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No new observations, no new theories, enduring scientific value

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Unlike most highly cited papers, Kühr et al. (1981) presents no new observations or astrophysical theories. It contains "only" published and unpublished data on the 518 radio sources stronger than $S = 1$ Jy at $\nu \approx 5$ GHz over the whole sky with $|b| > 10°$, along with radio continuum spectra, accurate positions, and optical identifications where available. For many years Kühr et al. (1981) has been the definitive catalog of strong sources selected at centimeter wavelengths, where flat- and steep-spectrum sources appear in roughly equal numbers. Its enduring value lies in the research it enables.

The radio sky was originally explored at much lower frequencies, and the leading source catalog was the revised 3C (Bennett 1962) complete to 9 Jy at 178 MHz. Nearly all 3C sources have the "steep" spectral indices $\alpha \equiv \mathrm{d}\ln S/\mathrm{d}\ln\nu \sim -0.8$ characteristic of optically thin synchrotron radiation from extended regions, but a few (e.g., 3C 84, 3C 120, 3C 273, and 3C 454.3) have relatively "flat" ($\alpha \sim 0$) or "inverted" ($\alpha > 0$) spectra indicating synchrotron self-absorption in bright ($T \sim 10^{11}$ K) compact components. Kellermann et al. (1968) demonstrated that surveys at higher frequencies yield statistically useful numbers $N \gg \sqrt{N}$ of flat-spectrum sources. It is difficult to observe the whole sky at high frequencies because the field-of-view of a telescope is proportional to ν^{-2}, but a decade-long series of surveys made at $\nu = 2.7$ GHz with the Parkes telescope in the southern hemisphere and at $\nu = 5$ GHz with the NRAO 140-foot and MPIfR 100 m telescopes in the northern hemisphere finally covered the extragalactic sky in 1980.

Kühr et al. (1981) added value to these surveys by (1) gathering all of the relevant radio and optical data scattered across many publications into a single easy-to-use catalog, (2) rescaling the disparate flux densities to bring them onto the Baars et al. (1977) scale, and (3) selecting the 518 extragalactic sources that are stronger than 1 Jy at 5 GHz. This realized the primary goal of today's electronic International Virtual Observatory Alliance: "By providing the tools to assemble and explore massive data sets quickly, the VO will facilitate and enable a broad range of science. It will make practical studies which otherwise would require so much time and resources that they would be effectively impossible" (Hanisch & Quinn 2002).

Which studies have been made practical by the strong flat-spectrum radio sources listed in Kühr et al. (1981)?

The population of strong flat-spectrum radio sources is dominated by blazars, highly variable quasars, and BL Lac objects at cosmological distances. Many contain radio components that appear to move faster than the speed of light in projection onto the sky (Kellermann et al. 2004; Britzen et al. 2007), implying relativistic motions toward the observer. Statistical studies used sources in the Kühr et al. (1981) sample to test and refine "unified schemes" that attribute observed differences among blazars and other active galactic nuclei to relativistic beaming and absorption effects that depend on source orientation relative to the line of sight (Fossati et al. 1998). Most known gigahertz peaked-spectrum (GPS) sources are compact doubles found in the Kühr et al. (1981) catalog. They appear to be extremely young radio sources that will evolve to become classical FR I radio galaxies (O'Dea 1998). Most of the strong extragalactic γ-ray sources discovered by EGRET can be identified with radio-loud blazars (von Montigny et al. 1995).

Strong flat-spectrum radio sources can also be valuable tools. They provide the best available astrometric standards. The realization of the International Celestial Reference Frame (Ma et al. 1998, ICRF) by very long baseline interferometry (VLBI) is based on strong flat-spectrum sources spread around the sky (Argue et al. 1984), most of which are listed in Kühr et al. (1981). These sources are (1) very compact, so they can be detected by interferometers having milliarcsecond angular resolution; (2) extremely distant, so they define a very stable inertial frame; and (3) optically bright and compact (Stickel et al. 1994), so they can be tied to optical reference frames. Similarly, VLBI observations of ICRF sources realize the International Terrestrial Reference Frame (IRTF) used to study tectonic-plate motions, interactions between the Earth's core and mantle, "post glacial" vertical rebound, and Earth rotation and wobble. Strong flat-spectrum quasars are the brightest beacons against which redshifted neutral hydrogen can often be detected (Carilli et al. 1998). The intraday "flicker" of some flat-spectrum sources is scintillation and can be used to study the interstellar medium of our Galaxy (Lovell et al. 2003).

Flat-spectrum sources are the largest foreground-contaminating, angular power spectrum measurements of the cosmic microwave background on small scales. A 1 Jy source produces a $T \sim 200$ μK brightness fluctuation in Wilkinson Microwave Anisotropy Probe (WMAP) images. Areas surrounding sources likely to be strong at WMAP frequencies (22–90 GHz) must be masked to minimize source contamination, and the Kühr et al. (1981) catalog contains most

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of those sources. The median spectral index of sources detected by WMAP is $\langle\alpha\rangle \approx -0.09$, and there is no evidence of any new population of inverted-spectrum sources emerging in the WMAP frequency range (Wright et al. 2009). Consequently, higher-frequency radio surveys do not add significantly to the source population found at 5 GHz, so the Kühr et al. (1981) sample, as updated in Stickel et al. (1994), is likely to remain the standard for years to come.

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