

# Relic jet activity in "Hanny's Voorwerp" revealed by the LOFAR Two metre Sky Survey

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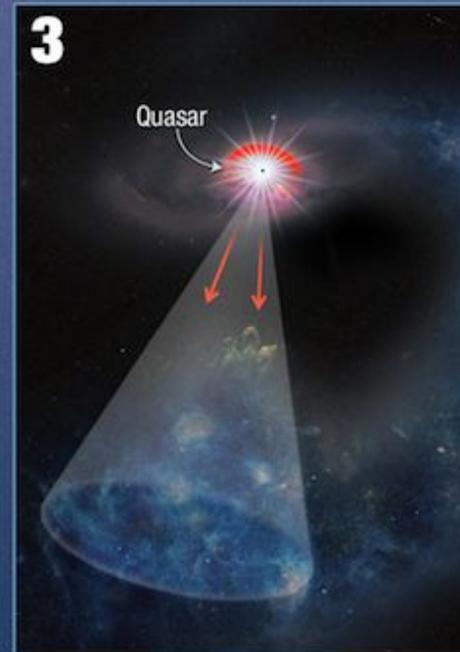
## Hanny's Voorwerp\* — A Space Oddity



1 Spiral galaxy IC 2497 gravitationally interacts with a bypassing galaxy.



2 A large tidal tail of gas is pulled out of the spiral galaxy.



3 Engorged with gas, a black hole at the center of IC 2497 "turns on" as a quasar and emits a powerful cone of light, which ionizes a portion of the tidal tail, creating Hanny's Voorwerp.



4 Gas streaming out from the galaxy's center impacts the tidal tail and triggers star formation.

\*Hanny's Object

WSRT (Józsa + 09)

Beam=22-38":

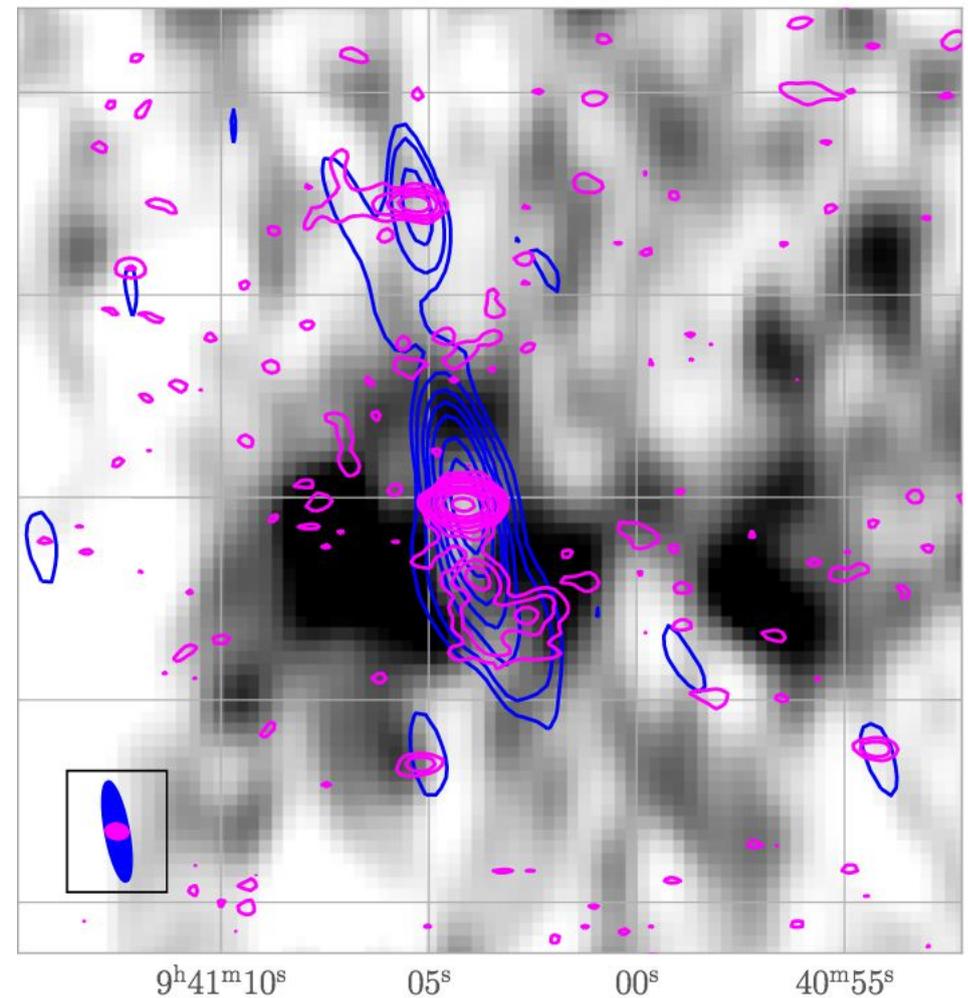
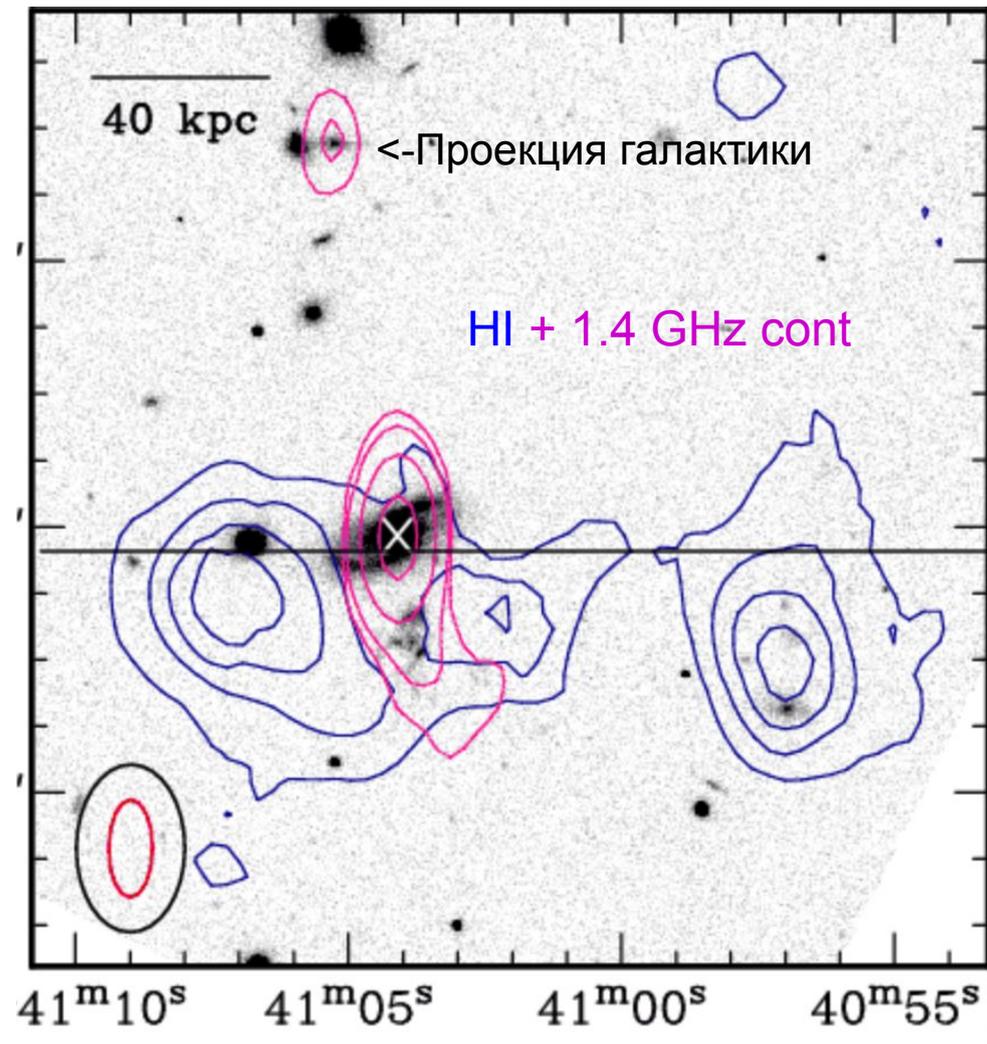
*...radio continuum emission possibly originates from the interaction between this jet and the large cloud complex...*

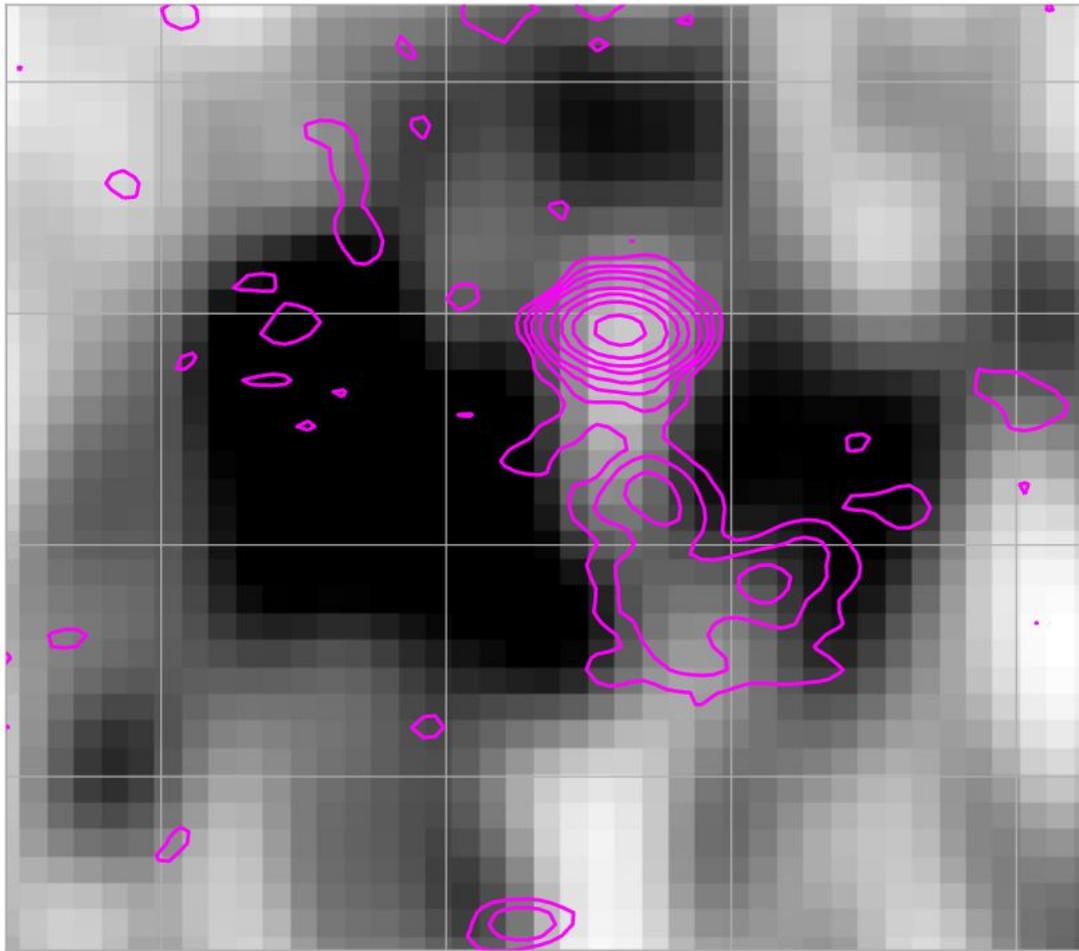
the LOFAR Two-metre SkySurvey (LoTSS)

(DR2; [Shimwell et al. 2022](#)) reaches a median 150 MHz sensitivity of  $84 \mu\text{Jy beam}^{-1}$  over  $5700 \text{ deg}^2$ , detects more than 4.3 million 150 MHz sources, and benefits from a range of further improvements

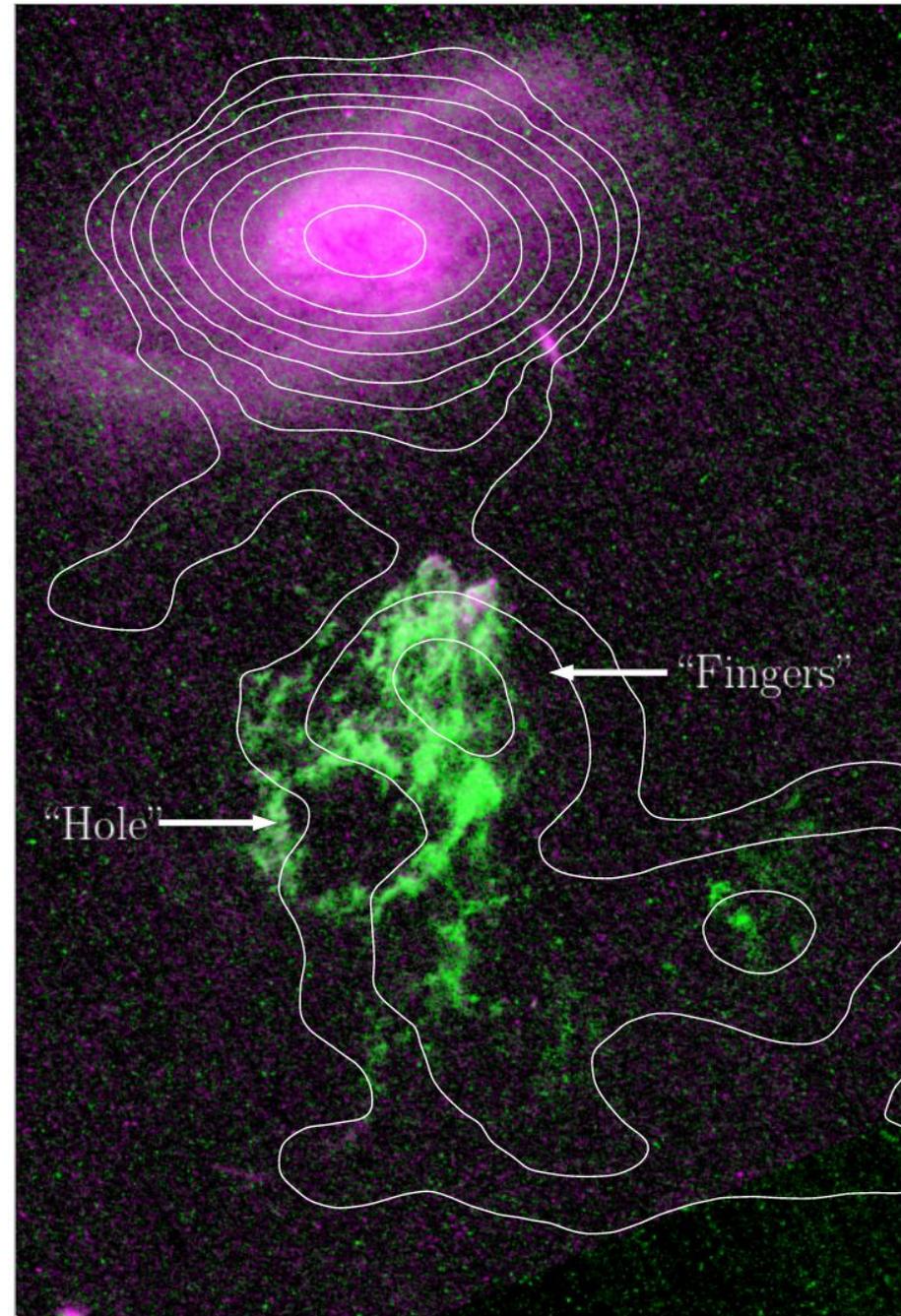
Beam  $\sim 8''$  @ 150 MHz

WSRT (blue +HI in gray) + LOFAR (magenta)

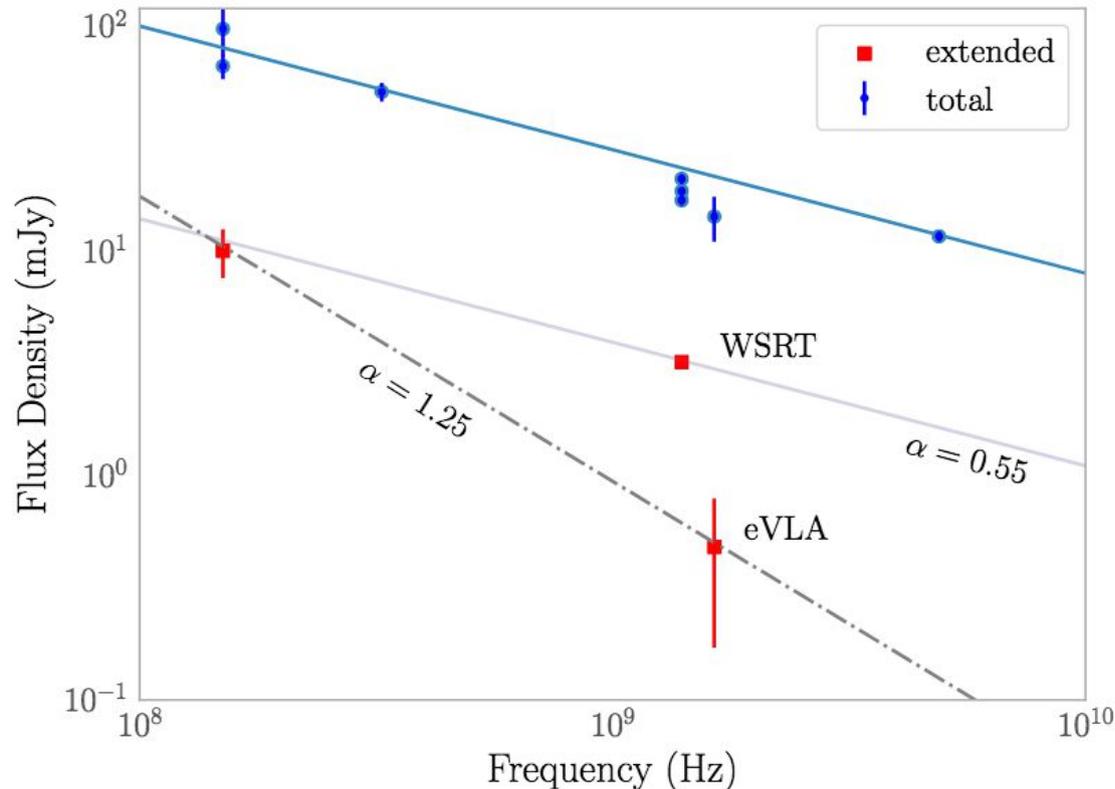




*it is clear that the clearly-resolved structure emanating from the nucleus of IC2497 coincides with a minimum in the surrounding  $10^9 M$  reservoir of HI gas*



Оценка возраста радиоструктуры ( $a=0.5 \rightarrow 1.0$ ) –  $10^8$  лет  
Что сильно старше, чем выключение рентгена ( $\sim 10^5$  лет)



**Figure 4.** Radio frequency spectra of HV, including values for the total (blue circles) and extended components (red squares), as detailed in Table 1. The solid blue line indicates a power-law spectrum with spectral index  $\alpha = -0.55$ , while the dotted and dot-dashed lines indicate the spectral index obtained using the 150 MHz data alongside the WSRT 1.4 GHz or eVLA 1.64 GHz flux densities, which are formally inconsistent as discussed in the text.

Протяженные радиоджеты в спиральных галактиках – само по себе явление редкое (см. Предыдущие VOLGA...)

В случае же HV – надо в существующие модели вводить радиоджет, в статье обсуждаются разные альтернативы, включая возможную случайную проекцию джета на “дыру” в HI, созданную, к примеру, ветром от ЗО в ядре.

Еще раз пересмотрена ситуация в ядре, включая уточнение по L(150 Mhz)-SFR:

SFR~40 Mo/yr (по IRAS, т.е. - LIRG!)

Пока эволюция системы выглядит так:

- взаимодействие создало HI приливной хвост ( $10^9$  Mo)
- радиоджет  $10^8$  лет назад пробил “дыру” в облаке, в нем идет ЗО, сейчас видим что-то вроде SNR, в том числе
- На севере низкая плотность газа – реликтовой радиоструктуры не осталось
- $10^5$  лет назад – последняя вспышка ионизирующей активности, включая рентген.

Т.е. ситуация более сложная, сравнительно с принятой моделью быстрого изменения режима аккреции. Рекуррентная активность?

*This timeline is clearly in contrast with the previous suggestion that fading AGN could indicate a lasting change in accretion mode (from being dominated by radiative to mechanical output... In the IC2497-HV system, the situation is clearly more complex, with evidence for recurring episodes of mechanical (or radiatively inefficient) jet activity in addition to the radiatively efficient activity responsible for ionising HV*

