Massive Star Birth: A Crossroads of Astrophysics
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Summary Talk II – Massive star birth sequence

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Abstract. I begin with a very brief summary of the nature of the physics problems facing us in massive star birth, and present a couple of (now belated) admonitions to the participants. I will say a few words about several of the high spots from papers on the newly born massive stars that caught my attention. This is thus a very personal and highly biased summary. There is no way I could mention all of the really new and interesting results presented at this meeting and I apologize in advance for leaving out many fine reports.

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1. Introduction

Aside from Henny Lamers' contribution, all the oral talks at this conference used "power point" presentations. In using his view graphs and over head projector, Henny mentioned that you could tell your grandchildren about once seeing such a ancient technique. In that spirit, without using either of these methods, I decided to really return to the basics and speak only from notes, which are written on the "backs of" the LOC sheets (those pages of paper provided by the Local Organizing Committee). This way you know I have done this summary *at* the meeting. The use of paper notes eliminate you having to read my impossible "chicken scratching" on viewgraphs, and I can just stand up in front of you and make a fool of myself face to face.

2. What's with understanding massive star birth anyhow?

For massive stars, the environment (natal dust and gas) dominates what is observed and controls the physics of the interacting and accreting phenomena. What we would like to do is to infer the properties of the underlying star(s) from the surrounding molecular gas (e.g., masers), the ionized gas (the UCHII region) and the natal dust (IR SEDs). In some (as yet still too few) cases we can observe the star (stellar atmosphere) directly in the NIR or even shorter wavelengths. In many objects, the interstellar dust (both natal and line of sight) is still too *absorbent* even at these wavelengths. Unfortunately, at longer wavelengths the stellar atmospheric features are overwhelmed by thermal dust and/or free- free *emission.*

3. What's with the jargon?

I was astonished during the presentations by the variety and extent of the use of abbreviations, many of which duplicated each other in what was being described but with different acronyms and shorthand. I'm going to give you my opinion about what's good jargon and what's not. This will probably not make any difference to any of you but I feel so strongly about this that I have to say something. The jargon is getting in the way of our understanding of the physics and certainly is adding to the confusion. You must keep in mind that the field of massive star birth *is* a crossroads of astrophysics between very different subsets of astronomy. We need to communicate with each other better.

◯ Here are some examples of what I think of a good jargon; they have stood the test of time and are universally understood.

• For the STARS:

◦ CORES (open to adjectives such as “hot”, “massive”, “central”, etc.). This might be a pre-MS (H-burning) phase in terms of stellar evolution but this has not yet been demonstrated. For the present it’s a good term for what is seen in the IR prior to the UCHII region being observed.

◦ MYSOs (Massive Young Stellar Objects). Has been taken to refer to stars within UCHII regions, and those still retaining discs.

◦ EXCITING SOURCES Referring to objects (cores or stars) that are within an observed extended IR or radio source. Note that massive stars are being thought of as those which will produce an HII region at some point.

◦ STARS Always a useful and well understood word that in the present context might be reserved for objects which have a detectable stellar photosphere.

• For the ENVIRONMENTS:

◦ Masers, HCHII regions, UCHII regions, dust cocoons, natal dust.

◯ Now for some BAD jargon:

◦ HMSF regions (is it high mass stars or lots of mass in the SF regions?).

◦ HMPOs (huh?).

◦ PUCHs (sorry Ed).

◦ High Mass Proto stars (we still don’t know when massive stars begin H-burning).

◦ Class O/I, II Protostars (for massive stars the disc distinction so readily seen in low mass stars is not readily available to observation).

4. What’s wrong with power point?

During many, although not all the talks, I kept waiting for the interpretation and connection to the main topics of the Symposium. The presentations were spectacular - color images with imbedded blow-ups, cute graphs which grow with new data, multiwavelength presentations, etc. In many cases I waited in vain for what it all meant. I have the impression that in your desire to have the very best presented material, you have forgotten to tell us what it all means. The best papers tell a story; it has a beginning, a tale, and an ending. Don't loose track of why you are giving a talk and what you are trying to tell us.

5. What's with masers?

I knew very little about astronomical masers before this meeting. Let me tell you what I learned, emphasise some obvious questions, and suggest what needs to be done now. Certainly masers are a signpost/tracer of massive star birth regions, describing properties of the environments. The physics involves population inversions in such common molecules as water, methanol, and the hydroxyl radical, followed by a down cascade, giving a set of lines in the (typically) radio frequency region. The inversions come about from either collisions, or radiation, or some combination of the two within the molecular gas clouds. The spatial morphology appears to be disc, or jet, or ring like but differs in different sources. Wouldn't it be nice to know the relationship between the origin of the inversion (collision or radiation) and the spatial morphology? I heard (and saw) lots of data being presented but no connection to these basic issues. What might masers tell us about the underlying star(s)? I have *no* idea if they could be used for it but such an investigation might really help our understanding of the earliest processes of star birth. Finally, I heard that most are MIR sources. Are all? Someone ought to look at this; it might help us know what is going on.

6. What's some of the highlights?

• The various descriptions of outflows from hot cores and exciting stars with various opening angles and with jets observed in many systems assures us that the birth process is non-spherical.

• Disc signatures seem now to be well established in some sources. It seems to me that this proves that accretion dominates at some point in the stellar birth.

• There was breakthrough 3-D modeling, including disc morphology, of the SEDs from the dust surrounding massive cores and exciting sources. This modeling will constrain the underlying stellar properties as the luminosity and total mass will be able to be inferred. There will be lots of data from Spitzer becoming available that will be suitable for interpretation.

• There was extensive ASCA and CHANDRA detections of point sources in SF regions. Many of these, especially in the closest ones, will turn out to be HAeBe or T Tau stars - low mass stars. But some are identified as OB stars, some buried in their natal clouds. Could these be attributed to wind-natal cloud interactions? These very short wavelength observations may well help us to lay out more of the parameters of massive star birth.

• Are all massive stars born in clusters? I heard a pretty compelling analysis of O type field stars, using deep NIR images. Some stars remain apparently single from the images. However, given their galactic locations or their kinematics many of these are likely runaway stars. The bottom line: about 4% of the O-type field stars appear to be truly isolated, thus exceptions to the cluster formation rule. Personally, I am not suprised that a few are single, given the situation for the nearest O-type star, Zeta Pup, which is an isolated object.

• There were convincing simulations of gas dynamics and gravity leading to star cluster formation. I was astonished to see the formation of close binaries. More details are going to be needed to include in further modeling, especially the radiation pressure contribution, but this work seems to be on the right track.

• It is important to infer the spectral types of stars in their birth environments as one could then begin to connect the status of each stellar parameter with the situation in the environment. This work has just begun in earnest but will be limited as only a small subset of exciting stars is visible in the NIR.

• Spectral analysis of the CO emission/absorption lines seen in many MYSOs was presented for a few of them. High spectral resolution in the NIR is needed. Discs or torus-like mophology seems to be present, again emphasising the non-spherical nature of the birth process.

• It is now possible to model the fine structure (f-s) lines found in the MIR. These lines are formed in the ionized gas surrounding the exciting stars. Models exist and a calibration of the method by analysis of the f-s lines in otherwise "naked" O stars is underway. This is a classic "inverse problem" for HII regions which has been well studied at optical wavelengths for years using recombination and forbidden emission lines. The idea is to tease out the properties of the exciting star from the nebula surrounding it.

• An extensive MSX survey of the galactic plane was presented. A large set of sources that are not connected with UCHII regions was found. These can be considered "hot cores" in terms of the terminology I am using here. Their spatial distribution and luminosity function were not all that different from the UCHII region objects. Many are plenty bright (10^5 $L_\odot$) leading us to infer that these hot cores are precursers to those objects exciting UCHII regions and they will eventually become O type stars.

7. What's next?

Considerable new multiwavelength data is now becoming available for investigations of massive stars and of their environments in the early stages of formation. One must be prepared to study, connect, and interpret the interaction between the environment and the star. Both objects need each other and we need to keep in mind their interactions. Let's all look forward to another meeting along the lines of this one in a few more years. I anticipate there will certainly be plenty of publications in the interim.