2nd International Granular Flow Workshop, 2017

Institute of Physics, CAS

Institute of Modern Physics, CAS

National University of Defense Technology

Guizhou University

Agenda

Date	Time	Program
Aug.21 Monday	9:00-20:00	**Registration**
Aug.22 Tuesday	**Morning**	
	08:30-12:00	**Hosted by Xiaosong Chen**
	08:30~08:50	Welcome and introduction **Speaker：Meiying Hou,** Institute of Physics, CAS
	08:50~09:35	**Title：**Concept and progress of the granular target **Speaker：Lei Yang**, Institute of Modern Physics, CAS
	09:35~10:10	**Break and Photo**
	10:10~10:55	**Title：**Origins of shear jamming and force networks **Speaker：Bob Behringer,** Duke University
	10:55~11:40	**Title：**Granular stat. mech.: different structural entropy sources, exact calculations, and the origin of N! **Speaker：Rafi Blumenfeld,** Imperial College London
	11:40~12:00	**Title：**Study of an athermal quasi static plastic deformation in a 2D granular material **Speaker：Jie Zhang,** Shanghai JiaoTong University
	12:00~14:00	**Lunch**
	Afternoon	
	14:00~15:30	Hosted by **Zhigang Zheng**
	14:00~14:45	**Title：**A taxonomy of granular flows down inclines: how different bases produce widely different scaling of mass flow rate with depth **Speaker： Michel Yves Louge**, Cornell University
	14:45~15:30	**Title：** Statistical mechanical theory of the rheology of suspensions: the divergence of viscosity and the shear thickening **Speaker：Hisao Hayakawa**, Kyoto University
	15:30~16:10	**Break and Poster**
	16:10~18:15	Hosted by **Wenshan Duan**
	16:10~16:55	**Title：**Unjamming of Hoppers: Modeling the Dynamics of Arches by a Continuous Time Random Walk **Speaker：Bulbul Chakraborty**, State University of New York
	16:55~17:15	**Title:** Granular packing as model glass formers **Speaker：Yujie Wang**, Shanghai Jiao Tong University
	17:15~17:35	**Title：**Rate dependent behavior of granular geomaterials: measurements and mathematical models **Speaker：Xiaohui Cheng**, Tsinghua University
	17:35~17:55	**Title：**The Structural Re-organisation in a Sheared Granular Material **Speaker：Xia Li**, Southeast University
	18:00~19:30	**Banquet**

Aug.23 Wednesday	Morning	
	08:30~10:20	Hosted by **Jie Zhang**
	08:30~09:15	**Title：**From Micro to Macro: From Particles to Continuum Theory **Speaker：Stefan Luding**, University of Twente
	09:15~10:00	**Title：** Why Thermodynamics is the proper Foundation for Granular Media **Speaker： Mario Liu**, University of Tubingen
	10:00~10:20	**Title：**A thermodynamic model of grain-grain contact force **Speaker：Yimin Jiang,** Central South University
	10:20~11:00	**Break**
	11:00~12:10	Hosted by **Xiaohui Cheng**
	11:00~11:45	**Title：**Collective Dynamics of Active Granular Particles **Speaker：Thorsten Poeschel**, Universidad Erlangen Germany
	11:45~12:10	**Title：**Pulsed beam experiment at CERN **Speaker：Chris Densham**, STFC
	12:10~14:00	**Buffet**
	Afternoon	
	14:00~18:30	Hosted by **Yujie Wang**
	14:00~14:45	**Title：**Clog and flow in silo with oscillating exit **Speaker：Kiwing To,** Institute of Physics, Academia Sinica
	14:45~15:30	**Title：**Flowing, squeezing, clogging, and jamming of oil droplets **Speaker：Eric Weeks,** Emory University
	15:30~15:50	**Title：** Size scaling of velocity field in granular flows through apertures **Speaker：Xiaosong Chen**, Institute of Theoretical Physics, CAS
	15:50~16:30	**Break & POSTER**
	16:30-18:10	Hosted by **Yimin Jiang**
	16:30~18:10	**Title：**Self-propulsion of a grain-filled dimer in a vertically vibrated channel **Speaker：Ning Zheng**, Beijing Institute of Technology
	16:50~17:10	**Title：** Interface Facilitated Energy Transport in Coupled Nonlinear Lattices **Speaker：Zhigang Zheng**, Huaqiao University
	17:10~17:30	**Title：**Review on the measurement of grain motion in dense granular materials **Speaker：Hui Yang**, University of Shanghai for Science and Technology
	17:30~17:50	**Title：**The Study of the performance of the PMMA granular sample in photo-elasticity experiment of the contact force measurement **Speaker： Zhengyu Yong**, NUDT
	17:50~18:10	**Title：**Rogue wave and the envelop solitary wave in granular medium **Speaker：Wenshan Duan**, Northwest Normal University
	18:10~19:30	**Buffet**

Dinning

Date	Time		
Aug.22	Breakfast	07:00-08:00	The restaurant, floor 1 of building 2
	Lunch	12:00-14:00	The restaurant, floor 1 of building 2
	Dinner	18:00-19:30	The XiWai hall, floor 2 of building 3
Aug.23	Breakfast	07:00-08:00	The restaurant, floor 1 of building 2
	Lunch	12:10-14:00	The restaurant, floor 1 of building 2
	Dinner	18:10-19:30	The restaurant, floor 1 of building 2

Notices

1) **Wifi name: huaxihotel**
2) **Please check out before 12:00. Extension until 18:00 is charged by half a day.**
3) **Please return your room key when check out. 100RMB is charged for key lost.**
4) **Any causation of extended accommodation is self-payed.**
5) **Tips:**
   a) RMB cash for small payment
   b) Resident ID card, passport or other legal documentation for traffic and accommodation.
   c) Medicines. (car sick etc.)
   d) High temperature precaution and rain gear
6) **Please take care of your safety. Conference affair committee is duty free.**

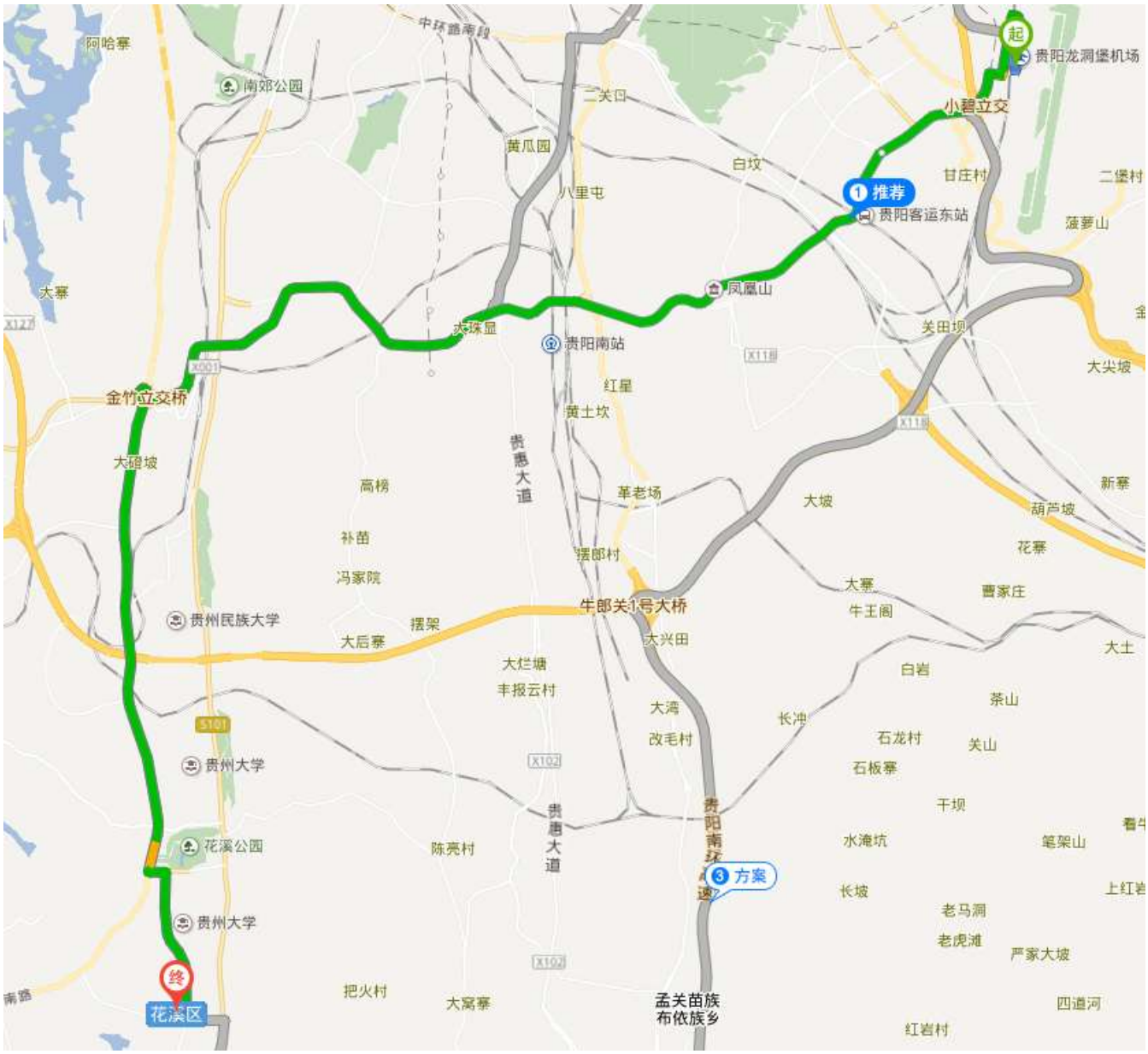
Transport to Hotel

Address：210 Yingbin Road (Yingbin Lu), Guiyang

Telephone: 0851-85368002

1) **Airport - Huaxi Hotel:**
   - Taxi: 28km for about 50min and 80 Yuan RMB
   - Airport shuttle: Get off at Stadium Station(Railway station) and take bus no.255 and get off at Gui'an Government Affairs Center Station
2) **Railway station - Huaxi Hotel:**
   - Taxi: 22km for about 50min and 60 Yuan RMB
3) **North Railway station - Huaxi Hotel:**
   - Taxi: 28km for about 40min and 70 Yuan RMB

Airport - Huaxi Hotel：



Around the Huaxi Hotel:

Abstract of talks

Concept and progress of the granular target

Lei Yang, Wenlong Zhan
Institute of Modern Physics, CAS

Abstract: The concept of granular target was proposed in 2012 and has a remarkable potential of removal of high heat deposition [1, 2]. Recently the prototype of the loop has been built to test the capacity of long running, beam coupled and heat removal. Last year the project of CIADS, located in Guizhou, was launched. Here the origin and development of the concept will be introduced and the challenge of physics in the system will be concluded.

Ref:

1. Zhan, W.-L. Accelerator Driven Sustainable Fission Energy. In 7th International Particle Accelerator Conference (IPAC'16), Busan, Korea, May 8-13, 2016. 2016. JACOW, Geneva, Switzerland.
2. Yang, L. and W.L. Zhan, New concept for ADS spallation target: Gravity-driven dense granular flow target. Science China-Technological Sciences, 2015. 58(10): p. 1705-1711.

Origins of shear jamming and force networks

Bob Behringer
Duke University

Abstract: Systems of frictional particles shear jam, i.e. in a non-zero range of density, starting from a stress-free state, they evolve robust force networks (force chains) in response to shear strain. As a consequence, the system develops non-zero stresses that are typically anisotropic, and mean contact numbers above the isostatic value. This phenomena, which is related to Reynolds dilatancy, is striking because the system can exist in stress free, fragile and strongly jammed states, all at the same density. Since shear strain is a volume preserving deformation, there must be some mechanism that allows frictional grains to evolve stable force networks. For instance, pure shear compresses a system in one direction, elongates it in the other (in two dimensions) without changing the area. Force networks form initially along the compression direction for small shear strain, but extend in all directions for large enough strain. Why don't the particles that are being pushed together along the compression direction slip and flow into the dilation direction? For instance, in systems of frictionless particles, force chains form transiently, but are unstable and subject to failure. Here, we consider basic observations of shear jamming as a function of inter-particle friction and particle shape. We then search for small scale features that enable frictional particle systems to shear jam. To characterize key features of force chains, we consider 'trimers', sequences of three grains such the center grain is in contact with two neighboring grains. During shear, trimers show key evolutionary features that lead to the formation of additional contacts, to robust force networks, and hence to jammed states. These features depend on whether the particles have friction or not, which indicates a fundamental difference between systems of grains with and without friction.

anular stat. mech.: different structural entropy ources, exact calculations, and the origin of N!

Rafi Blumenfeld
NUDT, Changsha, China, Imperial College, London, UK
& Cambridge University, Cambridge, UK

Abstract: We identify several sources of structural entropy in granular systems, the two most prominent being affine and topological. The former involves contact-preserving structural deformations and the latter corresponds to different topologies of the contact network. The two are separated naturally by considering, within the recently developed connectivity-based granular statistical mechanics [1a, b], by associating the structural degrees of freedom with spanning trees on the graph of the contact network. Using this formalism, the following results are obtained [2]: (i) We calculate the partition function and the different entropies in the high-angoricity limit. We show that the topological entropy explains the factor of N! , observed numerically [3a, b]. (ii) We derive expectation values of several macroscopic quantities. (iii) We verify the existence of an equi-partition principle. (iv) We derive an equation of state relating the volume and boundary stress.

Ref:

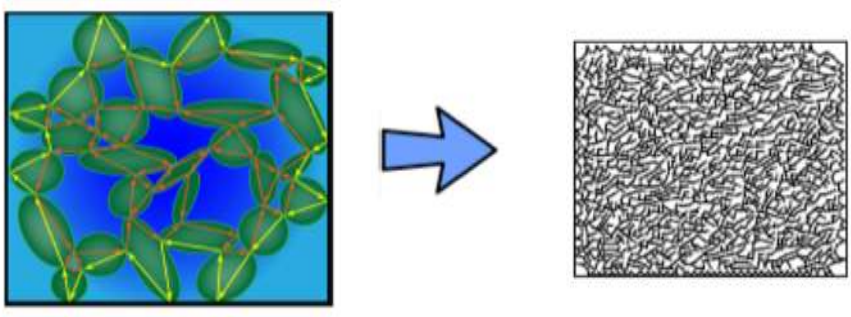
1a. R. Blumenfeld et al., Phys. Rev. Lett. 116, 148001 (2016).

1b. R. Blumenfeld et al., Phys. Rev. Lett., Reply to Comment on 1a, to appear (2017).

2. S. Amitai and R. Blumenfeld, Phys. Rev. E 95, 052905 (2017).

3a. D. Asenjo et al., Phys. Rev. Lett. 112, 098002 (2014).

3b. S. Martiniani et al., Phys. Rev. E 93, 012906 (2016).



Study of an athermal quasi static plastic deformation in a 2D granular material

Jie Zhang
Shanghai Jiao Tong University
Shanghai, China 200240

Abstract: In crystalline materials, the plasticity has been well understood in terms of dynamics of dislocation, i.e. flow defects in the crystals where the flow defects can be directly visualized under a microscope. In a contrast, the plasticity in amorphous materials, i.e. glass, is still poorly understood due to the disordered nature of the materials. In this talk, I will discuss the recent results we have obtained in our ongoing research of the plasticity of a 2D glass in the athermal quasi static limit where the 2D glass is made of bi-disperse granular disks with very low friction. Starting from a densely packed homogeneous and isotropic initial state, we apply pure shear deformation to the system. For a sufficiently small strain, the response of the system is linear and elastic like; when the strain is large enough, the plasticity of the system gradually develops and eventually the shear bands are fully developed. In this study, we are particularly interested in how to relate the local plastic deformation to the macroscopic response of the system and also in the development of the shear bands.

Taxonomy of granular flows down inclines: how different bases produce widely different scaling of mass flow rate with depth

Michel Louge
Cornell University

Abstract: We review granular flows down inclines and the dependence of their mass flow rate on the nature of the base, focusing on flat, bumpy and erodible boundaries. To illustrate their widely different behavior, we present recent results for wall-bounded flows of sand over a sensor-enabled composite geotextile fabric that dissipates granular fluctuation energy. In those experiments, we record strain of the fabric along the flow direction with imbedded fiber-optic Bragg gratings, flow velocity on the surface by correlating grain position in successive images, flow thickness with the streamwise shift of an oblique laser light sheet, velocity depth profile through a transparent side wall using a high-speed camera, and overall discharge rate. These independent measurements at inclinations between 33◦ and 37◦ above the angle of repose at 32.1 ± 0.8◦ are consistent with a mass flow rate scaling as the 3/2 power of the flow depth, which is markedly different than flows on a rigid bumpy boundary. However, this power changes to 5/2 when flows are forced on the sand bed below its angle of repose. Strain measurements imply that the mean solid volume fraction in the flowing layer above the angle of repose is relatively small at 0.268 ± 0.033, independent of discharge rate or inclination.

Statistical mechanical theory of the rheology of suspensions: the divergence of viscosity and the shear thickening

Hisao Hayakawa
Kyoto University

Abstract: In this talk, I pursue the possibility of the microscopic statistical mechanical theory of the rheology of suspensions. In the first part, I derive the singular behavior of dense non-Brownian suspension near the jamming point including the divergences of the viscosity and the pressure as well as the so called mu-J rheology. Our theoretical results are consistent with the experimental and the numerical results [1]. In the second part, we discuss the shear thickening for both dilute and moderately dense granular suspensions. We found that the theoretical results perfectly agree with the results of simulation in the dilute case. where there is the discontinuous shear thickening (DST) [2]. For moderately dense suspensions, the agreements between the theory and the simulation become fare and the DST in the dilute suspension becomes continuous [3].

Ref:

[1] K. Suzuki and H. Hayakawa, in preparation.

[2] H. Hayakawa and S. Takada, arXiv:1611.07295

[3] H. Hayakawa, S. Takada, and V. Garzo, arXiv:1707.0964

Unjamming of Hoppers: Modeling the Dynamics of Arches by a Continuous Time Random Walk

Carl Merrigan[1] , Sumit Birwa[2] , Shubha Tewari[3] and Bulbul Chakraborty[1]
1 Martin Fisher School of Physics, Brandeis University, Waltham MA 02454
2 ICTS, Bangalore, India
3 University of Massachusetts Amherst

Abstract： Gravity driven granular flows such as in hoppers and silos are susceptible to clogging due to the formation of an arch that blocks the exit. Arches are structures that self-assemble in a flowing state and lead to the arrest of the flow. Stability of arches is of paramount importance in supporting a solid-like structure, and their failure is the key to the re-initiation of flow or unclogging. Clogging occurs as soon as a stable arch is formed. The process of unclogging in response to an external perturbation is, however, sensitive to the structure and stability of the arch. In an intriguing set of experiments, the distribution of unclogging times was shown to obey a power law with exponents that varied with vibration amplitude and the width of the hopper opening. In this talk, I will provide evidence, based on numerical simulations, that the dynamics of the arches can be modeled as a continuous time random walk in which the distribution of waiting times is broad and sensitive to the amplitude of vibration and the width of the hopper opening. Failure of the arches, and thus unclogging, is a first-passage process of this random walk, which leads naturally to the broad distribution of unclogging times.

Granular packing as model glass formers

Yujie Wang

School of Physics and Astronomy, Shanghai Jiao Tong University, 800 Dong Chuan Road, Shanghai 200240, China

Abstract: The nature of glass transition has remained a hotly debated issue. Static granular packing are model hard-sphere glass formers. Using x-ray fast CT technology, we systematically investigated the glass transition in granular packing. We focus on the growth of glass order with five-fold symmetry in granular packing and relate the findings to both geometric frustration and random first-order phase transition theories. We also studied the plastic deformation of granular materials under shear and identified the corresponding structural defect and the celmentary plastic event, which can help our understanding of yield transition and shear band formation for amorphous materials in general and also dense granular flows..

Ref:

1. J.D. Li, Y.J. Cao, C.J. Xia, B.Q. Kou, X.H. Xiao, K. Fezzaa, and Y.J. Wang, Nature Commun, 5, 5014 (2014).

2. C.J. Xia, J.D. Li, Y.J. Cao, B.Q. Kou, X.H. Xiao, K. Fezzaa, T.Q. Xiao, and Y.J. Wang, Nature Commun, 6, 8409 (2015).

3. C.J. Xia, J.D. Li, B.Q. Kou, Y.X. Cao, Z.F. Li, X.H. Xiao, Y.N. Fu, T.Q. Xiao, L. Hong, J. Zhang, W. Kob, and Y.J. Wang, Phys. Rev. Lett.,118, 238002 (2017).

Rate dependent behavior of granular geomaterials: measurements and mathematical models

Xiaohui Cheng
Tsinghua University

Abstract: Granular geomaterials exhibit complicated rate-dependent behavior. A better understanding and interpretation of these rate-dependent behavior possess important theoretical and practical values. Classical and relatively new experimental findings of rate dependent behavior of soils are outlined and some underlying physical mechanisms are assumed. The emphasis of this talk is then placed on the mathematical modeling aspects based on two different approaches, i.e. the traditional elasto-viscoplastic models and GSH-based models. The GSH-based models have been jointly investigated by Tsinghua and MIT soil mechanics' groups and the preliminary results and research progresses are also presented.

The Structural Re-organisation in a Sheared Granular Material

Xia Li

Email: xia.li@seu.edu.cn

School of Civil Engineering, Southeast University, Nanjing, Jiangsu, P.R. China

Abstract: The past few decades saw ever-increasing availability of particle-scale information due to the fast developments in techniques for experimental measurements and numerical simulations. More interesting phenomena exhibited by granular materials have been revealed than before, and promoted deeper understanding in its fundamental mechanisms. The structure dependence and structural re-organization are often the reason leading to the complexity in the observed granular material responses. Using the two-cell systems, i.e., a solid cell system and a void cell system, proposed by (Li and Li 2009) to describe the material internal structure, the continuum-scale behaviour of granular materials could be interpreted based on the information of force/displacement in the solid/void cells. This paper concerns the flow of granular material when subjected to continuous shearing with multiscale data obtained from discrete element simulations (Cundall and Strack 1979). The statistical features of the void/solid cell systems and its correlation with material deformation and strength will be presented. Discussion will be extended to particle-scale kinematics including both contact sliding and rotation, their triggering mechanism, the spatial distribution and their local structural dependence.

Ref:

1. Cundall, P. A. and O. D. L. Strack (1979). The development of constitutive laws for soil using the distinct element method. Third International Conference on Numerical Methods in Geomechanics. Rotterdam, A.A. Balkema. **1:** 289-317.

Li, X. and X.-S. Li (2009). "Micro-macro quantification of the internal structure of granular materials." Journal of Engineering Mechanics **135**(7): 641-656.

From Micro to Macro: From Particles to Continuum Theory

Stefan Luding
University of Twente

Abstract：The dynamic behavior of granular materials is of considerable interest in a wide range of industries and disciplines like geophysics or mechanical engineering, but the full understanding or control of the different phenomena and mechanisms of the particle systems, natural phenomena, or processes is an essential challenge for both science and application.

The fundamentals can be studied by direct particle simulation methods, where often the fluid between the particles is important too, in order to gain a microscopic understanding of the processes and mechanisms. For large-scale applications, a micro-macro transition towards continuum theory is necessary, however, only smaller applications can be modeled nowadays directly by discrete micro-scale methods. Instead, more often meso-scale methods are used where the particles are up-scaled, representing a certain number of primary particles. As one example for such meso-models, we use experiments and discrete particle simulations (DEM) to investigate the dosing of cohesive fine powders. Other applications involve chute flow or ring-shear rheology testing of granular flow as well as the study of the elastic, or elastic-plastic material behavior.

The micro-macro transition from discrete particulate systems to continuum theory involves a mathematical homogenization or coarse-graining that translates particle-positions, -velocities and -accelerations into density-, stress-, and strain-fields, by statistical spatial- and temporal averaging. The macroscopic fields are compatible with the conservation equations for mass and momentum of continuum theory, and also the fluctuating kinetic energy provides a measure for the importance of fluctuations in those systems. The ultimate goal is to find constitutive relations that contain information about the micro-structure and -fluctuations, and to solve those on the macro-level for solving application and optimization problems. Examples considered are chute-flows down slopes, ring-shear testers as well as rotating drums, where the local rheology models all should work, independent of the geometry.

Why Thermodynamics is the proper Foundation for Granular Media

Mario Liu, Prof Jiang
University of Tubingen

Abstract：Two approaches exist to account for granular dynamics: The athermal one takes grains as elementary, the thermal one considers the total entropy of the grains and their true temperature. Discrete element method (DEM), granular kinetic theory and athermal statistical mechanics (ASM) belong to the first, granular solid hydrodynamics (GSH) to the second one. A discussion of the conceptual differences between both is given, showing when it is essential to adopt the thermal approach.

A thermodynamic model of grain-grain contact force

Yimin Jiang

Central South University

Abstract: The starting premise of soft DEM simulation, widely used in granular physics and mechanics, is the contact force model for grain-grain interaction. For most models employed in the literature (including the famous ones by Hertz-Mindlin and Luding) – especially because of frictional forces, the associated elastic potential and dissipative function either do not exist or are unknown. This renders their thermodynamic consistency doubtful. An alternative model closely related to the continuum-mechanical GSH-theory is proposed that has explicit expressions for both. A preliminary numerical calculation shows the variation of the restitution coefficient with the impact velocity, demonstrating its heightened realism.

Thorsten Poeschel--Collective Dynamics of Active Granular Particles

Thorsten Pöschel,[1] Ernesto Altshuler,[2] Michael Engel,[1] Christian Scholz,[1] and Harol Torres[1]
[1] *Institute for Multiscale Simulation, Universität Erlangen, Germany*
[2] *Group of Complex Systems and Statistical Physics, Physics Faculty, University of Havana, Cuba*

Systems of granular particles driven by external vibrations reveal a variety of collective phenomena such as cluster formation, self-organized convection patterns and others. Here, we consider systems of *active* granular particles which are driven by an internal source of energy. In particular, we consider VIBROTS [1], that is, particles which rotate when placed on a horizontal plate subjected to vertical vibrations [2–4]. Collectives of such particles may be considered as two-dimensional active matter. in the dilute case, such systems are well described by the paradigm of homogeneously heated granular gases, revealing high-energy tails of the velocity distribution function [5] predicted by Kinetic Theory. The velocity distribution function of active granular systems depends on the density [6] and mixtures of clockwise and anti-clockwise spinning particles segregate via spinodal decomposition [7].

[1] Ernesto Altshuler, Jose Martin Pastor, Angel Garcimartín, Iker Zuriguel, and Diego Maza, "Vibrot, a Simple Device for the Conversion of Vibration into Rotation Mediated by Friction: Preliminary Evaluation," PLoS ONE **8**, e67838 (2013).
[2] Christian Scholz and Thorsten Pöschel, "Actively rotating granular particles manufactured by rapid prototyping," Rev. Cuba. Física **33**, 37–38 (2016).
[3] Christian Scholz, Sean D'Silva, and Thorsten Pöschel, "Ratcheting and tumbling motion of Vibrots," New Journal of Physics **18**, 123001 (2016).
[4] Hariol Torres, V. M. Freixax, and D. Perez, "The Newtonian Mechanics of a Vibrot," Rev. Cuba. Física **33**, 39–43 (2016).
[5] Christian Scholz and Thorsten Pöschel, "Velocity distribution of a homogeneously driven two-dimensional granular gas," Physical Review Letters **118**, 198003 (2017).
[6] Harol Torres, Christian Scholz, and Thorsten Pöschel, "Velocity distribution of dense gases of actively rotating particles," preprint (2017).
[7] Christian Scholz, Michael Engel, and Thorsten Pöschel, "Rotating robots move collectively and self-organize," preprint (2017).

Dynamics and Rheology of Driven Granular Media

Matthias Sperl

German Aerospace Center (DLR)

Abstract: The flow behavior is an important aspect of granular dynamics in the non-linear regime, typically encoded in constitutive equations. While such constitutive equations for rheology may be established from macroscopic considerations, we demonstrate here how constitutive laws can be derived from microscopic interactions. Based on the homogeneously driven granular states discussed earlier, an approach known from colloids, the integration through transients (ITT) method, is used to derive in the sheared case first transient correlation functions and finally flow curves. These flow curves show rich phenomena such as Newtonian viscosity, yielding behavior, shear thinning and thickening. Also, the well-known Bagnold law can be derived in this way from first principles, and the calculation also predicts the coefficient of proportionality between the shear stress and the square of the shear rate.

Clog and flow in silo with oscillating exit

Kiwing To

Institute of Physics, Academia Sinica, Nankang, Taipei, Taiwan 11529

Abstract: The starting premise of soft DEM simulation, widely used in granular physics and mechanics, is the contact force model for grain-grain interaction. For most models employed in the literature (including the famous ones by Hertz-Mindlin and Luding) – especially because of frictional forces, the associated elastic potential and dissipative function either do not exist or are unknown. This renders their thermodynamic consistency doubtful. An alternative model closely related to the continuum-mechanical GSH-theory is proposed that has explicit expressions for both. A preliminary numerical calculation shows the variation of the restitution coefficient with the impact velocity, demonstrating its heightened realism.

Flowing, squeezing, clogging, and jamming of oil droplets

Eric Weeks

Emory University

Abstract: We use quasi-two-dimensional emulsions as experimental models to study the flow of jammed materials. Our emulsions are oil droplets in water and are compressed between two parallel glass plates so that the droplets are deformed into pancake-like disks. We use microscopy to observe these droplets as they flow. From the deformed outlines of the droplets, we can measure all of the inter-droplet forces to within 10%. In this way, we study the relationship between the local stresses in the system and the rearrangements as the sample is sheared. The simplest rearrangement involves four droplets (a 'T1 event') and we confirm theoretical predictions for the quadrupolar spatial pattern of the stress redistribution around the T1 events. We also study gravity-driven flow in hoppers and investigate the probability of clogging as a function of the hopper exit size. Here, experiments and simulations show that the softness of the particles is important, as soft particles form less stable arches and thus reduce the probability of clogging.

Self-propulsion of a grain-filled dimer in a vertically vibrated channel

Ning Zheng

Beijing Institute of Technology

Abstract: Steady dissipation of energy is a crucial property that distinguishes the active matter from Brownian particles. However, it is not straightforward to explicitly model the dissipative property of the existing active particles driven by a vibrating plate. We come up with a novel active particle that can be explicitly modeled by Newtonian dynamics of conservative force field plus two asymmetrical dissipative terms. The particle is a dimer consisting of two Ping-Pong balls connected by a hard rod, and its two balls are filled with granular particles of the same total mass but of different grain size. This dimer placed on a vibrating plate exhibits 3 types of motion – by tuning the frequency and the amplitude of the vibrating plate, the dimer either undergoes a directed motion toward the small (or large) grain-filled side or an unbiased random motion. We investigate the various modes of motion both experimentally and numerically and show that the directed motion is a result of the asymmetric damping due to the size difference in the grain filling of the two balls. Furthermore, the numerical simulation reveals that the dimer's dynamics in either directed motion mode resembles a limit cycle attractor that is independent to its initial condition.

Interface Facilitated Energy Transport in Coupled Nonlinear Lattices

Zhigang Zheng, Ruixia Su, Zongqiang Yuan, Jun Wang
Huaqiao University

Abstract: It is generally expected that the interface coupling leads to the suppression of thermal transport through coupled nanostructures due to the additional interface phonon-phonon scattering. However, recent experiments demonstrated that the interface van der Waals interactions can significantly enhance the thermal transfer of bonding boron nanoribbons compared to a single freestanding nanoribbon. To obtain a more in-depth understanding on the important role of the nonlinear interface coupling in the heat transports, we explore the effect of nonlinearity in the interface interaction on the phonon transport by studying the coupled one-dimensional (1D) Frenkel-Kontorova lattices. It is found that thermal conductivity increases with increasing interface nonlinear intensity for weak inter-chain nonlinearity. By developing the effective phonon theory of coupled systems, we calculate the dependence of heat conductivity on interfacial nonlinearity in weak inter-chain couplings regime which is qualitatively in good agreement with the result obtained from molecular dynamics simulations. Moreover, we demonstrate that, with increasing interface nonlinear intensity, the system dimensionless nonlinearity strength is reduced, which in turn gives rise to the enhancement of thermal conductivity. Our results pave the way for manipulating the energy transport through coupled nanostructures for future emerging applications. References.

Ref:

[1] Ruixia Su, Zongqiang Yuan, Jun Wang and Zhigang Zheng*, Scientific Reports 5, 19628 (2016);
[2] Ruixia Su, Zongqiang Yuan, Jun Wang and Zhigang Zheng*, Front. Phys. 11(1), 114401 (2016).
[3] Ruixia Su, Zongqiang Yuan, Jun Wang and Zhigang Zheng*, J. Phys. A 49(25), 255003 (2016).
[4] Ruixia Su, Zongqiang Yuan, Jun Wang, and Zhigang Zheng*, Phys. Rev. E 91, 012136 (2015).
[5] Zongqiang Yuan, Min Chu, Jun Wang, Zhigang Zheng*, Phys. Rev. E 88, 042901 (2013).
[6] Zongqiang Yuan and Zhigang Zheng, Frontiers of Physics 8, 3, 349 (2013)

Review on the measurement of grain motion in dense granular materials

Hui YANG[1], Guohua ZHANG[2], Qicheng SUN[3]*

1) School of Optical-Electrical and Computer Engineering, University of Shanghai for Science and Technology, Shanghai 200093

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Abstract: A dense granular material is composed of a large number of coarse grains, which in widely encountered in nature, engineering and industries, such as granular debris flows, rock-filled dams, and pebble-beds in nuclear reactors. Both the motion of a grain, including translation and rotation, and the structures formed by contacting grains would be dominated in determine the macroscopic properties of granular materials. Therefore, the measurements of grain motion and inter-grain structures in dense granular materials are of great importance. In this review paper, the non-intrusive measurements of grains velocity are firstly summarized and discussed, including particle image velocimetry, particle tracking velocimetry, spatial filtering velocimetry, laser Doppler velocimetry, laser speckle velocimetry. To measure the flection's of grain velocities, speckle visibility spectroscopy is used and summarized as well. The related progress are discussed. It is suggested that when being applied to granular material measurements, these methods would be adjusted for specific detecting requirements. Meanwhile, various kinds of measurements should be used together to better reveal the mechanism.

The Study of the performance of the PMMA granular sample in photo-elasticity experiment of the contact force measurement

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Abstract: Study the transmission of force in the granular system is very significant for human to understand the granular material which is a very special physical form. And when it comes to the study of the contact force in the granular system, the photo-elasticity experiment is generally accepted by scientists. In the photo-elasticity experiment, materials such as polymers and glasses are usually used. In this article, PMMA was picked as the granular samples. According to the special property of the PMMA, linear polariser was decided to be set up in the photo-elasticity experiment. We introduced the analysis method-local mean intensity to study the contact force between granular particles. The article starts from the comparison of two different colour models which are RGB image model and Green channel of it, and finally the Green channel was decided to be used in the experiment analysis. With the introduction of the method of contact area measurement between two vertically ellipse discs, we compared the curve fitting in stress-local mean intensity and force-local mean intensity functional images and it turns out though force-local mean intensity functional images, more accurate results were attained. In the following, three different force directions were set up and the comparison of the force directions which were perpendicular to the major axis of the ellipse discs, at a 45-degree angle towards the major axis of the ellipse discs and along with the major axis of the ellipse discs were made. The result indicate that we can use local mean intensity to measure the force in different direction and in the different location around the ellipse discs. This article also checked the fringes near one contact point while other contact points are in different types but didn't influence the contact point we measure. It turns out the local intensity only reflect the force condition near the contact point and will not influenced by other contact points. We concluded that it is very useful to study using the PMMA material in the photo-elasticity experiment to measure the force between granular samples. By analysis the local mean intensity, we can easily get the information of the magnitude of the force between two particles, and this method is not influenced by the force location and force direction.

Rogue wave and the envelop solitary wave in granular medium

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Abstract: By using the traditional perturbation technique, a focusing nonlinear Schrodinger equation (NLSE) is first obtained for the one-dimensional (1D) bead chain with the initial priestess. The Peregrine solution, called the rogue wave, the super rogue wave and the envelope solitary waves are investigated both numerically and analytically. It is noted that these waves do exist in the 1D bead chain. The solutions from the NLSE can correctly describe these waves in the limiting case of small amplitude.

Poster:

Name	*Organization*	*Title*
Decai Huang	*Nanjing University of Science and Technology*	*Dynamical Janssen Effect of Moving Granular Packing*
Yanpei Chen	*Institute of process engineering, CAS*	*The anisotropy of free path in a vibro-fluidized granular gas*
Qi Zhang	*Taiyuan University of Technology, TUT*	*Study on arch jamming of u-shaped particles in two-dimensional hopper*
Qi Cheng	*National University of Defense Technology*	*Numerical simulation of the movement of a spinning sphere in granular matter*
Ping Liu	*National University of Defense Technology*	*Vertical dynamics of a horizontally-oscillating immersed ball in 3D granular system*
Chaung Zhao *Chengbo Li*	*Guizhou University* *Anyang Institute of Technology*	*1.Discrete element simulation of bonded particle system* *2.DEM simulation of direct shear test of non-spherical* *3.Rolling and sliding between non-spherical particles* *4.Influence of particle packing structure on sound velocity*
Gaoke Hu	*Institute of Theoretical Physics*	*Size Scaling of Velocity Field in Granular Flows through Apertures*

Study on arch jamming of u-shaped particles in two-dimensional hopper

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Abstract: Arch jamming of U-shaped particles at the opening of a two-dimensional hopper is studied experimentally. The hopper slope and opening width are varied to determine their influence on the jamming probability. It shows that the arch shape of U-shaped particles is more complicated than that of spherical disks. Even the particles block the outlet of the hopper without pronounced arch sometimes. These measurements shed light on the role of effective cohension between U-shaped particles caused by entanglements. The jamming probability decreases as the width of opening increases linearly. Increasing hopper slope decreases the jamming probability in most cases.

Numerical simulation of the movement of a spinning sphere in granular matter

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Abstract: In recent years, problems on the desert lizards running, hiding and swimming in the desert attracts the attention of people in related region. With the spherical object as the object of study, LIGGGHTS, a 3 dimensional discrete element numerical simulation program, is used to simulate the translation and rise / fall behavior of the object spinning in the granular matter. And the influence of spin velocity(ω) and friction coefficient(μ) between the object and granular matter on the motion of the object is analyzed. The simulation result shows that both ω and μ have notable influence on the motion of the object. The bigger the μ is, the more violent the movement of the ball is. And in a certain range, the larger the ω is , the more obvious the movement of the object is. The object spins in the X axis, with significant motion in both the Y and Z directions, and little movement in the X direction. The object always moves upward in the Z direction, the rising velocity of the object is proportional to the logarithm of ω when ω of the object is within a certain range and goes down when ω is beyond the range. And in the Y direction, the object may move in a positive or negative direction depending on the ω and μ. The object moves in the positive direction of Y axis if the ω and μ are relatively small, while moves in the negative direction if the ω and μ are larger. In the Hertz model, the tangential force between two particles increases with the relative tangential velocity when the relative tangential velocity is in a certain range, while reaches at a stable value if the relative tangential velocity is over this range. Therefore, we can guess that the tangential force between the particles is the main power source of the spinning object moving in three dimensions.

Keywords: Granular matter, Spin, LIGGGHTS, Hertz model

Vertical dynamics of a horizontally-oscillating immersed ball in 3D granular system

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Abstract: Inspired by the hiding behavior of lizards in sand [1, 2], we have used a three dimension discrete element model (DEM) [3] simulation to study the dynamics of a self-energized immersed object (IO) in granular medium. To get the relationship between the IO's vertical behaviors and its horizontal oscillation amplitude and frequency, we have done a series of numerical simulation. The data reveal several systematic features: (i) the IO never sinks for oscillations with amplitudes A＜4m/sec, regardless of frequency, and as the horizontally-oscillating frequency increases, the IO's vertical ascending behavior gradually fades away;（ii）when 4m/sec＜A＜15m/sec and frequency over 10Hz, the IO may sink; (iii) when A＞15m/sec, the IO rises for all the frequency. In addition, we have explored the influence that the friction coefficient between the bed particles and the IO, as well as the size of the IO on the vertical motion of the IO. We see that the friction coefficient have little impact on the vertical movement and the bigger the IO, the faster it rises, in the case that the amplitude and frequency of horizontal oscillation is relatively small.

Key Words: DEM simulation, horizontal oscillating, Granular media

Ref:

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【2】Maladen R D, Ding Y, Umbanhowar P B, Kamor A, Goldman D I 2011 J. R. Soc.Interface 8 1332

【3】Kloss C, Goniva C, Hager A, Amberger S, Pirker S 2012 Prog. Comput. Fluid Dyn. 12 140

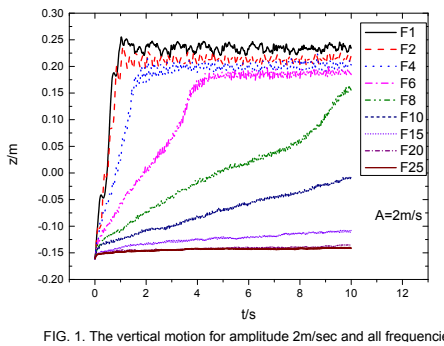

FIG. 1. The vertical motion for amplitude 2m/sec and all frequencies.

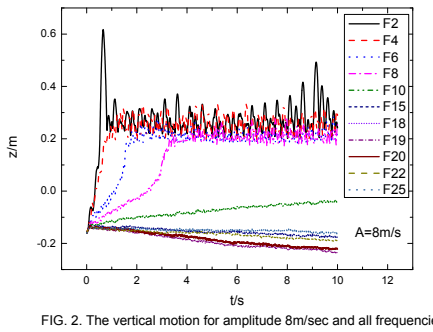

FIG. 2. The vertical motion for amplitude 8m/sec and all frequencies.

Discrete element simulation of bonded particle system

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Abstract: Based on the normal, tangential, rolling, sliding and torsional interactions between particles, the bond interaction is introduced. The compression, tensile, bending and torsion forces of bond are calculated by the relative displacement and rotation. In the calculation of the relative displacement and rotation, the incremental method is used to ensure the objectivity of movement and force. The correctness of the model is verified by the simulation of the velocity and the force and collision process of the bonded particles. This program can be used to simulate the mechanical behavior of rock, concrete and other continuous media.

DEM simulation of direct shear test of non-spherical

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Abstract: In this paper, the rolling deformation is calculated by the rolling velocity of spherical particles in Ref. [1]; the rolling resistance and torque are calculated from the elastic damping model. The rolling resistance model is applied to the four normal and tangential contact models, and the shear and dilatancy curves that meet the rate independence are obtained. After verifying the correctness of the rolling velocity between spherical particles, it is generalized to arbitrary shape to obtain the rolling velocity and calculate the rolling resistance between non-spherical particles. Also, the discrete element simulation of non-spherical particle direct shear system is carried out. The results show that the shear and dilatancy curves both satisfy the rate independent law and are consistent with the experimental results.

Ref:

[1] Luding, S. Cohesive, frictional powders: contact models for tension. Granular matter 10, 235-246 (2008)

Rolling and sliding between non-spherical particles

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Abstract: In this work, based on the physical mechanisms of rolling and sliding, the velocities of rolling and sliding between non-spherical particles are derived, and follow the objectivity. In the special case, the rolling velocity is consistent with that of two-dimensional circular or three-dimensional spherical particles [1, 2]. The rolling velocity and deformation are used to simulate direct shear tests of non-spherical particles, and the typical shear curves obtained not only are consistent with experiments but also satisfy the rate independent theory.

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Influence of particle packing structure on sound velocity

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Abstract: Four different packing structures in two-dimensional photoelastic experiment are simulated by DEM [1]. The relationship between longitudinal and transverse wave velocities and normal stress is calculated by the time of flight method. The influence of different packing structures on the sound velocity under the same normal stress is analyzed. The stress tensor and the stiffness tensor under different packing structures are calculated. The wave velocities calculated by the stiffness tensor are compared with those obtained by the time of flight method. The variation of sound velocity with stress and packing structures can be explained by the difference of system stiffness and stress tensor. The results are consistent with the existing experiments and theories. The change of sound velocity reflects the difference of stress distribution and geometrical structure in the system, which can provide reference for acoustical probing the structure of system.

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Size Scaling of Velocity Field in Granular Flows through Apertures

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For vertical velocity field $v_z(r,z;R)$ of granular flow through an aperture of radius R, we propose a size scaling form $v_z(r,z;R) = v_z(0,0;R)f(r/R_r, z/R_z)$ in the region ($r \leq R_r = R - 0.5d, z \leq R_z = R + k_2 d$). The effective acceleration derived from v_z follows the size scaling form $a_{\rm eff} = v_z^2(0,0;R)R_z^{-1}\theta(r/R_r, z/R_z)$. From granular flow under gravity, there is a boundary condition $a_{\rm eff}(0,0;R) = -g$ which gives rise to $v_z(0,0;R) = \sqrt{\gamma g R_z}$ with $\gamma = -1/\theta(0,0)$. From the size scaling form of vertical velocity field and its boundary condition, we can obtain the flow rate $W \propto \rho\sqrt{g}R_r^{D-1}R_z^{1/2}$, which is in agreement with the Beverloo law. Using the discrete element method (DEM) and GPU program, the vertical velocity fields $v_z(r,z;R)$ of different R have been simulated in three-dimensional (3D) and two-dimensional (2D) hoppers. The size scaling form of $v_z(r,z;R)$ and the R-dependence of $v_z(0,0;R)$ have been confirmed by simulation data.

PACS numbers: 45.70.Mg

Tourism in Guizhou

Guiyang Dining

It is said that Guiyang people working outside Guiyang would be sure to lick their lips when they think of the food of their hometown. This reflects their love of food and the culture. Food there mainly includes Qian cuisine and local snacks.

Qian (Guizhou) Cuisine tastes numb and spicy, which are two indispensable elements in Guiyang food. Numb refers to the condiment made from several spices and the spicy is mainly refined from the red pepper.

Another typical local dish, **Suan Tang Yu** (Sour Soup Fish) is most delicious. Originating not in Guiyang, but in the Miao region, this dish has become a typical dish in this city. You can have the dish at Kaili Sour Sour Fish Restaurant, No. 55, Shengfu Lu.

Si Wa Wa (Sliced Vegetable Baby) could well be the cheapest local snack. It literarily means the Baby because it takes the shape of a baby in swaddling clothes. Actually it is a thin cake made of flour and stuffed with various sliced cooked vegetables such as the carrot, radish, celerie and other vegetables. Sour and spicy juices are necessities when tasting the Si Wa Wa.

Zhangji Si Wa Wa (restaurant): at the entrance of Wenhua Lu

Chang Wang Mian (Chang Wang Noodle) could be the most popular snack in the city. The name of Chang Wang implies auspiciousness. With a long history of more than 100 years, Chang Wang Noodle has been highly-praised by the local people.

Huaxi Park

Huaxi Park, which means a park where flowers are in full bloom and streams flow, forms the center of the Flower Stream Scenic Area. Blending natural hills and rivers, idyllic scenery with ethnic features, it has gained the name of "Back Garden of Guiyang City". It is located in the south suburb of Guiyang City, Guizhou Province.

Unlike man-made parks, the stream and the four hills in this park are all naturally formed. The Flower Stream winds elegantly across the park while the four hills, Lin (Kylin, an animal in Chinese legend), Feng (Phoenix), Gui (Tortoise), and She (Snake) Hills stand at its two sides. With its clean water and intoxicating scenery along its banks, the Flower Stream is regarded as "The First Love Stream" in China. Lin Hill is the highest of the four. It is like a ferocious kylin howling angrily at the sky. Standing on the hilltop, tourists can take in the full view of the park. On top of Phoenix Hill, one can overlook the stone houses, stone walls and stone village roads that crisscross the field. On Tortoise and Snake Hills, with various stones in peculiar shapes bordering the roads, the scenery is also appealing.

Jiaxiu Tower

Jiaxiu Tower, situated in downtown Guiyang in Guizhou Province, is a grand wooden tower built on a huge turtle-shaped rock on Nanming River. Initially built in the Ming Dynasty (1368 - 1644), the tower has been renovated for six times. It used to be one of Eight Great Sights in Guiyang. Now regarded as a landmark and a cultural symbol of Guiyang, it should certainly be included in your plan.

Entrance Archway

Jiaxiu Tower, Guiyang

Walking from the Fuyu Bridge, you will reach Jiaxiu Tower. In ancient times, many intellectuals studied very hard here for the scholarly honor or official rank. Tto encourage them, the local majesty ordered a tower to be built and conferred on it the name of Jiaxiu, which means "getting the first place in imperial examinations". It is interesting that since the tower was built, Guizhou has seen three Top one Scholars and two of them are said to live near the Nanming River. Nowadays, Guizhou is still a propitious place where talents emerge in an endless stream.

Jiaxiu Tower is a three-storey tower rising 20 m (66 feet) high. Green tiles, red pillars, engraved windows and white stone parapets make the tower superb and striking. Ascending the tower one can enjoy a great view of the surrounding city scenery. If you are not that into old buildings, the night scene of the tower is equally impressive. Decorated with colorful lanterns, the tower is beautifully reflected in the water. Strolling on the bridge in a cool summer evening is also a delightful experience.

As a cultural and historical relic, Jiaxiu Tower was favored by men of letters in the past. They have left valuable works, such as calligraphy pieces, woodcrafts and stone tablets inscribed with poems, which are displayed on the first floor. Among all these relics, the most outstanding one is a long couplet written by Liu Yushan, a scholar in the Qing Dynasty (1644 - 1911). This masterpiece comprises two parts: the first line describes the beautiful scenery in Guizhou Province and the second line tells visitors about Guizhou's history. This long couplet of 206 Chinese characters rivals the "No.1 Couplet" in the Grand View Park in Kunming. You can easily find the long couplet on the door of the first floor.

Qianling Hill Park

Entrance of Qianling Hill Park Situated on Qianling Hill 1.5 kilometers (0.9 miles) from the center of Guiyang City, Qianling Hill Park covers an area of 426 hectares (1052.7 acres). First built in 1957, it is a uniquely large park in the city proper and a 4A National Tourist Attraction. The name was derived from the Qianling Mountain that lies in the park, which is the most famous mountain in southern Guizhou. As one of the noted gardens on the Guizhou plateau, it boasts clear waters, green mountains, tranquil forests and old temples. There are eight predominant scenic locations: Sanlingwan, Macaque Garden, Hongfu Temple, Kylin Cave, the Zoo, Qianling Lake, Two-Dam Wind-Rain Bridge, and the Winding Mountain Path.

Qianling Lake

Qianling Hill and Qianling LakeQianling Lake was man-made by the damming of Daluo Spring in 1954. Since 1999 when the project of clearing up the silt in the lake was completed, it has an area of 35 hectares (86.5 acres) with clearer water and a steadfast dam. A crystalline surface mirrors the green and gentle willows and the surrounding pavilions that are ornately decorated and finely built. On its western bank stands a memorial for the martyrs who died during the war of liberation of Guizhou Province. Also during 1999, the municipal government of Guiyang rebuilt it, changing the parapet into one of white marble, and beautifying the surrounding plants. Every Tomb-Sweeping Day, thousands of people go there to worship the fallen heroes.

Kylin Cave

Down along the 382-step Nine-Twist Path which is the short cut, there is Kylin Cave. In front of the cave flows a spring at least 400 years old. Amongst stalactites of various shapes hanging inside, there is a huge one weighed down like a kylin, a beast symbolizing auspice in China, giving the cave its present name. The cave is noted for its reputation that Chiang Kai-Shek, the leader of Chinese Nationalist Party at that time, captured the patriotic generals Zhang Xueliang and Yang Hucheng at the cave during the War of Resistance against Japan. Hundreds of thousands of people have visited here because of its story.

Besides these above, there are also other attractions like the new Xiangwang Mountain, Ancient-Buddha Cave, and Kanzhu Pavilion, etc. All of them have their own picturesque charm.

Guizhou Provincial Museum

Guizhou Provincial Museum is opposite the International Conference Center of Guiyang, China. The main exhibition hall, covering an area of 7,800 square meters (9,300 square yards), presents over 200,000 precious fossils, pictures, weapons, handiworks, videos, and models. You can gain a vivid knowledge of prehistoric animals, history of Guizhou City, as well as the ethnic culture of local nationalities there.

Handiworks of Ethnic Groups

The most typical and important exhibition of Guizhou Provincial Museum is the ethnic relics. Since various kinds of ethnic groups are distributed among Guizhou Province, ethnic culture has become the essence of this land. There are over 1,000 ethnic objects displayed in the museum including embroidery, batik, cross-stitch works, brocade, silver jewelries… Among them, the most precious ones are wooden marriage notes and wine cups of Miao people, headmen's clothes of Yi people, as well as the burial carved stones of Shui nationality. Miao nationality has the largest population and the longest history, so Miao's dresses and jewelries cover the majority of exhibits there. You can definitely gain a rough knowledge of the local ethnic culture and customs after visiting the museum.

If you want to pick some national-style souvenirs, there is a shop on the 1st floor of the museum, selling artworks and jewelry of the Miao nationality.

Prehistoric Fossils

Prehistoric relics of Guizhou Provincial Museum include fossils of human teeth and skulls during the Paleolithic Period. Various kinds of typical stone implements and bone tools are also presented there. What's more, specimens of prehistoric animals are another highlight of this museum. You can find fossils of marine reptiles like Keichousaurus, Thalattosaur, and Ichthyosaurs, as well as Crinoid there.

Treasures during the Past 2,500 Years

Historical relics of almost all dynasties of ancient China are displayed there, including weapons and sacrificial vessels of Yelang State of the Warring States Period (475 - 221 BC), bronze chariots of the Han Dynasty (202 - 220), the clay pot carved with long inscriptions made in the Southern and Northern Dynasties (220 - 589), and golden crown of the Ming Dynasty (1368 - 1644). What's more, visitors can also observe lacquer ear cups, colored enamel figures, as well as iron swords with bronze handle… There are also some relics demonstrating the modern history of Guizhou from 1840 to 1949 including armors of the Taiping Rebellion (1850 – 1864), announcements and documents of the government, as well as printing machines and leaflets of that period.

Besides these fixed exhibitions, temporary displays or activities of various themes and forms will be held in Guizhou Museum from time to time. Sometimes, there will be singing and dancing performance played by the Miao people.