Summary Talk: THE OBSERVATIONAL PERSPECTIVE

Ian Gatley
National Optical Astronomy Observatories*
Tucson, Arizona

Well, you all look a little tired, and it's getting late; perhaps now is a good time to offer you some oversimplifications............ -- I've been sitting here this week listening to a large number of presentations of a very high caliber. There can be no doubt that this has been a remarkable conference. We've all learned a vast amount; I can't possibly make a coherent explanation of what I've seen and heard, any more than any one of you can. But I want to emphasise a few topics that struck me very forcibly.

Most striking of all was the repeated assertion that we live at some privileged time. I think you are all giving up too easily when you keep making those kinds of excuses, saying, "Well, it was an explosion, or it was a collision, or it was just a passing phase." Gene (Serabyn) brought that home to us very clearly, when he said something special happened in 1942. Now, I could make my point more strongly if we didn't see explosions in other astrophysical environments, but I want to urge you to consider that you've already given up the best kinds of explanations when you resort to transient phenomena. I want to try to explain to you in just a few minutes why I think that the only remarkable temporal aspect of what you've witnessed here this week is this: in the 1980's the technology is really booming, and the observations are starting to unravel this most fascinating problem, of what's happening in the center of the Galaxy.

It was a remarkable time before we opened any of the observational windows on the galactic center; for at that time we knew more about external galaxies than we did about our own Galaxy. To see the nucleus of our own galaxy proves to be an extraordinarily difficult observational problem, and it's only very lately that we've made any real progress in solving it. Of course, because we're virtually surrounded by the problem, we have a tremendous difficulty when we finally start to break through with high-technology solutions; the number of problems one can work on is vast. We want to know about the large-scale structure; we want to know about the small-scale structure. Fashions in theory, techniques, and observation affect our perspective as we ask ourselves, "Which problems can I work on, which problems can I think about?" The fact that the nuclei of other galaxies are active makes us dive in immediately with our highest-resolution instrumentation to see if we can find activity in the nucleus of our

* Operated by the Association of Universities for Research in Astronomy, Inc. under contract with the National Science Foundation.

M. Morris (ed.), The Center of the Galaxy, 645–648.

https://doi.org/10.1017/S0074180900187157 Published online by Cambridge University Press

own galaxy. The fact that the Milky Way surrounds us makes us want to classify the galaxy and see, "Is it a normal galaxy, is this the kind of galaxy other people live in?"

Well, for many reasons quite firmly related to the reason why we don't want to admit that this is a special point in time, we don't want to say, "This is a special galaxy." We want to say, "This is an ordinary galaxy, of course it is," and I was very relieved in the first few hours of this conference, to hear some of the pundits get up and say, "Yes, this is a normal galaxy. This is ok, we do have a representative sample, the one sample we've got. It's ok, it's a normal galaxy." I think that's a real sign of maturity in the observational aspects of the study of our own Galaxy, that we can start to recognize perhaps that it's not so strange. It better not be strange; if it's strange, we're in a lot of trouble; we're never going to find the answers to many of our questions. So don't give up, don't start saying "It's peculiar" before you've had a hard look at it. Assume it's perfectly ordinary, assume it's just like all the others, and then maybe you have a chance of finding out what all the others look like, too. I want you to think about that when you plan your observations.

Let me blow the whistle on a lot of the "special" ideas: all week, people kept putting up their particular special times, and they were all different; every one of them was different from every other one, everybody's special event happened at some special time. They're all wrong! They're all wrong; which doesn't mean to say that explosions don't happen in the nuclei of galaxies. Of course they do; but why don't we start off here with a different set of hypotheses; why don't we say, when we look into the center of our galaxy, the persistent thing that strikes us is that there is some activity in there. We're agreed it's a normal galaxy; we look in there, we say, "ok, there is some activity: all kinds of measurement at every scale size suggest activity in the galaxy; it's an engine." We've seen all these electrodynamic phenomena; they're fabulous! They should open our eyes anew to the fact that dynamical phenomena in this engine we live in -- the Galaxy --are the important things, the things that we should be concerned about.

So how do you take this abstract, philosophical notion -- that we live in an engine, and that it is representative of all these other engines in the sky -- and proceed to translate the idea into real experiments? Well, since it's an engine, you might start by asking, "Where is the fuel?" You heard a lot of time-scale arguments about rates of things: accretion, dissipation, turbulence, relaxation of stellar populations; let me ask you again, "Where is the fuel for the engine?" Only a decade ago we didn't know anything about the distribution of neutral material in the inner galaxy. Spectacular discoveries -- a combination of far infrared observations, molecular line observations, radio recombination line observations -- have now revealed this huge disk of material, with a mass of 10,000 solar masses, rotating around the center of the galaxy. Its density increases as the distance from the center decreases from about ten parsecs into about two parsecs, and then there's a great hole in the middle of it. How do you make something like that? Where did it come from? Where's it going?

Well, first of all, it's approximately axisymmetric. Obviously, if you're in the business of studying it, you get fascinated by the details; in its defects, in its azimuthal variations, and its warping and twisting; but the fact is that it's a great big ring around

https://doi.org/10.1017/S0074180900187157 Published online by Cambridge University Press

the center of the galaxy. It's got a hole in the middle. It's made primarily of neutral material. Now, a very common source of neutral material in the galaxy is mass loss from the stars, and this, after all, is a place where there are lots of stars; it's the middle of the galaxy. So one thing you might focus some attention on is the process of mass loss from all those stars in the middle of the galaxy. That, after all, will give you a situation where the density distribution peaks naturally into the center, is axisymmetric, and falls into a disk. What about the hole in the middle? If there's some activity from an engine in the middle, that might make a hole.

How do you make the engine go? Accrete material on to it. Don't be too hasty to assume that everything you see ought to be interpreted as outflow, because if you do that, you'll have a profound problem with conservation of mass, and you'll generate all kinds of difficult questions about the origins of the outflowing material. In other words, the assumption of steady state immediately provides a very simple argument for accretion, and it's not difficult to get the models to accommodate. We heard it suggested here that the molecular ring is indeed slowly collapsing. And we heard it suggested that there is a high velocity wind from IRS16. This combination of accretion and mass loss may lead very naturally to both the streamers and the central hole in the ring.

The hole in the middle of the ring is a fabulous place to focus your attention. What makes the hole, what maintains the hole, and what about these streamers of material that fall down through the hole? I was surprised not to hear more speculation that the very high polarization in these streamers is causally related to the fact that are they falling inwards. In particular, is the hole really empty? Most likely not. What about the material -- tenuous material -- between the streamers? Can we focus some observational capability on that issue? Clearly in the long run we may very well, because, as we saw, the ability to make very high energy observations is something that's going to be very important in the future.

We have heard a good description this week of the opening of the observational windows on the center of the Galaxy, as the technology emerged historically. Radio astronomy began it, and we heard a lovely anecdote about how radio astonomy first found the galactic center, a very charming story. We heard about how the Galactic center was observed at two microns in the starlight. (Incidentally, the sturdiest number that's emerged at this conference proved to be the radial dependence of the brightness of the starlight; those observations were made twenty years ago, and the theory was explicated almost immediately thereafter. Just this morning we saw that everyone is still plotting that power law on their latest observations. Clearly, those were very valuable observations; they told us a tremendous amount right from the beginning.) Ever since those earliest days radio astronomy has set the pace, discovering many exotic phenomena, and producing extraordinary images. More recently, far infrared and molecular line observations have discovered the molecular ring, and infrared spectroscopic observations of the infalling plasma showed us the orbits of accreted material. As we have seen repeatedly, a great deal of attention continues to be focused, and rightly so, on the study of the interstellar material in the Galactic center.

But when we get right down to it, what we really want to look at in the middle of our own

Galaxy is the stars. If it wasn't for this quirk that the dust gets in the way, we would have studied it in the stars long ago; and that's still what we want to do right now. This week we saw the gigantic progress being made in the detailed measurements of the stars; measurements of the distribution and nature of the stellar population, of the extinction to and in the galactic center, of the variability of the stars, and (perhaps most importantly) of the kinematics of the stars.

Now, the good news is that those observations are only the first of a new breed. As the detectors needed to make those observations are fully implemented -- two-dimensional infrared array detectors -- the topic will be opened up very, very thoroughly. It will finally be possible to make all kinds of measurements with much greater precision. For example, the arrays will be used in spectrometers before long; also, we will be able to take pictures with much higher angular resolution, either from sites with exceptionally good seeing, or from space, or by using adaptive optics techniques from the ground.

It is splendid news that a technology boom is taking hold right where we need it most, in our ability to look at the stars; I think one can justifiably expect, by the time we next meet on this topic, that the observations of the stars themselves will be very much more advanced. Then, in the midst of all the manifold observational possibilities, we can focus right down, and have a hard look at the way the stars are performing in the Galactic nucleus. As for me, I'm pretty reluctant to believe -- as we unravel this enigma and get down into the heart of it, as we study the sources of luminosity in the center of our own galaxy, as we chase down and interpret all the clues -- I don't believe we'll only find that a few puny stars have formed -- that nothing very much is happening. I don't believe that for a second. So I'm also looking forward to the day when the high-energy observations become sufficiently sophisticated to prove that something much more dramatic is taking place.

Meanwhile, I take great consolation in the fact that we now know -- and we've seen it proved very emphatically this week -- that our galaxy is a good place in which to understand other galaxies. We have joined together here in a splendid synthesis based on our mutual ability to make good observations: the observed large-scale structure ties us to the fact that we are a normal galaxy; then, as we change scale size -- with enough information overlapping in each regime that we don't inevitably get lost or confused -- we proceed down into the unknown territories of the nucleus. These are unique places we'll never see in any other physical environment. It's the only galactic center we've got, and it's so close that it's the only place where we have a chance to sort out the most interesting problems. This has been a remarkable week, because for the first time I think you can see very clearly that these steps <u>are</u> being taken, that we're succeeding in these ways, that we're going to understand these problems. We can get there from here! And so we do live in a remarkable time -- because we are beginning to understand the center of our own Galaxy!

<u>Acknowledgements</u>: I am grateful to Mark Morris, both for his invitation to give this talk, and for his help in its transcription. Mike Merrill edited the transcript, and Janet Grace prepared the manuscript. Sam and Cathy Gatley provided crucial emotional and logistical support.