

MO 9: Poster 2

Time: Friday 17:30–19:30

Location: P

MO 9.1 Fri 17:30 P

LiK B¹Π potential: combining short and long range data — ●SOFIA BOTSIS¹, ANBANG YANG¹, SAMBIT B. PAL¹, MARK M. LAM¹, SUNIL KUMAR¹, MARKUS DEBATIN¹, and KAI DIECKMANN^{1,2} — ¹Centre for Quantum Technologies (CQT), 3 Science Drive 2, Singapore 117543 — ²Department of Physics, National University of Singapore, 2 Science Drive 3, Singapore 117542

We report on high-resolution spectroscopic measurements of the long-range states of the ⁶Li⁴⁰K molecule near the ⁶Li(2²S_{1/2})+⁴⁰K(4²P_{3/2}) dissociation threshold, which in combination with existing data in the short-range lead to the complete characterization of the B¹Π potential. Starting from weakly bound ultracold Feshbach molecules, we perform one-photon loss spectroscopy of the B¹Π and record the transition frequencies to twenty-five vibrational levels. Level assignment to the spin-orbit coupled potentials is facilitated by existing data in the long-range and by examining the Zeeman effect for the Hund's case (c) coupling scheme. The C₆ coefficients are deduced by fitting our vibrational energies together with the long-range levels to the LeRoy-Bernstein formula. We present a complete set of data for the Ω=1^{up} state, by combining the long-range measurements with data from the short-range states of the B¹Π obtained for the ⁷Li³⁹K isotopologue. Using mass-scaling, we model the short- and the long-range states simultaneously and produce an improved Rydberg-Klein-Rees curve for the complete potential. ¹Ridinger *et al.*, *EPL*, 2011, **96**, 33001, ²Pashov *et al.*, *Chem. Phys. Lett.*, 1998, **292**, 615-620

MO 9.2 Fri 17:30 P

New Lifetime Limit of the Ground State Vinylidene Anion H₂CC⁻ — ●FELIX NUSSLIN¹, KLAUS BLAUM¹, JÜRGEN GÖCK¹, MANFRED GRIESER¹, SEBASTIAN GEORGE², ROBERT VON HAHN¹, ÁBEL KÁLOSI^{3,1}, HOLGER KRECKEL¹, DAMIAN MÜLL¹, OLDŘICH NOVOTNÝ¹, HENRIK PEDERSEN⁴, VIVIANE SCHMIDT¹, and ANDREAS WOLF¹ — ¹Max-Planck-Institut für Kernphysik, Heidelberg, 69117, Germany — ²Institut für Physik, Universität Greifswald, Greifswald, 17487, Germany — ³Columbia Astrophysics Laboratory, Columbia University, New York, 10027, USA — ⁴Department of Physics and Astronomy, Aarhus University, Aarhus, 8000, Denmark

The isomers acetylene (HCCH) and vinylidene (H₂CC) form one of the simplest systems for studying isomeric reactions involving hydrogen. In anionic form the vinylidene isomer has the lowest total energy with an electron affinity of ~0.5 eV. It lies 1.5 eV above the lowest neutral level of acetylene, which gives rise to the hypothesis that isomerization linked with electron emission could limit the lifetime of H₂CC⁻. An experiment at a room-temperature storage ring obtained a finite lifetime of ~110 s [1] by extrapolating from collision-limited (~10 s) to collision-free beam lifetimes of H₂CC⁻ and a stable reference ion. To access longer ion beam lifetimes (up to 3000 s) and thereby enable a better estimate of the ground state H₂CC⁻ lifetime, we employed the Heidelberg electrostatic Cryogenic Storage Ring [2]. From comparing the decays of H₂CC⁻ and the stable reference ion CN⁻ we find that the ground state H₂CC⁻ lives at least 3500 s, i.e., more than an order of magnitude longer than assumed previously. The latest results will be presented.

[1] M. Jensen *et al.*, *Phys. Rev. Lett.* 84 (2000) 1128.[2] R. von Hahn *et al.*, *Rev. Sci. Instrum.* 87 (2016) 063115.

MO 9.3 Fri 17:30 P

Towards the coherent control of Penning collisions between metastable helium atoms — ●ALEXANDRA TSOUKALA, LASSE BINKOWSKI, TOBIAS SIXT, NICOLAS VANHAECKE, FRANK STIENKEMEIER, and KATRIN DULITZ — Institute of Physics, University of Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany

Our research focuses on understanding the mechanistic details of reactive collisions in order to enable control of their outcome. The coherent control of reactive collisions, which relies on the interference between two or more reaction paths, has been long sought for. We are in the process of realizing an experiment, in which we coherently control the Penning collisions between metastable helium atoms in 2³S₁ and 2¹S₀ states.

Our control scheme is based on the preparation of a coherent superposition of the M_J=-1 and M_J=+1 quantum states in the He(2³S₁) via an off-resonant two-photon Rabi excitation scheme. The two states are

coupled by light of counter-rotating circular polarization, which also imprints its phase onto each state. By varying the phase difference between the two circularly polarized light components, the relative phase between the involved reaction pathways follows the same trend. This control scheme will allow for a precise tuning of the overall reaction cross section. Our detection scheme is based on the monitoring of ions produced in the collision process using a time-of-flight detector.

In this contribution, I will describe our experimental apparatus and its characterization.

MO 9.4 Fri 17:30 P

A direct comparison of buffer gas molecular beams of AlF, CaF and MgF — ●MAXIMILIAN DOPPELBAUER, SIDNEY WRIGHT, XIANGYUE LIU, SIMON HOFSSÄSS, JESÚS PÉREZ-RÍOS, GERARD MEIJER, and STEFAN TRUPPE — Fritz Haber Institute of the Max Planck Society, Berlin, Germany

The production of dense, controlled samples is crucial for many applications of ultracold molecules. Cryogenic buffer gas sources are widely used for producing bright, slow beams of internally cold molecules. We aim to understand the formation process of the laser-coolable monofluorides AlF, CaF and MgF after laser ablation of a metal target and reaction with a fluorine donor gas. We combine theoretical calculations with a systematic experimental approach for this study.

We first examined the reaction rate for different reactants using molecular dynamics simulations. The electronic interaction energy was calculated on the fly using the BHLYP-D3 functional, and the def2-TZVP basis set. The calculations predict that AlF is produced more efficiently using NF₃, than with SF₆, and that the formation of AlF is one order of magnitude more efficient than that of CaF.

In the experiment, we measured the brightness of Al and Ca atomic beams and compared it to AlF, CaF and MgF molecular beams. We show that the AlF beam is one order of magnitude brighter than a CaF or MgF beam formed in the same buffer gas source, both in absorption and in fluorescence. The fact that the atomic beams of Al and Ca are similar in brightness supports the theoretical result. All atomic and molecular beams have similar forward velocity distributions.

MO 9.5 Fri 17:30 P

Ozone formation through three-body collisions: Theory and experiment reconciled — ●MARJAN MIRAHMADI¹, JESÚS PÉREZ-RÍOS^{1,2}, OLEG EGOROV³, VLADIMIR TYUTEREV^{3,4}, and VIATCHESLAV KOKOULINE⁵ — ¹Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, D-14195 Berlin, Germany — ²Department of Physics, Stony Brook University, Stony Brook, New York 11794, USA — ³Quamer Laboratory, Tomsk State University, Tomsk, Russia — ⁴Groupe de Spectrométrie Moléculaire et Atmosphérique, UMR CNRS 7331, University of Reims Champagne-Ardenne, Reims, France — ⁵Department of Physics, University of Central Florida, Florida, USA

We present a direct three-body recombination approach to study the formation of ozone through the ternary collision O₂ + O + M → O₃ + M, where M can be N₂, O₂ or Ar. The rate coefficients for the formation of O₃, without using two-steps approximations, were computed for the first time as a function of collision energy. Accordingly, thermally-averaged rates were derived for temperatures 5-900 K. As a result, we find that most of the ozone molecules are formed in weakly bound states that are further vibrationally quenched into deeply bound vibrational states relevant for UV absorption, in agreement with the experimental observations. Moreover, our formalism, based on classical trajectory calculations, allows having a fully *ab initio* and pressure-independent rate for ozone formation.

MO 9.6 Fri 17:30 P

State-selective cross sections from Ring PolymerMolecular Dynamics — ●ADRIEN MARJOLLET — CFEL-DESY, Hamburg, Germany

Understanding the influence of different forms of energy (e.g., translational, vibrational, rotational) on chemical reactions is a key goal and great challenge in physicalchemistry. Very recently we proposed a new approach to obtain state-selective cross sections that approximately includes quantum effects like zero-point energy and tunneling. The method is a combination of the widely used quasiclassical trajectory approach(QCT) and the ring polymer molecular dynamics method

(RPM). The approach is then applied and assessed to several prototypical $X+H_2(\nu=0,1)$, $X=Mu,H,D,F,Cl$ and $H/F+CH_4$ reactions. Good agreement with rigorous quantum dynamics simulations is found for most cases.

MO 9.7 Fri 17:30 P

Quantitative detection of C_2H_2 in a dusty plasma environment using sensitive mid-IR frequency modulation spectroscopy — ●MITHUN PAL¹, MICHAEL STUHR¹, NANCY FASSHEBER¹, ANDREAS PETERSEN², FRANKO GREINER², and GERNOT FRIEDRICH¹ — ¹Institut für Physikalische Chemie, Christian-Albrechts-Universität zu Kiel, Germany — ²Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, Germany

We report both the implementation of single- and two-tone mid-IR frequency modulation (FM) schemes to measure acetylene (C_2H_2) concentration transients in a low-temperature dusty plasma arising from a RF discharge in low-pressure argon with C_2H_2 admixture. The key underlying concept of the FM technique is to shift the detection bandwidth of the optical spectrometer to a high-frequency region, where conventional technical noise from the laser source and experimental environment become negligible. Moreover, due to the derivative nature of the acquired spectra, broadband background absorption and scattering from interfering species or particles are efficiently suppressed. In order to quantify the concentration of acetylene, we experimentally probed the P(25)e rovibrational transition of C_2H_2 at 3233.08 cm^{-1} , originating from the fundamental vibrational band ν_3 (asymmetric C-H stretch). Additionally, we monitored the periodic C_2H_2 dynamics under variable discharge conditions to demonstrate the high potential of transient mid-IR FM spectroscopy to gain insight into the kinetics of the nanoparticle nucleation, growth, and precipitation.

MO 9.8 Fri 17:30 P

Core-level intermolecular Coulombic decay in pyrimidine enabled by aqueous environment — ●DANA BLOSS¹, CATMARNA KÜSTNER-WETEKAM¹, PHILIPP SCHMIDT¹, SASCHA DEINERT², FLORIAN TRINTER², GREGOR HARTMANN¹, ARNO EHRESMANN¹, LORENZ S. CEDERBAUM³, NIKOLEI V. KRZYŻEWOI³, ANDRÉ KNIE¹, and ANDREAS HANS¹ — ¹Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany — ²Deutsches Elektronen-Synchrotron (DESY), Notkestrasse 85, 22607 Hamburg — ³Theoretische Chemie, Physikalisch-Chemisches Institut, Universität Heidelberg, Im Neuenheimer Feld 229, 69120 Heidelberg, Germany

We investigated the effect of the presence or absence of an aqueous environment for bio-relevant molecules after their exposure to X-ray irradiation in a photoelectron-ion-ion coincidence experiment performed at the P04 at Petra III. In the decay of carbon inner-shell vacancies of hydrated pyrimidine we found evidence for direct intermolecular Coulombic decay. This process protects the molecule from reaching dicationic states via Auger decay and the inevitable fragmentation. The observations are compared with the results of theoretical calculations for a deeper understanding of the occurring effects.

MO 9.9 Fri 17:30 P

Ultrafast Spectroscopy of Perylene Derivative Nanoparticles — ●CHRIS REHHAGEN¹, SHAHNAWAZ RAFIQ², KYRA N. SCHWARZ³, STEFAN LOCHBRUNNER¹, and GREGORY D. SCHOLES² — ¹Institute for Physics and Department of Life, Light and Matter, University of Rostock, 18051 Rostock, Germany — ²Frick Laboratory, Princeton University, 08540 Princeton, USA — ³School of Chemistry, University of Melbourne, Parkville, VIC, 3010 Australia

Organic nanostructures are of increasing interest in opto-electronic applications due to their potentially large exciton mobilities. While as inorganic nanoparticles are already applied in many scenarios, the properties of organic nanostructures are yet to be explored. Among a breadth of organic systems available, Perylene derivatives attract much interest as they provide a high oscillator strength, photostability, and a tuneability of the transition energy and supramolecular structure. We use flash precipitation to prepare nanoparticles of the dye Perylene Red and correlate their optical spectra, quantum yields and emission lifetimes. Ultrafast pump-probe spectroscopy is then performed on samples of different classes to characterize their excited state dynamics. An intermediate charge-transfer state, formed after photoexcitation, was observed. Remarkably, no such intermediate state was observed in the monomer of Perylene Red. We further characterize the exciton diffusion in the nanoparticles by analyzing signatures in the transient dynamics resulting from exciton-exciton annihilation. The resulting diffusion constant is $0.2\text{ nm}^2/\text{ps}$ resulting in a diffusion length of 10

nm within the singlet exciton lifetime of 90 ps.

MO 9.10 Fri 17:30 P

Predicting *ortho-para* transitions of water from first principles — ●GUANG YANG^{1,2}, ANDREY YACHMENEV^{1,3}, SERGEI YURCHENKO⁴, EMIL ZAK¹, and JOCHEN KÜPPER^{1,2,3} — ¹Center for Free-Electron Laser Science, Deutsches Elektronen-Synchrotron DESY, Hamburg — ²Department of Physics, Universität Hamburg — ³Center for Ultrafast Imaging, Universität Hamburg — ⁴Department of Physics and Astronomy, University College London, UK

We present a complete room-temperature hyperfine-resolved line list of $H_2^{16}O$, including forbidden *ortho-para* transitions. The predicted strongest forbidden *ortho-para* transition intensities are at the order of $10^{-31}\text{ cm}^2/\text{molecule}$, which is an order of magnitude stronger than the previous results. The calculations were based on the variational approach TROVE with including the hyperfine effects by nuclear spin-rotation and spin-spin interactions. The computed line list cover transitions between energy levels up to $F = 39$ ($J = 40$) and vibrational band centers up to 15000 cm^{-1} . The comparison between the calculated hyperfine transitions and the available experimental data shows good agreement. This line list will be useful for guiding future experimental spectroscopic studies of hyperfine structure and nuclear spin dynamics.

- [1] G. Yang, et al., *J. Chem. Phys.*, in preparation (2021)
- [2] S. N. Yurchenko, et al., *J. Mol. Spectrosc.*, **245**, 126 (2007)
- [3] A. Miani, et al., *J. Chem. Phys.*, **120**, 2732 (2004)
- [4] H. Bluysen, et al., *Phys. Lett. A*, **24**, 482 (1967)
- [5] G. Cazzoli, et al., *Chem. Phys. Lett.*, **473**, 21 (2009)

MO 9.11 Fri 17:30 P

Statistical analysis of correlations in the x-ray induced Coulomb explosion of iodopyridine — BENOÎT RICHARD^{1,2,3}, ●JULIA SCHÄFER^{1,4}, ZOLTAN JUREK¹, ROBIN SANTRA^{1,2,3,4}, and LUDGER INHESTER^{1,2} — ¹Center for Free-Electron Laser Science CFEL, Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany — ²The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany — ³Department of Physics, Universität Hamburg, Notkestr. 9-11, 22607 Hamburg, Germany — ⁴Department of Chemistry, Universität Hamburg, Martin-Luther-King-Platz 6, 20146 Hamburg, Germany

Coulomb explosion imaging is a promising experimental tool to study individual molecules. However, the amount of information about the original molecule that can be retrieved from the measured final momenta of the produced ions is unclear. In particular, little study has been made about how to exploit information about the correlations between the ion momenta that state-of-the-art multi-coincidence techniques can acquire. In this work simulation data for the x-ray induced Coulomb explosion of 2-iodopyridine is analyzed and the involved fragmentation dynamics are described. It is found that particular final ion momenta show correlations that reflect a collision of two atoms during the explosion. Moreover covariances of the forces along the explosion can be utilized to simplify the description of the dynamics in reduced dimensionality using only four collective coordinates.

MO 9.12 Fri 17:30 P

Spectral deep-learning for (ro-)vibrational calculations of weakly-bound molecules — ●JANNIK EGGERS^{1,2}, YAHYA SALEH^{1,2}, VISHNU SANJAY^{1,2,3}, ANDREY YACHMENEV^{1,3}, ARMIN ISKE², and JOCHEN KÜPPER^{1,3,4} — ¹Center for Free-Electron Laser Science CFEL, Deutsches Elektronen-Synchrotron DESY, Hamburg — ²Department of Mathematics, Universität Hamburg — ³Center for Ultrafast Imaging CUI, Universität Hamburg — ⁴Department of Physics, Universität Hamburg

Planning and elucidating experiments on resonances in dissociation dynamics of molecules and molecular clusters requires accurate quantum mechanical calculations of (ro-)vibrational energies up to dissociation, which is a big challenge especially for larger molecules. Standard approaches represent wavefunctions as linear combinations of some fixed basis set and the quality of the predictions highly depends on the choice of the basis set. Furthermore, the computational costs scale poorly with the dimension of the problem.

We present a nonlinear neural network-based variational framework to simultaneously compute several eigenstates and eigenfunctions of the Hamiltonian. Unlike linear variational methods, neural network-based models seem to scale relatively well with the dimension of the problem. While they were mainly used to successfully model ground states of quantum systems, our approach extends to excited states. The key

principle is to use neural networks as an adaptive basis and to optimize it, enabling us to use a much smaller basis set than in standard approaches without sacrificing accuracy.

MO 9.13 Fri 17:30 P

eCOMO - A new endstation for controlled molecule experiments — •WUWEI JIN¹, SEBASTIAN TRIPPEL^{1,3}, HUBERTUS BROMBERGER^{1,3}, TOBIAS RÖHLING¹, KAROL DLUGOLECKI¹, and JOCHEN KÜPPER^{1,2,3} — ¹Center for Free-Electron Laser Science, Deutsches Elektronen-Synchrotron DESY, Hamburg — ²Department of Physics, Universität Hamburg — ³Center for Ultrafast Imaging, Universität Hamburg

We present details on our newly established transportable endstation eCOMO (Endstation for Controlled Molecules). The apparatus has been designed for use at various photon sources for investigating the molecular dynamics of small molecules in the gas phase [1].

The endstation consists of three main parts: 1) An Evan-Lavie-valve-based gas source. 2) An electrostatic deflector for the generation of pure molecular samples [2]. 3) A double-sided VMI spectrometer coupled with the time- and position sensitive Timepix3 camera [3].

The endstation was designed to be highly transportable, with built-in transport wheels, adjustable height, integrated controllers, power supplies as well as water and gas lines for easy beamtime installation. Here, we discuss our first results on the UV dissociation dynamics of carbonyl sulphide (OCS) [4].

[1] M Johny, J Onvlee, et al., *Chem. Phys. Lett.*, **721**, 149 (2019)

[2] S Trippel, M Johny, et al., *Rev. Sci. Instrum.*, **89**, 096110 (2018)

[3] A.F Al-Refai, M Johny, et al., *J. Instrum.*, **14**, P10003 (2019)

[4] In collaboration with the group of Francesca Calegari, within the Center for Molecular Water Science (CMWS)

MO 9.14 Fri 17:30 P

Method of Kinetic Energy Reconstruction from Ion-Time-of-Flight Spectra — •AARON NGAI¹, KATRIN DULITZ¹, MARCEL MUDRICH², and FRANK STIENKEMEIER¹ — ¹Institute of Physics, University of Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — ²Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, 8000 Aarhus C

We present a method which makes use of ion trajectory simulations to reconstruct ion-kinetic-energy (KE) distributions from ion-time-of-flight (TOF) spectra. Sufficient conditions for a unique calibration to experimental parameters are presented, where the calibrated simulation extrapolates to a set of energy-dependent TOF basis functions, allowing conversion between TOF and KE coordinates. We demonstrate this reconstruction method on a recent XUV-UV pump-probe laser experiment on helium nanodroplets at the free-electron laser FERMI in Trieste [1], where relaxation from the 1s3p/1s4p droplet absorption band was time-resolved, using a Wiley-McLaren-type ion-TOF spectrometer in combination with a magnetic bottle electron spectrometer [2,3].

[1] J. D. Asmussen *et al.* *Phys. Chem. Chem. Phys.* advance article (2021).

[2] W. C. Wiley and I. H. McLaren. *Rev. Sci. Instrum.* **26**, 1150 (1955).

[3] J. H. Eland *et al.* *Chem. Phys.* **327**, 85 (2006).

MO 9.15 Fri 17:30 P

Coherent two-dimensional photoelectron spectroscopy — •DANIEL UHL, ULRICH BANGERT, LUKAS BRUDER, and FRANK STIENKEMEIER — Institute of Physics, University of Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany.

Coherent multidimensional spectroscopy (CMDS) is probably the most complete spectroscopic technique to study couplings, coherence properties and real-time dynamics of a quantum system [1,2,3]. Another

spectroscopic method is photoelectron spectroscopy which provides detailed information about the chemical composition and electronic states of the sample [4].

In our work we present a combination of both methods in a single experiment. This becomes feasible with the implementation of efficient single-counting detection and multichannel software-based lock-in amplification [5]. The approach offers high temporal, spectral and kinetic energy resolution. It enables differential CMDS experiments with unprecedented selectivity and enhances the dynamic range of CMDS by up to two orders of magnitude.

[1] D.M. Jonas, *Annu. Rev. Chem. Phys.* **54**, 425-463 (2003).

[2] R.M. Hochstrasser, *PNAS* **104**, 14190-14196 (2007).

[3] L. Bruder *et al.*, *Nat Commun* **9**, 4823 (2018).

[4] S. Hüfner, *Photoelectron Spectroscopy: Principles and Applications* (Springer Science & Business Media, 2013).

[5] D. Uhl, L. Bruder, and F. Stienkemeier, *ArXiv*, 2105.12124 (2021).

MO 9.16 Fri 17:30 P

Driving Waveform Dependency of Energy Dissipation of Trapped Particles — •MARTIN KERNBACH^{1,2}, PAUL OSKAR SUND¹, and ANDREAS W. SCHELL^{1,2} — ¹Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany — ²Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, D-38116 Braunschweig, Germany

Trapping is an beneficial tool for investigations on and experiments with ions or microparticles. Optical resonance and fluorescence probing of isolated microparticles are essential to determine their spectroscopic fingerprints which gives information about their structural properties or internal degrees of freedom. On the other hand trapped ions are used for quantum computing or atomic clocks by manipulating their quantum states with systematic laser-light interaction. Ions can be trapped by optical cooling techniques such as Doppler cooling, while microparticles mainly lose their energy due to atmospheric friction. Although both processes are based on a different physical background, the dynamic of both can be described by an energy dissipation term proportional to the velocity of the particle. We have simulated the trapping process for a better understanding of the underlying dynamics and to test different trapping optimization approaches, for example exotic driving waveforms respectively for single particle trapping and two particles in a sympathetic cooling scheme.

MO 9.17 Fri 17:30 P

Interplay of periodic dynamics and noise: insights from a simple adaptive system — •FREDERIC FOLZ¹, KURT MEHLHORN², and GIOVANNA MORIGI¹ — ¹Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — ²Algorithms and Complexity Group, Max-Planck-Institut für Informatik, Saarland Informatics Campus, 66123 Saarbrücken, Germany

We study the dynamics of a simple adaptive system in the presence of noise and periodic damping. The system is composed by two paths connecting a source and a sink, the dynamics is governed by equations that usually describe food search of the paradigmatic Physarum polycephalum. In this work we assume that the two paths undergo damping whose relative strength is periodically modulated in time and analyse the dynamics in the presence of stochastic forces simulating Gaussian noise. We identify different responses depending on the modulation frequency and on the noise amplitude. At frequencies smaller than the mean dissipation rate, the system tends to switch to the path which minimizes dissipation. Synchronous switching occurs at an optimal noise amplitude which depends on the modulation frequency. This behaviour disappears at larger frequencies, where the dynamics can be described by the time-averaged equations. Here, we find metastable patterns that exhibit the features of noise-induced resonances.