Exploring the origin of jets in embedded protostars with ELT and ALMA

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Paradigm for solar-mass star formation

- $t = 0 - 10^4$ yr (pre-stellar core)
- $10^4 - 10^5$ yr (proto-star)
- $10^6 - 10^7$ yr (T Tauri star)
- $10^8$ yr (debris disk ZAMS star)

**Class 0/ I objects**

Highly embedded accreting sources

$\dot{M}_{\text{jet}} / \dot{M}_{\text{acc}} \sim 0.05 - 0.1$
Protostellar jets

Class 0 (Av > 100 mag)
- molecular flows
- tracers: CO, SiO

Class I (Av ~ 20-50 mag)
- molecular and atomic flows
- tracers: H₂, FeII

How the jets are launched and collimated
How angular momentum is transferred from the accretion disk to the jet
Which is the initial heating process

Codella et al. 2008

Brunella Nisini INAF-OAR E-ELT-ALMA workshop ESO Garching 26-March-2009
MODELS BASED ON OBSERVATIONS ON T TAUURI STARS:
- jet launching zone within 10 AU
- jet acceleration/collimation zones 10-100 AU (~70-700 mas at 150 pc)

CAVEAT TO EXPORT THESE RESULTS ON YOUNGER SOURCES
- different mass accretion/mass ejection rates
- thick massive envelopes and disks
- Large densities --> large B and low Xe

Role of ELT and ALMA to give observational constraints resolving the collimation scales
Excitation structure in the inner 100 AU region

Probe excitation mechanisms: steady shocks, X-rays, ambipolar diffusion..

More than 140 diagnostic emission lines detected in HH99 (mainly H2, HI, FeII, PII..)

--> maps of molecular and atomic gas physical parameters: T, n, x_e, Av, dust depletion...

IFU Sinfoni seeing limited
(Davis et al. in prep.)

IFU Sinfoni 2D maps of the HH99 bow-shock

Sinfoni 2D maps of the HH99 bow-shock

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Excitation studies in Class 0 molecular jets

The molecular jets are ‘warm’:

Excitation conditions at the base can be probed through ALMA multiline analysis

- tracers: CO, SiO

- synergy with ELT mid-IR observations
Velocity structure as a test for ejection models
ALMA and ELT may provide a unified picture

IRAS04166+2706

Santiago-Garcia, Tafalla et al. 2007

Romanova et al. 2009

IRAS04166+2706

SiO 2-1
HV

CO 2-1
LV

PdB

Romanova et al. 2009

ISAAC spectroscopy of class I jets

Garcia Lopez, Nisini et al. 2008

Disk-wind model

> 100 AU

HVC

LVC

< 100 AU
Role of jets in removing AM: probing jet rotation

- Rotation signatures observed in class 0/I objects
  - Interaction with ambient medium and/or precession may cause velocity asymmetries
  - Need tests as close as possible to the launching zone

\[ v_\phi \sim 2-3 \text{ km/s} \rightarrow \text{need for high resolution} \]

- NIR jets \(ightarrow\) HARMONI with R\(>10000\), SIMPLE
- (sub-)mm jets \(ightarrow\) ALMA 350 GHz SiO (8-7), CO 3-2

ALMA will also test disk rotation
Additional issues

- Proper motion measurements: of the order of 0.1″/yr in the nearby clouds

- chemistry

- ALMA polarimetric studies: structure of magnetic field
Summary of requirements

Similar requirements for ELT and ALMA

* For excitation studies at the jet base:
  - Angular resolution better than 100 mas
  - Spectral resolution 1000-10000
  - Integral field (~3x3 arcsec)

E-ELT: e.g. Harmoni

ALMA: Baselines > 1 km, Bands 7/8

* For dynamical studies (rotation/origin of the different gas components):
  - Spectral resolution ~ 50000 (e.g. E-ELT/ SIMPLE)
Caveats

E-ELT

AO systems with IR sensors or LGS
- no optical sources in the field
- IR sources usually fainter than m(H) = 12

ALMA

- sensitivity limit for observations with long baselines?
  expected $T_{MB} \sim 10$-100 K for resolved emission
- which are the suitable tracers? SiO 5-4/8-7, high-J CO, CI?
chemical models needed...