



## The disk-driven jet of Cygnus A

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## Jet formation: disk-driven vs. BH-driven jet

#### Simulations

- Spinning BHs efficiently power jets (e.g. Tchekhovskoy et al. 2011 -MNRAS.418L..79T)
- Diverse results for disk winds:  $\Gamma \sim 10$  (e.g. Komissarov 2007 - MNRAS.380...51K)  $\Gamma < 3$  (e.g. McKinney & Gammie 2004 -ApJ...611..977M)





#### Observations

- BH spin necessary to account for blazars jet powers (Ghisellini et al. 2014 -Natur.515...376G)
- ▶ Jet width in M87 ≤ 5.5 R<sub>S</sub>: jet is anchored close to ISCO (Doeleman et al. 2012 - Sci...338..355D)

## The radio galaxy Cygnus A

 $\blacktriangleright \ \theta \sim 75^\circ$ 

- ▶ **z=0.056,**  $M_{\rm BH} = 2.5 \times 10^9 \ M_{\odot}$
- Only FRII with bright two-sided structure on sub-parsec scales.



Image Credit: X-ray: NASA/CXC/SAO; Optical: NASA/STScI; Radio: NSF/NRAO/AUI/VLA

### GMVA observations



#### 1 mas∼1.084 parsecs

#### Boccardi et al. 2016b

- 3 epochs (May 2009, Oct 2009, May 2010)
- ► Beam ~0.1×0.05 mas  $\Rightarrow$  down to ~ 200 $R_{\rm S}$

### Stacked image at 86 GHz

#### Each epoch restored with a circular beam of 0.1 mas



Jet structure better recovered, limb-brightening

▶ Reduced noise level of  $\sim 0.1 \text{ mJy/beam}$ 

 $\Rightarrow$  Pixel-based study of the transverse intensity profiles.



## The nuclear region is transversally resolved



#### $d_{\min} = (227 \pm 98) R_{\mathbf{S}} \gg$ than ISCO radius!

## A disk-driven jet in Cygnus A

#### ► 1) Stratified in flux density



# 2) Of parabolic shape (mean opening angle θ~5°)



See VLBI study at 43 GHz (Boccardi et al. 2016a)

# A disk-driven jet in Cygnus A

- 3) Mildly relativistic
- ► 4) Accelerating on parsec scale
- ► 5) Stratified in bulk speed



Intrinsic speed (top) and Lorentz factor (bottom) vs. distance from t<u>he core</u>.



Compatible with expectations for a magnetically-driven jet with spine-sheath structure

# A disk-driven jet in Cygnus A

#### **BUT NOTE:**

Existence of both a narrower and broader component is not excluded!

#### On the contrary

- Faster and invisible central spine (BH-driven?) suggested by kinematics+limb brightening (Boccardi et al. 2016a).
- Jet appears as a wide (~9000 R<sub>S</sub>), almost cylindrical flow at 5 GHz (Carilli et al. 1991 - AJ....102.1691C)



If BH-driven and disk-driven jet coexist, relativistic effects select the dominant component based on the orientation,

as observed.

### Summary

- First evidence for an accretion-disk origin of this jet (mildly relativistic, parabolically expanding, stratified)
- Suggest coexistence of a wide, slow disk wind with a fast and narrow central spine.

#### Charlottesville, June 1977



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## Happy birthday!