GHOST

GIARPS High-resolution ObservationS of T Tauri Stars

S. Antoniucci (INAF-OAR)

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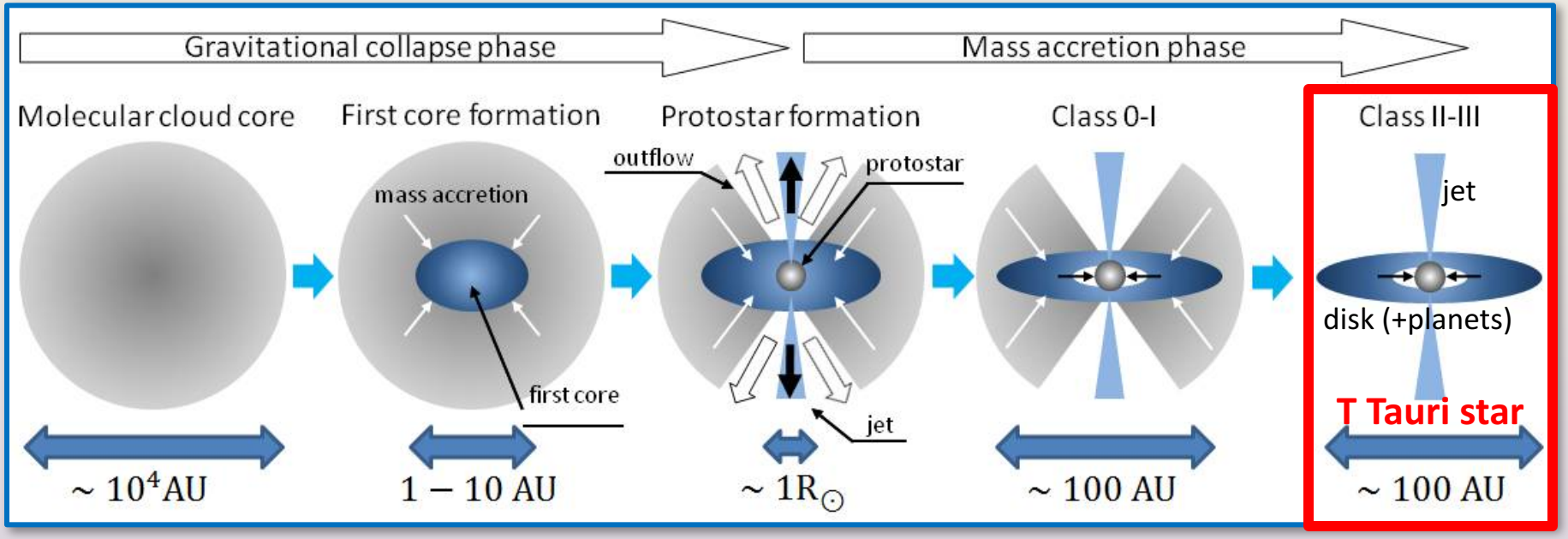
Low-Mass Star Formation: T Tauri Stars

SED peaks at...

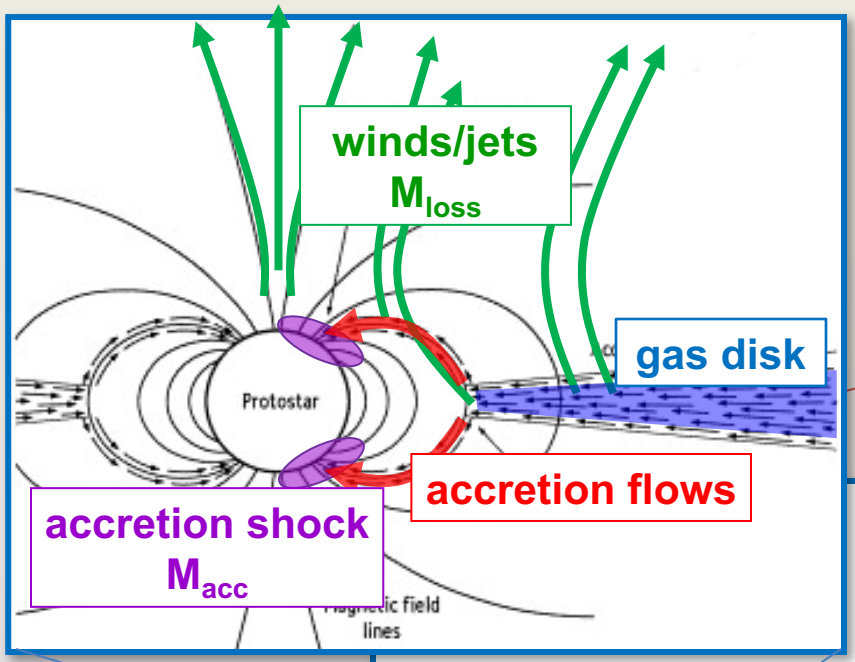
submm-far IR ***infrared*** ***optical***

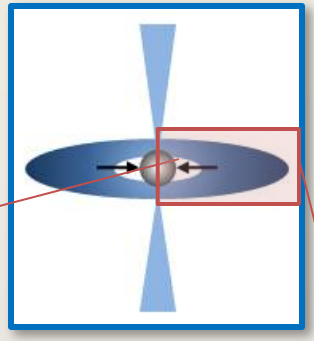


time (yr)

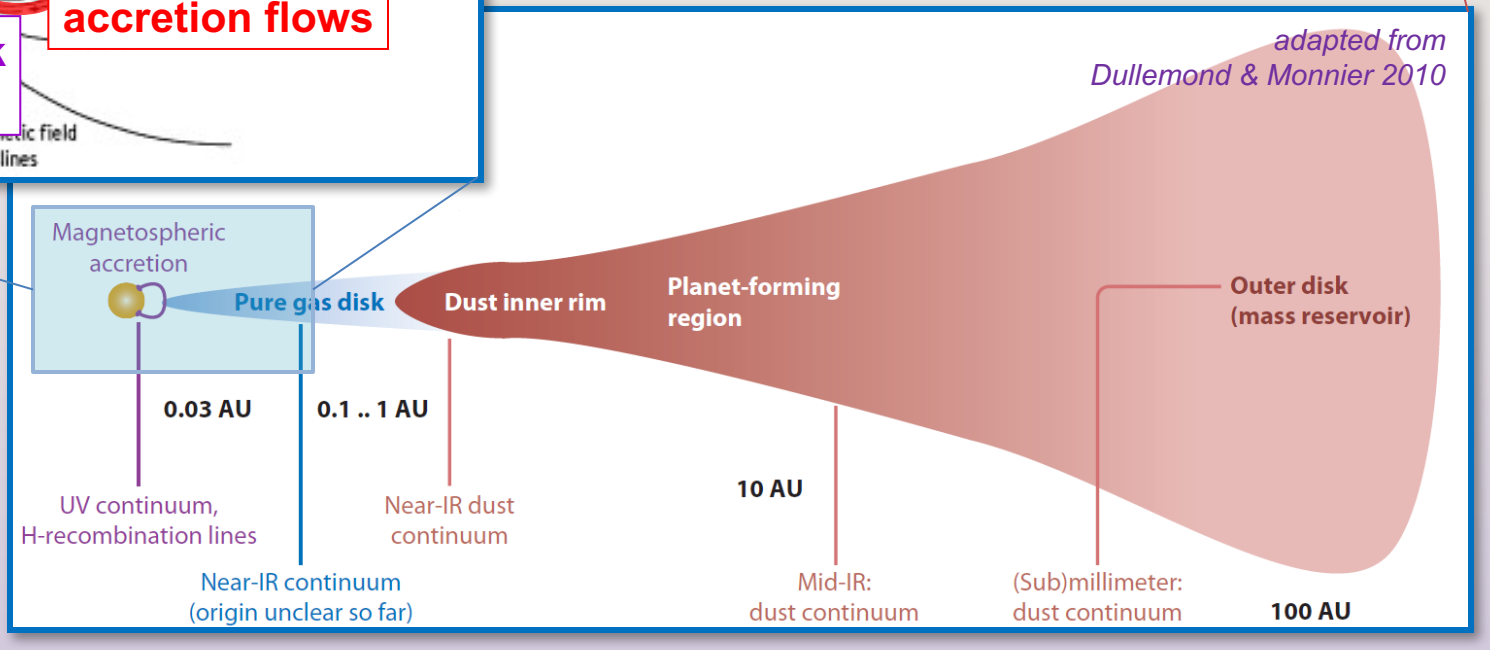
10^4 10^5 10^6 10^7

T Tauri Stars: Accretion & Ejection

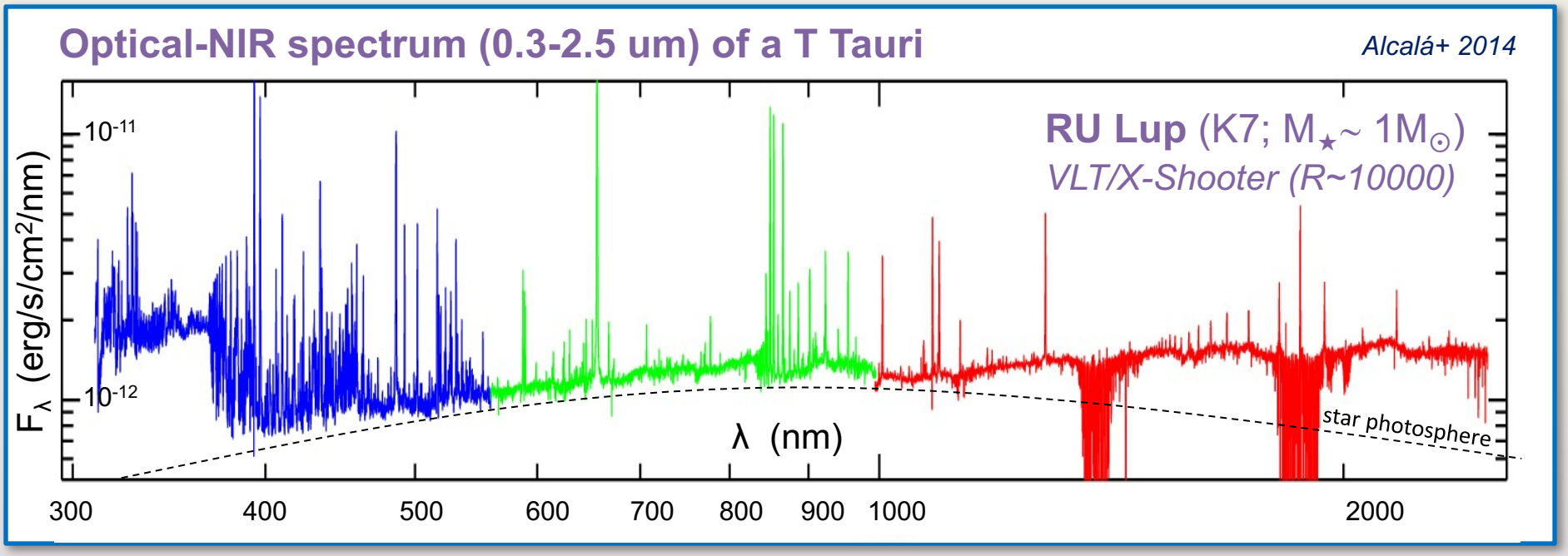




adapted from Dullemond & Monnier 2010



YSO Optical-to-NIR Spectra: Multiple Tracers



- UV-Optical excess emission → *accretion shock*
- NIR excess → *inner disk*
- HI lines & other permitted lines (HeI, CaI, CaII, FeI, TiI, NaI, …) → *accretion columns, winds*
- Forbidden lines ([FeII], [OI], [SII], [NII], …) → *winds, atomic jet diagnostics*
- Molecular lines (H_2, CO) → *inner disk, molecular jet diagnostics*
- Photospheric absorption features → *spectral type, veiling, abundances, v sin i*

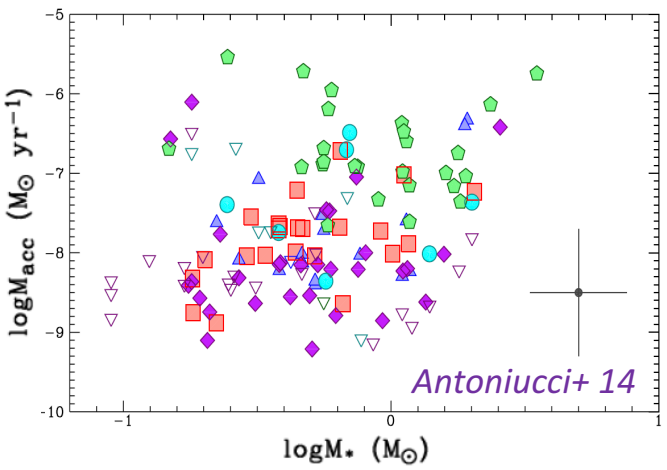
X-Shooter YSO surveys

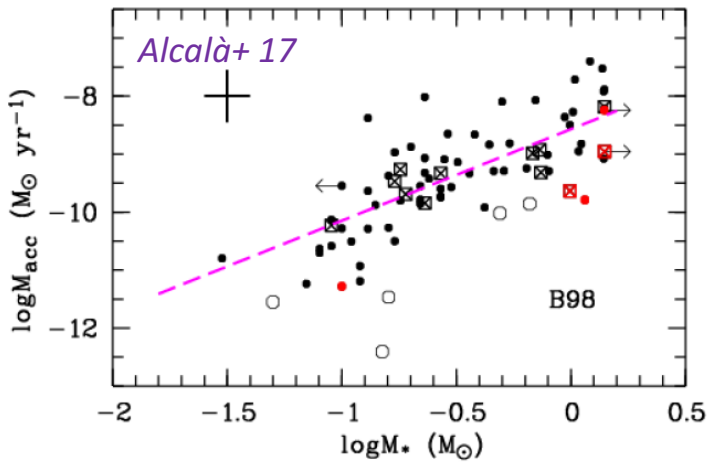
- Simultaneous spectra, wide spectral coverage

→ remove systematics and variability effects

→ use multiple tracers → star+accretion/ejection params in homogeneous way

→ improved accuracy of correlations





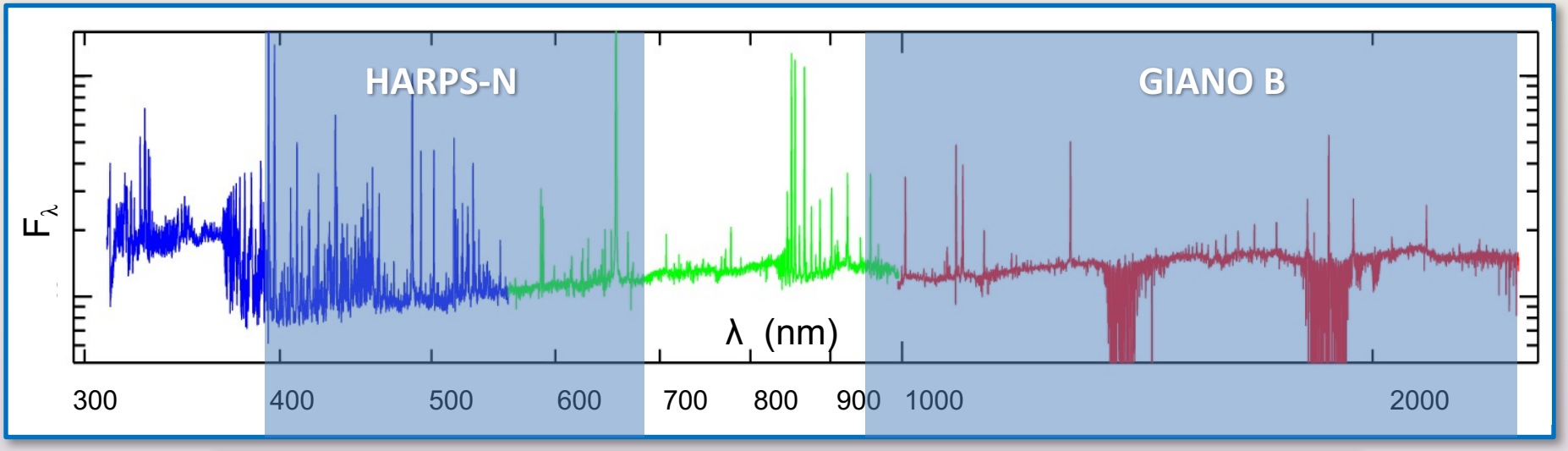
- *Accretion vs star params from UV excess and spectrum fit (Alcalà+14, 17, Manara+16)*
- *Stellar params and abundances (Frasca+17, Biazzo+17)*
- *Slow winds, Jets (Natta+ 14, Nisini+ 17, Whelan+14)*
- *HI gas conditions (Antoniucci+ 17)*

Only moderate resolution → limited analysis on line profiles (profile "degeneracy" issues)

use acquired expertise → first systematic optical-NIR survey of T Tauri stars in Taurus

GHOST - GIARPS High-resolution ObservationS of T Tauri stars

+ ancillary photometry to flux-calibrate data (Asiago, Serra La Nave, Campo Imp.)



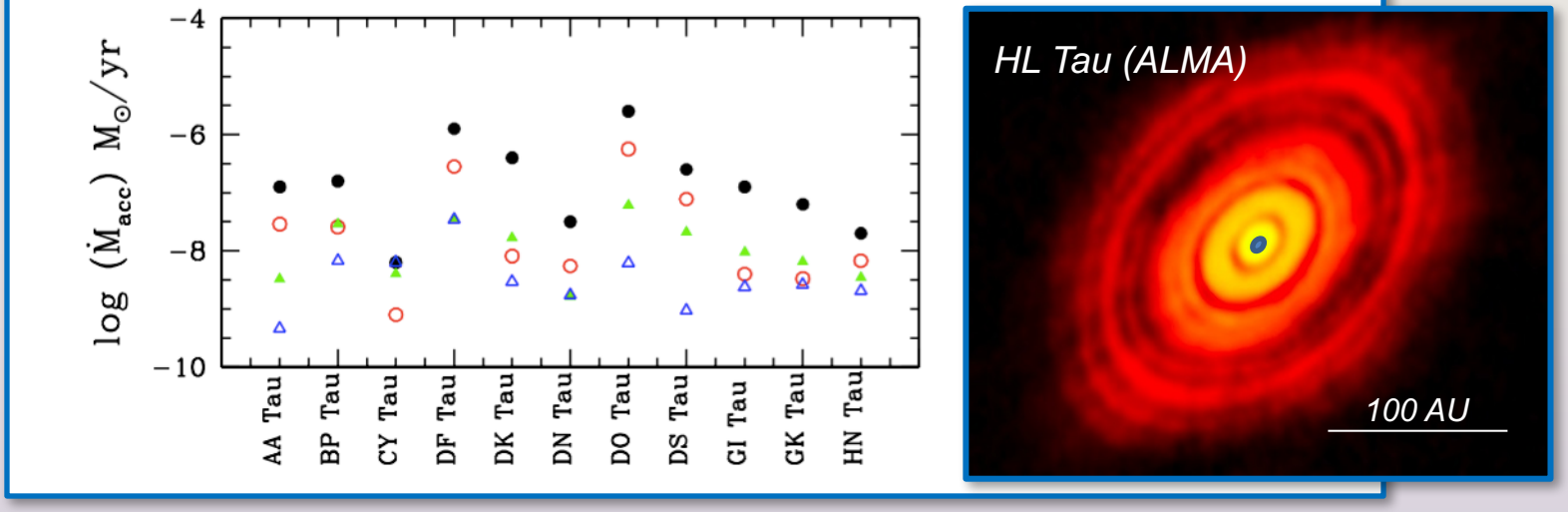
GIARPS only instrument now available with simultaneous optical-NIR coverage at high spectral resolution

→ detailed emission line profiles + absorption features analysis in optical and NIR
→ stellar + accretion/ejection parameters & veiling simultaneously

GHOST: The Taurus-Auriga Sample

Nearby (140 pc) low-mass SFR, population >350 objects

- benchmark region for low-mass star formation
- not suited for large surveys from VLT
- complements samples seen by X-Shooter (larger M and M_{acc})
- source parameters never derived through wide-band, homogeneous techniques



- Reference sample for jet and disk observations (ALMA/LBT/VLT)

→ Cycle 4 ALMA accepted proposal to study disks in Taurus sources *(P.I. Herczeg)*

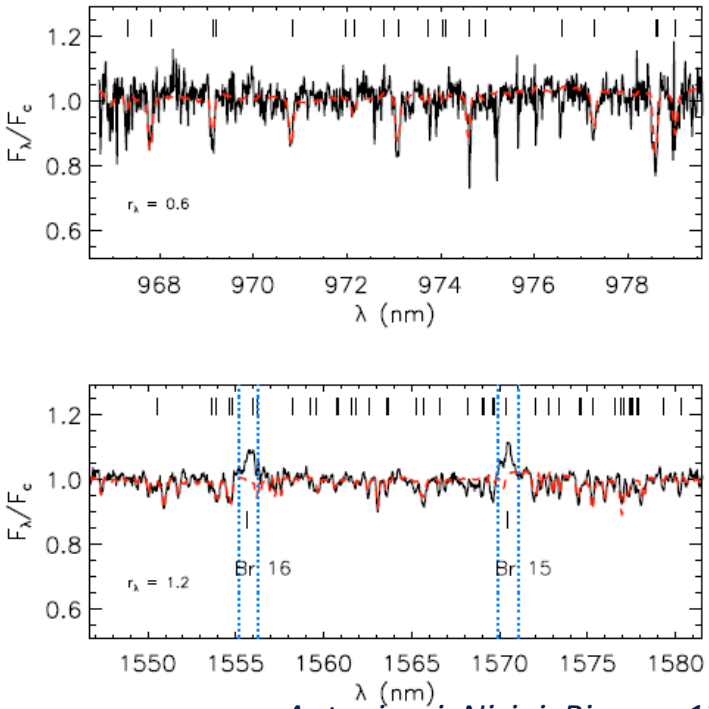
→ Ongoing LBT-LUCI and VLT-SPHERE observations of Taurus sources

GHOST Science: Stellar Parameters & Veiling

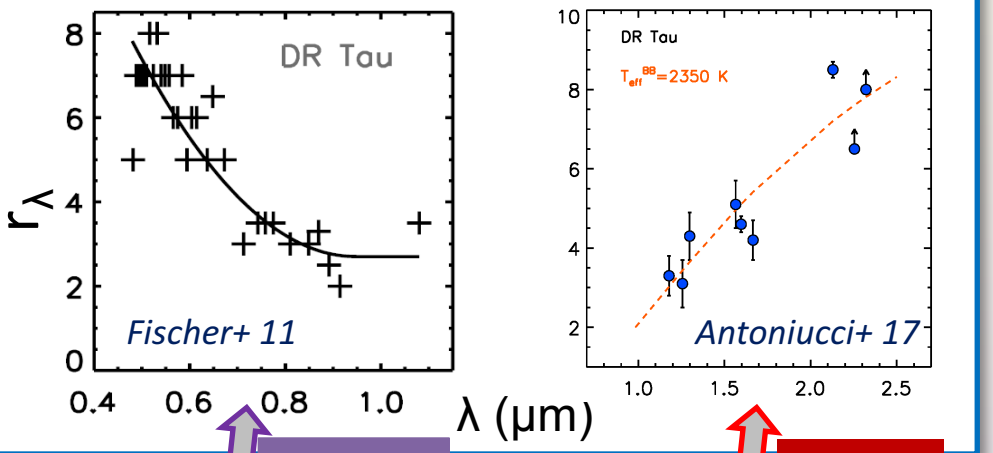
- absorption features → templates → stellar params, veiling
- correlate optical veiling (accretion shock excess) and IR veiling (disk excess)

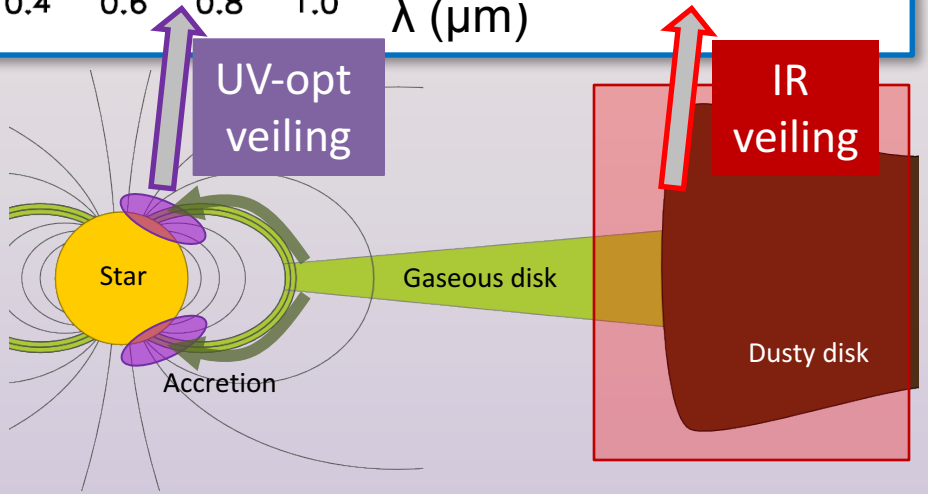
GIANO spectra of DR Tau

(ROTFIT tool, Frasca+)



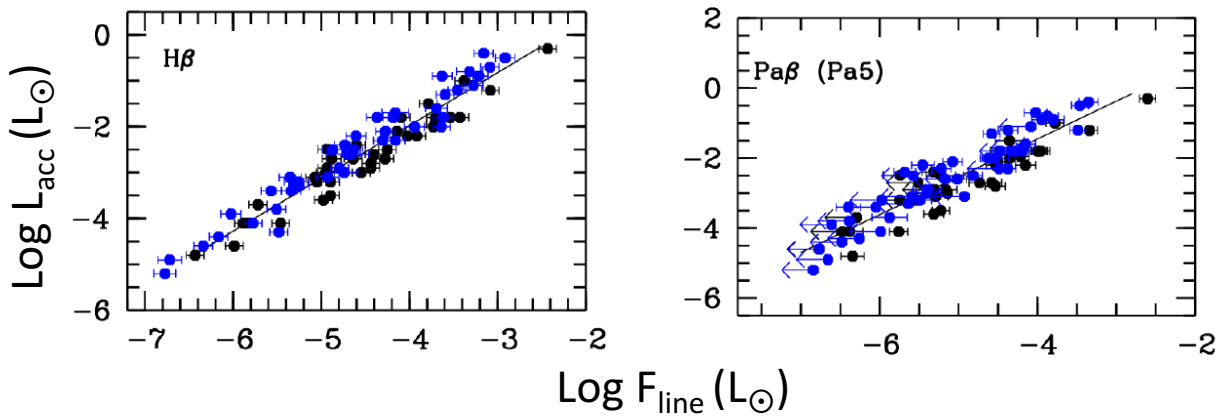
Antoniucci, Nisini, Biazzo+ 17





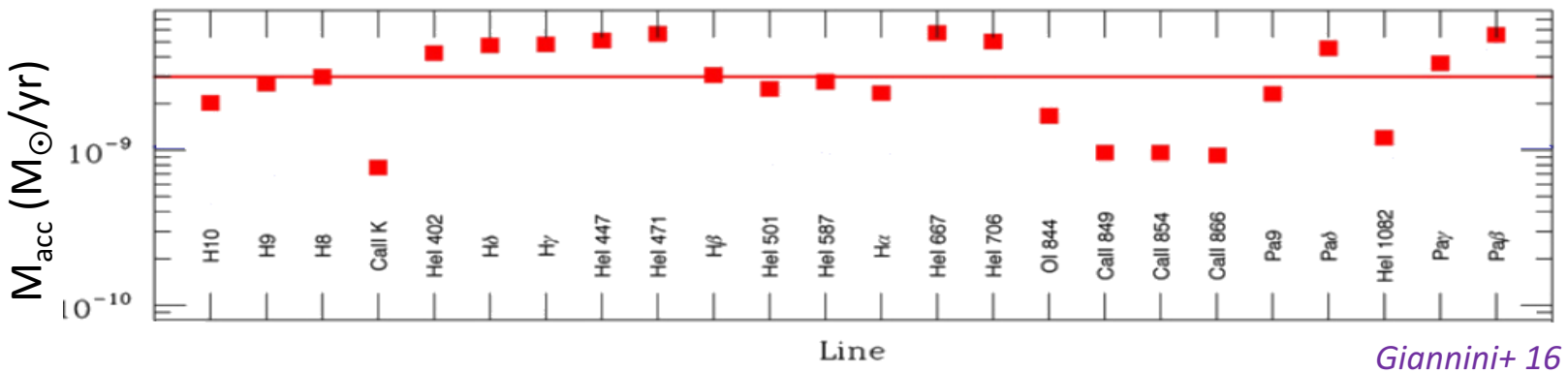
GHOST Science: Accretion

- Use L_{acc} vs L_{line} relationships: multiple tracers from optical to near-IR
- Correlate M_{acc} and other params



Alcalà+ 17

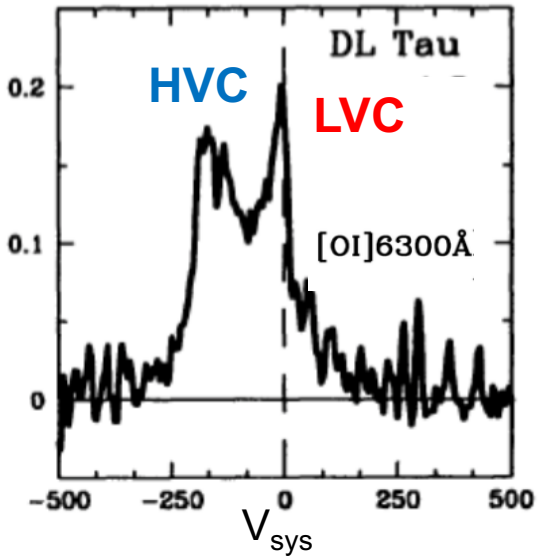
$$\dot{M}_{acc} \approx \frac{R_* L_{acc}}{G M_*}$$



Giannini+ 16

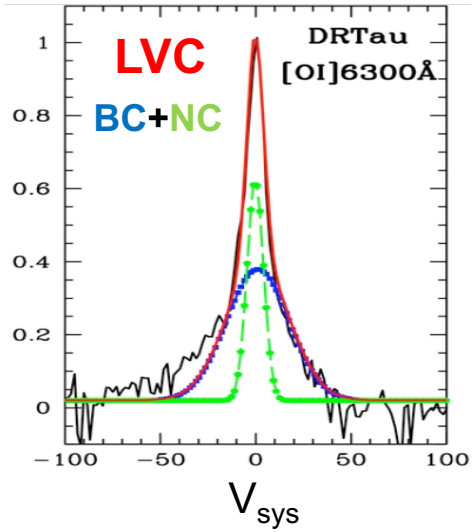
GHOST Science: Winds & Jets

- Forbidden lines ([OI], [FeII], …) and molecular emission (H_2) from winds/jets
- Multiple components (High/Low Velocity components, Broad/Narrow Components)
- R~50 000 to resolve different contributions from jets, slow-winds, gaseous disks
- Ratios of optical/NIR lines → params in different components



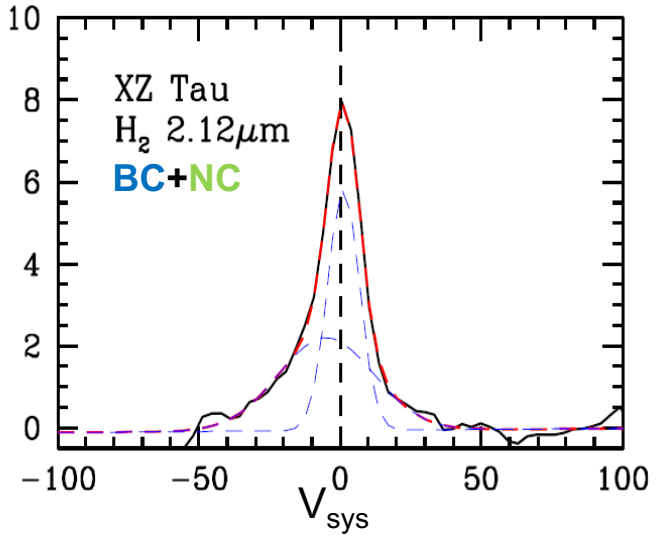
Hartigan+ 95

UVES R~60 000



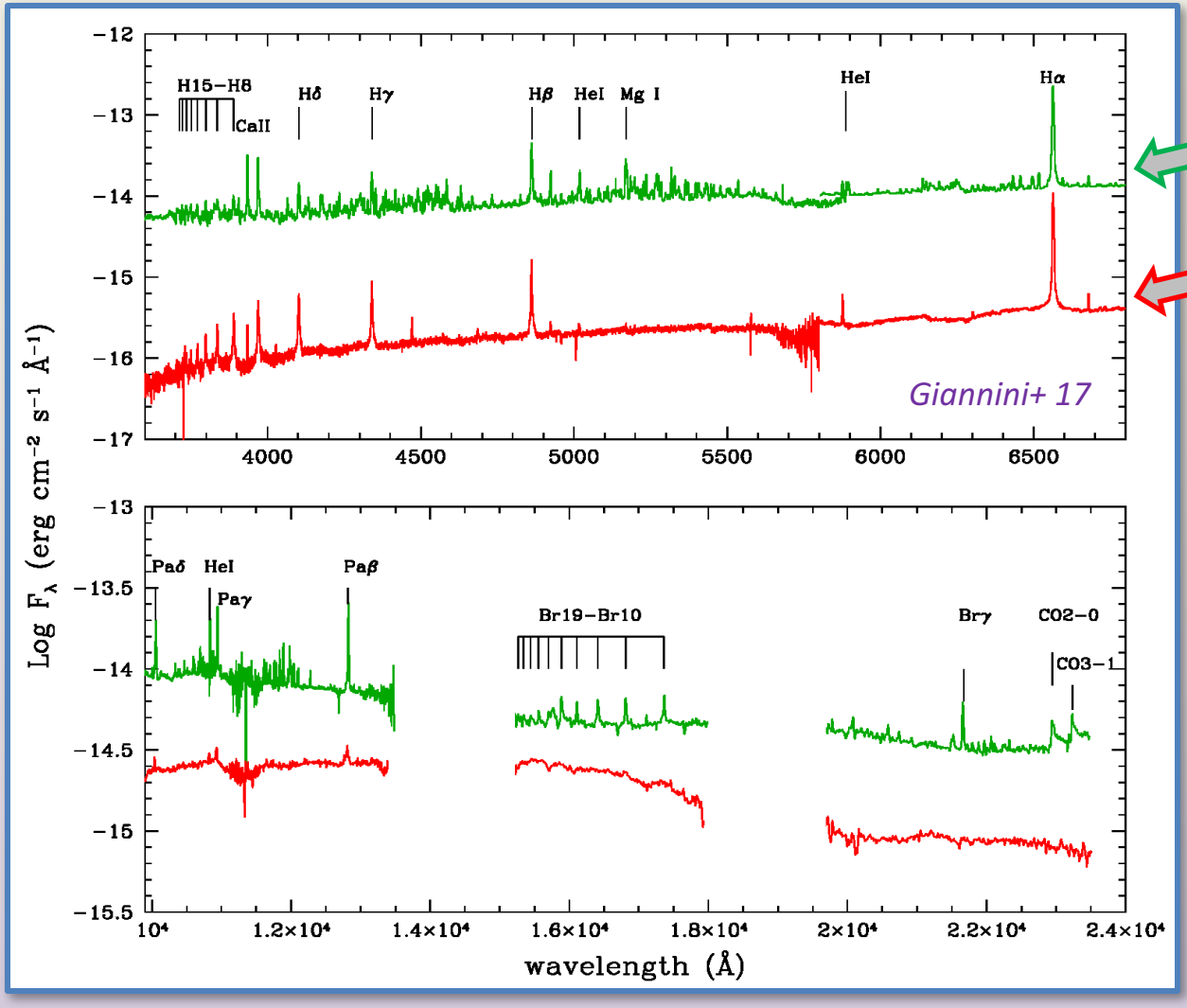
Rigliaco+ 14

GIANO R~50 000



Antoniucci+ 17

GHOST Science: Spectral Variability



accretion outburst

quiescence

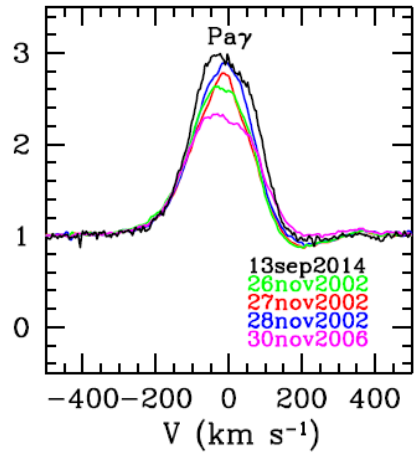
- accretion and ejection are variable
- in some objects dramatic accretion outburst events (e.g. EXors, ΔM_{acc} ~10^2-10^3 $M_\odot$/yr)

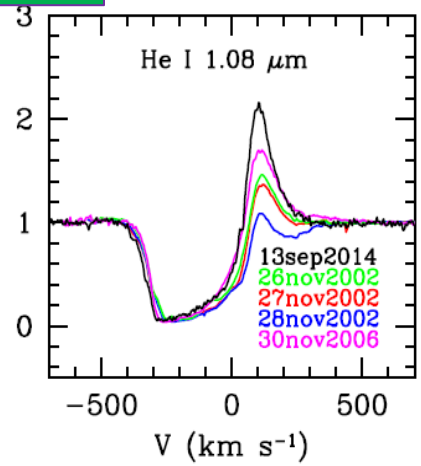
→ continuum + line variations

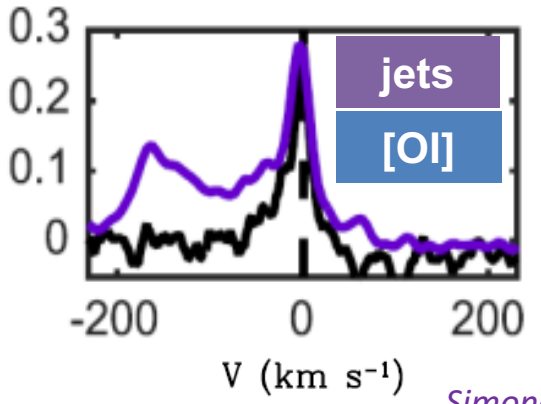
GHOST Science: Spectral Variability

GIANO

DR Tau





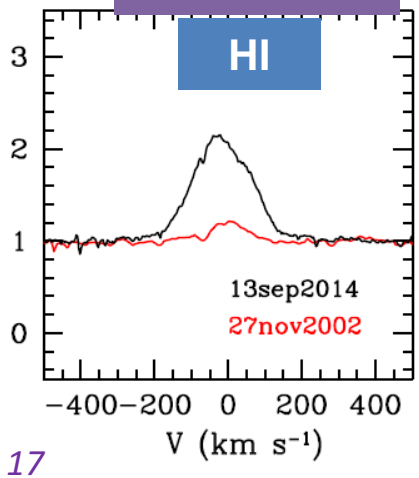


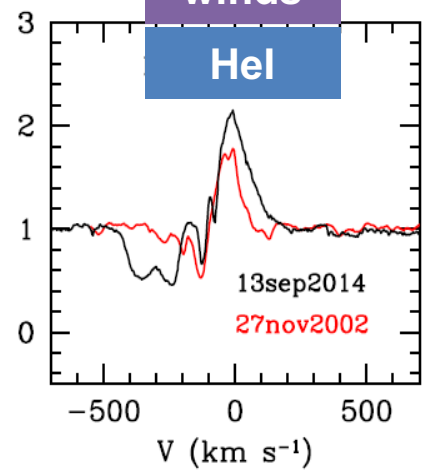
Simon+ 16

accretion **winds**

XZ Tau

HI **HeI**





Antoniucci+ 17

- correlate profile variations in different tracers=structures
- accretion/ejection connection
- M_{loss}/M_{acc} variations
- Variations on times-scales from hours to years

GHOST: Observations & Scheduling

- **70-90 Taurus objects with mag R < ~13 (1-3 Myr, 0.3-2 $M_{\odot}$)**

flux-limited Spitzer-selected sample

- **Monitoring of small sub-sample of ~10 objects**

from different "categories" (strongest line emitters, EXors, …)

- **Observation of spectral templates**

in common with other projects?

- 45-min/source, 75 objects, 10 objects x 6 times (monitoring), 15 templates → **~110 h** of integration + 30% calib and overheads → **~18 nights**; distributed on **4 years** → **4.5 nights/year**
- scheduling can be highly flexible
- long timespans between observations give opportunity to sample variability on long time-scales: weeks to years

GHOST: Work Packages

Observations and data

Source selection
Antoniucci, Alcalà, Nisini, Giannini

Data reduction
Sanna, Harutyunyan, Antoniucci

Ancillary photometry
CImp (NIR), Asiago+SLN (VIS)
Munari, Di Paola, Giunta, Frasca, Biazzo

Star and accretion

Stellar parameters, veiling, elemental abundances
Biazzo, Frasca, Alcalà, Origlia

Mass accretion rate measurement
Manara, Antoniucci, Biazzo, Alcalà, Fedele

Ejection

Characterization of winds
Rigliaco, Nisini, Manara, Fedele

Characterization of jets
Podio, Nisini, Bacciotti, Giannini

Variability

Spectro-photometric variability
Antoniucci, Giannini, Frasca, Biazzo

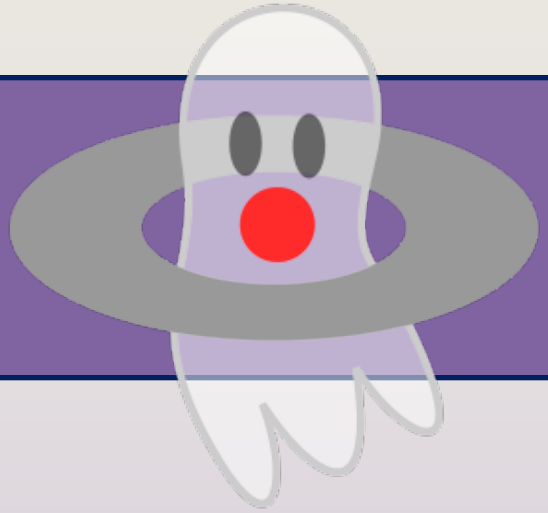
Opt-IR-submm connection

Link with complementary observations (ALMA, LBT/LUCI, VLT/SPHERE)
Herczeg, Antoniucci, Podio, Alcalà, Nisini, Rigliaco, Manara

- **G**IARPS **H**igh-resolution **O**bservation**S** of **T** Tauri stars
- Unique simultaneous optical-NIR coverage at high spectral resolution
- Stellar + acc/eject params and veiling simultaneously and homogeneously
- Correlate tracer (= structure) variations

- Sample of 70-90 T Tauri objects in Taurus (monitoring on ~10 object)
- ~18 nights (4.5 nights/yr on 4 years)
- Complementary to ALMA and opt-NIR high-angular-resolution observations

Thank You

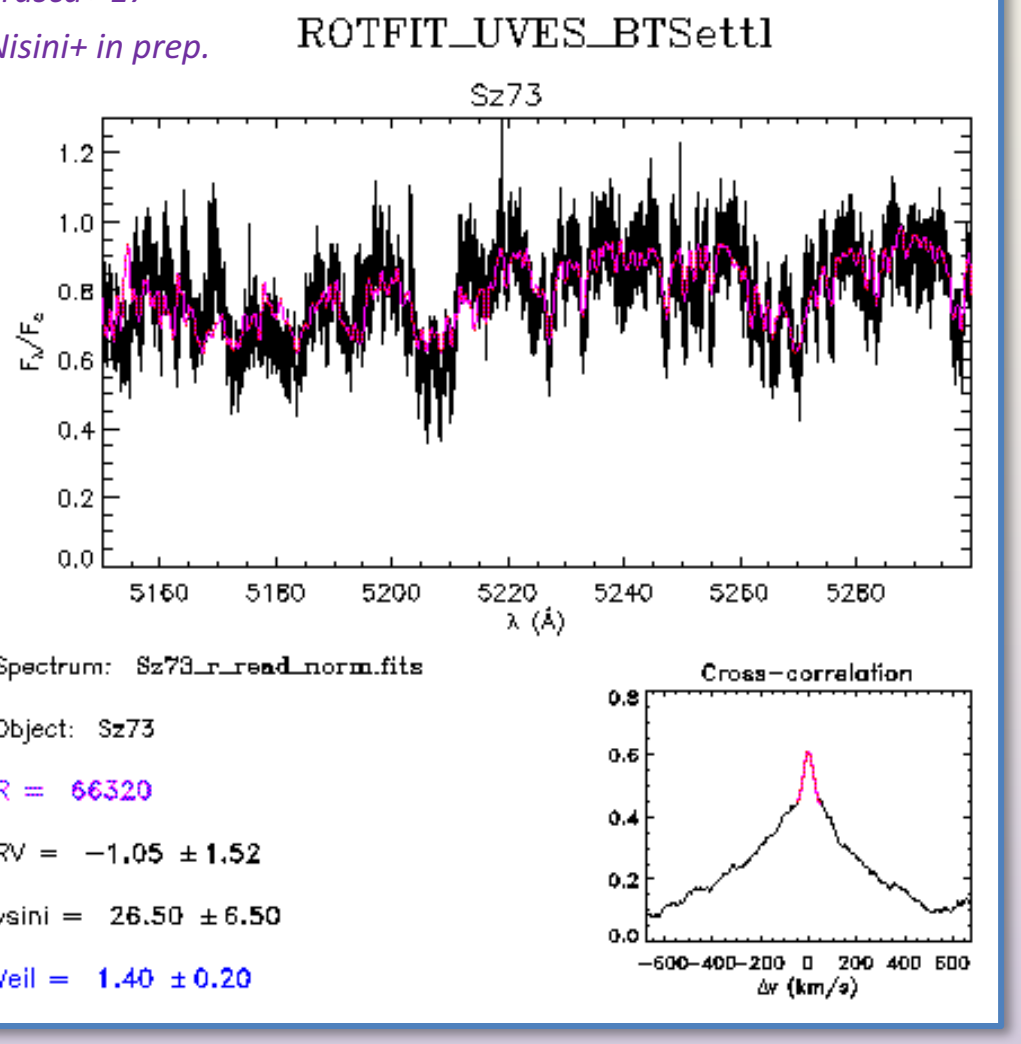


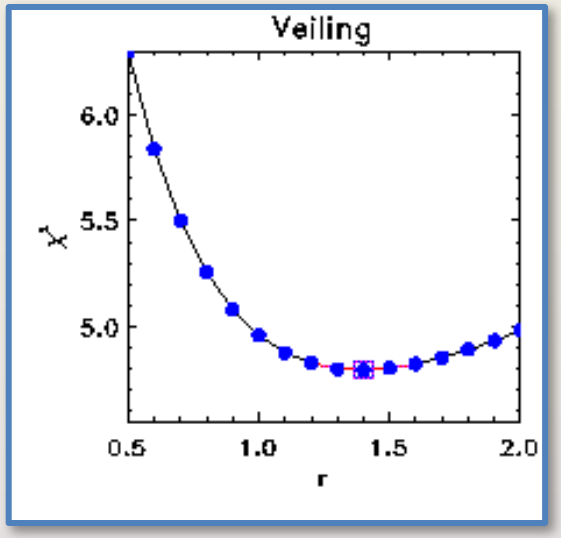
Xtra Slides

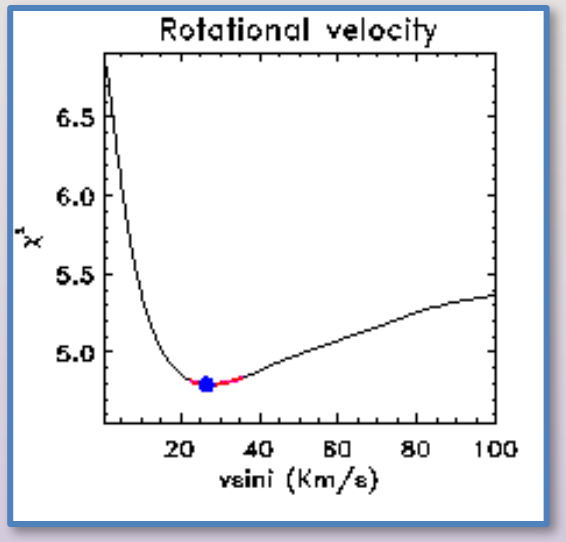
GHOST Science: ROTFIT tool

Frasca+ 17

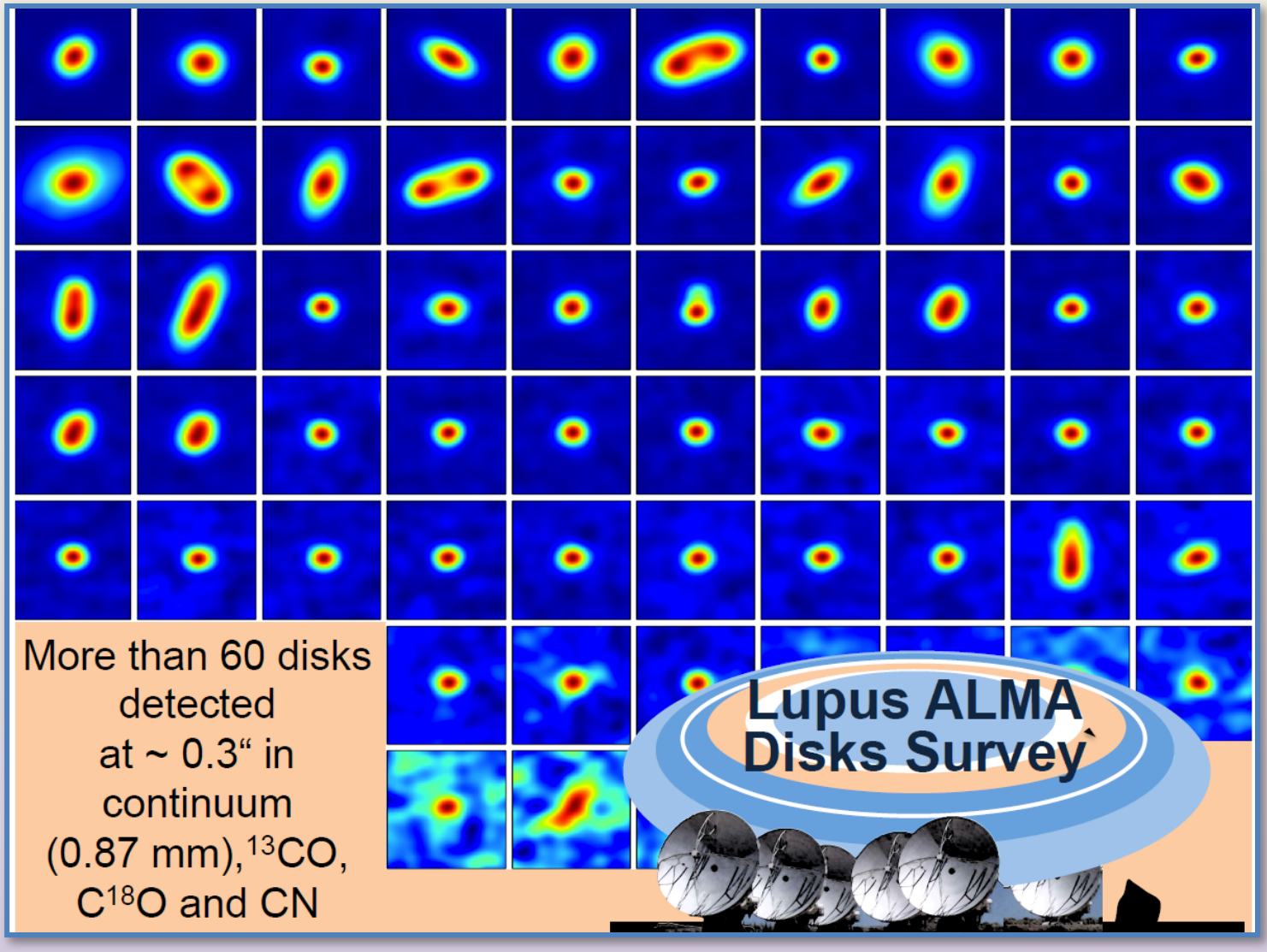
Nisini+ in prep.



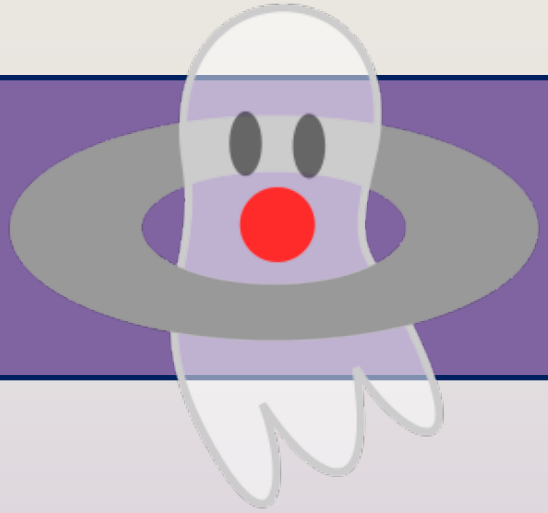




GHOST: ALMA Complementary Observations

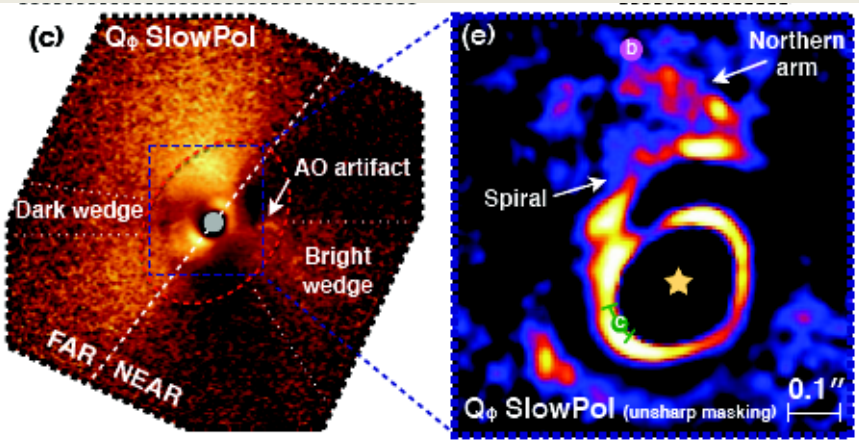


Ansdell+ 16
Manara+ 16

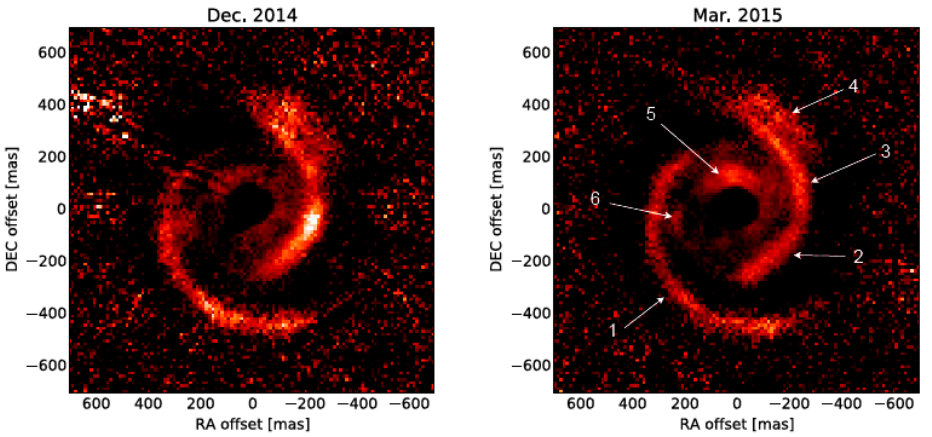


Thank You

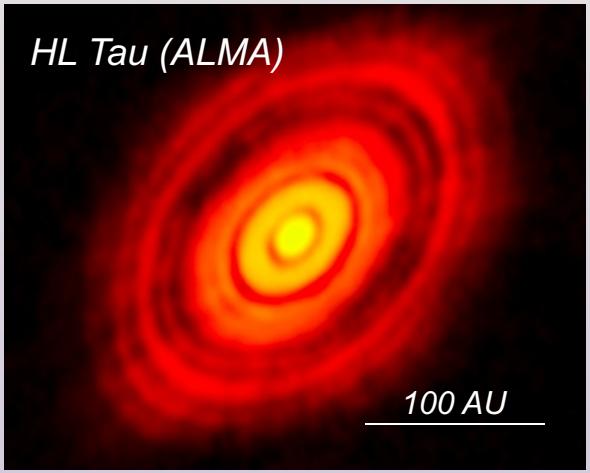
Jets and disks



HD100546 disk (DPI with ZIMPOL)
Garufi+ 2016



MWC 758 disk (DPI with IRDIS)
Benisty+ 2016

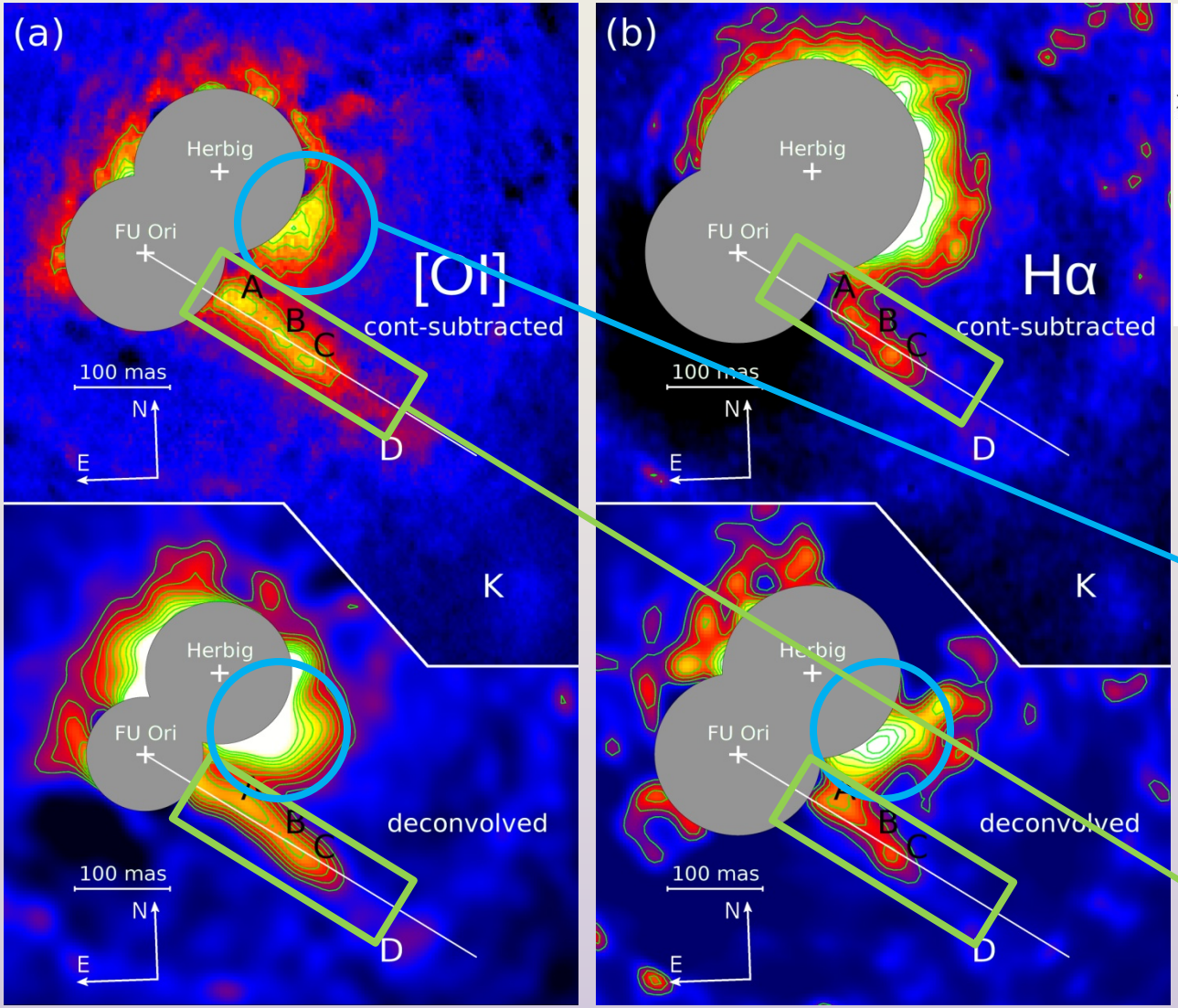


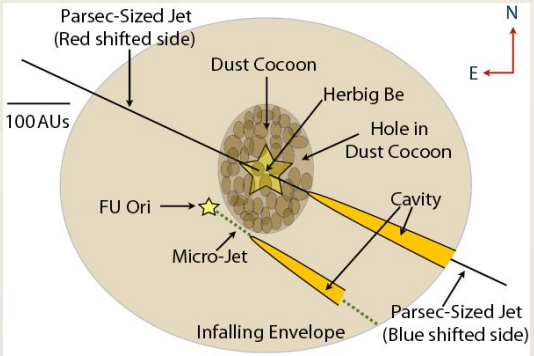
- Complementary high-resolution images of disk around jet-driving sources:
- ALMA (mm-size grains)
- SPHERE, LUCI, LBTI, SHARK (μm-size grains) down to a few AUs from star

- Connect jet and disk properties!

(e.g. inclination/jet velocities; correlation between disk gaps and jet wiggling indicating unseen companions; jet ejection timescales vs orbital period of disk features; …)

Z Cma SPHERE images





Herbig.

Collimated jet not revealed.

Compact **wide-angle wind**: possibly related to past accretion outbursts

FUor.

Highly **collimated jet, wiggling!**