ISSI Helium Cone Paper series

We plan to publish the ISSI Helium Cone papers as part of a Special Section in JGR that will be devoted to the Local Interstellar Medium and Its Interaction with eth Heliosphere. Tentative deadline for paper submission is: December 1, 2002. This date may slip slightly, depending on the date when the final approval is given to us by JGR. At this point I have received the preliminary approval by the Editors of JGR. The official approval process still has to go through the AGU Office.

We decided to organize the papers according to the key diagnostic methods and add an overview paper that compares the results and discusses the remaining differences.
The individual papers according to methods will be on:
- Direct neutral gas observations
- Pickup ion diagnostics
- UV scattering diagnostics
- Overview Paper

Therefore, a key element in the conclusions of each of these papers needs to be a table with best results of the LISM parameters at the Termination Shock (for He with high confidence the real values in the undisturbed LISM) with their respective error bars (including a discussion of estimated systematic errors). These parameters are: density (n_{He}), temperature (T_{He}), bulk speed (v_b), and direction ($\square_b$, $\square_b$). In particular, we should make an attempt to compare these new results with values quoted in past using the same method. An assessment should be presented where and as much as possible why values have been different.
The overview paper will synthesize the combined results, by starting with a combined table of these results. Based on the estimates of systematic errors in the other papers a consensus set of parameters will be presented. It should become clear which of the methods returns the most reliable parameters (may be different for different parameters) with the current set of tools. These results will then be compared with In the overview paper we will also attempt to discuss the reasons for observed differences and which additional constraints on relevant conditions in the heliosphere this puts, such as ionization rates and their spatial/temporal dependence, illumination by the sun and spatial/temporal dependence. Finally, the synthesis should allow going back in the history of observations to identify any solar cycle related effects and point to any other temporal effects (if there are any; or simply conclude that with the current accuracy no such changes can be identified).

As far as the author lists are concerned, we have determined lead authors for each of the papers. We have agreed that the entire ISSI Team should be co-authors on the Overview paper (possibly alphabetically after the lead author? TBC). As far as the other papers are concerned I am suggesting a policy that includes all of the team members connected with the relevant observations of the method, providers of ancillary data, modelers and those who significantly contributed to the result discussion that is reflected in the paper. We need to take on such a discussion at our meeting. ***I would like to ask each lead author to present a first cut strawman author list at the meeting.***

a) **Neutral Gas diagnostics of the physical parameters of He in the Local Interstellar Medium (LISM)**
Witte et al. + All of the Team, who contributed to the Neutral Gas discussion (observers, modelers, contributors of ancillary data, substantial contribution to interpretation)
This should be a paper that summarizes all Ulysses GAS observations (from the early 90's through early 2002). It is understood that the parameter values will probably still vary somewhat between sky scans. It is the hope that the scatter is contained within reasonable bounds (True Manfred?). At this point I don't think that anything about IMAGE LENA observations, except some side notes on future information from such an instrument, should be included.
The main instrumental discussion will probably include the following:
- Brief discussion of the modeling; emphasis should be put on how this modeling compares with the models of the neutral gas that are used within the other methods.
I think we should perform a direct comparison of the spatial distribution of the neutral He and its velocity distribution (without instrument functions etc.) between what is used here, Daniel's model (maybe that has been done between Marek and Daniel; ***Maciek, Manfred do you know about this?***)
- Presentation of the good observation times, discussion why
- Improved pointing accuracy throughout the datasets, how done and how much that improves the older results.
- Ionization rates from EUV and from indirect orbit observations. How do they compare? Together with the modeling we can derive what the additional ionization is that is needed over and above UV ionization. This should be compared with observed electron distribution functions and the resulting ionization. (***Maciek, Daniel has started the extraction of electron ionization rates from real electron distributions. Ruth Skoug had given us some first data sets and promised more through 2002. Do you know where this activity stands? Can you help us to use Daniel's program? I will contact Ruth again about the data sets.***)
The final result should be a set of: n, **T, V, direction** for He**,** including errors and an estimate of systematic error sources. I assume that this method will yield the most precise values for **T, V, and direction**, while pickup ions probably will return the best values for n.

Input (as known from the last workshop):
MW:
New data mid 2000 – early 2002 (available through early 2001 at the last workshop)
Checked pointing accuracy (200 star observations); accuracy of S/C attitude; corrected elevation angle by 0.4 deg and azimuth 0.5 deg; in terms of modeling of the inflow velocity distribution this is a major effect, because the atoms are only deflected by at most 20 deg from their inflow direction.
There is still significant scatter in the results (data were not fully screened yet at that time)
The resulting flow direction has slightly changed over previous results (***Manfred, we hope to get a more or less finalized update at the upcoming workshop***);
Densities derived with fixed ionization
For 2000: ionization 1.5 10^{-7} s^{-1} (*I don't recall, whether that was from indirect orbits or from EUV observations?*). The resulting density is: n = 0.016 cm^{-3}
-> Add electron ionization at 1 AU and from Ulysses (get data from Ruth from Ulysses)
[***Maciek, the idea here was to use SW electron distributions at 1 AU (from ACE and/or***

Wind + at Ulysses), model the electron ionization at these two points, and then extrapolate to < 1 AU with the general information from Helios in the 70's (e.g. paper by Pilipp et al.)]

b) **Pickup Ion diagnostics of the He parameters in the LISM**
Gloeckler et al. + All of the Team, who contributed to the PU Ion discussion (observers, modelers, contributors of ancillary data, substantial contribution to interpretation)

The paper should summarize the determination of the LISM He parameters using mainly ACE and Ulysses SWICS pickup ion data. The results should be augmented, wherever possible in terms of overlap and/or temporal extension by data from Geotail, Nozomi, SOHO and AMPTE.
There will probably two steps in the paper:
1) Determination of the He density: **n** is probably determined best by making use of He^{2+} pickup ions from Ulysses. Even compared with direct neutral observations this method has fewer unknown as far as absolute values are concerned. This method eliminates the need of accurate absolute calibration, because both He^{2+} pickup ion fluxes and solar wind He^{2+} fluxes (responsible for double charge exchange) come from the same instrument.
Next within the same section the values derived from He2+ should be compared with those derived from He+ pickup ions. In order to stay away from strong spatial variations in the cone, this should probably comprise the data from the upwind direction (i.e. summer of each year) allowing possibly even longer integration times for data points. The He+ spectra allow to derive the total ionization rates (for loss of He neutrals). These values can be compared with the observed EUV ionization rates. In this section it is important to fine-tune the modeling of the pickup ion spectra. (***Sergei, George, are there significant changes over what we heard last year? The slope of the spectra and thus the derived ionization rate depends crucially on the model.***)
Again in the comparison between deduced total ionization rate and EUV ionization, we can derive a required electron ionization rate, which then should be compared with predictions we get from observed SW electron spectra (see above).
including ionization rates from EUV, electrons; modeling
2) Using the time-averaged He+ fluxes for several cone traversals of ACE the direction, T, V should be derived through fits of the cone; It is understood that T and V will probably arise, with a) substantial scatter from data set to data set and b) with much larger error than from neutral observations, but a comparison will be useful. The direction (at least in ecliptic longitude) should come out relatively precise. Since there are claims in the literature that the cone may be shifted as observed through pickup ions, this should be tested within achievable error limits.
Also the resulting V and T will probably show a sensitivity to transport effects, in the sense that most likely T will be somewhat higher and V somewhat lower than observed directly from the neutrals.

Input (as known from the last workshop):
GG: Reanalysis 2001: variations of N_{He} have diminished to ≈20%.
Combined analysis for one period (1995): 0.014 cm-3
He2+, He+; also H+ (high speed wind)
1998: 0.02 cm-3;
2001: 0.016 cm-3 (1998 and 2001, both slow wind (no He2+))
Dens. of He fit for 95/96 and 2001; but diff. in 98; -> do spectra of ACE data and double-check [***George, has this been done?***]

(compared with n = 0.016 cm^{-3}, as quoted by MW, this is a relatively good agreement; comment EM) [***George, apparently the 1995 value is from He2+, whereas the newer ones are from He+. As pointed out above, it would be important to make this comparison an important part of the pickup ion paper. Have any of these values changes since last year? Do you have any more recent He2+ values from Ulysses?***]

From our discussion last year: Ionization rate in 1998 may be lower than derived by GG from spectra. Thus n would turn out higher, but we have to be cautious. (*I think, we should try to get to this point by comparison of He2+ and He+ data; EM*)
Daniel offered to compute ionization rates from UV + electrons and started on this. (***Maciek, do you know where that stands? Goes along with the same task for neutrals.***)
Cone: fit ionization vs. T; peg ionization at actual + slope derived -> T; transport effects?
HN: Geotail 2000 cone crossing; comparison with ACE SWICS data
Geotail spotty coverage -> averaging not possible; suffers from inherent variability of pickup ions (***Hirotomo, Toshio, has anything more happened on this? Can we compare any Geotail or Nozomi data with SWICS data?***)
TT: Calibrate Geotail with ACE SWICS data, then go back to 95 with density (***Toshio, dto.??***)

The following applies to our extension to hydrogen
GG: new H+ results fit with Vlad's model;

c) **UV scattering diagnostics of the He parameters in the LISM**
Lallement, Raymond, Vallerga et al. + All of the Team, who contributed to the UV discussion (observers, modelers, contributors of ancillary data, substantial contribution to interpretation)
The goal for this paper should be to provide a LISM He parameter set that is derived from SOHO UVCS and EUVE, possibly also including Nozomi data. The values should come out as consistent as possible within these data sets.

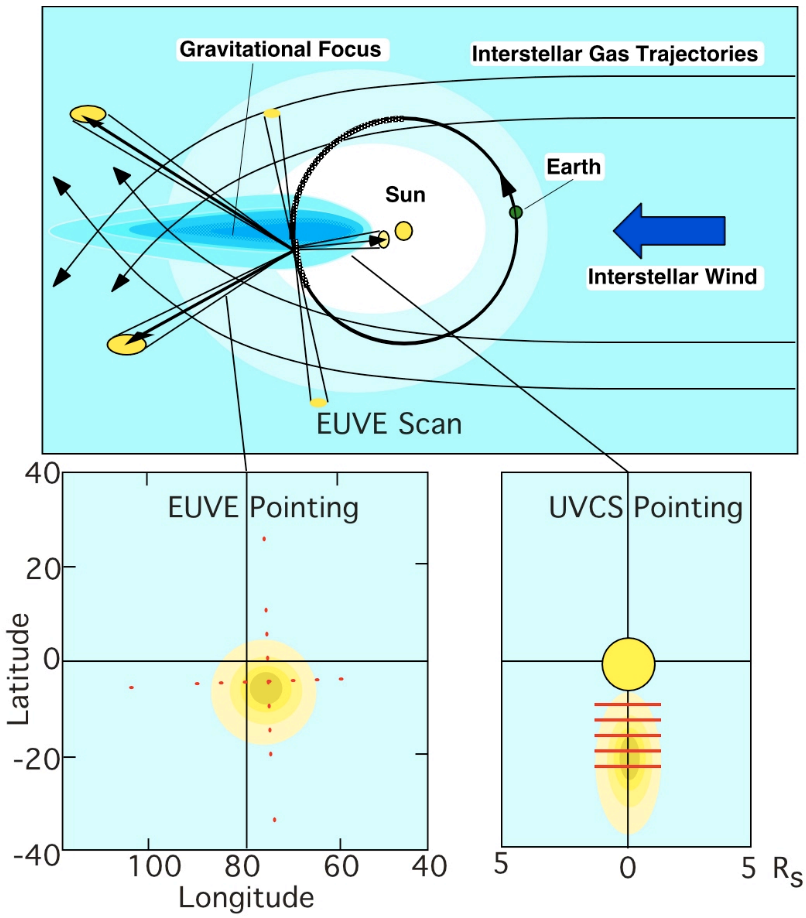

Fig. xx: Schematic representation of the UV scattering geometry for SOHO UVCS and EUVE and the respective viewing cones.

The modeling should be tried with
- ionization from EUV fixed through SOHO SEM data, include a contribution from electrons (***as discussed already above, Maciek***);
- He 584 illumination fixed from SOHO CDS data, including spectral information from SUMER;
- which other parameters in the model can then still be adjusted to optimize the fits (***Rosine?***)

We should arrive at a complementary set of n, T, V, direction to the other methods. Probably the UVCS data will now enable us to probe the electron ionization, which should be strongest close to the sun. Together with electron ionization derived from observed electron distributions at 1 AU and at Ulysses, we could use UVCS observations to further constrain the radial dependence of the electron ionization closer to the sun.

We also discussed uneven illumination of the neutral gas flow past the sun depending on the surface feature distribution on the sun.
Finally, we should try to use what we learned from better constraints on ancillary parameters, such as ionization and He 584 illumination in order to attempt an **extension to earlier observations**.
At least a good fraction of the past variability of the He parameters in the literature may be due to their sensitivity to not so well known illumination and ionization.

Input (as known from the last workshop):
JR: UVCS recalibrated (***John R., what is the word on a the calibration of UVCS for the He 584 line?***)
The cone intensity has varied substantially over the course of the solar cycle.

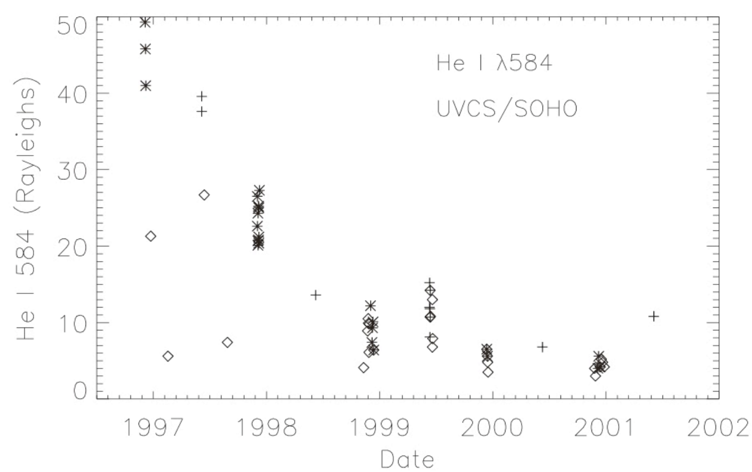

Fig. xx: Temporal evolution of the He cone intensity as seen with UVCS over the past solar cycle.

UVCS cone data require substantial additional ionization; illumination still a problem; first results were based on too high illumination; (***Rosine, John R., what is the latest word here?***)
JR: Changes of illumination may lead to changes of cone intensity? However, doesn't seem to be the case; (***John R., do you have clear examples that show this? As a discussion point in the paper, an illustrative example in a figure may be helpful.***)
Time-dependent ionization may lead to cone variations, because the typical time scales for the He flow through the inner heliosphere is longer than the time scale of ionization changes and that of neutrals traversing through the cone. To evaluate this will need 3-D time dependent model.
DR: So far no such model; closest anisotropic H model. (***Maciek, this refers to your area of expertise. You have written several time dependent models of the neutral gas flow. Do you have something for He that could be applied here? If yes, it would be good to have the model available for some trials at ISSI.***)

JV: Scan data show significant variations with r;
Calibration of EUVE remained constant over the mission: observed □-Cma after launch and at end of mission: no change!

(***John V., I remember you talking about the subtraction of exospheric glow and other near Earth effects. Do we have a better handle on these issues, which could improve the accuracy?***)
JV: now good fit of EUVE data with 7000 K, 26 km/s; flow direction nailed; free parameters: ionization rate -> el. Ionization

AP: CDS and SUMER track each other very well for HeI 584 Å. However, there is a difference between them by ≈35% in the absolute values.
We may be able to constrain the UV illumination by using the particle derived He density and EUVE and UVCS observations. [***Rosine, can you figure out which of the two values lead to a better agreement between UV scattering and particle (neutral and pickup ion) results for the He density?***]

RL: Prognoz data: reemphasizes that UV scattering leads to high T and/or high ionization rate, if fit is left free to optimize
Calibration problem between EUVE and Prognoz: Prognoz gets factor 2-3 higher flux
RL: Prognoz data, so far not fitting with reasonable ionization rate;
using known irradiance, new UVCS calibration, needs still 2.5x -> el. Ionization rate;
Calibration still uncertain; SUMER line width as used before; (***Rosine, if this can be resolved, we would have a wonderful vehicle to extend results to previous years, with the chance to get at least at solar cycle dependencies.***)

TT: Nozomi went through cone in spring (***Toshio, I don't recall, which year. 2000 or 2001?***); also sees consistent cone structure; density comes out high (0.03 cm-3), but:
- absolute calibration not finished
- not completely averaged
UV map taken over several months: v = 29 km/s, T = 12000 K, n = 0.013 cm^{-3};
(***Toshio, what was the meaning of the two different values for n that I recorded (0.03 and 0.013)? Or did I just misrecord? 0.013 would be well in line with the particle results. Is there a paper on the Nozomi results now that we could start from?***)

Input on Ancillary Data(as known from the last workshop):
DMcM: UV ionization very well defined (≈15% higher than quoted 2000; calibration adjustment), calibrated with direct observations through ionization cell etc.;
Ionization record available back through 1970’s using MgII index;
584 Å irradiance: short term variations track with MgII index; but swing from sol min to sol max less than that of MgII index (or HeII 304 Å line)
Ly□ flux changes factor of ≈ 1.7, while MgII changes more than factor of 2; so He 584 may be between the two

These data sets will provide a basis for extending any of the modeling and input data improvements to data sets that go back as far as the 1970’s, i.e. applicable for UV scattering and early pickup ion observations.

d) **The Physical Parameters of He in the Local Interstellar Medium (LISM) as Derived from a Combined Analysis of Complementary Techniques Inside the Heliosphere**
Möbius et al., all of the Team and contributors

Abstract:
In a dedicated ISSI (International Space Science Institute) Team we have analyzed the combined data sets from coordinated campaigns to observe the interstellar helium cone with in-situ and remote sensing methods, including the necessary supporting observations over three years from 1998 through 2000. The data sets are comprised of observations of pickup ions with ACE and Ulysses SWICS (Geotail, Nozomi??), neutral atoms with Ulysses GAS, and UV backscattering with SOHO UVCS and EUVE (Nozomi). We have made use of simultaneous monitoring of solar UV radiation with SOHO and of the interplanetary conditions with SOHO, ACE and WIND. The analysis is comprised of detailed modeling of the interstellar gas and its secondary products in the heliosphere. The combined analysis has resulted in a consistent set of interstellar He parameters. Previous apparent differences between the complementary observations can be traced to incomplete information on ionization rates and solar illumination of the interstellar gas in the inner heliosphere. In particular, it becomes possible to put constraints on additional contributions to the ionization by electron impact in the inner heliosphere. With a consolidated database on solar UV ionization and illumination it becomes possible to extend the improvements in the analysis to previous data sets with UV backscattering information and pickup ion information, such as Prognoz, Geotail and AMPTE.

Introduction

General description of the state of the knowledge of LISM parameters and the LISM - Heliosphere interaction.

Diagnostic Techniques to Determine the LISM Parameters

Description of combined observations, comparison of methods, their accuracy, versatility,

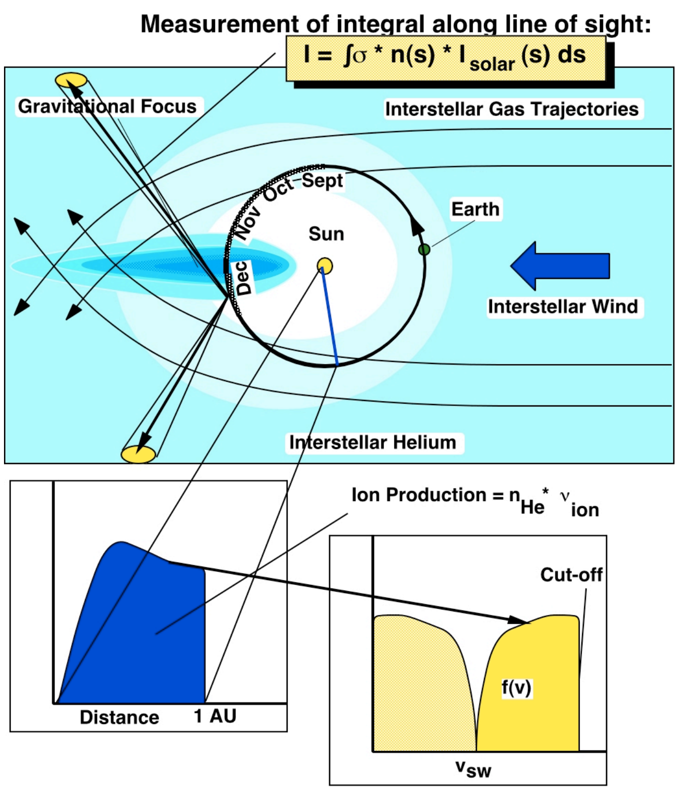

Fig. xx: Comparison of the sampling of interstellar gas in the heliosphere using different diagnostic techniques

and potential long term monitoring capabilities;
Which methods provide most accurate results for which parameter?
n from pickup and neutral gas (with independent ionization rates)
consistent ionization rates from EUV + electrons vs. pickup spectra and neutral gas;
T, V, direction from neutral kinetics (most direct method)
n, T, V, direction from UV: discuss sensitivities; -> **electron ionization close to sun** -> radial dependence

Compilation of the Observational Results
Summary of the data sets used and their respective temporal coverage.
Summary of available ancillary data and what purpose they serve.
Table I: **Consensus values with error bars**

In-Situ Methods

	Pick-up Ions (AMPTE SULEICA)	**Pick-up Ions (SWICS)**	**Neutral Atoms (Ulysses GAS)**
n_{He} [cm^{-3}]	0.009 - 0.012	0.016±0.002 (Ulysses)	0.016-0.017±0.002
T_{He} [K]	4800 – 7200 (corr. for diffusion)	7850±550; 9900±500 (ACE*)	5800 - 7600
V_{rel} [km/s]	23 - 30.5 (corr. for diffusion)	-	25.3±0.4
□, □			
Reference	*Möbius et al. 1995a; 1995b*	*Gloeckler et al. (1998; priv. Comm.*)*	*Witte et al. 1996*

Remote Sensing Methods

	UV Scattering	**UV Scattering**	**UV Absorption (non-local)**
n_{He} [cm^{-3}]	0.015 - 0.02	0.0055 - 0.0145	-
T_{He} [K]	16000	8000 (shifted UV line)	7000 ±200
V_{rel} [km/s]	24 - 30	19 – 24 (shifted UV line)	25.7 ±1
□, □			-
Reference	*Dalaudier et al. 1984*	*Chassefiere et al. 1988*	*Bertin et al. 1993*

Description and relative weighting of statistical and systematic errors.

Discussion and Implications
All discussions that involve the comparison of data from the different methods may be combined in this paper.

What causes the tendency to find high T? Is a variation of shapes of the cone involved??? -> **influence of varying solar activity**??
T, V, direction: from pickup cone: influence of pickup ion **transport effects (*This discussion could be either in the pickup ion paper or here. George what do you think?*)**;
Observation of sub-structures in the cone?? -> influence of varying solar activity??
Finally, we want to compare the consensus results with observations outside the heliosphere, e.g. through UV absorption measurements. **(*Rosine, is the Bertin et al. Paper still the most recent of these efforts, or is there something more recent?*)**

Conclusions
Current status of knowledge of He parameters, accuracy and prospects for improvement;
how do these results constrain the general knowledge of the LISM and modeling?
how can we extend the temporal coverage?
Need and prospects to extend the presented techniques to H and other LISM species.

Input (as known from the last workshop):
Get electron ionization using:
  neutral observations
  UVCS observations
+ electron observations at 1 AU
DR: electron ionization ≈ 12% of EUV ionization (5 – 30%);
variation with r can be stronger than r^2 even for n (***Maciek, see my questions above. Dto.***)

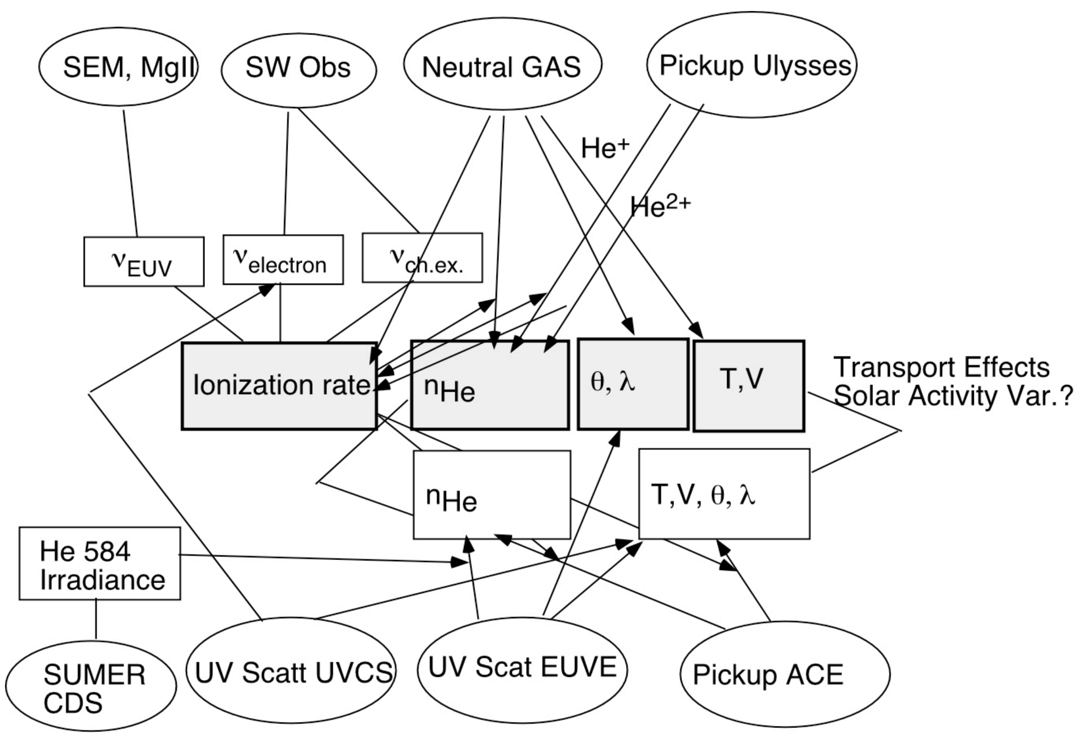

Fig. xx: Flow of determination of parameters