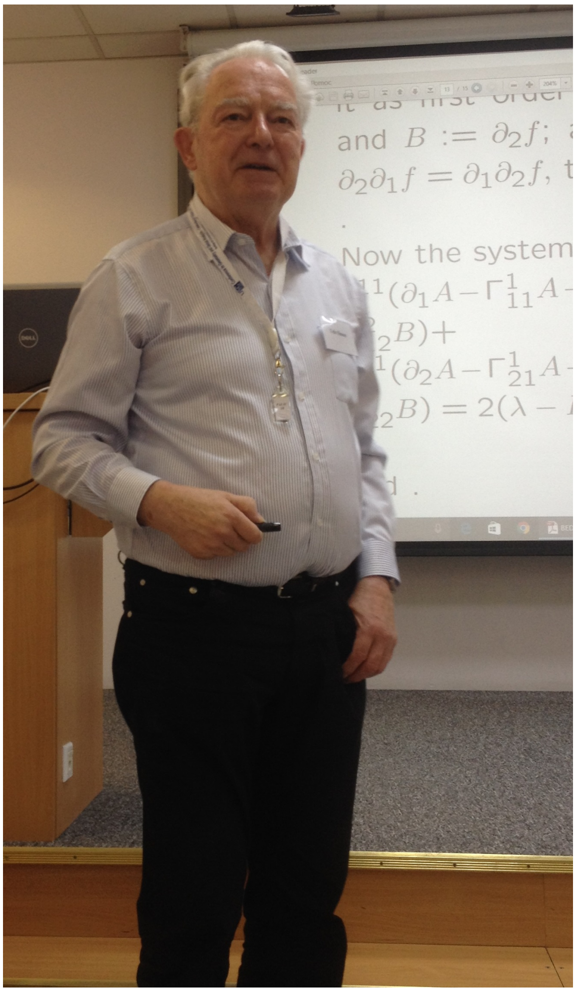
Differential Geometry in honor of Udo Simon's 80th birthday
Banach Center, Będlewo Conference Center, Poland

September 7-10, 2018



Andrzej Derdzinski
Ryszard Deszcz
Wendy Goemans
Stana Nikčević
Barbara Opozda
Zoran Rakic
Luc Vrancken

Program

		Saturday, September 8, 2018
08:00 - 09:45		BREAKFAST
09:45 - 10:00		OPENING CEREMONY
		CHAIR: Barbara Opozda
10:00 - 10:40	Andrzej Derdzinski	Left-invariant Einstein connections
10:40 - 11:10	Joeri Van der Veken	Lagrangian submanifolds of the complex quadric
11:10 - 11:40		Coffee break
		CHAIR: Josef Dorfmeister
11:40 - 12:10	Zejun Hu	On submanifolds of 3-sphere immersions
12:10 - 12:30	Shimpei Kobayashi	General-affine invariants of plane curves and space curves
12:30 - 14:30		LUNCH
		CHAIR: Ryszard Deszcz
14:30 - 15:00	Sheng Li	A Bernstein property of certain types of fourth order partial differential equations
15:00 - 15:30	Aleksandra Borówka	C-projective symmetries of submanifolds in quaternionic geometry
15:30 - 16:00		Coffee break
		CHAIR: Christine Scharlach
16:00 - 16:40	Eduardo Garcia-Rio	Conformally Einstein and Bach flat homogeneous manifolds
16:40 - 17:10	Zbigniew Olszak	The equi-affine curvatures of curves in 3-dimensional pseudo-Riemannian manifolds
17:30 - ...		DINNER (weather dependent: garden party or banquet)

Sunday, September 9, 2018.		
08:00 - 09:45		BREAKFAST
		CHAIR: An-Min Li
10:00 - 10:40	Luc Vrancken	Warped product hypersurfaces
10:40 - 11:10	Keti Tenenblat	The Mean Curvature Flow by parallel hypersurfaces
11:10 - 11:40		Coffee break
		CHAIR: Wendy Goemans
11:40 - 12:10	Roland Hildebrand	Self-associated three-dimensional cones
12:10 - 12:30	Xabier Valle-Regueiro	Some applications of the affine quasi-Einstein equation
12:30 - 14:30		LUNCH
		CHAIR: Boguslaw Hajduk
14:30 - 15:00	Zoran Rakic	On Nonlocal Modified Theory of Gravity
15:00 - 15:20	Handan Yıldırım	On applications of Chen's invariants to centroaffine differential geometry
15:20 - 15:50		Coffee break
		CHAIR: Stana Nikčević
15:50 - 16:20	Zuzanna Szancer	On 3-dimensional $\widetilde{J}$-tangent centro-affine hypersurfaces with null-directions
16:20 - 17:00	Barbara Opozda	Curvature bounded conjugate symmetric connections with complete metrics
17:00 - 17:15		CLOSING CEREMONY
17:30 - ...		DINNER (weather dependent: banquet or garden party)

POSTERS

Ryszard Deszcz, Małgorzata Głogowska, Marian Hotloś	Hypersurfaces satisfying curvature conditions determined by the Opozda-Verstraelen affine curvature tensor
Stana Nikčević	Short story on some Udo's results
Maria Robaszewska	Bäcklund transformation for surfaces with locally symmetric non-metrizable Blaschke connection

Abstracts

Aleksandra Borówka – C-projective symmetries of submanifolds in quaternionic geometry

Quaternonic structure on a manifold induce c-projective structures on its totally complex submanifolds, that is a special class of torsion free complex connections. In this talk we will discuss a relation between the algebra of infinitesimal quaternionic symmetries on the manifold and the algebra of infinitesimal c-projective symmetries on its c-projective submanifold, provided that it arises as a fixed points set of an S^1 action of a special kind. As both c-projective and quaternionic manifolds are examples of parabolic Cartan geometries, they admit so called gap phemomenon for the algebra of infinitesimal symmetries, which means that the maximal dimension of symmetries in the non-flat case (called the submaximal dimension) is significantly smaller than the dimension of the symmetries of the flat model. We will discuss the relations between submaximally symmetric spaces of each type.

Andrzej Derdzinski – Left-invariant Einstein connections

The set $\mathcal{E}$ of Levi-Civita connections of left-invariant pseudo-Riemannian Einstein metrics on a given semisimple Lie group G always includes D, the Levi-Civita connection of the Killing form. When G is noncompact, a still wide-open 1975 conjecture of Dmitry Alekseevsky, if true, would imply that such left-invariant Einstein metrics on G are all indefinite. This talk explicitly describes several connected components of $\mathcal{E}$ for the groups G of the SL series, which extends an earlier description, obtained in collaboration with Światosław R. Gal, of the component $\mathcal{C}$ of $\mathcal{E}$ containing D. The picture that emerges is consistent with Alekseevsky's conjecture. The approach focuses on connections rather than metrics, which has the advantage of simultaneously generalizing and simplifying the algebraic aspect of the question.

Ryszard Deszcz, Małgorzata Głogowska and Marian Hotloś – Hypersurfaces satisfying curvature conditions determined by the Opozda-Verstraelen affine curvature tensor

Let $\mathbb{A}^{n+1}$, $n \geq 2$, be the $(n+1)$-dimensional real affine space, i.e. $\mathbb{R}^{n+1}$ equipped with its standard flat connection $\widetilde{\nabla}$ and the volume element $\widetilde{\Theta}$ given by the determinant. Let M be a non-degenerate hypersurface in $\mathbb{A}^{n+1}$ with the affine normal ξ and the induced equiaffine structure (∇, θ) (see, e.g., [5, 7]). Using the curvature tensor R of ∇, the affine shape operator $\mathcal{S}$, the Blaschke metric h of M, the Gauss equation $R(X,Y)Z = h(Y,Z)\mathcal{S}X - h(X,Z)\mathcal{S}Y$ and the Ricci equation $h(X, \mathcal{S}Y) = h(Y, \mathcal{S}X)$ of M in $\mathbb{A}^{n+1}$ we can define the generalized curvature tensor R^* of M named the *Opozda-Verstraelen affine curvature tensor* R^* of M [5, 6]. Namely, we have

$$\begin{aligned} R^*(X_1, \ldots, X_4) &= h(R(X_1,X_2)\mathcal{S}X_3, X_4) = h(h(X_2, \mathcal{S}X_3)\mathcal{S}X_1 - h(X_1, \mathcal{S}X_3)\mathcal{S}X_2, X_4) \\ &= h(X_2, \mathcal{S}X_3)h(\mathcal{S}X_1, X_4) - h(X_1, \mathcal{S}X_3)h(\mathcal{S}X_2, X_4) \\ &= S(X_1,X_4)S(X_2,X_3) - S(X_1,X_3)S(X_2,X_4), \end{aligned}$$

where the $(0,2)$-tensor S is defined by $S(X,Y) = h(X, \mathcal{S}Y)$ and $X, Y, Z, X_1, \ldots, X_4$ are tangent vector fields on M. We denote by $\mathrm{Ricc}(R^*)$, $\kappa(R^*)$ and $\mathrm{Weyl}(R^*)$ the Ricci tensor, the scalar curvature and the Weyl tensor determined by the metric h and the tensor R^* [5].The non-degenerate hypersurface M in $\mathbb{A}^{n+1}$, $n \geq 3$, is said to be *affine quasi-umbilical* at a point of $x \in M$ if at x we have $\mathrm{rank}(S - \alpha\, h) = 1$, for some $\alpha \in \mathbb{R}$ [5]. In [5] it was proved that for affine quasi-umbilical M in $\mathbb{A}^{n+1}$, $n \geq 3$, the tensor $\mathrm{Weyl}(R^*)$ vanishes. The converse statement is true when $n \geq 4$ [2]. We refer to [8] for examples of affine quasi-umbilical hypersurfaces. In [1, 2, 5, 6] results on hypersurfaces M in $\mathbb{A}^{n+1}$ satisfying other conditions imposed on R^*

are studied. For instance, we have $R^* \cdot R^* = Q(\mathrm{Ricc}(R^*), R^*)$ on M [2]. Using results of [3, 4] we can obtain further results on this class of hypersurfaces. In particular, if the conditions $R^* \cdot R^* = L\, Q(h, R^*)$ and $\mathrm{rank}(\mathrm{Ricc}(R^*) - \rho\, h) \geq 2$, for some functions L and ρ, are satisfied on a subset $U \subset M$, then at every point of U the tensor R^* is a linear combination of the Kulkarni-Nomizu products $\mathrm{Ricc}(R^*) \wedge \mathrm{Ricc}(R^*)$, $h \wedge \mathrm{Ricc}(R^*)$ and $h \wedge h$. This implies that at every point of U the difference tensor $\mathrm{Weyl}(R^*) \cdot R^* - R^* \cdot \mathrm{Weyl}(R^*)$ is a linear combination of the Tachibana tensors $Q(\mathrm{Ricc}(R^*), \mathrm{Weyl}(R^*))$ and $Q(h, \mathrm{Weyl}(R^*))$. Precisely, we have on U

$$\mathrm{Weyl}(R^*) \cdot R^* - R^* \cdot \mathrm{Weyl}(R^*) \quad = \quad Q(\mathrm{Ricc}(R^*), \mathrm{Weyl}(R^*)) - (\kappa(R^*)/(n-1))\, Q(h, \mathrm{Weyl}(R^*)).$$

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Eduardo Garcia-Rio – Conformally Einstein and Bach flat homogeneous manifolds

The classification of conformally Einstein manifolds is still an intriguing open problem nowadays. Despite recent progress on product manifolds and Kahler manifolds, the general situation needs to be elucidated. Our purpose on this lecture is to determine all four-dimensional conformally Einstein homogeneous manifolds. In addition to the symmetric cases (which contain the Einstein and the locally conformally Einstein situations) there are three new homogeneous geometries containing an Einstein representative in their conformal class.

Roland Hildebrand – Self-associated three-dimensional cones

For every regular convex cone $K \subset \mathbb{R}^3$ there exists a unique complete hyperbolic affine 2-sphere with mean curvature -1 which is asymptotic to the boundary of the cone. Two cones are associated with each other if the Blaschke metrics of the corresponding affine spheres are related by an orientation-preserving isometry. We call a cone self-associated if it is linearly isomorphic to all its associated cones. We give a complete classification of the self-associated cones and compute isothermal parametrizations of the corresponding affine spheres. The solutions can be expressed in terms of degenerate Painlevé III transcendents. The boundaries of generic self-associated cones can be represented as conic hulls of vector-valued solutions of a certain third-order linear ordinary differential equation with periodic coefficients. The technique developed in this paper can also be applied to the three-dimensional semi-homogeneous cones, with similar results.

Zejun Hu – On submanifolds of 3-sphere immersions

In this lecture, I will talk about some researches on submanifolds of the 3-sphere immersions. This includes in particular our recent study with ambient spaces the complex projective space and the homogeneous nearly Kähler manifold $S^3 \times S^3$.

For the former case, we notice that the equivariant CR minimal immersions from the round 3-sphere S^3 into the complex projective space $\mathbb{C}P^n$ have been classified by Zhenqi Li explicitly (J London Math Soc **68** (2003), 223-240). Then, by employing the equivariant condition which implies that the induced metric is left-invariant, and that all geometric properties of $S^3 = \mathrm{SU}(2)$ endowed with a left-invariant metric can be expressed in terms of the structure constants of the Lie algebra $\mathfrak{su}(2)$, we establish an extended classification theorem for equivariant CR minimal immersions from the 3-sphere S^3 into $\mathbb{C}P^n$ without the assumption of constant sectional curvatures.

For the latter case, we first show that isotropic Lagrangian submanifolds in a 6-dimensional strict nearly Kähler manifold are totally geodesic. Then, under some weaker conditions, a complete classification of the J-isotropic Lagrangian submanifolds in the homogeneous nearly Kähler $S^3 \times S^3$ is obtained, which mainly consists of 3-sphere immersions. Here, a Lagrangian submanifold of $S^3 \times S^3$ is called J-isotropic, if there exists a function λ, such that the metric g, the almost complex structure J and the second fundamental form h satisfy $g((\nabla h)(v, v, v), Jv) = \lambda$, for all unit tangent vector v.

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Shimpei Kobayashi (joint work with Takeshi Sasaki) – General-affine invariants of plane curves and space curves

In this talk I shall present a fundamental theory of curves in the affine plane and the affine space equipped with the general-affine groups $\mathrm{GA}(2) = \mathrm{GL}(2, \mathbf{R}) \ltimes \mathbf{R}^2$ and $\mathrm{GA}(3) = \mathrm{GL}(3, \mathbf{R}) \ltimes \mathbf{R}^3$, respectively. In particular I present the extremal problem of the general-affine length functional and derive a variational formula.

Sheng Li – A Bernstein property of certain types of fourth order partial differential equations

We derive a Bernstein theorem for a class of fourth order partial differential equations. We also give a geometric interpretation for the partial differential equations.

Stana Nikčević – A short story of some Udo's results

We present some Udo Simon's results which have been published since 2006, focusing on the topics related to the geometry of affine curvature tensors using the curvature decompositions; Osserman conjecture (more specifically, the projectively Osserman manifolds, the Jacobi operator associated to the conformal curvature tensor), the Weyl geometry, as well as the gradient Ricci solitons. The results have been obtained in collaboration with Novica Blazic, Peter Gilkey, Miguel Brozos-Vazquez and Stana Nikčević.

Zbigniew Olszak and Karina Olszak – The equi-affine curvatures of curves in 3-dimensional pseudo-Riemannian manifolds

As it is well-known, a pseudo-Riemannian manifold (M, g) can always be treated as an equi-affine manifold (M, ∇, Ω) with the ∇ being the Levi-Civita connection and Ω the natural volume form. For curves in a 3-dimensional pseudo-Riemannian manifold, relations between equi-affine curvatures and the standard Frenet curvatures will be presented.

Barbara Opozda – Curvature bounded conjugate symmetric connections with complete metric

Conjugate connections naturally appear in affine differential geometry. Namely, for a non-degenerate equiaffine hypersurface $f : M \to \mathbf{R}^{n+1}$ and its conormal map $f^* : M \to (\mathbf{R}^{n+1})^*$ we have the induced connections which are conjugate relative to the second fundamental form g for f. Conjugate connections exist in the theory of Hessian manifolds and their generalizations, that is, statistical manifolds. The first publications on Hessian and statistical structures appeared in the 80-ties, see e.g. the monograph texts by A. Amari [1] and Lauritzen [2]. In [3] Nomizu and Simon, the leading experts in affine differential geometry, published a paper in which they proposed the study of conjugate connections on abstract manifolds, that is, in the situation where the conjugate connections are not necessarily those obtained on equiaffine hypersurfaces. In the 90-ties, after almost 90 years of existing and developing the theory of affine hypersurfaces, there were a lot of beautiful geometric results on the induced structures on affine hypersurfaces and a lot of examples of remarkable models, although the case of hypersurfaces is very special. The study of conjugate connections on abstract manifolds intensified after 2010. Usually the name "a statistical structure" is now used. In particular, in 2015 in [4] a sectional curvature for conjugate connections was introduced and basic properties of this curvature were established. The notion of sectional curvature is attributed to Riemannian geometry in a strong way and it is very unusual that it can be successfully extended to non-metric connections. In fact, we have two new sectional curvatures for statistical structures. The first one is defined by the curvature tensor $\mathcal{R} = \frac{R+\overline{R}}{2}$, where R and $\overline{R}$ are the curvature tensors for the conjugate connections. The second one is determined by the difference tensor of the structure. In general, Schur's lemma does not hold for any of the new sectional curvatures. It holds for conjugate symmetric statistical structures. This category of structures corresponds to the category of equiaffine spheres in the theory of affine hypersurfaces, but, even from the local view-point, it is much larger. The conjugate symmetric structures were also noticed by statisticians. In particular, the name "a conjugate symmetric statistical structure" is taken from [2]. The class of conjugate symmetric statistical structures is as important in the theory of statistical structures as the class of equiaffine spheres in affine differential geometry. Within the last class we have affine spheres which are trace-free equiaffine spheres. Again, the class of trace-free conjugate symmetric statistical structures is much larger than the class of affine spheres, even from the local view-point. For instance, the sectional curvature determined by the curvature tensor $\mathcal{R}$ on connected equiaffine spheres is constant. In [5] the following generalization of famous theorems of Blaschke, Deicke and Calabi for affine spheres are proved in the case of statistical structures on abstract manifolds of non-constant sectional curvature:

Theorem 1 *Let $(g, \nabla, \overline{\nabla})$ be a trace-free conjugate symmetric statistical structure on a manifold M. Assume that g is complete on M. If the sectional curvature determined by $\mathcal{R}$ is bounded from below and above on M then the Ricci tensor of g is bounded from below and above on M. If this sectional curvature is non-negative everywhere on M then the statistical structure is trivial, that is, ∇ is the LeviCivita connection for g. If this sectional curvature is positive and bounded from 0 by a positive constant then, additionally, M is compact and its first fundamental group is finite.*

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Zoran Rakic (joint work with Ivan Dimitrijević, Branko Dragović and Jelena Stanković) – On nonlocal modified theory of gravity

Despite many significant gravitational phenomena have been predicted and discovered using general relativity, it is not a complete theory. One of actual approaches towards more complete theory of gravity is its nonlocal modification. We consider nonlocal modification of the Einstein theory of gravity in framework of the pseudo-Riemannian geometry. The nonlocal term has the form $\mathcal{H}(R)\mathcal{F}(\Box)\mathcal{G}(R)$, where $\mathcal{H}$ and $\mathcal{G}$ are differentiable functions of the scalar curvature R, and $\mathcal{F}(\Box) = \sum_{n=0}^{\infty} f_n\Box^n$ where f_n are is an analytic function of the d'Alambert operator $\Box$. Using calculus of variations we derived the corresponding equations of motion. The variation of action is induced by variation of the metric tensor $g_{\mu\nu}$. We consider several models of the above mentioned type, as well as the case when the scalar curvature is constant. Moreover, we consider space-time perturbations of the de Sitter space. It was shown that gravitational waves are described in the class of nonlocal models $\mathcal{H}(R)\mathcal{F}(\Box)\mathcal{G}(R)$, with respect to Minkowski metric by the same equations as in general relativity.
The work was partially supported by the project ON174012 of MPNTR of Republic of Serbia.

Maria Robaszewska – Bäcklund transformation for surfaces with locally symmetric non-metrizable Blaschke connection

For a non-degenerate surface on which the affine normal vector field induces a locally symmetric connection satisfying the conditions $\dim \operatorname{Im} R = 1$, $\operatorname{sgn} \operatorname{Ric} = -1$ one can construct a one-parameter family of surfaces with the same property.

Zuzanna Szancer – On 3-dimensional $\widetilde{J}$-tangent centro-affine hypersurfaces with null-directions

In this talk we study 3-dimensional centro-affine hypersurfaces with a $\widetilde{J}$-tangent centro-affine vector field ($\widetilde{J}$ is the canonical para-complex structure on $\mathbb{R}^4$) with the property that at least one null-direction of the second fundamental form coincides with either $\mathcal{D}^+$ or $\mathcal{D}^-$ ($\mathcal{D} = \mathcal{D}^+ \oplus \mathcal{D}^-$). Here $\mathcal{D}$ is the biggest $\widetilde{J}$-invariant distribution in TM and $\mathcal{D}^+$, $\mathcal{D}^-$ are eigen spaces related to eigen values $+1$ and -1 respectively. We give a full local classification of such hypersurfaces. Moreover we classify 3-dimensional $\widetilde{J}$-tangent affine hyperspheres with the above properties. In particular, we show that every nondegenerate centro-affine hypersurface of dimension 3 with a $\widetilde{J}$-tangent centro-affine vector field which has two null-directions $\mathcal{D}^+$ and $\mathcal{D}^-$ must be both an affine hypersphere and a hyperquadric. We provide also some examples.

Keti Tenenblat (joint work with Hiuri Fellipe Santos dos Reis) – The Mean Curvature Flow by parallel hypersurfaces

It is shown that a hypersurface of a space form is the initial data for a solution to the mean curvature flow by parallel hypersurfaces if, and only if, it is isoparametric. By solving an ordinary differential equation, explicit solutions are given for all isoparametric hypersurfaces of space forms. In particular, for such hypersurfaces of the sphere, the exact collapsing time into a focal submanifold is given in terms of its dimension, the principal curvatures and their multiplicities.

Xabier Valle-Regueiro (joint work with P. Gilkey) – Some applications of the affine quasi-Einstein equation

An affine manifold (M, ∇) is said to be *affine quasi-Einstein* if there is a solution $f \in \mathcal{C}^\infty(M)$ of the equation

$$\mathrm{Hes}_f^\nabla - \mu f \rho_{\mathrm{sym}}^\nabla = 0 \tag{1}$$

for some $\mu \in \mathbb{R}$, where Hes_f^∇ and $\rho_{\mathrm{sym}}^\nabla$ denote the Hessian of f and the symmetric Ricci tensor, respectively. Solutions to this equation provide self-dual quasi-Einstein metrics of signature $(--++)$ which are not necessarily locally conformally flat by means of the Riemannian extension of the affine connection ∇ to T^*M.
The dimension of the space of solutions of the affine quasi-Einstein equation corresponding to $\mu = -1$ provides a strong projective invariant for affine surfaces. In particular, strongly projectively flat connections can be (locally) parametrized by solutions of the affine quasi-Einstein equation [1]. Our purpose in this lecture is to show how this distinguished parametrization may be used to investigate different geometric properties: linear equivalence [2] and geodesic completeness of (M, ∇).

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Joeri Van der Veken – Lagrangian submanifolds of the complex quadric

The complex quadric Q^n is the complex hypersurface of complex $(n+1)$-dimensional projective space given in homogeneous coordinates by the equation $z_0^2 + z_1^2 + \ldots + z_{n+1}^2 = 0$. This manifold inherits a Kähler structure from the complex projective space, carries a family of non-integrable almost product structures and its curvature can be relatively easily described in terms of these two. Moreover, Q^n is the natural target space when considering the Gauss map of a hypersurface of a round sphere. In fact, such Gauss maps are related to minimal Lagrangian submanifolds of Q^n. We will discuss this relation – in particular for isoparametric hypersurfaces of spheres – and then study minimal Lagrangian submanifolds of Q^n, obtaining examples and some classifications, such as that of minimal Lagrangian submanifolds of Q^n with constant sectional curvature.

Luc Vrancken (joint work with Marilena Moruz) – Warped product hypersurfaces

Classical examples of warped product hypersurfaces in a real space form are the rotational hypersurfaces. In this talk we show that in some sense the reverse statement is also true, i.e. let $M = I \times_f N(\tilde{c})$ be a warped product manifold of an interval with a real space form and assume that M is contained as a hypersurface in a real space form. Then either M is itself a space of constant sectional curvature or M is a rotational hypersurface in the sense of Dajczer and Do Carmo.

Handan Yıldırım – On applications of Chen's invariants to centroaffine differential geometry

Chen's invariants and applications of these invariants have been of great interest among geometers for almost three decades (for instance, see [1]).
In this talk, as an application of these invariants to centroaffine differential geometry, some recent results which are based on a joint work with Luc Vrancken will be presented.
Acknowledgements. This talk is based on a work which was supported by the Scientific Research Projects Coordination Unit of Istanbul University with the project numbered 33525.
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Participants

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Zejun Hu	Joeri Van der Veken
Shimpei Kobayashi	Luc Vrancken
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