

## LUNAR INTERFEROMETRIC ASTRONOMY: SOME BASIC QUESTIONS

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It had seemed likely that many of the key technical points would have already been discussed now, and so I have brought some general questions for your consideration. When, or if there is ever an astronomical facility on the far side of the Moon, I expect to be dead. (At this point in the talk, Dr. Burke suggested that I should speak only for myself!) One cannot force the future over long periods of time. And as George Herbig once commented, in 100 years everything which we now know will be seen to be obvious, irrelevant, or wrong. Nonetheless, we have to move from the here and now, and the focus of our enquiry has to be whether we are doing something appropriate. Is this a proper use for human resources? What are our real goals? And is our concept the best match to our goals?

We are proposing an activity that is very expensive, and before the start we must answer a fundamental question. "Why do you not use this money instead to feed the starving billions?" The same question was in effect asked about the anointing at Bethany (John 12.8) and the reply was that the poor will always be with us. Our answer today can be more detailed--and more hopeful.

But first let me say that as astronomers our goal is surely to improve the quality of life, not the quantity. Up to a point quantity has survival value, but beyond that point--and we are well beyond that point--we pose a threat to humanity's own survival. We are such a large fraction of the terrestrial ecosystem that in our attempt to survive a disaster we are likely to destroy the recovery potential of the system. Our model is the reindeer population of St. Matthews island (Klein 1968). In this ecosystem a small introduced population expanded to the point that in a food shortage the deer killed off the potential for their future food. The entire population then died of starvation.

I am undoubtedly one of a very few astronomers who have computer-modelled famine. That is, I have studied the effects of environmental stochasticity producing a fluctuating food

supply, and that food supply causing population fluctuations. There will be a sigmoidal curve relating the fractional food adequacy to the death rate. And this curve allows the prediction of the number of deaths from the number alive and the available food. Undoubtedly past history of food supply and details of the food distribution must modify the shape of the curve, but this is a start in such models. I got into this study from astronomy, first by trying to understand the growth of quasar nuclei, then by modelling the population of the Mt. Graham red squirrel--but that is another story.

From the models, I can tell you that giving food and medical attention to people can be helpful in a famine--if help is in a small enough quantity. It is also possible for it to result in an increase in the number of people that will, in the future, die of starvation. Rather surprisingly, the risk of the population is reduced if the food is unevenly distributed. It is only possible to eliminate starvation by population control, that is by deliberate reduction of the birth rate or increase of the death rate. With a population balanced at an appropriately reduced level, feeding the starving masses becomes unnecessary. Without population control, the action is unhelpful because it only sets the stage for the next famine. That is, with population control there is no problem: without it there is no solution.

Science does not always give us new options; witness the laws of the thermodynamics and the limiting speed of light. In the area of population we learn that the real choices are between involuntary birth control, involuntary euthanasia, and involuntary starvation. There is no doubt in my mind that involuntary birth control is the most favorable of these choices. The mechanism is up to the couple, or country, until the limit is reached. Then it becomes a matter for everyone else.

Whether it is better to have a well-fed 100 million or 10 billion starving people is our choice. There has always been a human choice whether its goals are to produce heaven or hell. I would suggest that all past religious and ethical systems have indicated a choice in favor of the former, and there is no doubt which choice points which way. Malthus explained the problem in 1798. It is about time everybody paid attention.

True charity seeks to change the problem, not to perpetuate it. Any resources we put into this problem should go first into inculcating the message of "**Never Again**," and secondly in trying to ease the pain during the transition. With population control it is possible to build a better life here on Earth, and on the Moon.

Without it all we can do is watch more suffering while perhaps fooling ourselves that we are helping because we are spending our resources doing something that appears superficially to help others. It is possible for such activities to be stupid rather than moral. Likewise there is no simple moral issue involved in deciding whether to spend money on astronomy.

### The Appropriateness of a Lunar Base and Colony

The second question is whether astronomical study is the reason for humans making a new colony on the Moon. I believe that the colony should exist regardless of whether there is an observatory, but running an observatory is an appropriate colony activity.

The ammonoid fossil on the clasp of my string tie was one of a group of creatures that existed for far longer than there have been primates on Earth, and like us the ammonoids were one of the commonest creatures of their day. They vanished as part of the catastrophe 65 million years ago that appears to have been precipitated by a collision with some small astronomical body. But not all catastrophes are the same. An earlier and even more dramatic extinction event seems quite different (Holser et al. 1989), and we have to wonder what potential ends to humanity lie beyond our current horizon of understanding.

Here on earth we are concentrated into  $10^{-8}$  AU<sup>2</sup> in area. If we develop a self-sufficient colony on the Moon, we have expanded into an area 1000 times greater, and with the risk of extinction substantially reduced. I believe that humankind is special. We are the first to store knowledge and understanding from one generation to the next. We hold that knowledge in trust for the entire universe, at least until we encounter some similarly recording entity. That trust gives us a responsibility to avoid extinction. It is somewhat like Pascal's reason for believing in God. However low the probability of extinction in the near future may be, and however high the cost, the benefit of being prepared against it is so high as to weigh the odds in favor of that course of action. The Moon is potentially our ark.

With the potential for the Earth to become humankind's tomb, I do not believe that it is appropriate to build an isolation shelter here. Also, I do not believe that space stations allow adequate shielding of humans. Here on earth we are benefiting from a mass layer of 1Kg per square cm above our heads. Large amounts of matter for shielding are available on the Moon, but not in a space station. I do not see a substitute for the Moon.

For similar reasons we need to somewhat redirect our energies. What kinds of astronomical processes might put us at risk? For example, is there any stage of development of a main sequence Sun-like star that could precipitate a catastrophe?

### Our Motives

Enough. It is time to turn the searchlight in the other direction. So it is all to be for that great store of knowledge of which science is a major part? What about the fun we are getting? Some space cowboys just want the ride. Other telescope cowboys want to ride the giant aperture. Some want to design it, plan it, build it, sell it, talk about it, ride to power using it, go out in a blaze of glory with it. We are human, and have the usual mixed motives. And even if things are done as well as they possibly can be done for science, there will be those kinds of side effects. Is it the greatest treason to do the right thing for the wrong reason, or is it a greater treason to fail to do the right thing? I must agree with Chesterton that if a thing is worth doing, it is worth doing badly.

One does the best one can with the available resources.

There is no substitute for projecting the consequences to help decide whether a course of action leads too far astray. The science needs to direct the plan, and be at the center of the design of the interferometers. We should not be surprised or dismayed by minor diversions.

As we plan for higher and higher resolution observations of the universe around us, we find that getting a long, well-controlled, and predictable baseline becomes harder and harder. The Moon is very special in providing controlled baselines of up to 3,000 km without the associated seeing problems we have here on Earth. While short baselines are fine for cutting our teeth, it is those baselines that beckon, and suggest that lunar interferometry is not just another quickie project, but rather a long-term effort for more than one generation.

We need to be very careful and thoughtful about the justification of the facility. We have already seen at this conference that the public can all too easily be sold on any project to look for planets around other stars, and particularly to look for evidence of life on those planets from the presence of oxygen. Interferometers and large telescopes both offer opportunities for this kind of search as well as a host of interesting additional science benefits. Unfortunately, the search for planets is quite specialized and very difficult at any wavelength. Searches for planets need the

experience and sophistication that are best developed by using lower precision devices first. The natural and appropriate order is to delay the planet search until our techniques are better under control.

### Special Aspects of Optical Interferometry

There seem to be two aspects of optical interferometry that are quite special. The first is that the optical region offers strong spectral lines as well as continuum. Even a cursory study of the beautiful radio maps of energetic galaxies reveals the limits to interpretation because there is no spectral line information. For our optical two-element interferometers it is easy to apply spectral dispersion at right angles to the fringes. When we have a multi-element 2-D interferometer, we need to plan on the method of beam interference to preserve this possibility.

The second point is that optical wavelengths are so short that potential angular resolution is incredibly high. A 1500 km baseline at a wavelength of 5000Å is equivalent in resolution to about 1AU at 5 cm wavelength. With that resolution we could place 100 resolution elements across the disk of our Sun even if it were 1Kpc away! One hundred resolution elements are just enough for seeing sunspots. We could similarly study the surface detail of the nearest white dwarf stars. The baseline is still a little shy of resolving the velocity of light surface of the Crab Nebula pulsar. It just resolves the Schwartzchild diameter of energetic galactic nuclei.

For the galactic nuclei, the region where the material is expected to be optically thick at optical wavelengths is much larger, and interferometers with baselines of 10-100 m can yield information on orientation and structure of such regions. Even shorter baselines will start to yield the structure of the line emitting regions and allow us to relate such structures to the position angles found for radio lobes and jets.

Such observations are pointed in a direction that has been our current rationale for the study of astronomy. The universe reveals to us a range of conditions that are not met on Earth or available in even the most sophisticated laboratories. Astronomical observations allow us to check our extrapolation of laboratory experience and theoretical calculation and improve our understanding of the laws of physics and their consequences.

I would like to suggest that with our basic reason for going to the Moon--to guarantee human survival--astronomy starts to have a different and certainly more human-oriented

significance. We clearly need to shift gears to recognize this. For example, we should be very attuned to detailed confirmation of our understanding of the evolution of solar-type stars. Are there any nasty surprises that occur at intervals? Would observations of surface details in many such stars be of help? Are other stars in our galaxy going to produce unpleasant surprises?

The advent of lunar astronomical observing will prompt a reorientation of astronomers toward different goals. We hope it will also orient us toward different ways of doing things and thinking about things. I do not believe that when the time comes we will find it irrelevant that we are fundamentally inhabitants of Earth, and humans concerned with human survival. We can hope that by then it will be obvious.

### References

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