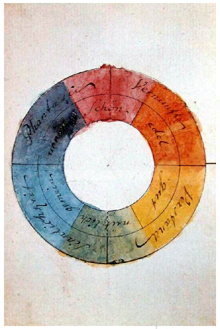
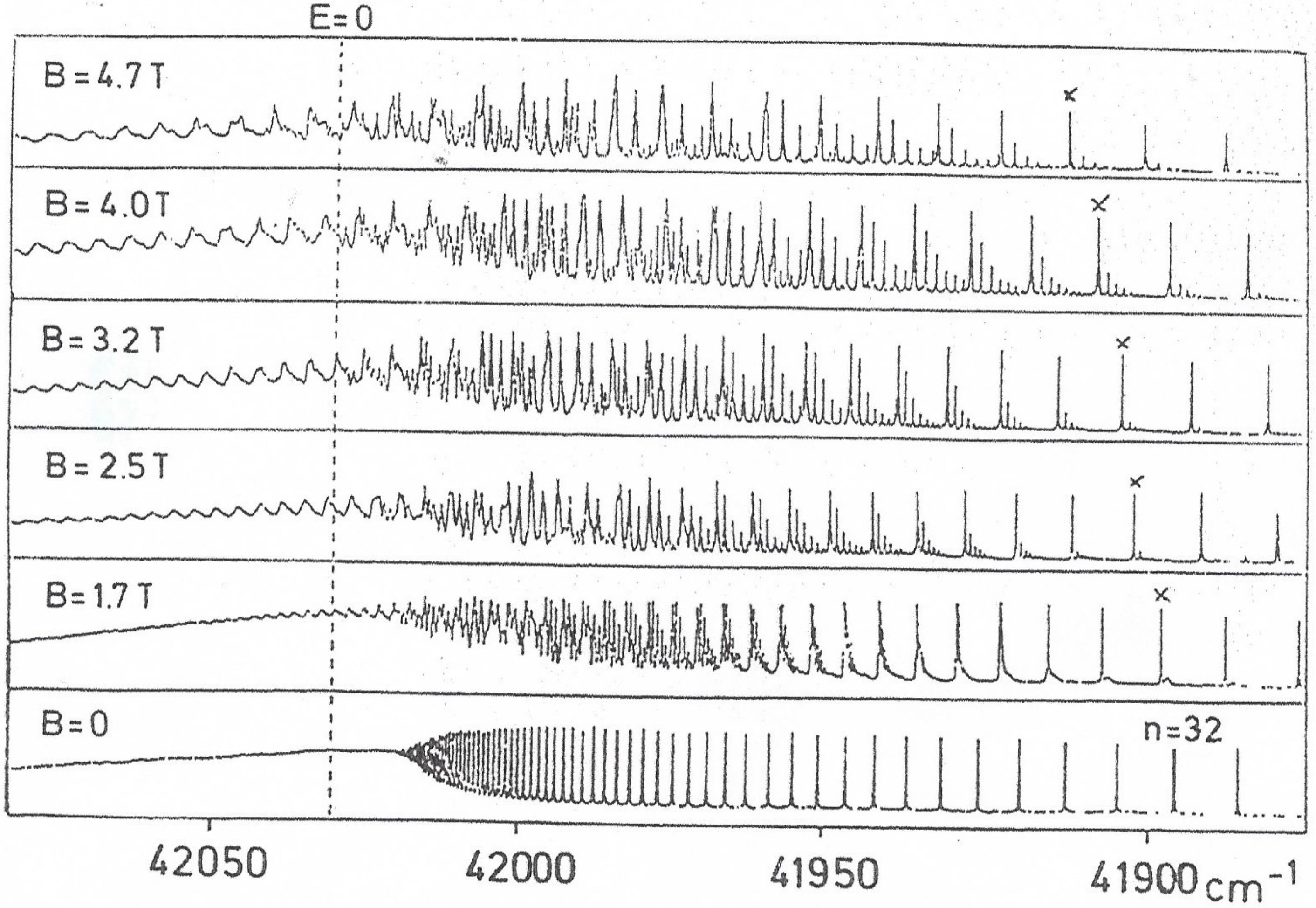
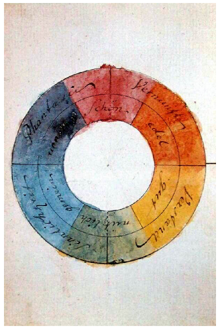


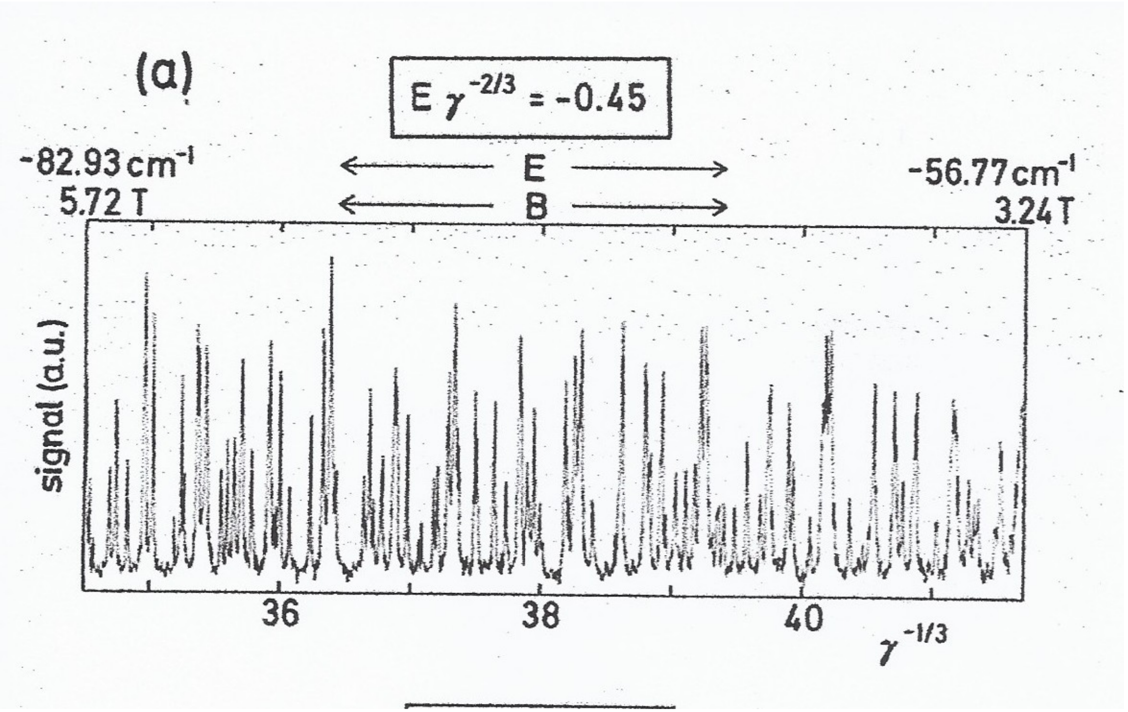
Spektren und Bahnen: Wasserstoff im Magnetfeld

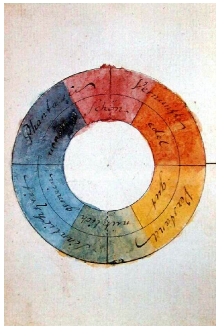


Garton, Tomkins, Astrophys. J. 158, 839 (1969)

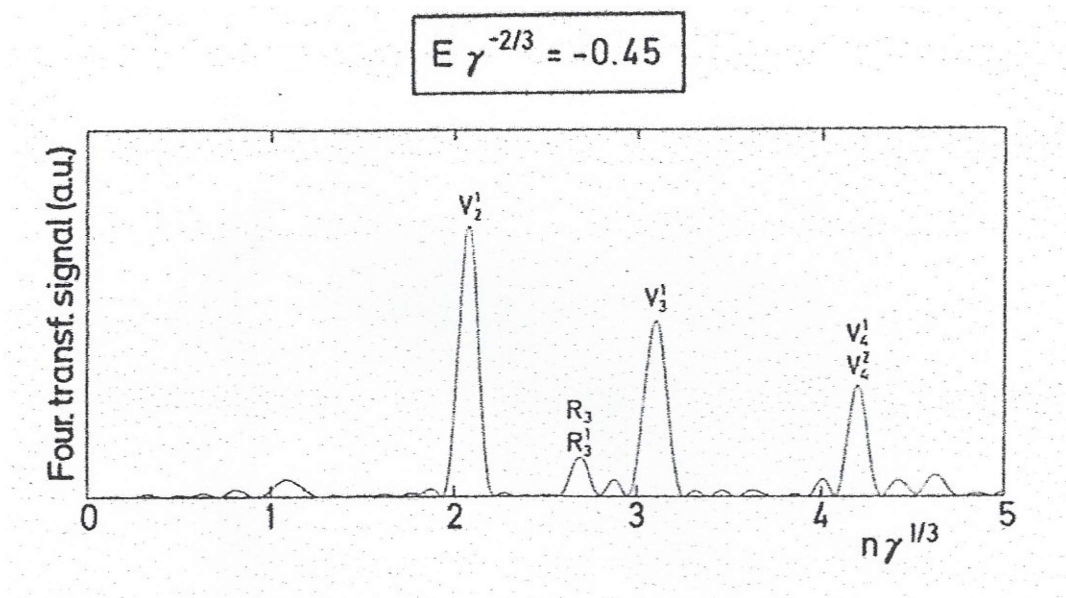


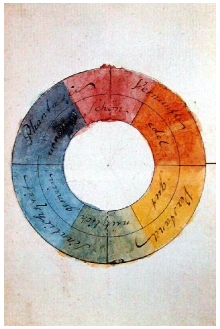
Spektren und Bahnen: Wasserstoff im Magnetfeld





Spektren und Bahnen: Wasserstoff im Magnetfeld





Spektren und Bahnen: Wasserstoff im Magnetfeld

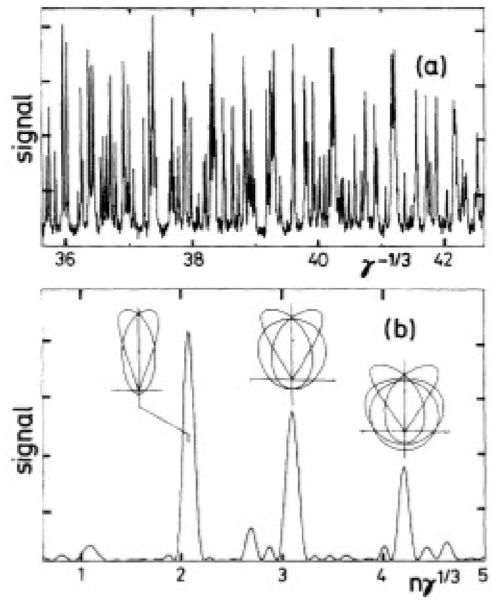
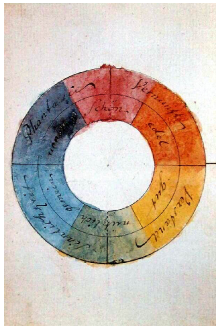


FIG. 1. (a) Scaled-energy spectrum at $\tilde{E} = -0.45$ as a function of $\gamma^{-1/3}$. Range of excitation energy $-77.7\ \mathrm{cm}^{-1} \le E \le -54.3\ \mathrm{cm}^{-1}$ and field strength $5.19 \ge B \ge 3.03$ T. (b) Fourier-transformed action spectrum of (a); closed orbits correlated to respective resonances in (ρ,z) projection; z coordinate vertically.



Spektren und Bahnen: Wasserstoff im Magnetfeld

VOLUME 61, NUMBER 2 PHYSICAL REVIEW LETTERS 11 JULY 1988

Quasi-Landau Spectrum of the Chaotic Diamagnetic Hydrogen Atom

A. Holle, J. Main, G. Wiebusch, H. Rottke, and K. H. Welge
Fakultät für Physik, Universität Bielefeld, D-4800 Bielefeld 1, Federal Republic of Germany
(Received 28 September 1987)

By the employment of "constant–scaled-energy spectroscopy" as a novel spectroscopic technique, the quasi-Landau resonance system of the diamagnetic H atom in even-partity $m=0$ magnetic final states is observed for the first time in its entirety from the regular $1/n$ into the chaotic quasi-Landau regime. It evolves, fully unexpectedly, into a systematically structured hierarchy of generations of resonances, correlated to three physically different types of closed classical orbits.

PACS numbers: 32.80.−t, 05.45.+b, 32.60.+i

The physics of the highly excited diamagnetic hydrogen atom has recently attracted much attention,[1-8] largely because this simple nonseparable quantum system turns classically chaotic as it approaches the ionization limit.[6,9] In this context the quasi-Landau (QL) oscillations and their correlation to classical periodic orbits are of particular interest.[10] Until recently, it was accepted that only one QL resonance type, discovered by Garton and Tomkins,[11] exists. Experiments with the H atom[3-5] and theoretical studies[7,8,12,13] have uncovered further, basically new resonances correlated with three-dimensional orbits. Nevertheless, the central question as to the *entire* set of QL resonances resulting from final states with a given m quantum number and parity evolving from the regular into the chaotic QL regime has remained open.

We have addressed this basic problem and studied the H-atom Balmer spectrum with even-parity $m=0$ magnetic final states as a function of both the excitation energy E and the magnetic field B, employing for the first time "constant–scaled-energy spectroscopy." Different from previous experiments at constant B,[3-5] this technique makes a systematic search for, in principal, *all* possible QL resonances associated with closed classical orbits.[12] In analogy to theoretical work, it is based on the scaling property of the classical Hamiltonian[14]:

$$H(\mathbf{r},\mathbf{p};\gamma)=\gamma^{2/3}\tilde{H}(\tilde{\mathbf{r}},\tilde{\mathbf{p}};\gamma=1),$$

where scaled variables are defined by $\tilde{\mathbf{r}}=\gamma^{2/3}\mathbf{r}$, $\tilde{\mathbf{p}}=\gamma^{-1/3}\mathbf{p}$, and $\gamma=B/(2.35\times10^5\ \mathrm{T})$. The semiclassical Bohr-Sommerfeld quantization condition[15] for the two nonseparable coordinates ρ,z (cylindrical coordinates) is transformed accordingly to scaled form[13]

$$(2\pi)^{-1}\oint_i(\tilde{p}_\rho d\tilde{\rho}+\tilde{p}_z d\tilde{z})=n\gamma^{1/3}=C_i, \qquad (1)$$

where i denotes a closed classical orbit. Since the scaled action C depends on the scaled energy $\tilde{E}=E\gamma^{-2/3}$ only, it has a constant value C_i for $\tilde{E}=$const and a given i. In this case, $C_i=n\gamma^{1/3}$ describes a spectrum of *equidistant* lines on a scale $\gamma^{-1/3}$, the Fourier transform of which in the conjugate coordinate, $n\gamma^{1/3}$, consists of *one* resonance for each i, to which is correlated the respective orbit i. By application of these theoretical concepts to experiment, constant–scaled-energy spectra have been taken accordingly to our scanning the field strength linearly with $\gamma^{-1/3}$, simultaneously adjusting E (via the laser wavelength) such that $\tilde{E}=E\gamma^{-2/3}=$const was obeyed. Apart from this novel spectroscopic procedure the experiments have been carried out as previously.[3]

Figure 1(a) shows, as a typical example, a $\gamma^{-1/3}$ spectrum at $\tilde{E}=-0.45$, and Fig. 1(b) the corresponding Fourier-transform $n\gamma^{1/3}$ action spectrum. The orbits shown correlate to the respective resonances, and have been obtained by classical trajectory calculation.[4,13] Such action spectra have been taken (physically with a

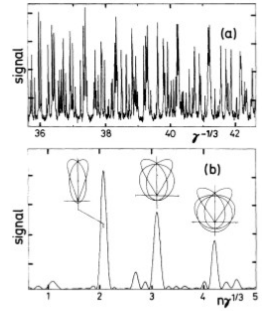
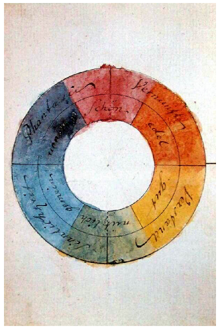
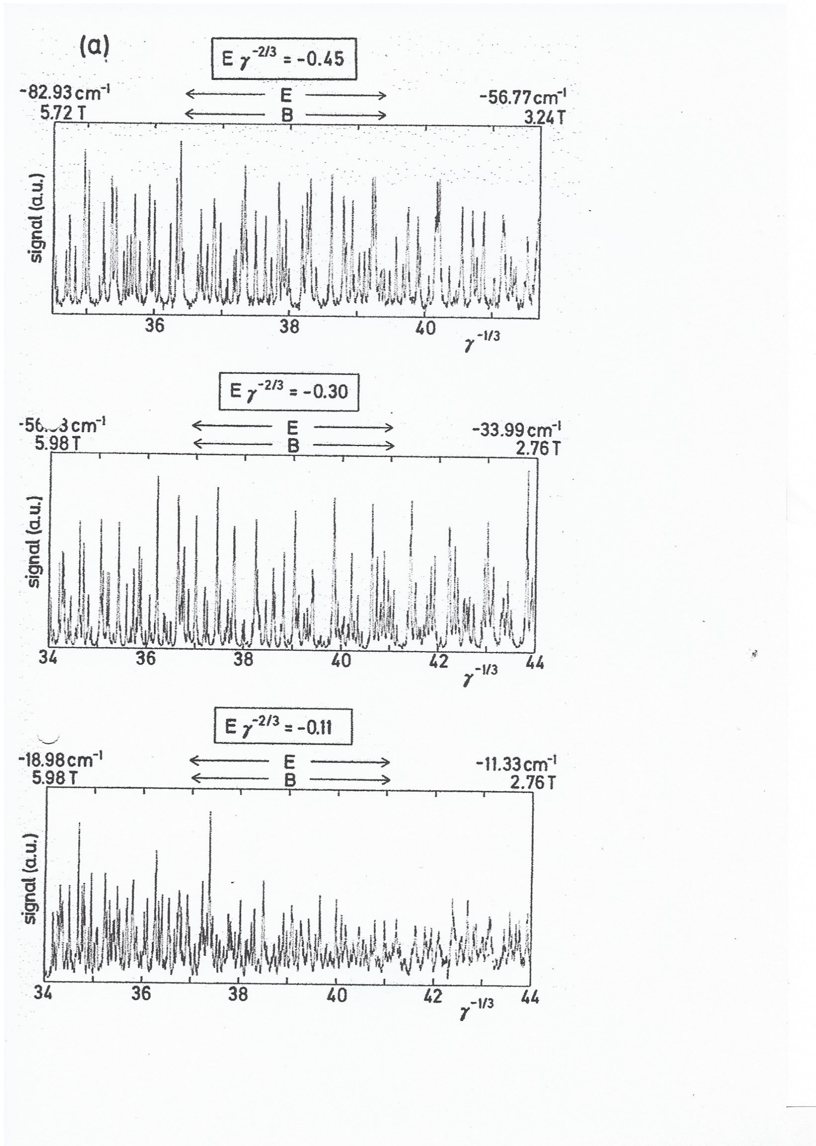
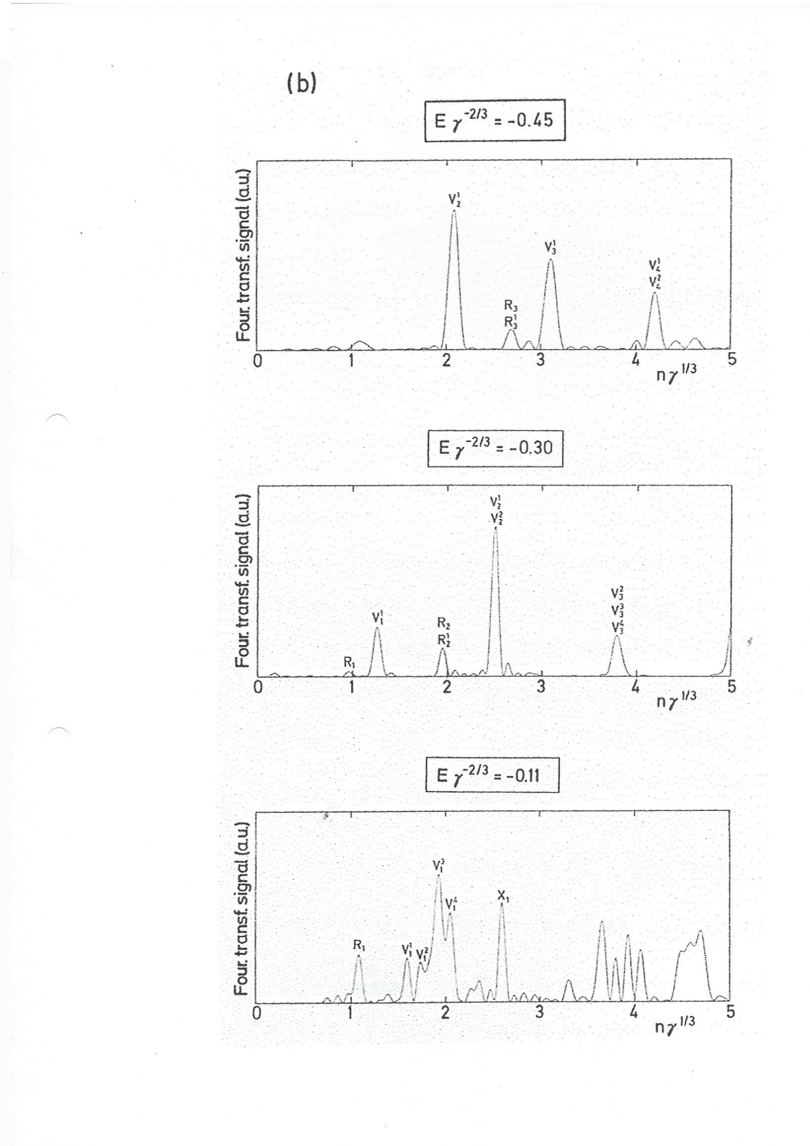


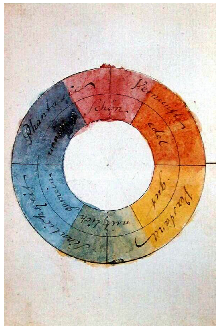
FIG. 1. (a) Scaled-energy spectrum at $\tilde{E}=-0.45$ as a function of $\gamma^{-1/3}$. Range of excitation energy $-77.7\ \mathrm{cm}^{-1}\le E\le -54.3\ \mathrm{cm}^{-1}$ and field strength $5.19\ge B\ge 3.03$ T. (b) Fourier-transformed action spectrum of (a); closed orbits correlated to respective resonances in (ρ,z) projection; z coordinate vertically.



Spektren und Bahnen: Wasserstoff im Magnetfeld







Spektren und Bahnen: Wasserstoff im Magnetfeld