roccatagliata[5,6,7]



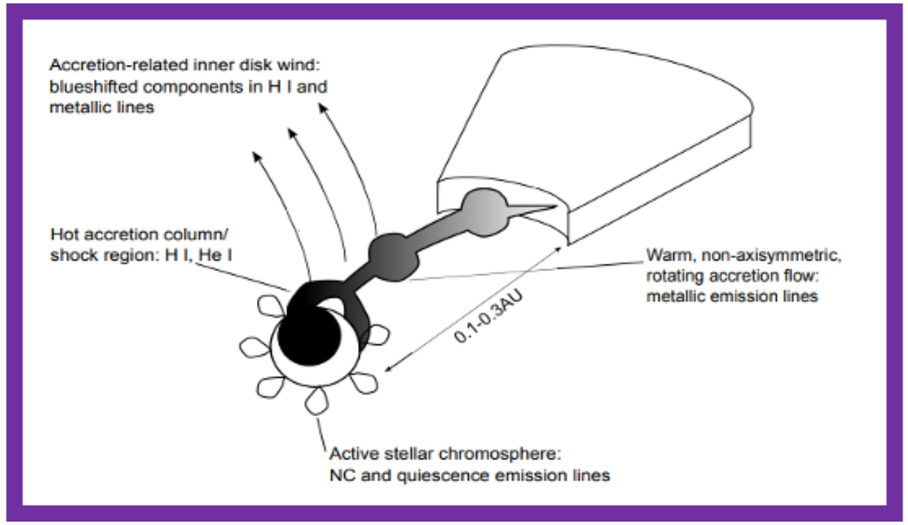
Development of spectroscopy analysis package, PENELLOPE data used in first paper

github.com/justyncw/STAR_MELT

SCIENCE: accretion dynamics



Fit double Gaussian to multuple H and Ca lines across all 4 epochs



Similar to Sicilia-Aguilar, et al. 2012

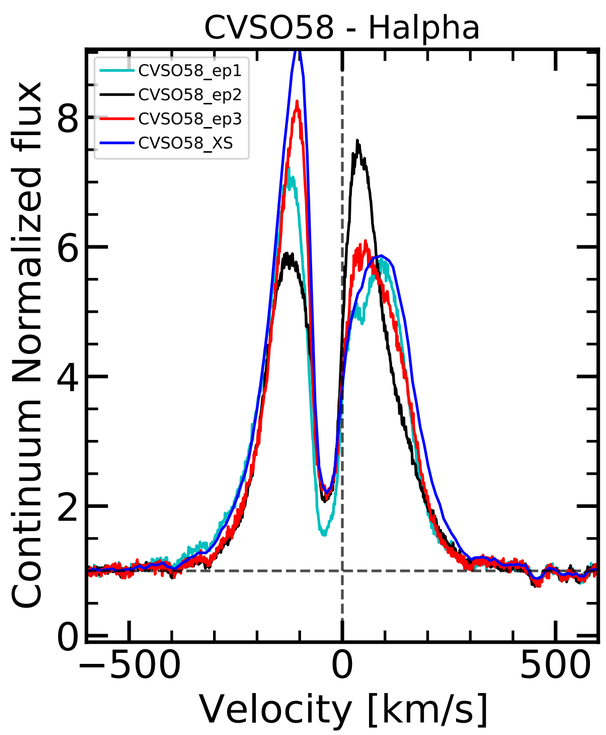
Campbell-White, Sicilia-Aguilar, Manara, et al. 2021

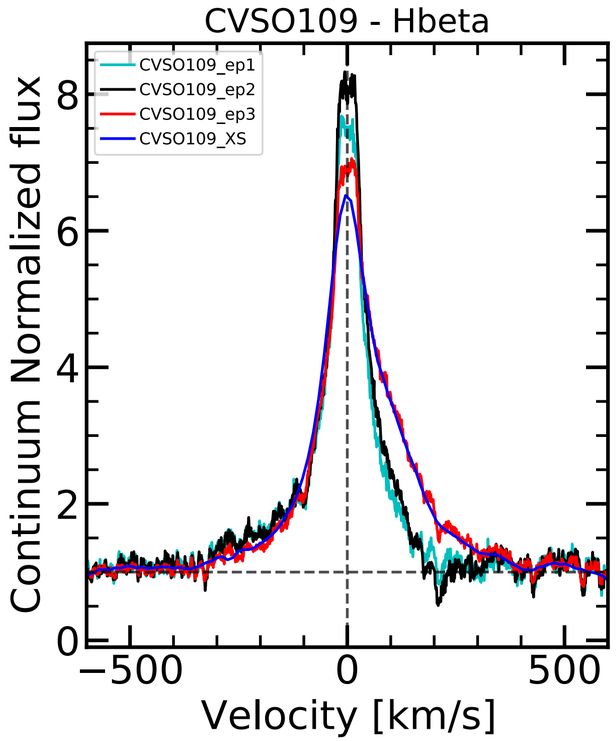
CVSO109

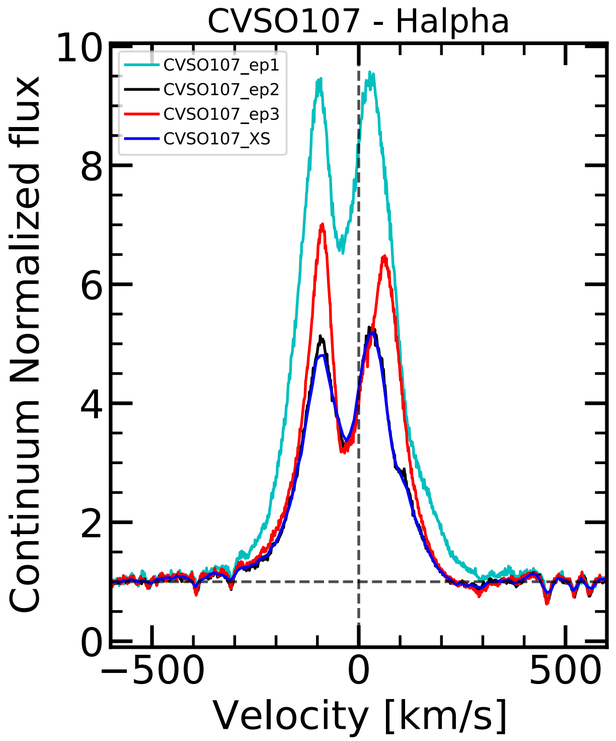
- Variability of feature suggestive of rotating, infalling material
- Redshifted wing component velocity in H lines correlated with transition parameters
- Probing different optical depths across column

SCIENCE: accretion variability

XX Cha study by Rik Claes from yesterday





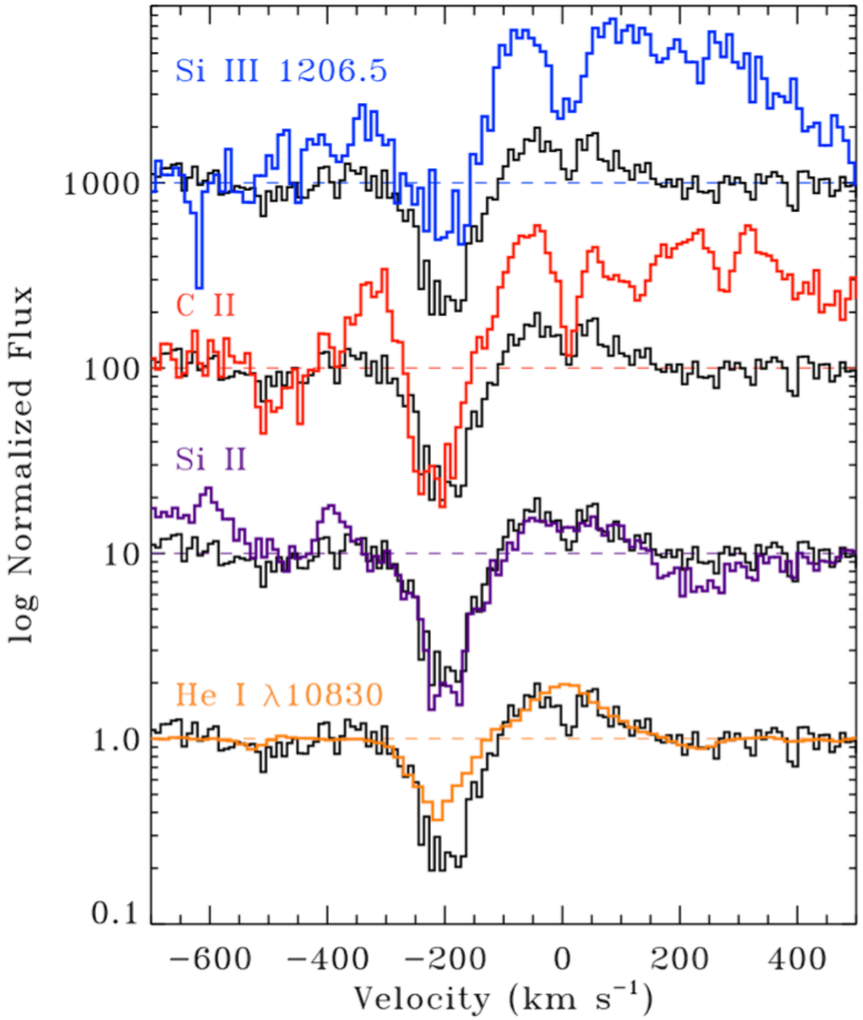


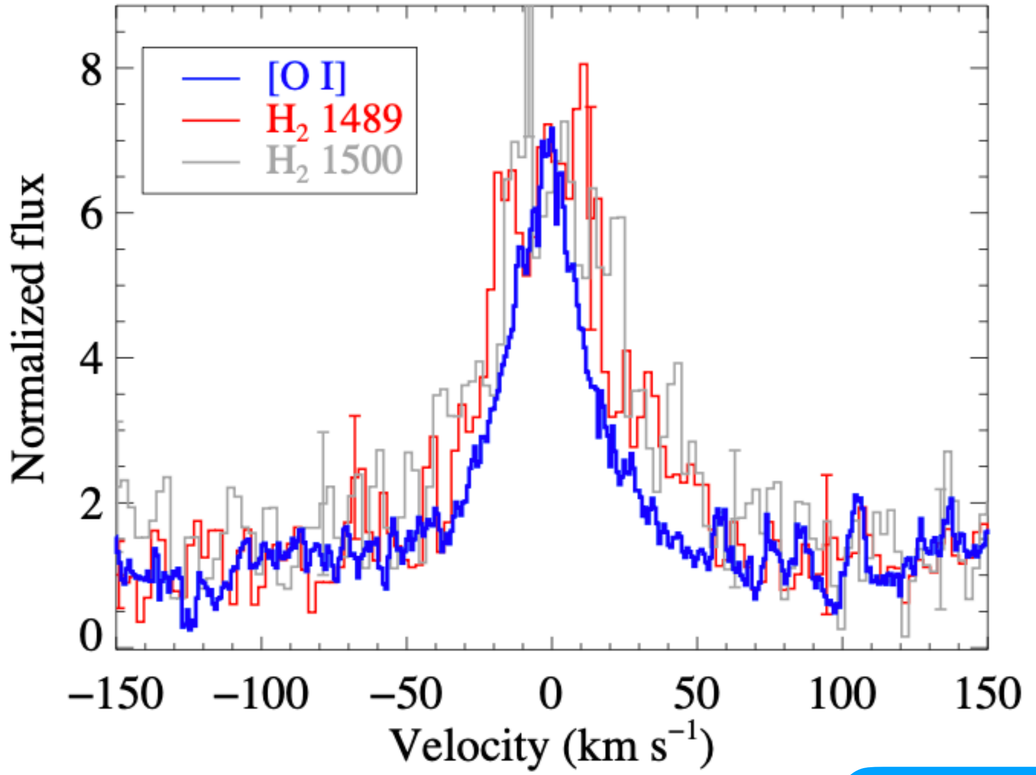
Manara, Frasca and the PENELLOPE team, 2021

Little EW/flux variations in the line emission on timescales of ~3-4 days, but more important variations in the line profiles:

- variability of accretion rates less than factor ~3 (e.g., *Costigan et al. 2014, Venuti et al. 2014*)
- complex and varying structure of the accretion flow on short timescales *(see also Campbell-White et al. 2021)*

SCIENCE: winds on the HST side



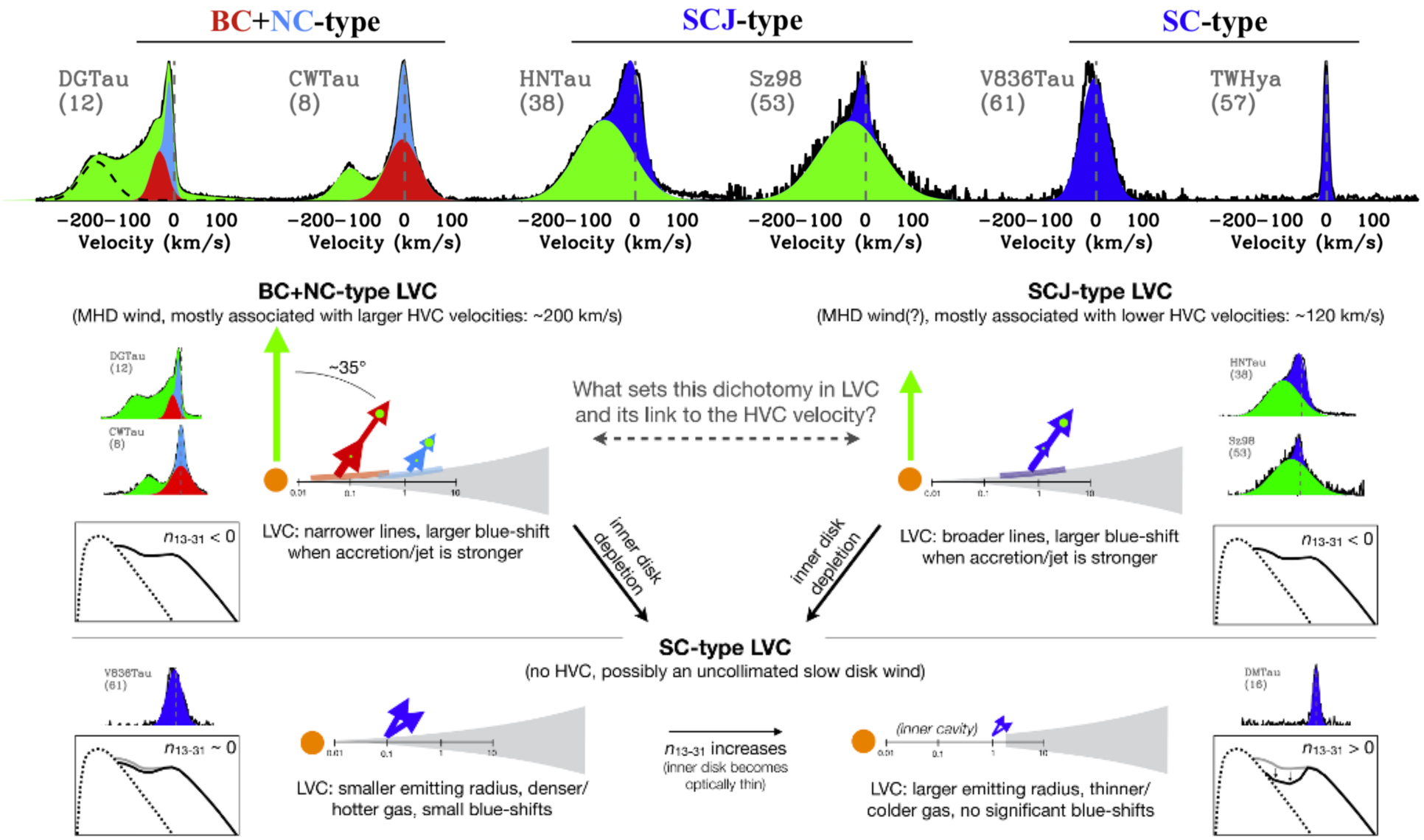


Espaillat, Herczeg and the ODYSSEUS team, 2022

And see talk by Nicole Arulanantham up next!

New possibility to combine high-resolution optical spectra with UV spectra to trace fast, cool winds (Si III, C II…) and cooler winds ([OI], H2)

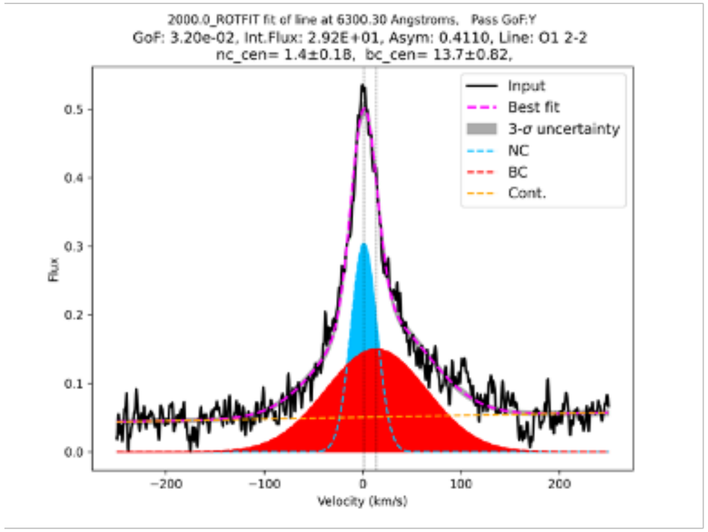
Previous studies of disk winds from the ground

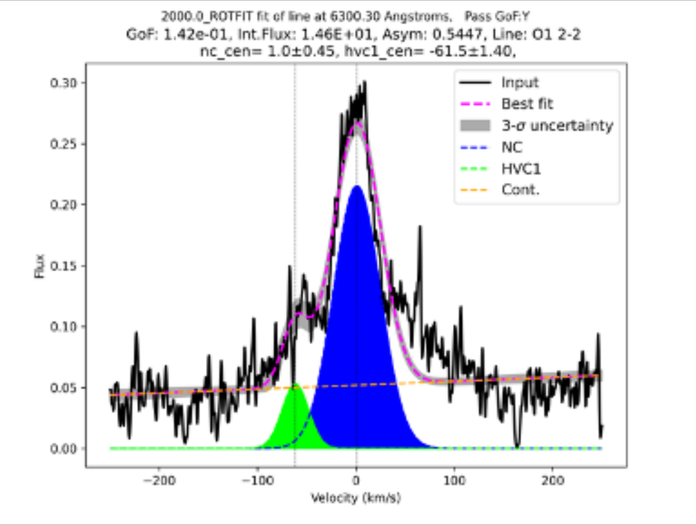


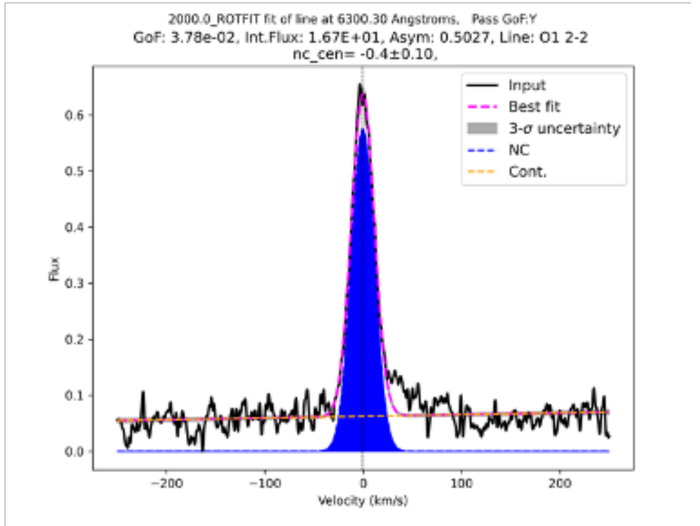
Banzatti et al. 2019

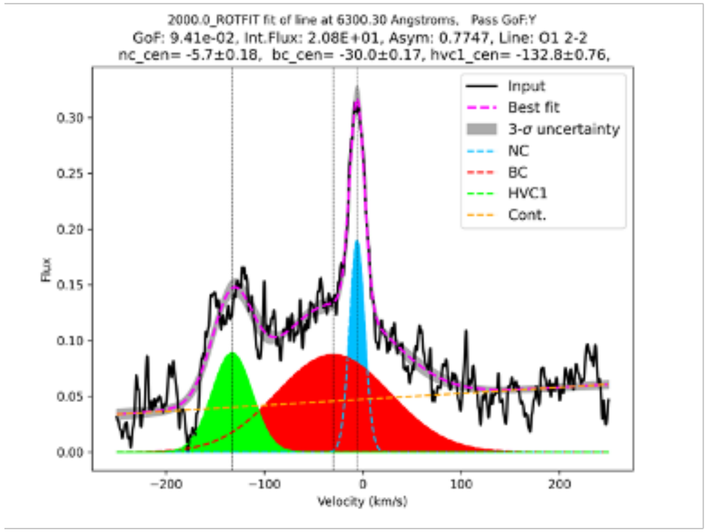
See also Rigliaco et al. 2013, Natta et al. 2014, Simon et al. 2016, Nisini et al. 2018, McGinnis et al. 2019, Pascucci et al. 2020, Weber et al. 2020

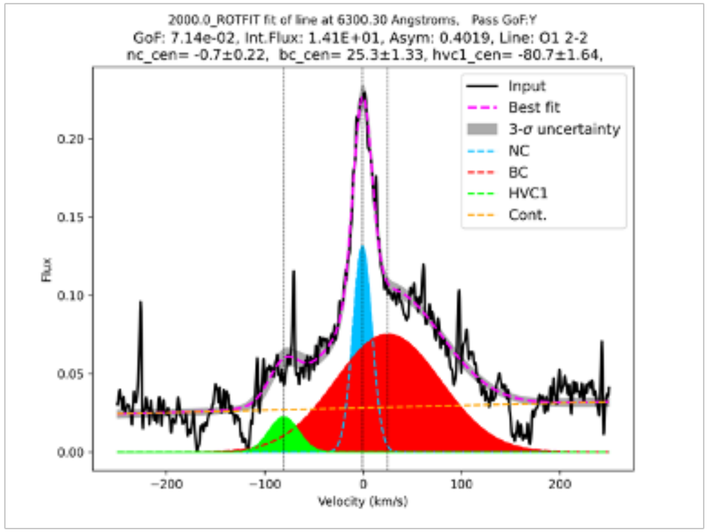
SCIENCE: winds from the VLT

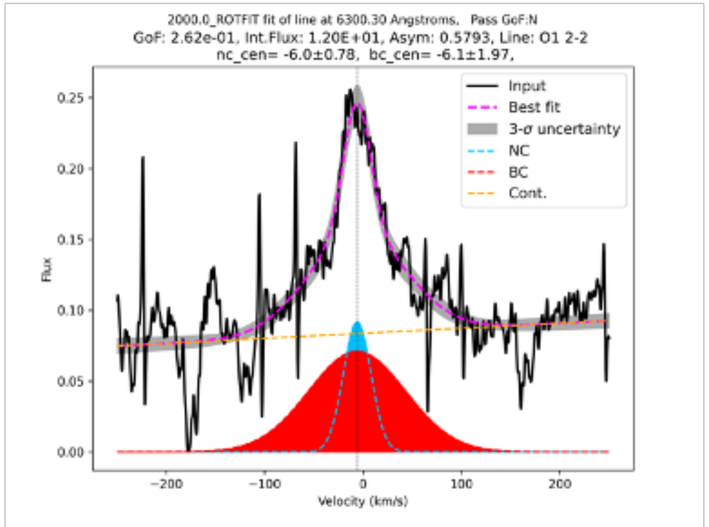








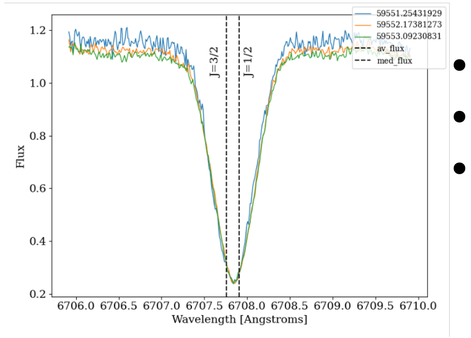




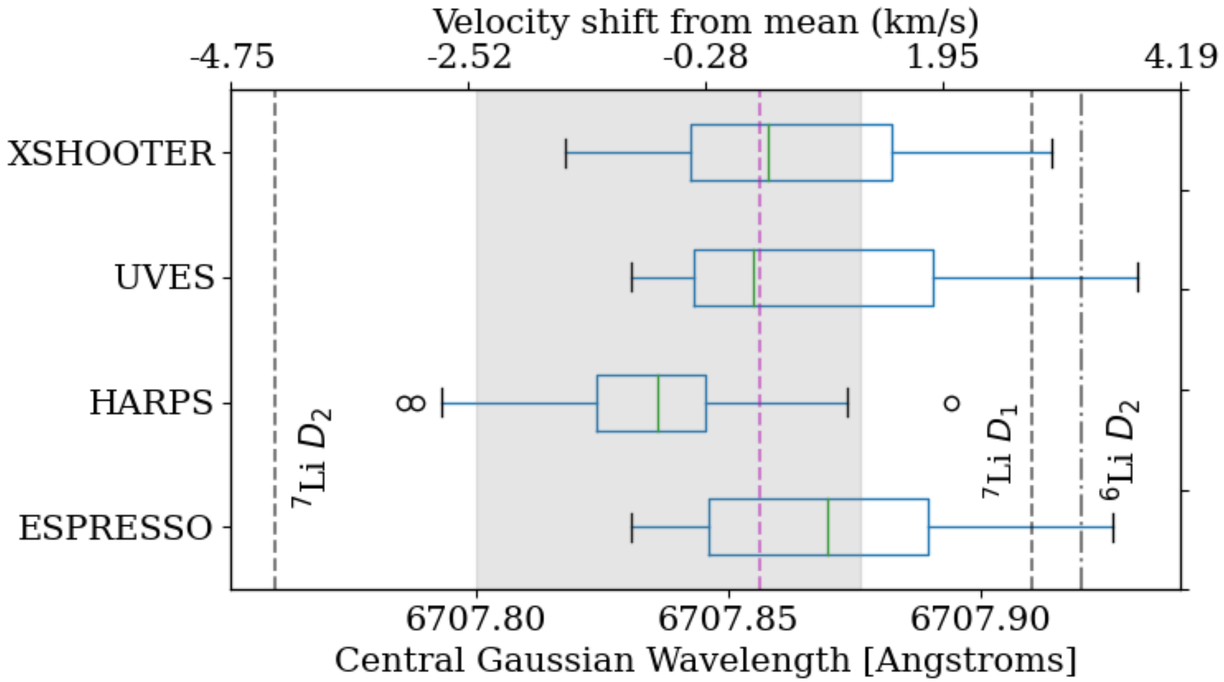
Campbell-White et al. in prep

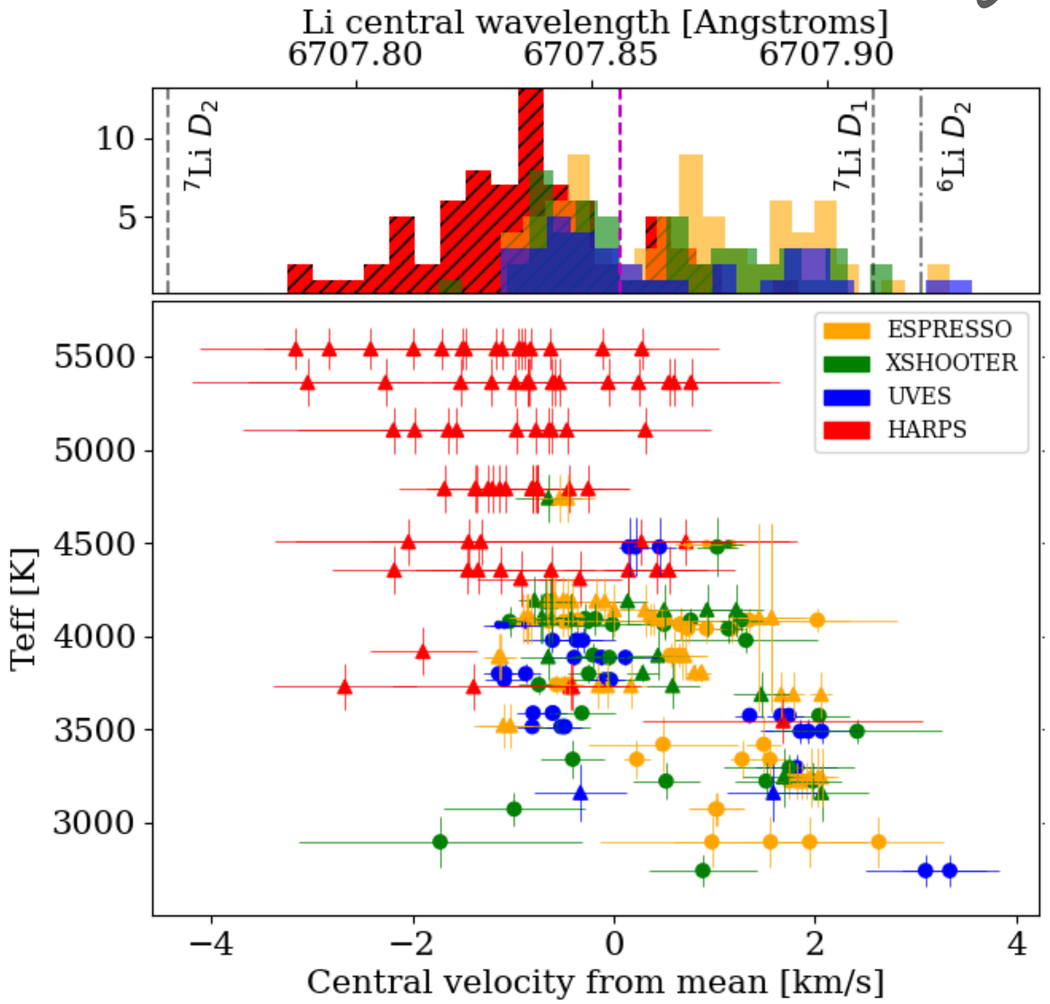
High-resolution ESPRESSO/UVES spectra to determine multiple components of the winds

SCIENCE: empirically measuring Li λ



- Li ~6708Å feature highly complex
- We measure **6707.856±0.002Å**
- But with a range of 0.145Å or 6.5km/s





Campbell-White, Manara, et al. in prep

Using STAR-MELT to measure position from 241 individual spectra

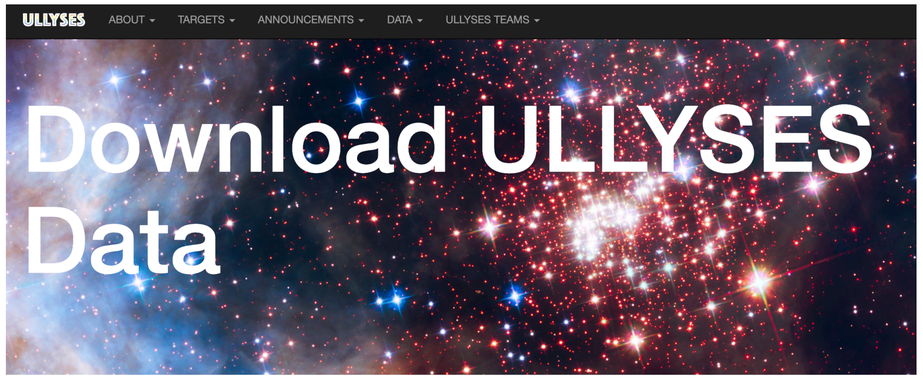
How do we share data

ODYSSEUS slack

- first reductions
- ancillary data (e.g., photometry)
- coordination of observations

https://zenodo.org/communities/odysseus

- Fully reduced data



In addition to the static download tables below, you may also utilize the ULLYSES interactive search and download web application here. The tables below list each target included in the latest ULLYSES data release, separated by galaxy/Milky Way region. By clicking the download link for an individual target, you will receive a tarball that includes both the HST and, if available, FUSE 1-D extracted spectra for the target as well as all High Level Science Products (HLSPs) created by the ULLYSES team. For TW Hydra, only HLSPs are available for download due to the large number of contributing 1-D spectra. You can also download all data for each region, which again includes individual 1-D spectra as well as HLSPs:

- Download all LMC targets:
  - HLSPs (164.5 MB)
  - HST/FUSE 1-D spectra (733.9 MB)
- Download all SMC targets:
  - HLSPs (189.2 MB)
  - HST/FUSE 1-D spectra (1.0 GB)
- Download all T Tauri targets:
  - HLSPs (193.8 MB)
  - HST 1-D spectra (340.1 MB)

WANT TO GET INVOLVED?

E-mail Gregory Herczeg

https://ullyses.stsci.edu/ullyses-download.html

How do we share data

PENELLOPE Teams

- intermediate reduction steps
- reduction scripts (e.g., flux calibration, spectra combination)
- fully reduced data
- photospheric subtracted emission lines

https://zenodo.org/communities/odysseus

- Fully reduced data

Phase 3 Archive: coming soon

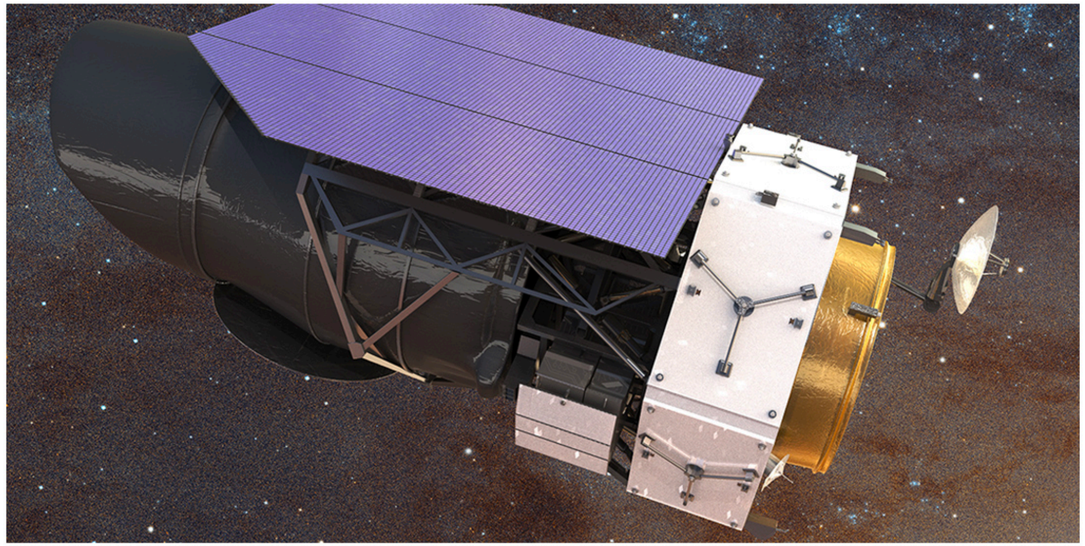
- Fully reduced data
- Ancillary products (e.g., stellar parameters)
- Photospheric subtracted emission lines

WANT TO GET INVOLVED?

E-mail cmanara@eso.org

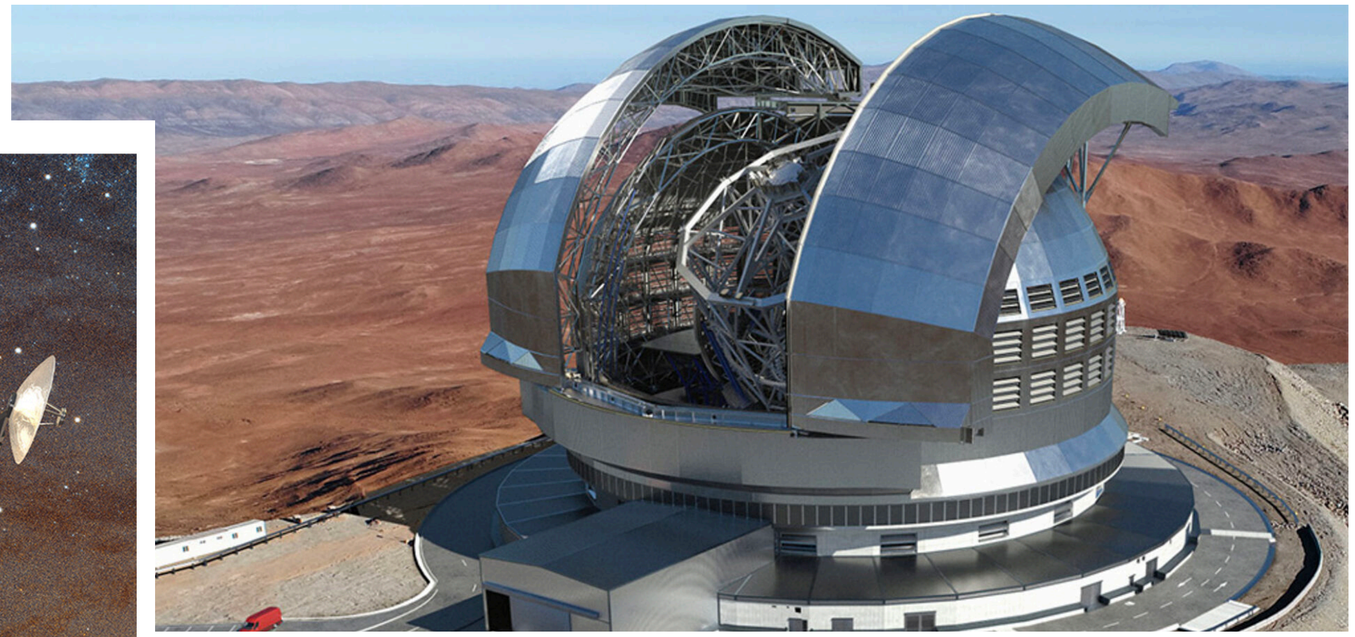
Future Synergies

From space

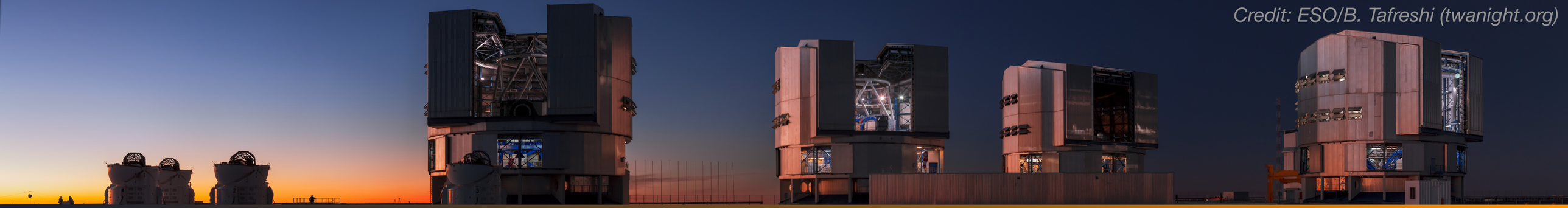


Credit NASA/GSFC

And the ground



Credit ESO



TAKE HOME POINTS:

1. ULLYSES/ODYSSEUS initiative + PENELLOPE and other efforts will revolutionize our understanding of young stars and protoplanetary disks
2. Initial discrepancies between UV and optical estimates, new strong variability found, wealth of synergies between datasets
3. These data and the results from multiple studies will be fundamental in future observation planning — new and next generation of telescopes

PENELLOPE

https://sites.bu.edu/odysseus/

ODYSSEUS

European Research Council
Established by the European Commission

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Council. Neither the European Union nor the granting authority can be held responsible for them.

Justyn Campbell-White
ESO/WANDA Postdoc
@justyncw