Proposal for a UC Center for Adaptive Optics:

A Multi-Campus Center within the IGPP at UCSC

Submitted <date goes here> to
Office of Research
UC Office of the President

Principal Investigator: Prof. Claire Max, UCSC
Participants: <list names and campuses here>

1. Executive Summary

[To be written]

2. An IGPP Multi-Campus Center

2.1 Introduction and Background

Adaptive optics (AO) is an enabling technology that sharpens images by removing optical aberrations. This new technology is transformative for ground-based astronomical telescopes and for imaging the living human retina. New applications such as imaging structures on the interior of cells are just now developing. Figures 1 and 2 show the dramatic improvement in spatial resolution attained using adaptive optics to image the planet Neptune, and to image cone photoreceptors in the living human retina. It is not uncommon for adaptive optics images made with the 10-m diameter Keck Telescopes in Hawaii to have 50 times the spatial resolution of images made using conventional techniques. (!)

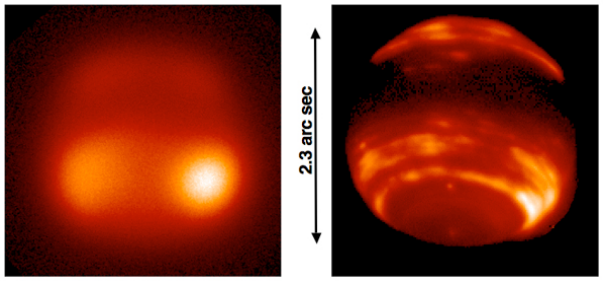

Figure 1. Two Keck Telescope images of the planet Neptune in infrared light (wavelength 1.6 microns). Left: normal image. Right: adaptive optics image. Credit: Gibbard et al. 2003

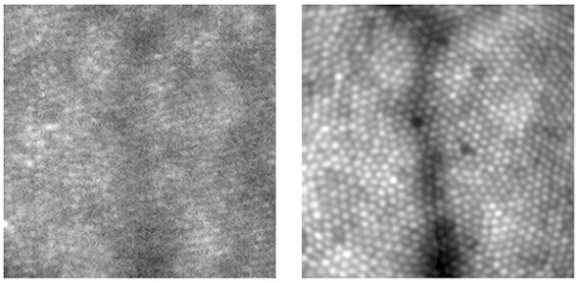

Figure 2. Two fundus camera images of part of a living human retina. Left: normal image. Right: adaptive optics image. Credit: A. Roorda and D. Williams

Under NSF Science and Technology Center funding, the Center for Adaptive Optics (CfAO) has been key to the spectacular success of astronomical AO systems at UC's Keck and Lick Observatories, and has led to the establishment of UC as a leading center for three dimensional imaging of the living human retina. Our challenge is to exploit UC's leadership and continue to grow UC's capabilities in this rapidly expanding and increasingly competitive field, now that NSF Science and Technology Center (STC) funding is nearing its end. All NSF STCs are limited to 10 years; funding to the CfAO is already decreasing and will go fully to zero in Nov 2009.

This proposal outlines the role of a new entity, the CfAO as a University of California multi-campus center within the IGPP, that we believe will be key to new imaging modalities and discoveries enabled by adaptive optics technology.

CfAO achievements over the past eight years have positioned UC researchers to compete very strongly for research and technology funding from agencies such as the NSF, NIH, and NASA. Hence we are **not** seeking core research funds from UCOP. Rather, the key areas for which a new UCOP-sponsored IGPP multicampus center will make a unique contribution are a) fostering collaboration and communication between AO researchers and users at nine (and possibly all ten) UC campuses, and between the astronomical and vision science communities, b) funding small seed research projects so that they can successfully compete for external funds, c) providing a setting for UC's CfAO graduate students to discuss career paths and develop their professional options, as part of an innovative professional development program, and d) co-sponsoring a Summer Research School in Adaptive Optics for the benefit of graduate students

and postgraduate researchers on all UC campuses. [should we include the Summer School in this proposal?] Together, the IGPP and the current NSF-funded CfAO have extensive experience and track records in each of these types of activities.

2.2 Mission of the UC CfAO

The mission of the UC Center for Adaptive Optics will be to develop, apply, and disseminate adaptive optics science and technology in service to scientific research, health care, and industry applications. [Is this a good mission statement? It's the one left over from the existing CfAO. Should we write a new one? We probably should include "creating a community" and "increasing the confidence of our graduate students" or some such thing.] The initial research focus of the UC CfAO will be on astronomy and vision science. Other applications will be added in the future, as appropriate. [Should we say this?]

2.3 Structure of the UC CfAO

We propose to host the new UC Center for Adaptive Optics (CfAO) as a multi-campus center within the IGPP. CfAO headquarters will be at UCSC, in the existing CfAO building next door to UCSC's IGPP headquarters (Figure 3). As a result, the UC CfAO will be able to take strong advantage of the UCSC-IGPP's existing infrastructure for workshops, conferences, and retreats; will tie in closely with IGPP members in planetary sciences at UCSC; and will capitalize on excellent geographical proximity on the UCSC campus.

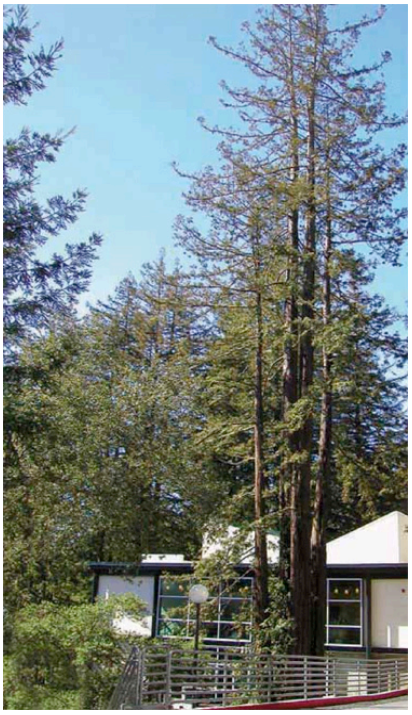

Figure 3. Existing CfAO building at UC Santa Cruz

The UC CfAO will involve faculty and students at nine UC campuses (possibly all ten) and at the Lawrence Livermore National Laboratory. The UC CfAO will function as a unitary center: it will not have "branches" at each campus as MRUs do. The CfAO in its previous NSF incarnation demonstrated that this unitary model can be extremely effective. It consists of holding regularly scheduled face-to-face meetings (retreats, workshops, and inter-laboratory visits), which are then augmented by the use of videoconference facilities, web-sharing, and teleconferencing. The face-to-face meetings establish personal trust and mutual interests, while videoconferencing and related techniques allow relationships and collaborations to be maintained in the intervals between meetings. As has been shown by several social-science studies of research collaborations, it is the graduate students who are the real "glue" between faculty members in different labs and at difference campuses. Hence special attention will be paid to programs that bring the center's graduate students together for education and professional development experiences, as well as for joint research.

2.4 Management and Governance of the UC CfAO

Management of the UC CfAO will be via its Director and Executive Committee, which will report to the Director. The Executive Committee will consist of approximately 6 faculty members, selected from campuses other than that of the Director. Membership on the Executive Committee will be for two-year staggered terms. The Director of UCSC's IGPP branch will

serve on the Executive Committee *ex officio*. The Executive Committee will meet once a month via videoconference. [What other governance do we need? We should probably have an external advisory committee of some sort.]

2.5 Participants in the UC CfAO

Faculty and researchers from 9 of the 10 UC campuses have indicated strong interest and the intention to participate in a new UC CfAO. The following campuses are represented in the areas of Astronomy and AO technology: UCSC, Berkeley, UCLA, Riverside, LLNL, Irvine, and UCSB. Astronomy faculty members from Merced and UCSD may join in the future. The following campuses are represented in the areas of Vision Science and AO technology: Berkeley, Davis, LLNL, UCSF, and San Diego. Vision science faculty members from UC Irvine's new Eye Institute may join in the future. Specific participants and their research areas are listed in Table 1. Most have labs and research groups (graduate students and post-docs) who would participate as well.

Last Name	First Name	Title	Field	Campus
de Pater	Imke	Prof.	Astronomy	UCB
Graham	James	Prof.	Astronomy	UCB
Klein	Stanley	Prof.	Vision	UCB
Marchis	Franck	Dr.	Astronomy	UCB
Roorda	Austin	Prof.	Vision	UCB
Choi	Stacey	Dr.	Vision	UCD
Werner	Jack	Prof.	Vision	UCD
Zawadski	Robert	Dr.	Vision	UCD
Barth	Aaron	Prof.	Astronomy	UCI
Chanan	Gary	Prof.	Astronomy	UCI
Ghez	Andrea	Prof.	Astronomy	UCLA
Larkin	James	Prof.	Astronomy	UCLA
Canalizo*	Gabriela	Prof.	Astronomy	UCR
Treu	Tommaso	Prof.	Astronomy	UCSB
Gavel	Donald	Dr.	Technology	UCSC
Hunter	Lisa	Ms.	Education	UCSC
Koo	David	Prof.	Astronomy	UCSC
Kubby	Joel	Prof.	Technology	UCSC
Le Maistre	Chris	Dr.	Technology	UCSC
Max*	Claire	Prof.	Astronomy	UCSC
Bartsch	Dirk-Uwe	Prof.	Vision	UCSD
MacLeod	Don	Prof.	Vision	UCSD
Duncan	Jacque	Prof. MD	Vision	UCSF
Dawson	Jay	Dr.	Technology	LLNL
Macintosh*	Bruce	Dr.	Astronomy	LLNL
Olivier	Scot	Dr.	Technology	LLNL
Poyneer	Lisa	Dr.	Technology	LLNL

Table 1. Faculty and researchers who have indicated their intention to actively participate in a new UC CfAO. Of the 26 people listed, 17 are already members of the existing NSF CfAO, while 9 are newly requesting to participate in the proposed UC CfAO. These 9 represent newly affiliated campuses at Davis, Riverside, Irvine, and Santa Barbara. Participants marked with an asterisk* are affiliated with IGPP branches at their home campuses.

3. Science and Engineering at the UC CfAO

[From here on, the text is in the form of notes only]

- Describe the science that UC CfAO members will be doing, even though the lion's share of it won't be paid for by UCOP funds
  - Astro
  - Vision
  - AO technology (including lasers)
  - New fields such as biological imaging

4. Proposed Programs of the UC CfAO

4.1 Retreats and workshops

- Function of twice-annual retreats
  - Updates on latest research results
  - Plenary sessions on both astronomy and vision science, attended by all
  - Also topical sessions where astronomers and vision scientists split up
  - Time to relax (e.g. games after dinner, hikes)
  - Creates a center where "whole is bigger than sum of parts"
  - Creates an occasion where faculty, grad students, postdocs can let down their hair and learn to trust each other
  - Typically have lasted 2.5 days

Retreat photo #1

Retreat photo #2

- Retreat locations
  - Under NSF funds: twice a year at UCLA Lake Arrowhead conf ctr and similar places; CfAO paid all expenses for participants (including travel)
  - Under UCOP funds: will seek less expensive options, and explore implications of having CfAO only pay some of the expenses for participants. Probably still desirable to have 2.5 day retreats twice a year. [need to discuss this]
- Workshops
  - Typically one day, at UCSC or another campus
  - Focus on one particularly timely topic
  - Selected subset of participants interested in that topic
  - Want to continue these: many of the NSF CfAO's new ideas have come out of these workshops

Workshop photo #1

4.2 Multi-Campus Projects

- Seed grants for research funding to get new projects going [Andrea Ghez]. Consider the idea that only proposals with genuine multi-campus collaborations will be considered. Have some sort of internal proposal cycle, with peer review. [Have to consider how peer review would work. Is NSF CfAO model a good one?]
- Small grants for students to spend time (e.g. a week to a month) at another campus [Jack Werner]. Put young people working shoulder-to-shoulder in each other's labs. Under NSF CfAO these have proven very valuable in transferring knowledge and technology between astronomy and vision science.
- [from Stan Klein] A tremendous boon for the vision part of the CfAO would be to provide some funds for supporting a Laboratory for Adaptive Optics in Vision Science. Many UC vision researchers could benefit from the AO instruments being developed by Roorda, Werner and Olivier. A modest amount of funds could open a powerful capability up for all the UC campuses and national labs to share that unique equipment. Could consider starting with common software development, and then going on to a hardware-based lab when sufficient funds are available.

4.3 Graduate Student Professional Development

One way to create a climate in which Center graduate students reach out to other campuses and disciplines is via educational programs aimed specifically at them. The NSF CfAO's education programs have been a huge success in this regard: our students learn the research-based teaching methods of inquiry-based learning, and then use these new skills to teach in outreach programs aimed at the recruitment and retention of students from groups under-represented in science and engineering. Graduate students have gained valuable teaching experience, and simultaneously created a supportive, productive, and highly interdisciplinary community that we consider a key ingredient to our success as an NSF STC center. We anticipate that many of these education programs will continue on independent funding after the end of NSF's STC support.

For the new UC CfAO, we propose to create a multi-campus graduate student community structured upon the growing need for expanded professional development for doctoral students ("Reshaping the Graduate Education of Scientists and Engineers," National Academy Press, 1995). Graduate students will gain real life proposal writing skills through our internal seed funding process. Students will be encouraged to prepare and submit proposals, under the guidance of faculty advisors, thus gaining experience in setting research goals, generating a plan, and preparing budgets. Annual retreats will include sessions to help generate these seed-proposal ideas and to stimulate the formation of multi-campus teams. The proposal review committee will give constructive feedback on all submitted proposals, specifically aimed at professional development. [a more radical idea: all seed proposals need to be submitted by grad students!]. Our focus on graduate student professional development will establish a strong intellectual community, and will increase our competitiveness in attracting the nation's top doctoral students in our fields to University of California campuses.

Figure caption: graduate students and mentors at one of the NSF CfAO's Professional Development Workshops. We envision having one-days versions under UC CfAO auspices, focused on career knowledge and skills for which our graduate students have requested activities and programs.

[QUESTIONS: Should these activities be aimed just at doctoral students? Masters? Postdocs? What does it mean to be a UC CfAO grad student? How does one enter and leave? Add a grad student day onto retreat? Or just integrate into the retreats?]

4.4 AO Summer School

The NSF CfAO has held an annual week-long Summer School on Adaptive Optics, at UCSC. To date more than 600 people have attended. The target audience is graduate students, postdocs, faculty members, and industrial researchers who are just entering the field. Emphasis is given to

topics that are of interest to both astronomers and vision scientists. These summer schools play a very substantial role in bringing newcomers to AO at our UC campuses up to speed rapidly.

In 2007 there were approximately 80 participants - 41 graduate students, 3 post docs and 14 industrial researchers. There were about 20 lecturers and laboratory assistants as well. In the past, the NSF CfAO has paid all Summer School expenses, including lectures, meals, lodging, and transportation. In 2007 the fee structure of the Summer School was modified to make the program financially more self-sustaining, in anticipation of the end of NSF Center funding after 2009. This transition appears to be proceeding successfully. In anticipation of more industrial attendees, the laboratory content of the program in 2007 was increased to provide more "hands on" experience. Based upon our follow-up survey, the new labs were extremely well received.

Based on our 2007 experience, we anticipate bringing the cost of the annual AO Summer School down further in our last two years of NSF STC funding. However our market survey of similar summer schools around the world indicates that if we charge academic participants the full cost, attendance (and hence revenues) will fall. To deal with this supply and demand curve, we are requesting $50K per year as partial support of AO Summer School expenses for UC students, researchers, and faculty. Industrial attendees will pay the full cost.

Summer School Photo #1: Barbeque at Stevenson College, UCSC

5. Proposed annual budget

[Should we present two options – this one and a lower one, showing what activities would be lost with the lower budget?]

	Activity	*Funding per year*
Core funding request		
	Retreats and workshops (2 retreats at UCSC or equivalent, plus 4 one-day workshops)	$80K
	Multi-campus projects (approx. 10 grad students supported for 6 months each)	$120K
	Professional Development Program for graduate students	$50
	Administration (1.5 office staff)	$80K
Summer School co-funding	AO Summer School (co-funding)	$50K
Grand total		$380K

6. References

Gibbard, S. G.; de Pater, I.; Roe, H. G.; Martin, S.; Macintosh, B. A.; Max, C. E. 2003, "The altitude of Neptune cloud features from high-spatial-resolution near-infrared spectra," Icarus 166, 359

Junzhong Liang, David R. Williams, and Donald T. Miller 1997, "Supernormal vision and high-resolution retinal imaging through adaptive optics", J. Opt. Soc. Am. A 14, 2884.

National Academy of Sciences, "Reshaping the Graduate Education of Scientists and Engineers," National Academy Press, 1995, http://www.nap.edu/readingroom/books/grad/

Website of the current NSF CfAO: http://cfao.ucolick.org

Annual Reports of the current NSF CfAO: http://cfao.ucolick.org/pubs/annualreports.php

Internet resources for graduate students, National Academy of Sciences: http://www.nap.edu/readingroom/books/mentor/7.html#internet

Appendix: Participants, campuses, and research areas

[Add list of participants by campus. For each campus or subgroup on a campus, include a short paragraph describing research fields and past participation (or not) in the NSF CfAO]