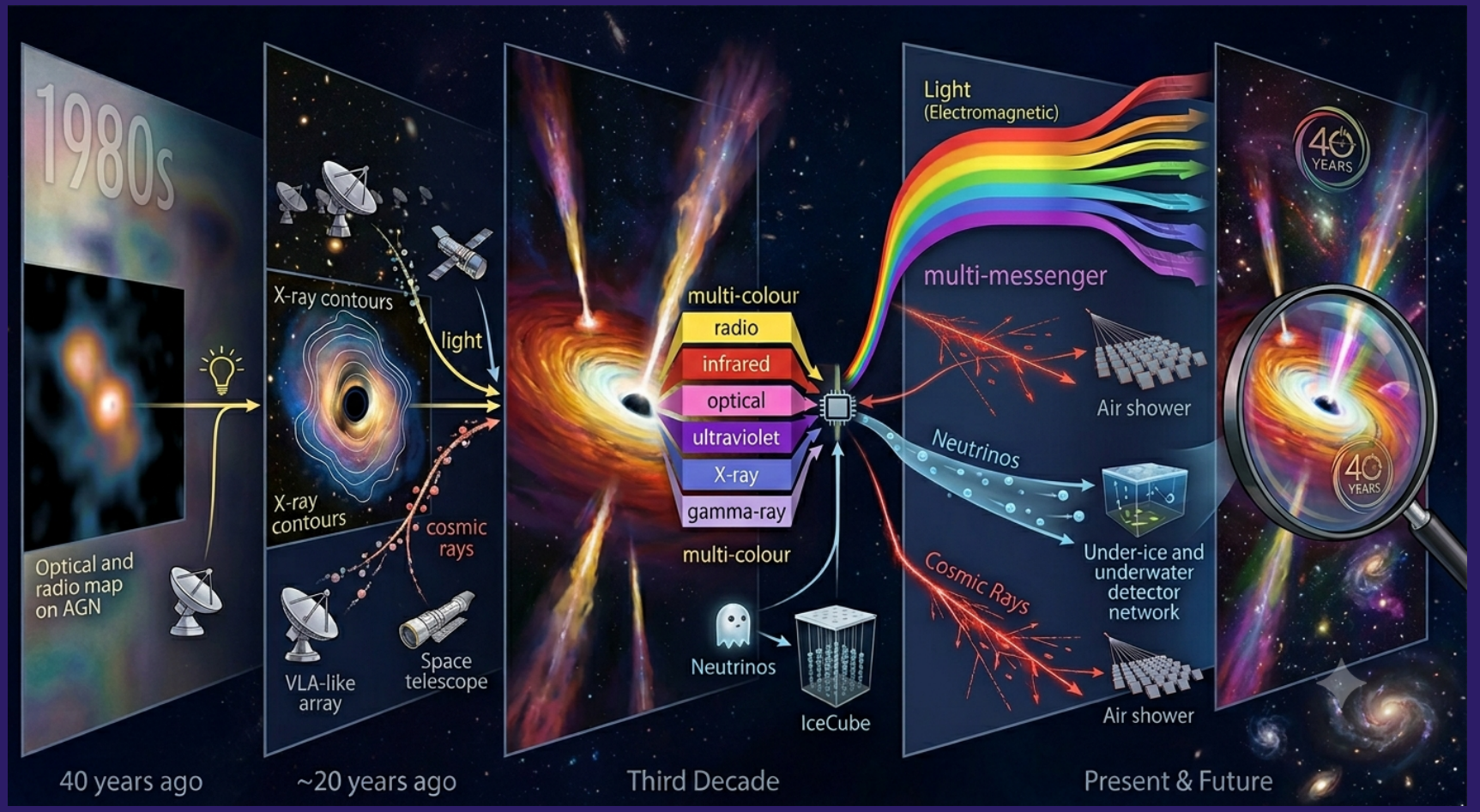
Four decades of multi-colour and multi-messenger AGN

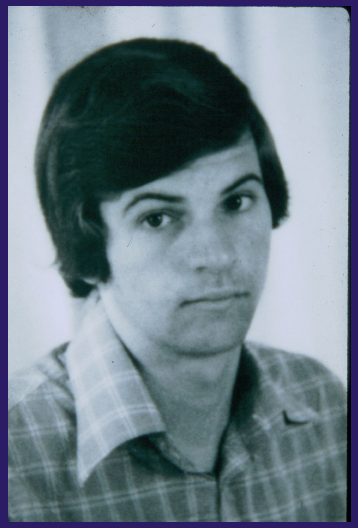
Paolo Padovani

Technische Universität München and European Southern Observatory



1979 – 1985: Master in Astronomy @ Padova





1984: start of my Master thesis

Alfonso Cavaliere



Cavaliere in 2003

Born	Alfonso Giuseppe Cavaliere 27 August 1933 Crotone, Italy
Died	28 March 2026 (aged 92) Rome, Italy
Alma mater	Sapienza University of Rome
Occupations	Astrophysicist · cosmologist

AGN in the mid-1980s: what we knew

- AGN main classes (Seyferts, quasars, BL Lac objects, radio galaxies, …)
- The radio-loud/radio-quiet distinction (Sandage 1965)
- The likely existence of supermassive black holes
- Multi-wavelength astronomy was rapidly emerging:
    - Gamma-rays: **SAS 2** (1972 – 1973) and **COS-B** (1975 – 1982)
    - X-rays: **Einstein** (1978 – 1981), **EXOSAT** (1983 – 1986)
    - UV: **IUE** (1978 – 1996)
    - Many optical observatories: largest telescopes were 5.1m [**Palomar**, USA] and 6m [**SAO**, USSR]
    - Infrared: **IRAS** (1983)
    - Many radio observatories: largest telescopes were **Arecibo** [Puerto Rico], **Effelsberg** [Bonn], plus **VLA** [New Mexico]

AGN in the mid-1980s: select unknowns

- The relation between AGN main classes (unification; but Antonucci & Miller 1985)
- The radio-loud/radio-quiet physical difference
- Relativistic jet physics
- Were supermassive black holes the engines of quasars? If so, how large were their masses?

AGN in the mid-1980s: select unknowns

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large

THE ASTROPHYSICAL JOURNAL, 305:175–186, 1986 June 1
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$$\mathbf{U = n_\gamma / n_H} = \frac{Q}{4\pi c n_H r^2} \rightarrow U \bullet n_H = \frac{Q}{4\pi c r^2}$$

Ionization parameter

LINE VARIATIONS IN QUASARS AND SEYFERT GALAXIES

C. MARTIN GASKELL
Astronomy Department, University of Texas

AND

LINDA S. SPARKE
Institute of Astronomy, Cambridge, England

Received 1985 April 22; accepted 1985 November 25

ABSTRACT

We present quantitative estimates of the sizes of broad-line regions (BLRs) in three well-studied Seyfert I galaxies and discuss how these differ from previously reported size estimates for NGC 4151. We analyze both Lick Observatory and *IUE* satellite data on NGC 4151 and show that both are consistent with the high-ionization filaments (those emitting C IV, He II, and the high-order Balmer lines) mostly lying ~5 lt-day from the central source. The low-ionization filaments are 3 or 4 times further out. The Ohio State data on Akn 120 show the Hβ emitting region to be ~6 lt-day from the central source, and *IUE* data suggest that the Lyα region in Mrk 509 is ~10 lt-day out. Our results imply that the densities in broad-line regions are a couple of orders of magnitude higher than in current standard models. For the objects studied here, the light crossing times are of the same order of magnitude as the continuum variability time scales, so kinematic mapping of the broad-line regions will be extremely difficult.

Subject headings: galaxies: Seyfert — line profiles — quasars

AGN in the mid-1980s: select unknowns

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THE ASTROPHYSICAL JOURNAL, 305:175–186, 1986 June 1
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Subject headings: galaxies: Seyfert — line profiles — quasars

AGN in the mid-1980s: select unknowns

- The relation between AGN main classes (unification; but Antonucci & Miller 1985)
- The radio-loud/radio-quiet physical difference
- Relativistic jet physics
- Were supermassive black holes the engines of quasars? If so, how large were their masses?
- AGN (quasar) evolution was well established; but very little information on luminosity functions, duty cycle, and connection with host galaxies

AGN in the mid-1980s: select unknowns

- The r… …cci & Mille…
- The r…
- Relati…
- Were … …y large were …
- AGN … …mation on lu… …axies

THE ASTROPHYSICAL JOURNAL, 269:35–41, 1983 June 1
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ANALYSIS OF COMPLETE QUASAR SAMPLES TO OBTAIN PARAMETERS OF LUMINOSITY AND EVOLUTION FUNCTIONS

H. L. MARSHALL, Y. AVNI,[1] H. TANANBAUM, and G. ZAMORANI[2]
Harvard-Smithsonian Center for Astrophysics
Received 1982 August 4; accepted 1982 November 3

ABSTRACT

We present a parametric likelihood analysis of the joint redshift-luminosity distribution for a composite, complete sample of 32 quasars with $17.0 < B < 19.2$ selected on the basis of ultraviolet excess. We determine best estimates and joint confidence regions for the parameters of several models of the quasar optical luminosity and evolution function. These models are also tested explicitly for their acceptability. We find a steeper luminosity function than found for previous samples. We reject a model invoking pure density evolution on the basis of its extrapolation to fainter magnitudes through comparisons with the optical number counts and independently with the observed 2 keV X-ray background. Assuming an average value for L_x/L_{opt}, we discuss the contribution of quasars to the X-ray background at 2 keV.

Subject headings: functions: numerical methods — luminosity function — quasars — X-rays: general

1988: first paper

Astron. Astrophys. 192, 9–12 (1988)

ASTRONOMY AND ASTROPHYSICS

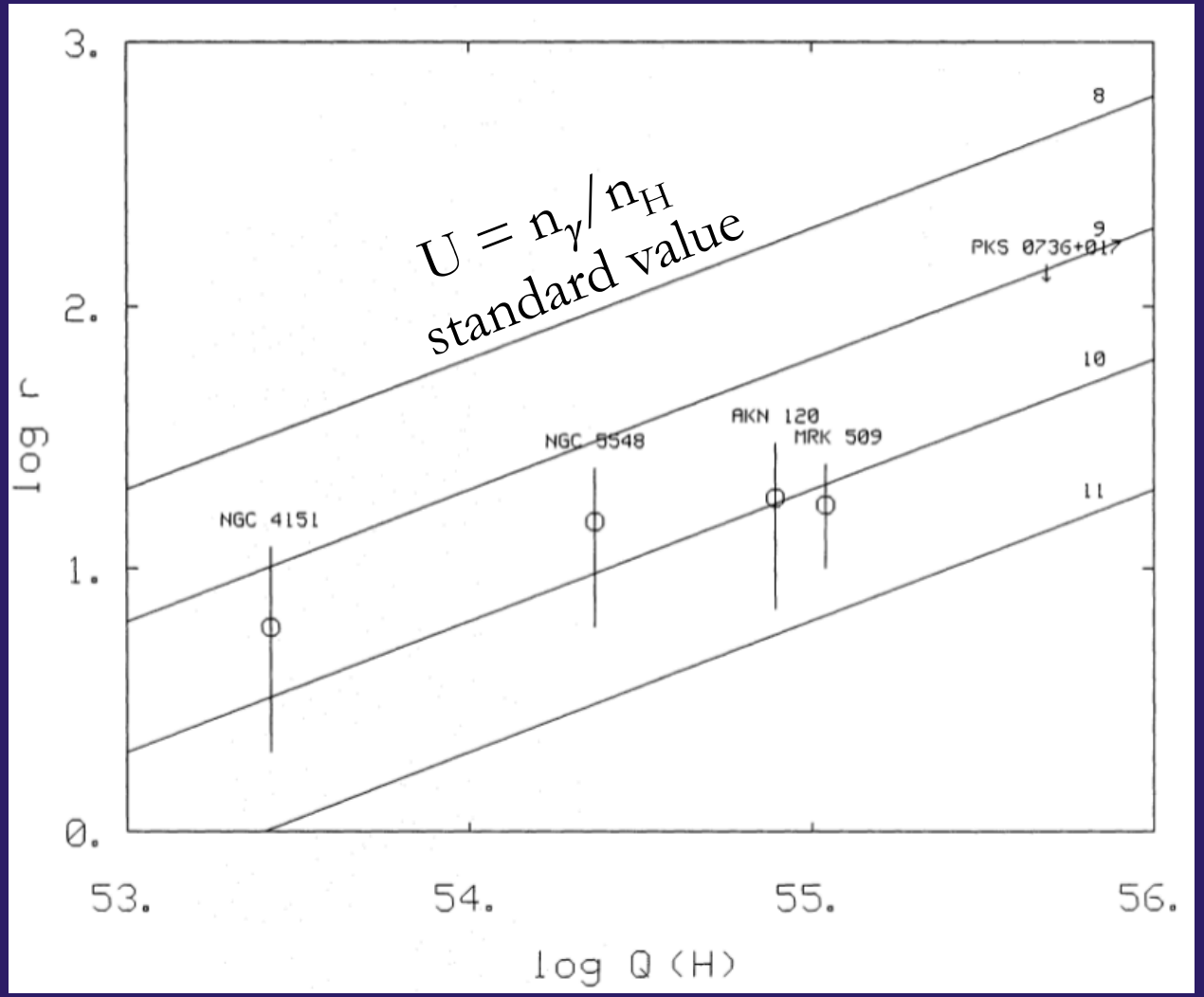
Ionizing photon densities in the broad line regions of active galactic nuclei

P. Padovani

Dipartimento di Astronomia, Vicolo dell'Osservatorio 5, I-35122 Padova, Italy

Received March 31, accepted May 27, 1987

BLR radii were much smaller than predicted! Hence masses had to be smaller as well



1988 – 1990: AGN masses and L/L_{Edd}; evolution

- Derivation of masses and Eddington ratios for samples of ~ 60 – 140 (mostly) local AGN using also new spectroscopic data ($M \propto r\, v^2$) normalized to the first reverberation mapping measurements [with P. Rafanelli]



Piero Rafanelli

1988 – 1990: AGN masses and L/L_{Edd}; evolution

- Derivation of masses and Eddington ratios for samples of ~ 60 – 140 (mostly) local AGN using also new spectroscopic data ($M \propto r\, v^2$) normalized to the first reverberation mapping measurements [with P. Rafanelli]
- Eddington ratio increased with redshift
- Quasars could not be long-lived, and many massive remnants should hide in the nuclei of currently inactive galaxies (from theoretical arguments: with A. Cavaliere)
- First Seyfert black hole mass function: the total mass density of Seyfert 1s is ~ 100 times smaller than the total mass density accumulated in all AGN contributing to quasar counts (from Soltan 1982) [with R. Burg and R. Edelson]

1988 – 1990: AGN masses and L/L_{Edd}; evolution

- Derivation of m… s of ~ 60 – 140 (mostly) local A… ($M \propto r\, v^2$) normalized to t… ments [with P. Rafanelli]
- Eddington ratio…
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- First Seyfert bla… ensity of Seyfert 1s is ~ 100 time… cumulated in all AGN contribut… [with R. Burg and R. Edelson]

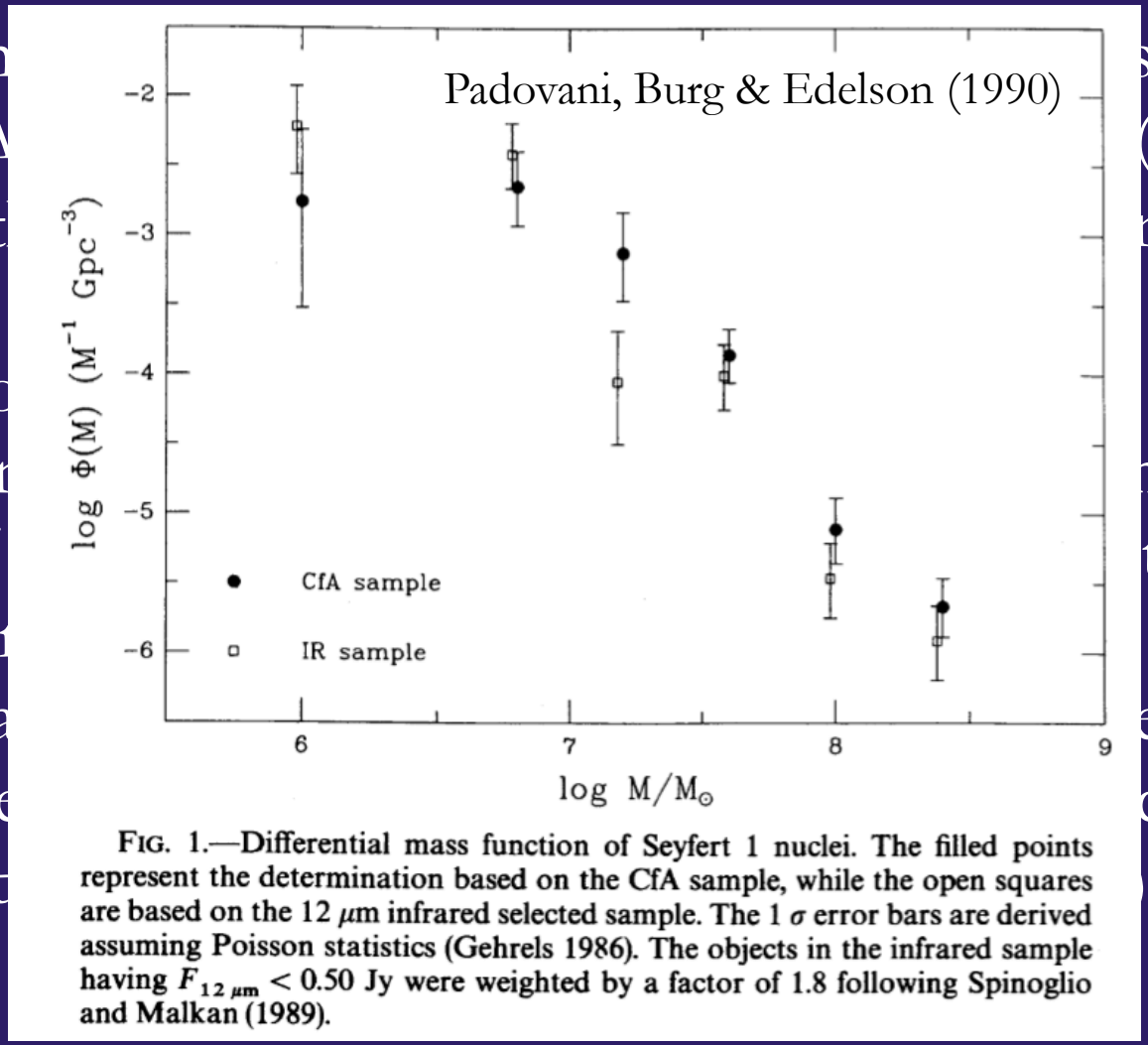


FIG. 1.—Differential mass function of Seyfert 1 nuclei. The filled points represent the determination based on the CfA sample, while the open squares are based on the 12 μm infrared selected sample. The 1 σ error bars are derived assuming Poisson statistics (Gehrels 1986). The objects in the infrared sample having $F_{12\,\mu m} < 0.50$ Jy were weighted by a factor of 1.8 following Spinoglio and Malkan (1989).

1988 – 1990: AGN masses and L/L_{Edd}; evolution

- Derivation of masses and Eddington ratios for samples of ~ 60 – 140
  ectroscopic data ($M \propto r\, v^2$)
  apping measurements [with P.

  t
  nany massive remnants should hide
  xies (from theoretical arguments:

  the total mass density of Seyfert
  l mass density accumulated in all
  rom Soltan 1982) [with R. Burg and



Richard Burg



Rick Edelson

1987 – 1990: post-doc @ STScI, Baltimore





Meg Urry

1989: 23rd ESLAB Symposium in Bologna



- Talk *Star-forming Galaxies and the X-Ray Background* given by Richard Griffiths
- Poster *X-ray constraints on the beaming hypothesis for BL Lacertae objects* with Meg

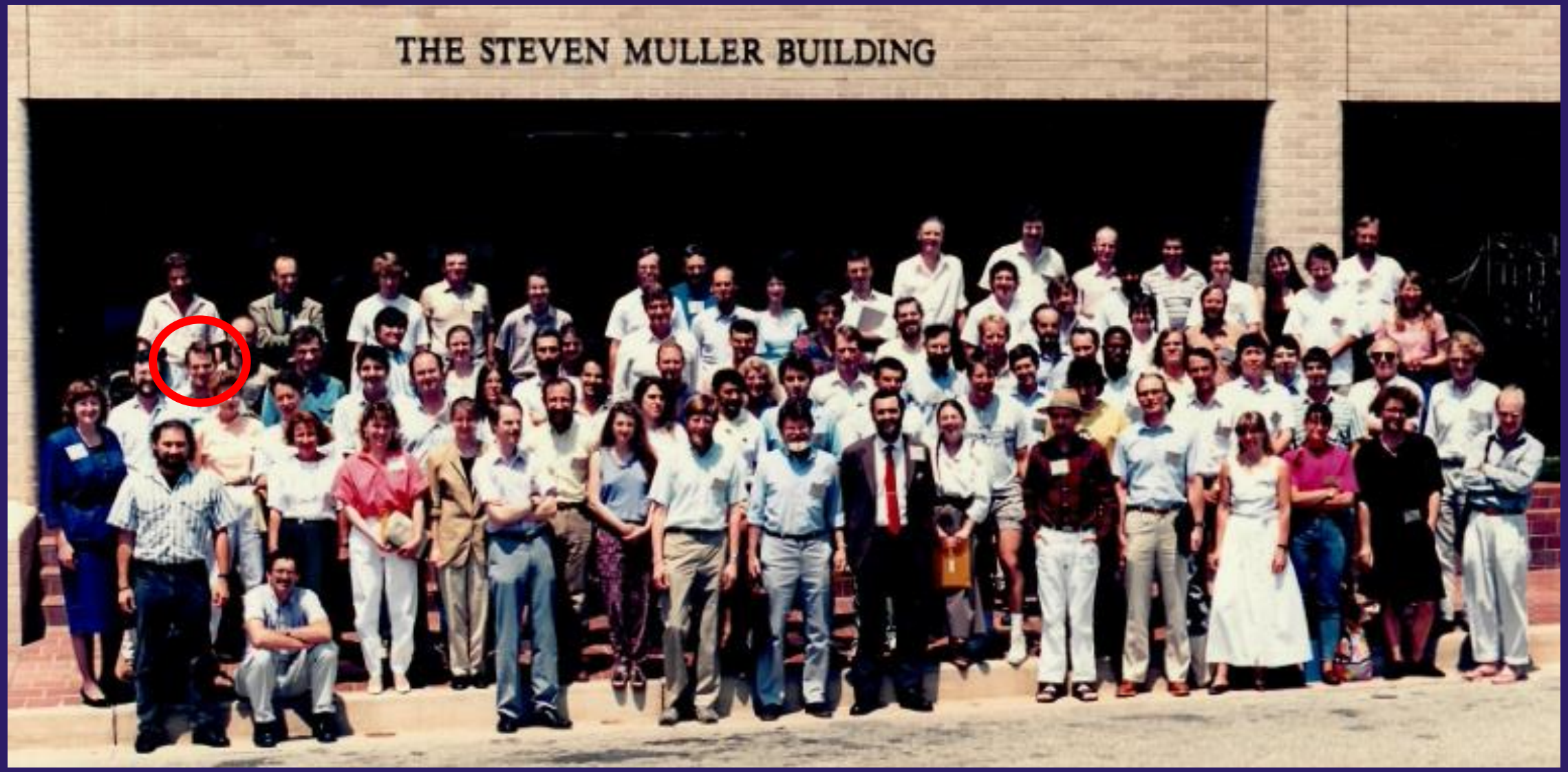


Richard Griffiths



Paolo Giommi

1990: Grand Unified Theories of AGN @ STScI



1990 – 1995: unification of radio sources, 1 Jy BL Lac sample

- Doppler boosting means blazars are much more powerful and much rarer than radio galaxies

1990 – 1995: unification of radio sources, 1 Jy BL Lac sample

- Dopple much rarer than ra

emission is blue-shifted (essentially the inverse relation):

$$\nu = \delta \nu' . \tag{B2}$$

The intensity enhancement ("Doppler boosting") is an even more dramatic effect. Because I_ν / ν^3 is a relativistic invariant, the transformation of specific intensity is

$$I_\nu(\nu) = \delta^3 I'_{\nu'}(\nu') \tag{B3}$$

(Rybicki and Lightman 1979). One power of δ comes from the compression of the time interval [Eq. (B1)] and two come from the transformation of the solid angle, $d\Omega = \delta^2 d\Omega'$.

If the emission is isotropic in the source rest frame (i.e., $I'_{\nu'}$ is not a function of angle), the flux density, F_ν, transforms in the same way as the specific intensity. For a power-law spectrum of the form $F'_{\nu'} \propto (\nu')^{-\alpha}$, Eq. (B3) becomes

$$F_\nu(\nu) = \delta^{3+\alpha} F'_{\nu'}(\nu); \tag{B4}$$

as $\delta^{2+\alpha}$, where α refers to the observed integrated spectrum rather than the spectral index of the local emission (Cawthorne 1991).

Additional complications in the evaluation of the amplification factor include the lifetimes of the emitting components, the radial dependence of the their emissivities, and the presence of shocks (Lind and Blandford 1985). In the following we will hide all these possibilities in a single parameter, p, by assuming that the observed luminosity, L_j, of a relativistic jet is related to its intrinsic luminosity, $\mathscr{L}_j$, via

$$L_j = \delta^p \mathscr{L}_j , \tag{B7}$$

with $p = 3 + \alpha$ for a moving, isotropic source and $p = 2 + \alpha$ for a continuous jet (other values are certainly possible).

The recent detection of superluminal motion within our own galaxy (Mirabel and Rodríguez 1994) permits for the first time a direct estimate of p. Since proper motions are measured for both the approaching and receding components, $\beta \cos\theta$ is uniquely determined to be 0.323 ± 0.016

1990 – 1995: unification of radio sources, 1 Jy BL Lac sample

- n rarer

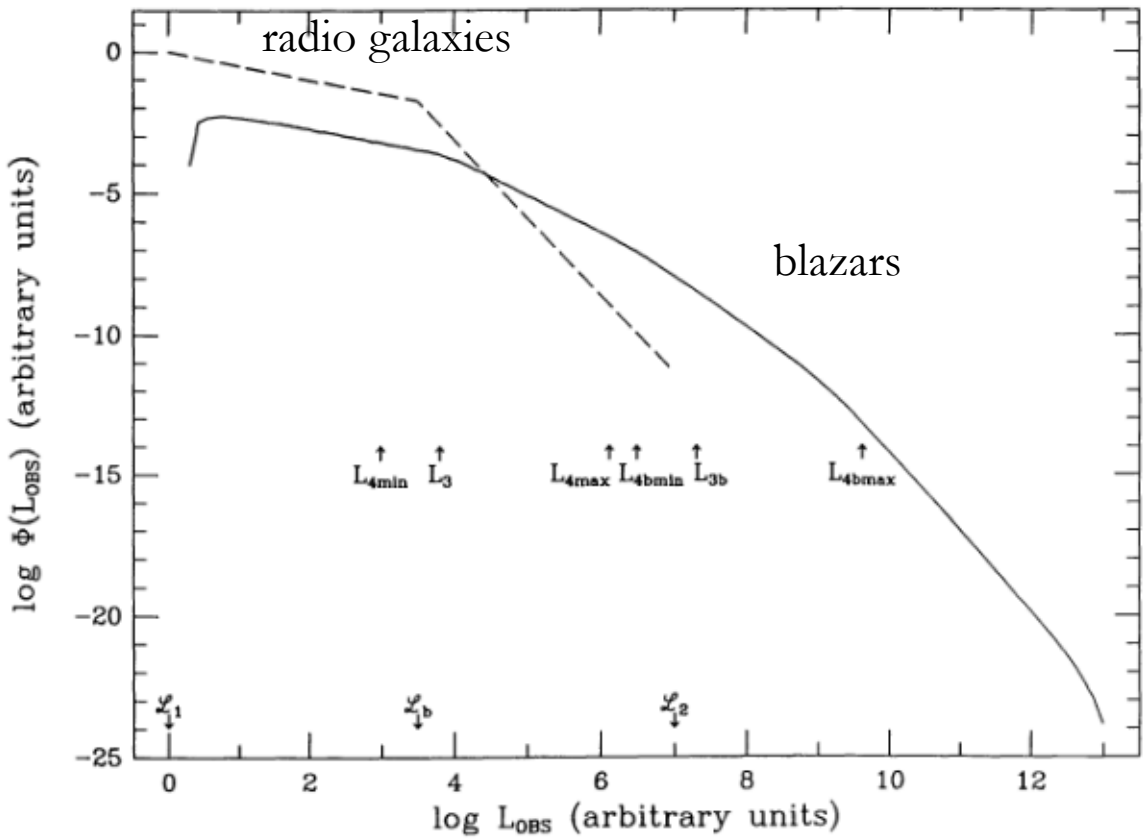


FIG. 7.—Calculation of the beamed luminosity functions including all effects: a complex intrinsic luminosity function (*dashed line*), two emission components, and a distribution of Lorentz factors. The intrinsic luminosity function is a double power law (*dashed line*) with differential indices $B_1 = 0.5$ and $B_2 = 2.75$ between $\mathscr{L}_1 = 1$ and $\mathscr{L}_2 = 10^7$ and a break at $\mathscr{L}_b = 10^{3.5}$ (arbitrary units). The solid line represents the corresponding beamed luminosity function assuming $p = 4, f = 0.1$, $\gamma_1 = 5, \gamma_2 = 30$, and $n(\gamma) \propto \gamma^{-2}$. The low-luminosity slope is 0.5 (or B_1), the intermediate-luminosity slope is 1.25 (or $(p + 1)/p$), and the high-luminosity slope is 2.75 (or B_2). The fiducial values of observed luminosity (defined in text) are shown for reference.

1990 – 1995: unification of radio sources, 1 Jy BL Lac sample

- Doppler boosting means blazars are much more powerful and much rarer than radio galaxies
- Quantitative comparison between "parent" and "beamed" LFs in various bands (radio, optical, X-ray) for BL Lacs and FSRQs (radio): test of idea plus "best fit" orientation angles and Lorentz factor range

1990 – 1995: unification of radio sources, 1 Jy BL Lac sample

- Doppler boosting means blazars are much more powerful and much rarer than radio galaxie
- Quantitative com eamed" LFs in various bands (radio, opti s (radio): test of idea plus "best fit" ori r range

TABLE 3
Beaming Model Parameters

Class	γ_1	γ_2	$\langle\gamma\rangle$	G	f	θ_c	% Total
FSRQ	5	40	11	−2.3	0.5×10^{-2}	14°	2%
SSRQ[a]	5	40	11	−2.3	0.5×10^{-2}	38°	10%
RBL	5	32	7	−4.0	1.3×10^{-2}	12°	2%
RBL[b]	2	20	3	−4.0	4.8×10^{-2}	19°	5%
XBL	...	...	3	...	1.0×10^{-1}	30°	14%

a – By assumption there are no free parameters for this fit; θ_c is determined by R_{min} and the rest are fixed at the best-fit values for FSRQ.
b – Alternative fit with lower γ_1.

1990 – 1995: unification of radio sources, 1 Jy BL Lac sample

- Doppler boosting means blazars are much more powerful and much rarer than radio galaxies
- Quantitative comparison between "parent" and "beamed" LFs in various bands (radio, optical, X-ray) for BL Lacs and FSRQs (radio): test of idea plus "best fit" orientation angles and Lorentz factor range
- First well-defined homogeneous radio sample with M. Stickel: LF and evolution

1990 – 1995: unification of radio sources, 1 Jy BL Lac sample

- Do … h rarer tha…
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THE ASTROPHYSICAL JOURNAL, 374:431–439, 1991 June 20
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THE COMPLETE SAMPLE OF 1 JANSKY BL LACERTAE OBJECTS. I. SUMMARY PROPERTIES

M. STICKEL,[1] P. PADOVANI,[2,3] C. M. URRY,[2] J. W. FRIED,[1] AND H. KÜHR[1]

Received 1990 August 17; accepted 1990 December 12

ABSTRACT

This paper describes the first homogeneous, flux-limited sample of radio-selected BL Lac objects, taken from the 1 Jy survey of Kühr et al. These 34 BL Lac objects comprise the only well-defined sample of BL Lac objects outside the X-ray band. The selection criteria include flat radio spectra, optical counterparts visible on Sky Survey Plates, and optical emission lines weaker than 5 Å equivalent width in the rest frame. With two exceptions, all of the BL Lac objects also have high optical polarization, $P_{opt} > 3\%$.

Redshifts from weak emission lines, usually narrow [O II] λ3727, [O III] λ5007, or broad Mg II λ2798, are available for $\sim\frac{3}{4}$ of the sample. The nearby ($z < 0.2$) BL Lac objects, at least, sit in elliptical galaxies and may occur in groups or small clusters of galaxies. Gravitational lensing appears to affect one of the high-redshift ($z \gtrsim 0.5$) BL Lac objects and could be important in others as well. The radio number counts derived from the 1 Jy BL Lac sample are roughly Euclidean over the range between 1 and $\sim$5 Jy, and there is evidence for evolution at the 2 σ level. The local radio luminosity function of BL Lac objects is derived and the total number density for $P_{5\,\mathrm{GHz}} \gtrsim 6 \times 10^{31}$ ergs s^{-1} Hz^{-1} is $\sim$40 Gpc^{-3}.

Subject headings: BL Lacertae objects — gravitational lenses — luminosity function — radio sources: galaxies

1990 – 1995: unification of radio sources, 1 Jy BL Lac sample

- Doppler boosting means blazars are much more powerful and much rarer than radio galaxies
- Quantitative comparison between "parent" and "beamed" LFs in various bands (radio, optical, X-ray) for BL Lacs and FSRQs (radio): test of idea plus "best fit" orientation angles and Lorentz factor range
- First well-defined homogeneous radio sample with M. Stickel: LF and evolution
- These papers (and many more!) summarized in Urry & Padovani (1995)

1990 – 1992: post-doc @ ESO





Francesca Matteucci

1993: stellar mass loss and chemical evolution in ellipticals

THE ASTROPHYSICAL JOURNAL, 416:26–35, 1993 October 10
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STELLAR MASS LOSS IN ELLIPTICAL GALAXIES AND THE FUELING OF ACTIVE GALACTIC NUCLEI

PAOLO PADOVANI[1,2] AND FRANCESCA MATTEUCCI[1]

Received 1993 January 22; accepted 1993 March 31

ABSTRACT

The connection between some observational properties of active galactic nuclei and their host galaxies is studied using a self-consistent model of galactic evolution which reproduces the main features of elliptical galaxies. It is shown that stellar mass loss, calculated in detail from a mixture of stellar generations, can explain the bolometric luminosities and active nucleus-to-host galaxy luminosity ratios of local quasars residing in ellipticals (i.e., the radio-loud ones), under the hypothesis that the power supply is primarily gravitational. The time dependence of the mass-loss rate, however, seems to be too weak to explain quasar evolution as inferred from observations. Stronger time dependencies could be obtained, for example, with much flatter initial stellar mass functions, but the resulting ellipticals would be totally unrealistic. Therefore, either quasar evolution is much less than presently estimated or, more likely, the evolution is not only in luminosity (i.e., it is not driven mainly by the stellar mass-loss rate of the host galaxy), but some density evolution, possibly due to galaxy interactions, has to be present as well. This could be consistent with very recent observational results on the shape of the quasar luminosity function.

Subject headings: galaxies: active — galaxies: elliptical and lenticular, cD — galaxies: evolution — galaxies: nuclei — quasars: general — stars: mass loss

THE ASTROPHYSICAL JOURNAL, 419:485–493, 1993 December 20
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CHEMICAL EVOLUTION OF GALAXIES AND QUASAR METALLICITIES

FRANCESCA MATTEUCCI[1] AND PAOLO PADOVANI[2]

Received 1993 April 20; accepted 1993 June 29

ABSTRACT

As part of a continuing investigation of the connection between observational properties of active galactic nuclei and their host galaxies, we study the evolution of the chemical composition of the gas lost by stars in elliptical galaxies and bulges of spirals by means of a self-consistent model of galactic evolution. It is found that with Salpeter-like, or flatter, initial mass functions, solar abundances are reached in a few 10^8 yr, thereby explaining in a natural way the standard emission lines observed in high-redshift quasars. Furthermore, after the first Gyr, the same mass functions give rise to overabundances of N, Si, and Fe, and roughly solar abundances of C, Ne, O, and Mg, only weakly time-dependent. These results are consistent with the (few) available abundance estimates for the gas emitting the broad lines observed in quasar spectra and, in particular, they could solve the puzzle of the quasi-similarity of quasar spectra at different redshifts. Finally, the metal overabundances inferred in high-redshift quasars are inconsistent with the association of these objects with newly formed galaxies as prescribed, for example, by the starburst model of active galactic nuclei, since in this case quasars should have abundance ratios very different from the estimated ones as well as lower absolute abundances. A criterion for distinguishing between the early burst and other hypothesis is given on the basis of the predicted abundance ratios.

Subject headings: galaxies: abundances — galaxies: elliptical and lenticular, cD — galaxies: evolution — quasars: general

1993 – 1997 (2014): relativistic motion, γ-ray background from blazars, jets and accretion

- Relativistic bulk motion in AGN, mean values of $\boldsymbol{\Gamma}$and orientation agreed with independent LF results [with L. Maraschi]
- Link between L_{rad} and L_{kin} (from SSC) for radio-loud AGN
- First estimate of blazar contribution to γ–ray background based on 16 EGRET detections: ~ 66% [with A. Fabian]
- Jet-disc connection in blazars and radio galaxies, transition between radiatively efficient and inefficient discs at L_{disc}/L_{Edd} ~ 1%



Gabriele Ghisellini



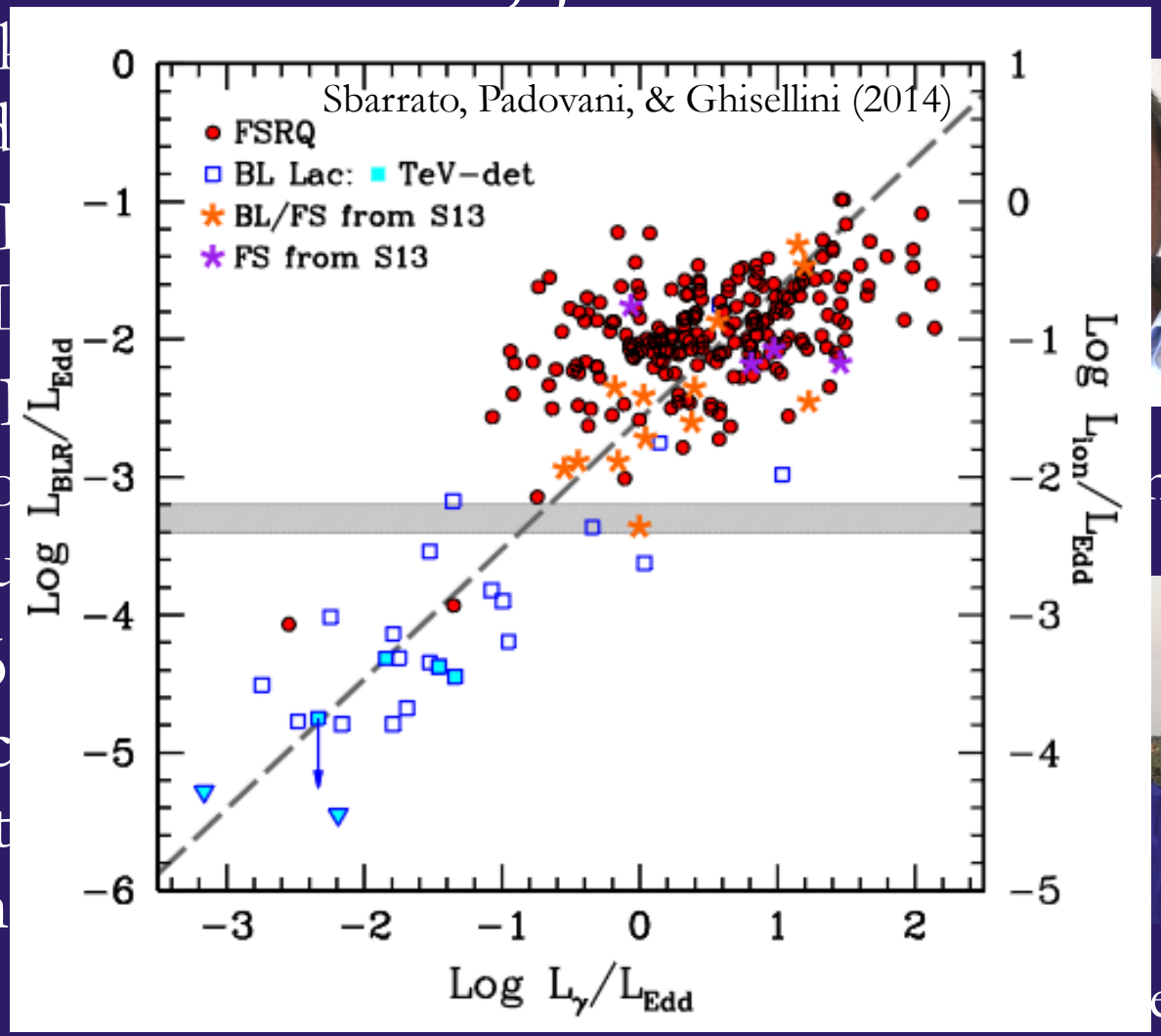
Tullia Sbarrato



Annalisa Celotti

1993 – 1997 (2014): relativistic motion, γ-ray background from blazars, jets and accretion

- Relativistic bull
  values of **Γ** and
  independent LI
- Link between I
  radio-loud AGI
- First estimate o
  γ–ray backgrou
  detections: ~ 6
- Jet-disc connec
  galaxies, transit
  efficient and in
  L_{Edd} ~ 1%





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Tullia Sbarrato

1992 – 1997: assistant professor @ Rome Tor Vergata





Alfonso Cavaliere

1994: first paper with Paolo Giommi

Mon. Not. R. Astron. Soc. **268,** L51–L54 (1994)

BL Lac reunification

Paolo Giommi[1] and Paolo Padovani[2]
[1] *ESIS, Information Systems Division of ESA, ESRIN, Via G. Galilei, I-00044 Frascati, Italy*
[2] *Dipartimento di Fisica, II Università di Roma 'Tor Vergata', Via della Ricerca Scientifica 1, I-00133 Roma, Italy*

Accepted 1994 March 24. Received 1994 March 14; in original form 1994 February 5

ABSTRACT
X-ray-selected BL Lacs (XBLs) are generally thought to outnumber the more extreme radio-selected objects (RBLs), on the grounds that their properties could be understood if the X-ray jet were broader than the radio one. Here we present an alternative explanation: RBLs and XBLs may well be two aspects of the same population, whose main difference is the frequency of the high-energy cut-off in their energy distribution, with XBLs constituting the small subclass with cut-offs at X-ray (or higher) energies. Under this assumption, we are able to reproduce the *X-ray* number counts of XBLs starting from the *radio* counts of RBLs. We also calculate the distribution of radio fluxes of BL Lacs in current and future (deeper) X-ray surveys (e.g. *ROSAT*), wherein we predict that a strong selection effect arising from radio constraints will lead to the preferential discovery of objects of the RBL kind. Our hypothesis implies that there is a single family of BL Lacs and that, within this family, XBL-like objects are a small minority, contrary to the common belief that they represent the most numerous class.

Key words: galaxies: active – BL Lacertae objects: general – radio continuum: galaxies – X-rays: galaxies.



Paolo Giommi

1995: greatly expanded analysis

THE ASTROPHYSICAL JOURNAL, 444:567–581, 1995 May 10
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THE CONNECTION BETWEEN X-RAY– AND RADIO-SELECTED BL LACERTAE OBJECTS

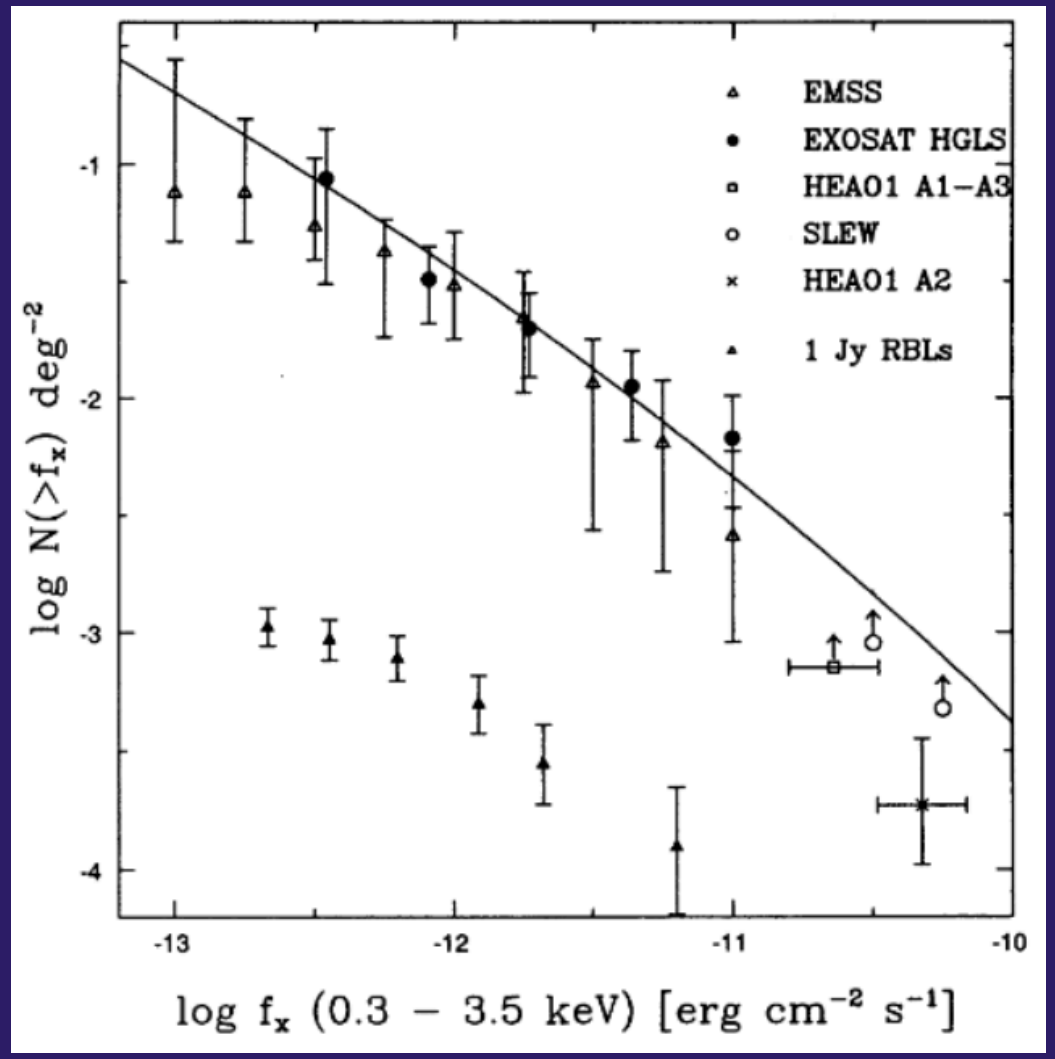
PAOLO PADOVANI[1] AND PAOLO GIOMMI[2]
Received 1994 July 12; accepted 1994 October 28

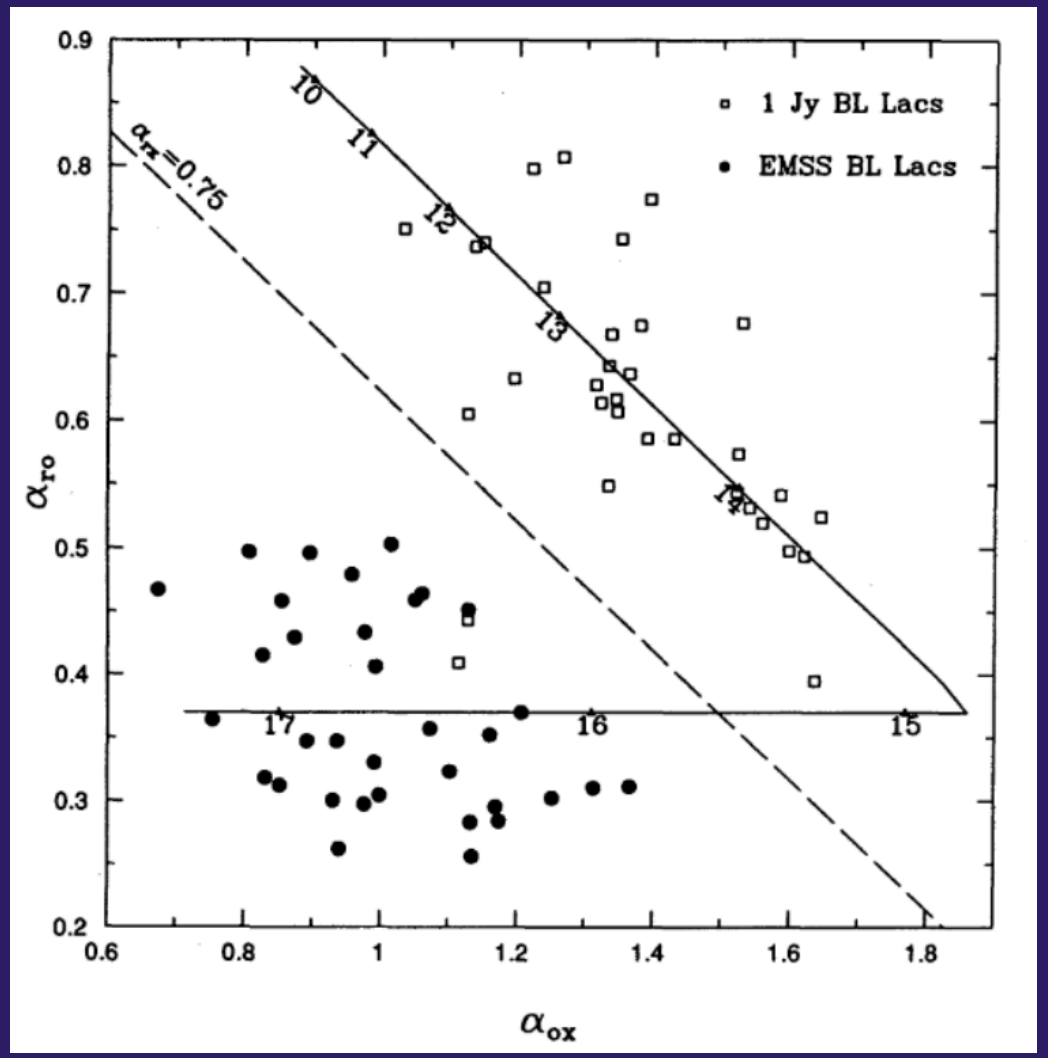
ABSTRACT

We explain the properties of X-ray–selected BL Lacertae objects, under the assumption that they constitute the small minority of the BL Lac population with energy cutoff located in the UV/X-ray band, as suggested by their multifrequency spectra. In particular, we derive their X-ray luminosity function, log N–log S, and radio flux distribution starting from radio-selected BL Lac objects using a method that does not require any free parameters. Our hypothesis is at variance with the most common explanation for the existence of two classes of BL Lac objects, namely, that X-ray–selected objects are viewed significantly off the beaming axis while radio-selected ones have their jets more aligned with the line of sight. In this case, in fact, X-ray–selected sources should be intrinsically more numerous than objects selected in the radio band at a fixed value of some isotropic luminosity such as that of the diffuse radio emission. While also accounting for most of the properties of BL Lac objects detected in current X-ray surveys, this latter scenario would predict their radio emission to be dominated by the extended (unbeamed) component, in contrast with observations. We also address the question of the negative evolution apparently exhibited by X-ray–selected BL Lac objects, showing that neither recognition problems nor a break in the X-ray spectrum are likely to be responsible for it. Our hypothesis explains in a simple way the bimodal distribution of BL Lac objects in the α_{ro}-α_{ox} diagram. It also makes specific predictions for the X-ray, radio, and optical properties of BL Lac objects which will be tested by future deep X-ray surveys.

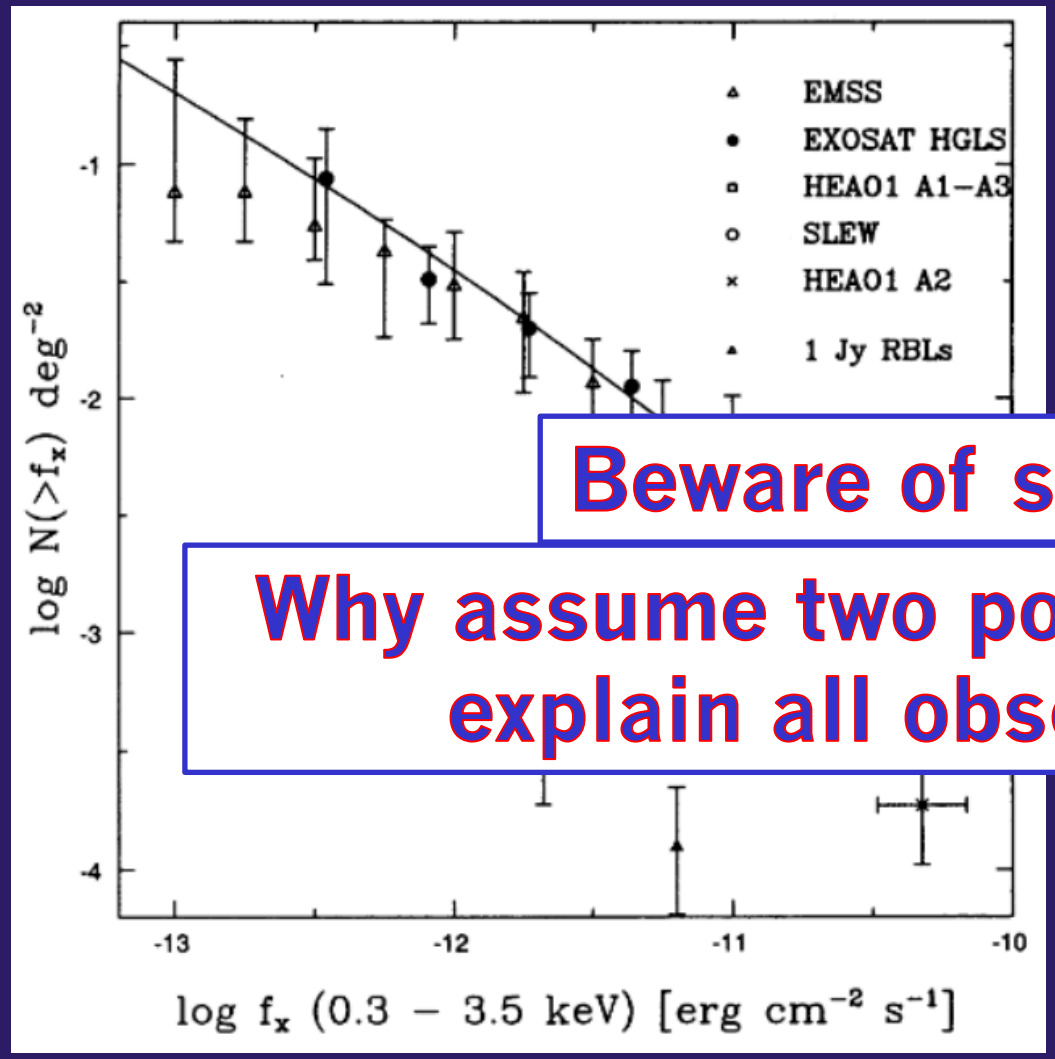
Subject headings: BL Lacertae objects: general — radio continuum: galaxies — X-rays: galaxies

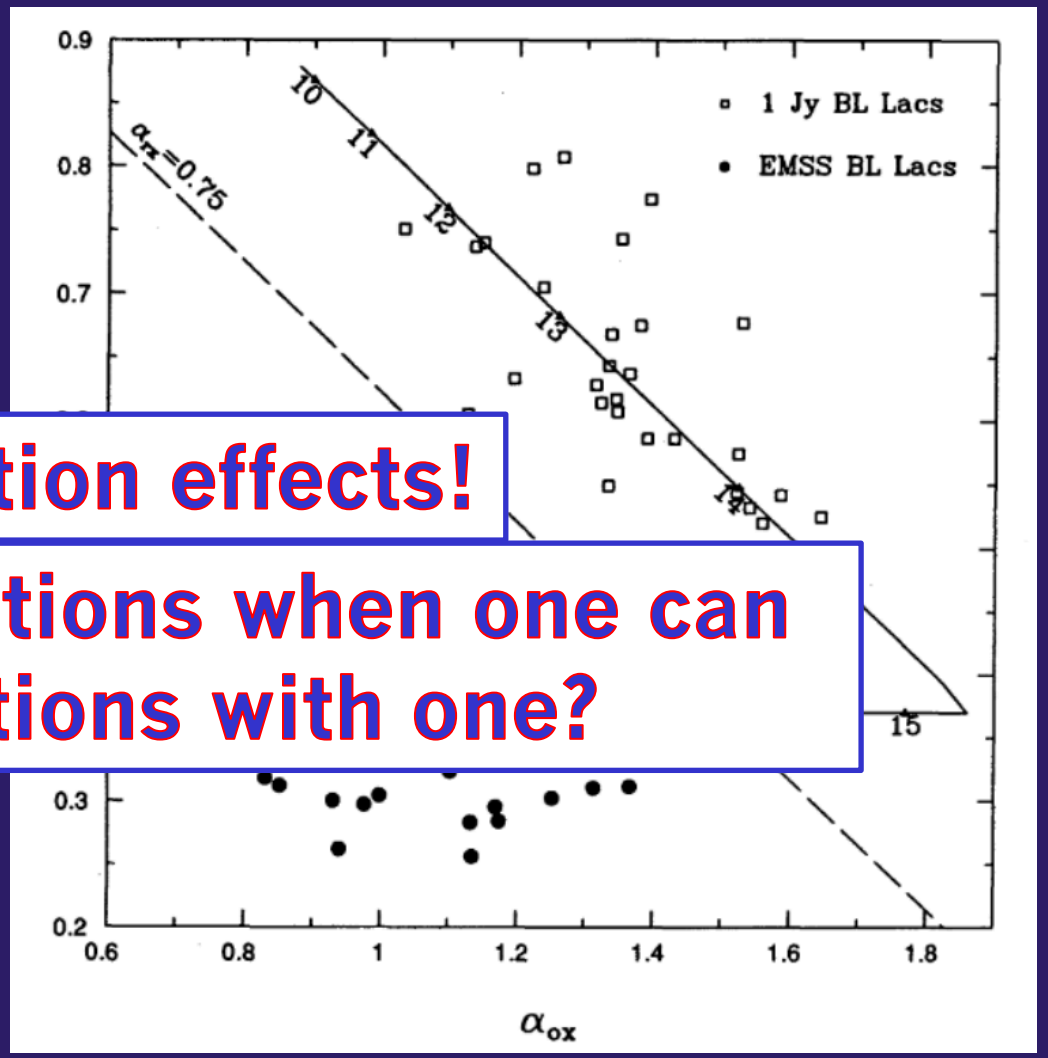
1995: greatly expanded analysis





1995: greatly expanded analysis





Beware of selection effects!

Why assume two populations when one can explain all observations with one?

1998 – 2007: New blazar surveys

We started our own blazar surveys:

- the Deep X-Ray Radio Blazar Survey (DXRBS) [with P.G., Eric Perlman, Hermine Landt, and others]



Eric Perlman



Hermine Landt

1998 – 2007: New blazar surveys

We started our own

- the Deep X [illegible]RBS) [with P.G., Eric [illegible]thers]

A number of features make DXRBS a unique sample with which to address a variety of issues, as follows:

1. DXRBS is currently the faintest and largest blazar sample with nearly complete identifications; it therefore allows us to reach fainter and intrinsically weak blazars, thereby providing further tests of unified schemes.
2. DXRBS includes both FSRQs and BL Lac objects *within the same sample*; it is thus possible to compare the properties of the two classes, including number densities, luminosity functions, and evolution, independently of selection effects due to different sample criteria and definitions. This is vital also to test the idea of an evolutionary link between the two classes.
3. DXRBS includes both LBLs and HBLs *within the same sample*; this has never been achieved before and makes it possible to compare the properties of the two classes independently of obvious effects due to the different selection bands and methods, HBLs being normally X-ray selected and LBLs being typically radio selected.
4. DXRBS reaches radio (and X-ray) fluxes faint enough to provide definite tests to the so-called blazar sequence (Fossati et al. 1998), which posits an inverse dependence of ν_{peak} on intrinsic power. This scenario not only envisions the nonexistence of FSRQs with SEDs similar to those of HBLs, which are present in DXRBS, but predicts also a dominance of HBLs in X-ray and relatively deep radio surveys, which, until now, could not be proven or disputed due to the lack of deep samples.

Padovani et al. (2007)



Eric Perlman

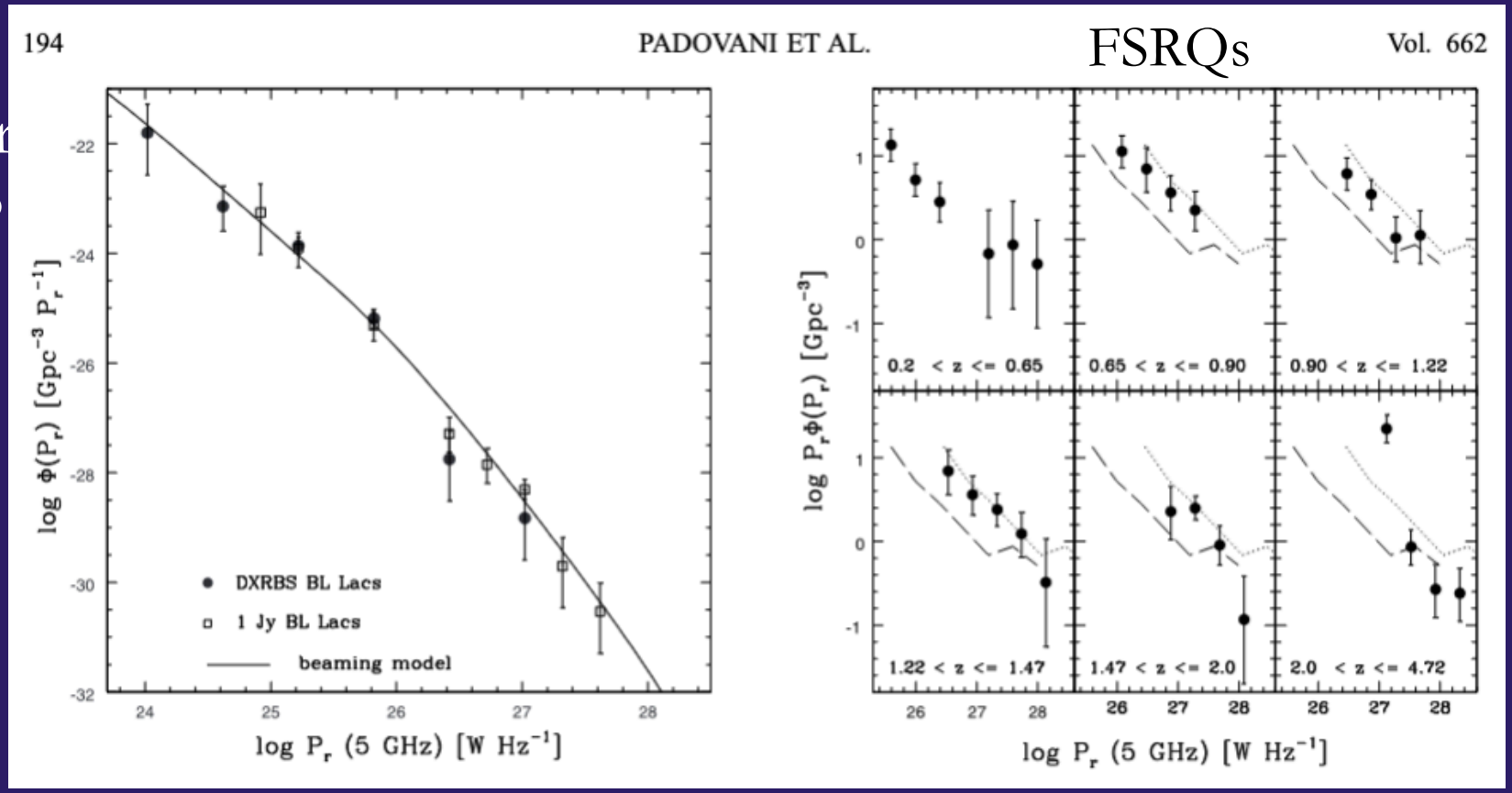


Hermine Landt

1998 – 2007: New blazar surveys

We star

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Padovani et al. (2007)



Eric Perlman



Hermine Landt

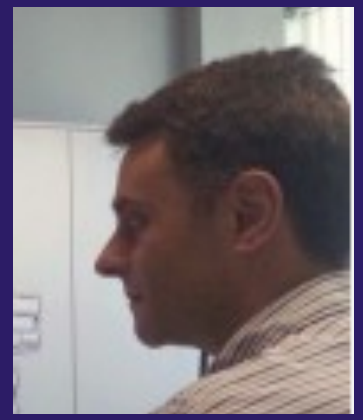
1998 – 2007: New blazar surveys

We started our own blazar surveys:

- the Deep X-Ray Radio Blazar Survey (DXRBS) [with P.G., Eric Perlman, Hermine Landt, and others]
- the sedentary survey of extreme high energy peaked BL Lacs [with P.G., Silvia Piranomonte, Eric Perlman, Matteo Perri, Maria Teresa Menna]



Silvia Piranomonte



Matteo Perri

1998 – 2007: New blazar surveys

We started our o
- the Dee
  P.G., E
- the sed
  BL Lac
  Perlma

A&A 470, 787–809 (2007)
DOI: 10.1051/0004-6361:20077086
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Astronomy & Astrophysics

The sedentary survey of extreme high-energy peaked BL Lacs

III. Results from optical spectroscopy

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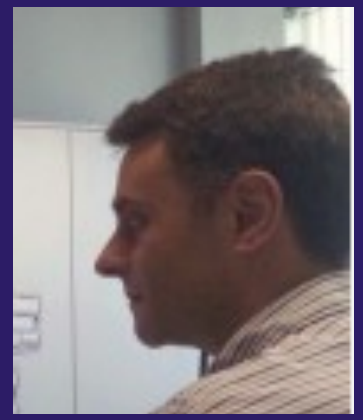
Received 11 January 2007 / Accepted 5 April 2007

ABSTRACT

Aims. The multi-frequency sedentary survey is a flux-limited, statistically well-defined sample of highly X-ray dominated (i.e., with a very high X-ray to radio flux ratio) BL Lacertae objects, which includes 150 sources. In this paper, the third of the series, we report the results of a dedicated optical spectroscopy campaign that, together with results from other independent optical follow-up programs, led to the spectroscopic identification of all sources in the sample.
Methods. We carried out a systematic spectroscopic campaign for the observation of all unidentified objects of the sample using the ESO 3.6 m, the KPNO 4 m, and the TNG optical telescopes.
Results. We present new identifications and optical spectra for 76 sources, 50 of which are new BL Lac objects, 18 are sources previously referred as BL Lacs but for which no redshift information was available, and 8 are broad emission-line AGNs. We find that the multi-frequency selection technique used to build the survey is highly efficient (~90%) in selecting BL Lacs objects. We present positional and spectroscopic information for all confirmed BL Lac objects. Our data allowed us to determine 36 redshifts out of the 50 new BL Lacs and 5 new redshifts for the previously known objects. The redshift distribution of the complete sample is presented and compared with that of other BL Lacs samples. For 26 sources without recognizable absorption features, we calculated lower limits to the redshift using a method based on simulated optical spectra with different ratios between jet and galaxy emission. For a subsample of 38 object with high-quality spectra, we find a correlation between the optical spectral slope, the 1.4 GHz radio luminosity, and the Ca H&K break value, indicating that for powerful/beamed sources the optical light is dominated by the non-thermal emission from the jet.



Silvia Piranomonte



Matteo Perri

Observing runs @ La Silla, Chile





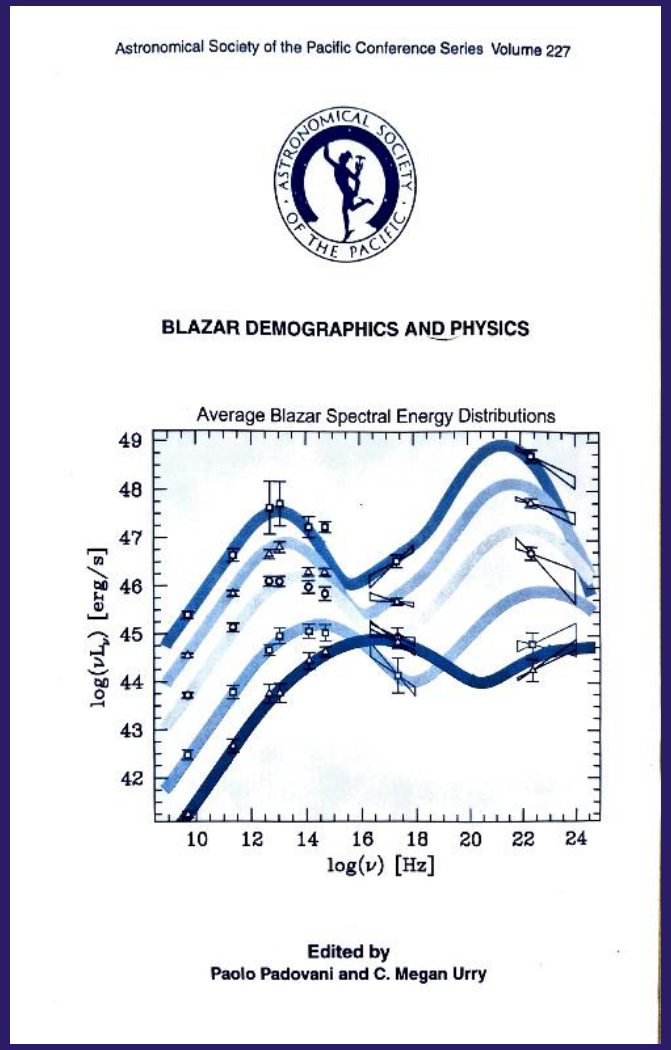
1997 – 2003: ESA staff member @ STScI, Baltimore (Archive Scientist)



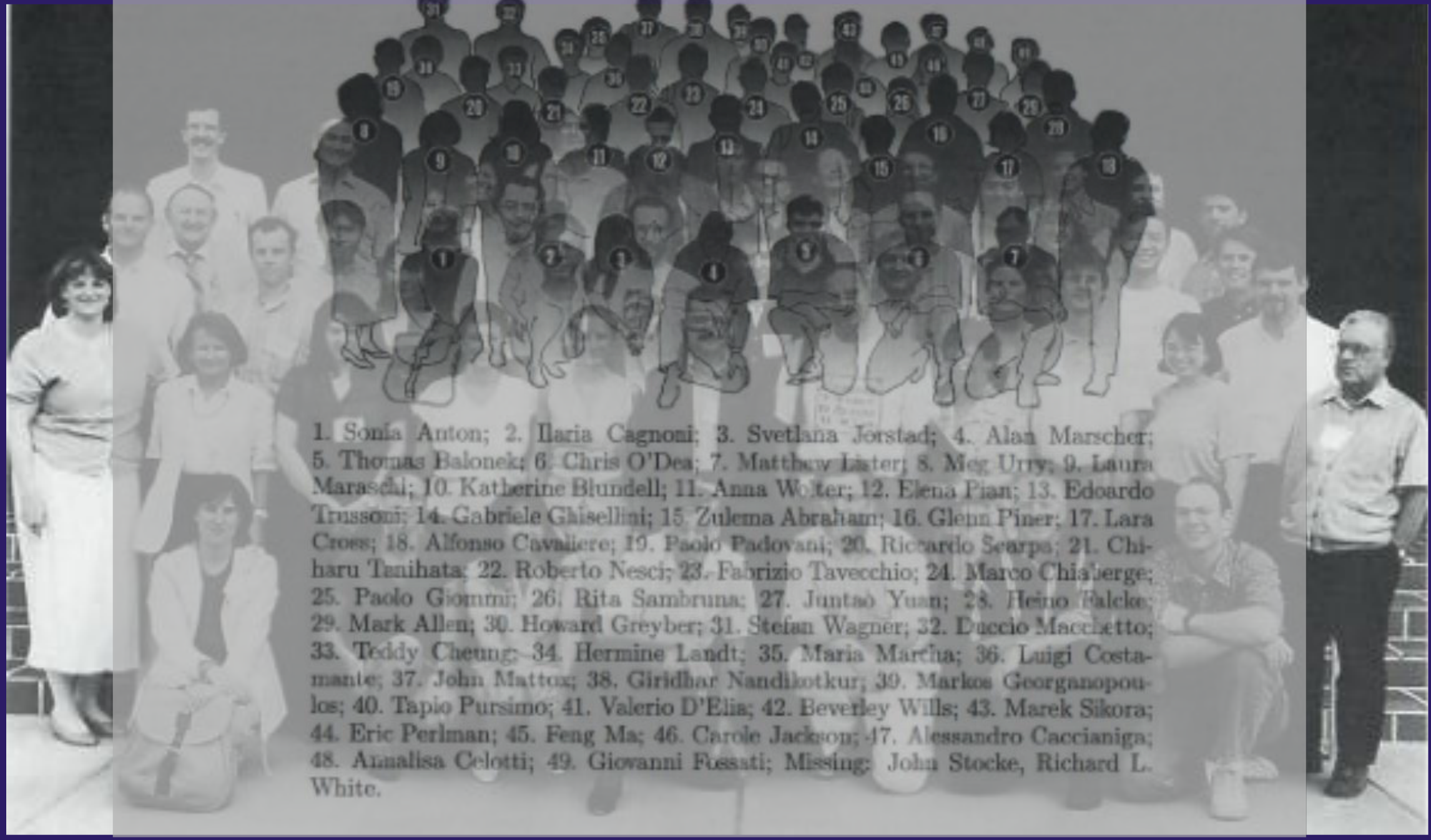
1998: Turku Conference on the BL Lac Phenomenon



2000: Blazar Demographics and Physics @ STScI



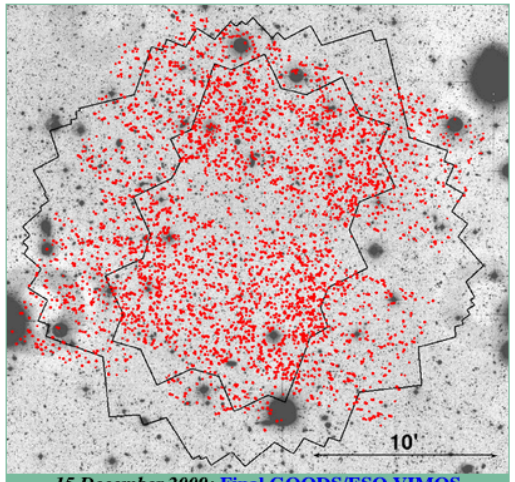




1. Sonia Anton; 2. Ilaria Cagnoni; 3. Svetlana Jorstad; 4. Alan Marscher; 5. Thomas Balonek; 6. Chris O'Dea; 7. Matthew Lister; 8. Meg Urry; 9. Laura Maraschi; 10. Katherine Blundell; 11. Anna Wolter; 12. Elena Pian; 13. Edoardo Trussoni; 14. Gabriele Ghisellini; 15. Zulema Abraham; 16. Glenn Piner; 17. Lara Cross; 18. Alfonso Cavaliere; 19. Paolo Padovani; 20. Riccardo Scarpa; 21. Chiharu Tanihata; 22. Roberto Nesci; 23. Fabrizio Tavecchio; 24. Marco Chiaberge; 25. Paolo Giommi; 26. Rita Sambruna; 27. Juntao Yuan; 28. Heino Falcke; 29. Mark Allen; 30. Howard Greyber; 31. Stefan Wagner; 32. Duccio Macchetto; 33. Teddy Cheung; 34. Hermine Landt; 35. Maria Marcha; 36. Luigi Costamante; 37. John Mattox; 38. Giridhar Nandikotkur; 39. Markos Georganopoulos; 40. Tapio Pursimo; 41. Valerio D'Elia; 42. Beverley Wills; 43. Marek Sikora; 44. Eric Perlman; 45. Feng Ma; 46. Carole Jackson; 47. Alessandro Caccianiga; 48. Annalisa Celotti; 49. Giovanni Fossati; Missing: John Stocke, Richard L. White.

2003 – 2004: The Great Observatories Origins Deep Survey survey @ STScI (GOODS)

GOODS unites extremely deep observations from NASA's Great Observatories, *Spitzer*, *Hubble*, and *Chandra*, ESA's *Herschel* and *XMM-Newton*, and from the most powerful ground-based facilities, to survey the distant universe to the faintest flux limits across the electromagnetic spectrum. GOODS data track the formation and evolution of galaxies across cosmic time and map the history of universal expansion using high redshift supernovae. The survey covers a total of roughly 320 square arcminutes in two fields centered on the Hubble Deep Field North and the Chandra Deep Field South. It incorporates a *Spitzer Space Telescope* Legacy Program to carry out the deepest observations with that facility at 3.6 to 24 microns, a *Hubble Space Telescope* Treasury Program for deep high-resolution optical imaging, and a *Herschel Space Observatory* open time Key Program with the deepest far-infrared observations at 100 to 500 microns. The space-based observations are complemented by ground-based imaging and spectroscopy, including extensive commitments of ESO and NOAO observing time. GOODS public data products are extensively used by the astronomical community at large.



15 December 2009: Final GOODS/ESO VIMOS

Overview	A description of the project
News and Status	Survey progress, news, data releases, etc. NEW *2010-04-10:* *Deep VLA 1.4 GHz data for GOODS-North* NEW *2010-03-02:* *Deep VLT/ISAAC K-band imaging of the HUDF* NEW *2010-03-02:* *HST WFC3-IR Multi-cycle Treasury Program* NEW *2009-12-29:* *Gemini FLAMINGOS-2 NOAO survey program: near-infrared spectra of 1000 galaxies* NEW *2009-12-22:* *First Herschel observations of GOODS-North*
Data Products	Access to reduced data products from: • Spitzer IRAC+MIPS • Hubble ACS *2008-05-22:* ACS v2.0 data products • Chandra Deep Fields North and South *2008-11-01:* 2 Msec Chandra CDF-S • ESO imaging & spectroscopy (GOODS-S) NEW *2009-12-15:* VIMOS spectroscopy v2.0 NEW *2009-12-07:* ISAAC data paper NEW *2009-04-24:* VIMOS U+R imaging • KPNO+Subaru imaging (GOODS-N) • NEW Deep VLA 1.4 GHz (GOODS-N)
GOODS at ESO	The ESO/ST-ECF GOODS web pages
Publications	GOODS-related publications by the collaboration and from the broader astronomical community.
GOODS in the news	• Press release on hidden black holes revealed by GOODS mid-infrared observations of galaxies at z=2. • Press release on GOODS observations of a candidate massive post-starburst galaxy at z=6.5. • GOODS IMAX film Quicktime and MPEG versions also available.



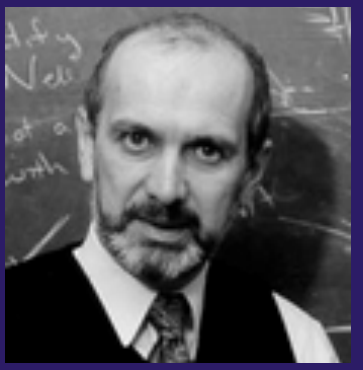
Mauro Giavalisco



Mark Dickinson

1997 – 2004: AGN and blazar X-ray spectra

- X-ray spectra of AGN from the WGA catalog of ROSAT sources (0.1 – 2.4 keV) [with P.G., Martin Elvis, and Fabrizio Fiore]



Martin Elvis



Fabrizio Fiore

1997 – 2004: AGN and blazar X-ray spectra

- X-ray spectra of AGN from the WGA catalog of ROSAT sources (0.1 – 2.4 keV) [with P.G., Martin Elvis, and Fabrizio Fiore]
- BeppoSAX X-ray spectra (0.1 – 10 keV) [with P.G., **Luigi Costamante**, Anna Wolter, Raffaella Morganti, Andrea Comastri, Andrea Cimatti, Meg Urry, Gabriele Ghisellini, Gianpiero Tagliaferri, Laura Maraschi, Annalisa Celotti]



Luigi Costamante

1997 – 2004: AGN and blazar X-ray spectra

Padovani, Costamante, Giommi, et al. (2004)

- X-ray spectra of AG ROSAT sources (0.1 – 2.4 ke d Fabrizio Fiore]
- BeppoSAX X-ray sp , **Luigi Costamante**, Anna ndrea Comastri, Andrea C isellini, Gianpiero Tagliaferr elotti]

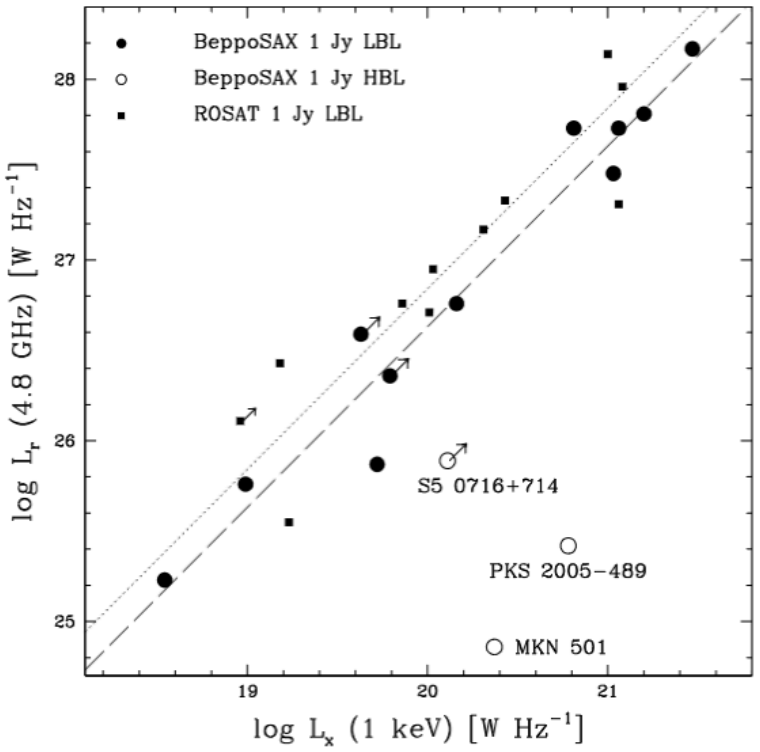


Figure 6. Nearly simultaneous X-ray and radio luminosities of 1-Jy BL Lacs objects observed by *BeppoSAX* (circles) and *ROSAT* (squares). Lower limits indicate sources for which no redshift is available but $z > 0.2$ was assumed, based on the fact that the host galaxies are optically unresolved. The dashed line indicates a value of $\alpha_{rx} = 0.861$, the mean value for the *BeppoSAX* LBLs, while the dotted line indicates a value of $\alpha_{rx} = 0.89$, the mean value for the *ROSAT* LBLs. Labels identify the HBLs (open circles).

2003 – 2025: ESO staff member





Piero Rosati



Vincenzo Mainieri

The Astrophysical Virtual Observatory (AVO)

(AVO)



The Astrophysical Virtual Observatory (AVO) enabled the AVO science team, led by Paolo Padovani, (seen in this image) to discover some of the hidden objects in our Universe, Type-2 quasars and their associated black holes. The AVO project

The Astrophysical Virtual Observatory (AVO)

A&A 424, 545–559 (2004)
DOI: 10.1051/0004-6361:20041153
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Astronomy & Astrophysics

Discovery of optically faint obscured quasars with Virtual Observatory tools

P. Padovani[1], M. G. Allen[2], P. Rosati[3], and N. A. Walton[4]

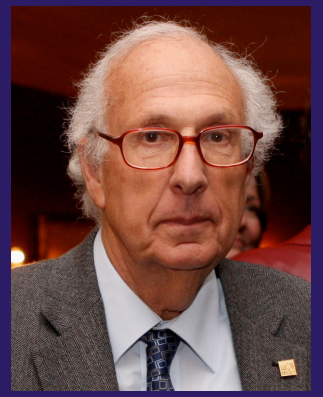
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Received 23 April 2004 / Accepted 2 June 2004

Abstract. We use Virtual Observatory (VO) tools to identify optically faint, obscured (i.e., type 2) active galactic nuclei (AGN) in the two Great Observatories Origins Deep Survey (GOODS) fields. By employing publicly available X-ray and optical data and catalogues we discover 68 type 2 AGN candidates. The X-ray powers of these sources are estimated by using a previously known correlation between X-ray luminosity and X-ray-to-optical flux ratio. Thirty-one of our candidates have high estimated powers ($L_x > 10^{44}$ erg/s) and therefore qualify as optically obscured quasars, the so-called "QSO 2". Based on the derived X-ray powers, our candidates are likely to be at relatively high redshifts, $z \sim 3$, with the QSO 2 at $z \sim 4$. By going ~3 mag fainter than previously known type 2 AGN in the two GOODS fields we are sampling a region of redshift – power space which was previously unreachable with classical methods. Our method brings to 40 the number of QSO 2 in the GOODS fields, an improvement of a factor ~ 4 when compared to the only 9 such sources previously known. We derive a QSO 2 surface density down to 10^{-15} erg cm^{-2} s^{-1} in the 0.5–8 keV band of $\geq$330 deg^{-2}, ~30% of which is made up of previously known sources. This is larger than current estimates and some predictions and suggests that the surface density of QSO 2 at faint flux limits has been underestimated. This work demonstrates that VO tools are mature enough to produce cutting-edge science results by exploiting astronomical data beyond "classical" identification limits ($R \lesssim 25$) with interoperable tools for statistical identification of sources using multiwavelength information.

2007 – 2016: deep radio fields, source identification with a multi-wavelength approach

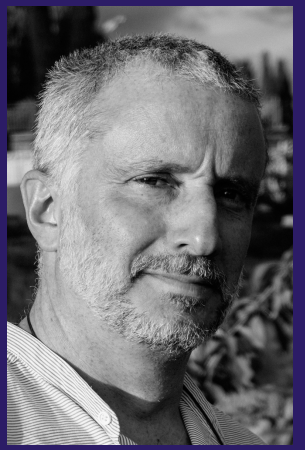
- Chandra Deep Field South (CDFS) and Extended CDFS [with Ken Kellermann, Piero Rosati, Vincenzo Mainieri, Margherita Bonzini, Paolo Tozzi, Neal Miller, and others]



Ken Kellermann



Margherita Bonzini



Paolo Tozzi

2007 – 2016: deep radio fields, source identification with a multi-wavelength approach

- Chandra Deep Fi DFS
  [with Ken Keller eri,
  Margherita Bonzi ers]



2007 – 2016: deep radio fields, source identification with a multi-wavelength approach

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2016

Table 1 Effectiveness of faint radio source classifiers

Indicator	AGN		SF sources
	RL	RQ	
FIR - radio correlation	Y		Y
L_X	~Y	Y	
IRAC diagram	~Y		
X-ray spectrum and variability	Y		
other radio	Y		
optical	~Y		~Y
VLBI detection	Y		
radio polarization	Y		
$D_{4000} - P_{1.4GHz}/M_\star$ plane	~Y		~Y

2007 – 2016: deep radio fields, source identification with a multi-wavelength approach

- Chandra Deep
  [with Ken Kel
  Margherita Bo

2016

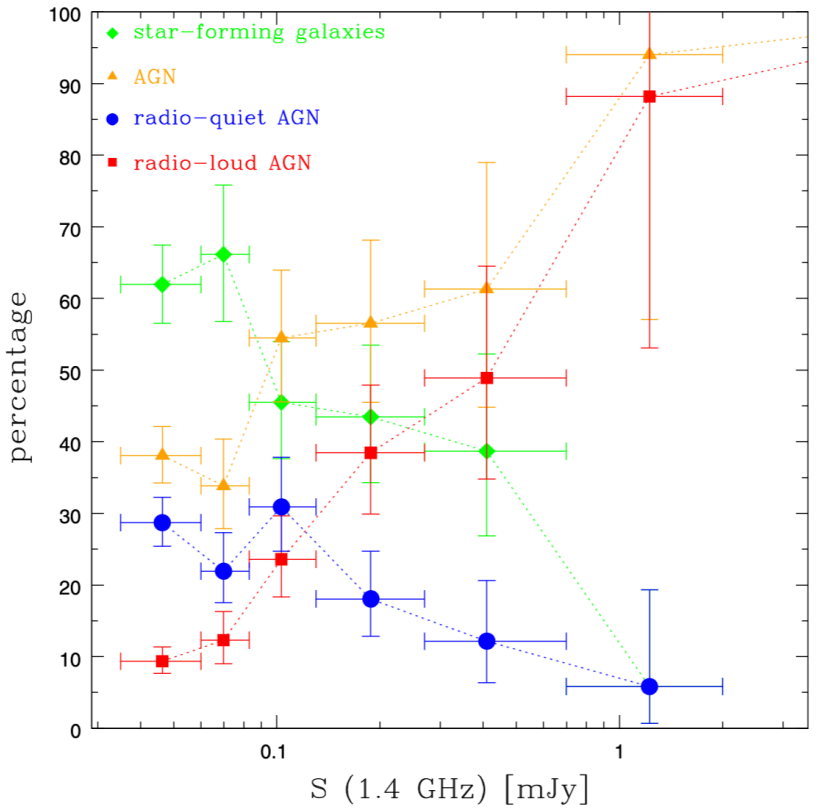


Fig. 8 Relative fractions (in percentage) of the various sub-classes of E-CDFS radio sources as a function of flux density: SFGs (*green diamonds*), all AGN (*orange triangles*), RQ AGN (*blue circles*), and RL AGN (*red squares*). Error bars correspond to 1σ Poisson errors (Gehrels 1986)

2015 – 2019: WISE High Synchrotron Peak (WHSP) Surveys

- WISE High Synchrotron Peak (WHSP) surveys [with P.G., Bruno Arsioli, Yu-Ling Chang, and others]



Bruno Arsioli



Yu-Ling Chang

2015 – 2019: WISE High Synchrotron Peak (WHSP) Surveys

- WISE H… …lth P.G., Bruno A…

A&A 579, A34 (2015)
DOI: 10.1051/0004-6361/201424148
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Astronomy & Astrophysics

1WHSP: An IR-based sample of ~1000 VHE γ-ray blazar candidates⋆

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Received 6 May 2014 / Accepted 1 April 2015

ABSTRACT

Context. Blazars are the dominant type of extragalactic sources at microwave and at γ-ray energies. In the most energetic part of the electromagnetic spectrum ($E \gtrsim 100$ GeV) a high fraction of high Galactic latitude sources are blazars of the high synchrotron peaked (HSP) type, that is BL Lac objects with synchrotron power peaking in the UV or in the X-ray band. Building new large samples of HSP blazars is key to understand the properties of jets under extreme conditions, and to study the demographics and the peculiar cosmological evolution of these sources.
Aims. High synchrotron peaked blazars are remarkably rare, with only a few hundreds of them expected to be above the sensitivity limits of currently available surveys, some of which include hundreds of millions of sources. To find these very uncommon objects, we have devised a method that combines ALLWISE survey data with multi-frequency selection criteria.
Methods. The sample was defined starting from a primary list of infrared colour–colour selected sources from the ALLWISE all sky survey database, and applying further restrictions on IR-radio and IR-X-ray flux ratios. Using a polynomial fit to the multi-frequency data (radio to X-ray), we estimated synchrotron peak frequencies and fluxes of each object.
Results. We assembled a sample including 992 sources, which is currently the largest existing list of confirmed and candidates HSP blazars. All objects are expected to radiate up to the highest γ-ray photon energies. In fact, 299 of these are confirmed emitters of GeV γ-ray photons (based on *Fermi*-LAT catalogues), and 36 have already been detected in the TeV band. The majority of sources in the sample are within reach of the upcoming Cherenkov Telescope Array (CTA), and many may be detectable even by the current generation of Cherenkov telescopes during flaring episodes. The sample includes 425 previously known blazars, 151 new identifications, and 416 HSP candidates (mostly faint sources) for which no optical spectra is available yet. The full 1WHSP catalogue is online at http://www.asdc.asi.it/1whsp/, providing a direct link to the SED building tool where multi-frequency data for each source can be easily visualised.

2015 – 2019: WISE High Synchrotron Peak (WHSP) Surveys

- WISE High… with P.G., Bruno Arsi…

A&A 632, A77 (2019)
https://doi.org/10.1051/0004-6361/201834526
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Astronomy & Astrophysics

The 3HSP catalogue of extreme and high-synchrotron peaked blazars★

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[4] Italian Space Agency, ASI, Via del Politecnico snc, 00133 Roma, Italy
[5] Institute for Advanced Study, Technische Universität München, Lichtenbergstrasse 2a, 85748 Garching bei München, Germany
[6] European Southern Observatory, Karl-Schwarzschild-Str. 2, 5748 Garching bei München, Germany
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Received 29 October 2018 / Accepted 13 September 2019

ABSTRACT

Aims. High-synchrotron peaked blazars (HSPs or HBLs) play a central role in very high-energy (VHE) γ-ray astronomy, and likely in neutrino astronomy. Currently, the largest compilation of HSP blazars, the 2WHSP sample, includes 1691 sources, but it is not complete in the radio or in the X-ray band. In order to provide a larger and more accurate set of HSP blazars that is useful for future statistical studies and to plan for VHE/TeV observations, we present the 3HSP catalogue, the largest sample of extreme and high-synchrotron peaked (EHSP; HSP) blazars and blazar candidates.

Methods. We implemented several ways to improve the size and the completeness of the 2WHSP catalogue and reduced the selection biases to be taken into consideration in population studies. By discarding the IR constraint and relaxing the radio–IR and IR–X-ray slope criteria, we were able to select more sources with $\nu_{\rm peak}$ close to the 10^{15} Hz threshold and objects where the host galaxy dominates the flux. The selection of extra sources now commences with a cross-matching between radio and X-ray surveys, applying a simple flux ratio cut. We also considered *Fermi*-LAT catalogues to find reasonable HSP-candidates that are detected in the γ-ray band but are not included in X-ray or radio source catalogues. The new method, and the use of newly available multi-frequency data, allowed us to add 395 sources to the sample, to remove 73 2WHSP sources that were previously flagged as uncertain and could not be confirmed as genuine HSP blazars, and to update parameters obtained by fitting the synchrotron component.

Results. The 3HSP catalogue includes 2013 sources, 88% of which with a redshift estimation, a much higher percentage than in any other list of HSP blazars. All new γ-ray detections are described in the First and Second Brazil ICRANet γ-ray blazar catalogues (1BIGB & 2BIGB) also taking into account the 4FGL list of γ-ray sources published by the *Fermi* Large Area Telescope (*Fermi*-LAT) team. Moreover, the cross-matching between the 2WHSP, 2FHL HSP, and IceCube neutrino positions suggests that HSPs are likely counterparts of neutrino events, which implies the 3HSP catalogue is also useful in that respect. The 3HSP catalogue shows improved completeness compared to its predecessors, the 1WHSP and 2WHSP catalogues, and follows the track of their increasing relevance for VHE astronomy.

2016 – 2023: AGN outflows

- SINFONI Survey for Unveiling the Physics and Effect of Radiative feedback (SUPER) collaboration [with Vincenzo Mainieri, Darshan Kakkad, Chiara Circosta, and many others]



Darshan Kakkad



Chiara Circosta

2016 – 2023: AGN outflows

- SINFONI Su
  Radiative fee
  Mainieri, Dar
  others]

A&A 620, A82 (2018)
https://doi.org/10.1051/0004-6361/201833520
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Astronomy & Astrophysics

SUPER

I. Toward an unbiased study of ionized outflows in z ~ 2 active galactic nuclei: survey overview and sample characterization★

C. Circosta[1,2], V. Mainieri[1], P. Padovani[1], G. Lanzuisi[3,4], M. Salvato[5,6], C. M. Harrison[1], D. Kakkad[1,2,7], A. Puglisi[8,9], G. Vietri[6,1], G. Zamorani[4], C. Cicone[10], B. Husemann[11], C. Vignali[3,4], B. Balmaverde[10], M. Bischetti[12,13], A. Bongiorno[12], M. Brusa[3,4], S. Carniani[14,15], F. Civano[16], A. Comastri[4], G. Cresci[17], C. Feruglio[18], F. Fiore[18], S. Fotopoulou[19], A. Karim[20], A. Lamastra[12,21], B. Magnelli[20], F. Mannucci[17], A. Marconi[22,17], A. Merloni[5], H. Netzer[23], M. Perna[17], E. Piconcelli[12], G. Rodighiero[24], E. Schinnerer[11], M. Schramm[25], A. Schulze[25], J. Silverman[26], and L. Zappacosta[12]

(Affiliations can be found after the references)

Received 28 May 2018 / Accepted 3 September 2018

ABSTRACT

Theoretical models of galaxy formation suggest that the presence of an active galactic nucleus (AGN) is required to regulate the growth of its host galaxy through feedback mechanisms, produced by, for example, AGN-driven outflows. Although many observational studies have revealed that such outflows are common both at low and high redshift, a comprehensive picture is still missing. In particular, the peak epoch of galaxy assembly ($1 < z < 3$) has been poorly explored so far, and current observations in this redshift range are mostly limited to targets with high chances to be in an outflowing phase. This paper introduces SUPER (a SINFONI Survey for Unveiling the Physics and Effect of Radiative feedback), an ongoing ESO's VLT/SINFONI Large Programme. SUPER will perform the first systematic investigation of ionized outflows in a sizeable and blindly-selected sample of 39 X-ray AGN at $z \sim 2$, which reaches high spatial resolutions (~2 kpc) thanks to the adaptive optics-assisted IFS observations. The outflow morphology and star formation in the host galaxy will be mapped through the broad component of [O III]λ5007 and the narrow component of Hα emission lines. The main aim of our survey is to infer the impact of outflows on the on-going star formation and to link the outflow properties to a number of AGN and host galaxy properties. We describe here the survey characteristics and goals, as well as the selection of the target sample. Moreover, we present a full characterization of its multi-wavelength properties: we measure, via spectral energy distribution fitting of UV-to-FIR photometry, stellar masses ($4 \times 10^9 - 2 \times 10^{11}\ M_\odot$), star formation rates ($25-680\ M_\odot\ \mathrm{yr}^{-1}$) and AGN bolometric luminosities ($2 \times 10^{44} - 8 \times 10^{47}\ \mathrm{erg\ s}^{-1}$), along with obscuring column densities (up to $2 \times 10^{24}\ \mathrm{cm}^{-2}$) and luminosities in the hard 2–10 keV band ($2 \times 10^{43} - 6 \times 10^{45}\ \mathrm{erg\ s}^{-1}$) derived through X-ray spectral analysis. Finally, we classify our AGN as jetted or non-jetted according to their radio and FIR emission.



Darshan Kakkad



Chiara Circosta

> 2014: the neutrino era

- Astrophysical counterparts of IceCube neutrino sources



Elisa Resconi

21/11/13 (Thursday)

16:15, Auditorium Telescopium (ESO HQE, Garching) | ESO Garching

Munich Joint Astronomy Colloquium

Talk — High energy neutrinos from the Cosmos? Recent results from the IceCube Neutrino Telescope

Elisa Resconi

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> 2014: the neutrino era

- Astrophysical c
  sources

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MNRAS **443,** 474–484 (2014) doi:10.1093/mnras/stu1166

Are both BL Lacs and pulsar wind nebulae the astrophysical counterparts of IceCube neutrino events?

P. Padovani[1]★ and E. Resconi[2]

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[2]*Technische Universität München, James-Frank-Str. 1, D-85748 Garching bei München, Germany*

Accepted 2014 June 10. Received 2014 June 10; in original form 2014 May 28

ABSTRACT

IceCube has recently reported the discovery of high-energy neutrinos of astrophysical origin, opening up the PeV (10^{15} eV) sky. Because of their large positional uncertainties, these events have not yet been associated to any astrophysical source. We have found plausible astronomical counterparts in the GeV–TeV bands by looking for sources in the available large area high-energy γ-ray catalogues within the error circles of the IceCube events. We then built the spectral energy distribution of these sources and compared it with the energy and flux of the corresponding neutrino. Likely counterparts include mostly BL Lacs and two Galactic pulsar wind nebulae. On the one hand many objects, including the starburst galaxy NGC 253 and Centaurus A, despite being spatially coincident with neutrino events, are too weak to be reconciled with the neutrino flux. On the other hand, various GeV powerful objects cannot be assessed as possible counterparts due to their lack of TeV data. The definitive association between high-energy astrophysical neutrinos and our candidates will be significantly helped by new TeV observations, but will be confirmed or disproved only by further IceCube data. Either way, this will have momentous implications for blazar jets, high-energy astrophysics, and cosmic ray and neutrino astronomy.

Key words: neutrinos – radiation mechanisms: non-thermal – pulsars: general – BL Lacertae objects: general – gamma-rays: galaxies.



Elisa Resconi

The neutrino era: neutrino Astronomy

- Astrophysical counterparts of IceCube neutrino sources [with Elisa Resconi, Paolo Giommi, Andrea Turcati, Theo Glauch, Martin Huber, Bruno Arsoli, Yu-Ling Chang, Foteini Oikonomou, Martina Karl, Chiara Bellenghi, Roberto Gilli]



Theo Glauch



Roberto Gilli



Chiara Bellenghi



Martina Karl



Foteini Oikonomou



Andrea Turcati

The neutrino era: lepto-hadronic modelling

- Theoretical modelling of neutrino source candidates [with Foteini Oikonomou, Maria Petropoulou, Narek Sahakyan, Xavier Rodrigues, Frank Rieger, Elisa Resconi, Paolo Giommi]



Frank Rieger



Xavier Rodrigues



Narek Sahakyan



Maria Petropoulou

The neutrino era: optical identification and spectra

- Identification and spectra of neutrino source candidates [with Simona Paiano, Renato Falomo, Aldo Treves, Alberto Ulgiati, Elisa Resconi, Paolo Giommi]



Alberto Ulgiati



Simona Paiano & Renato Falomo

ESO, the GTC, and the LBT meet IceCube: the SIN project

- The Spectra of IceCube Neutrinos (SIN) sources: redshift and characterization of the Giommi et al. (2020) sample



ESO VLT



Gran Telescopio CANARIAS



Large Binocular Telescope

ESO, the GTC, and the LBT meet IceCube: the SIN project

- The Spectra o ft and characterizatio



ESO VLT

1 ☐ 2021MNRAS.504.3338P 2021/07 cited: 16
The spectra of IceCube neutrino candidate sources - I. Optical spectroscopy of blazars
Paiano, Simona; Falomo, Renato; Treves, Aldo; Padovani, Paolo; Giommi, Paolo; Scarpa, Riccardo *show less*

2 ☐ 2022MNRAS.510.2671P 2022/02 cited: 32
The spectra of IceCube neutrino (SIN) candidate sources - II. Source characterization
Padovani, P.; Giommi, P.; Falomo, R.; Oikonomou, F.; Petropoulou, M.; Glauch, T.; Resconi, E.; Treves, A.; Paiano, S. *show less*

3 ☐ 2023MNRAS.521.2270P 2023/05 cited: 16
The spectra of IceCube Neutrino (SIN) candidate sources - III. Optical spectroscopy and source characterization of the full sample
Paiano, Simona; Falomo, Renato; Treves, Aldo; Padovani, Paolo; Giommi, Paolo; Scarpa, Riccardo; Bisogni, Susanna; Marini, Ester *show less*

4 ☐ 2023MNRAS.526..661K 2023/11 cited: 5
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Karl, Martina; Padovani, Paolo; Giommi, Paolo

5 ☐ 2024A&A...689A.147R 2024/09 cited: 16
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Rodrigues, X.; Karl, M.; Padovani, P.; Giommi, P.; Paiano, S.; Falomo, R.; Petropoulou, M.; Oikonomou, F. *show less*



Binocular Telescope

ESO, the GTC, and the LBT meet IceCube: the SIN project

- The Spectra of Ic dshift and characterization o



ESO VLT

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS **510,** 2671–2688 (2022) https://doi.org/10.1093/mnras/stab3630
Advance Access publication 2021 December 13

The spectra of IceCube neutrino (SIN) candidate sources – II. Source characterization

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ABSTRACT

Eight years after the first detection of high-energy astrophysical neutrinos by IceCube, we are still almost clueless as regards to their origin, although the case for blazars being neutrino sources is getting stronger. After the first significant association at the 3–3.5 σ level in time and space with IceCube neutrinos, i.e. the blazar TXS 0506+056 at $z = 0.3365$, some of us have in fact selected a unique sample of 47 blazars, out of which ∼16 could be associated with individual neutrino track events detected by IceCube. Building upon our recent spectroscopy work on these objects, here we characterize them to determine their real nature and check if they are different from the rest of the blazar population. For the first time we also present a systematic study of the frequency of masquerading BL Lacs, i.e. flat-spectrum radio quasars with their broad lines swamped by non-thermal jet emission, in a γ-ray- and IceCube-selected sample, finding a fraction >24 per cent and possibly as high as 80 per cent. In terms of their broad-band properties, our sources appear to be indistinguishable from the rest of the blazar population. We also discuss two theoretical scenarios for neutrino emission, one in which neutrinos are produced in interactions of protons with jet photons and one in which the target photons are from the broad-line region. Both scenarios can equally account for the neutrino–blazar correlation observed by some of us. Future observations with neutrino telescopes and X-ray satellites will test them out.

Key words: neutrinos – radiation mechanisms: non-thermal – galaxies: active – BL Lacertae objects: general – gamma-rays: galaxies.



Large Binocular Telescope

Blazar-boosted dark matter

Setting limits on blazar-boosted dark matter with xenon-based detectors

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(Received 8 September 2025; accepted 17 December 2025; published 5 January 2026)

Dual-phase xenon time projection chambers achieve optimal sensitivity for dark matter in the 10 to 1000 GeVc^{-2} mass range, but sub-GeV dark matter (DM) particles lack sufficient energy to produce nuclear recoils above detection thresholds in these detectors. Blazar-boosted dark matter offers a way to overcome this limitation. Relativistic jets in active galactic nuclei can accelerate light dark matter in their host-galaxy halos to energies that can leave detectable nuclear recoil signals in xenon-based detectors on Earth. We present the first blazar-boosted dark matter search that incorporates detector response modeling, using public data from XENON1T and LZ for the blazar TXS 0506 + 056. We model dark matter-proton scattering in the jet environment, covering the full process from jet acceleration through to detector response. We explore how the host galaxy dark matter density profile impacts our analysis. We set model-dependent exclusion regions on the dark-matter–nucleon scattering cross section for $m_\chi \simeq 1$ MeVc^{-2} dark matter, between 5.8×10^{-31} cm^2 and 6.3×10^{-29} cm^2 using XENON1T data, and between 9.9×10^{-32} cm^2 and 2.5×10^{-28} cm^2 from LZ effective field theory dark matter searches. Our results show that astrophysical uncertainties, especially those in the dark-matter distribution near the supermassive black hole, are the main limitation of this search rather than detector effects. The limits are therefore model-dependent and should be seen as exploratory. They highlight both the potential and the present uncertainties of blazar-boosted dark matter as a probe of light dark matter.



Laura Manenti



Isaac Sarnoff



Francesco Arneodo

Cosmic rays

Exploring Cosmic Rays from Gravity-Limited Acceleration at Supermassive Black Holes

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[6] *Max-Planck-Institute for Physics, Boltzmannstr. 8, 85748 Garching bei München, Germany*

We show that horizon-scale magnetic fields around supermassive black holes (SMBHs), only limited by gravity, yield a universal, model-independent ceiling on electromagnetic energy density. For rotating SMBHs, this field enables particle acceleration up to $\sim 10^{27}$ eV set solely by fundamental constants. We identify a parameter space in accretion rate and magnetic field strength in which quiescent nuclei simultaneously satisfy the transparency conditions for Ultra-High-Energy Cosmic Rays (UHECR) escape and the field requirements for reaching Ultra-High Energies (UHE), naturally complementing photon-rich Active Galactic Nuclei (AGN), which favor neutrino production but suppress UHECR escape. We observe that, when including curvature energy losses, the energy of the primaries scales weakly as $E_{\rm curv} \propto M^{1/4}$ and allows to achieve UHE across different compositions and SMBHs masses (10^6–$10^{10}\,M_\odot$), without requiring extreme spins or super-Eddington accretion. A cross-correlation of the Pierre Auger Observatory (PAO) public data with galaxies hosting reliably measured SMBH masses, separating AGN from quiescent hosts, reveals marginal local excesses ($\lesssim 2.8\sigma$) consistent with isotropy after correcting for the look-elsewhere effect. The framework provides a direct link between black-hole physics and the maximum energies of cosmic particles, and defines concrete observational tests for next-generation UHECR datasets.



Elena Manao

Review papers

- *Unified Schemes for Radio-Loud Active Galactic Nuclei,* C. M. Urry & P. Padovani, 1995
- *The faint radio sky: radio astronomy becomes mainstream,* P. Padovani, 2016
- *Active galactic nuclei: what's in a name?,* P. Padovani, D. M. Alexander, R. J. Assef, B. De Marco, P. Giommi, R. C. Hickox, G. T. Richards, V. Smolčić, E. Hatziminaoglou, V. Mainieri, M. Salvato, 2017
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- *Astrophysical Neutrinos and Blazars,* P. Giommi & P. Padovani, 2021
- *Active Galactic Nuclei and Their Demography Through Cosmic Time,* S. Bianchi, V. Mainieri, P. Padovani, 2022
- *High-energy neutrinos from the vicinity of the supermassive black hole in NGC 1068*, P. Padovani, E. Resconi, M. Ajello, C. Bellenghi, S. Bianchi, P. Blasi, K.-Y., Huang, S. Gabici, V. Gámez Rosas, H. Niederhausen, E. Peretti, B. Eichmann, D. Guetta, A. Lamastra, T. Shimizu, 2024

Review papers

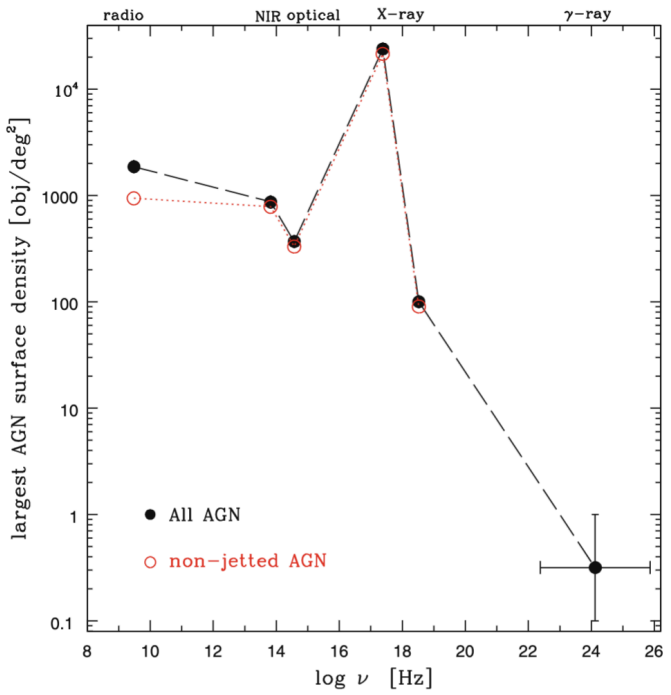


Fig. 2 The largest observed AGN surface density by surveys over the whole electromagnetic spectrum. Black-filled points refer to all AGN, and open red points are for non-jetted AGN. The latter are actually directly measured only in the radio band, while in the NIR to X-ray bands, they have been derived by simply subtracting 10% from the total values. Non-jetted AGN have not been detected in the γ-ray band. Figure updated from Padovani (2016), Fig. 11, and Padovani et al. (2017), Fig. 21, where one can find the references to the relevant samples and facilities, to include new radio (Delvecchio et al., 2017, and V. Smolčić, private communication) and γ-ray results (Marcotulli et al., 2020). The γ-ray point is the mean of the two values shown in Fig. 6, bottom, of the latter reference, which refer to photon and energy fluxes

What have we learnt?

AGN: 40 YEARS OF DISCOVERY – FROM MYSTERY TO MULTI-MESSENGER PHYSICS

From the first ideas to a unified, multi-wavelength, multi-messenger understanding

1980s
The foundations

- AGN as extreme energy sources
- Accretion onto supermassive BHs
- Radio jets and lobes discovered

1990s
Building the unification

- AGN Unified Model
- Broad & narrow lines
- Obscuration by a torus
- Host galaxy links

2000s
Going deeper

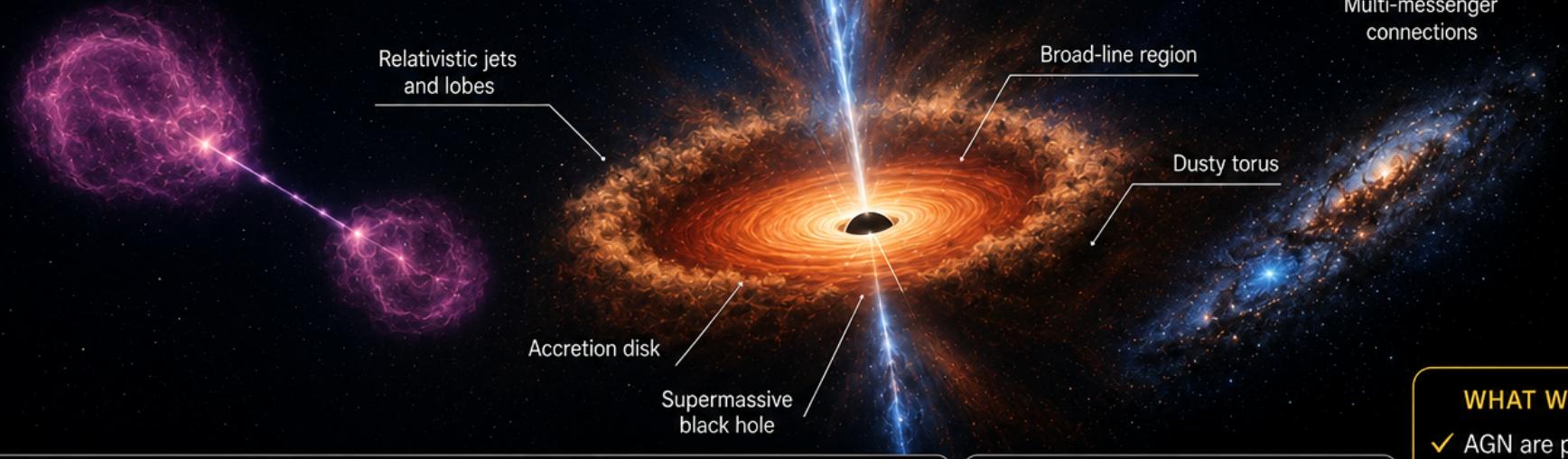
- Black hole mass measurements
- X-ray view of accretion & obscuration
- Blazars and jets at all wavelengths

2010s
A new, connected view

- Time-domain AGN
- Jet physics and feedback
- Population studies and cosmological evolution

2020s
Multi-messenger era

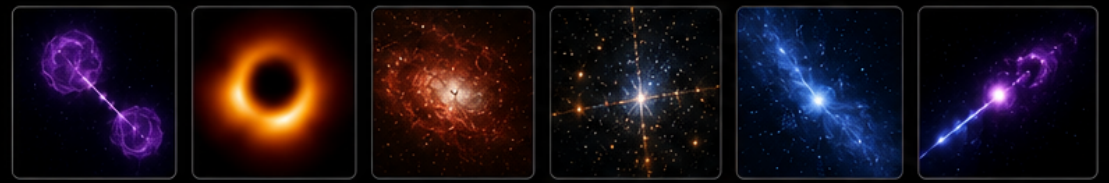
- Neutrinos from AGN
- Gravitational waves + EM counterparts
- High-resolution imaging (EHT)
- Multi-messenger connections



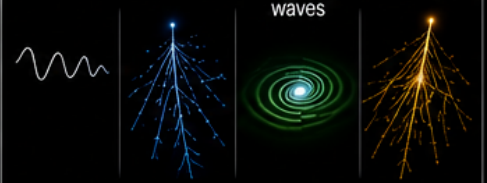
WHERE WE ARE

- SMBH growth and co-evolution with galaxies
- Accretion physics across regimes
- Jets as particle accelerators
- AGN as cosmic laboratories
- Open questions and new frontiers

THE MULTI-WAVELENGTH VIEW



THE MULTI-MESSENGER VIEW



WHAT WE HAVE LEARNT

- ✓ AGN are powered by accretion onto supermassive black holes
- ✓ They come in many faces, but are fundamentally connected
- ✓ They shape their host galaxies and the cosmos
- ✓ They are engines of extreme physics and particle acceleration

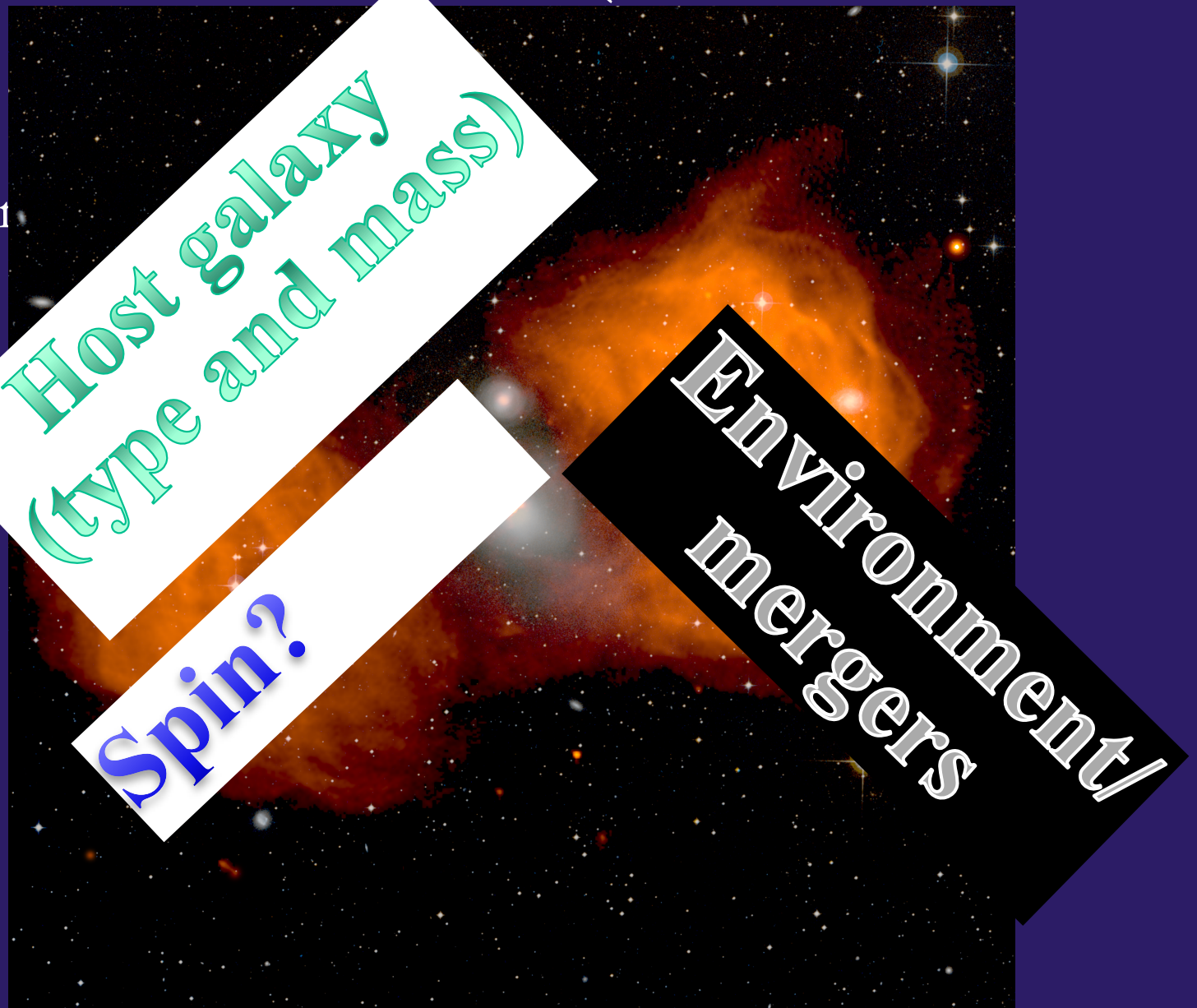
From isolated discoveries to a coherent picture AGN as engines of cosmic evolution

What we still do not know (biased and incomplete)

- Why do a minority of AGN have jets?

What we still do not know (biased and incomplete)

- Why do a mi

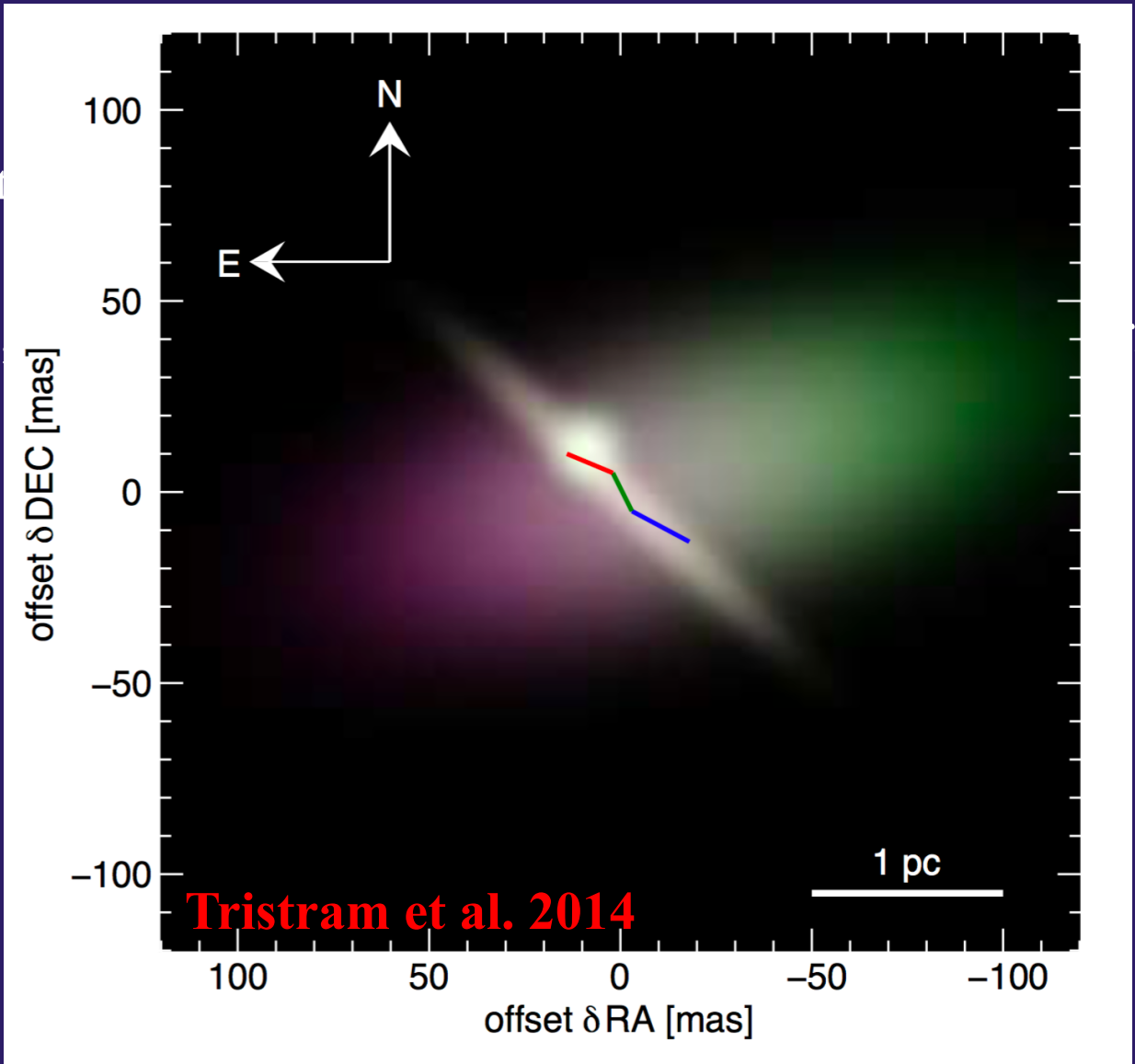


What we still do not know (biased and incomplete)

- Why do a minority of AGN have jets?
- Composition, geometry, and morphology of the obscuring dust

What we still do not know (biased and incomplete)

- Why do a mi
- Composition ing dust



What we still do not know (biased and incomplete)

- W
- C

The Astrophysical Journal, 884:171 (13pp), 2019 October 20 https://doi.org/10.3847/1538-4357/ab4591
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Redefining the Torus: A Unifying View of AGNs in the Infrared and Submillimeter

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Received 2019 August 2; revised 2019 September 12; accepted 2019 September 16; published 2019 October 23

Abstract

The advent of high-angular-resolution IR and submillimeter interferometry allows for spatially resolved observations of the parsec-scale environment of active galactic nuclei (AGNs), commonly referred to as the "torus." While molecular lines show the presence of large, massive disks, the IR observations appear to be dominated by a strong polar component that has been interpreted as a dusty wind. This paper aims at using characteristics shared by AGNs in each of the wavebands and a set of simple physical principles to form a unifying view of these seemingly contradictory observations: dusty molecular gas flows in from galactic scales of $\sim$100 pc to the subparsec environment via a disk with small to moderate scale height. The hot, inner part of the disk puffs up due to IR radiation pressure and unbinds a large amount of the inflowing gas from the black hole's gravitational potential, providing the conditions to launch a wind driven by the radiation pressure from the AGN. The dusty wind feeds back mass into the galaxy at a rate of the order of $\sim$0.1–100 $M_\odot$ yr^{-1}, depending on the AGN luminosity and Eddington ratio. Angle-dependent obscuration as required by AGN unification is provided by a combination of disk, wind, and wind-launching region.

Unified Astronomy Thesaurus concepts: Active galaxies (17); Quasars (1319); Active galactic nuclei (16); Infrared astronomy (786); Submillimeter astronomy (1647); Optical interferometry (1168)

What we still do not know (biased and incomplete)

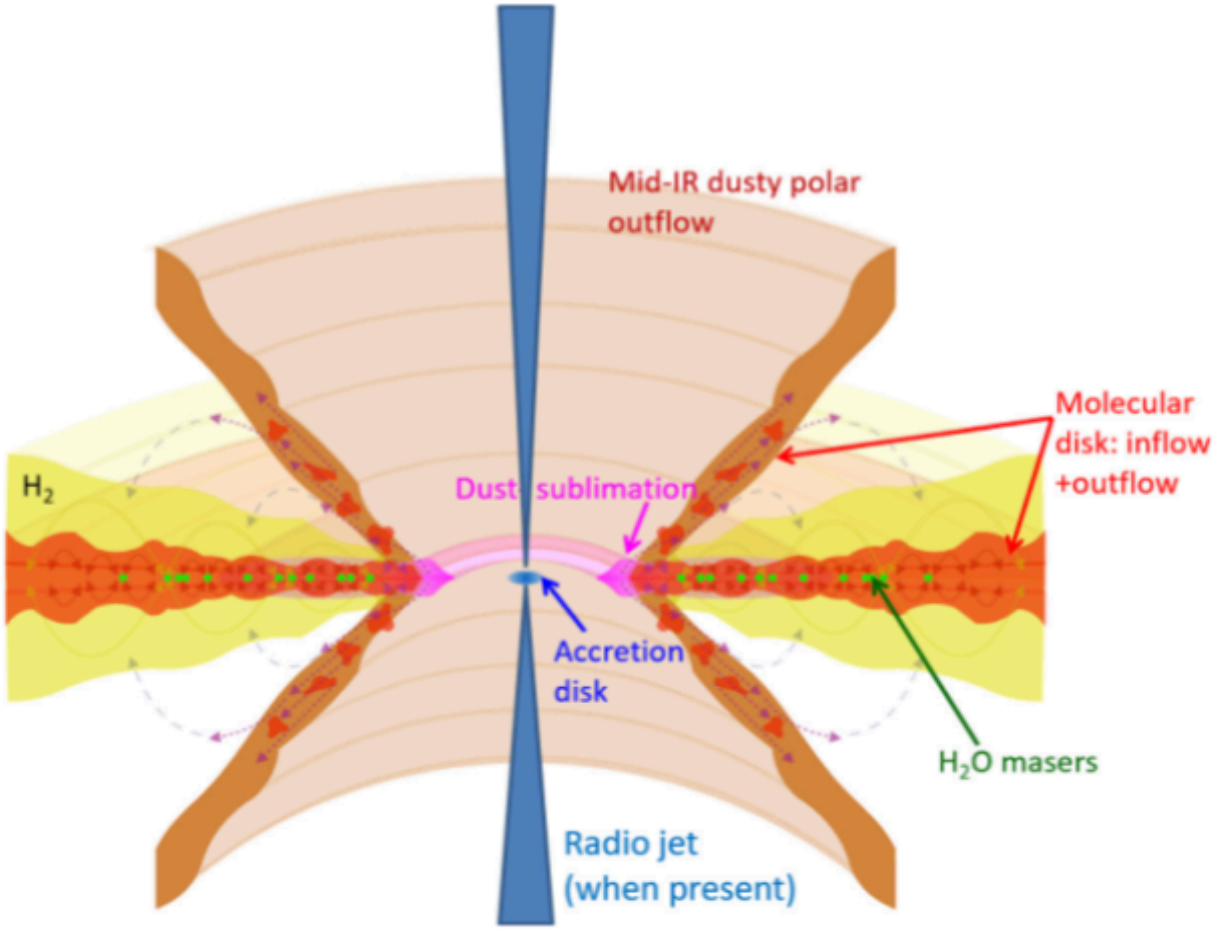


Fig. 10. Schematic view of the circum-nuclear environment of the SMBH, with the radio jet, the molecular circum-nuclear disk, or molecular torus, the hollow dusty polar cone shaped by the AGN wind, and molecular outflows tracing the cone. In some nearby AGN, the circum-nuclear disk contains H_2O maser emission. The density of the disk is expected to decrease exponentially with radius and height.
Source: Adapted from Fig. 4 of Hönig (2019).

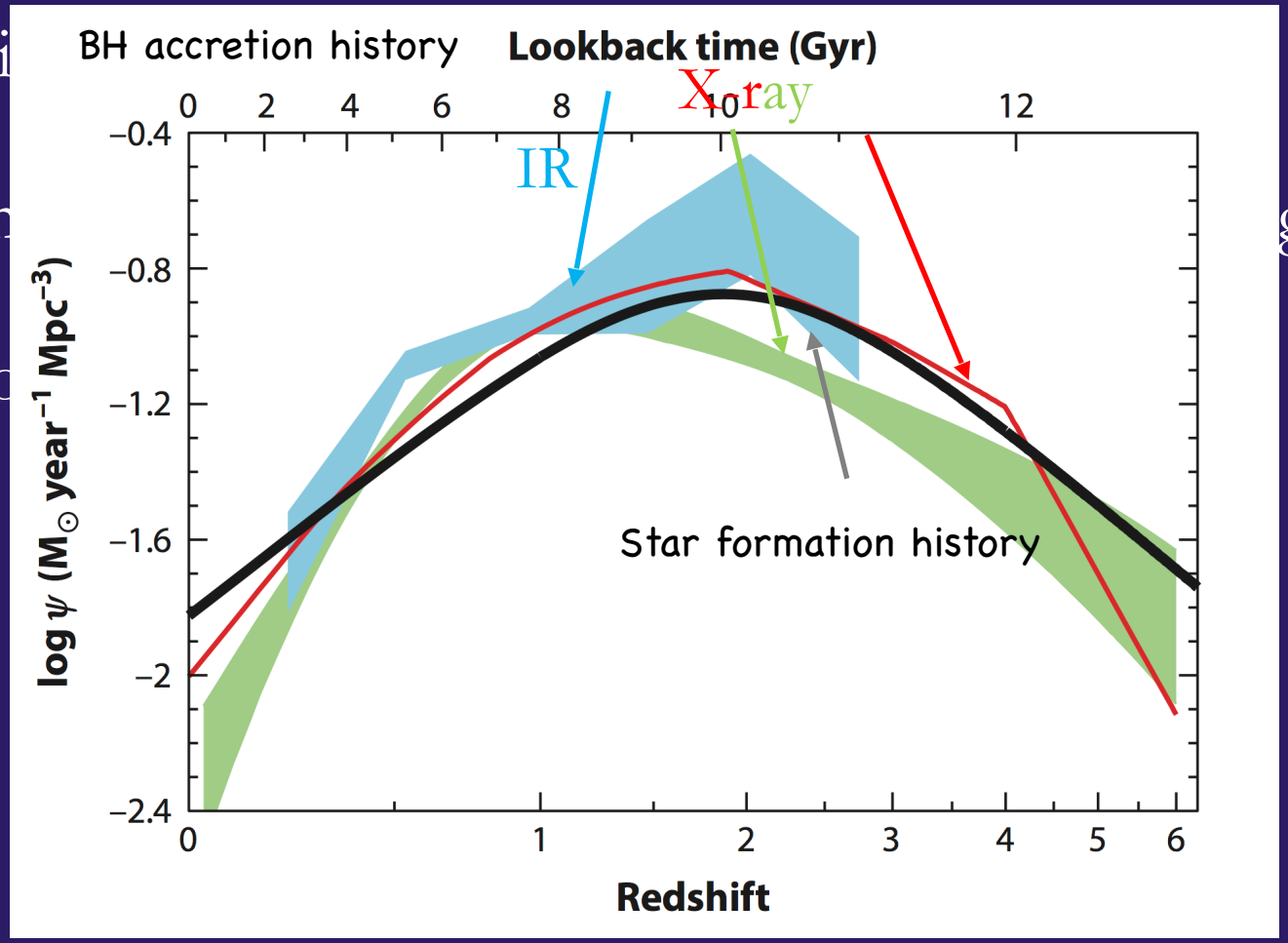
What we still do not know (biased and incomplete)

- Why do a minority of AGN have jets?
- Composition, geometry, and morphology of the obscuring dust
- AGN and host galaxy co-evolution

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- Why do a mi
- Composition
- AGN and ho

g dust



Madau & Dickinson (2014)

What we still do not know (biased and incomplete)

- Why do a minority of AGN have jets?
- Composition, geometry, and morphology of the obscuring dust
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- What is the geometry of the corona?

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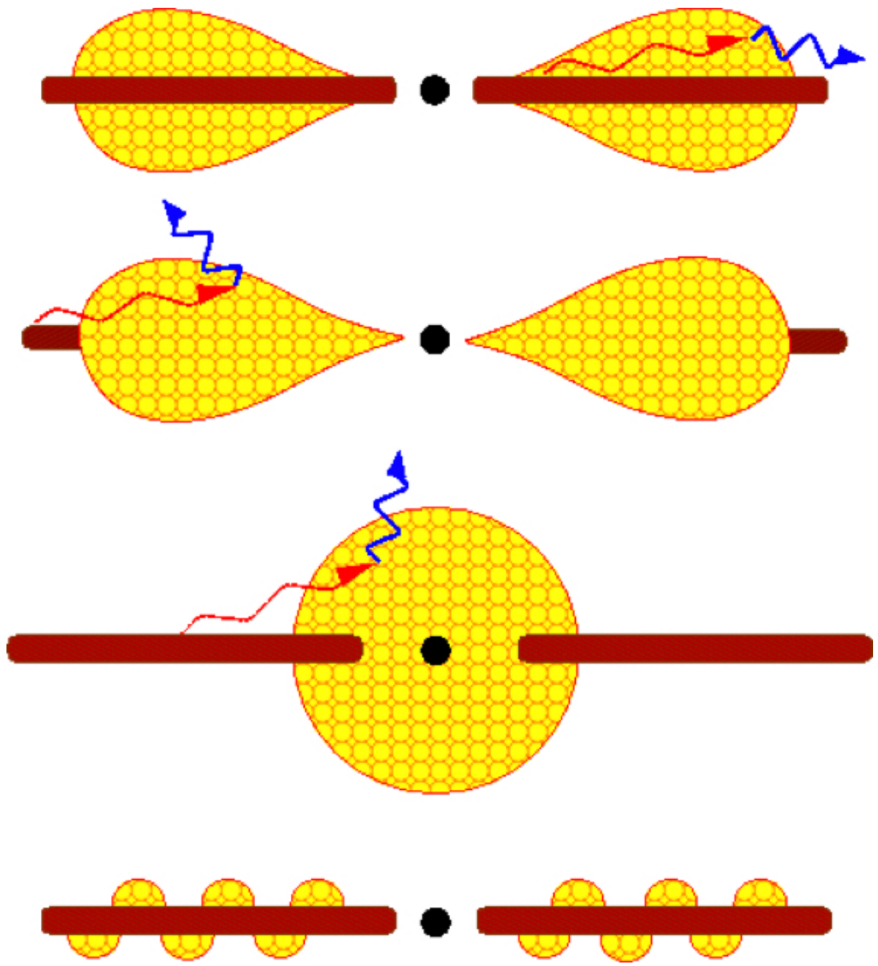


Figure 10: Various possible (in principle) disc-coronal structures. [*Courtesy: Chris Done.*]

Lasota (2023)

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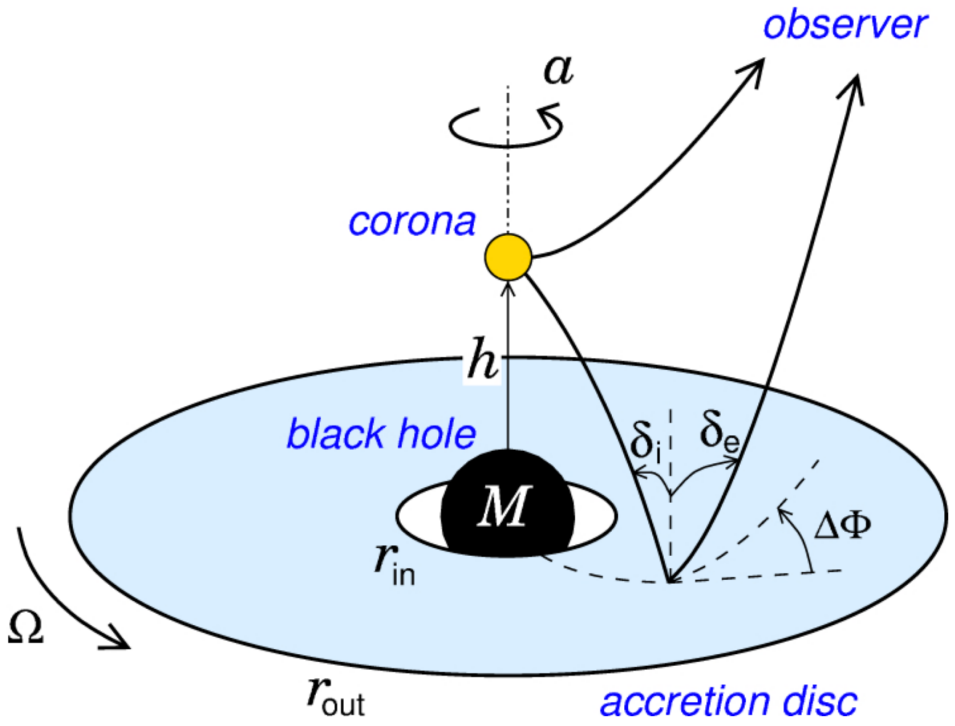


Figure 11: A scheme representing the lamppost "coronal" model. The feature called "corona" is the lamppost in question. [*From Caballero-Garcia et al. (2019).*]

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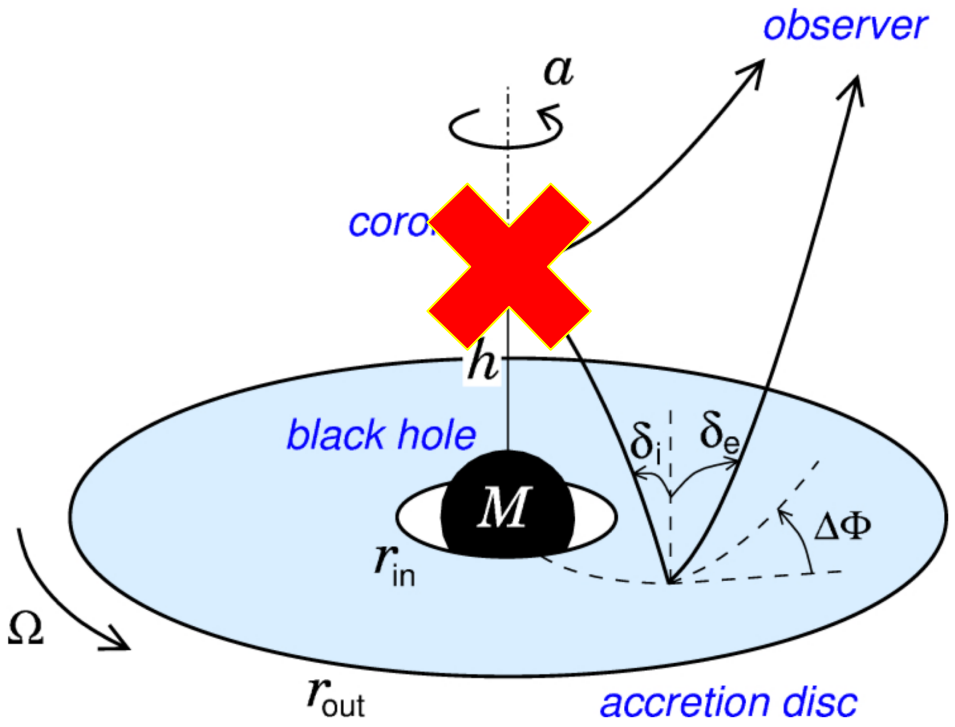


Figure 11: A scheme representing the lamppost "coronal" model. The feature called "corona" is the lamppost in question. [*From Caballero-Garcia et al. (2019).*]

Lasota (2023)

What we still do not know (biased and incomplete)

- Are AGN multi-messenger emitters?
- If so, why only some classes? and which ones?
- What accelerates particles in AGN (shocks, magnetic reconnection, shear, magnetosphere of rotating region, …)?
- And do not mention Little Red Dots …. 😡

Maybe this makes sense?

The greater the sphere of our knowledge, the larger is the surface of its contact with the infinity of our ignorance*

* Anonymous quotation in *A Short History of Astronomy*, A. Berry (New York, Dover)

And finally …



- **Move around and talk to people: the more colleagues you'll meet the more ideas you'll have**

And finally …

Success is dangerous. One begins to copy oneself, and to copy oneself is more dangerous than to copy others. It leads to sterility (Pablo Picasso)

And finally …



- Move around and talk to people: the more colleagues you'll meet the more ideas you'll have



- Change topic every now and then; start from scratch



- Don't publish too much: use the time you save to think



- Have fun!