Ab initio calculation of the anisotropy effect of multiple bonds and the ring current effect of arenes—application in conformational and configurational analysis

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Substituents containing magnetically anisotropic chemical bonds, *e.g.* double bonds, triple bonds or the aromatic phenyl ring, influence the shielding of any nucleus in the molecule by their anisotropy effect dependent on its geometrical position. This effect of the magnetic anisotropy of neighbouring groups on the chemical shift of nuclei is usually specified qualitatively by the anisotropy cone. In this paper, the magnetic anisotropy effect of unsaturated chemical bonds and the ring current effect in arenes have been quantitatively calculated as nuclear independent chemical shieldings (NICSs) in a three dimensional grid of lattice points around the molecule using the GIAO method integrated into the GAUSSIAN 94 calculation program. Plotting the shielding/deshielding data thus obtained as iso-chemical-shielding surfaces (ICSS) around the magnetically anisotropic moieties allows us to quantify both direction and scale of the anisotropy effect.

The calculation of the anisotropy effect of double and triple bonds, and the ring current effect of the phenyl ring, has been applied to a number of stereochemical problems; especially in conformational analysis this method proved very successful in quantitatively assigning ^{1}H chemical shifts and hereby the stereochemistry of the molecules studied. In addition, contributions to ^{1}H chemical shifts based on the anisotropy effect of neighbouring groups and based on other substituent effects could be differentiated quantitatively. Considerable deviations from the qualitative sketches of the anisotropy effects of double and triple bonds published in text books were found.

Introduction

Due to the different susceptibilities along the three directions in space, chemical bonds are magnetically anisotropic in general. In 1957, H. M. McConnell[1] quantitatively calculated the anisotropy effect for groups of axially symmetric charge distribution by employing the point dipole approximation—the contribution to the shielding of a certain nucleus A was considered as a function of both the distance r(A–C) to the point dipole centre C and the angle between the line A–C and the direction of the induced magnetic moment. This contribution to the shielding of nucleus A becomes zero at 54.7°; shielding and deshielding contributions to the chemical shift of nucleus A are dependent on its geometrical position with respect to the magnetically anisotropic functional group.

This *anisotropy effect*, visualized as anisotropy cones of functional groups, was employed to explain the respective shielding or deshielding of protons spatially close to the corresponding functional groups and served in innumerable conformational analyses to assign proton chemical shifts in various possible conformers and/or isomers, where other methods failed.[2]

Protons attached to, or located in the plane near to, arene ring systems (with [4n + 2] π-electrons cyclically conjugated) are less shielded than those in alkenes and antiaromatic ring systems (with [4n] π-electrons cyclically conjugated). J. A. Pople[3] explained this effect in terms of a *ring current* of the delocalized [4n + 2] π-electrons induced in the applied magnetic field. This ring current develops a secondary magnetic field which leads to additionally shielding and deshielding regions near to the arene ring system—aromatic protons and nuclei in-plane with the arene ring system are deshielded, nuclei above the arene ring system are shielded by this *ring current effect* which is also visualized by an anisotropy cone similar to those of the multiple bonds aforementioned. The chemical shifts of protons attached to antiaromatic ring systems could be explained by the same theory.[3]

The quantitative calculation of the ring current effect for aromatic ring systems was recently reviewed by P. Lazzeretti.[4] In his remarkable review article, he showed that in an applied magnetic field (i) the 6 π-electrons in the phenyl ring circulate in a preferred direction and build up hereby a *diamagnetic* ring current, that (ii) in enlarged aromatic ring systems the ring current of the [4n + 2] π-electrons is extended over the whole molecule and that (iii) in antiaromatic ring systems a *paramagnetic* ring current is built up. Accordingly, the corresponding lowfield shift of protons attached to the phenyl ring but also the abnormal chemical shifts of in-plane protons close to the center of enlarged aromatic ring systems or protons bridging the aromatic ring systems were employed to qualitatively classify the *aromaticity* of the ring system studied.

P. v. R. Schleyer *et al.*[5] used *nucleus independent chemical shifts* (NICS), calculated in the center of ring systems, to define aromaticity (positive NICS) or antiaromaticity (negative NICS). These NICS were discussed quantitatively for a series of different aromatic, antiaromatic and non-aromatic systems.[5–9]

The anisotropy cone as sketched in text books is a qualitative description of the anisotropy effect simply defining shielding and deshielding of double bonds, triple bonds or benzene rings (*cf.* Scheme 1) on the chemical shifts of nearby nuclei. Quantification of this effect from these sketches only is practically impossible. Therefore N. H. Martin *et al.*,[10] in order to determine the anisotropic effect of double bonds and a benzene ring quantitatively, calculated the shielding of methane protons, placed above ethylene[10,11] and benzene,[12,13]

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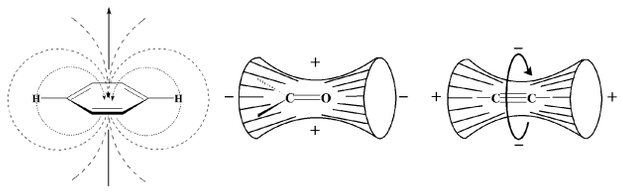

Scheme 1 Anisotropy cones,[21] classically used for signal assignment.

respectively, and developed empirical model equations that predict chemical shifts of nuclei in the above mentioned structural fragments.

Based on the NICS as employed by P. v. R. Schleyer *et al.*[5] we calculated the absolute magnetic shieldings in the vicinity of some functional groups and aromatic ring systems, resulting in quantitative information about the spatial extension, sign and scope of the corresponding anisotropy effect. In this way, the chemical shifts of protons near to these functional groups could be explained and assigned quantitatively.[14]

It is the objective of this paper to report on the calculated anisotropic effects of a series of functional groups and various aromatic, heteroaromatic and antiaromatic ring systems. As a result, it was possible (i) to classify the functional groups with respect to the intensity of their anisotropy effect, (ii) to quantify the influence of acceptor/donor substituents on both sign and scope of the anisotropy effect of the studied functional group, (iii) to calculate the overall anisotropy effect in molecular regions where the anisotropy cones of different functional groups are overlapping, (iv) to discuss the corresponding differences between aromatic and antiaromatic ring systems with respect to their anisotropy effect and (v) to quantify the anisotropy effect of aromatic ring systems dependent on the number of π-electrons.

Finally, the calculated anisotropy effects of several functional groups were applied to assign the proton chemical shifts in several stereoisomers in order to solve successfully a number of stereochemical problems.

Experimental

The *ab initio* MO calculations were performed on an SGI Octane and an SGI Origin 2000 using the program GAUSSIAN 94.[15] Geometry optimization was carried out using HF/6-31G* without constraints.[16] The chemical shieldings in the vicinity of the anisotropic functional group were calculated on the basis of the idea of NICS by P. v. R. Schleyer *et al.*[5] Accordingly, the molecule was placed in the center of a grid of lattice points ranging from −10.0 to +10.0 Å in all three dimensions with a step width of 0.5 Å, resulting in a cube of 68921 lattice points. Because of the restrictions of GAUSSIAN 94 to 1500 atoms we had to carry out 82 separate calculations in order to calculate values at all points comprising the grid (as far as possible, the symmetries of the calculated molecules were taken into account and adequately reduced numbers of lattice points were calculated). The chemical shielding calculations were processed with the GIAO method[17,18] using HF/6-31G*. The quality of the basis set (6-31G**, 6-31+G**, 6-311G**) was estimated as an example for benzene and was found to be of no influence on both shape and size of the ring current effect; identical ICSSs (*vide infra*) were obtained. Since the GIAO approach is gauge-invariant, it can be applied for the calculation of NICS.

From the results of the 82 GIAO calculations the coordinates and isotropic shielding values of the lattice points were extracted. After transformation of the tabulated chemical shieldings into a SYBYL[19] contour file, the anisotropy effect of the functional groups and aromatic/heteroaromatic/antiaromatic ring systems can be visualized as iso-chemical-shielding surfaces (ICSS). In this way is it possible to map the spatial extension, sign and scope of the anisotropy effect of the studied molecules at a certain stereochemical position.

In the cases of Fig. 10–12 only "fragmental ring current effects" of certain phenyl rings in the molecules studied are represented but the anisotropy effects of all functional groups of the whole molecule were also calculated. The stereochemically deciding influence on certain protons in the molecules proves very similar (± 0.01 ppm).

Results and discussion

To begin with, the anisotropy effects of ethylene, acetylene, formaldehyde, thioformaldehyde, hydrogen cyanide, *cis*- and *trans*-buta-1,3-diene, benzene, naphthalene, anthracene, tetracene, pentacene, furan, pyrrole, thiophene, and pentalene were calculated. First, the molecules were analysed with respect to both sign and intensity of the present anisotropy effect. Therefore, the ICSSs of identical shielding/deshielding areas were displayed (shielding area at 0.1 ppm in yellow, at 0.5 ppm in green, at 1 ppm in green-blue, at 2 ppm in cyan and at 5 ppm in blue; deshielding area at 0.1 ppm in red). For the discussion of the respective position of protons in various stereoisomers, only the surfaces with the shielding value of interest are given (mentioned in the corresponding captions). In cases of overlaying ICSS, the surfaces were cut vertically through the molecule center.

Functional groups

The anisotropy effect of the C–C double bond (*cf.* Fig. 1a) proves rather small. At a distance of 4 Å from the center only 0.1 ppm deshielding in-plane with the double bond and 0.1 ppm shielding perpendicular to this plane were calculated. As could be expected from the position of the π-orbitals, the shielding area is positioned above and below the plane of the C–C double bond.

The shielding/deshieldings obtained at a distance of 4 Å are in complete agreement with the results calculated by N. H. Martin *et al.*[10,11] However, closer to the double bond (at 2 Å) they found with their method ("methane above ethene") a deshielding effect above the plane of the C–C double bond contrary to our results. This lowfield effect on the methane protons (1.31 ppm) with respect to free methane (1.06 ppm), however, as a result of our calculations cannot result from the anisotropy effect of the C–C double bond, but could, probably due to steric reasons, originate from the closeness in space. In this case, electron density between hydrogen and carbon of the methane C–H bond is shifted more to carbon and away from the other three hydrogens of the methane molecule which become more shielded (0.86 ppm) hereby.

Conjugation of C–C double bonds strengthens the anisotropy effect. The scope of the anisotropy effect can even be quantitatively defined by the extent of π-electron delocalization. Better π-electron delocalization along the conjugated double bonds leads to a stronger overall anisotropy effect of the molecule (*cf.* in Fig. 2 *cis- vs. trans*-buta-1,3-diene).

The π-orbitals of the C–C triple bond are localized axially about the principal bond axis; shielding perpendicular to the bond axis could be expected. However, the classical anisotropy cone of the C–C triple bond displays deshielding around the C–C triple bond and shielding along the bond axis. The calculated anisotropy effect of the C–C triple bond (*cf.* Fig. 3a) corroborates the classical anisotropy cone in the principal sign of the anisotropy effect, but is smaller than expected. Only a very weak and restricted deshielding area perpendicular to the bond axis of the C–C triple bond was calculated (*cf.* Fig. 3a). In 4-phenanthrylacetylene the strong deshielding of the aromatic proton spatially close to the C–C triple bond ($\Delta\delta = -1.71$ ppm) was explained by the adequately shielding anisotropy effect of the triple bond.[21] However, the weak and spatially restricted

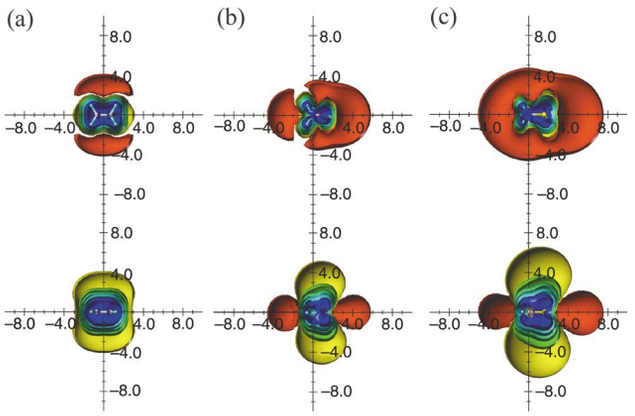

Fig. 1 Calculated anisotropy effect of the double bond: (a) ethylene, (b) formaldehyde, and (c) thioformaldehyde (shielding surfaces at 0.1 ppm in yellow, at 0.5 ppm in green, at 1 ppm in green-blue, at 2 ppm in cyan, and 5 ppm in blue, respectively; deshielding surface at 0.1 ppm in red). View from perpendicular to the molecules (above) and in the plane of the molecules (below).

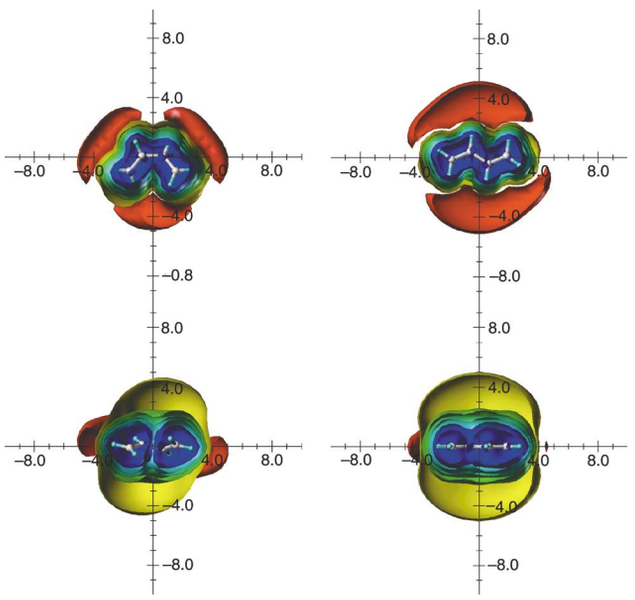

Fig. 2 Comparison of the calculated anisotropy effect of *cis*- and *trans*-buta-1,3-diene (shielding surfaces at 0.1 ppm in yellow, at 0.5 ppm in green, at 1 ppm in green-blue, at 2 ppm in cyan, and 5 ppm in blue, respectively; deshielding surface at 0.1 ppm in red). View from perpendicular to the molecules (above) and in the plane of the molecules (below).

calculated anisotropy effect of the C–C triple bond actually contradicts the latter explanation; obviously, steric compression, as aforementioned, and not the anisotropy effect of the C–C triple bond is the real reason for the highfield shift obtained for the phenanthrene proton.

The anisotropy effect of the C–C double bond is significantly strengthened if one carbon atom is replaced by a hetero atom (*e.g.* oxygen in formaldehyde, *cf.* Fig. 1b; sulfur in thioformaldehyde *cf.* Fig. 1c). The shielding/deshielding areas at an ICSS = 0.1 ppm are extended to 5 Å for the carbonyl and even 7 Å for the thiocarbonyl group. Also the anisotropy effect of the C–C triple bond is strengthened (*e.g.* by replacing carbon with nitrogen in hydrogen cyanide, *cf.* Fig. 3b). Especially the shielding area perpendicular to the principal axis of the molecule is extended; large anisotropy effects of cyano substituents and relevant stereochemical conclusions can be expected (*vide infra*).

The results of the present calculations of various aromatic and antiaromatic ring systems are completely in line with the corresponding conclusions of P. v. R. Schleyer in reference 5:

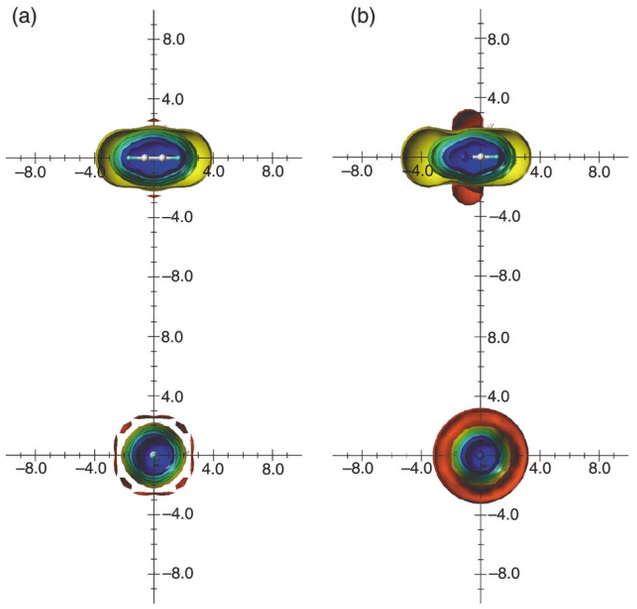

Fig. 3 Calculated anisotropy effect of the triple bond: (a) acetylene, and (b) hydrogen cyanide (shielding surfaces at 0.1 ppm in yellow, at 0.5 ppm in green, at 1 ppm in green-blue, at 2 ppm in cyan, and 5 ppm in blue, respectively; deshielding surface at 0.1 ppm in red). View from perpendicular to the molecules (above) and in the plane of the molecules (below).

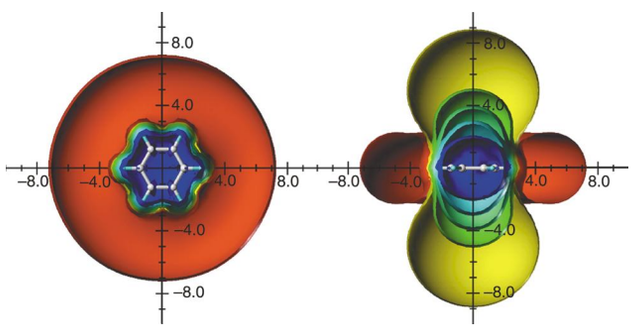

Fig. 4 Calculated ring current effect of benzene (shielding surfaces at 0.1 ppm in yellow, at 0.5 ppm in green, at 1 ppm in green-blue, at 2 ppm in cyan, and 5 ppm in blue, respectively; deshielding surface at 0.1 ppm in red). View from perpendicular to the molecule and in the plane of the molecule.

aromatic ring systems with [4*n* + 2] π-electrons have significant anisotropy effects. For benzene (*cf.* Fig. 4) deshielding of ICSS = 0.1 ppm at still 7 Å in-plane and shielding of ICSS = −0.1 ppm at 9 Å perpendicular to the plane of the benzene ring were calculated. In annelated aromatic ring systems the global anisotropy effect is increased along with the number of fused rings (*cf.* Fig. 5), based on the intramolecular interaction of the various ring currents. P. Lazzeretti[4] also calculated the ring currents for condensed aromatic systems and proved these intramolecular interactions to be true.

In the 5-membered heteroaromatic ring systems calculated, the anisotropy effect of the ring current is strengthened with the electron donor capacity of the present hetero atom. The deshielding area at ICSS = 0.1 ppm for thiophene is extended to 6.8 Å, in pyrrole the 0.1 ppm deshielding area reaches only 6.0 Å and in furan only 5.8 Å (*cf.* Fig. 6), corroborating the well known nearest similarity of benzene and thiophene among the 5-membered heteroaromatic compounds.

Ring systems of antiaromatic character with [4*n*] π-electrons like pentalene (*cf.* Fig. 7), on the other hand exhibit a reversed anisotropy effect of decreased intensity: a deshielding area above and below the plane of the ring system together with a shielding area in the plane of the ring system was calculated. It should be mentioned that the anisotropy cone of antiaromatic

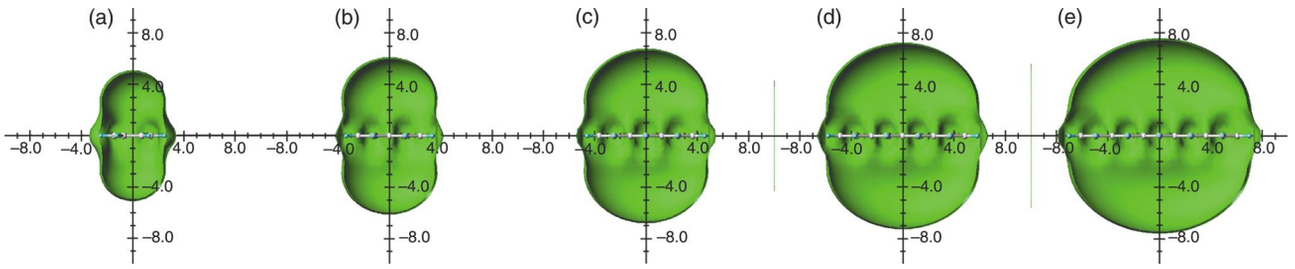

Fig. 5 Comparison of the calculated 0.5 ppm shielding surface for annelated aromatic ring systems: (a) benzene, (b) naphthalene, (c) anthracene, (d) tetracene and (e) pentacene. View in the plane of the molecules.

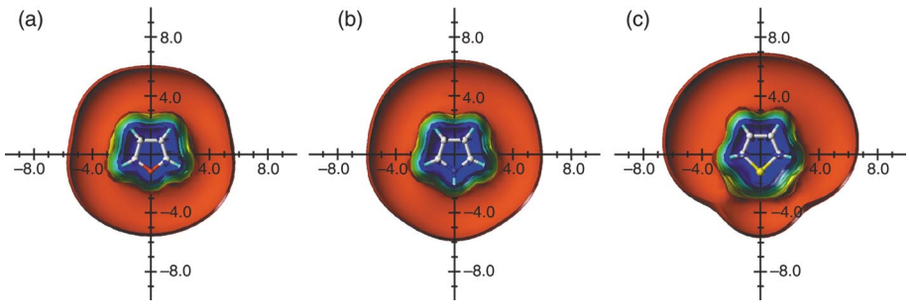

Fig. 6 Comparison of the ring current effects of 5-membered heteroaromatic ring systems: (a) furan, (b) pyrrole, and (c) thiophene (shielding surfaces at 0.1 ppm in yellow, at 0.5 ppm in green, at 1 ppm in green-blue, at 2 ppm in cyan, and 5 ppm in blue, respectively; deshielding surface at 0.1 ppm in red). View from perpendicular to the molecules.

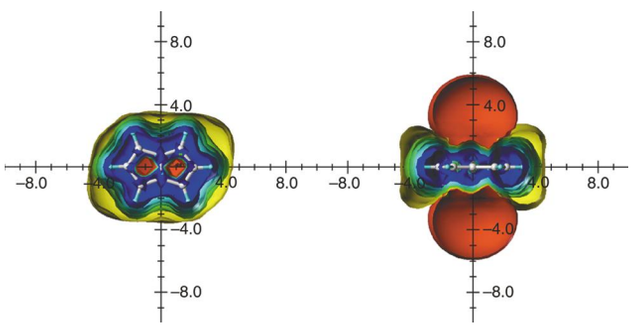

Fig. 7 Calculated reversed ring current effect of antiaromatic compounds using pentalene as an example (shielding surfaces at 0.1 ppm in yellow, at 0.5 ppm in green, at 1 ppm in green-blue, at 2 ppm in cyan, and 5 ppm in blue, respectively; deshielding surface at 0.1 ppm in red). View from perpendicular to the molecule (left) and in the plane of the molecule (right).

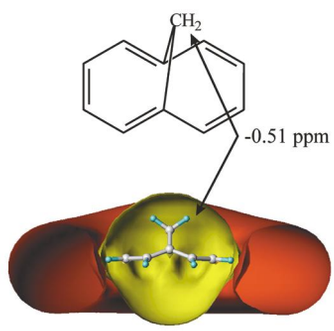

Fig. 8 Stereochemistry and ring current effect of the 10 π-electron aromatic ring system 1,6-methano[10]annulene: only the shielding surface at 2 ppm of the global minimum conformation of 1,6-methano[10]annulene is visualized; the bridge methylene protons are positioned within this shielding area.

compounds (*e.g.* of pentalene in Fig. 7 calculated by the HF/6-31G* method) should be employed in a qualitative manner only, because these antiaromatic compounds are not described properly by a single-determinant wave function (as used in the Hartree–Fock theory). Therefore, for the treatment of antiaromatic systems, the application of MCSCF wave functions proved to be essential.[20]

Stereochemical applications

Due to the characteristic positions of the protons in different parts of their anisotropy cone, annulenes serve as probes for the sign and scope of the ring current effect. In 1,6-methano[10]-annulene the strong shielding of the bridge protons is supposed to result from the ring current effect of the 10 π-electron system.[21] We calculated the anisotropy effect for this compound; the result is visualized in Fig. 8: the bridge protons are located in the ICSS = −2 ppm shielded area above the plane of the 10 π-electron system. Thus, the experimentally determined chemical shift of −0.51 ppm for the bridge protons as compared to 1.5 ppm for this kind of methylene protons in a saturated hydrocarbon can be readily explained.

For a substituted quinazoline derivative bearing an exocyclic nitrile group (*cf.* Fig. 9a) two sets of NH signals were obtained in the ^{1}H NMR spectrum: the lowfield set of signals could be assigned to the conjugated (to the annelated phenyl) NH protons *via* NOE measurement; the chemical shift difference, however, within the two sets was at *ca.* 0.2 ppm rather small[22] to assign to the *cis*/*trans* isomers unequivocally. The anisotropy effect calculated for the whole molecules of the two isomers is given in Fig. 9b. It is easy to see that the anisotropy effects of the benzene ring and the nitrile group, as calculated as single fragments, reproduce the anisotropy effect of the molecule as a whole. The superposition of the ICSS obtained for the fragments and obtained as calculated for the whole molecule proved excellent both in shape and scope. Therefore, it was decided to calculate only fragmental anisotropy effects in order to save calculation time and make the representations clearer and more illustrative. In the case of the quinazoline derivative, the anisotropy effect of the nitrile group attached to the exocyclic double bond proves N^1–H in the 0.1 ppm shielding ICSS in the *cis* isomer and N^3–H in the 0.1 ppm shielding ICSS for the *trans* isomer (*cf.* Fig. 9c), both excellently in line with the experimental chemical shifts of the two sets of NH protons. The corresponding assignment of the signals to the *cis* and *trans* isomers could be readily concluded.

There follows an example of the application of the calculated anisotropy effects of the carbonyl group and the benzene ring in the configurational/conformational analysis of epoxides of *Z*-3-arylidene-1-thioflavan-4-ones[23] which due to three chiral

centres could exist as four isomers. In the NMR spectra of these compounds two sets of signals corresponding to only two isomers in solution were detected and could be assigned, by employing the vicinal coupling between H-2 and C-8a, to be the *trans*,*cis* and *trans*,*trans* epoxides. These two isomers could be differentiated by the chemical shift difference of *ca.* 0.8 ppm of H-3′. Therefore the anisotropy effect of the carbonyl group in the two isomers was calculated: H-3′ is located in the shielding area in the *trans*,*cis* isomer but in the deshielding area in the *trans*,*trans* isomer (ICSS = ±0.4). Each of the two H-3′ signals can be unequivocally assigned to the corresponding isomer (*cf.* Fig. 10). Additionally, the *ortho*-protons of the C-2-phenyl ring of the *trans*,*trans* isomer were found to be shifted to higher field by −0.3 ppm. The calculated anisotropy effect of the 3′-phenyl ring corroborates the former assignment: only in the *trans*,*trans* epoxide are the *ortho*-protons of C-2 phenyl located spatially close to the C-3′-phenyl, and are highfield shifted hereby (*cf.* Fig. 10c).

The ring current effect of aromatic rings proved a very useful tool in the conformational analysis of orthometacyclophanes in solution by NMR spectroscopy. The ^{1}H NMR spectrum of *N*,*N*′-ditosyldiaza[2.2]orthometacyclophane at 180 K exhibits two different signals for the aromatic proton H-2 in the *meta*-disubstituted phenyl ring separated by *ca.* 2.5 ppm.[24] These two signals were classically assigned to the chair and boat conformations using the ring current effect of the *ortho*-substituted phenyl ring (*cf.* Fig. 11), which strongly shields H-2 in the chair conformation but not in the boat conformation. Using the calculated anisotropy effect of the *ortho*-phenyl ring, a more accurate assignment of the shift of these two H-2 signals arises. For the H-2 in the chair conformer an additional shielding of 1.5 ppm is calculated, less than the experimentally obtained 2.5 ppm. But at the same time an additional deshielding of 0.5 ppm of H-2 in the boat conformer was calculated; together 2.0 ppm from anisotropy effects. Obviously, other additional effects besides anisotropy are active in these highly strained cyclophanes, corroborating that the ring current effect is not the only source of the chemical shift differences of *meta*-disubstituted cyclophanes (*cf.* Fig. 11).

The last example of the successful application of the calculated ring current effect in conformational analysis comes from our research in several series of differently substituted hydantoin derivatives[25,26] (*cf.* Fig. 12). In 5-benzyl substituted hydantoins the proton NH-3 is highfield shifted by 0.5 ppm with respect to other 5-substituted hydantoins; the *folded conformation* (benzyl substituent positioned above the hydantoin ring) seems to be preferred[25] (*cf.* Fig. 12). Also in the 3-phenyl benzyl substituted hydantoins the *ortho*-protons of the 3-phenyl ring are highfield shifted by *ca.* 0.3 ppm. Otherwise, the compounds with 5-phenyl substituents have a 0.5 ppm deshielded proton NH-1 as compared to the 5-benzylhydantoins.[26] Calculating now both shielding and

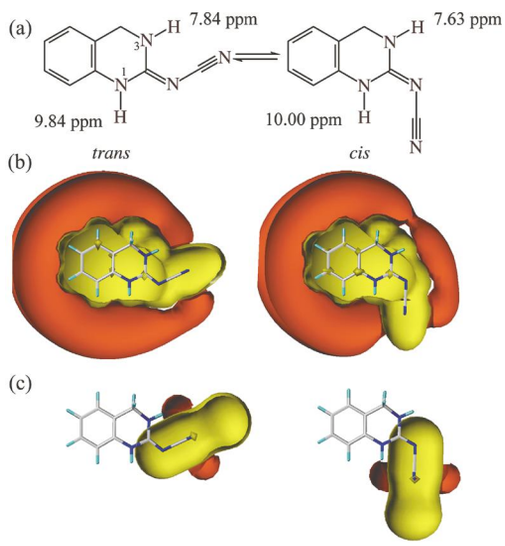

Fig. 9 *cis*/*trans*-Isomerism at the exocyclic C–N double bond of a quinazoline derivative (a), calculated anisotropy effect for the two isomers as a whole (yellow 0.1 ppm shielding, red 0.1 ppm deshielding) (b), and separately calculated anisotropy effects of the nitrile group and the benzene ring, respectively (c), NH-3 in the *cis* isomer and NH-1 in the *trans* isomer are located in the shielding area of the calculated anisotropy effect of the cyano substituent.

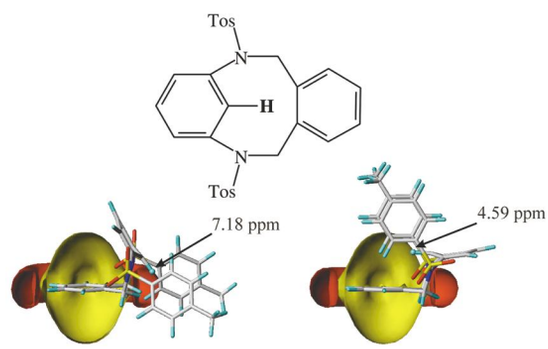

Fig. 11 Calculated ring current effect of boat and chair conformers of *N*,*N*′-ditosyldiaza[2.2]orthometacyclophane (1.5 ppm shielding surface (yellow) and 0.5 ppm deshielding surface (red) of the *ortho*-disubstituted phenyl ring): H-2 of the *meta*-disubstituted phenyl ring positioned in the shielding area of the *ortho*-disubstituted phenyl ring in the chair conformer (right) but in its deshielding area in the boat conformer (left).

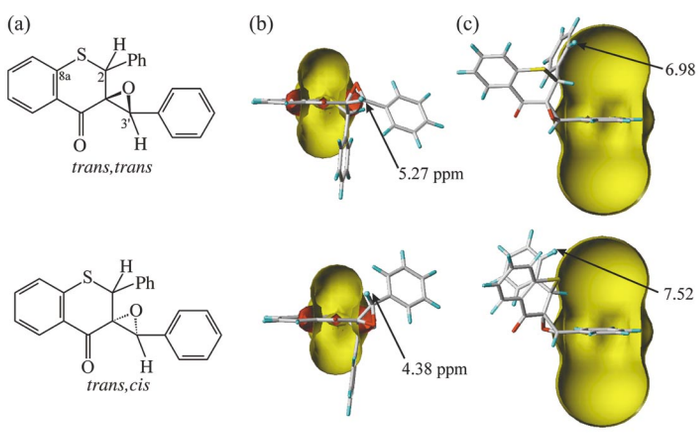

Fig. 10 *trans*,*trans* and *trans*,*cis* isomers of the epoxides of *Z*-3-arylidene-1-thioflavan-4-ones in solution (a), signal assignment of the H$^{3'}$ protons in the two isomers *via* the calculated anisotropy effect of the carbonyl group (yellow 0.4 ppm shielding, red 0.4 ppm deshielding) (b) and signal assignment of the C-2 *ortho*-phenyl protons in the *trans*,*trans* isomer (c).

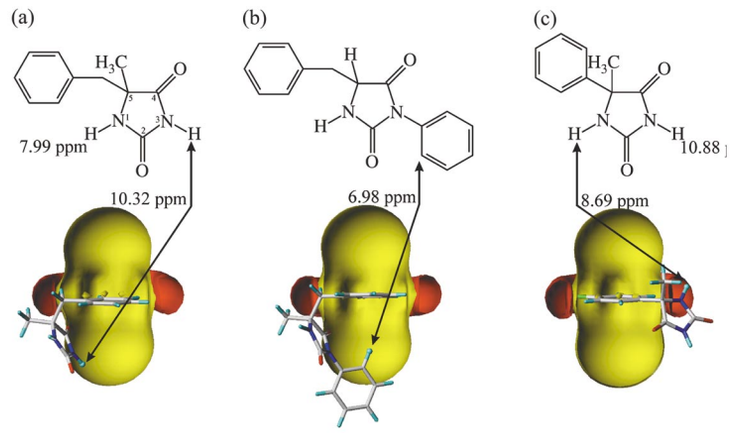

Fig. 12 Conformational analysis of 5,5-disubstituted hydantoins: the NH-3 of 5-benzyl-5-methylhydantoin (a) and the *ortho*-protons of the N-3-phenyl ring of 3-phenyl-5-benzylhydantoin (b) on the 0.5 ppm shielding surface of the benzyl phenyl ring current effect; the deshielding of NH-1 in 5-methyl-5-phenylhydantoin (c) due to the position on the 0.5 ppm deshielding area of the 5-phenyl ring current effect.

deshielding areas of the ring current effects of the various phenyl substituents in these hydantoin derivatives easily allows the assignment of the experimentally obtained proton chemical shift variations: NH-3 of the 5-benzyl-substituted hydantoins proved to be located in the 0.4 ppm shielding ICSS of the benzyl phenyl ring in the folded conformation (*cf.* Fig. 12a). Also the *ortho*-protons of the 3-phenyl ring are 0.4 ppm shielded by the ring current effect of the benzyl phenyl ring (*cf.* Fig. 12b). The folded conformation proved to be preferred also in solution. Finally (*cf.* Fig. 12c), NH-1 in the 5-phenyl substituted hydantoins was found to be positioned in the 0.5 ppm deshielding area of the ring current effect of the 5-phenyl ring also in complete agreement with the experiment.

Comparison of calculations of the phenyl ring current effects in the hydantoin derivatives with the experimentally obtained proton chemical shifts proves both assigned preferred conformations and chemical shift assignments.

Conclusions

A theoretical method to quantitatively calculate anisotropy effects of functional groups and the ring current effect of aromatic and antiaromatic ring systems was presented. With this *ab initio* calculation it was possible to visualize the influences of heteroatoms and attached substituents on the anisotropy effect of single functional groups as well as the mutual influences of the anisotropy effects of more than one isolated functional group.

The calculated anisotropy effects could be very successfully employed in the assignment of proton chemical shifts of stereoisomers and the interpretation of the corresponding ^{1}H NMR spectra. Qualitative conclusions about preferred conformers and present isomers could be reached using the *ab initio* calculated anisotropy effects of involved functional groups.

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