Jets 2013 - Granada

A sensitive study of the peculiar jet structure HST-1 in M87

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and

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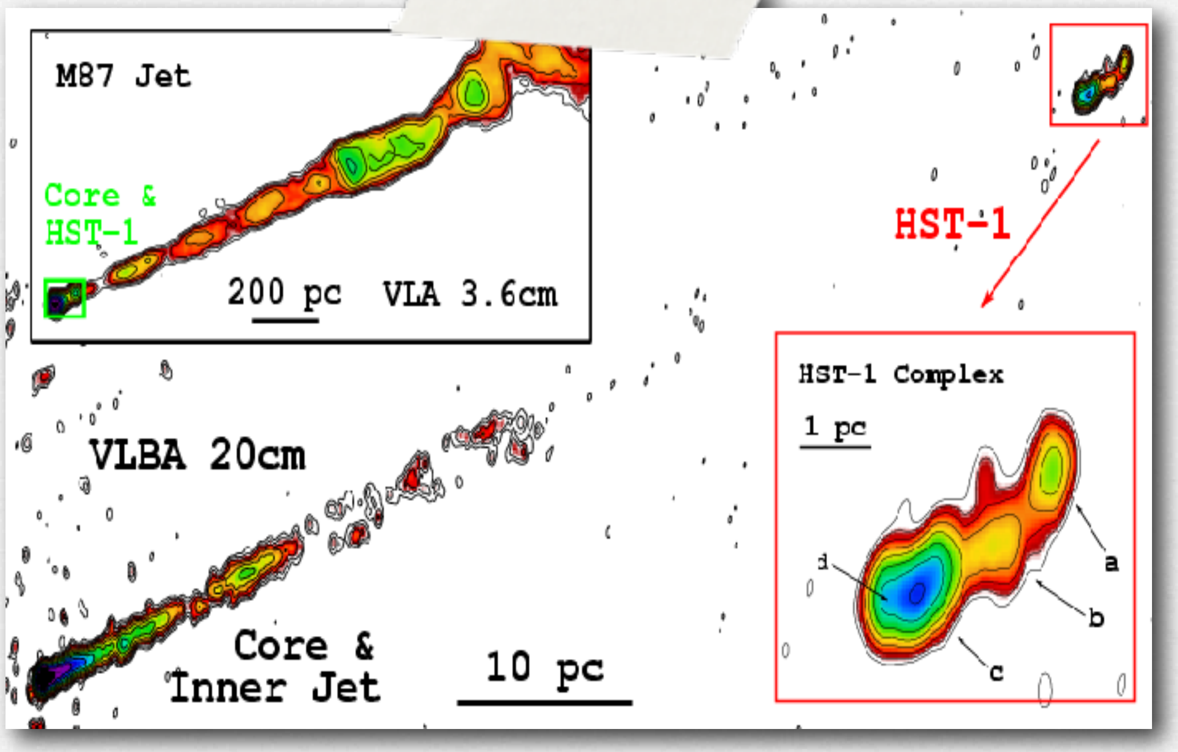
M87 and HST-1 scenario.

M87

- nearby galaxy (D=16Mpc),
- massive BH (6.4×10^9 M_{sun}),
- bright and resolved jet
- well studied at all wavelengths from radio to gamma + TeV



Cheung et al., 2007

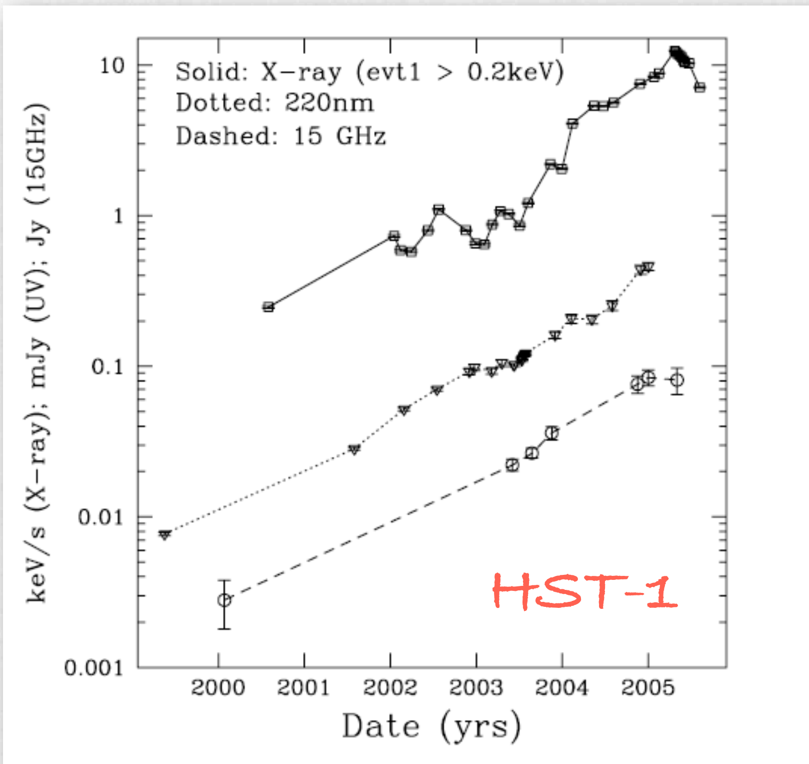
HST-1

- 0.8-0.9 arcsec from the core (~70pc, projected)
- at high resolution, composed by superluminal components
- it emits at different frequencies

Flare gamma (TeV)

2005 -H.E.S.S
2008 -MAGIC,VERITAS
(09/02/2010) - MAGIC
(09/04/2010) -MAGIC,VERITAS

M87 core and HST-1 as potential candidates for the TeV emission



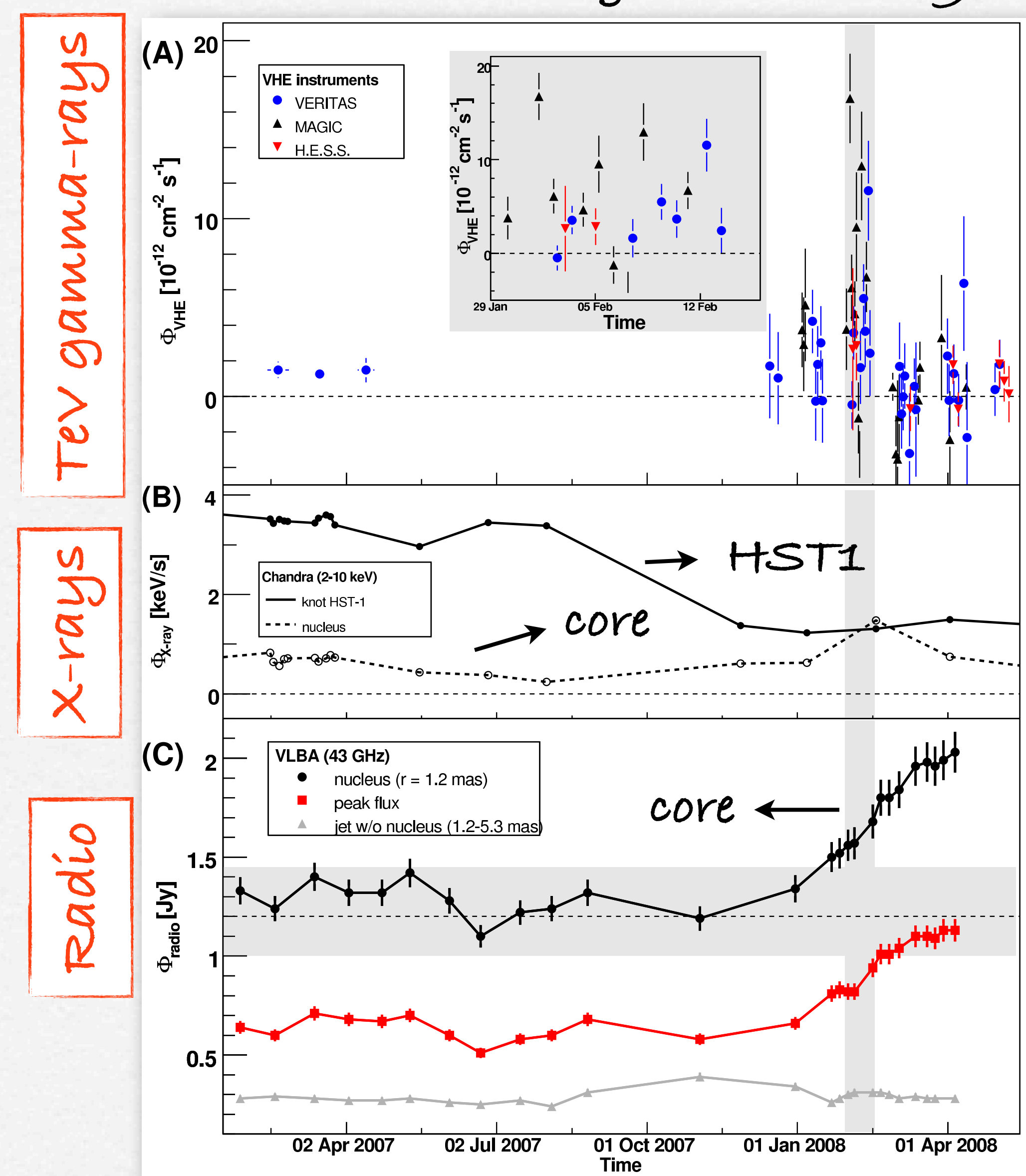
Harris et al., 2006

TeV flare 2005

HST-1 - brightest state in radio, UV and X-rays

M87 core - Not in a particular active state at any frequency

Wagner et al., 2009



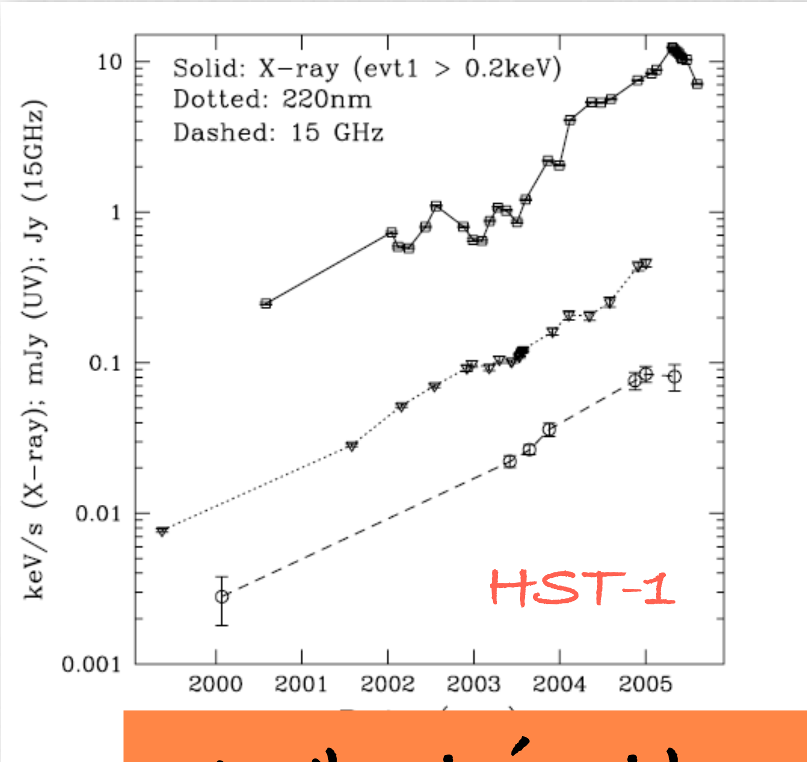
TeV flare 2008

HST-1 - lowest state of flux in X-rays

M87 core - large increase in radio and X-rays

TeV flare 2010

NO prominent low energy flares from the core or the HST-1 region complicate the scenario. (Abramowski et al. 2012)



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TeV flare 2005

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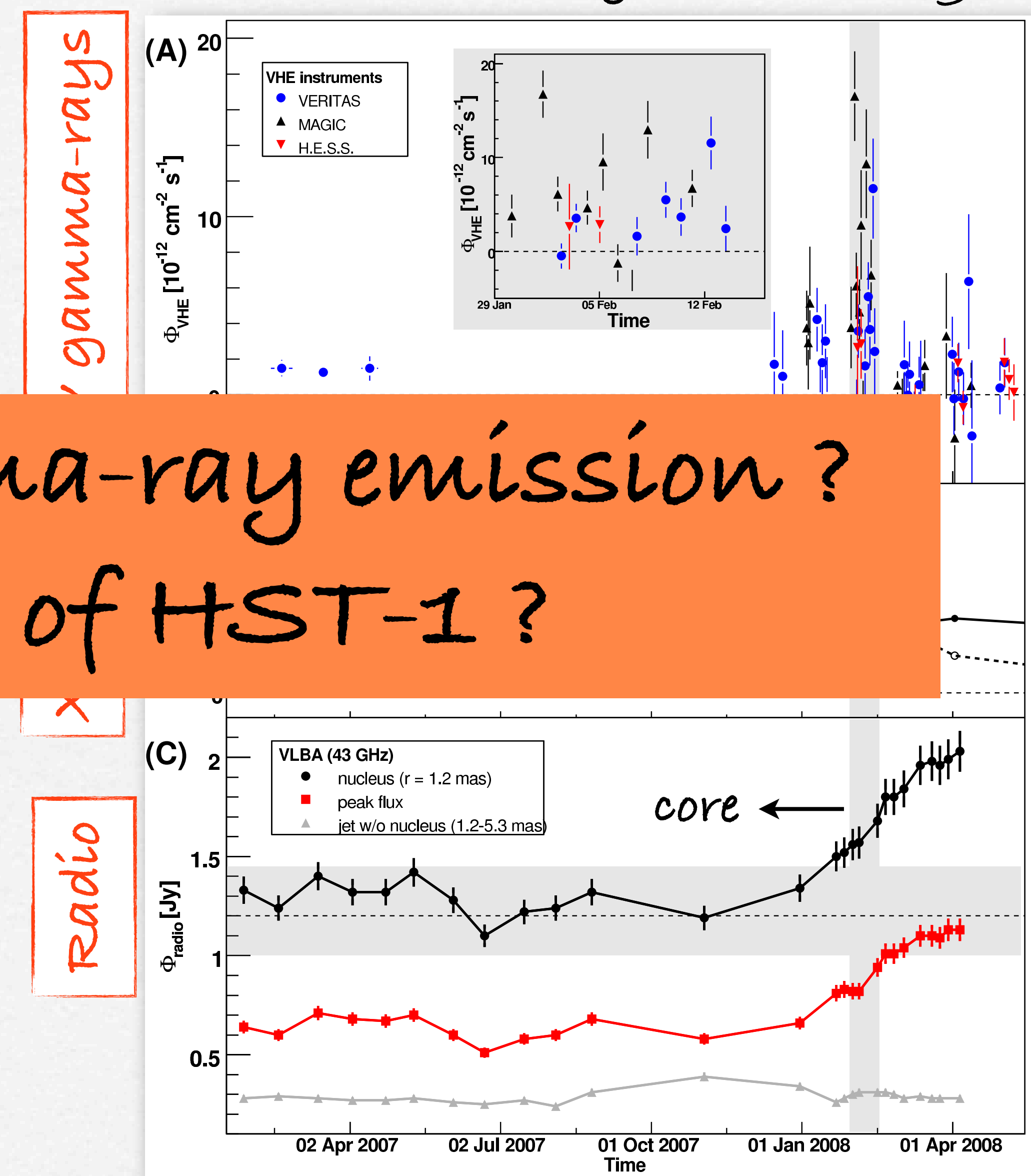


What is the region of gamma-ray emission ?

.....what is the nature of HST-1 ?

HST-1 - lowest state of flux in X-rays

M87 core - large increase in radio and X-rays

TeV flare 2010

NO prominent low energy flares from the core or the HST-1 region complicate the scenario. (Abramowski et al. 2012)

2. What is the nature of HST-1 ?

From previous studies:

- reconfinement nozzle expected at 800-900 mas from the core. (Stawarz et al. 2006)

- the hypothesis of a recollimation shock is supported by semi-analytical and numerical MHD models. (Gracia et al. 2009, Bromberg & Levinson 2009, Nalewajko 2012)

- recent VLBI observations show HST-1 corresponds to the location at which the jet of M87 changes from parabolic to a conical shape. (Asada & Nakamura 2012) + model in Potter and Cotter ('12)

↓

HST-1 as a recollimation shock

(reacceleration of particles in situ ⟶ possible gamma emitter)

Some evidences but No conclusive observational indications for the existence of a stationary feature in HST-1 associated with the recollimation shock - as expected from numerical simulations (i.e., Gómez et al., 1995, 1997) and observed in other sources (3C120 - Agudo I., Gómez J. L., Casadio C., et al., 2012).

Some evidences of stationary emission

1. Cheung, Harris, Stawarz (2007) from 1.7 Ghz VLBA observations they measured an upper limit for the proper motion of the upstream region of HST-1 (labeled as HST-1d) of 0.25c

2. Giroletti et al. (2012): monitoring combining new EVN data (5 GHz) and archival VLBA data (1.7 GHz) for a total of 24 observations between November 2006 and October 2011.

Main results:

1) HST-1 size in radio band ~100 mas, with sub-structures on smaller angular scales;

2) two sub-components (comp 1 and 2) are moving regularly at similar superluminal speeds (v~4c);

3) a slower weak component (comp 2b) detected between 2008.5 and 2010, up upstream comp 2

4) a new substructure (comp 3) has appeared from 2010 at 875 mas from the core, upstream comp 2 and 1

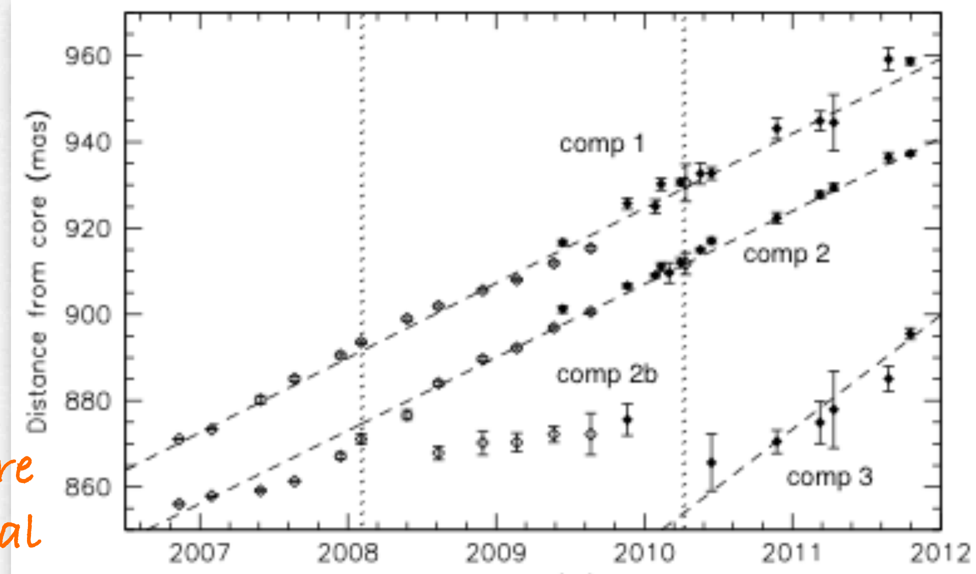
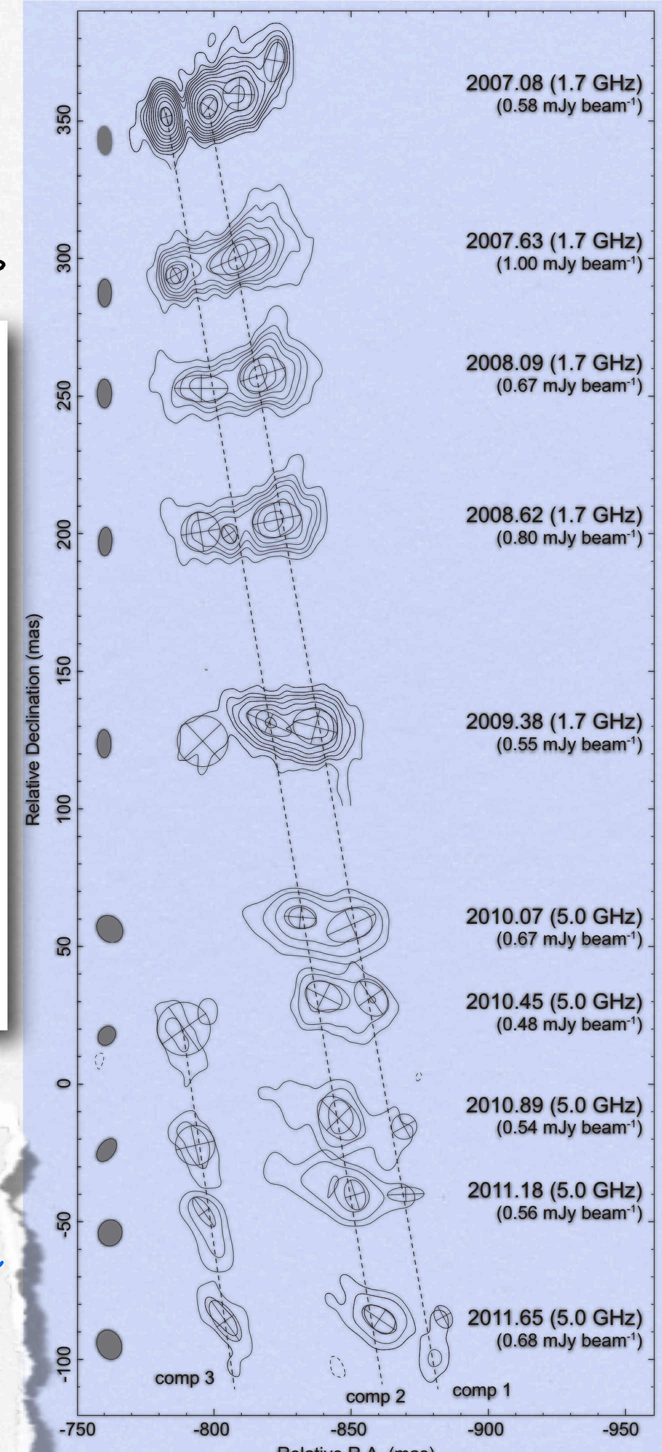


Fig. 2. Distance of compact components within HST-1 as a function of time. Note the new component appearing in late 2010. Reproduced from Giroletti et al. (2012).

Possible explanation:

the components 2b and 3 could be part of a weaker emission located in the upstream that start to bright only when a new component pass trough it.

Giroletti et al., 2012



New relativistic hydrodynamics simulations

(RHD model of Perucho et al. 2010)

Figure 2 - the jet is launched with an initial over-pressure 10 times larger than the external medium.

Figure 3 - a perturbation in the jet inlet (increase in the injection pressure by a factor of 8) develops into a moving shock.

the interaction between the shock and a second recollimation shock leads to a significant increase in pressure.

Stationary model

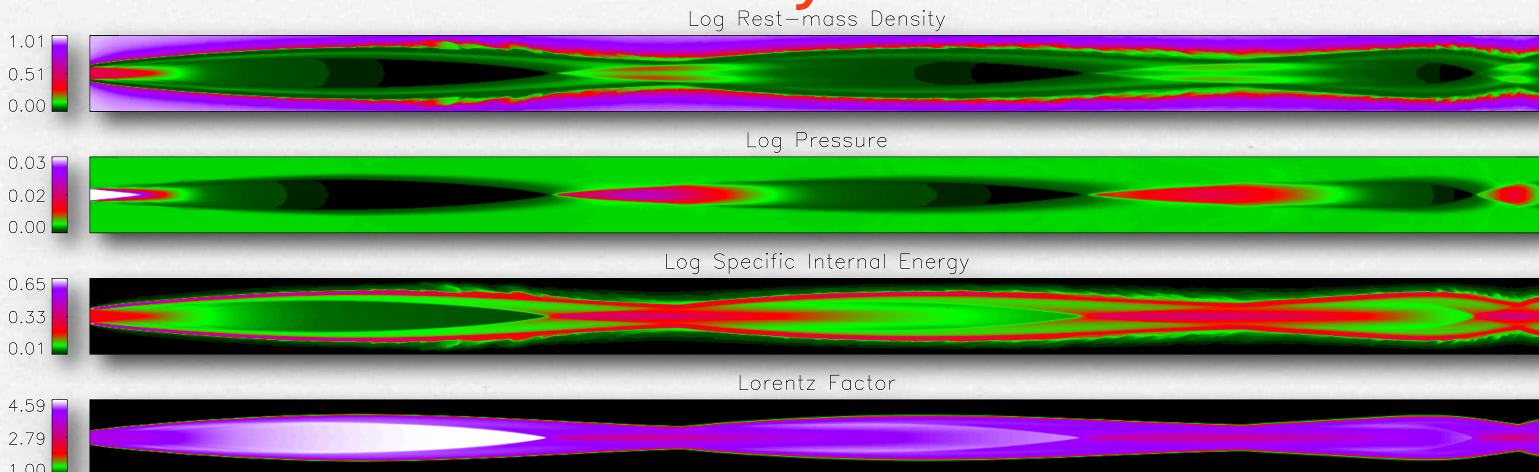


Figure 2. Relativistic hydrodynamical simulation of a jet with an initial over-pressure 10 times larger than the external medium.

Thermal Pressure Evolution

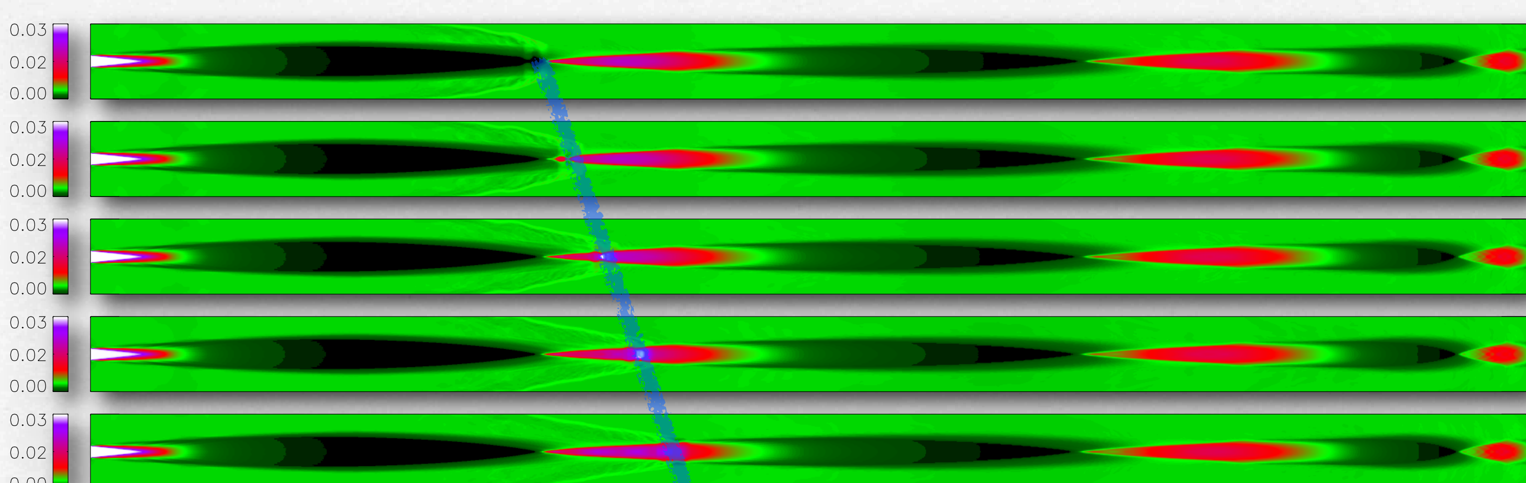
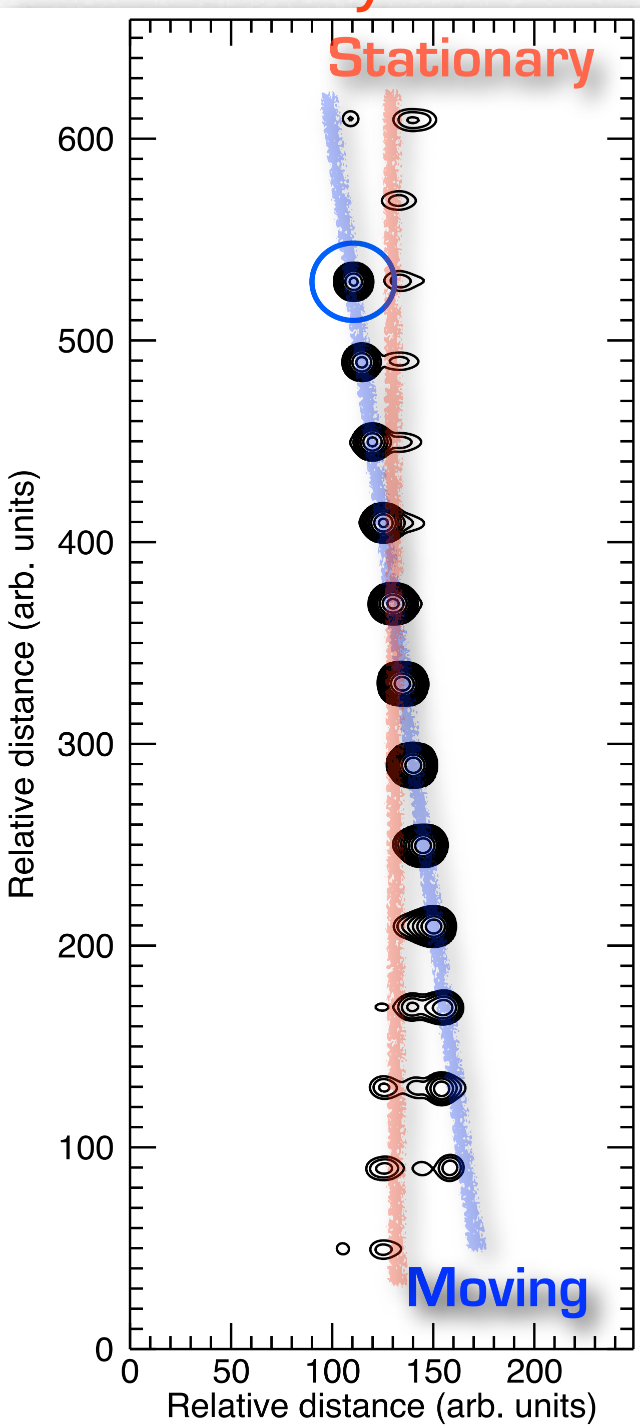


Figure 3. Five snap-shots in the time evolution (from top to bottom) of the jet particle pressure after the introduction of a short increase in the jet inlet pressure by a factor of 8.

Simulation / Observations

Figure 4.

Total Intensity evolution



Total intensity images obtained by computing the synchrotron emission using RHD simulation's results as input.

* Figure 4: a new superluminal component appears in the third epoch due to the interaction between the moving shock and the standing recollimation sock.

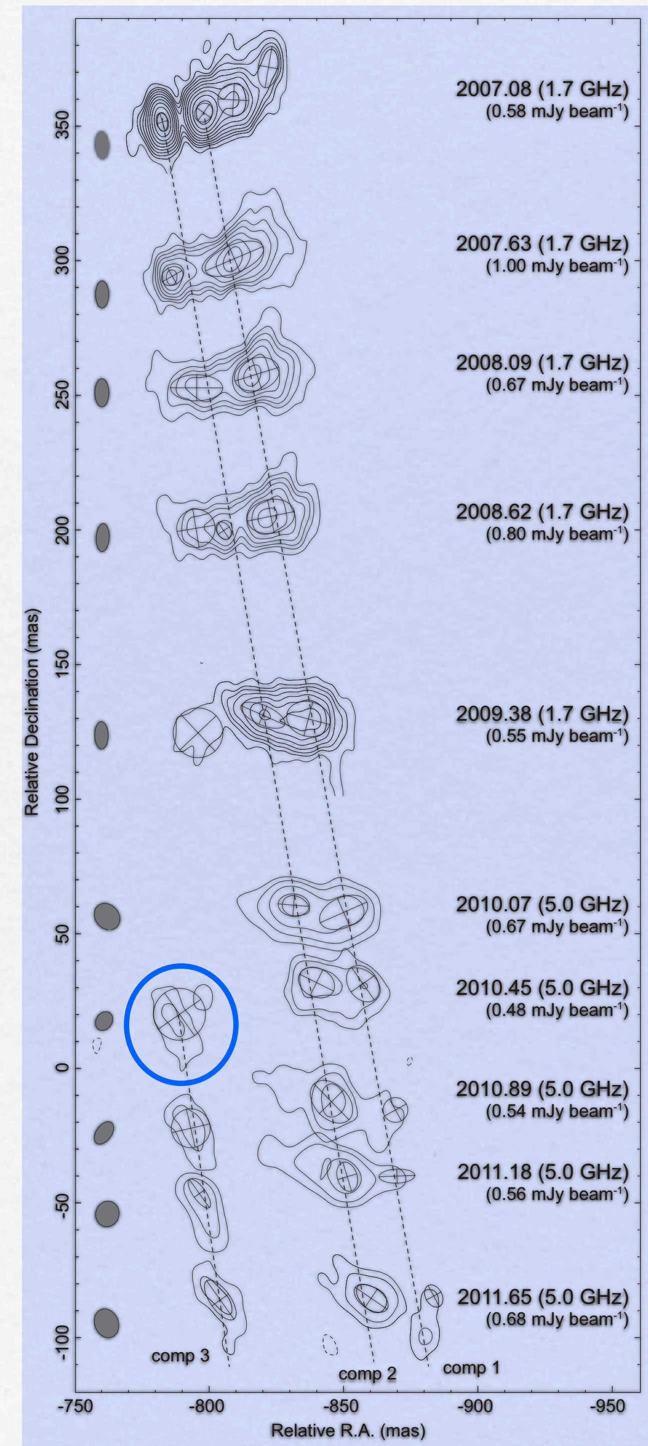
* During the interaction: the particle and magnetic field energy density increase + particle acceleration (radio and X-ray flares observed during 2005 TeV flare ..?)

* the appearance of a new superluminal component (Figure 4) matches with the observed COMP 3 (Figure 1) that appears in a position similar to that observed previously for COMP 2b.

* the quasi-stationary component associated with the recollimation shock is significantly weaker than the moving component.

* the position of the stationary component can shift as a consequence of the passing of the superluminal component (numerical simulations by Gómez et al. 1997).

Figure 1. (Giroletti et al., 2012)



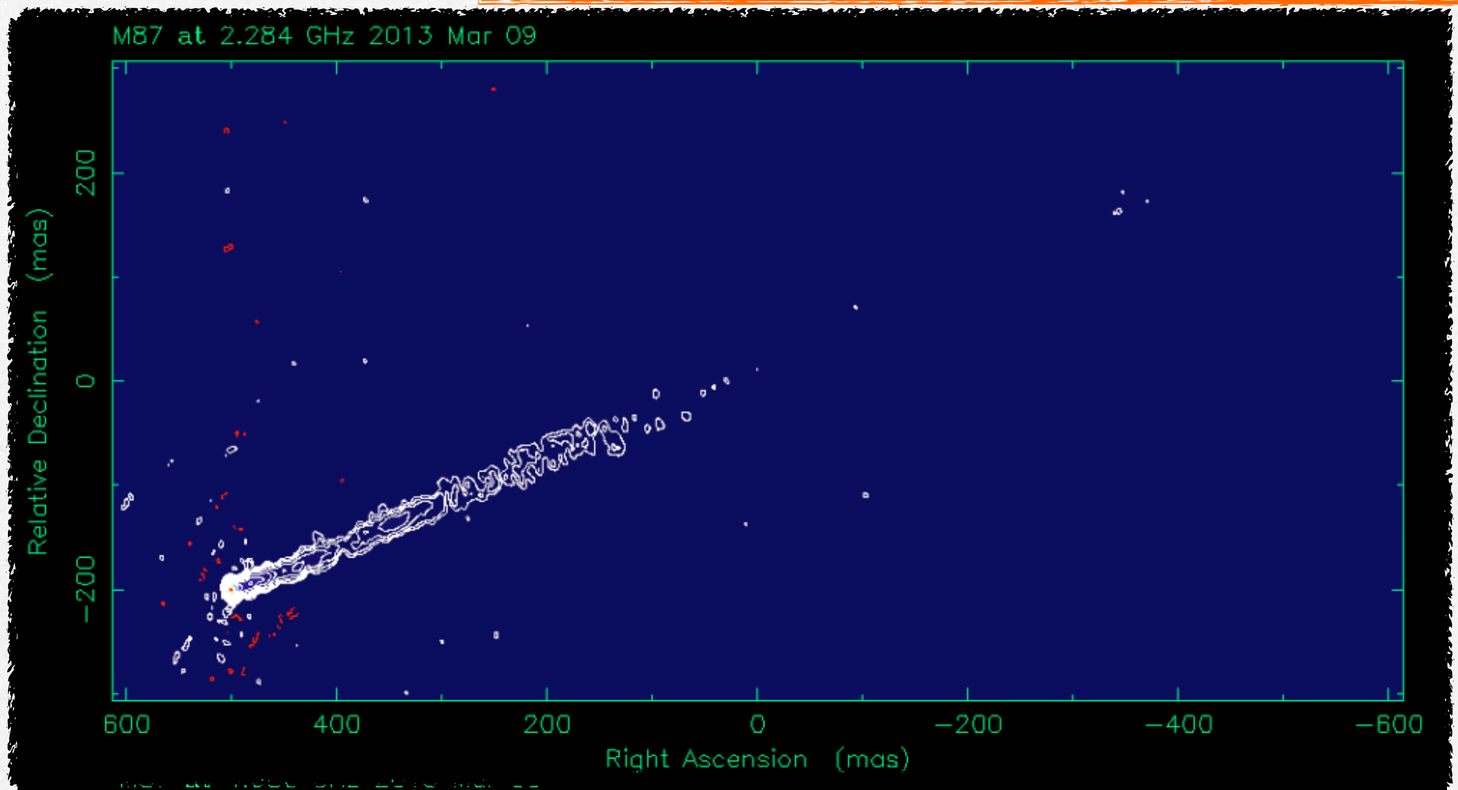
New observations

To test our hypothesis we need new High sensitivity and High resolution observations to study in detail the complex structure in HST-1.

* JVLA polarimeric observations at 15, 22 and 43 GHz in A-conf. (new 2 GHz bandwidth) performed between 28th October 2012 and 22nd December 2012.

* VLBA polarimeric observations at 2.2 and 5 GHz (new recording rate of 2048 Mbps)
The first epoch has been already performed on 9th March 2013.
We have two epochs more that will be performed within this year.

Preliminary Images and Results



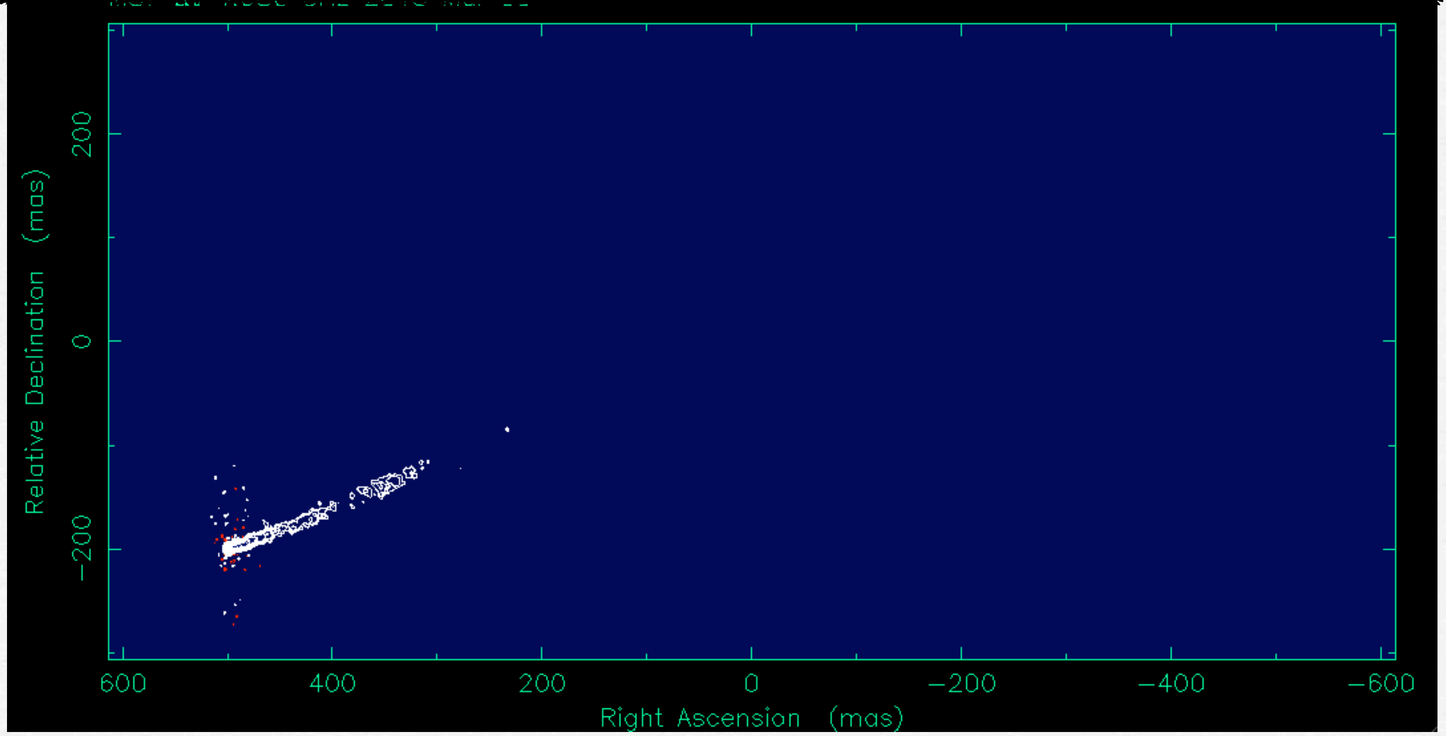
Vlba 2.2 GHz - 09 March 2013

Peak: 1.16 Jy/beam

rms: ~ 200 μJy/beam (1σ)

first contour: 800 μJy/beam

beam: 8.81 X 4.61 mas



Vlba 5 GHz - 09 March 2013

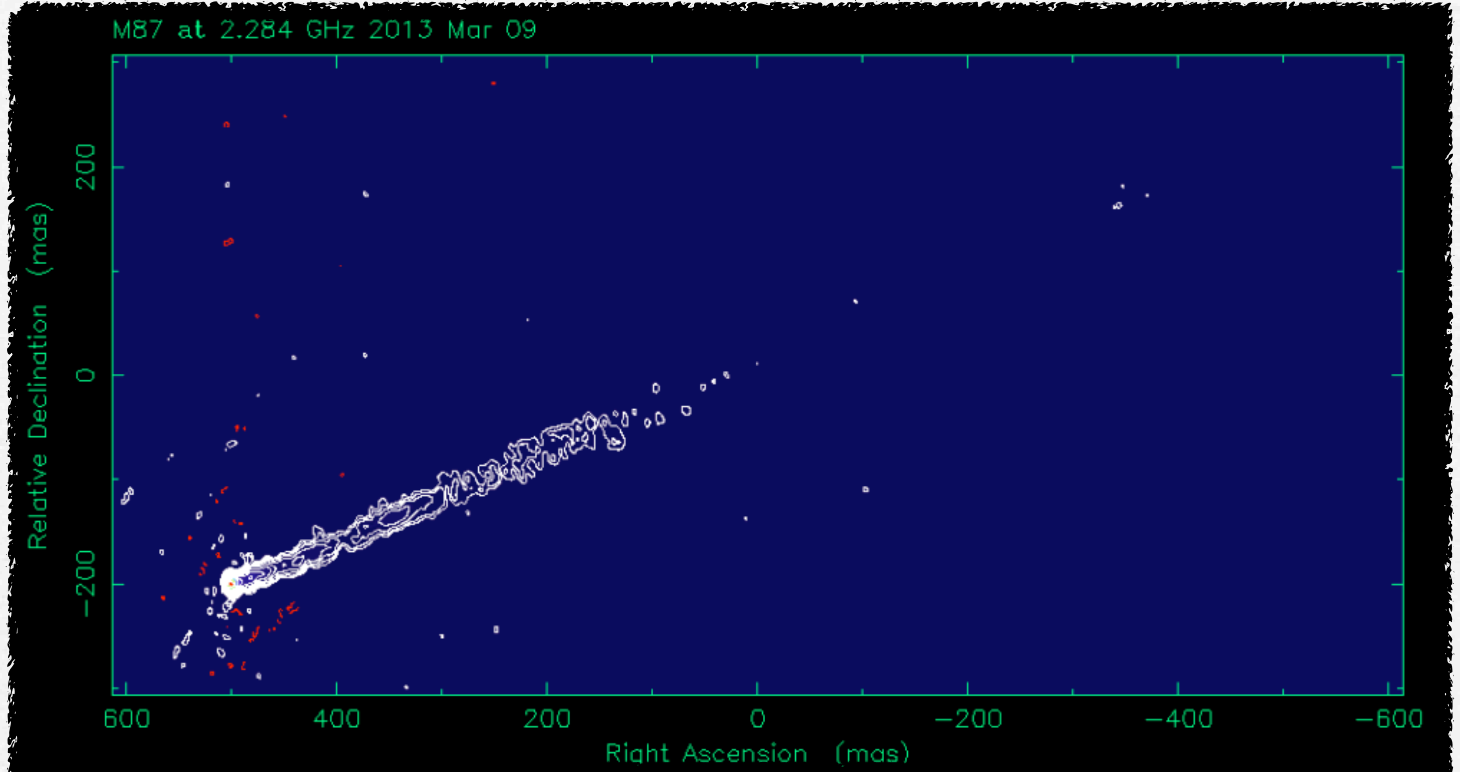
Peak: 1.03 Jy/beam

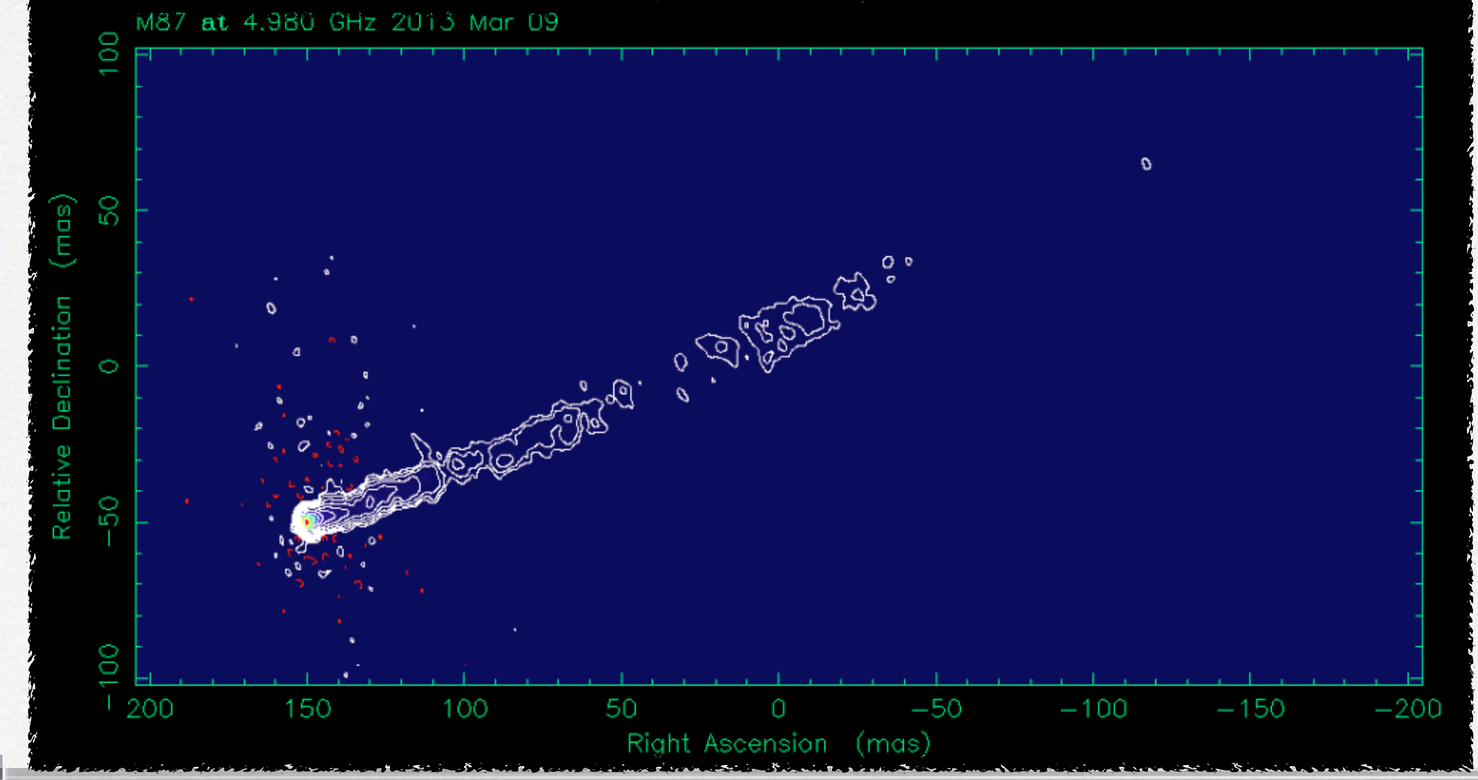
rms: ~ 50 - 150 μJy/beam (1σ)

first contour: 700 μJy/beam

beam: 3.95 X 2.06 mas

Preliminary Images and Results





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HST-1

flux upper limit ~ 500 microJy (5 σ)

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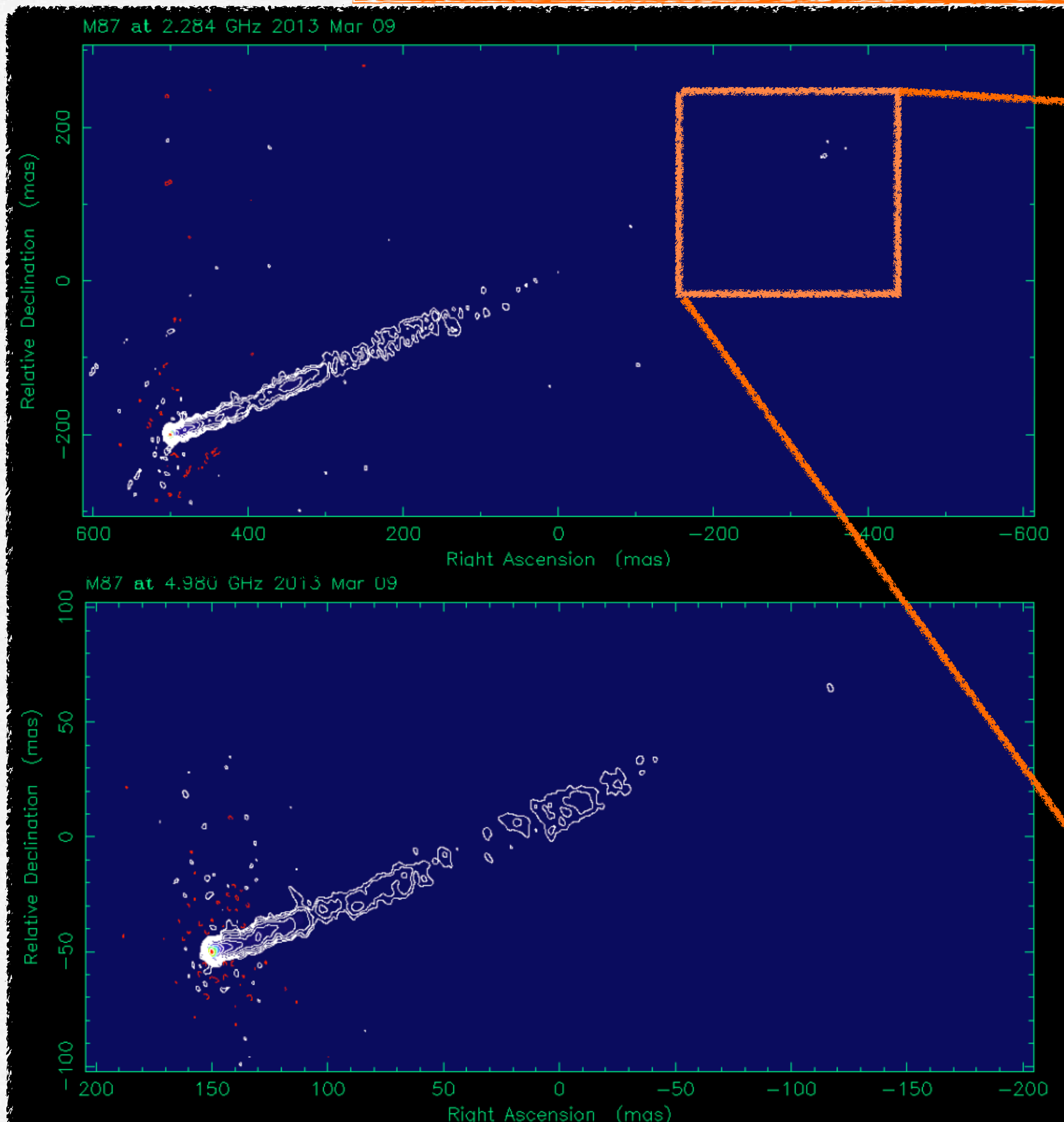
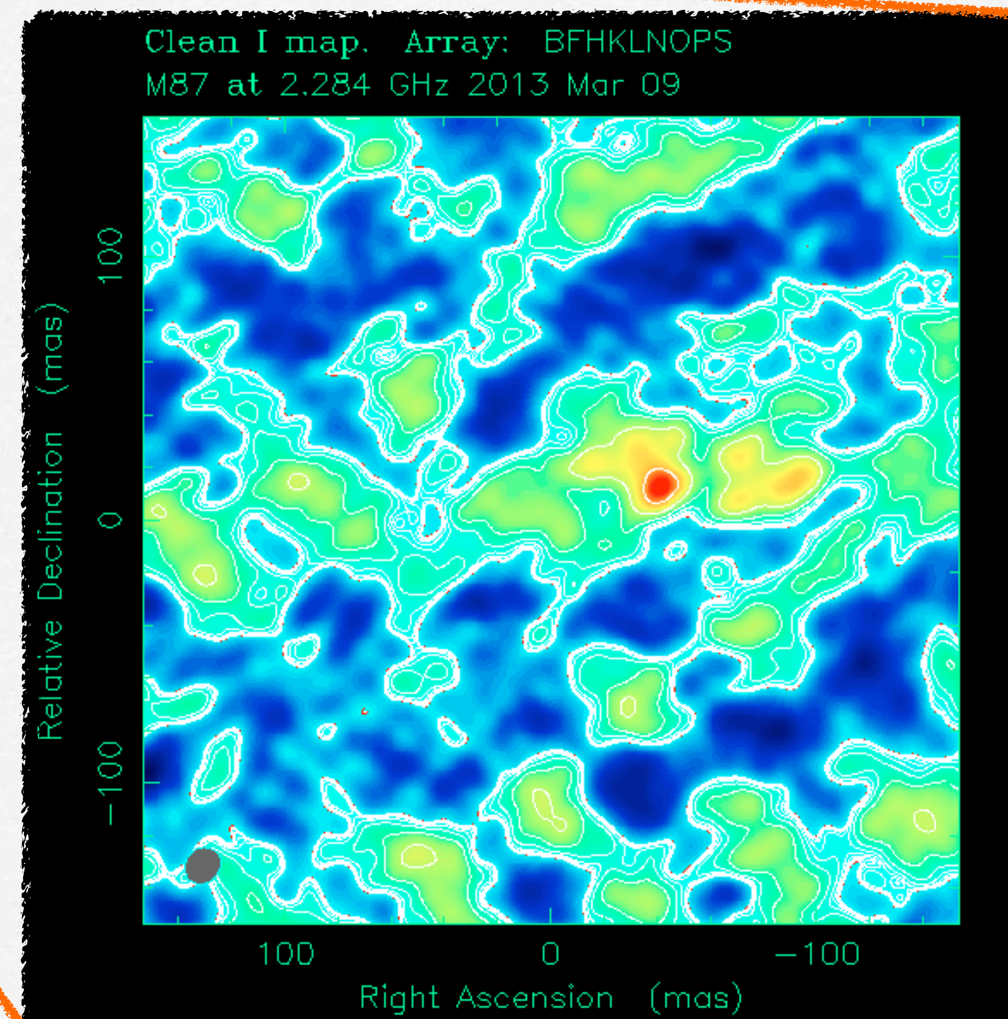


Vlba 2.2 GHz - 09 March 2013



Peak: 1.35 mJy/beam

rms: ~ 200 μJy/beam

beam: 14.7 X 12.9 mas

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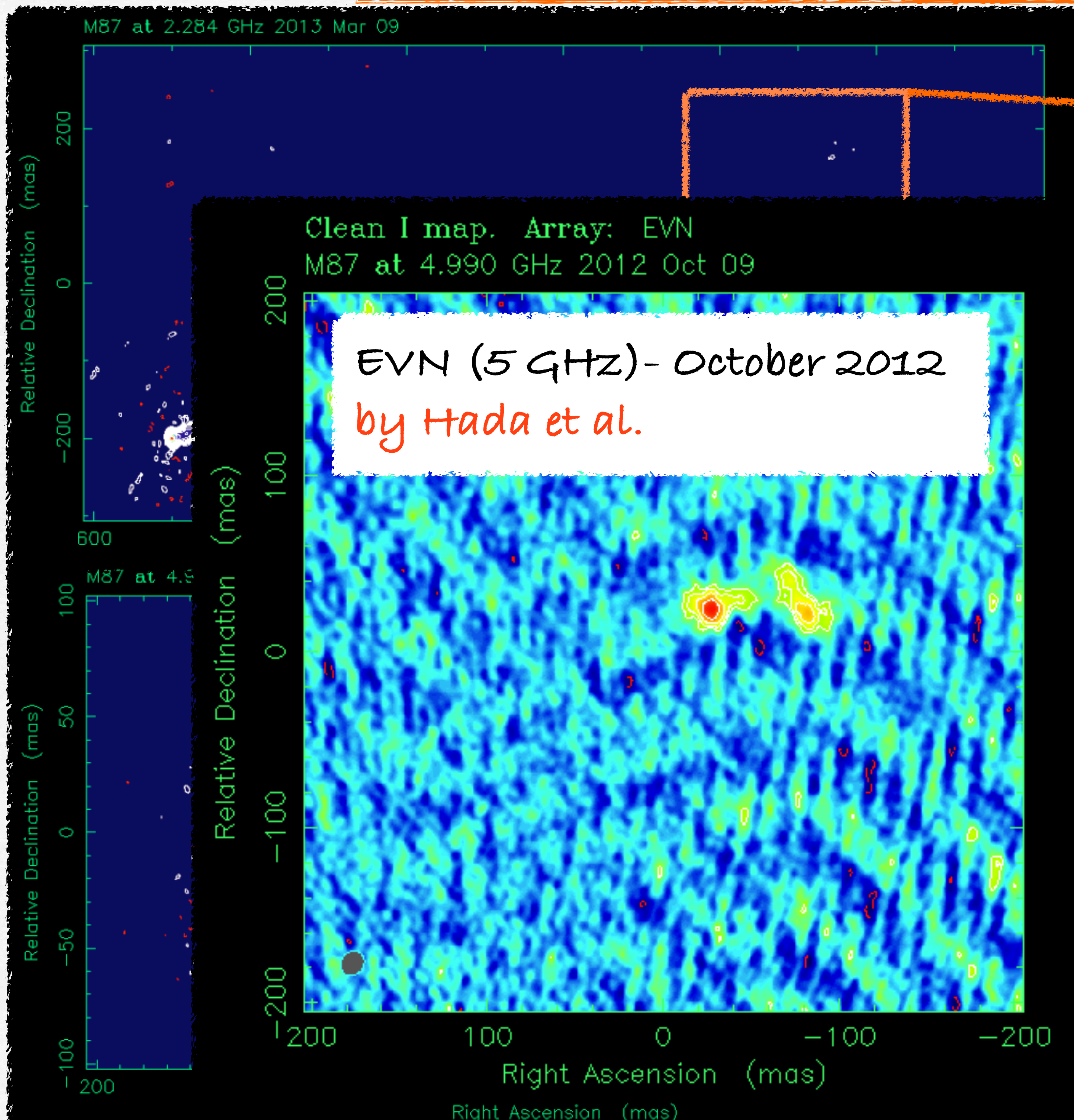
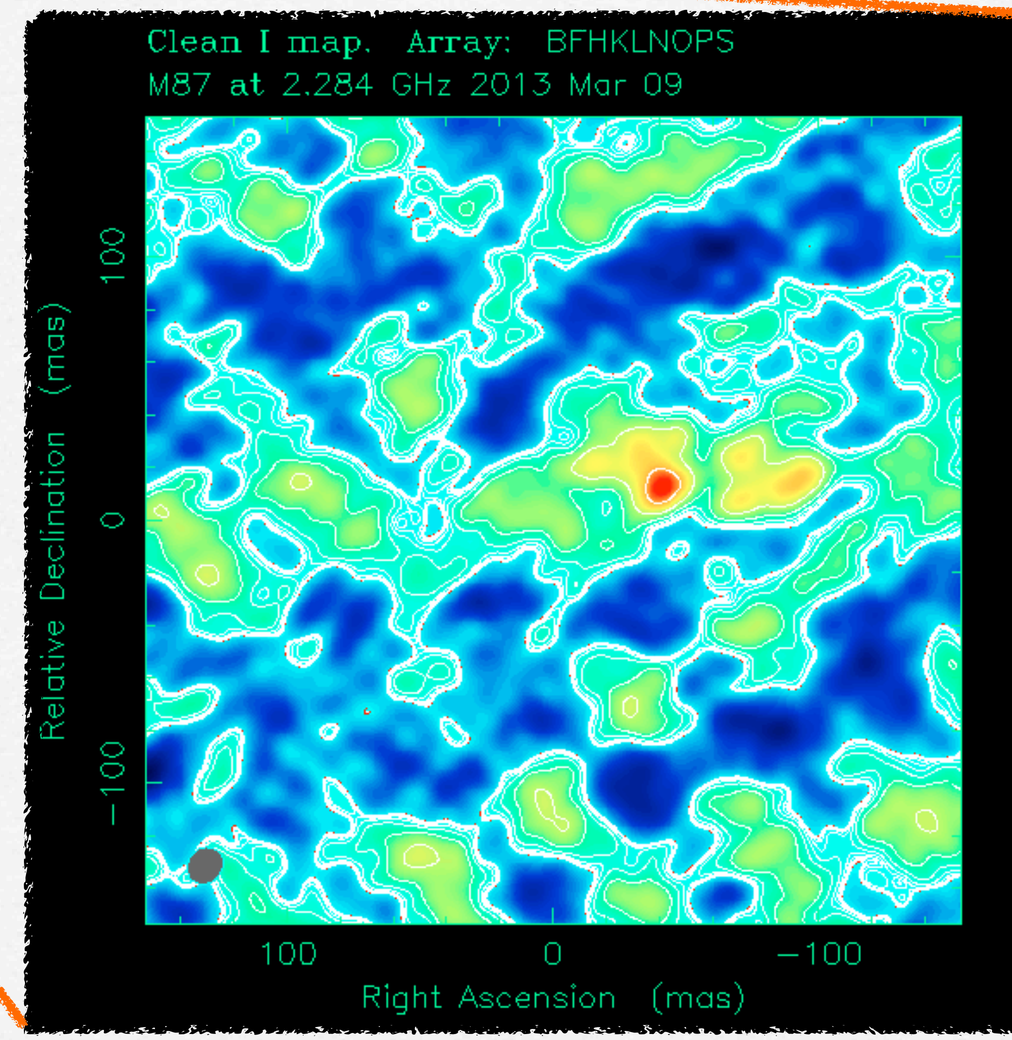
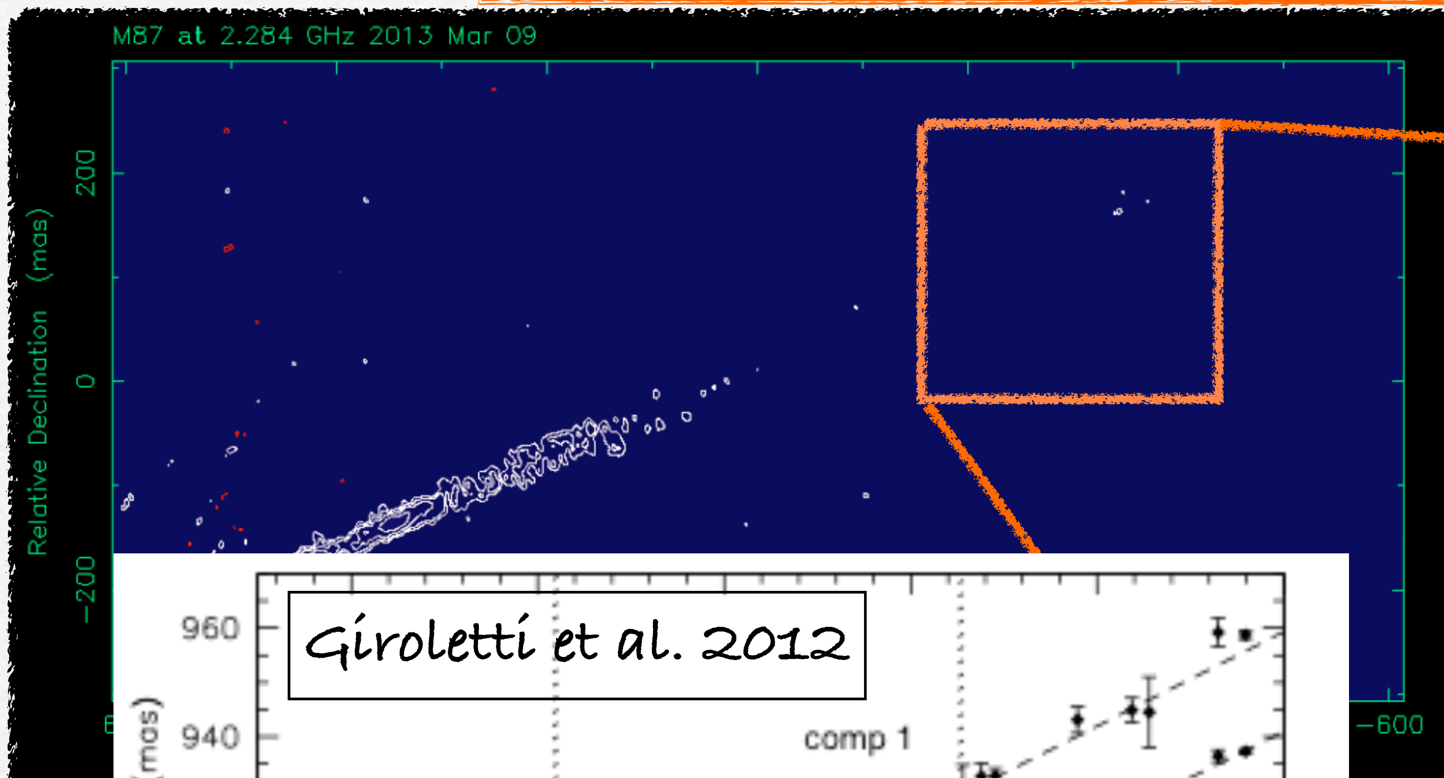


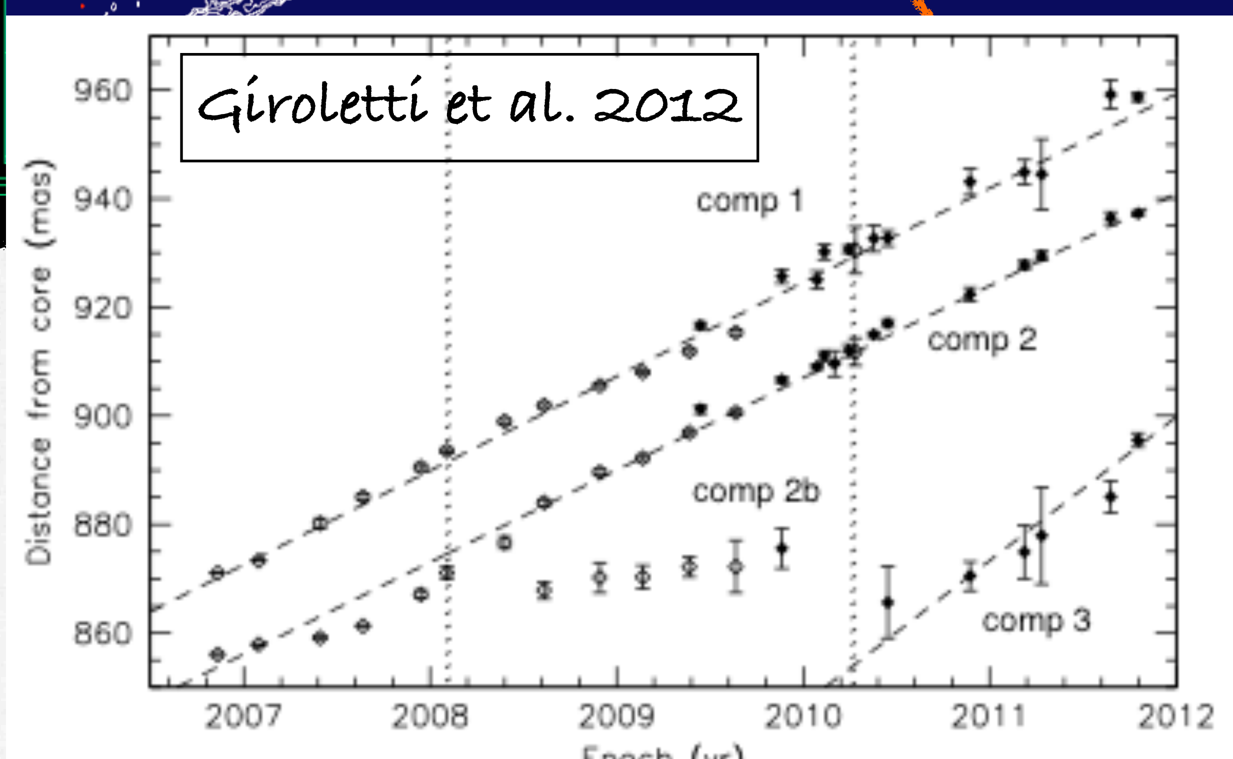
Vlba 2.2 GHz - 09 March 2013



EVN-5GHz	VLBA-2GHz
Peak: 0.96 mJy/beam	Peak: 1.35 mJy/beam
beam: 14.7 X 12.9 mas	beam: 14.7 X 12.9 mas

Preliminary Images and Results





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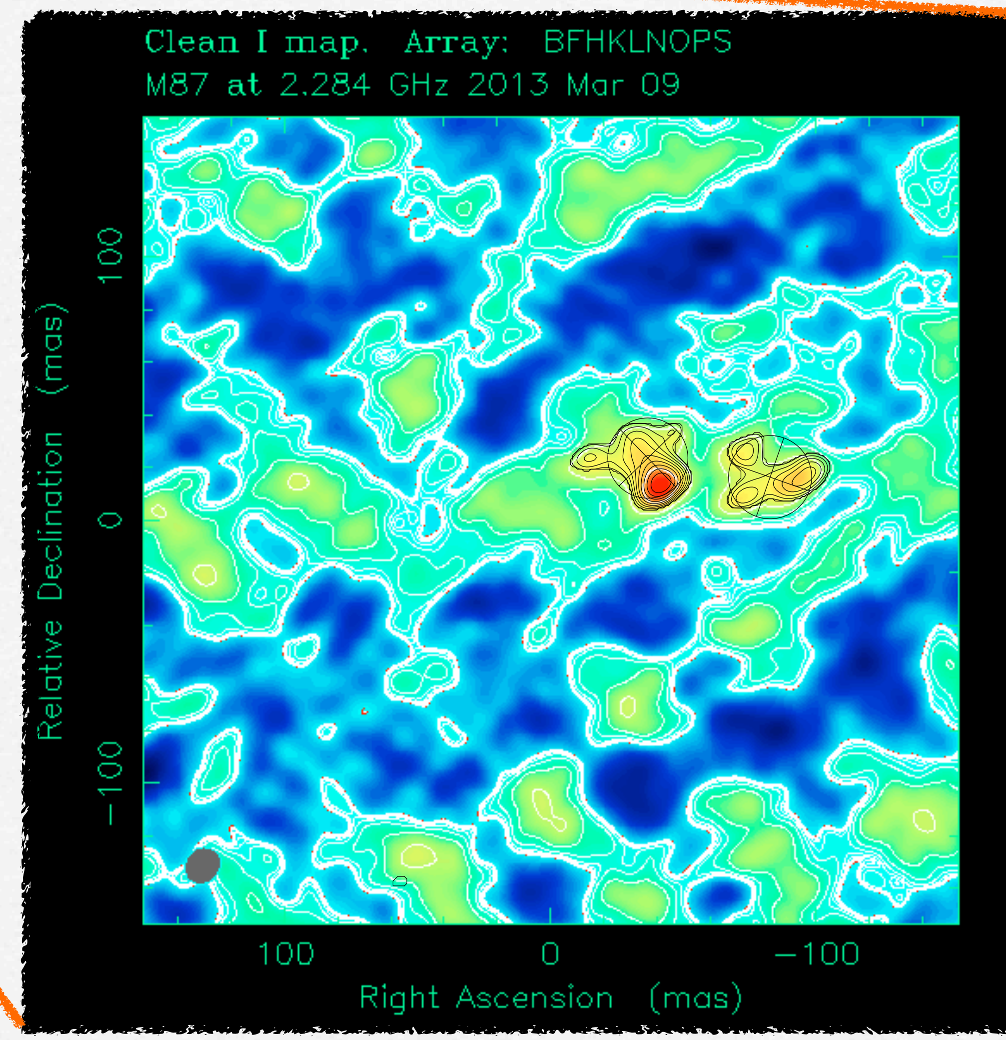
VLBA 2.2 GHz - 09 March 2013



Gaussians poistions

913, 953 mas from the core

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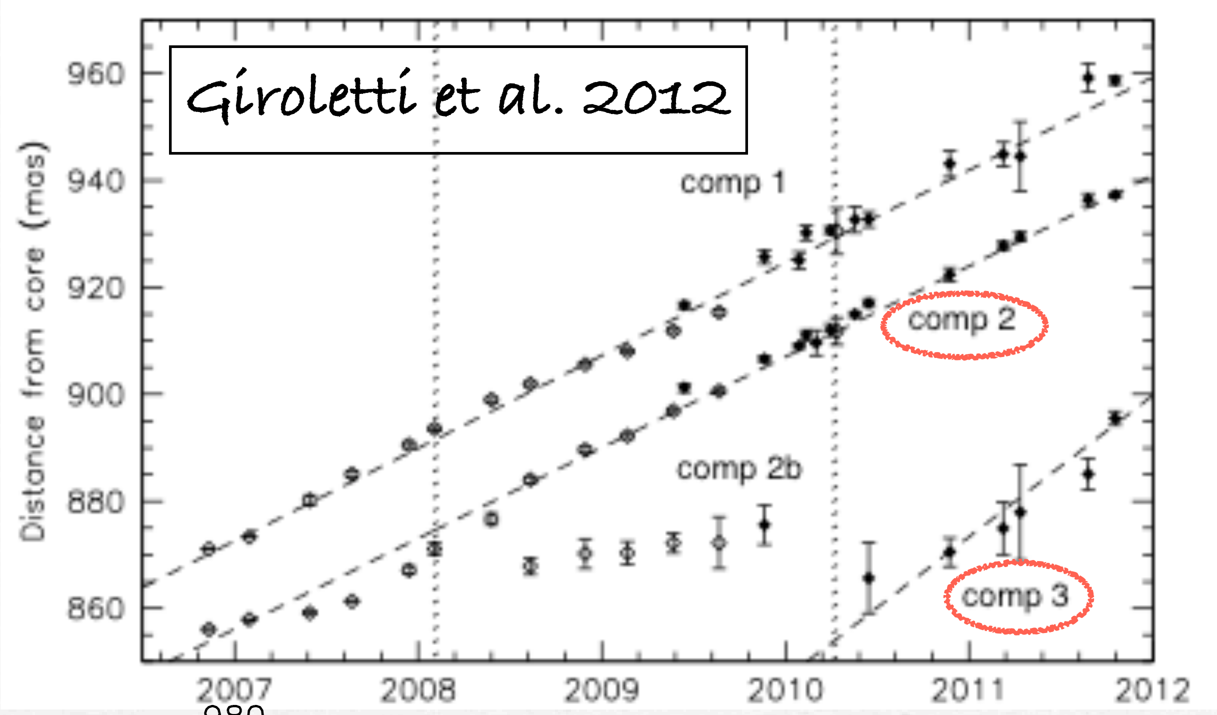
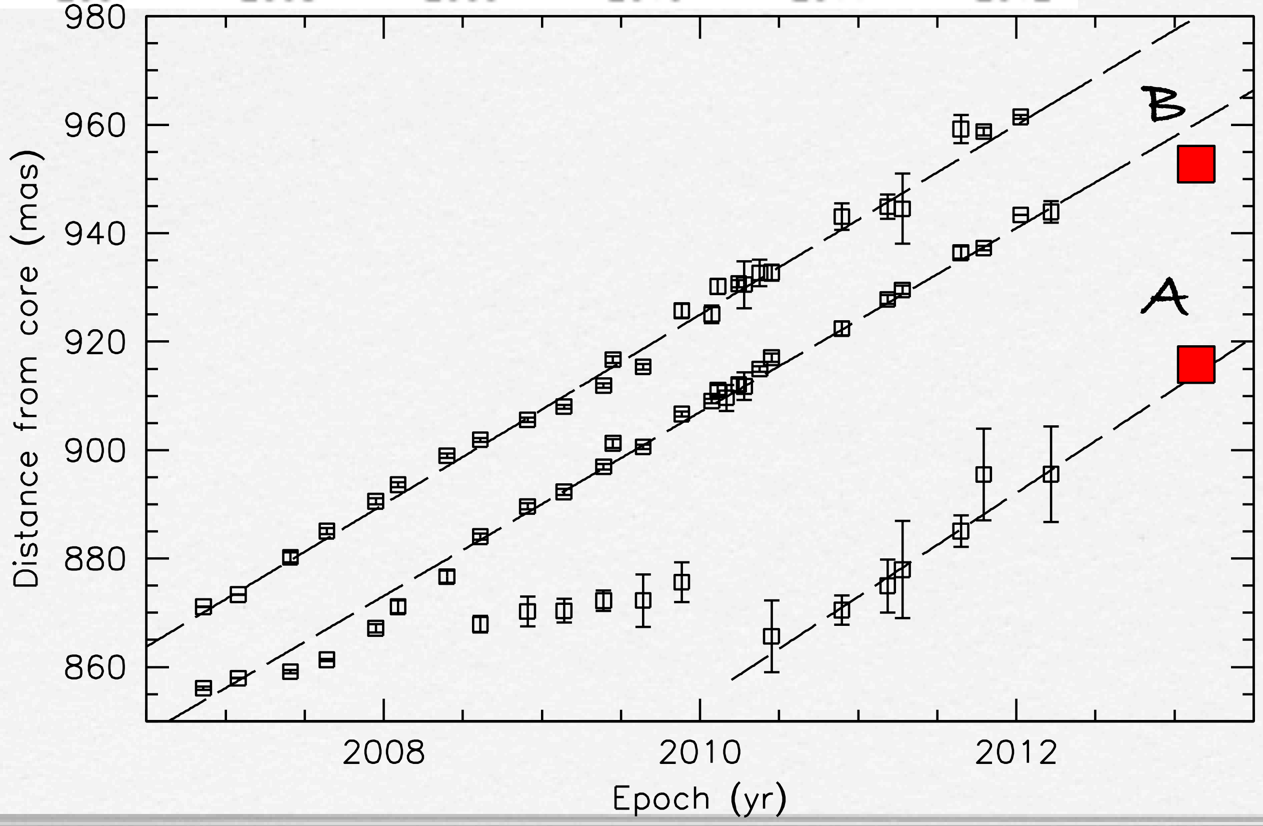
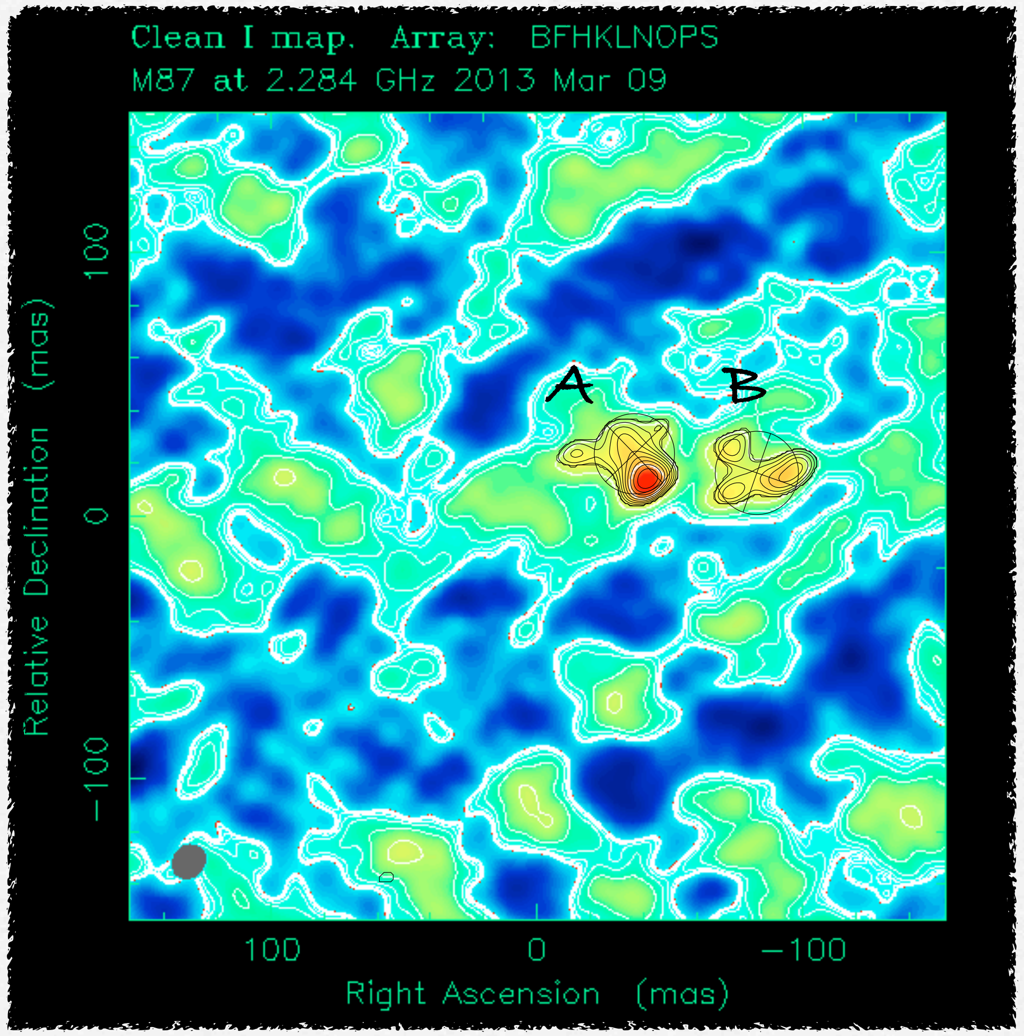




VLBA 2.2 GHz - 09 March 2013



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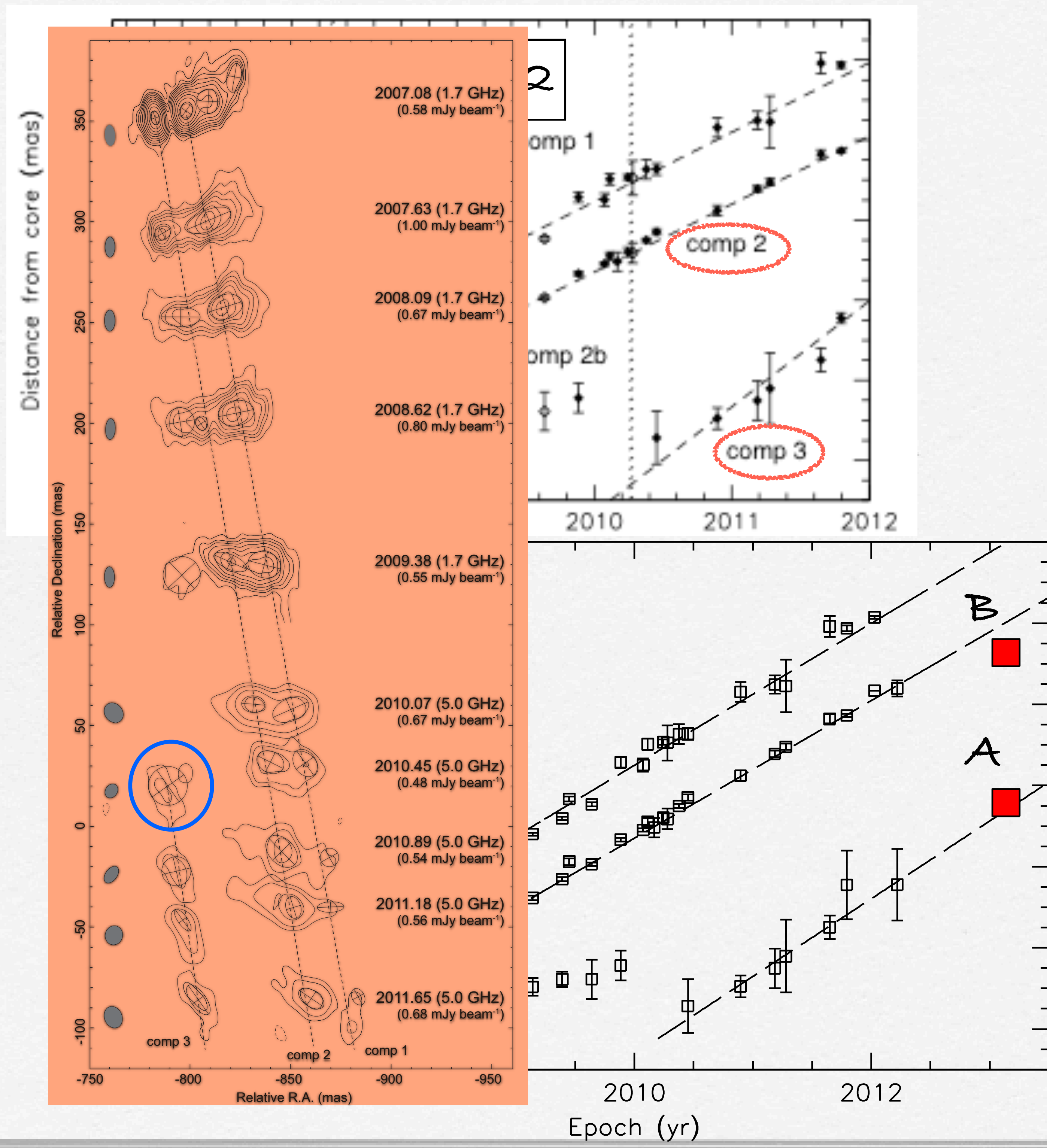
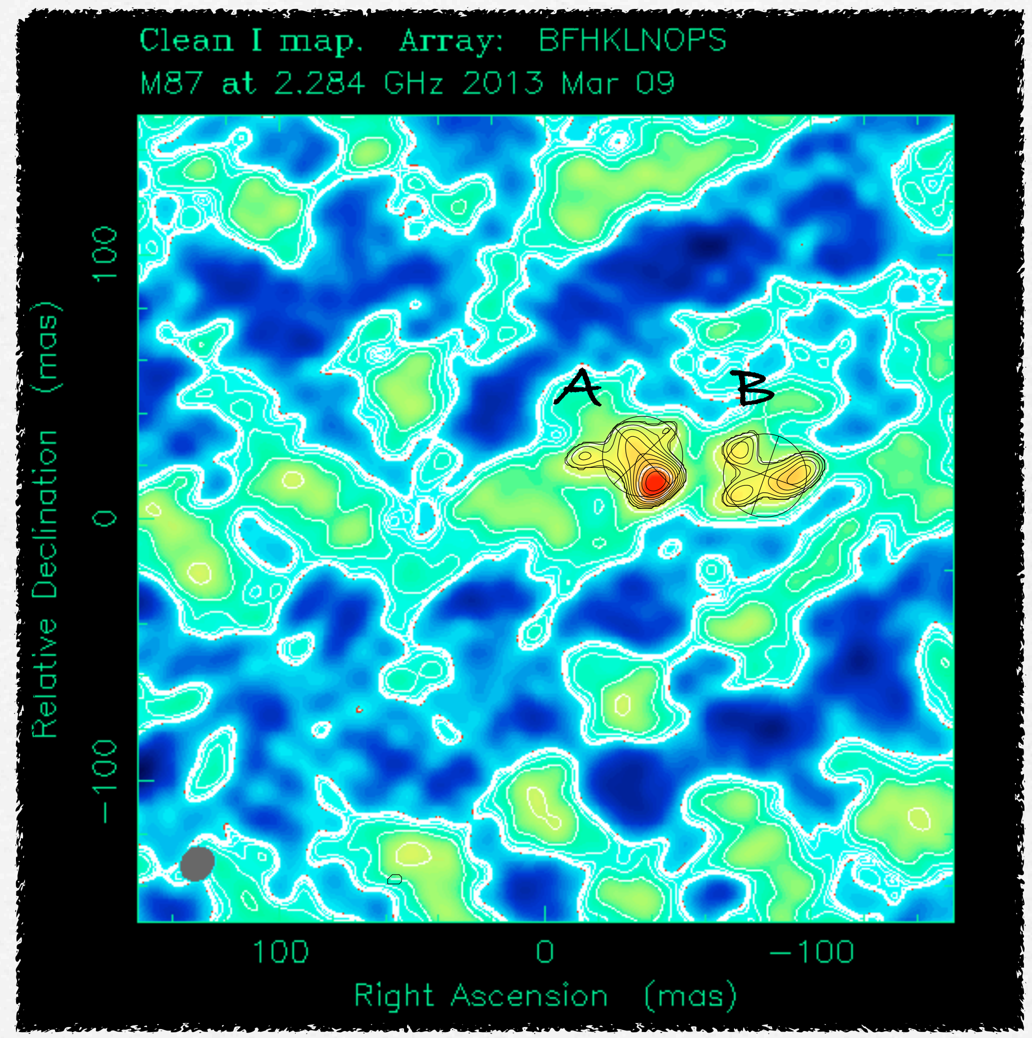


Vlba 2.2 GHz - 09 March 2013



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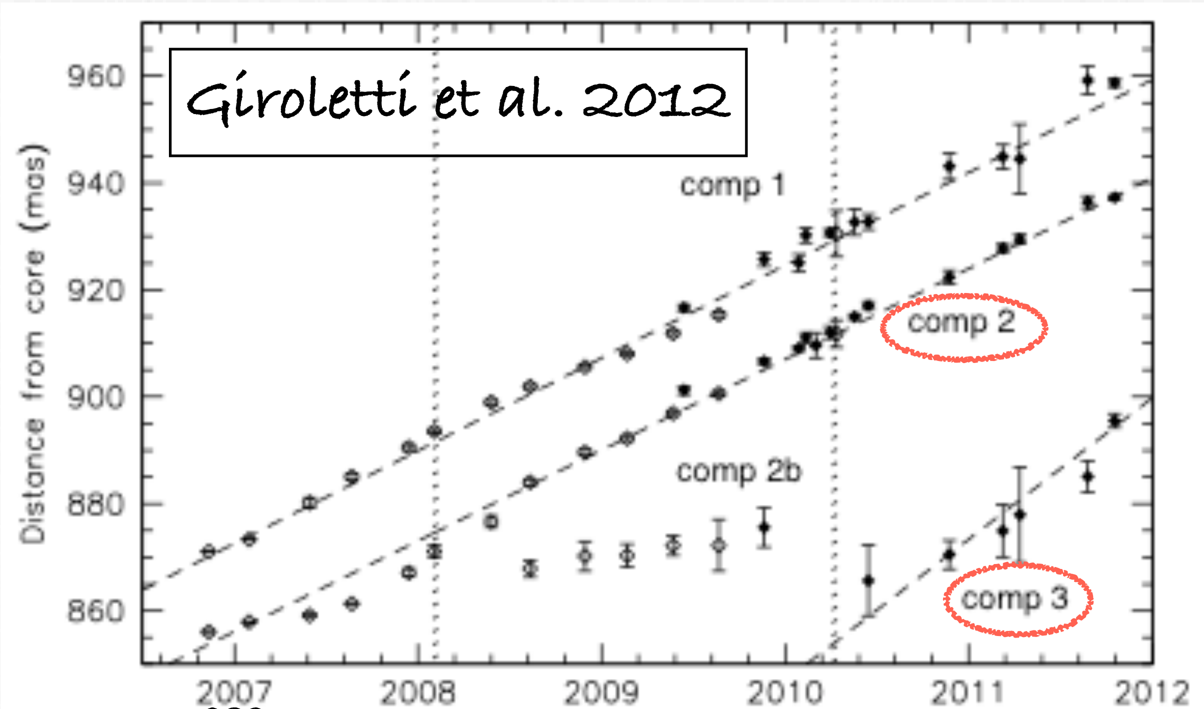

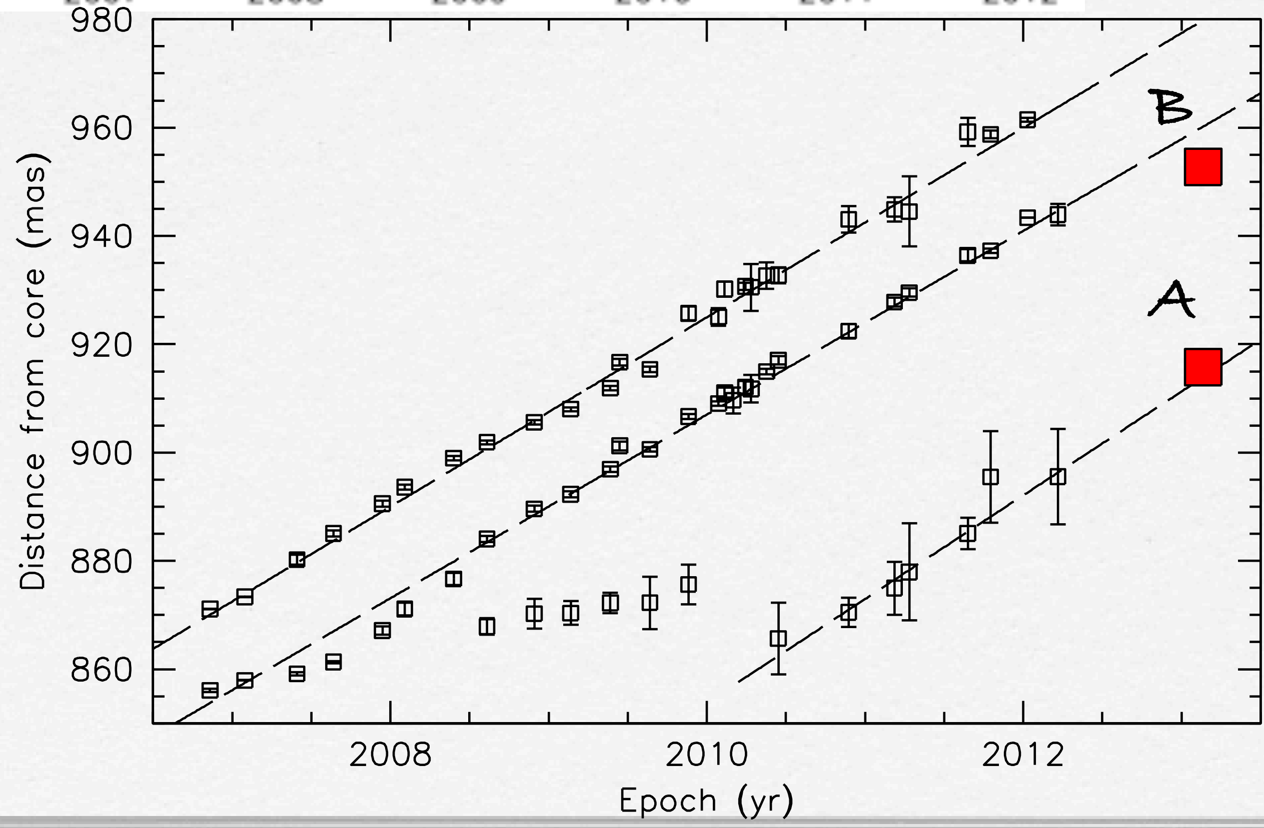

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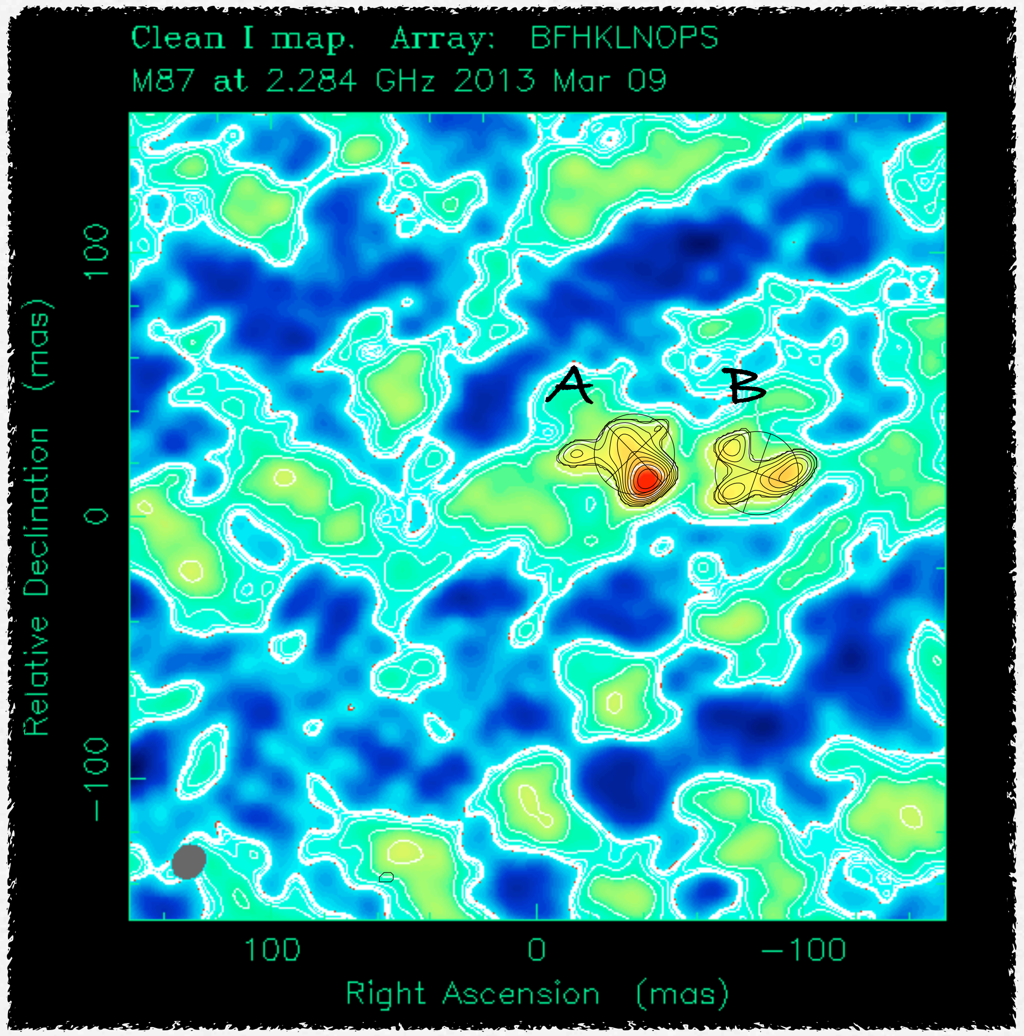


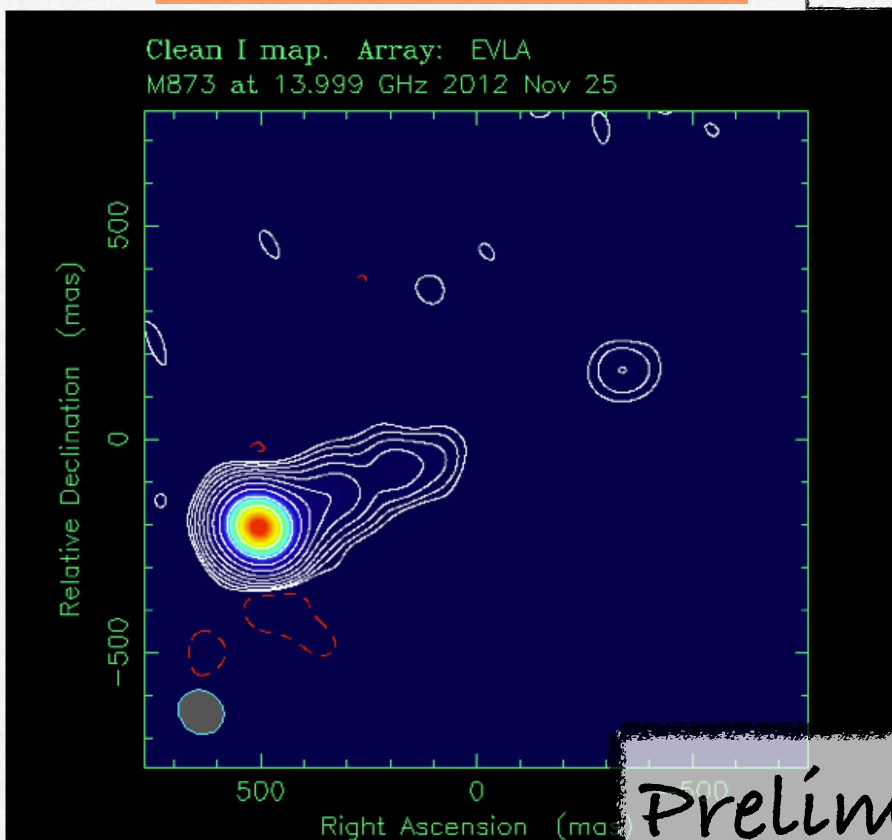
Gaussians poistions

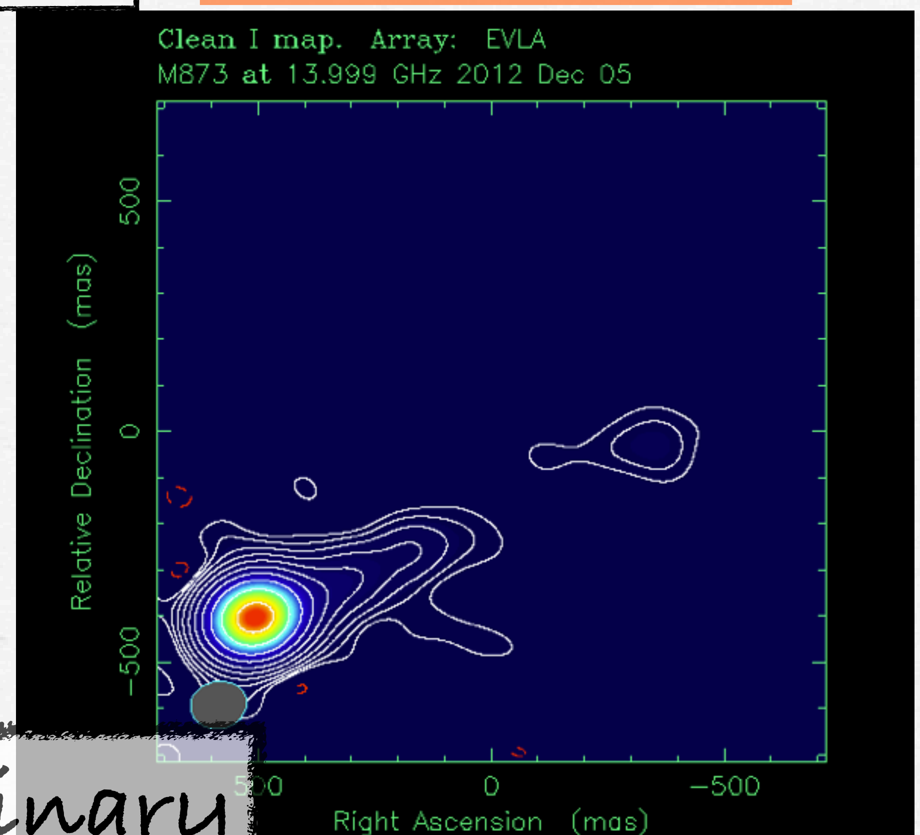
913, 953 mas from the core

Preliminary Images and Results

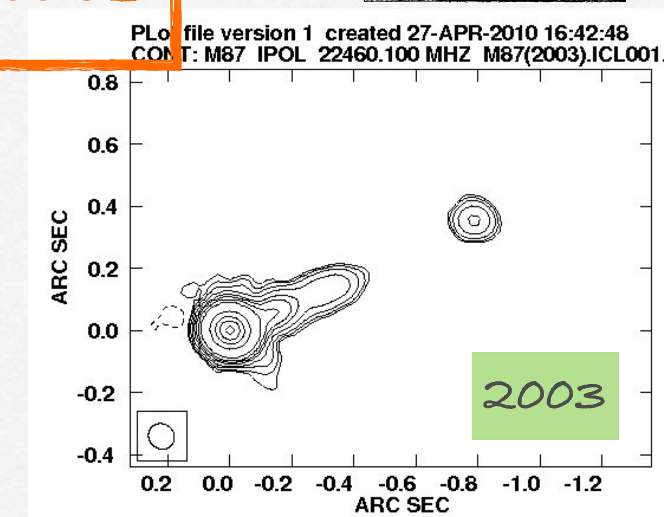
15 GHz

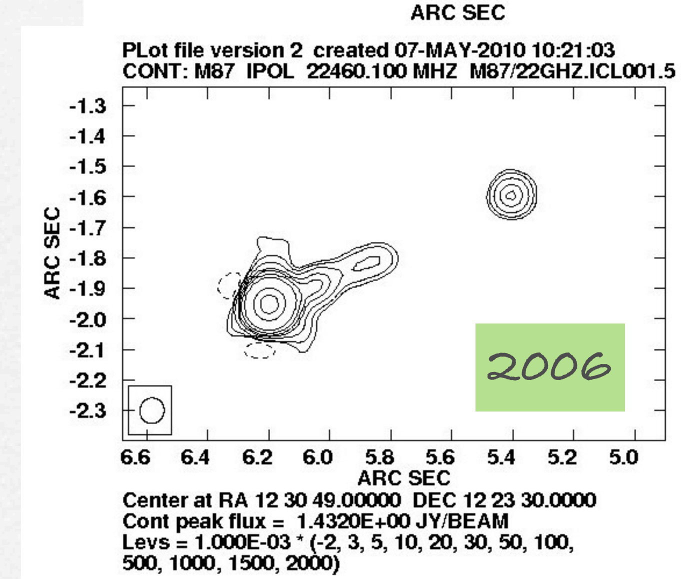
25 November 2012 | 15 GHz | 5 December 2012





Preliminary





Date	HST-1 (Tot.)
25/11/2012	~ 9 mJy
05/10/2012	~ 10,7 mJy

Date	Core (Peak) Jy/beam	HST-1 (Peak) mJy/beam	HST-1 (Tot.) mJy
02/05/1994	(2,28±0,07)	≤ 1,7	
28/03/1998	(1,94±0,06)	≤ 1,0	
24/08/2003	(2,36±0,07)	(28,1±1,2)	(26,5±1,1)
15/02/2006	(1,99±0,06)	(49,7±1,6)	(52,2±1,7)

.....work in progress

- to study the polarized emission in Vlba data
- to finish to analyze JVLA data
- to study in detail the kinematics, the flux density evolution and the polarization structure in HST-1 region

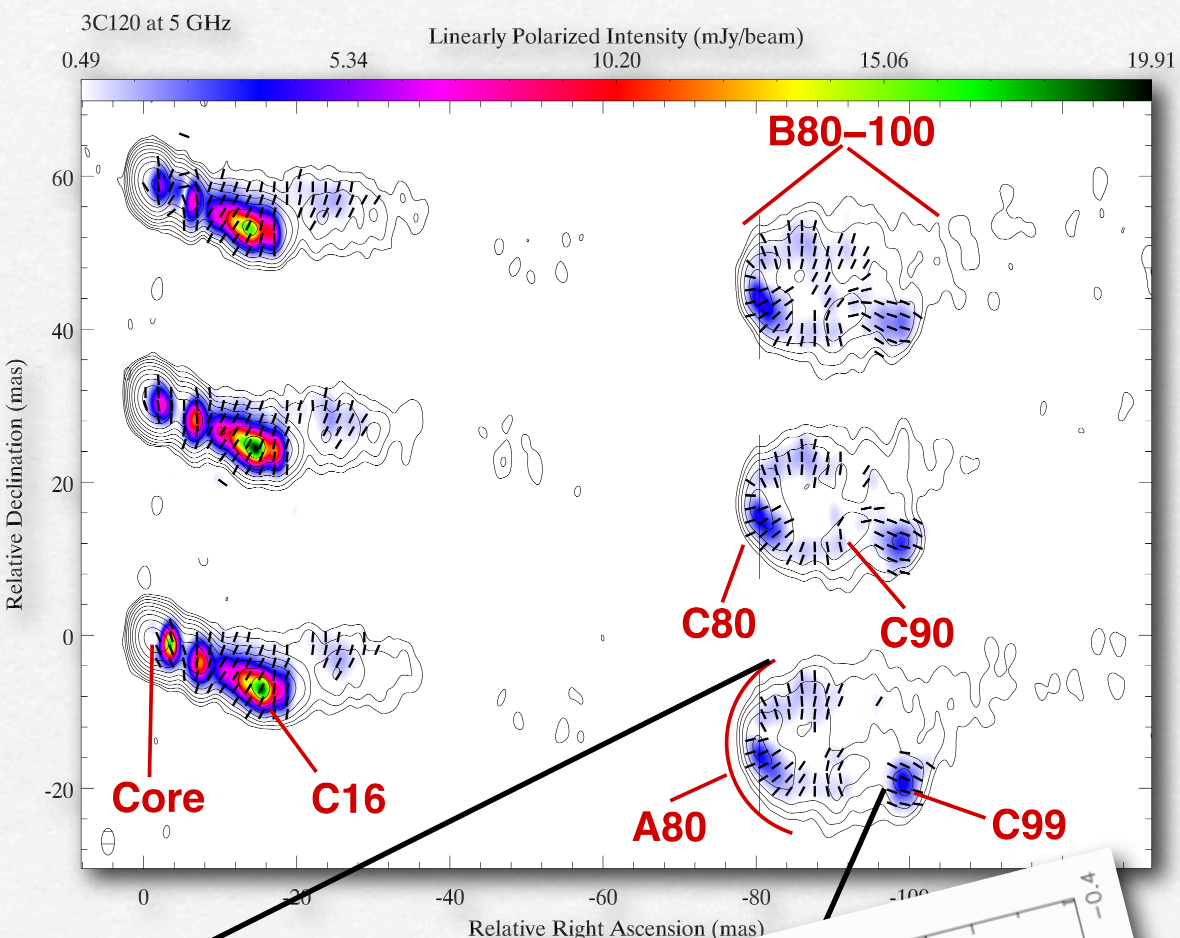
Summary

- ✳ Observational evidence that TeV flares may occur in HST-1 region;
- ✳ Previous observations in agreement with the hypothesis of a recollimation shock in HST-1 region;
- ✳ Results from our simulations agree with what we observe in VLBA (1.7 GHz) and EVN (5 GHz) data in a monitoring of M87 and HST-1 between November 2006 and October 2011 (Giroletti et al. 2012);
- ✳ Our new VLBA observations show a decrease in the flux of the superluminal components previously observed in HST-1, but no new ejections;

- We hope that HST-1 will increase again its flux, ejecting also a new component and we hope to detected it with our New VLBA observations that will be performed during next year
- We expect to detect polarization in HST-1 to test our hypothesis of the existence of a recollimation shock in the HST-1 region.

THANKS !

In M87, a polarization and stationary emission similar to that founded in 3C120 (Roca-Sogorb et al., 20120; Gómez et al., 2011; Agudo I., Gómez J. L., Casadio C., et al., 2012).... ?

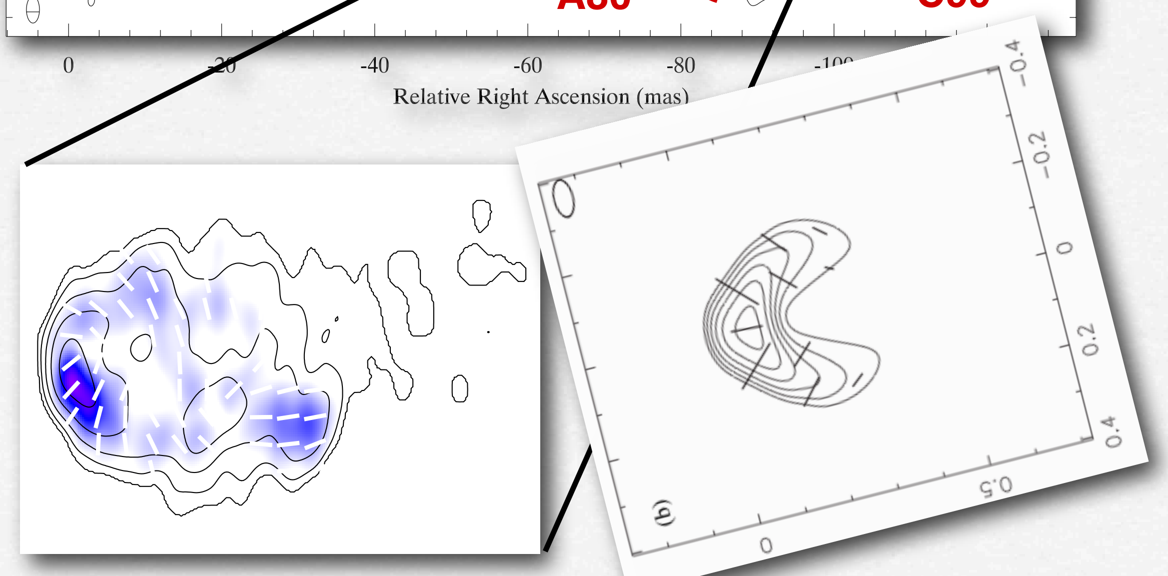


- C80, stationary emission,
- beyond C80, superluminal components,
- C80 has a peculiar structure in arc,
- EVPA suggest a magnetic field compressed in a direction that follows the structure in arc,

} Possible recollimation shock

+

Good fit with numerical simulations based on the synchrotron emission from a conical shock as described by Cawthorne 2006.



✦ **C80, well described by numerical simulation of a conical recollimation shock with a cone angle of 10 degrees, a viewing angle of 16 degrees, and the upstream Lorentz factor** $\gamma_u = 8.4$.