# Radio Sources at Large Scales

Observational and theoretical work done at the Institute of Radio Astronomy

presented by Paola Parma
on behalf of the IRA scientific staff

# Introduction

## General aims:

From source properties (structure, strength, spectral index, polarization) to understanding of origin, evolution and death of extragalactic radio sources.

Work started in the early seventies; definition of B2 samples of nearby radio galaxies: Colla et al. 1975 (first bright sample), Fanti et al. 1978 (second fainter sample).

Basically these are low luminosity (FRI) radio sources in nearby galaxies ($z<0.1$). Later: radio studies with the Westerbork Synthesis Radio Telescope and the Very Large Array.

This work has helped establishing the physical and statistical properties of FRI sources: twin jets are very common, they start relativistic and quickly decelerate; FR I are older than FRII. (Parma et al. 1987; 1999)

**Recent years:** work on the physics of radio sources on large scales has continued, following three main lines:

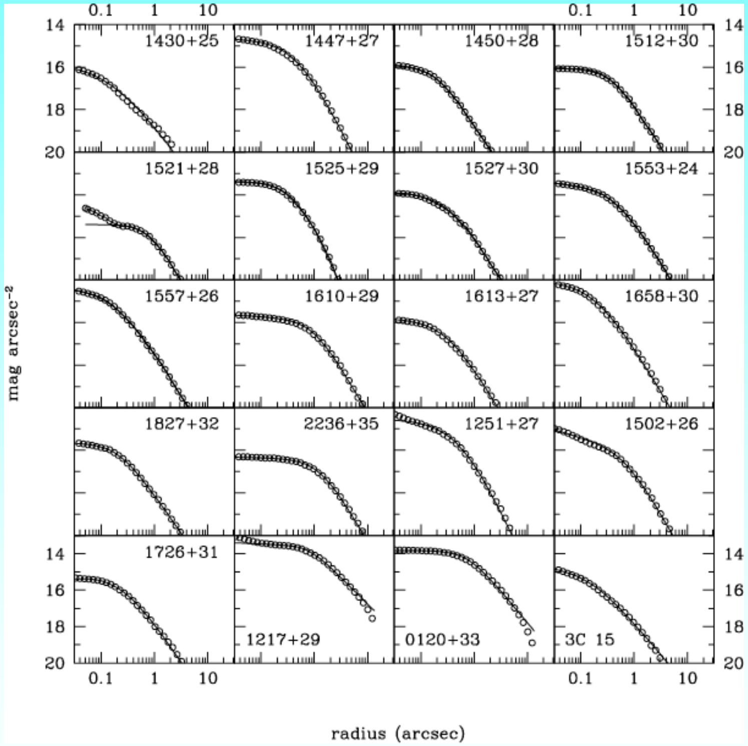
1. Origin of radio emission, differences between FRI and FRII. Data from HST and IRAM. Parma, Prandoni, Mack, IRA- and external collaborators.
2. Ages of radio sources, interaction with and influence of external medium. Data from particular subclasses of radio sources, using surveys like WENSS and NVSS:
   - Sources with recurrent activity and dying sources: Parma, Mack, IRA- and external collaborators.
   - Giant Sources: Mack, Feretti, Venturi, IRA- and external collaborators.
3. Physical properties of nuclei, hot spots and lobes. Multiwavelength data from HST, VLT, Chandra, Spitzer. Brunetti, Bondi, Stanghellini, Mack, Chiaberge, IRA- and external collaborators.

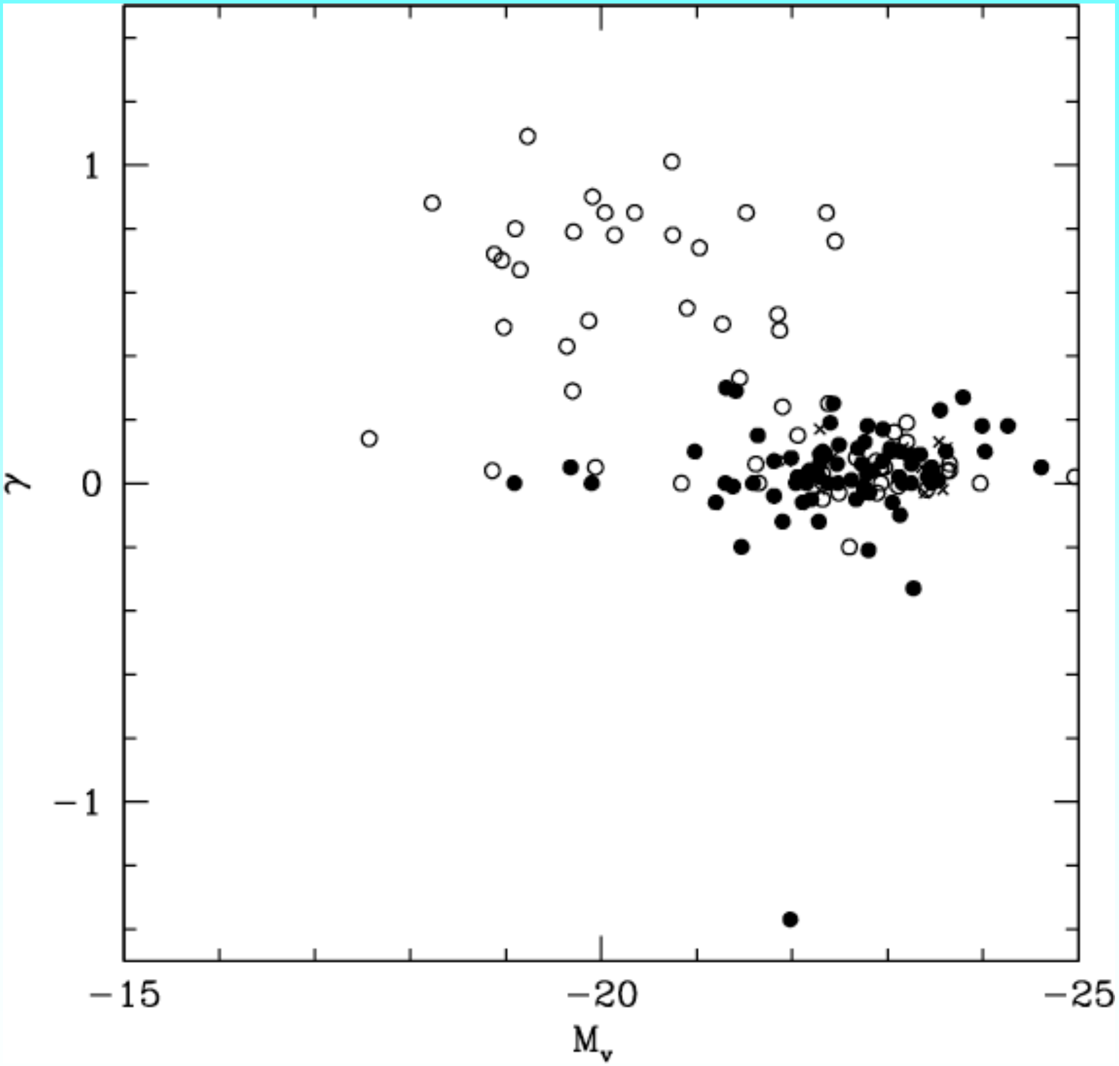
# Science Highlights:
# Origin and fuelling of radio emission

**Why do some galaxies produce a (powerful) radio source and others don't?**
Study nuclear regions with HST: B2 sample, imaging in V and I. (de Ruiter, Parma, Capetti, Fanti, Morganti & Santantonio 2005, A&A, 439, 487):

Radio active galaxies always have a "core"-type profile of the optical brightness, with $\gamma<0.3$.

No difference between FRI and FRII, but only non-active galaxies can have power-law profiles.






Absolute visual magnitude vs γ. Filled points are radio-active, open circles non-active objects. Objects with unknown radio power are indicated by crosses.

# Fuelling the radio source

**Is there cold (molecular) gas that powers the radio jets, through accretion onto central black hole?**

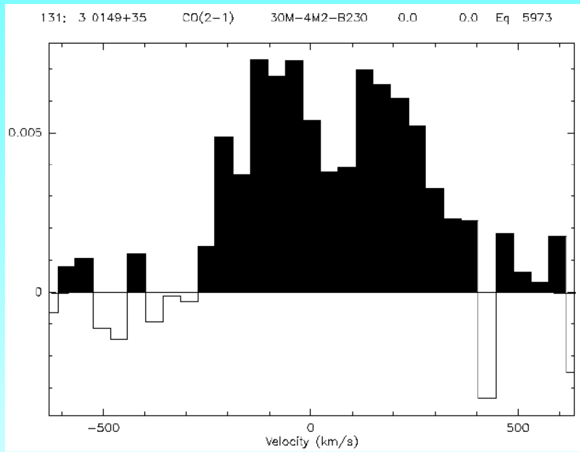
An observational study of B2 sources with IRAM:

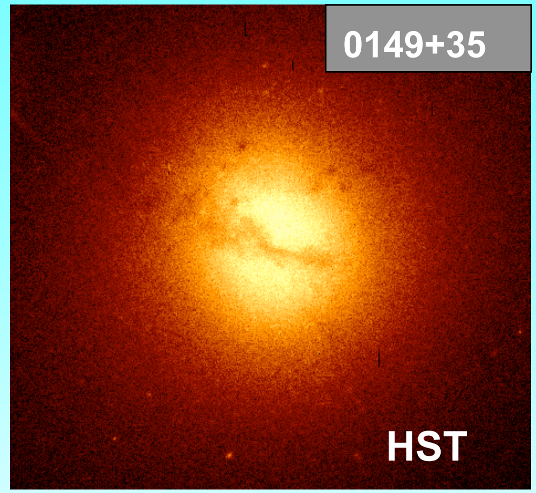
- Strong evidence for a physical link between the dust seen with HST and the molecular gas probed by CO.
- In two cases the CO line displays a double-horn profile indicating ordered rotation. Prandoni et al. 2007, NewAR, 51, 43

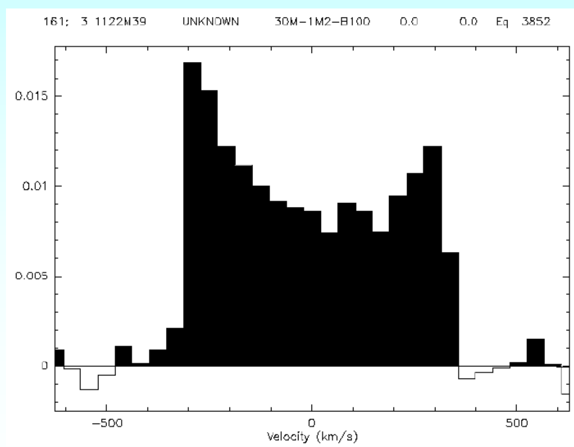
**Recurrent activity:**

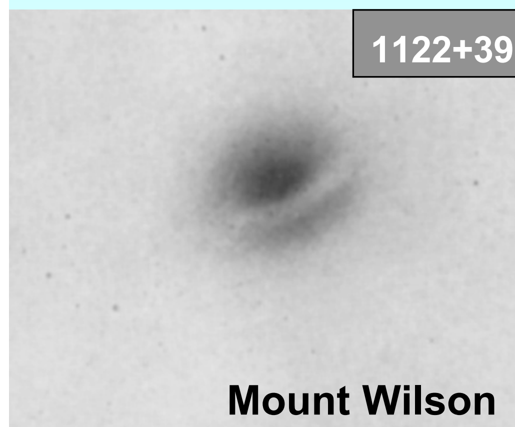
Search for CO emission in double-double galaxies with IRAM reveals that restarting radio galaxies are deficient in molecular gas; no accumulation of molecular gas to explain restarting. Saripalli & Mack 2007, MNRAS, 376, 1385

## double-horn CO lines associated to rotating dusty disks



# Science Highlights:
# Physical properties of radio source components

**Lobes: X ray using Chandra + XMM**

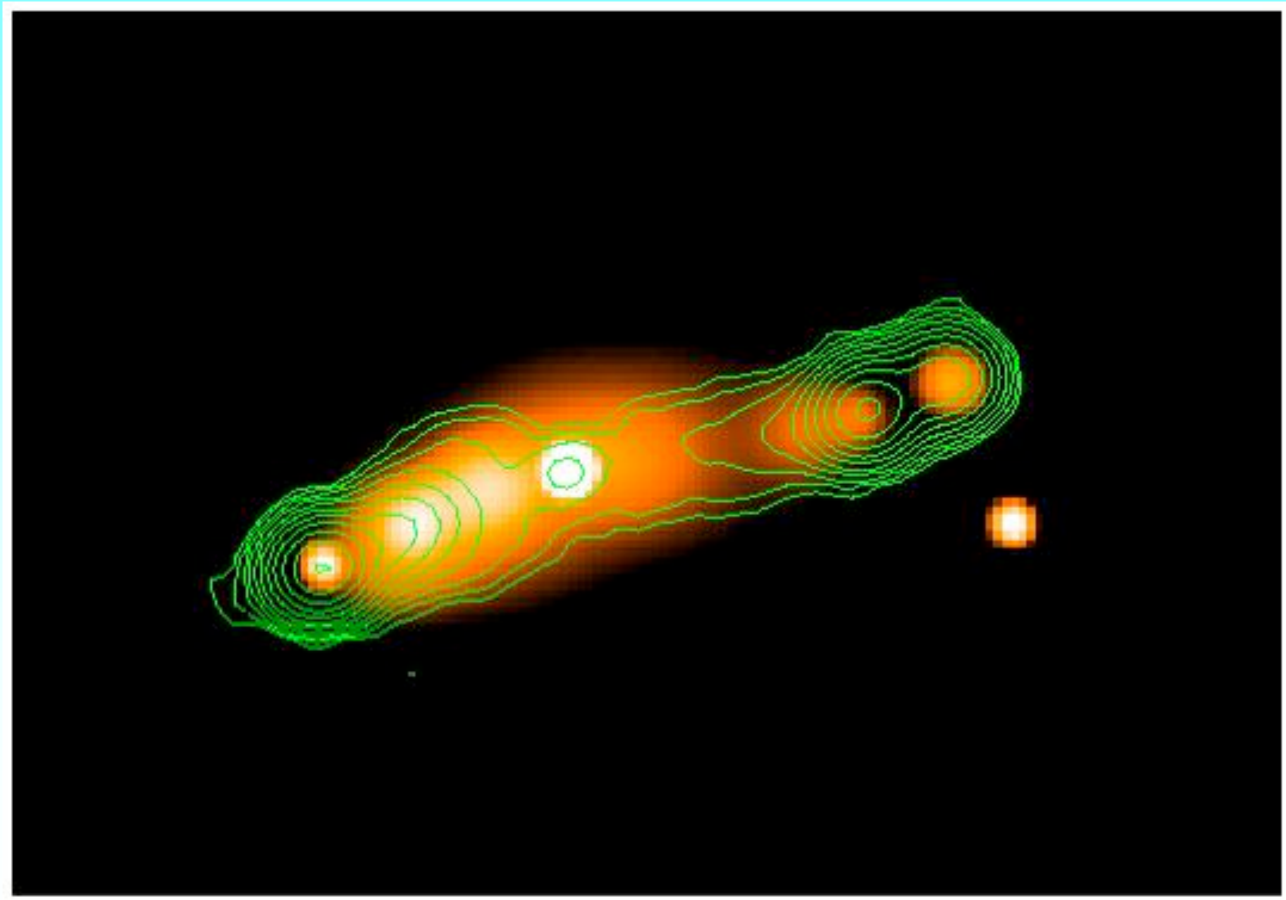
IC, two possible mechanisms:

- IC scattering between $\gamma \sim 10^3$ electrons with CMB photons (Grindlay 1979; Miley 1980).
- IC scattering between $\gamma \sim 100$-300 electrons and nuclear photons (Brunetti et al. 1997, A&A, 325, 898; Brunetti 2000, Astropart. Phys, 13, 107). In this case the IC is anisotropic ⇒ far lobe should appear more X ray luminous.

Comparison of radio and X fluxes provides direct estimate of the average magnetic field along the line of sight and, independently, the number density of the IC particles.

# 3C 265: example of IC scattering of nuclear photons

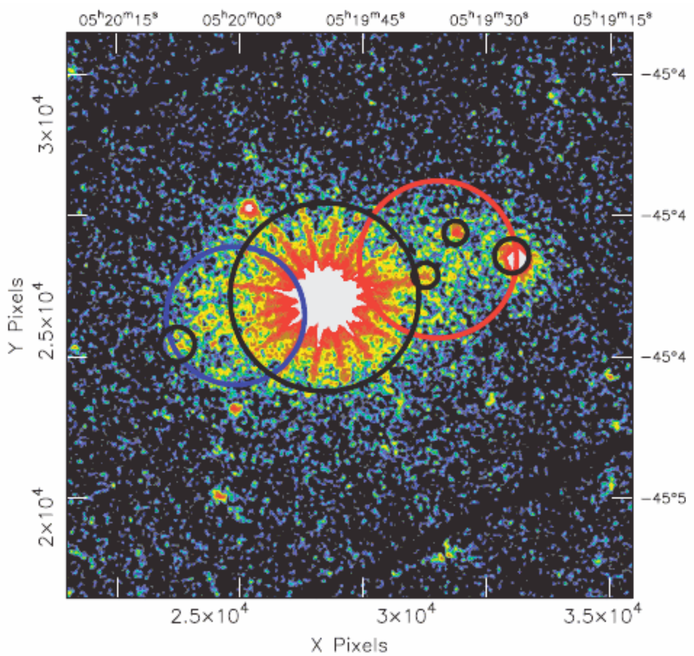
Bondi, Brunetti, Comastri & Setti 2004, MNRAS, 354, 43

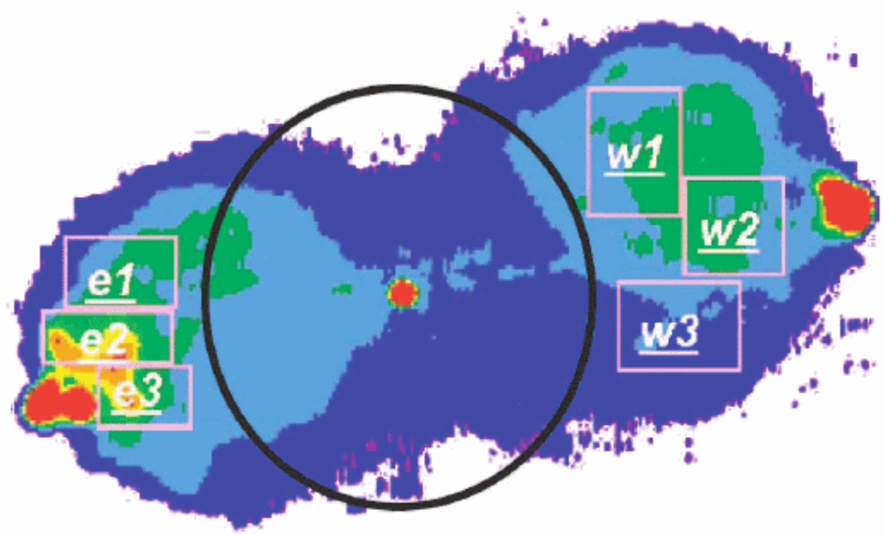


# Pictor A: example of IC scattering of CMB photons

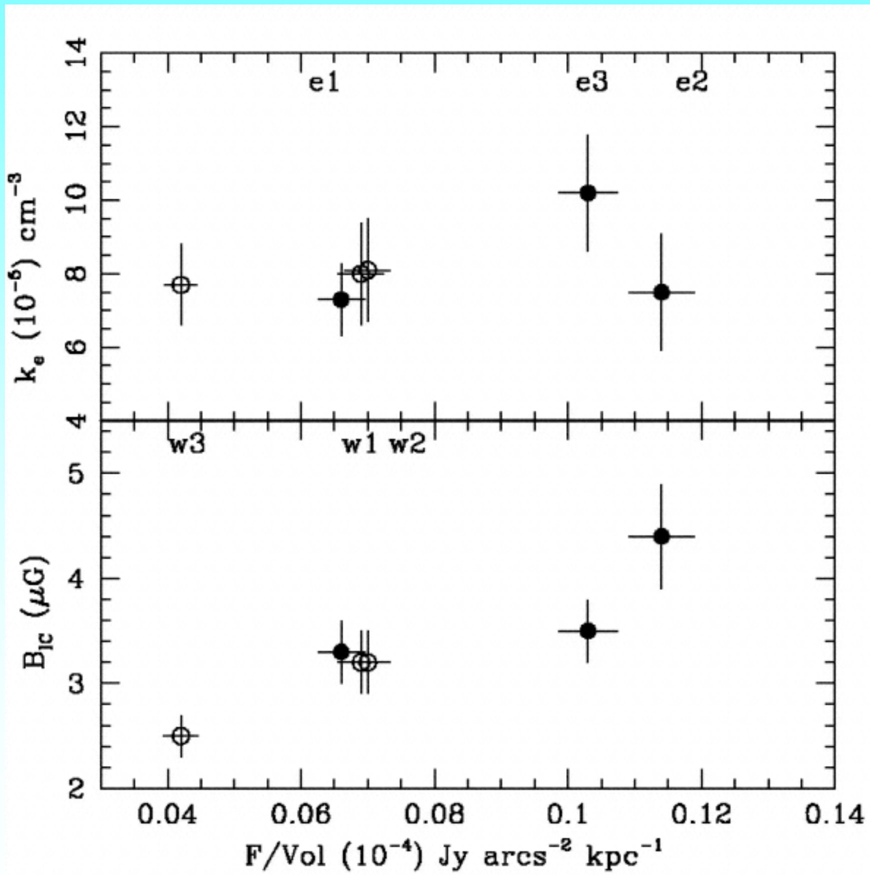
FIG. 1.—*Top*: *XMM-Newton* MOS1 image (0.2–10 keV) of Pic A observed on 2005 January 14. Several components are visible: the bright nucleus, the west hot spot, the jet, and the two lobes. The blue and red circles represent the east and west extraction regions of the lobes, respectively. Regions corresponding to the two hot spots, jet contribution, and a point source (*black circles*) are excluded. *Bottom*: VLA map (Perley et al. 1997) at 20 cm. Pink boxes represent the subregions used for the spatially resolved analysis. The labels are described in the text. The black circle delimits the excluded nuclear region.

(Migliori, Grandi, Palumbo, Brunetti & Stanghellini 2007, ApJ, 668, 203)



Inverse Compton value $B_{IC}$ (*bottom*) and particle density $k_e$ (*top*) values of the east (*filled circles*) and west (*open circles*) sub-regions plotted as a function of the radio flux (*F/V*) at 1.4 GHz, normalized by the relative volume



## People involved in "large scale" radio source studies:

IRA staff: Bondi, Brunetti, Chiaberge, Feretti, Mack, Parma, Prandoni, Stanghellini, Vigotti, Venturi
IRA collaborators: Dallacasa, de Ruiter, R. Fanti, Giovannini, Govoni, Gregorini, Murgia, Setti
Post-Docs: Orienti, Varano
Ph.D. students: Montenegro Montes
External collaborators: "many" (other INAF institutes, universities, etc.)

## External Funding:

ASI (Italian Space Agency), 2006-2007

## Instruments used:

VLA, GMRT, Effelsberg, WSRT
IRAM, Spitzer
HST, VIMOS, TNG
Chandra, XMM

# Future:

Continuation of existing research with existing instruments, using other samples, but a real break-through in our understanding will come with the new generation of telescopes:

SRT, ALMA, LOFAR, Symbol-X, EVLA, …(SKA)

We should be ready