Indian Institute of Technology, Kanpur
Proposal for a New Course

1. Course No: SPA 6XXM

2. Course Title: Introduction to Adaptive Optics and Applications

3. Lectures per week: 3 (L), Tutorial: 0 (T), Laboratory: 0 (P), Additional hours: (0-2): 0 (A), Module Credits (3*L+2*T+P+A): 5, Duration of Course: Half Semester

4. Proposing Department: Space Planetary & Astronomical Sciences & Engineering (SPASE)

5. Proposing Instructor: Prashant Pathak

6. Course Description

   (A) Objectives: To introduce the fundamental components and operation of adaptive optics systems, including wavefront sensing, reconstruction, and correction techniques for real-world applications.

   (B) Contents (preferably in the form of 5 to 10 broad titles):

   1. **Introduction:** Why adaptive optics? Imaging limitations of optical systems. Atmospheric turbulence and image degradation. Historical development of AO. Applications: Astronomy, Solar telescopes, Retinal imaging, Laser communications Defense and remote sensing. (2-lectures)
   2. **Atmospheric Turbulence:** Refractive index fluctuations, Kolmogorov turbulence theory, Structure function, Fried parameter r_0, Greenwood frequency, Isoplanatic angle, Coherence time, Seeing measurements, Turbulence profiling. (4 Lectures)
   3. **Wavefront Sensing, Reconstruction and Correction Devices:** Principle of wavefront sensing, Shack–Hartmann wavefront sensor, Centroiding algorithms, Curvature sensing, Pyramid wavefront sensor, Sensor noise sources, Sensitivity and dynamic range. Influence functions, Interaction matrix, Reconstruction matrix, Least-squares reconstruction, Modal versus zonal reconstruction, Singular Value Decomposition (SVD). Deformable mirrors, MEMS deformable mirrors, Tip-tilt mirrors, Spatial Light Modulators, Actuator geometry, Stroke and fitting error. (8 Lectures)
   4. **Closed-Loop Adaptive Optics Systems:** AO control loop architecture, Error budget, Servo lag error, Bandwidth considerations, Real-time control systems, Performance metrics. (4 Lectures)
   5. **Advanced AO Concepts**: Laser Guide Stars, Natural Guide Stars, Multi-Conjugate AO (MCAO), Ground-Layer AO (GLAO) Extreme AO (ExAO), Multi-Object AO (MOAO). (3 Lectures)

   (C) Pre-requisites: None

   (D) Short summary for including in the Courses of Study Booklet: This half-semester course introduces the principles of adaptive optics, including wavefront aberrations, atmospheric turbulence, wavefront sensing, and real-time correction techniques. Students will learn the fundamentals of AO system design and performance through applications in astronomy, vision science, etc.

7. Recommended Books:

   - Principles of Adaptive Optics, fourth edition, by Robert K. Tyson, (CRC Press, 2015)
   - Adaptive Optics for Astronomical Telescopes, by John W. Hardy, (Oxford University Press, 1998)

8. Any other remarks:

Dated: Proposer:

Dated: DUGC/DPGC Convener:

The course is approved/not approved

Chairman, SUGC/SPGC

Dated: